The Air Quality Strategy for England, Scotland, Wales and Northern Ireland

Volume 2

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The Air Quality Strategy for England, Scotland, Wales and Northern Ireland

(Volume 2)

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1.1 Key Points

- This Chapter assesses recent historic trends and projections of air quality emissions and measurements. The projections consider only the base case, i.e. projections for the current set of measures. The impact of possible new and additional policy measures is considered in Chapter 2. Historic and current air quality is assessed by measurements and modelling; future air quality has been modelled.
- Objectives are being achieved for many of pollutants (lead, benzene, 1,3-butadiene and carbon monoxide (CO)). Measurements and modelling however show that, without further measures, objectives for particles as particulate matter (PM_{10},) nitrogen dioxide (NO_2), ozone (O_3), and polycyclic aromatic hydrocarbons (PAHs) are unlikely to be achieved in some parts of our urban areas and along side busy roads.
- For sulphur dioxide (SO_2) it is likely that, although there are current monitored and modelled exceedences, the objectives are predicted to be met almost everywhere by 2010. There were no measured exceedences of the 15-minute, one-hour and 24-hour SO_2 objectives at Automatic Urban and Rural Network (AURN) monitoring sites in 2005, although exceedences were measured at some local authority run monitoring sites. Modelled exceedences of the 15-minute mean SO_2 objective were observed for 2005.
- In 2005[1], PM_{10} concentrations exceeded the 24 hour average objective for more than 35 days at the roadside monitoring sites at Marylebone Road and Camden roadside in London, Brighton Roadside and at the urban background site at Port Talbot.
- The NO_2 hourly objective was exceeded in 2005 at four sites, including London Marylebone Road with 853 exceedences. The NO_2 annual objective was exceeded more widely throughout England and Scotland with 27 sites exceeding, of which 11 were non-roadside sites.
- In 2005, roughly 40% of the 85 monitoring network sites exceeded the Air Quality Strategy's objective for O_3.
- In 2005, the PAH objective was exceeded at four urban background or industrial sites in the national network.
- Measurements show that long-term reducing trends for NO_2 and PM_{10} are flattening or even reversing at a number of locations, despite current policy measures. Projections suggest with a high degree of certainty that objectives for PM_{10}, NO_2 and O_3 will not be achieved by 2020. This indicates a need for additional policy measures to achieve some of the Strategy's objectives, as discussed in Chapter 2.
- There are uncertainties associated with the assessment of whether objectives have been/ will be reached. The sensitivity of the results to a number of these uncertainties has been tested. The weather in any given year will have a large influence on the extent of any exceedence of objectives. Furthermore, there are significant uncertainties in future emissions of pollutants, sources of PM_{10} and the effectiveness of mitigation measures in reducing pollutant concentrations.

[1] Data for 2006 are still provisional. Initial indications suggest that air quality in 2006 was broadly similar to 2005.

1.2 Introduction

1. Current air quality is assessed using a combination of measurements of pollutant concentrations and modelling, also referred to as mapping.

2. There are currently around 300 national air quality monitoring sites across the UK organised into several automatic and non-automatic networks, each with a different scope and coverage. Each network has clearly defined objectives covering network design, priority pollutants and appropriate measurement methods. Further information on the UK networks is given in Defra (2006)[2] and on the National Air Quality Information Archive (www.airquality.co.uk).

3. Mapping pollutant concentrations across the UK involves estimating concentrations where there are no ambient monitoring data. A description of the UK's modelling methods is provided in sections 1.2.3.2 and 1.2.3.3.

4. Air quality is assessed using a combination of measurements of pollutant concentrations and modelling, also referred to as mapping. The analysis presented here:

   - assesses historic trends and the current situation for concentrations of pollutants included in the Air Quality Strategy (SO_2, NO_2, particles as PM_{10}, particles as $PM_{2.5}$, benzene, 1,3-butadiene, O_3, CO, lead, PAHs and pollutants affecting ecosystems);
   - estimates future air quality assuming current measures, and
   - discusses the uncertainties associated with these estimates.

5. This Chapter sets out the scientific underpinning behind the conclusions presented in the Volume 1 of the latest Air Quality Strategy. There have been significant advances in the science behind many of the issues dealt with in the previous Strategy published in January 2000, notably on particles and the modelling of NO_2 and O_3. These have been fully documented and are referenced in full throughout this Chapter.

6. It does not reproduce all the detail of these scientific reports and papers, but rather distils the main features and results to enable readers to form a view on the conclusions reached. Where appropriate reference is made to the primary source material. These sources exist in several forms, but the UK Government and the devolved administrations are keen to maximise the use of IT and accordingly as much of the material as possible is available through the Defra web site, www.defra.gov.uk/environment/airquality/, the devolved administrations' websites: www.scotland.gov.uk/Topics/Environment/Pollution and the Air Quality Information Archive (www.airquality.co.uk).

1.2.1. What is the baseline?

7. The baseline is the best estimate of the current and future situations in terms of the emissions and concentrations across the UK for each of the pollutants under consideration in the Strategy. The baseline projections of future emissions and concentrations assume

[2] Defra, 2006. Air Pollution in the UK: 2005. Available from: www.airquality.co.uk/archive/reports/reports.php?report_id=421

that embodied in the projections are those policies or commitments that are already in place or those on which agreement has been reached, even if the full administrative and legal procedures have not been finalised.

8. The baseline projections also assume all relevant measures continue to be implemented and enforced. Progress on vehicle emissions, for example, is partially dependent upon the MOT system continuing to effectively monitor and regulate vehicle emissions. Forward thinking on particulates pre-supposes that the Clean Air Act controls on smoke from domestic premises will continue in force. The projections also assume that emissions reductions achieved through the Pollution Prevention and Control legislation and predecessor regimes will continue to be delivered and enforced by the Environment agencies and local authorities. The application of Best Available Techniques (BAT) may nonetheless result (e.g. because of new techniques or lower cost of existing techniques) in tighter emission standards for new products, but this is not included in the assumptions.

9. Section 1.2.4 summarises the changes to the baseline for the modelling carried out since the consultation document on the review of the Strategy issued in 2006. Individual pollutant sections discuss these changes in more detail.

1.2.2 Uncertainty

10. Predicting the future is inherently uncertain. The same uncertainties apply to the conclusions drawn in this Strategy about projected air quality and its impacts.

11. Air quality assessment is a complex procedure with many inputs, assumptions and some less well-characterised parameters. Section 1.5 presents an analysis and discussion of the uncertainty of outcomes to the following factors:

- measurements of current pollutant concentrations;
- accuracy of the national air quality model;
- geographic scale – national versus local;
- estimates of current air pollutant emissions;
- meteorology of the future year in question;
- estimates of future air pollutant emissions;
- for PM, assumptions about source apportionment of different components,
- estimates of the effectiveness of additional measures to mitigate emissions of air pollutants; and
- impacts of climate change on air quality.

12. 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.

13. The sensitivity of model results for PM_{10} and NO_2 (the priority pollutants for additional measures) to changes in certain input assumptions is discussed in section 1.5. 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. Uncertainty associated with estimating the benefits and costs of air quality impacts is discussed in the updated Third Report of the Interdepartmental Group on Costs and Benefits.

1.2.3 Data used and modelling methods

1.2.3.1 Air quality measurement

14. Air quality monitoring is a key component of any effective approach to air quality management. Its main purpose is to provide evidence to inform decisions on managing and improving our environment. Monitoring serves the following essential key functions:

- comparison of existing air quality against local, national or international standards;
- assessment of population health and ecosystem impacts;
- initial assessment of problem areas and pollutants requiring regulatory/control action;
- provision of baseline data for predictive models and environmental impact assessments;
- validation of emission inventory and model predictions;
- determination of long-term trends; and
- assessment of the effectiveness (or otherwise) of control strategies over time.

15. The UK monitoring networks started in the 1950s and 1960s measuring black smoke and SO_2. Automatic monitoring began in the 1970s and the AURN has developed and expanded over the years from around 30 sites in 1993 to 125 in 2005. The AURN provides hourly data on many of the key pollutants. These data can be found on the National Air Quality Information Archive (www.airquality.co.uk). Non-automatic monitoring increases the pollutants that can be measured to include heavy metals, PAHs, ammonia (NH_3), and those involved in acid deposition. At end of 2005 there were over 1200 sites in the network, but with the closure of the NO_2 diffusion tube network, there now closer to 200 sites. Much of the data from the non-automatic networks is available on the Archive, with the remainder available from the Network websites[3]. Further information on all the UK networks is available in the Air Pollution in the UK series of reports[4].

1.2.3.1.1 Measuring particulate matter

16. The reference method for the Air Quality Strategy's objectives and the 1st Air Quality Daughter Directive limit values for PM_{10} is the use of a gravimetric instrument. All the analyses of particle concentrations presented in this report are based on TEOM (Tapered Element Oscillating Microbalance) or equivalent instruments, which are currently widely used within the UK national monitoring networks. For PM_{10}, a scaling factor of 1.3 has been applied to all data before comparing with the EU limit value, as suggested by

[3] See the monitoring 'one-stop shop' on the Air Quality Archive: www.airquality.co.uk

[4] See footnote 2

the Airborne Particles Expert Group[5]. This factor was also recommended as an interim measure by the EC Working Group set up to address the issue of scaling automatic PM measurements in advance of Member States undertaking their own detailed inter-comparisons with the EU Directive's Reference Method.

17. The UK concluded its detailed comparison trials in June 2006[6]. The main result of this was to show that the TEOM was not equivalent to the Directive Reference Method within the uncertainties required and could not be made so through the application of factors. However, the assessment in this report remains valid and is likely to over/under predict the PM_{10} concentrations depending on the location. The 2004 base year assessment modelling was calibrated directly using gravimetric monitoring data and thus avoids this problem. Further work is currently underway to assess a further methodology to bring the TEOM to equivalence with the Reference Method. This will be made available on the Air Quality Information Archive once complete.

18. A sensitivity analysis for the scaling factor was included in the second report of the IGCB[7]. There is currently no agreed scaling factor for $PM_{2.5}$. Both TEOM and gravimetric $PM_{2.5}$ data are included in this report. The TEOM measurement data are presented and the model results are modelled directly on a gravimetric basis rather than scaled.

19. EU air quality directives set data quality objectives for uncertainties in measured individual data points of between less than 15% to less than 25% of the true value, depending on the pollutant. The most recent calculations for pollutants recorded at sites in the UK national monitoring network gave an accuracy range of around 8% to 11%[8] depending on the gaseous pollutant.

1.2.3.2 Projecting future air quality

20. A range of methods have been used to predict future air quality, based on projections of emissions. These range from simple empirical/statistical models, where air quality from low-level sources is assumed to be proportional to emissions rates, to more sophisticated deterministic models in the case of particles, O_3, NO_2 and SO_2. Furthermore, a national mapping methodology generates UK-wide maps of annual mean benzene, 1,3-butadiene, nitrogen dioxide, PM_{10} and $PM_{2.5}$ concentrations at background and roadside locations. A photochemical transport model (OSRM) has been used to model ozone concentrations. Figure 1.1 summarises the process for the national modelling to project future air quality for this report.

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[5] Airborne Particles Expert Group (1999), Source apportionment of airborne particulate matter in the United Kingdom. http://www.defra.gov.uk/environment/airquality/airbornepm/

[6] Harrison, D., Maggs, R., Booker, J., (2006), UK equivalence programme for monitoring of particulate matter" http://www.airquality.co.uk/archive/reports/cat05/0606130952_UKPMEquivalence.pdf

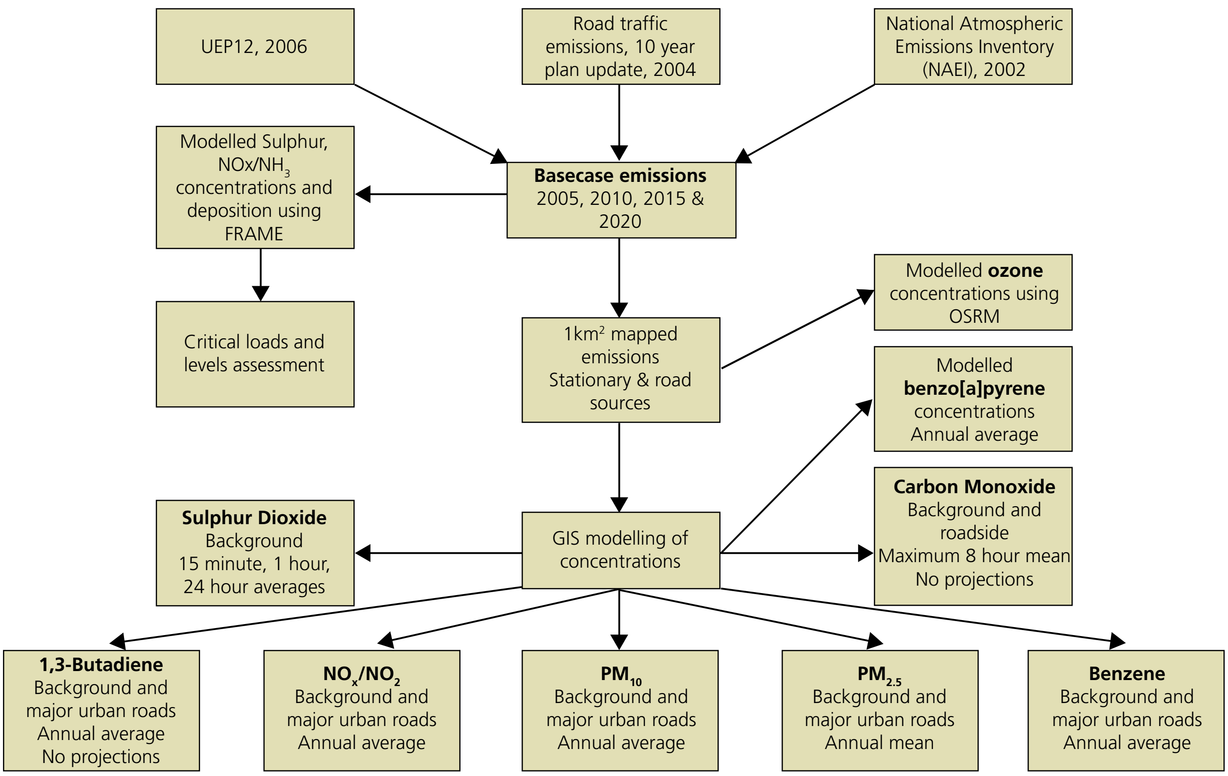
[7] "An economic analysis to inform the review of the Air Quality Strategy objective for particles" see www.defra.gov.uk/environment/airquality/igcb/pdf/igcb.pdf

[8] Unpublished estimate by netcen.

21. Modelled data for NO_2 and PM_{10} are also presented as population-weighted annual means in addition to maps and exceedence statistics for road length, area and population exceeding the objective in question, where appropriate. These represent the average concentration exposure of the UK population and can be used to calculate the health impacts and expected health benefits resulting from reductions in ambient concentrations.

22. We have not relied solely on the one national model to assess current and future concentrations for NO_2 and PM_{10}. We have also assessed likely future levels of these pollutants in London using ADMS-Urban[9]. This model uses a different process to the national model and a different emissions inventory[10]. Using two models gives greater confidence in the key conclusions for NO_2 and PM_{10} arising from the base case assessment. An intercomparison between the national model, ADMS-Urban and the UK Integrated Assessment Model (UKIAM) has been carried out to further increase confidence in the evidence in Volume 2. This is discussed in more detail in section 1.5.7.

Figure 1.1: Summary of inputs, processes and outputs for the national air quality modelling



[9] Williams, M.C., Caruthers, D.J., and Johnson, K.L. (2006), Modelling of current and future concentrations of PM, NO_x and O_3 in London Using ADMS-Urban. www.airquality.co.uk/archive/aqsreview2006.php

[10] The London Atmospheric Emissions Inventory (LAEI). See www.london.gov.uk/mayor/environment/air_quality/research/emissions-inventory.jsp

1.2.3.3 Modelling (mapping) air quality

23. The national mapping process involves several stages. Firstly, the relationships between current emissions and current air quality at particular locations are established using dispersion models. These models are then used to estimate concentrations across the whole country. The models can then be used to predict the future concentrations associated with the expected changes in emissions resulting from current policies (baseline projections) or possible additional measures (scenario projections).

24. For pollutants such as benzene and 1,3- butadiene (essentially primary pollutants over urban scales derived largely from vehicle emissions or low-level sources) future urban concentrations will be proportional to urban emissions, providing adequate account is taken of the contribution of other sources.

25. For the relationship between emissions of oxides of nitrogen (NO_X) and concentrations of NO_2 have to be taken into account, and this has involved using relationships in the oxidant-partitioning model[11]. Similarly, the calculation of future O_3 concentrations has involved modelling on a European scale, using the chemical/trajectory models developed to treat regional and global formation of O_3[12].

26. PM_{10} is also a complex pollutant – local and regional sources of primary emissions, together with longer-range transport of predominantly (but not exclusively) secondary particles from Europe, all contribute significantly to concentrations in the UK.

27. Maps of maximum daily 8-hour mean CO concentrations are produced with a similar approach to that used for NO_X and NO_2 but without the use of rural background concentrations as these are not well characterised in the monitoring networks.

28. Pollutants such as SO_2, lead and benzo[a]pyrene (B[a]P) do not lend themselves to the mapping approach in quite the same way. Sulphur dioxide originates primarily from elevated sources and the averaging time of interest for effects on health is short (hence our objective of a 15-minute mean). This means that concentrations of interest will be determined by the less frequent meteorological events and are addressed by more detailed modelling of high percentile concentrations from point sources using atmospheric dispersion models. Lead is treated in the same way as other primary pollutants with annual mean objectives, but urban lead concentrations are now generally very low since the phasing out of leaded petrol in 2000. The only possibility of exceedence of the lead objective is in the vicinity of individual emitters, which are best addressed on a site specific basis. Benzo[a]pyrene concentrations are mapped using similar methods to those adopted for the other pollutants, but estimated concentrations are subject to greater uncertainty due to the greater uncertainty surrounding the source apportionment of ambient concentrations and the characterisation of some emission sources.

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[11] Jenkin, M. E. (2004). Analysis of sources and partitioning of oxidant in the UK - Part 1: the NO_X-dependence of annual mean concentrations of nitrogen dioxide and ozone. *Atmospheric Environment* **38** 5117–5129.

[12] Hayman, G. (2006). Modelling of Tropospheric Ozone. Report AEAT/ENV/R/2100 www.airquality.co.uk/archive/aqsreview2006.php

29. The detailed mapping methodology for the relevant pollutants is set out in a series of reports (Stedman *et al* 2005a[13]; Stedman *et al* 2005b[14]; Vincent *et al* 2006a[15]; Vincent *et al* 2007[16]) but essentially involves the use of dispersion models to estimate the contribution to ambient concentrations from emissions sources. These models are calibrated using data from the national monitoring networks.

Box 1.1: The Importance of Weather

The eventual fate of most pollutants emitted to atmosphere is chiefly governed by the weather. Wind speed and direction are crucial, as is the stability of the atmosphere as this will govern how well the pollutant mixes in with cleaner air. A further important feature of the lowest levels of the atmosphere is the boundary layer. This effectively 'caps' the atmosphere by impeding the upward movement of pollutants. Therefore, the volume of air available to mix and dilute the pollutant is governed by the height of the boundary layer. When the boundary layer height (BLH) is low there is a less available clean air and so higher pollution concentrations are likely. The BLH varies with climatic conditions, with the lowest BLH typically occurring in still, cold conditions, such as cloudless winter nights, and highest BLH normally occurs at midday in summer. Thus, the BLH can vary on a diurnal as well as an annual cycle.

Once in the atmosphere the released pollutant is free to interact with other pollutants and will sometimes form secondary pollutants (e.g. ozone). These secondary pollutants can be formed through a variety of chemical reactions and/or by the action of incident sunlight. These speed of these reactions will depend on the temperature, humidity, amount of sunlight, and wind speeds.

Different pollutants stay in the atmosphere for different lengths of time (i.e. they have different atmospheric residence times) depending on a range of factors. Their eventual removal from the atmosphere occurs as a result of quite complex deposition processes. Some pollutants can be entrained within the processes of cloud formation and then removed from the atmosphere in falling rain. Alternatively, these pollutants may be washed out of the atmosphere by rain falling and literally knocking them out of the atmosphere. Both of these processes are known as "wet deposition".

[13] Stedman, J. R., Bush, T. J., Vincent, K. J., Kent, A. J., Grice, S., Abbott, J. (2005a) UK air quality modelling for annual reporting 2003 on ambient air quality assessment under Council Directives 96/62/EC, 1999/30/EC and 2000/69/EC. National Atmospheric Emissions Inventory, AEA Technology, National Environmental Technology Centre. Report AEAT/ENV/R/1790. http://www.airquality.co.uk/archive/reports/cat05/0501121424_dd12003mapsrep4.pdf

[14] Stedman, J. R., Bush, T. J., Grice S., Kent, A. J., Vincent K. J., Abbott J., Derwent, R. (2005b). UK air quality modelling for annual reporting 2004 on ambient air quality assessment under Council Directives 96/62/EC, 1999/30/EC and 2000/69/EC. AEA Technology, National Environmental Technology Centre. Report AEAT/ENV/R/2052

[15] Vincent, K. J., Passant, N., Coleman, P., Stedman, J. R. (2006a) Assessment of heavy metal concentrations in the UK. AEA Technology, National Environmental Technology Centre. Report AEAT/ENV/R/2013. www.airquality.co.uk/archive/aqsreview2006.php

[16] Vincent, K. J., Bush, T., Coleman, P., (2007) Assessment of benzo[a]pyrene concentrations in the UK in 2005, 2010, 2015 and 2020. AEA Energy & Environment. Report AEA/ENV/R/2373. www.airquality.co.uk/archive/aqs2007.php

Box 1.1: The Importance of Weather *(continued)*

Those pollutants that are not wet deposited can be dry deposited due to gravitational settling as the pollutant comes into contact with the ground, by reaction on surfaces, or through take up by living organisms. The rate at which this happens is governed by characteristics of the pollutant, the ground surface or organism type and the weather. For example, plants form an important mechanism for removing ground level ozone from the atmosphere, but the rate at which they do so is influences by temperature, humidity, soil moisture, wind speed and so on.

Examples of the influence of weather conditions on typical air quality include:

- There is a diluting effect of **wind speed**: at London Hillingdon, an approximate halving of NO_X concentrations with a doubling of wind speed from 5 to 10 $m.s^{-1}$ has been shown.
- $PM_{2.5}$ decreases when **wind speed** increases due to dilution but PM_{coarse} increases with wind speed due to re-suspension. These effects show the different sources of PM components.
- Daily maximum ozone concentration is highly sensitive to **temperature**, particularly where this rises above around 24-25°C. At Lullington Heath in Sussex, between 1993 and 1998, a rise from 25-30°C typically produced a rise in ozone peak of around 60 $\mu g.m^{-3}$, compared to 13 $\mu g.m^{-3}$ for a 10-15°C rise (Anderson *et al*. (2001).
- **Precipitation** can reduce PM concentrations dramatically, although other weather factors are also associated with rainfall, such as wind speed. Around a 6 $ug.m^{-3}$ difference in PM_{10} has been observed in Edinburgh between days with with no rainfall and those with >20mm rainfall.
- The incidence of certain **wind directions** can also lead to high pollution concentrations. An unusually high number of easterly and south-easterly winds in February/March 1996 resulted in a increase in the exceedences of the PM_{10} 24hr average objective across the UK monitoring network.

1.2.3.3.1 Current years

30. UK maps of estimated annual mean background pollutant concentrations for current years are constructed by considering the pollutant concentration to be made up from several components: a contribution from relatively distant sources both within and outside the UK (the regional contribution, estimated from interpolated rural measurements); a contribution from point sources (calculated using a dispersion model) and a contribution from local area emissions (derived from emissions estimates using a dispersion kernel modelling approach).

31. The difference between the measured urban background concentrations and the sum of the underlying rural concentration field and point source contributions at the monitoring site locations is used to calibrate the area source models. This then allows the mapping of the urban component, using the National Atmospheric Emissions Inventory (NAEI) which is spatially disaggregated on a 1km x 1km OS grid square basis for the UK. The rural, point source and urban UK concentration fields are estimated separately and then combined to produce an overall assessment of pollutant concentrations. Secondary PM_{10} concentrations are estimated from rural measurements of sulphates and nitrates. For PM_{10} an additional component is also added, to take account of the coarse fraction of particles.

32. Annual mean benzene, 1,3-butadiene, PM_{10}, NO_2 and 8-hour CO concentrations have also been calculated for major urban UK roads, for 2003 and future years as appropriate. The production of these maps involves an examination of pollutant measurement data to derive a relationship between the "roadside increment" of pollutant concentrations and vehicle emission estimates. Current roadside concentrations have then been estimated from the sum of background concentrations and this increment. Future roadside concentrations for these pollutants have been predicted by applying emission reductions to the modelled roadside concentrations, and adding the appropriate projections for urban background concentrations.

1.2.3.3.2 Future years

33. A range of methods have been used to project future air quality, based on estimates of future emissions. Baseline projections for the review of the Air Quality Strategy are described by Grice *et al* 2006[17] and scenarios projections are described by Stedman *et al* (2006[18]). Mapping of current and future pollutant concentrations across the UK involves the estimation of concentrations at geographic points for which there is no ambient monitoring data. Mapping therefore introduces additional uncertainties when compared to analysis conducted at sites for which there is ambient monitoring data. Nevertheless, maps produce additional information which cannot be derived from analysis of ambient monitoring data alone. In particular they allow the estimation of:

- the extent of exceedences of the Strategy's objectives in urban background, roadside

17 Grice, S., Bush, T., Stedman, J., Vincent, K., Kent A. and Targa J. (2006) Baseline projections of air quality in the UK for the 2005 review of the air quality strategy. National Atmospheric Emissions Inventory, AEA Technology, National Environmental Technology Centre. Report AEAT/ENV/R/1936.
http://www.airquality.co.uk/archive/aqsreview2006.php

18 Stedman, J. R., Grice, S., Bush, T. J., Murrells, T. P. and Hobson, M. (2006) Projections of air quality in the UK for additional measures scenarios for the 2005 review of the air quality strategy. National Atmospheric Emissions Inventory, AEA Technology, National Environmental Technology Centre. Report AEAT/ENV/R/1986. www.airquality.co.uk/archive/aqsreview2006.php

or industrially influenced locations where there is no monitoring data;

- the health and non-health impacts across the UK (when combined with dose response relationships) associated with current and future pollutant concentrations expected on the basis of existing national policy measures; and
- a proportion of the additional health and non-health benefit that might accrue across the UK as a result of further reductions in pollutant emissions or the proportion of health and non-health disbenefits which might accrue across the UK as a result of increases in pollutant emissions.

1.2.3.3.3 Uncertainty in modelling

34. Quantifying uncertainty in the national models is difficult. The surest ways to judge the accuracy of the models is to compare model results with actual measurements where these are available.

35. The empirical models used to calculate the maps of air pollutants presented in Volume 2 have been calibrated using the measurements from the 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.

36. European air quality directives set data quality objectives for uncertainties in modelled data of either less than 30% or less than 50% of the true value depending on the pollutant. Verification of model results with measurements at monitoring sites not used to calibrate the model shows that model predictions are largely well within these objectives[19]. This represents uncertainty at individual sites in a particular year. 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. With one or two exceptions the majority of modelled O_3 results were usually within ±50% of that observed.

1.2.3.3.4 Uncertainties associated with the geographic scale of assessment

37. 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 NAEI estimates of emissions of air pollutants at a 1 km^2 scale and is calibrated to AURN measurements.

38. The national assessment provides a robust estimate of air quality throughout the UK that is appropriate for this 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 local air quality management (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

19 See footnote 13.

unlikely though 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.

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

1.2.3.4 Emissions

40. This section describes the approach to estimating future emissions of air pollutants and the assumptions about policies that have been included. Table 1.1 summarises the latest emissions projections for all the pollutants considered in the Strategy and used in the assessment of the baseline concentrations in the Strategy's 2006 consultation document. Information on the main sources and the trends is given in each pollutant section.

Table 1.1: Total UK emissions used for modelling concentrations (kilotonnes unless stated)

Pollutant	2002	2003	2004	2005	2010	2015	2020
PM_{10}	161	*156	n/a	148	134	134	142
$PM_{2.5}$	93	*89	n/a	81	73	72	75
NO_X	1582	*1525	n/a	1413	1119	992	869
SO_2	1002	*933	n/a	795	484	397	360
VOCs**	1186	*1120	n/a	990	848	857	883
B[a]P (kilograms)	n/a	n/a	11,533	11,463	11,182	11,128	11,346
Benzene	13.5	*12.8	n/a	11.3	10.1	9.9	10.4
1,3-Butadiene***	3.65	n/a	n/a	n/a	n/a	n/a	n/a
CO***	3238	n/a	n/a	n/a	n/a	n/a	n/a
Lead (tonnes)***	162	n/a	n/a	n/a	n/a	n/a	n/a
NH_3	n/a	n/a	336.4	n/a	276.5	275.2	272

* value interpolated from the 2002 and 2005 emission totals.

** estimated as non-methane volatile organic compounds.

*** no projections have been produced for 1,3-butadiene, CO or lead.

41. Motor vehicles are the major contributor to urban ground level concentrations of most of the pollutants covered by the Strategy. Projections of future emissions from this sector are therefore central to estimating future air quality. The projections for this work use the road traffic emissions factors and methods incorporated in the NAEI. Full details of the methods and factors are available on the web site www.naei.org.uk.

42. Emission projections[20] are based on Department of Trade and Industry UEP12 energy forecasts[21], Department for Transport ten year Plan for Transport updated in September 2004[22] and the 2002 NAEI[23]. It should be noted that the 2004 NAEI is now available. This has not changed these emissions significantly. Sensitivity analyses have been carried out using UEP21 and UEP 26 (see section 1.2.4.1) The emission projections assume that measures are introduced when required by legislation and not earlier and that all processes comply with this legislation.

43. The assumptions behind the activity data in the road transport emission projections contained in the current emission forecasts are:

- central traffic forecasts for Great Britain, by area and vehicle type, taking account of the Ten Year Plan for Transport;
- primary NO_2 assumptions – Model estimates of NO_2 concentration in the future have been calculated using relationships to NO_X concentrations derived from recent ambient monitoring data. Recent evidence has indicated that the primary NO_2 emission fraction has increased in recent years, particularly at some locations and may increase in the future. A sensitivity analysis has been undertaken using different percentage as primary NO_2 (see section 1.5.3.1)
- fleet turnover – the rate at which new vehicles penetrate the fleet and old ones are taken out are calculated by a fleet turnover model based on average survival rates and figures; and
- diesel car sales assumed to grow to 42% by 2010.

44. The dates that the Euro 3 and 4 standards come into effect are largely based on the regulatory implementation dates. However, early introduction of new petrol cars meeting the Euro 4 standard has been assumed starting at 1% of petrol car sales in 2000 and reaching 81% of sales by 2005 and 100% of sales by 2006. Also, the penetration of new diesel cars fitted with particulate traps and the retrofitting of some heavy duty vehicles (HDV) with particulate traps are assumed. It is assumed that the fraction of new diesel cars fitted with particulate traps rises from 5% in 2005 to 20% by 2004 at which point it is assumed to remain constant. The assumption is made that 4,000 HDV are retrofitted with particulate traps in 2000, rising each year to a cumulative total of 14,000 by 2005, representing about 20% of the bus fleet and 2-4% of the heavy goods vehicle (HGV) fleet.

45. The regulations that have been taken into account are: Large combustion plant Directive (LCPD)[24]; Integrated Pollution Prevention and Control Directive (IPPC) Directive; Solvent Emissions Directive; Marpol VI[25]; Sulphur content of liquid fuels regulations; and European directives on vehicle emissions and fuel quality. Current discussions in Europe on Euro 5

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[20] See Footnote 17.

[21] Department of Trade and Industry updated emissions projections. Final projections to inform the National Allocation Plan (NAP) 11 November 2004 www.dti.gov.uk/energy/sepn/uep2004.pdf?pubpdfdload=04%2F2099

[22] The Future of Transport White Paper CM6234. www.dft.gov.uk/stellent/groups/dft_about/documents/divisionhomepage/031259.hcsp

[23] UK emissions of air pollutants 1970 to 2002 (2005). www.airquality.co.uk/archive/reports/cat07/0505171411_1_main02_pt1_d1_FD1.doc

[24] The UEP12 projections are broadly consistent with an emissions limit value approach. UEP26 utilises a combined approach of National Emission Reduction Plan (NERP) and Emission Limit Value (ELV) as specified in the UK's National Plan submitted in February 2006. UEP21 however follows the same approach as UEP12 and is based on the ELV approach only.

[25] An international agreement under the UN for limiting air pollution by ships. From 19th May 2005 the fuel used must contain no more than 4.5% sulphur.

and Euro 6 have not been included in the baseline.

46. Table 1.1 and Figure 1.2 to Figure 1.9 below summarise the latest UK total emissions projections.

Figure 1.2 Total UK primary PM_{10} emissions, kilotonnes

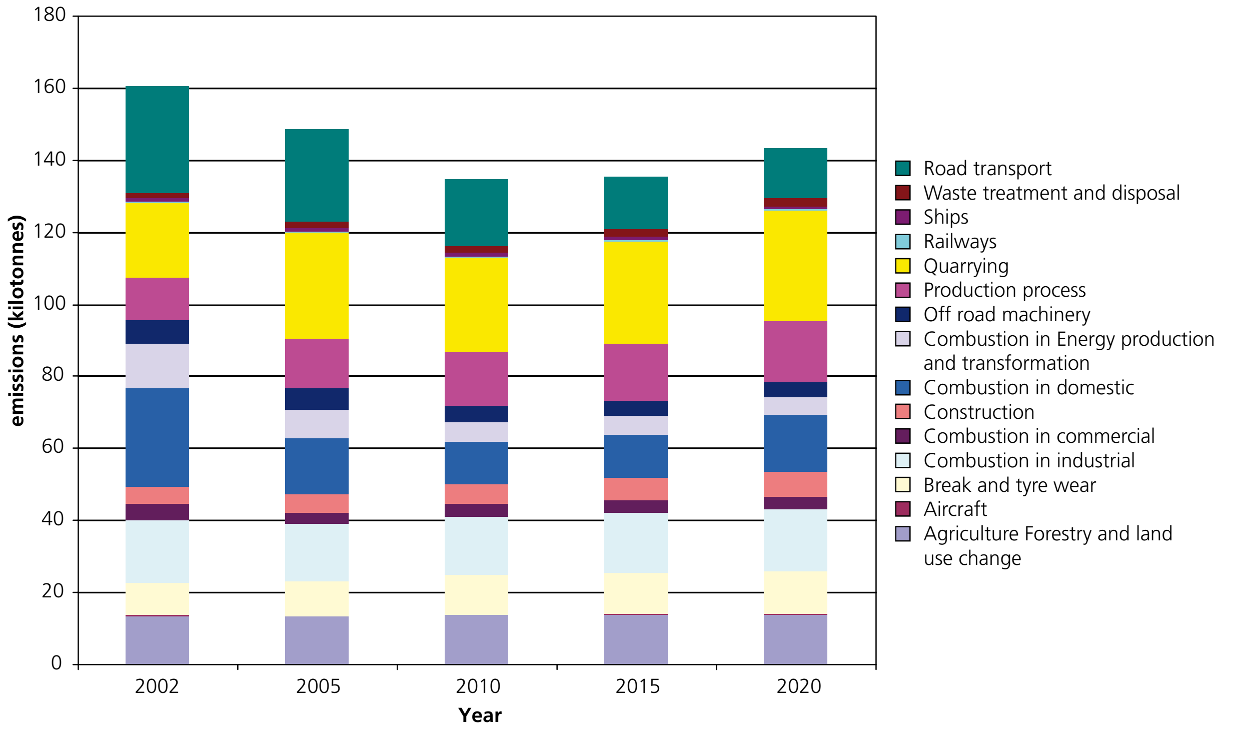


Figure 1.3 Total UK primary $PM_{2.5}$ emissions, kilotonnes

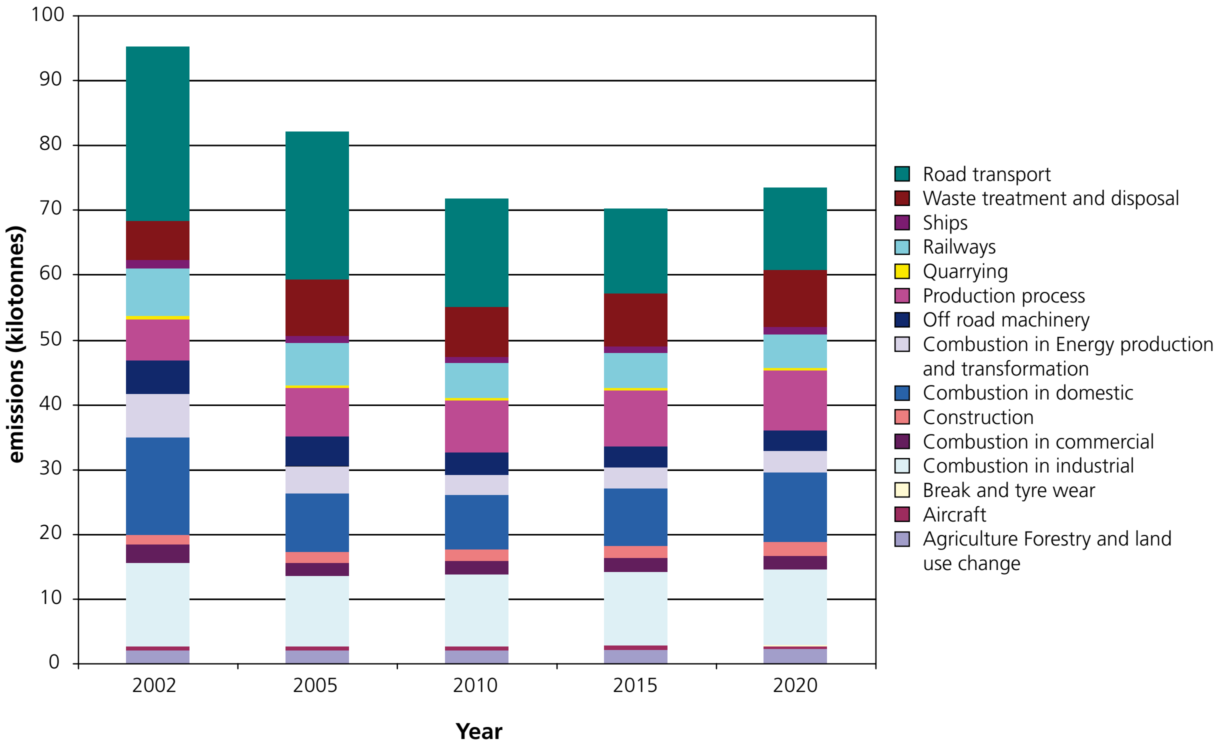
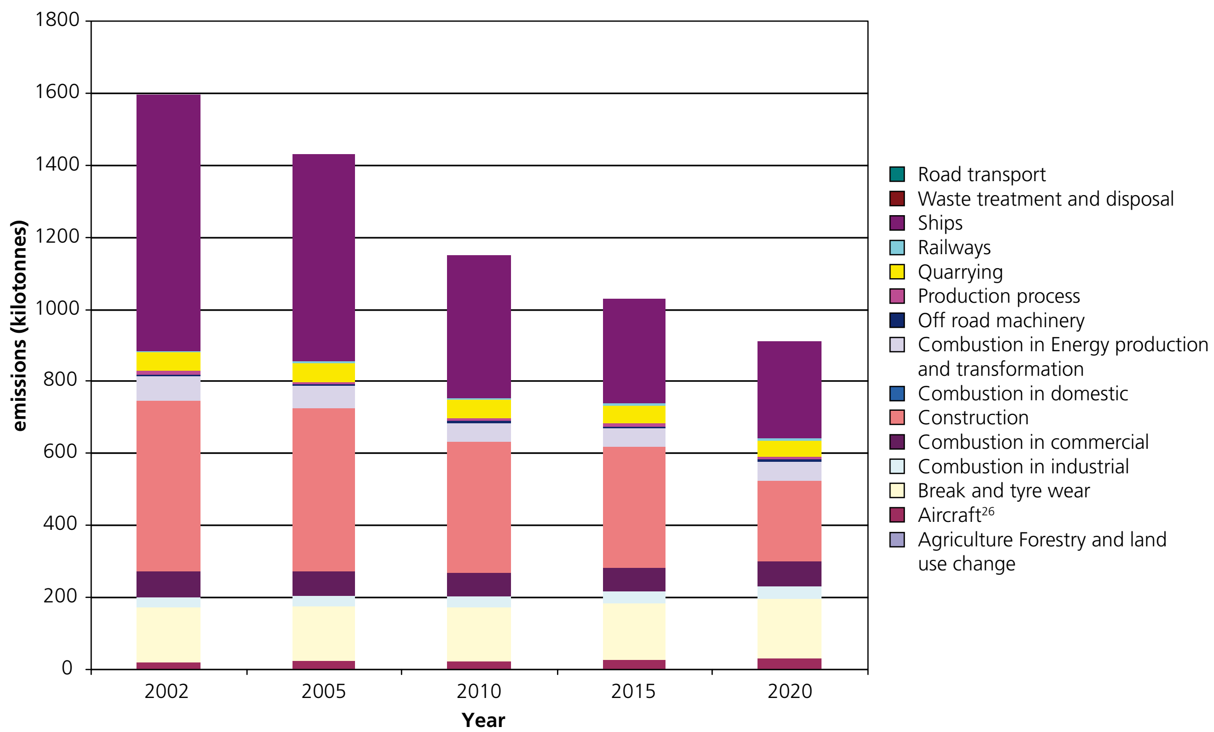


Figure 1.4 Total UK emissions oxides of nitrogen, kilotonnes



[26] Aircraft emissions refer to the landing and take off (LTO) cycle only.

Figure 1.5 Total UK emissions sulphur dioxide, kilotonnes

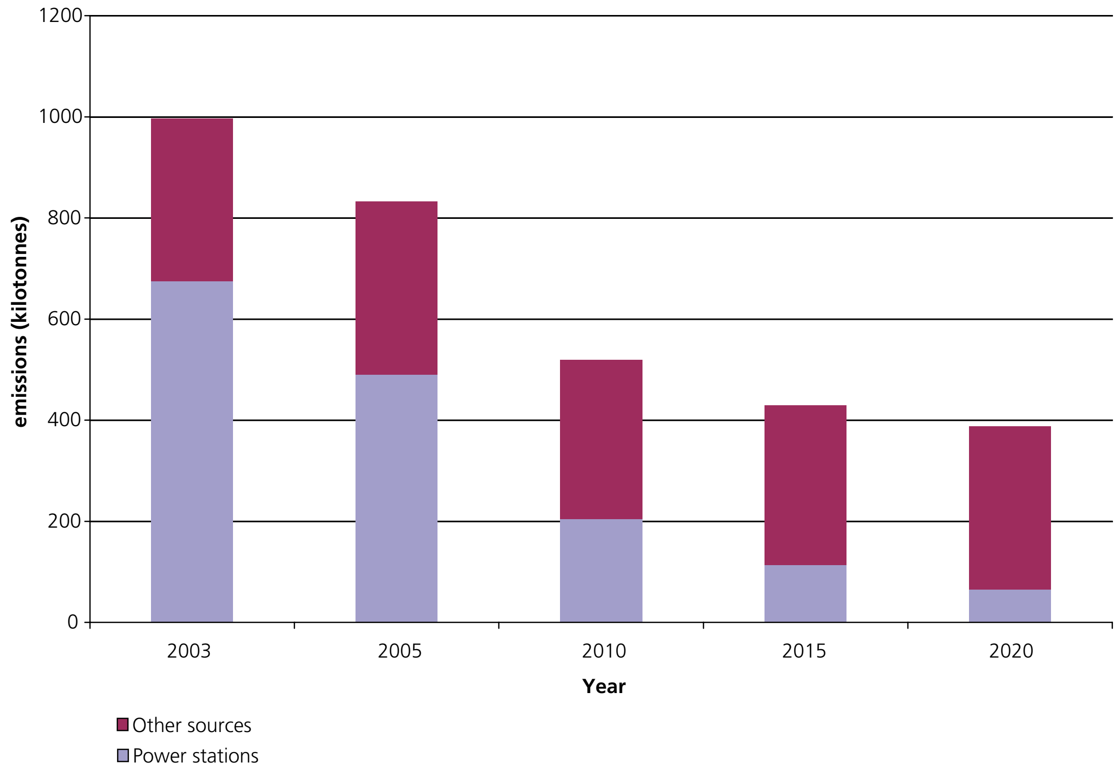


Figure 1.6 Total UK non-methane volatile organic compound emissions, kilotonnes

Figure 1.7 Total UK benzene emissions, kilotonnes

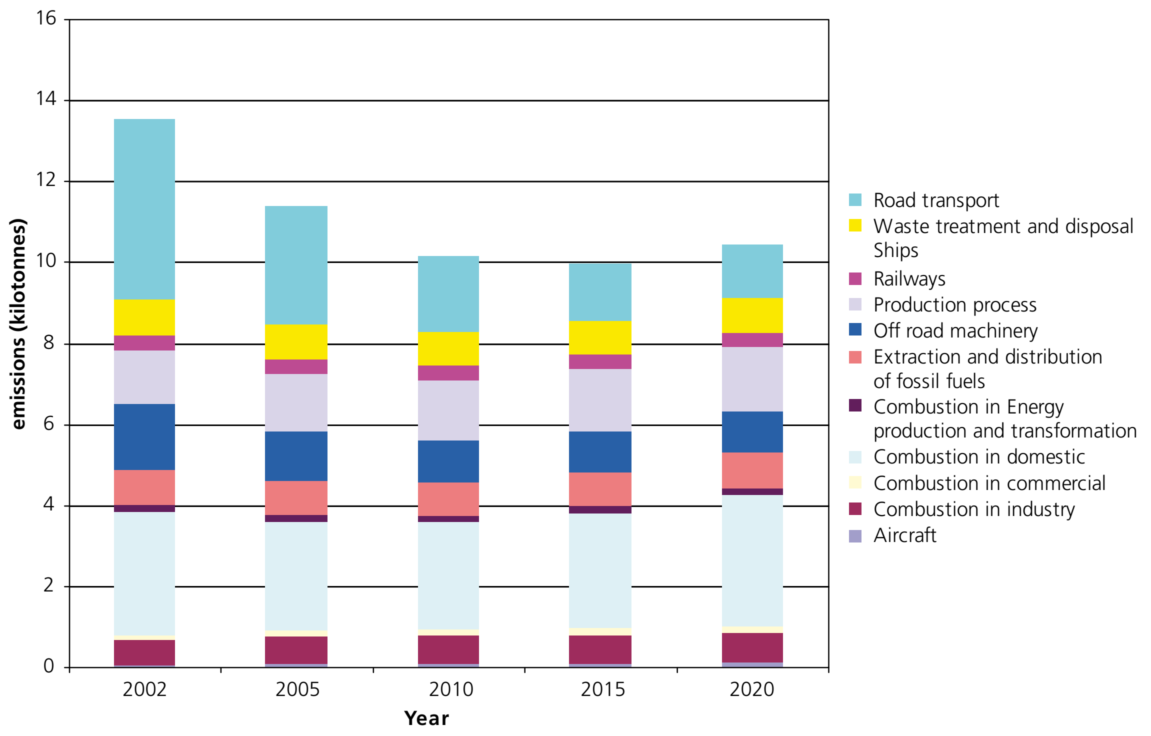


Figure 1.8 Total UK ammonia emissions, kilotonnes

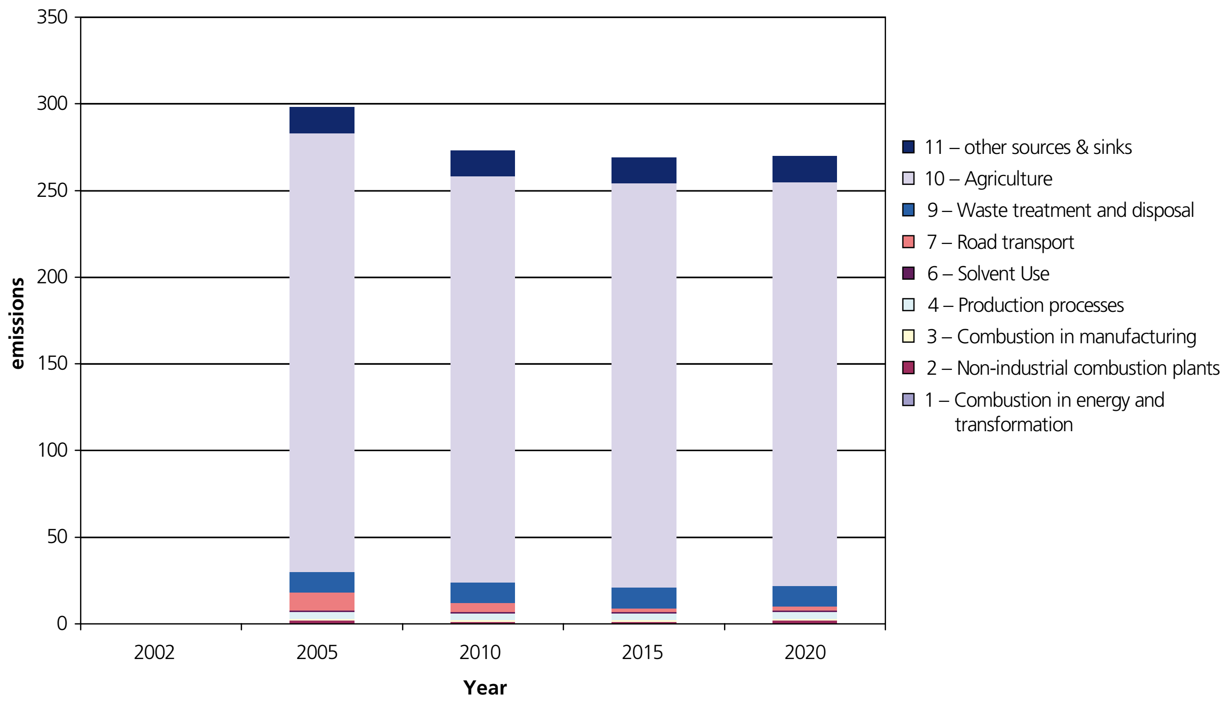
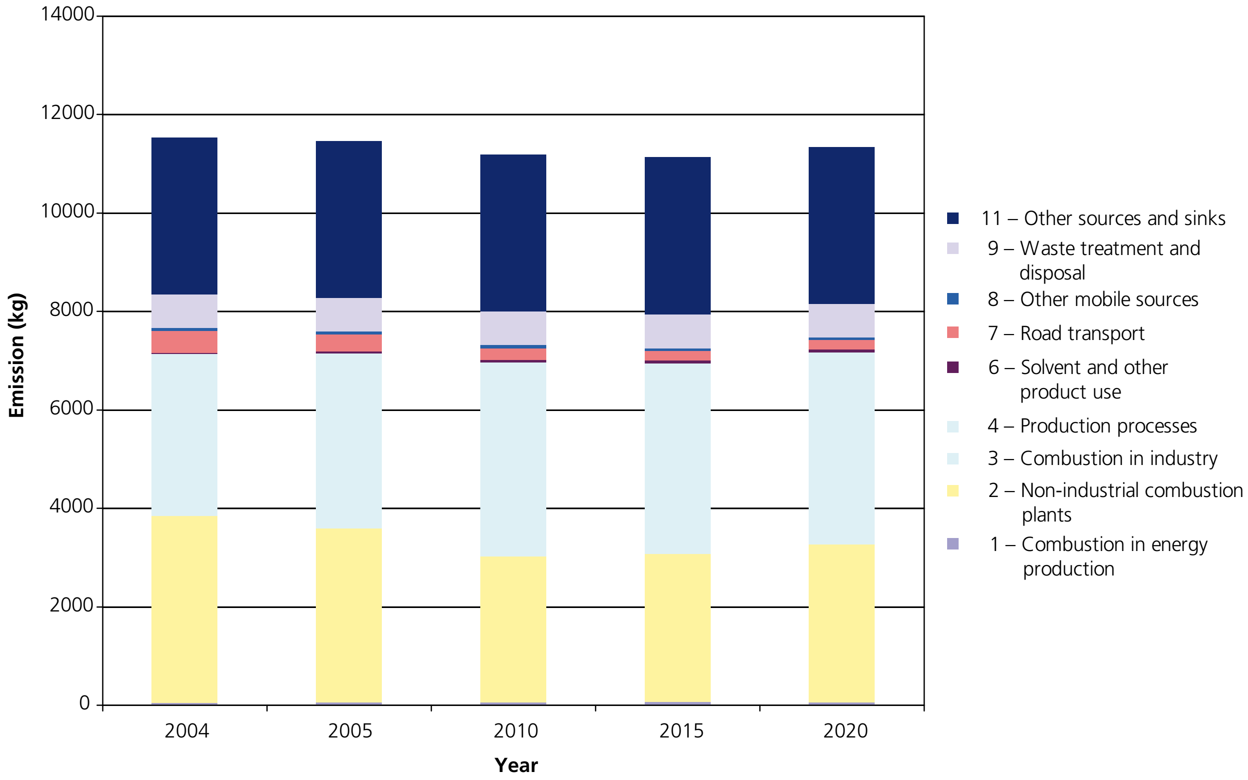


Figure 1.9 Total UK benzo[a]pyrene emissions, kilograms



1.2.3.4.1 Uncertainty associated with current estimates of pollutant emissions

47. The NAEI provides, in its annual report, a quantitative estimate of the uncertainty in emission inventories[27]. Table 1.2 summarises the range of uncertainty for the pollutants and O_3 precursors included in the Air Quality Strategy. Estimates of emissions for the main pollutants from fuel combustion are generally quite certain. These estimates are discussed further in the relevant pollutant sections.

[27] See footnote 23.

Table 1.2: Uncertainty of the Emission Inventories

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
PM_{10}	–20 to +50
$PM_{2.5}$	–20 to +30
PAH (Benzo[a]pyrene)	–70 to +200
Lead	–20 to +30

1.2.4 Changes in the baseline since the consultation document

48. These uncertainties refer to uncertainties in the UK total emissions. Uncertainties in emissions from specific sectors will usually be higher than these values, but statistically cancel out in the estimation of emission uncertainties over all sectors. The science has moved on with time and a number of improvements have been made to the baseline since the consultation document on the Air Quality Strategy was published. These can be grouped together under the headings:

- energy projections;
- model improvements;
- meteorology;
- primary NO_2;
- 15-minute mean SO_2 modelling; and
- PAH modelling.

49. It is recognised that these areas (and others) continue to move on and a line must be drawn beyond which it is not possible to incorporate any further changes into the evidence base for the review of the Air Quality Strategy. The final modelling for the Strategy was completed at the end of 2006 and any further changes since then to the energy projections, transport emission factors, model improvements and emission inventories have not been incorporated.

1.2.4.1 Energy projections

50. There have been several changes to the energy projections since the consultation document on the review of Strategy was produced. The projections used in the consultation document were UEP12. Sensitivity analysis has been undertaken for the baseline and the consultation document's policy Measure Q (combined measure including

early Euro 5, incentivising Low Emission Vehicle (LEV) and small combustion plant for UEP21[28] and UEP26[29] and for Measure R (new combined measure including [early] Euro 5, incentivising LEV and shipping) for UEP26 to consider the potential effects of these new energy projections on the combined measures to be taken forward and to enable comparison with the measures in the consultation document.

1.2.4.2 Updated model

51. The modelling undertaken in the Strategy's consultation document used the 2003 version of the national model as outlined in Stedman *et al*, 2005[30]. The model was revised and improved with changes to a number of areas (Kent *et al*, 2006[31]):

- a revised source apportionment of regional rural NO_X concentrations to take account of the contributions from shipping and sources in continental Europe;
- incorporation of non-linearity in the impact of changes in precursor emissions on secondary PM, equivalent to producing 1 unit of sulphate from every 2 units of SO_2. This is considered to be closer to real world atmospheric chemistry than using the one unit of secondary PM produced from one unit of precursor emissions, used in the original modelling for the consultation document. It is also more in line with the methodology used for modelling used by European Monitoring and Evaluation Programme (EMEP);
- a more consistent source apportionment of PM_{10} and $PM_{2.5}$ concentrations (Stedman *et al* 2007b[32]). Both PM_{10} and $PM_{2.5}$ maps for 2004 were calibrated using gravimetric monitoring data.

52. A sensitivity analysis has been conducted on this revised 2004 model using the UEP21 and UEP26 energy projections and on the baseline and Measure Q to enable comparison with the 2003 model. Further details are given in section 1.5.

1.2.4.3 Meteorology

53. Further sensitivity analysis has been carried out using the 2004 base year in addition to 2002 and 2003 which appeared in the Strategy's consultation document (see Section 1.5.1). This provides estimates for an additional base year with less unusual meteorological conditions.

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[28] DTI UEP21 was compiled in February 2006. The UEP21 scenario used in the sensitivity analysis was based on the average of two scenarios – favourable to coal and favourable to gas. The main difference with UEP12 is that higher levels of coal combustion in power stations is predicted in the future. Gas consumption on the other hand is predicted to be slightly lower.

[29] DTI UEP26 was compiled in October 2006. The UEP26 scenario used in this analysis is "favourable to coal". Therefore, higher coal consumption by power stations is predicted in 2010, 2015 and 2020 than in UEP12 and UEP21. The higher coal consumption does not however lead to higher SO_2 emissions from this sector than that predicted by UEP12 and UEP21 due to the fitting of more FGD.

[30] See footnote 13.

[31] Stedman, J. R., Bush, T. J., Grice, S., Kent, A. J., Vincent, K. J., Abbott, J., Derwent, R. G. (2005) UK air quality modelling for annual reporting 2004 on ambient air quality assessment under Council Directives 96/62/EC, 1999/30/EC and 2000/69/EC. AEA Technology, National Environmental Technology Centre. Report AEAT/ENV/R/2052 http://www.airquality.co.uk/

[32] Stedman, J. R., Kent, A. J., Grice, S., Bush, T. J. and Derwent, R. G. (2007b). A consistent method for modelling PM_{10} and $PM_{2.5}$ concentrations across the United Kingdom in 2004 for air quality assessment. *Atmospheric Environment*, **41**, 161-172.

1.2.4.4 Primary nitrogen dioxide

54. Since the Strategy's consultation document was published in 2006 the Air Quality Expert Group (AQEG) has produced a draft report on primary NO_2[33]. The report analyses the recently observed increasing levels of NO_2 at some monitoring sites in the UK and investigates the potential explanations for these increases. Sensitivity analyses have been carried out using the national and ADMS models to ascertain potential effects of an increase in direct NO_2 emissions (see Section 1.5.3.1).

1.2.4.5 15-minute mean sulphur dioxide modelling

55. Further work has been undertaken on the 15-minute mean SO_2 objective to understand what the effects would be of removing the objective. Some installations, in particular those using lower sulphur fuels to meet the 15-minute objective, could therefore theoretically increase their emissions as they would only need to comply with the 1-hour and 24-hour objectives for SO_2. The impact of this increase in emissions on concentrations of SO_2 and secondary PM (which is partially derived from atmospheric reactions involving SO_2) has been estimated using both the UEP21 and UEP26 energy projections and the non-linearity of the changes in precursor emissions on secondary particles described above. This is discussed in more detail in section 1.3.6.5.

1.2.4.6 Polycyclic aromatic hydrocarbons modelling

56. The modelling of B[a]P has been revised and improved over that undertaken for the Strategy's consultation document. Further details are given in section 1.3.6.5 and in Vincent *et al*, (2007)[34]. The improvements incorporated include an improved spatial distribution of domestic fuel use and revisions to emission factors.

1.3 Baseline air quality: pollutant by pollutant

57. The following sections present the results of our assessment of baseline air quality in terms of the expected extent of exceedence of the Air Quality Strategy's objectives and EU Directive limit values and population-weighted mean concentrations.

58. Assessments have been carried out for the years for which the objectives and limit values have been set as appropriate or for years under consideration within the Strategy review of possible additional new policy measures (2010, 2015 and 2020). Baseline projections for NO_2 and PM_{10} start from 2002 and 2003 to show the impact of different meteorology on predicted air quality. Projections for the other pollutants start from 2003. These projections are our current best estimate of the likely impact of current national and international air quality policies on the future concentrations of air pollutants. Sensitivity analyses have been undertaken using 2004 as the base year (see section 1.5.1.1).

[33] Air Quality Expert Group (2006) Trends in Primary Nitrogen Dioxide in the UK. www.defra.gov.uk/corporate/consult/aqeg-nitrogendioxide/index.htm

[34] See Footnote 16.

59. Data from the UK air quality monitoring networks for 2005 are presented within this chapter and compared to the Strategy's existing objectives at the beginning of each pollutant section. Data has only been used where there is 75% data capture over the year in question. All the measured data presented is fully ratified and finalised. Figures show the average concentration for that metric for sites in the national network and the maximum concentration for that metric among the national sites.

1.3.1 Particulate Matter

1.3.1.1 Health effects

60. Evidence has accumulated in recent years to show that day to day variations in concentrations of airborne particles, measured as PM_{10}, $PM_{2.5}$, Black Smoke or other measures, are associated with day to day variations in a range of health end-points. These include daily deaths, admissions to hospital for the treatment of both respiratory and cardiovascular diseases and symptoms amongst patients suffering from asthma. In addition to these effects there is evidence from the United States that long-term exposure to particulate air pollution is associated with a decrease in life expectancy[35]. This effect has been discussed in a 2001 Committee on the Medical Effects of Air Pollutants (COMEAP) report[36]; and a fuller updated report has recently been published as a draft for technical comment[37].

61. There is much current debate about whether the effects of PM10 are in fact due to fine particles, $PM_{2.5}$. The Expert Panel on Air Quality Standards (EPAQS) considered this issue in its report on the most appropriate metric on which to base a particle standard[38]. It noted that some epidemiological studies have suggested that the main toxic component is likely to be in the finer fraction but several have indicated that the toxic effects may not be confined to this fraction. The report concludes that PM_{10} continues to provide the most appropriate basis for a standard although it recommends that the issue should remain under active review.

62. The WHO recently published revised global guidelines for PM_{10} and $PM_{2.5}$ with two interim guidelines for each particulate fraction[39].

1.3.1.2 Sources

63. Particles as PM_{10} and $PM_{2.5}$ are emitted by a wide variety of sources including road vehicles, domestic heating (coal and wood fuels), quarrying, and other industrial sources. Secondary PM and a range of other PM, including natural sources, also contribute to ambient concentrations. Emissions of primary PM, both PM_{10} and $PM_{2.5}$, are expected to

[35] Health Effects Institute (2000) Reanalysis of the Harvard Six-Cities Study and American Cancer Study of air pollution and mortality: a special report of the Institute's Particle Epidemiology Reanalysis Project. Health Effects Institute, Cambridge, USA. Pope, C.A.III, Burnett, R.T., Thun, M.J., Calle, E.E., Krewski, D., Ito, K. and Thurston, G.D. (2002) *Lung cancer, cardiopulmonary mortality and long-term exposure to fine particulate air pollution*. JAMA. **287**(9), 1132-1141.

[36] Department of Health, 2001. Committee on the Medical Effects of Air Pollutants. Statement and Report on Long-Term Effects of Particles on Mortality. London: The Stationary Office, 2001. Available at: www.advisorybodies.doh.gov.uk/comeap/statementsreports/longtermeffects.pdf

[37] Department of Health (2007) Committee on the Medical Effects of Air Pollutants 'Long-term Exposure to Air Pollution: Effect on Mortality' Draft report for technical comment; www.advisorybodies.doh.gov.uk/comeap/statementreports/longtermeffectsmort2007.pdf

[38] Expert Panel on Air Quality Standards (EPAQS; 2001) Airborne particles London: The Stationary Office. Available at: www.defra.gov.uk/environment/airquality/aqs/air_measure/index.htm

[39] Air quality guidelines. Global update 2005. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide; WHO 2006; http://www.euro.who.int/Document/E90038.pdf

continue to decrease until around 2015 (see Figure 1.2 for PM_{10} emissions and Figure 1.3 for $PM_{2.5}$ emissions). The current projections indicate a small increase in PM emissions after 2015. This increase is mainly due to projected increases in activity in the quarrying and domestic coal use sectors. Since these projections were completed, the quarrying emission factor has been revised downwards substantially and projected emissions from this source are overestimated in this assessment. This is, however, a small contributor to total emissions and when the projections are updated in future are unlikely to effect materially the overall results of the assessment and this revision is included in the 2004 model. The emissions projections derived from the revised emission projections UEP21 and UEP26 do not include this increase in domestic coal use.

1.3.2 Particulate Matter PM_{10}

1.3.2.1 Objective attainment/status

64. There are now four PM_{10} objectives to consider: Note that in the new Strategy the 2000 Strategy/Addendum PM_{10} objectives have been replaced by exposure reduction approach for $PM_{2.5}$ – apart from Scotland.

- **for the whole of the UK, an annual mean concentration of 40 µg.m^{-3} by 31 December 2004.**

65. The annual mean 2004 objective was met as an average of all AURN sites in 2005. The highest recorded measurements however did not meet the objectives. Exceedences at both background and roadside locations are expected to have been almost completely eliminated by 2010.

- **for the whole of the UK, a 24-hour mean concentration of 50 µg.m^{-3} not be exceeded more than 35 times a year by 31 December 2004.**

66. The 24-hour mean 2004 objective was met as an average of all AURN sites in 2005. The highest recorded measurements however did not meet the objectives.

67. An annual mean concentration of 31.5 µg.m^{-3} (roughly equivalent to the 24-hour objective) is predicted to be met at background locations. At roadside locations this concentration is expected to be exceeded in some locations for all years, with percentage of total road length exceeding decreasing from around 16% in 2003 to less than 1% in 2020.

- **for Scotland, a 24-hour mean concentration of 50 µg.m^{-3} not be exceeded more than 7 times a year by 31 December 2010.**

68. The uncertainties in modelling seven exceedences a year are very large therefore this objective has not been modelled. Exceedence is highly dependent on the weather.

- **for Scotland, an annual mean concentration of 18 µg.m^{-3} by 31 December 2010.**

69. Exceedences of this objective were measured in 2005 particularly at roadside locations.

70. The objective will be met nearly everywhere by 2010 at background locations but there will still be some exceedences close to urban roads.

1.3.2.2 Current and historic ambient concentrations

1.3.2.2.1 Measurements

71. Figure 1.10 shows progress towards meeting the 2005 24-hour objective for PM_{10}. This objective allows no more than 35 exceedences in a calendar year of a 24-hour average value of 50 µg.m^{-3} and is the most stringent of the PM_{10} objectives currently in force. Four sites (London Marylebone Road, London Camden roadside, Brighton roadside and Bradford Centre) recorded more than the 35 days exceedence in 2005. Three of these sites are roadside or kerbside and are located close to exceptional sources of PM. Bradford Centre is a background site but in 2005 was affected by long-term construction work near the monitoring site that involved stonecutting.

72. Figure 1.11 shows progress towards meeting the 2005 annual mean PM_{10} objective. London Marylebone Road exceeded the annual mean objective with a mean of 44 µg.m^{-3} in 2005. The mean of all 65 PM_{10} sites was 23 µg.m^{-3}. Overall urban PM_{10} concentrations have levelled off since 2000 (with the exception of 2003 and Scotland), whilst emissions of primary PM_{10} have continued to decline.

73. Figure 1.12 gives the annual mean PM_{10} concentrations in Scotland. Four sites out of seven recorded concentrations higher than 18 µg.m^{-3} (the 2010 Scotland objective).

Figure 1.10: Measured 90th percentile of 24-hour mean PM_{10} concentrations in the UK (mean of all sites and highest site and 2004 air quality strategy objective)

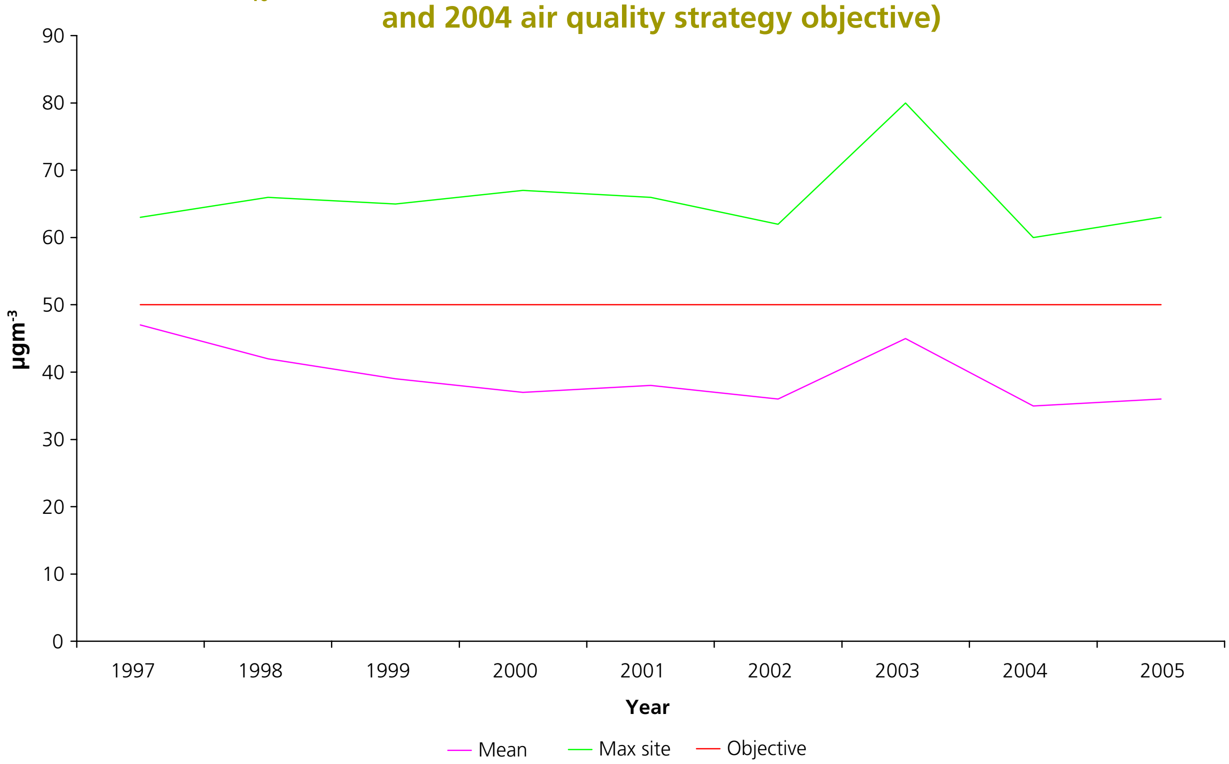


Figure 1.11: Measured annual mean PM_{10} concentrations in the UK (mean of all sites and highest site and 2004 air quality strategy objective)

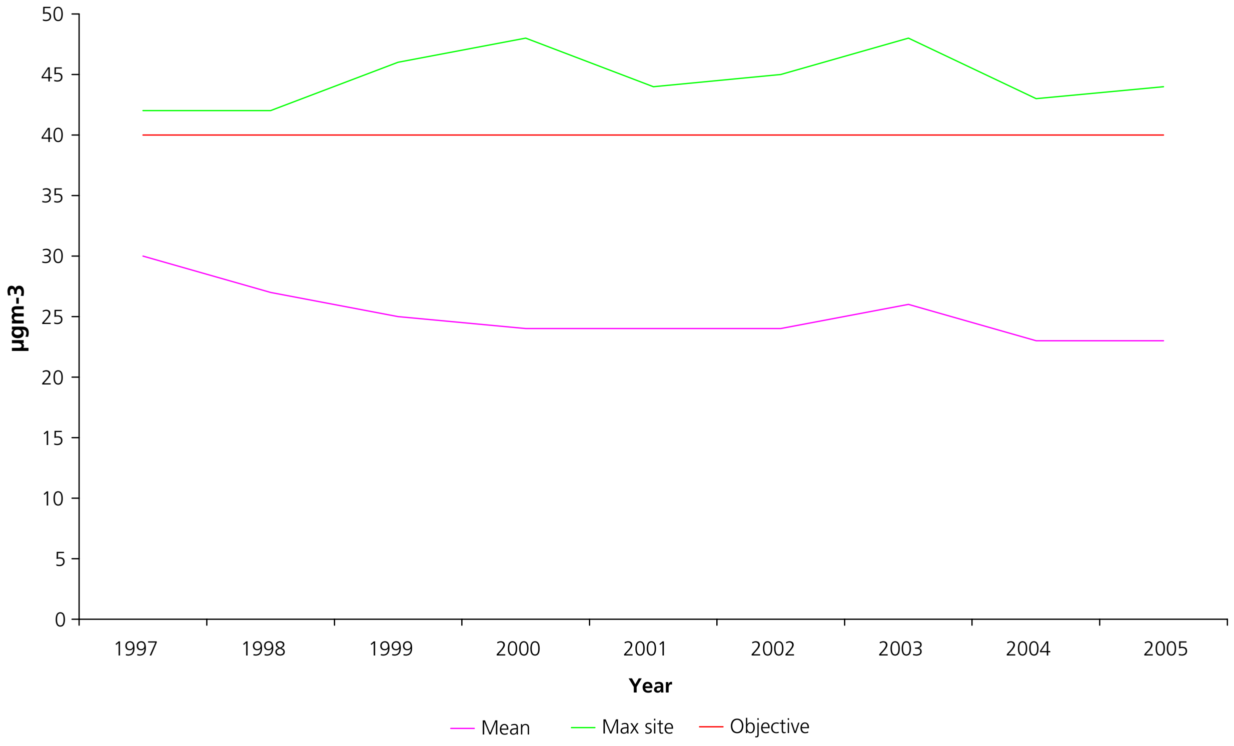
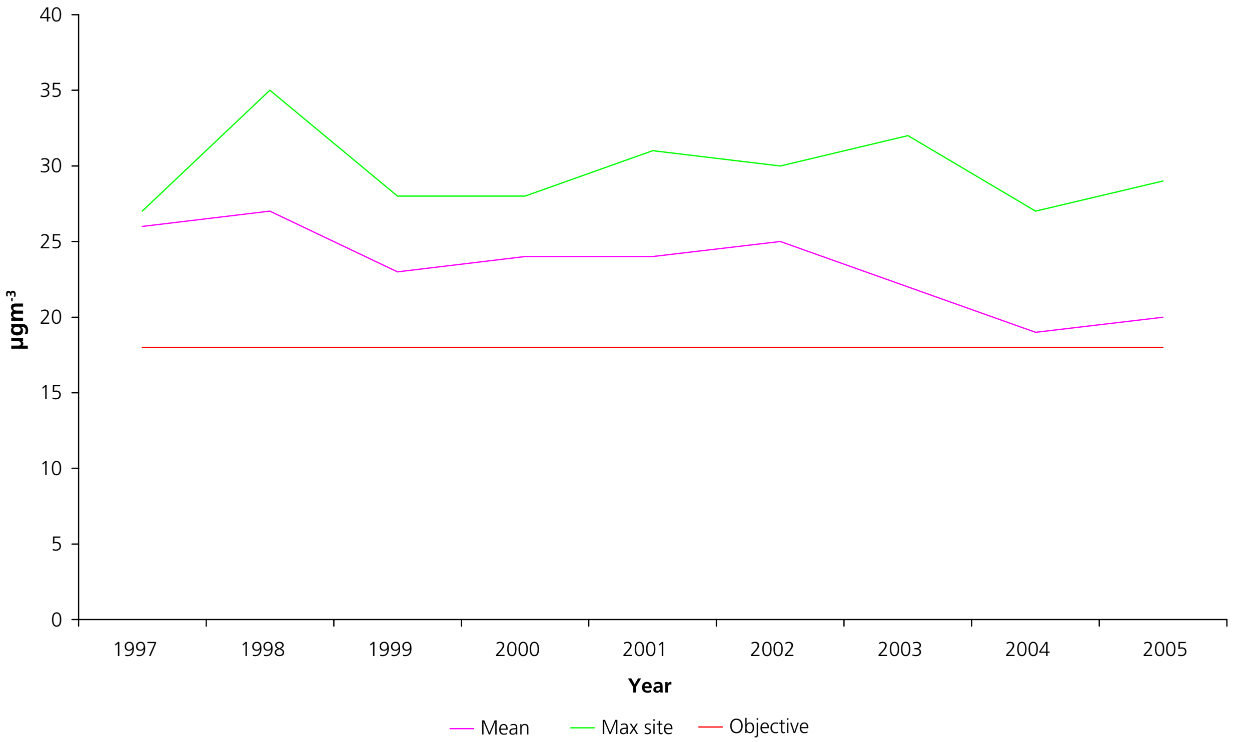


Figure 1.12: Measured annual mean PM_{10} concentrations in Scotland



74. Overall, trends in PM_{10} concentrations for all metrics in all parts of the UK appear to have levelled out in recent years, with the notable exceptions of Scotland in general and 2003 in particular. The AQEG noted in their report[40] that strong downward trends were a widely observed feature of urban PM_{10} levels in the UK during the 1990s, before the apparent levelling off during the 2000–2003 period. Annual average PM_{10} concentrations are declining at about –4.4% per year in the longer term, as indicated by the 12 long-running urban background sites during the 1990s, and this is close to the trend in PM_{10} emissions that has, over the same period, declined at about – 5% per year, according to the NAEI.

75. Although PM_{10} emissions have continued to decline strongly from 1997 to 2003, this is not the case for urban PM_{10} concentrations. Only 12 of 48 sites achieved annual percentage trends during the 1997–2003 period that approached those shown by PM_{10} emissions. The 48-site average showed a trend of – 2.2% per year, one-half of the trend shown by the estimated PM_{10} emissions over the same period. The PM_{10} emission inventory is therefore not giving a clear indication of the likely origin of the observed slowing up in the downwards trends in urban PM_{10} levels observed during 2000–2005.

76. The AQEG report reported on the source apportionment of PM_{10} in the UK. Secondary PM makes an important contribution to total PM_{10} concentrations and the current trends in secondary PM concentrations show a shallower decline than that seen in primary PM emissions or the precursors of secondary PM. There are also contributions to PM_{10} from sources of coarse particles, which remain roughly constant from year to year.

1.3.2.2.2 Modelling

Baseline projections

77. Projected annual mean PM_{10} concentration has been modelled for 2005, 2010, 2015 and 2020. The modelling method used in estimating projected annual mean concentrations in these years closely follows the method used to estimate concentrations in 2003 PM_{10} as described in Stedman *et al* (2005). The model has been calibrated using TEOM measurement data and the results have been multiplied by 1.3 before comparison with objectives and limit values. Maps at background and roadside locations for 2003, 2010 and 2020 are presented in Figure 1.13 to Figure 1.18.

[40] Air Quality Expert Group (2005), Particulate Matter in the United Kingdom. ISBN 0-85521-143-1 http://www.defra.gov.uk/environment/airquality/publications/particulate-matter/index.htm

Figure 1.13: Annual mean background PM_{10} concentration, 2003 ($\mu g.m^{-3}$ gravimetric)

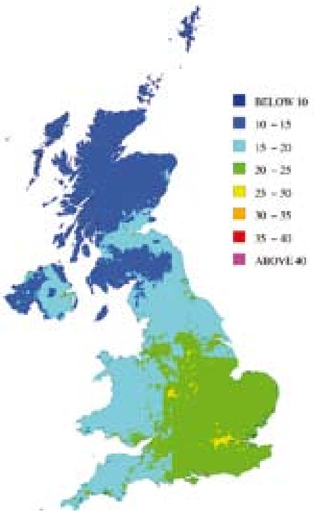


Figure 1.14: Urban major roads, annual mean roadside PM_{10} concentration, 2003 ($\mu g.m^{-3}$ gravimetric)

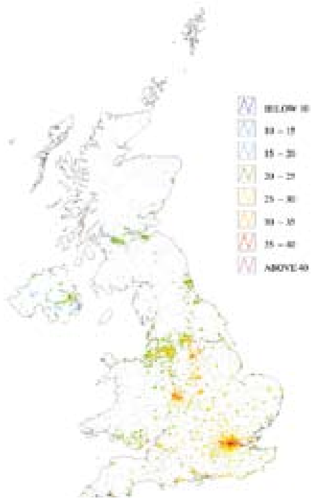


Figure 1.15: Annual mean background PM_{10} concentration, 2010 ($\mu g.m^{-3}$ gravimetric)

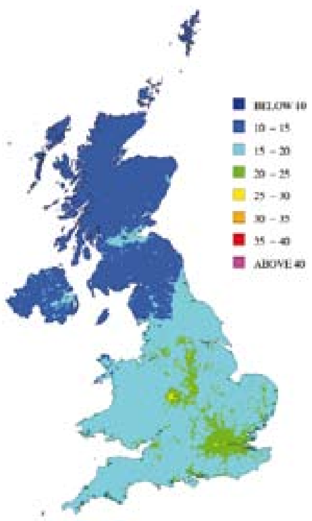


Figure 1.16: Urban major roads, annual mean roadside PM_{10} concentration, 2010 ($\mu g.m^{-3}$ gravimetric)

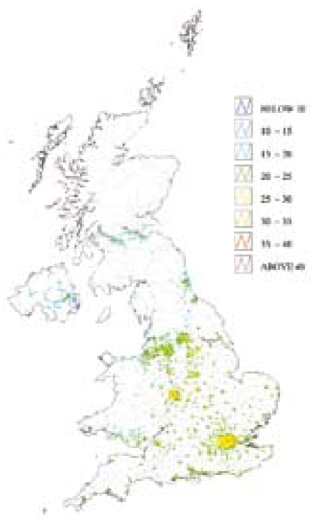


Figure 1.17: Annual mean background PM_{10} concentration, 2020 (µg.m^{-3} gravimetric)

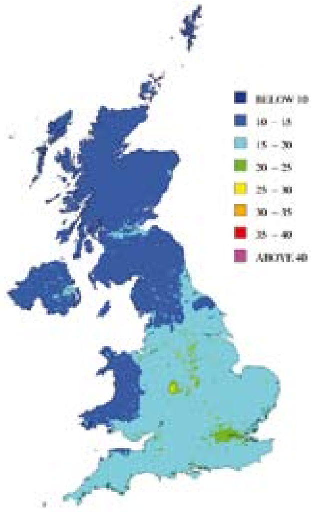
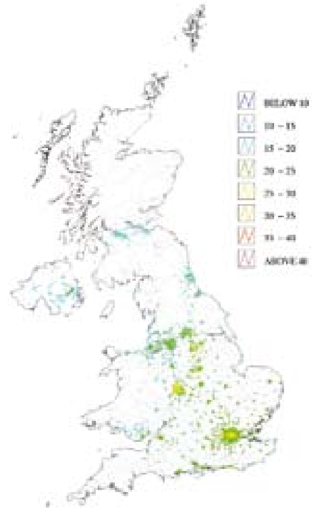


Figure 1.18: Urban major roads, annual mean roadside PM_{10} concentration, 2020 (µg.m^{-3} gravimetric)



78. Modelling results using a 2003 base year, in terms of a comparison of modelled concentrations with an annual mean concentration of 31.5 µg.m^{-3} (roughly equivalent to the Stage 1 PM_{10} 24-hour limit value and objective) are shown in Table 1.3. Estimates of area and population exposure have been derived from the background maps only. No attempt has been made to derive estimates of area and population exposure using maps of roadside concentrations as these maps only apply within approximately 10 metres of the road kerb.

79. Annual mean concentrations were below 31.5 µg.m^{3} across the majority of the UK in 2003 but this threshold was exceeded at a number of locations. The results indicate that it was exceeded at background locations representing less than 0.5% of the UK population and at roadside locations alongside 15.7% of the length of urban major roads. The roadside exceedences were mostly alongside major roads in London and England. The 24-hour Stage 1 limit value was exceeded at 23% of the national automatic monitoring sites.

80. Reductions in PM_{10} concentrations resulting from current policies are expected to lead to a reduction in the extent of exceedence of 31.5 µg.m^{-3}. The extent of exceedence at the roadside is expected to decline to 9.7% of the length of urban major roads by 2005, reducing further to 0.3% by 2020. By 2015 most of the roadside and background exceedences are predicted to be confined to England, particularly in London.

Table 1.3: Summary statistics for UK baseline PM_{10} projections comparison with 31.5 µg.m^{-3}, using a 2003 base year

Total major road length (km) exceeding an annual mean value of 31.5 µg.m^{-3}, gravimetric						
	Total assessed	2003	2005	2010	2015	2020
London	1,886	935.9	513.8	139.9	31.1	20.6
Rest of England (not London)	9,430	1225.8	825.5	158.1	40.6	27.7
Scotland	1,085	27.4	8.0	2.8	0	0
Wales	640	23.8	21	0	0	0
Northern Ireland	1,044	3.9	0	0	0	0
Total	14,084	2216.7	1368.3	300.9	71.7	48.4
% > 31.5 µg.m^{-3}, gravimetric		15.7%	9.7%	2.1%	0.5%	0.3%
Total background area (km^2) exceeding an annual mean value of 31.5 µg.m^{-3}, gravimetric						
	Total assessed	2003	2005	2010	2015	2020
London	1,624	0	0	0	0	0
Rest of England (not London)	128,770	75	51	6	4	5
Scotland	77,791	0	0	0	0	0
Wales	20,745	0	0	0	0	0
Northern Ireland	13,318	0	0	0	0	0
Total	242,248	75	51	6	4	5
% > 31.5 µg.m^{-3}, gravimetric		0.0%	0.0%	0.0%	0.0%	0.0%
Total population (x10^3) exceeding an annual mean value of 31.5 µg.m^{-3}, gravimetric						
	Total assessed	2003	2005	2010	2015	2020
London	7,730	0	0	0	0	0
Rest of England (not London)	41,011	83	57	10	3	5
Scotland	4,945	0	0	0	0	0
Wales	2,851	0	0	0	0	0
Northern Ireland	1,623	0	0	0	0	0
Total	58,160	83	57	10	3	5
% > 31.5 µg.m^{-3}, gravimetric		0.1%	0.1%	0.0%	0.0%	0.0%

81. Exceedences of an annual mean concentration of 18 $\mu g.m^{-3}$ in Scotland, the (provisional) objective for 2010, were much more extensive in 2003 (Table 1.4): at background locations representing 25.7% of the Scottish population and at roadside locations alongside 84.1% of the length of urban major roads. The extent of exceedences is expected to decline as a result of current policies but exceedences at background locations representing 2.1% of the UK population and at roadside locations alongside 23.2% of the length of urban major roads are expected to remain in 2020.

Table 1.4: Summary statistics for Scotland baseline PM_{10} projections in comparison with 2010 annual mean objective, using a 2003 base year

Total major road length (km) exceeding the objective, gravimetric						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
Scotland (18 $\mu g.m^{-3}$ annual average)	1,085	913	822	529	300	252
Total background area (km^2) exceeding the objective, gravimetric						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
Scotland (18 $\mu g.m^{-3}$ annual average)	77,791	647	468	115	68	60
Total population ($x10^3$) in area exceeding the objective, gravimetric						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
Scotland (18 $\mu g.m^{-3}$ annual average)	4,945	1,275	956	250	126	102

82. Population-weighted annual mean PM_{10} concentrations at background locations for a 2003 base year are also presented (Table 1.5). 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. There is a clear reduction in concentrations from 2003 to 2010, 2015 and 2020 with an expected total decline of about 4 $\mu g.m^{-3}$. Grice *et al* (2006)[41] also contains population-weighted annual mean PM_{10} concentrations at background locations with a 2002 base year. The difference, due to the weather in the different base years (i.e. 2003 vs 2002), is about 2 $\mu g.m^{-3}$.

[41] See footnote 17.

Table 1.5: Population weighted mean PM_{10} concentration using a 2003 base year, ($\mu g.m^{-3}$, gravimetric)

	2003	2005	2010	2015	2020
Inner London	27.0	25.7	23.6	22.5	21.8
Outer London	26.0	24.7	22.7	21.6	20.9
Rest of England	22.7	21.9	20.1	19.3	18.7
Scotland	17.2	16.5	15. 5	15.0	14.8
Wales	20.2	19.4	18.0	17.3	16.9
Northern Ireland	19.2	17.6	16.2	15.9	16.1
UK	22.4	21.6	19.9	19.1	18.5

83. Annual mean PM_{10} concentrations were below 40 $\mu g.m^{-3}$ across almost all of the UK in 2003. The 40 $\mu g.m^{-3}$ objective was not exceeded at background locations at all and was exceeded at roadside locations alongside 1.7% of the length of urban major roads. The majority of the exceedences were in Central London. Exceedences of 40 $\mu g.m^{-3}$ at both background and roadside locations are expected to have been almost completely eliminated by 2010.

84. These results are consistent with the conclusions of the independent AQEG report on PM in the United Kingdom, 2005[42].

Modelling results for London using ADMS-Urban

85. We have estimated future air PM_{10} concentrations in London using an alternative model. This allows us to compare the outputs from the national model with those from a different model that uses different processes and input assumptions. The AQEG have previously compared the outputs from the models in detail and concluded that they compared reasonably well taking account of uncertainties inherent in both types of model.

86. A brief description of ADMS-Urban to explain main differences in the assumptions between the national model and ADMS is in section 1.3.4.4.3.

87. Table 1.6 shows the results of the modelling for the base year (2001), 2010 and 2020. The national model and ADMS-Urban estimate near zero and zero exceedences of an annual average of 40 $\mu g.m^{-3}$ PM_{10} in all years. This provides increased confidence that annual average Stage 1 limit value will continue to be met in future years.

88. There is good agreement between model estimates for statistics related to the Stage I limit values. Both models estimate that background areas of Greater London meet the annual average or the 24-hour limit value in the base year and future years. Both models however project widespread exceedences of the stage I 24-hour limit value in future years near to major roads.

[42] See footnote 39.

Table 1.6: Comparison of PM_{10} concentration statistics for Greater London (London boroughs). Base year 2001 (ADMS-Urban) and 2003 (national model)

Year	% of area exceeding 40 $\mu g.m^{-3}$		% of area exceedence 31.5 $\mu g.m^{-3}$*	
	ADMS-Urban	National Model	ADMS-Urban	National Model
Base year	0	0	1	0
2010	0	0	0	0
2020	0	0	0	0
Rate of change from the base year to 2020				

* 31.5 $\mu g.m^{-3}$ is approximately equivalent to the Stage 1 24-hour limit value.

89. Table 1.7 shows population-weighted mean concentrations estimated by ADMS-Urban and the national model. They start from almost the same point in the base year but the national model projects a higher population-weighted annual average in 2010 and 2020. These differences are not large, considering the models use different emissions inventories and assumptions about PM source apportionment. The rate of change of the averages is the same over the full time-frame of the projections.

90. The AQEG PM report notes that current models are likely to provide more robust results for changes in population-weighted means resulting from air quality management options than for the extent of exceedence of threshold concentrations in the future.

Table 1.7: Population-weighted mean annual average PM_{10} concentration for Greater London (London boroughs). Base year 2001 for ADMS-Urban and 2003 for the national model

Year	Population weighted mean ($\mu g.m^{-3}$)	
	ADMS-Urban	National Model
Base year	25.8	25.8
2010	20.3	22.7
2020	18.0	20.9
Rate of change	-0.4	-0.3

91. Figure 1.19 to Figure 1.21 show mapped results for ADMS-Urban for 2001, 2010 and 2020. They show large decreases in background concentrations of PM_{10} between 2001 and 2020. Heathrow has not been modelled in detail and results for Heathrow should be treated with caution. Air quality in the vicinity of Heathrow is being modelled separately as part of the Project for the Sustainable Development of Heathrow[43].

[43] http://www.dft.gov.uk/stellent/groups/dft_aviation/documents/divisionhomepage/032204.hcsp

Figure 1.19: Annual average PM_{10} concentration in Greater London, 2001

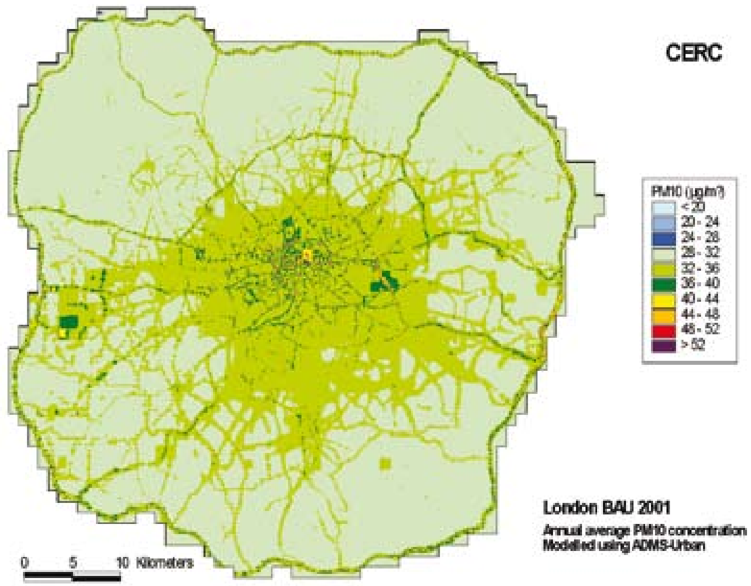


Figure 1.20: Annual average PM_{10} concentration in Greater London, 2010

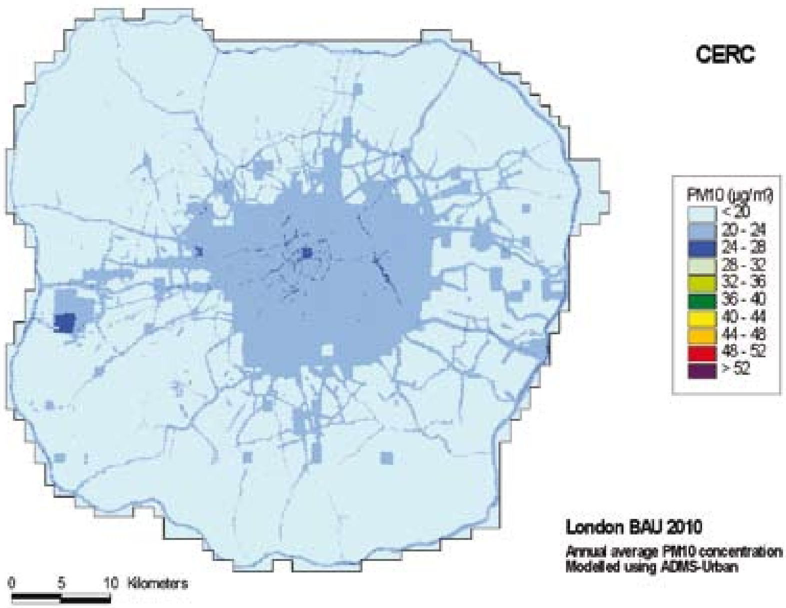
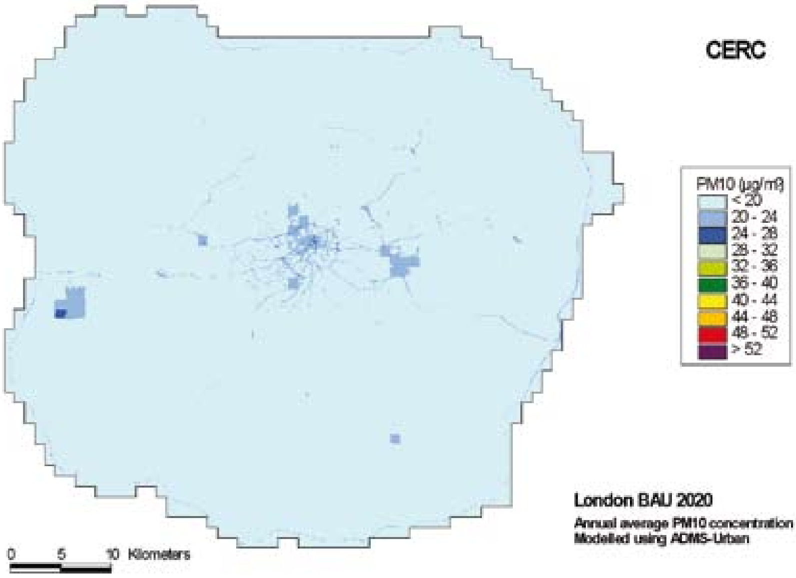


Figure 1.21: Annual average PM_{10} concentration in Greater London, 2020



1.3.2.2.3 Uncertainties in PM_{10} inventories

92. 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.

93. Emission factors are generally based on a few measurements from 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 PM 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.

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

1.3.3 Particulate matter $PM_{2.5}$

95. There are currently no objectives EU limit values or correspondingly, the Air Quality Strategy for $PM_{2.5}$. It is however possible that targets may be set in the future (see Chapter 4) and we have assessed historic concentrations and trends and baseline projections for

future years. We have considered performance against three illustrative $PM_{2.5}$ thresholds to illustrate changes in predicted concentrations in different years.

96. There is little measurement of $PM_{2.5}$ in the UK, compared to PM_{10}. There are currently four automatic $PM_{2.5}$ monitors in the national network, compared to 64 for PM_{10}. In addition there are seven non-automatic $PM_{2.5}$ monitors in the national network that provide additional information on concentrations and trends. Assessment of historic trends and current concentrations at the national level is however more uncertain than for PM_{10}. This should be kept in mind when considering projections of $PM_{2.5}$ concentrations and trends and achievability of any targets for $PM_{2.5}$. The relative uncertainty of $PM_{2.5}$ compared to PM_{10} will reduce if – as planned – the number of $PM_{2.5}$ monitors is significantly increased over the next few years.

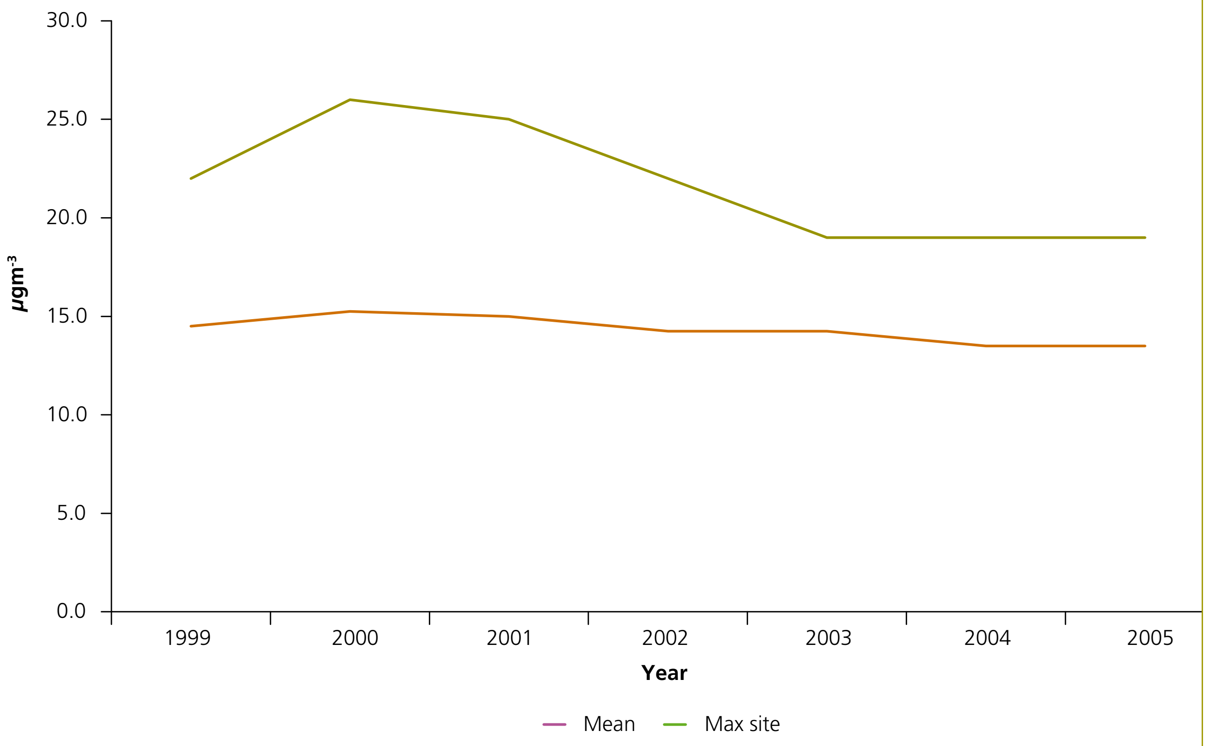
97. An annual mean of 20 $\mu g.m^{-3}$ (gravimetric) is predicted to be met nearly everywhere at background locations and nearly all roadside exceedences of this concentration are expected to have been eliminated by 2015. We have also modelled projected exceedences of lower concentrations to give an idea of what concentrations might be achievable. Background exceedences of an annual mean of 16 $\mu g.m^{-3}$ (gravimetric) are expected to have been eliminated by 2010. Roadside exceedences are expected for all years. Background and roadside exceedences of an annual mean concentration of 12 $\mu g.m^{-3}$ (gravimetric) are predicted for all years in the UK. In Scotland the new annual mean $PM_{2.5}$ objective of 12 $\mu g.m^{-3}$ is predicted to be met at background locations by 2010 and to be exceeded at only 4 km of major road length in 2020.

1.3.3.1 Measurements

98. Figure 1.22 shows the annual mean $PM_{2.5}$ concentrations of all the national sites and the highest site (London Marylebone Road). The mean of all four $PM_{2.5}$ national sites was 13.5 $\mu g.m^{-3}$ (TEOM) in 2005. The $PM_{2.5}$ annual mean concentrations have been declining slightly. AQEG's analysis (AQEG, 2005)[44] on the individual sites showed that London Bloomsbury's observed trend of –0.4 $\mu g.m^{-3}$ per year between 1998 and 2003 corresponds closely with the trend of –0.4 $\mu g.m^{-3}$ per year anticipated at Stoke Ferry on the basis of the observed trend in particulate sulphate. The decline in measured $PM_{2.5}$ is the result of changes in both primary and secondary PM concentrations.

[44] See Footnote 39.

Figure 1.22: Measured $PM_{2.5}$ annual mean concentrations in the UK (mean of all sites and highest site; TEOM measurements)



1.3.3.2 Baseline modelling

99. Maps of annual mean $PM_{2.5}$ at background and roadside locations for 2003 are presented in Figure 1.23 and Figure 1.24. The $PM_{2.5}$ concentrations for 2003 have been calculated using a similar approach to that adopted for PM_{10} described in Stedman *et al* (2005). Projected annual mean $PM_{2.5}$ concentrations have been modelled for 2005, 2010, 2015 and 2020. Background and roadside maps for 2010 and 2020 are presented in Figure 1.25 to Figure 1.28. The method for projecting $PM_{2.5}$ closely follows that adopted for PM_{10}.

100. Monitoring of $PM_{2.5}$ concentrations is currently limited to very few sites in the UK. The differences between concentrations measured by TEOM and gravimetric monitoring is expected to be greater than for PM_{10} and no attempt has been made to scale TEOM measurements to gravimetric equivalent concentrations. In contrast to PM_{10} we have therefore attempted to model gravimetric concentrations directly. The APEG receptor model[45] has been used to assess the source apportionment of the limited gravimetric $PM_{2.5}$ measurement data available for 2003 in the UK. This provides the appropriate scaling factors to derive the secondary $PM_{2.5}$ concentrations from measurements of sulphate and nitrate and a value for the residual $PM_{2.5}$ concentration.

101. The recent AQEG report on PM in the UK presented a comparison of modelled results from the national model and ADMS-Urban for London. This showed broad agreement between the models in terms of the road-lengths and background area exceeding

[45] See footnote 39; Table 8.15 p. 330.

20 µg.m^{-3} in 2010. There are differences in the total area and total road-length assessed in the two models and these are discussed in more detail in the AQEG report.

102. Annual mean $PM_{2.5}$ concentrations were below 20 µg.m^{-3} across much of the UK in 2003. The results indicate that it was not exceeded at background locations but it was exceeded at roadside locations alongside 9.0% of the length of urban major roads.

Figure 1.23: Annual mean background $PM_{2.5}$ concentration, 2003 (µg.m^{-3}, gravimetric)

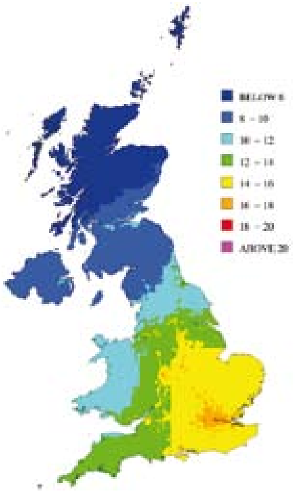


Figure 1.24: Urban major roads, annual mean roadside $PM_{2.5}$ concentration, 2003 (µg.m^{-3}, gravimetric)

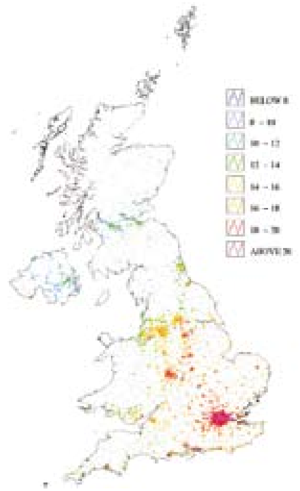


Figure 1.25: Annual mean background $PM_{2.5}$ concentration, 2010 (µg.m^{-3}, gravimetric)

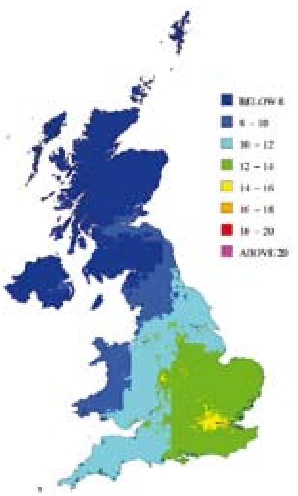


Figure 1.26: Urban major roads, annual mean roadside $PM_{2.5}$ concentration, 2010 (µg.m^{-3}, gravimetric)

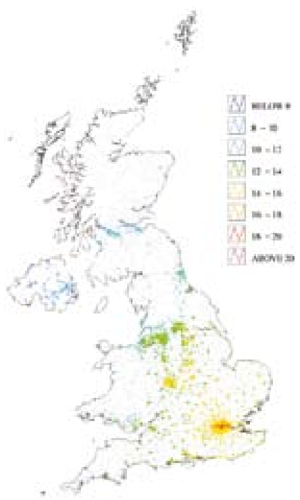


Figure 1.27: Annual mean background $PM_{2.5}$ concentration, 2020 (µg.m^{-3}, gravimetric)

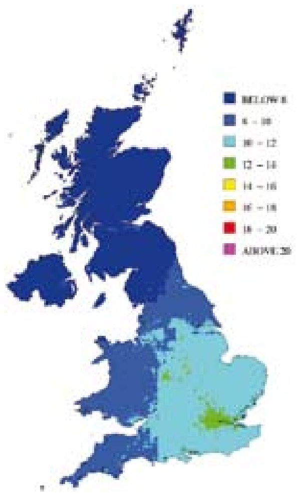
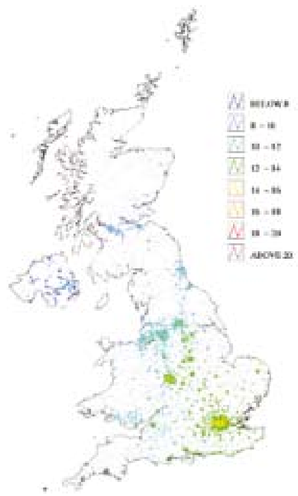


Figure 1.28: Urban major roads, annual mean roadside $PM_{2.5}$ concentration, 2020 (µg.m^{-3}, gravimetric)



103. Modelling results using a 2003 base year, in terms of a comparison of modelled gravimetric concentrations with annual mean concentrations of 20, 16 and 12 µg.m^{-3} are presented in Table 1.8, Table 1.9 and Table 1.10. The latest Air Quality Strategy does not set an absolute objective for $PM_{2.5}$ nor are there EU air quality limit values, but these threshold concentrations have been chosen to illustrate the changes in predicted concentration in different years.

Table 1.8: Summary statistics for UK baseline $PM_{2.5}$ projections comparison with 20 µg.m^{-3}, using a 2003 base year

Total major road length (km) exceeding an annual mean value of 20 µg.m^{-3}						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	1,886	986	333.1	22	1	0
Rest of England (not London)	9,430	271	267	3	0	0
Scotland	1,085	1	0	0	0	0
Wales	640	6	4	0	0	0
Northern Ireland	1,044	0	0	0	0	0
Total	14,084	1,264	603.3	24.2	1	0
% > 20 µg.m^{-3}		9.0%	4.3%	0.2%	0.0%	0.0%
Total background area (km^2) exceeding an annual mean value of 20 µg.m^{-3}						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	1,624	0	0	0	0	0
Rest of England (not London)	128,770	1	0	0	0	0
Scotland	77,791	0	0	0	0	0
Wales	20,745	0	0	0	0	0
Northern Ireland	13,318	0	0	0	0	0
Total	242,248	1	0	0	0	0
% > 20 µg.m^{-3}		0.0%	0.0%	0.0%	0.0%	0.0%
Total population (x10^3) in area exceeding an annual mean value of 20 µg.m^{-3}						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	7,730	0	0	0	0	0
Rest of England (not London)	41,011	0.016	0	0	0	0
Scotland	4,945	0	0	0	0	0
Wales	2,851	0	0	0	0	0
Northern Ireland	1,623	0	0	0	0	0
Total	58,160	0.016	0	0	0	0
% > 20 µg.m^{-3}		0.0%	0.0%	0.0%	0.0%	0.0%

Table 1.9: Summary statistics for UK baseline $PM_{2.5}$ projections comparison with 16 $\mu g.m^{-3}$, using a 2003 base year

Total major road length (km) exceeding an annual mean value of 16 $\mu g.m^{-3}$						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	1,886	1884.6	1879.2	943.2	257	105
Rest of England (not London)	9,430	5491.3	4028	587	73	26
Scotland	1,085	28.5	7	0	0	0
Wales	640	73.1	40.0	5.7	0	0
Northern Ireland	1,044	0	0	0	0	0
Total	14,084	7477.6	5953.8	1535.9	330.3	130.5
% > 16 $\mu g.m^{-3}$		53.1%	42.3%	10.9%	2.3%	0.9%
Total background area (km^2) exceeding an annual mean value of 16 $\mu g.m^{-3}$						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	1,624	1533	980	2	0	0
Rest of England (not London)	128,770	3736	839	21	3	2
Scotland	77,791	0	0	0	0	0
Wales	20,745	2	1	0	0	0
Northern Ireland	13,318	0	0	0	0	0
Total	242,248	5271	1820	23	3	2
% > 16 $\mu g.m^{-3}$		2.2%	0.8%	0.0%	0.0%	0.0%
Total population ($x10^3$) in area exceeding an annual mean value of 16 $\mu g.m^{-3}$						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	7,730	7,565	5,688	10	0	0
Rest of England (not London)	41,011	6,060	1,356	24	2	2
Scotland	4,945	0	0	0	0	0
Wales	2,851	0	0	0	0	0
Northern Ireland	1,623	0	0	0	0	0
Total	58,160	13,625	7,044	34	2	2
% > 16 $\mu g.m^{-3}$		23.4%	12.1%	0.1%	0.0%	0.0%

Table 1.10: Summary statistics for UK baseline $PM_{2.5}$ projections comparison with 12 $\mu g.m^{-3}$, using a 2003 base year

Total major road length (km) exceeding an annual mean value of 12 $\mu g.m^{-3}$						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	1,886	1884.6	1884.6	1884.6	1884.6	1881.8
Rest of England (not London)	9,430	9138.6	9042.5	8028.8	6274.2	4646.9
Scotland	1,085	336.3	166.1	38.1	5.1	4.0
Wales	640	611.0	560.1	233.5	91.9	50.1
Northern Ireland	1,044	0	0	0	0	0
Total	14,084	11970.6	11653.3	10185.1	8255.9	6582.9
% > 12 $\mu g.m^{-3}$		85.0%	82.7%	72.3%	58.6%	46.7%
Total background area (km^2) exceeding an annual mean value of 12 $\mu g.m^{-3}$						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	1,624	1624	1624	1624	1624	1468
Rest of England (not London)	128,770	101687	87973	57524	21866	3510
Scotland	77,791	6	2	0	0	0
Wales	20,745	3554	1954	93	25	13
Northern Ireland	13,318	7	2	0	0	0
Total	242,248	106878	91555	59241	23515	4991
% > 12 $\mu g.m^{-3}$		44.1%	37.8%	24.5%	9.7%	2.1%
Total population ($x10^3$) in area exceeding an annual mean value of 12 $\mu g.m^{-3}$						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	7,730	7,730	7,730	7,730	7,730	7,422
Rest of England (not London)	41,011	37,965	35,897	24,996	17,266	6,147
Scotland	4,945	14	2	0	0	0
Wales	2,851	1,891	1,444	206	33	10
Northern Ireland	1,623	20	7	0	0	0
Total	58,160	47,619	45,081	32,932	25,030	13,579
% > 12 $\mu g.m^{-3}$		81.9%	77.5%	56.6%	43.0%	23.3%

104. The results indicate that in 2003 a $PM_{2.5}$ annual mean concentration of 20µg.m-^{3} was exceeded at 1 km^{2} of background locations and was exceeded at roadside locations alongside 9.0% of the length of urban major roads.

105. Annual mean concentrations were below 16 µg.m^{-3} across much of the UK in 2003 (97.8%) but this threshold was exceeded at a number of locations. Results from the national GIS-based models indicate that it was exceeded at background locations representing 23.4% of the UK population and at roadside locations alongside 53.1% of the length of urban major roads. Reductions in $PM_{2.5}$ concentrations resulting from current policies are expected to lead to a reduction of exceedences of 16 µg.m^{-3}. The extent of exceedence at the roadside is expected to decline to 10.9% of the length of urban major roads by 2010, reducing further to 2.3% by 2015 and 0.9% by 2020. Exceedences at background locations are expected to be almost eliminated by 2010.

106. Exceedences of an annual mean concentration of 12 µg.m^{-3} were much more extensive in 2003: at background locations representing 81.9% of the UK population and at roadside locations alongside 85.0% of the length of urban major roads. The extent of exceedences is expected to decline as a result of current policies but exceedences at background locations representing 43.0% of the UK population and at roadside locations alongside 58.6% of the length of urban major roads are expected to remain in 2015 and 23.3% and 46.7%, respectively, in 2020. Overall the statistics for $PM_{2.5}$ tend to show a steeper decline in the extent of exceedences for the baseline scenario than similar statistics for PM_{10}.

107. Population weighted mean concentrations of $PM_{2.5}$ are presented in Table 1.11. On a UK wide basis population weighted mean concentrations are expected to decline by around 3.5µg.m^{-3} between 2003 and 2020. This ranges from around 2µg.m^{-3} in Scotland and Northern Ireland to around 4.5µg.m^{-3} in London.

Table 1.11: Population weighted mean $PM_{2.5}$ concentration (µg.m^{-3}, gravimetric)

	2003	2005	2010	2015	2020
Inner London	17.4	16.6	14.6	13.6	12.8
Outer London	16.9	16.2	14.3	13.4	12.5
Rest of England (not London)	14.4	13.8	12.3	11.6	10.9
Scotland	9.5	9.1	8.3	7.8	7.5
Wales	12.4	11.9	10.7	10.1	9.6
Northern Ireland	9.7	9.4	8.3	8.0	7.8
UK	14.1	13.5	12.1	11.3	10.7

1.3.3.2.1 Health effects and costs of man-made particles

108. The results for the current (2005) and projected (2020) annual average concentrations for the baseline have been used to both quantify and value the overall health impact of air pollution. Since the dominant component of the overall health impact is the effect of particles on life expectancy, the calculations are based on the effect of $PM_{2.5}$ on years of life lost. Given that not all particles in the air are anthropogenic, estimated non-

anthropogenic $PM_{2.5}$ is subtracted from the baseline concentrations. The effect of current levels of anthropogenic fine particles on those born in 2005 and exposed for the whole of their lifetimes is then calculated. 2005 concentrations are estimated to result in an average loss of life expectancy of up to around 7-8 months[46]. This calculation has also been repeated using the results for the baseline in 2020: average loss of life expectancy is then estimated at up to 5.5 months.

109. Estimates of the overall health effect of particles have also been made that take account not only of people who were born in 2005 or 2020 but also people of other ages. The estimated total life-years lost across the UK population from 2005 baseline levels of anthropogenic $PM_{2.5}$ are up to 38.7 million life years over a 100 year period. 2020 baseline levels of anthropogenic $PM_{2.5}$ result in a total loss of life years of up to 28.1 million life years over a 100 year period.

110. These total life year estimates have been valued according to the agreed methodology described in the IGCB report[47] and suggest societal impacts from the 2005 baseline levels of between £8.6 billion and £20.2 billion. The impact of 2020 baseline levels reduces to £6.2 billion – £14.6 billion.

111. Chapter 2 discusses the health impact of various additional measures to reduce levels of $PM_{2.5}$ further. The estimated total life years lost across the UK population from 2020 $PM_{2.5}$ levels after implementation of a package of measures (Measure R) are expected to be up to 25.6 million life years over a 100 year period. The corresponding value of this loss of life years is estimated at between £5.7 and £13.3 billion per annum.

112. Further details describing these calculations are provided in the IGCB report. It should be noted that these calculations are subject to a significant degree of uncertainty.

1.3.3.3 The Exposure Reduction approach

113. The underlying principle for an exposure reduction approach is that the most effective and efficient way to maximise health benefits for non-threshold pollutants is to ensure an overall reduction in exposure of the general population, irrespective of the concentrations at specific hotspots. As an illustration, the health benefits of reducing the average exposure of 10 million people (even if living in areas already below the objectives) by $1\mu g.m^{-3}$ are one hundred times greater than reducing the exposure of 10,000 people (even if living in areas above the objective) by $10\mu g.m^{-3}$.

114. Figure 1.29 gives a theoretical illustration of the relative benefits of the conventional limit values approach and the exposure reduction approach. It shows that, under the current system of absolute European limit values and air quality objectives, reducing exposure at pollution hotspots at which relatively few individuals are exposed (Area A) will in general be much less effective in generating health benefits than seeking to reduce average population exposure, even for the people already living in areas below the limit value (Area B).

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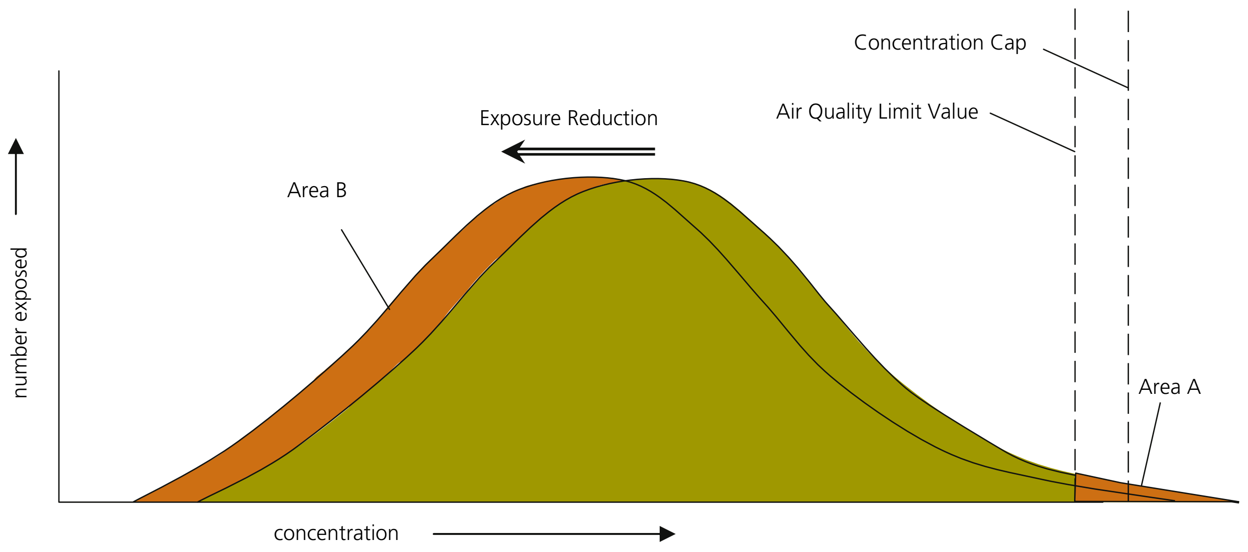
46 The maximum figure for life expectancy and life years lost given here and in the following paragraphs is based on a 6% hazard rate reduction per 10 $\mu g.m^{-3}$ and no lag between exposure and effect. See Volume II, Chapter 2 for further explanation.

47

Figure 1.29: Exposure reduction (theoretical)

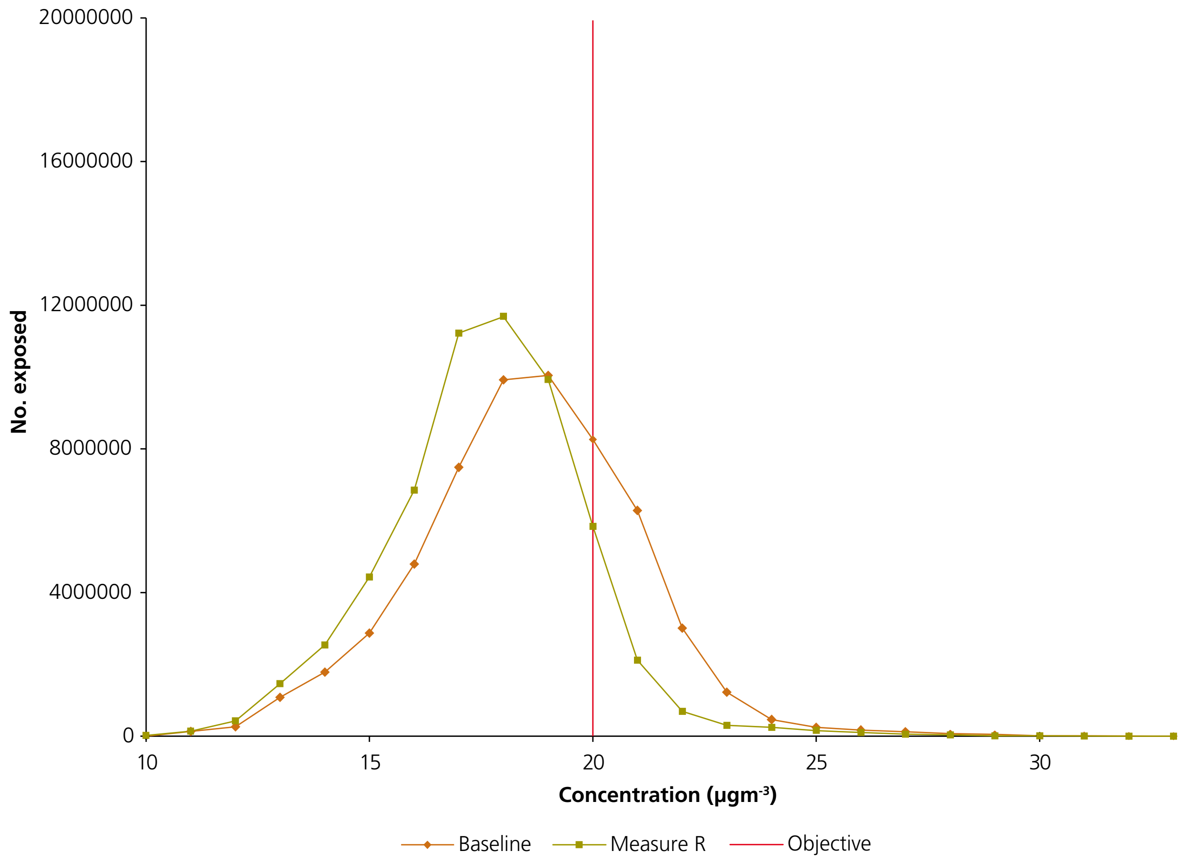


115. In other words, if future actions were to focus only on improving air quality in areas above the air quality limit value, the actions required and therefore the health improvement generated would be limited to a relatively small number of people. However given the non-threshold nature of particles[48], further cost effective health benefits would be accrued by continuing to reduce the average concentration at which a large number of people are exposed even if they are already within the air quality objective or limit value.

116. In practical terms, however, measures to improve air quality are unlikely to have any great impact on those exposed to the very lowest pollution levels. This means that the curve is unlikely to shift smoothly to the left, as shown in Figure 1.29. A more likely pattern is that the bottom end (the far left) of the curve will remain fixed, with the curve "piling up" as higher exposure are reduced. This is illustrated in Figure 1.30, below, which shows a modelled estimate of the impact of combined Measure R relative to the baseline for 2020 (see Chapter 2 for an explanation of Measure R). The graph shows that there is relatively little change at the top and bottom end of the graph, but that overall, the number of people exposed to higher concentrations is greatly reduced, while those exposed to lower concentrations is increased.

48 See Footnotes 48 and 53.

Figure 1.30: Exposure reduction (modelled estimate)



An Exposure Reduction Approach for the UK

117. The exposure reduction approach is formed of two inseparable parts: These are:

a) air quality objectives/limit values (often called "backstop objective" or "concentration cap") to ensure some basic level or quality of air which all citizens should experience, embodying the "environmental justice" concept; and

b) an objective based on reducing average exposures across the most heavily populated areas of the country (often called "percentage reduction" or *"exposure reduction"* objective), in order to generate further cost effective public health improvements over and above the basic level of protection generated by the objective above.

118. The effects of long term exposure to particles are the major driver of the benefits, so it makes sense to consider these as the major driver for the size of the exposure reduction objective. The Health Effects Institute re-analysis of the American Cancer Society cohort study and the extended follow-up of the American Cancer Society study have shown that there is a larger association between long term exposure to $PM_{2.5}$ and mortality than there is for PM_{10} or coarse particles. The concentration response function(s) for the effects of long term exposure to particles recommended by COMEAP are in terms of $PM_{2.5}$. It therefore makes sense that the exposure reduction objective should be defined in terms of $PM_{2.5}$.

119. It is acknowledged that predictions of future $PM_{2.5}$ concentrations are subject to greater uncertainty than predictions of future PM_{10} due to the small number of monitoring sites that currently measure $PM_{2.5}$. The relative uncertainty of $PM_{2.5}$ compared to PM_{10} will reduce if – as planned – the number of $PM_{2.5}$ monitors is significantly increased over the next few years.

120. While the percentage reduction objective is a relative measure of improvement (in this case 15% reduction in average concentrations in urban background areas across the UK between 2010 and 2020), the backstop objective (or concentration cap) is designed to deliver a minimum level of protection applicable to all areas in a country (25μg.m^{-3}). In Scotland, where background levels of pollution are generally lower, the Scottish Executive has decided to retain the Strategy's 2010 PM_{10} objective in addition to introducing the exposure reduction approach.

1.3.3.3.1 Practical operation of the exposure reduction approach

121. Having defined the backstop objective, and exposure reduction target, two further elements must be defined. The first is the baseline or start point against which progress towards the target can be assessed. This will be a three year running annual average of monitored $PM_{2.5}$ concentrations at a fixed set of monitoring sites. Using a three year running average means that the variation in meteorology between years has less of an influence on the start point than if a single year is used. We intend to assess the start point exposure between January 2008 and December 2010.

122. The second element is the method by which progress towards the target should be monitored. It has been decided to base this progress assessment on the same set of fixed monitoring points used to set the start point.

123. In 2005, Air Quality Consultants, in a report commissioned by Defra[49], assessed the different options available for defining these two elements. The central issue is that the exposure reduction objective is derived from modelled percentage reductions in population weighted concentrations but must be expressed in a form that is not too complex for monitoring and enforcement. The report concluded that this can be achieved by using monitoring sites in urban background locations, with the number of sites linked to the population. It is also important to consider the uncertainty in the average UK exposure, which is dependent upon the number of sites used to determine this average concentration.

124. An analysis of PM_{10} concentrations measured at urban background sites across the UK has demonstrated that once there are more than about 20 sites, the UK average would be defined to within ± 5%. Distribution of $PM_{2.5}$ is more homogenous than PM_{10} and it is likely that a similar number of sites would provide at least this level of accuracy. This suggests that only an exposure reduction target of around 5% or more could be assessed with confidence.

125. The approach will be based on broadly one site per 1 million population, applied to agglomerations over 250,000, i.e. about 24 sites in total for the UK, which will provide a

49 Options for an Exposure-Reduction approach to Air Quality Management in the UK and the EU for Non-Threshold Pollutants; Laxen, D. and Moorcroft S.; Defra; 2005; http/www.airquality.co.uk/archive/reports/cat09/050222330902_Exposure_Reduction_Report_Final_Jan_05.pdf.

robust indicator of exposure. It will also be possible to apply the monitoring requirements to agglomerations above 100,000. While this does not have a significant advantage in defining the UK urban population assessed (only 10% of the population live in agglomerations between 100,000 and 250,000), it does allow different geographical groupings to be used. This would require around 29 monitoring sites in total for the UK. However, the precise number and location of the sites to be used has not yet been finalised. This will only be done once the planned expansion of the UK's network of $PM_{2.5}$ monitoring sites reaches a more advanced stage.

1.3.3.3.2 The cost and benefits of the exposure reduction approach

126. The Air Quality Strategy Review consultation document gave the following example to illustrate the potential costs and benefits of the exposure reduction approach. It compared the costs and benefits of Measure Q, one of the previous combined measures, with a theoretical Measure Z, which assumes that actions are taken only to comply with the Limit Value for PM. Under Measure Z, no action is taken where the Limit Value is already being achieved. For the purposes of assessment, this is defined as an hypothetical scenario that eliminates background exceedences across the whole of the UK by reducing all concentrations in areas above 20µg.m^{-3} down to 20µg.m^{-3}.

127. This analysis has been repeated for combined measure R, and is presented in Chapter 4, section 4.4.

1.3.3.4 Uncertainties in $PM_{2.5}$ inventories

128. 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 $PM_{2.5}$.

1.3.4 Nitrogen Dioxide (NO_2)

1.3.4.1 Objective attainment/status

129. There are two objectives for NO_2:

- **1 hour mean concentration of 200 µg.m^{-3} not to be exceeded more than 18 times a year by 31 December 2005; and**
- **annual mean concentration of 40 µg.m^{-3} by 31 December 2005.**

130. 29% of monitoring sites exceeded the annual mean objective and 4% of monitoring sites exceeded the 1-hour objective in 2005.

131. The annual mean objective is expected to be met at all background locations across the UK by 2010 with only a small percentage (<1%) of the total area assessed exceeding in 2003 and 2005. The objective is not expected to be met at all roadside locations under baseline conditions by 2020. However, the percentage of total major road length exceeding is expected to decline from around 53% in 2003 to around 9% in 2020.

1.3.4.2 Health effects

132. The QUARK report[50] recorded inconsistencies in the evidence relating to the effects of NO_2 on health. Increases in daily deaths were found to be associated with increases in daily average concentrations of NO_2 but this finding was not supported by evidence of effects on either respiratory or cardiovascular deaths. There is some evidence that hospital admissions for respiratory diseases are related to concentrations of NO_2 although the COMEAP did not consider the evidence robust enough for quantification. UK work has shown that exposure to NO_2 enhances response to allergens and may increase the prevalence of respiratory infections in children. Volunteer studies have shown effects on lung function in asthmatics. There is some evidence for long-term effects of NO_2 although the evidence is weak[51]. The World Health Organisation has however confirmed the guideline value of 40 $\mu g.m^{-3}$ as an annual mean should be retained or lowered. Moreover, the short-term guideline for nitrogen dioxide of 200 $\mu g.m^{-3}$ is still justified.[52] Nitrogen dioxide can also be converted to nitrate which is a component of the particle aerosol. Nitrogen dioxide can also contribute to ground level O_3 via a complex series of photochemical reactions which also involve volatile organic compounds (VOCs).

1.3.4.3 Sources

133. Oxides of nitrogen are mainly emitted from combustion processes. There are a wide variety of sources of NO_X but road transport and the electricity supply industry are the main ones. Emissions of NO_X are expected to continue to decrease to 2020 (Figure 1.4). The main sectors contributing to this decrease are road transport and electricity generation.

1.3.4.4 Current and historic ambient concentrations

1.3.4.4.1 Measurements

134. Figure 1.31 and Figure 1.32 show progress towards meeting the 1 hour mean and annual average objectives for NO_2. Figure 1.31 shows the 99.8th percentile (equal to 18 exceedences) of the 1-hour mean NO_2 concentrations of all the national sites and the highest site. Four sites (London Marylebone Road; London A3 roadside; Camden roadside and Bristol Old Market roadside) exceeded the AQS 1-hour objective in 2005. Figure 1.32 shows the annual mean NO_2 concentrations. The mean of all 92 NO_2 sites in the UK was 34 $\mu g.m^{-3}$. Twenty-seven sites exceeded the annual mean NO_2 objective in 2005. Between 1993 and 2002, the 13 longest running sites have shown an average reduction in annual average NO_x concentrations of 5.1% per year and in annual average NO_2 concentrations at urban sites of 3.1% per year.

135. Concentrations of NO_2 have been declining on average, although the highest site (London Marylebone Road) – and a number of other sites not shown here – are showing increasing concentrations in the most recent years. We believe this may be due to increasing primary emissions of NO_2 (see section 1.5.3.1 below).

[50] COMEAP, 1998. The Quantification of the effects of air pollution on health in the United Kingdom. HMSO. London. http:// www.advisorybodies.doh.gov.uk/comeap/statementsreports/airpol7.htm

[51] World Health Organization. (2004) Health Aspects of Air Pollution – Answers to Follow-up Questions from CAFE. Report on a WHO Working Group Meeting, Bonn, Germany, 15-16 January 2004. Available at: http://www.euro.who.int/document/E82790.pdf

[52] Health aspects of air pollution. Results from the WHO project "Systematic Review of Health Aspects of Air Pollution in Europe, June 2004. http://www.euro.who.int/document/E83080.pdf

Figure 1.31: Measured 99.8th percentile of 1-hour nitrogen oxide concentrations in the UK (mean of all sites and highest site and 2005 air quality strategy objective)

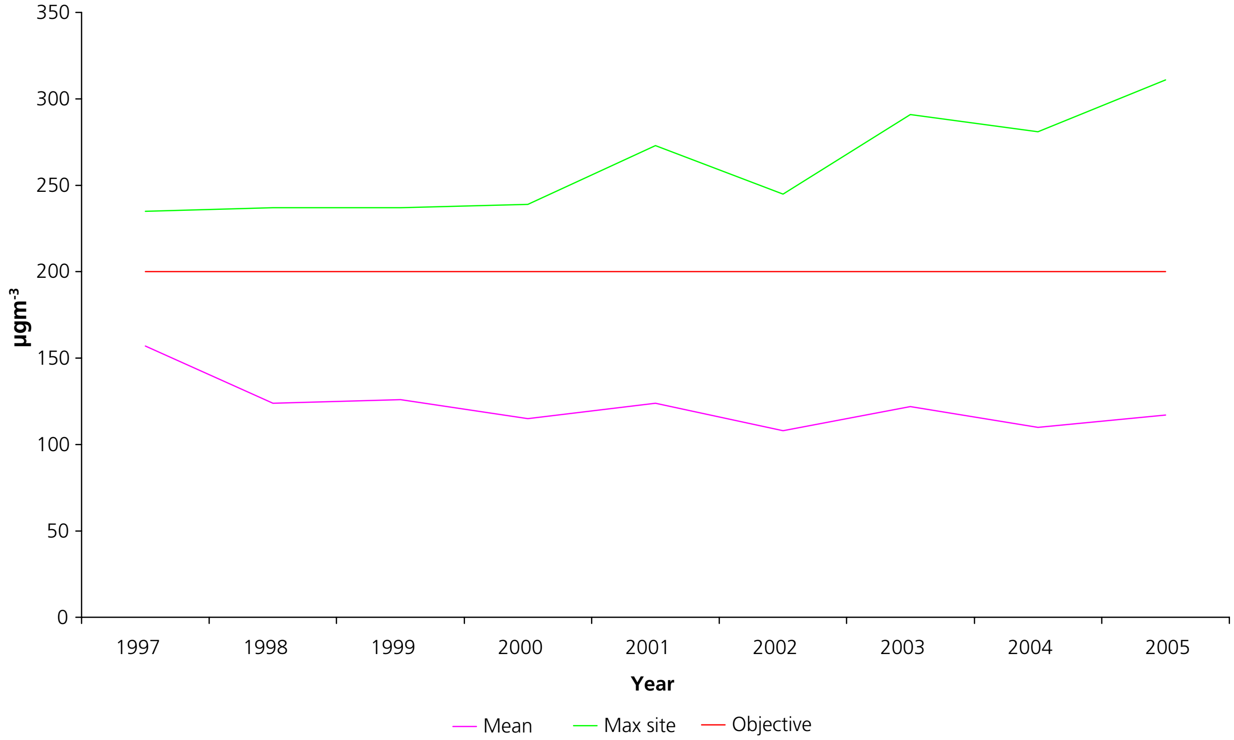
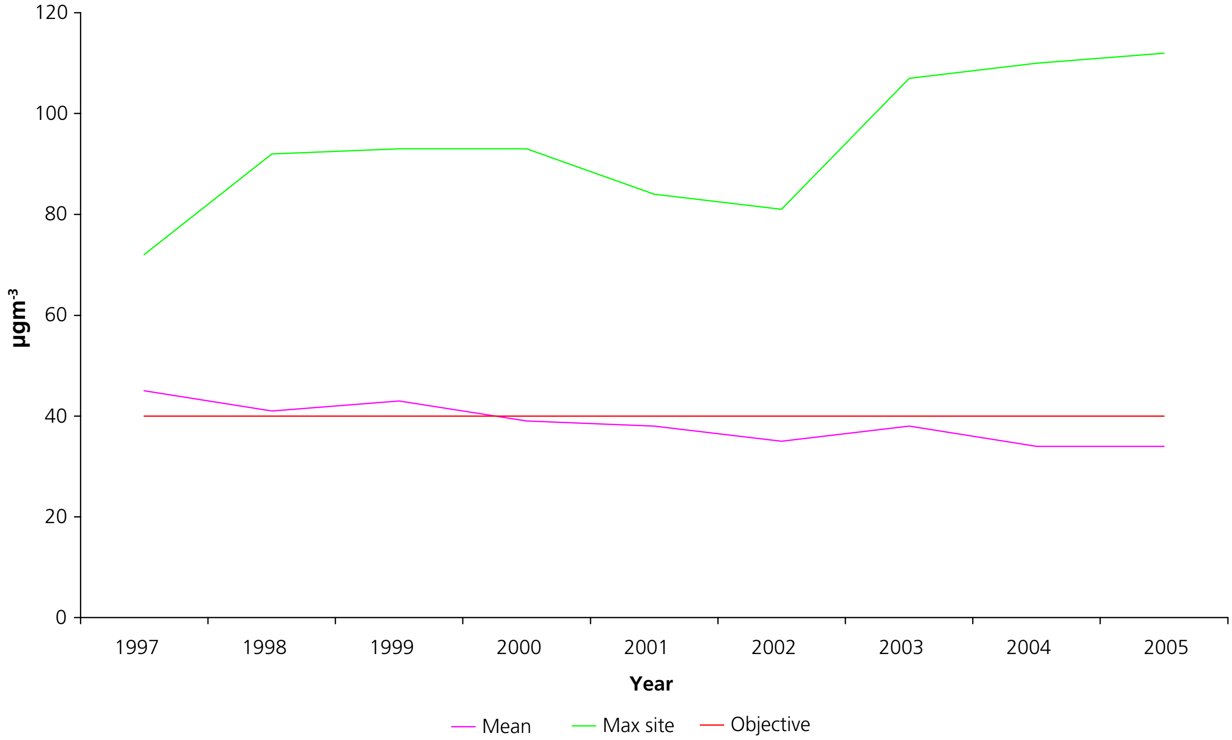


Figure 1.32: Measured annual mean nitrogen dioxide concentrations in the UK (mean of all sites and highest site and 2005 air quality strategy objective)



1.3.4.4.2 Model results and projections

136. Projected annual mean concentrations of NO_X and NO_2 have been modelled for 2005, 2010, 2015 and 2020. The modelling method used in estimating projected annual mean concentrations in these years closely follows the method used to estimate concentrations in 2003 for NO_X and NO_2 as described in Stedman *et al* (2005). Figure 1.33 and Figure 1.38 show the modelled maps of mean projected NO_2 concentrations at background and roadside locations for 2003, 2010 and 2020. Only annual mean concentrations for comparison with the EU limit value have been modelled because this is expected to be more stringent than the one hour limit value.

Figure 1.33: Annual mean background nitrogen dioxide concentration 2003 ($\mu g.m^{-3}$)

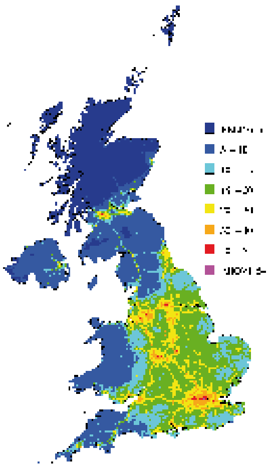


Figure 1.34: Urban major roads, annual mean roadside nitrogen dioxide concentraion, 2003 ($\mu g.m^{-3}$)

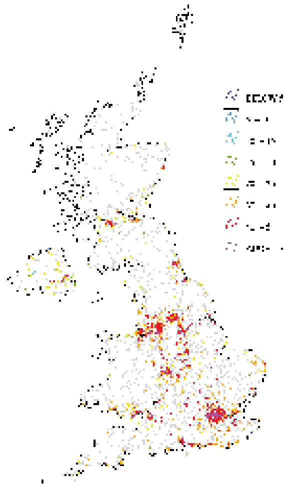


Figure 1.35: Annual mean background nitrogen dioxide concentration 2010 ($\mu g.m^{-3}$)

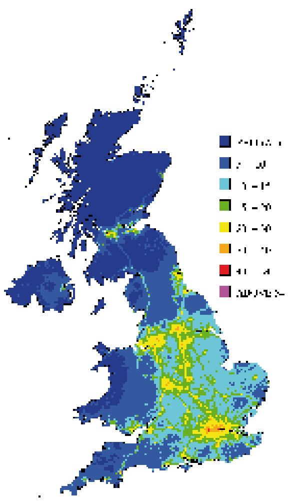


Figure 1.36: Urban major roads, annual mean roadside nitrogen dioxide concentraion, 2010 ($\mu g.m^{-3}$)

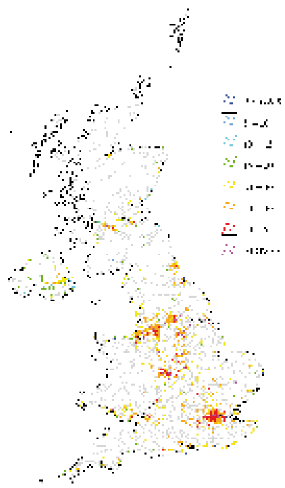


Figure 1.37: Annual mean background nitrogen dioxide concentration 2020 (µg.m^{-3})

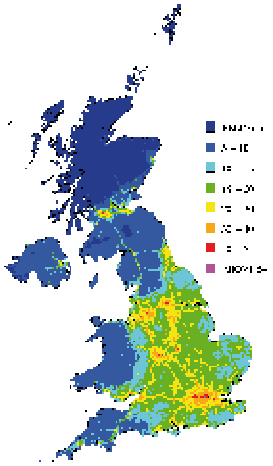
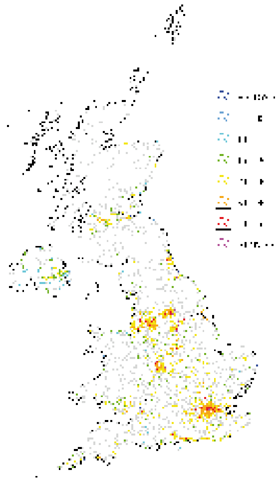


Figure 1.38: Urban major roads, annual mean roadside nitrogen dioxide concentration 2020 (µg.m^{-3})



137. Table 1.12 summarises the modelling results for 2005, 2010, 2015 and 2020 using a 2003 base year, to show the major urban road length exceeding, total background area exceeding and total population in the background area exceeding the annual mean objective and limit value. Modelled annual mean NO_2 concentrations were below 40 µg.m^{-3} across the majority of the UK in 2003 but this threshold was exceeded at a number of locations. Results from the national GIS-based models indicate that it was exceeded at background locations representing 4.0% of the UK population in 2003, declining to 0.3% in 2020 and at roadside locations alongside 52.5% of the length of urban major roads in 2003, declining to 8.5% in 2020. It was also exceeded at 30% of the national automatic monitoring sites.

138. Central London had the greatest proportion of background exceedences compared with total area covered and 40 µg.m^{-3} was also exceeded alongside most of the major roads in London. By 2015, the majority of the roadside exceedences are expected to be confined to England (largely in London). Reductions in exceedences at roadside range from 100% in Northern Ireland between 2003 and 2020 and 68% in London and in background area exceedences from 100% in Scotland to 84% in London.

Table 1.12: Summary statistics for UK baseline NO_2 projections using a 2003 base

Major urban road length (km) exceeding the annual mean objective of 40 µg.m^{-3}						
Region	**Total assessed**	**2003**	**2005**	**2010**	**2015**	**2020**
London	1,886	1775	1625	1024	651	564
Rest of England	9,430	4949	3686	1372	680	570
Scotland	1,085	371	278	112	51	43
Wales	640	168	110	42	22	17
Northern Ireland	1,044	131	114	18	0	0
Total	14,084	7394	5813	2567	1405	1194
Total background area (km^2) exceeding the annual mean objective of 40 µg.m^{-3}						
Region	**Total assessed**	**2003**	**2005**	**2010**	**2015**	**2020**
London	1,624	232	13	55	39	38
Rest of England	128,770	269	147	19	12	15
Scotland	77,79	15	11	2	0	0
Wales	20,745	0	0	0	0	0
Northern Ireland	13,318	0	0	0	0	0
Total	242,248	516	297	76	51	53
Total population (x10^3) in area exceeding the annual mean objective of 40 µg.m^{-3}						
Region	**Total assessed**	**2003**	**2005**	**2010**	**2015**	**2020**
London	7,730	1,772	1,062	319	157	155
Rest of England	41,011	468	229	17	6	6
Scotland	4,945	64	42	7	0	0
Wales	2,851	0	0	0	0	0
Northern Ireland	1,623	0	0	0	0	0
Total	58,160	2,304	1,334	343	162	161

139. Modelling for annual mean NO_2 concentrations has been carried out using a 2002 base year and is described along with the results in Grice *et al* 2005. 2003 was a year of unusually high air pollutant concentrations due to the unusual meteorological conditions. Annual mean NO_2 concentrations were lower in 2002. Results from the national GIS-based modelled indicate that 40 µg.m^{-3} was exceeded during 2002 at background locations representing 1% of the UK population and at roadside locations alongside

39% of the length of urban major roads. It was also exceeded at 27% of the national automatic monitoring sites. Predicted concentrations derived from a 2002 base year are therefore lower than those derived from 2003. The extent of exceedence at the roadside is expected to decline to 25% of the length of major urban roads by 2005, reducing further to 12% by 2010 and 7% by 2015.

140. Population-weighted annual mean NO_2 concentrations at background locations are also illustrated in Table 1.13 for a 2003 base year. 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. On a UK wide basis population weighted mean concentrations are expected to decline by around 7.5µg.m^{-3} between 2003 and 2020. This ranges from around 5.2µg.m^{-3} in Northern Ireland to around 10.4µg.m^{-3} in Inner London.

Table 1.13: Population weighted mean NO_2 concentration using a 2003 base year (µg.m^{-3}).

	2003	2005	2010	2015	2020
Scotland	17.3	16.2	13.4	11.9	11.3
Wales	17.6	16.5	13.5	12.0	11.2
Northern Ireland	12.6	11.5	9.3	8.0	7.4
Inner London	41.3	38.8	34.0	31.6	30.9
Outer London	34.1	32.0	27.8	25.5	24.8
Rest of England	24.2	22.8	19.3	17.3	16.4
UK	24.5	23.0	19.5	17.6	16.8

1.3.4.4.3 Modelling results for London using ADMS-URBAN

141. Future NO_2 concentrations in London have been estimated using an alternative model. This allows the outputs from the national model to be compared with those from a model that uses a different array of processes and input assumptions.

142. ADMS-Urban is one of a suite of ADMS air pollution models used for industrial and urban air quality management. Like the other ADMS models, it is a 'new generation' model which incorporates science regarding the structure of the atmosphere that goes beyond the simplistic stability categories used by earlier models. Being capable of modelling 70,000 road links, 1500 point, area, line or volume sources and 3000 grid cells, ADMS-Urban is considered to be an appropriate tool to model large conurbations.

143. ADMS-Urban will share much of the basic science incorporated within the model used for the national analyses. The different model results relate more to the differences in the input data. The two analyses used different emissions inventories (the NAEI and the London Atmospheric Emission Inventory (LAEI), different meteorological years (2001 and 2003) and consequently potentially different background data (i.e. there was a higher level of secondary particulates experienced in 2003).

144. Table 1.14 shows the results of the modelling for the base year (2001), 2010 and 2020 for Greater London. There are differences in the absolute results but both models project exceedences of an annual average of 40 µg.m^{-3} NO_2 in 2010 and 2020. This provides increased confidence that annual average limit value will not be achieved everywhere with current measures. There are however differences between model estimates for future years. This can be explained partly because the projections start in different years and therefore assume different meteorology in the projected years.

145. Both models estimate large decreases in NO_2 between the base year and projected years with similar rates of change. The spatial resolution of the ADMS-Urban modelling is finer, and this would be expected to lead to a greater area exceeding 40 µg.m^{-3}. The ADMS-Urban results include an area of influence of the modelled roads which will be included in the calculated exceedence and population weighted mean statistics. Overall the agreement between the two models is good in terms of exceedences and population-weighted mean concentrations and the trends in population-weighted mean concentration from 2003 to 2010 and 2020. The AQEG NO_2 report provides more information on the comparisons between the different models.

Table 1.14: Comparison of annual average nitrogen dioxide concentration statistics for Greater London (London boroughs). Base year 2001 for ADMS-Urban and 2003 for the national model.

Year	% of area exceeding 40 µg.m^{-3}		% of population exceeding 40 µg.m^{-3}		Population weighted mean (µg.m^{-3})	
	ADMS-Urban	National model	ADMS-Urban	National model	ADMS-Urban	National model
Base year	51	14	67	23	44.0	36.6
2010	13	3	20	4	35.6	29.9
2020	6	2	11	2	31.2	26.9
Rate of change base year to 2020	–2.2	–0.7	–2.8	–1.2	–1.1	–0.6

146. The figures below show the mapped results from ADMS-Urban for the base and future years. They show large decreases in area of Greater London exceeding 40 µg.m^{-3} annual average NO_2 between 2001 and 2020. Exceedences are restricted to close to major roads by 2020. Heathrow has not been modelled in detail and results in that area should be treated with caution; for example, emissions for take off, climb out, and taxiing have been allocated to a single point, rather than distributed to the actual location and height of emission, which tends to produce higher emissions. Air quality in the vicinity of Heathrow is being modelled separately, and at a greater level of detail, as part of the Project for the Sustainable Development of Heathrow (PSDH)[53], and will be subject to a separate consultation process.

[53] http://www.dft.gov.uk/pgr/aviation/environmentalissues/heathrow/

Figure 1.39: Annual average nitrogen dioxide concentration in Greater London, 2001

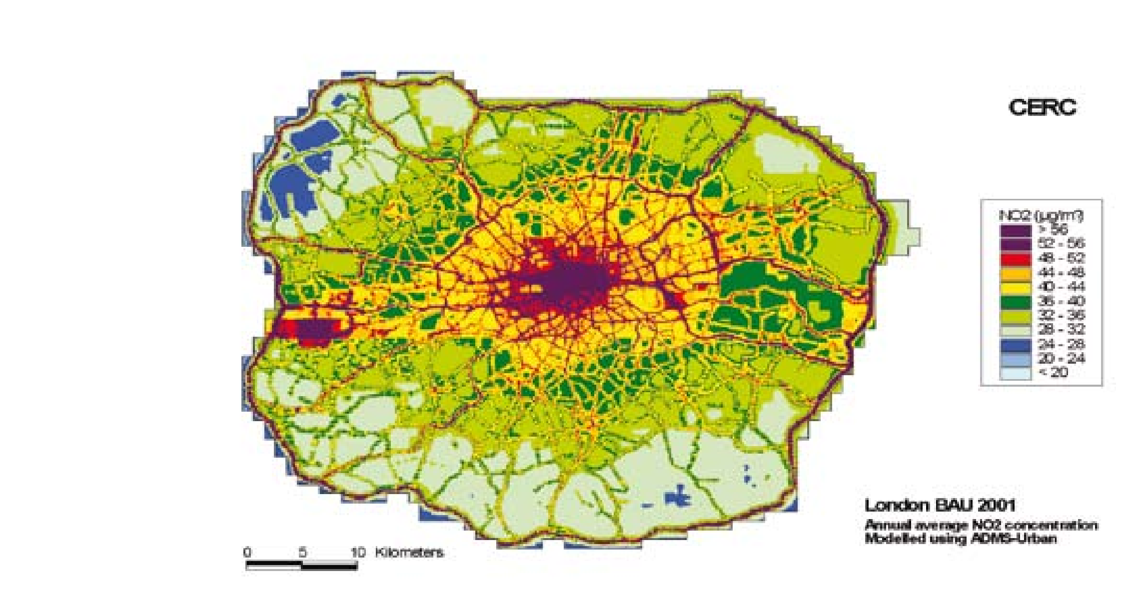


Figure 1.40: Annual average nitrogen dioxide concentration in Greater London, 2010

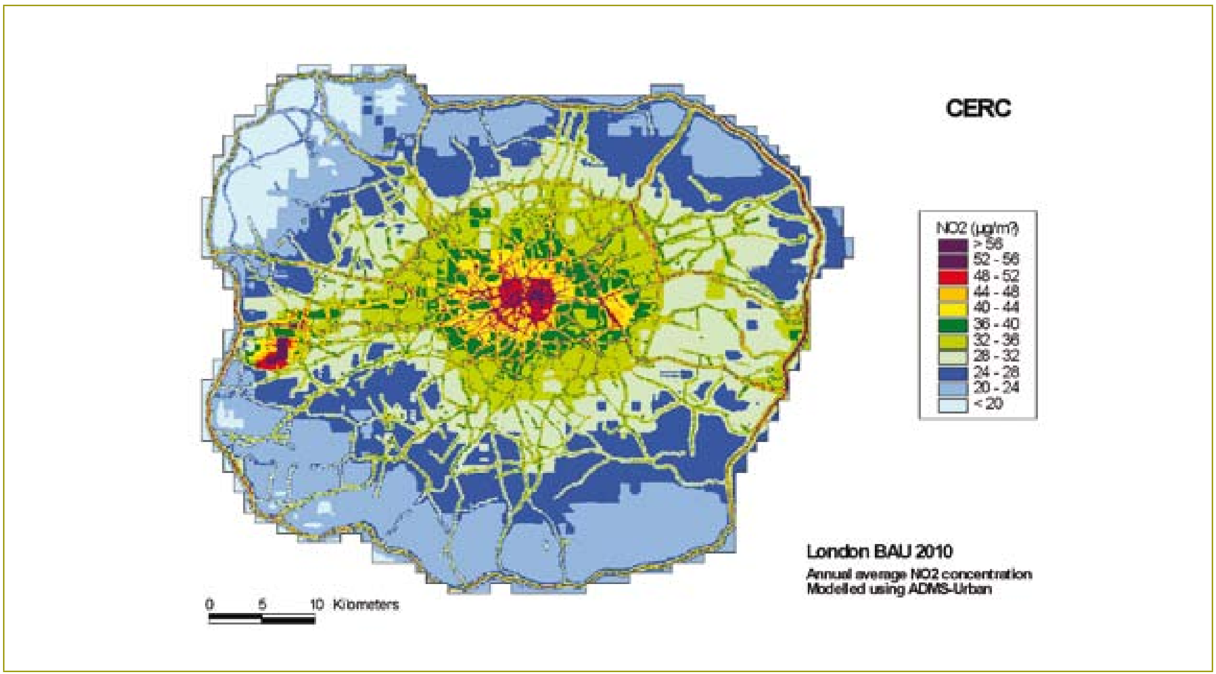
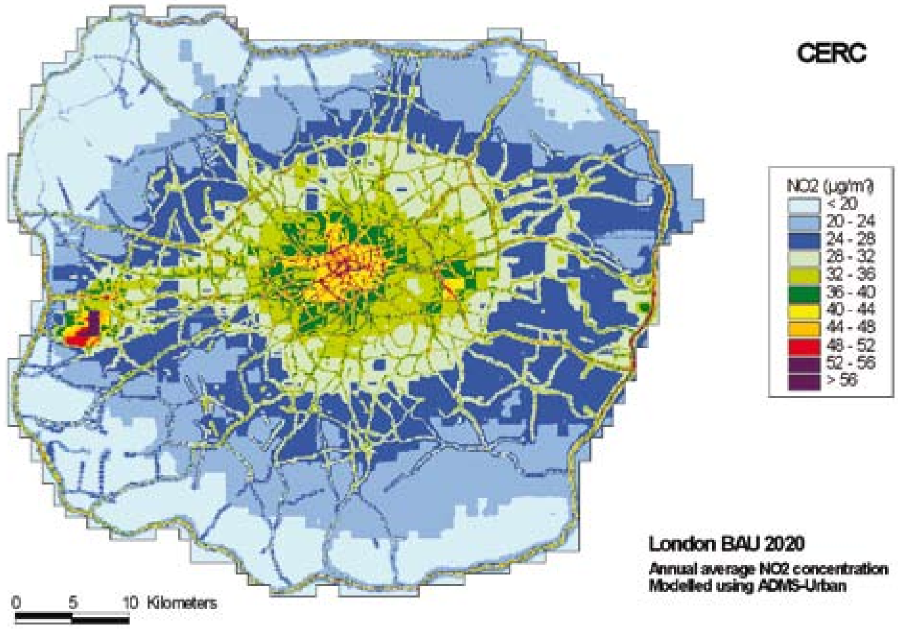


Figure 1.41: Annual average nitrogen dioxide concentration in Greater London, 2020



1.3.4.4.4 Uncertainties in inventories

147. Oxides of nitrogen emission estimates are less accurate than SO_2 because NO_X emissions 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.

148. 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 VOCs, PM_{10}, metals, and persistent organic pollutants (POPs), 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.

149. A further uncertainty is the proportion of NO_X released as NO_2. This is important for estimating roadside concentrations. There is evidence to suggest that efforts to reduce particle emissions from diesel engines may be increasing the amount of direct NO_2 emissions from that source. Further work has been carried out using the national model and ADMS-Urban to quantify the size of this uncertainty. This is discussed in more detail in section 1.5.3.1 in the Sensitivities section.

1.3.5 Ozone (O_3)

1.3.5.1 Objective attainment/status

- **for the whole of the UK, an 8 hour mean concentration of 100 µg.m^{-3} not to be exceeded more than ten times a year by 31 December 2005.**

150. Measurements from the AURN network indicate that this objective was widely exceeded in 2005.

151. Modelling of future ozone concentrations suggests that, without additional measures, there is likely to be a gradual deterioration in O_3 air quality. This is both for average levels and exceedences of the objective (episodes). Concentrations will still exceed the Strategy's objective in 2020. Average levels are likely to rise in urban and rural areas.

1.3.5.2 Health Effects

152. There is consistent evidence for associations between daily deaths and admissions to hospital with daily average concentrations of O_3[54 55 56]. It is not currently known whether there is a threshold for the effects of O_3 on health: evidence can be martialled for and against such an assumption. The COMEAP is currently working on the issue.

153. The QUARK report[57] concluded that only the data relating to daily deaths and respiratory admissions was sufficiently well founded to be used for quantification of effects on health in the UK. Volunteer studies have shown irritant effects on the airways. There is evidence from USA studies that long term exposure to raised O_3 concentrations leads to lower levels of lung function and may impair development of lung function. Whether this occurs in the UK is unknown. The evidence on whether long term exposure to O_3 increases mortality is not clear cut.

1.3.5.3 Sources

154. Ozone is not emitted directly from any man-made sources in any significant quantities. It arises from chemical reactions in the atmosphere caused by sunlight. In the stratosphere, where O_3 plays a beneficial role by shielding the earth from harmful ultra-violet radiation, sunlight acting initially on oxygen molecules produces O_3.

155. Ozone in the lower layers of the atmosphere is primarily formed by a series of chemical reactions initiated by sunlight. Oxides of nitrogen and VOCs, derived mainly from man-made sources (Figure 1.4 and Figure 1.6), react to form ozone and are the most important sources of elevated levels of O_3. Production can also be stimulated by CO, methane and other VOCs that arise from plants, trees and other natural sources. O_3 in the lower atmosphere is also a greenhouse gas.

[54] WHO (2004a). Meta-analysis of Time-Series Studies and Panel Studies of Particulate Matter (PM) and Ozone (O_3). Report of a WHO Task Group, Copenhagen: World Health Organisation. http://www.euro.who.int/document/E82792.pdf

[55] WHO (2006) Air Quality Guidelines – Global update 2005 http://www.euro.who.int/Document/E90038.pdf

[56] Committee on the Medical Effects of Air pollutants (1998) 'The quantification of the effects of air pollution on health in the United Kingdom' http://www.advisorybodies.doh.gov.uk/comeap/statementsreports/airpol7.htm

[57] See Footnote 54.

156. These chemical reactions do not take place instantaneously, but over several hours or even days depending on the VOCs, and once O_3 has been produced it may persist for several days. Consequently, O_3 measured at a particular location may have arisen from VOC and NO_X emissions many hundreds or even thousands of kilometres away, and then may travel further for similar distances. Maximum concentrations therefore generally occur downwind of the source areas of the precursor pollutant emissions. Indeed, in urban areas, where concentrations of traffic gases may be high, nitric oxide (NO) from exhaust emissions may react with O_3 to form NO_2, reducing or "quenching" O_3 concentrations. As the air movement however carries the primary pollutants away, more O_3 is generated and concentrations rise in the down wind areas.

157. In terms of O_3 measured at ground level, these photochemical episodes of high O_3 concentrations are superimposed on a baseline that varies slightly throughout the year but averages around 78 $\mu g.m^{-3}$ [58] (+/- 12 $\mu g.m^{-3}$) at UK latitudes as measured over the last five years to March 2003 at Mace Head in Ireland. This is made up partly of O_3 transported from the stratosphere, and some O_3 produced in the lower layers of the atmosphere from naturally occurring and man made precursors (in broadly equal proportions). This baseline has roughly doubled since the beginning of the 20th century, largely due to the increase in man-made NO_X emissions in the whole of the northern hemisphere.

158. These factors, particularly the importance of sunlight in the reactions, mean that elevated O_3 levels occur more frequently:

- in summer;
- in the southern UK more than in the north; and
- in rural and suburban areas more than in city centres.

159. However the long-term rise in background O_3 concentrations – combined with large decreases in emissions of O_3 precursor gases in the European Union – is gradually changing the characteristics of the O_3 climate.

160. In Northwest Europe, it takes time for O_3 to form and then be destroyed, and hence the distance it can travel makes the problem an international one. For examples of this transport see 2006 and 2003 air pollution episode reports[59].

1.3.5.4 Current and historic ambient concentrations

161. Ozone is a regional and transboundary pollutant. Measurements and trends in the UK are influenced to a large extent by precursor emissions and trends on a hemispheric and European scale.

162. Measurements reveal two major trends in O_3 concentrations in the UK: long-term reduction in high peak O_3 events, and: long-term increase in average O_3 levels. There is

[58] Simmonds, P.G., Derwent, R.G., Manning, A.L. and Spain, G. (2004) Significant growth in surface ozone at Mace Head, Ireland, 1987-2003. Atmospheric Environment 38 (2004) 4769-4778.

[59] Targa, J (2007) Air Pollution Forecasting: Ozone Pollution Episode Report (June/July 2006) AEA Technology Environment, National Environmental Technology Centre (Netcen), AEA/ENV/R/2168 Issue 3
http://www.airquality.co.uk/archive/reports/cat12/0701241100_APF_episode_JunJul06_FINAL_low.pdf
Kent, A., (2003) Air Pollution Forecasting: Ozone Pollution Episode Report (August 2003)
http://www.airquality.co.uk/archive/reports/cat12/o3_episode_august2003.pdf

however no discernable long-term trend in moderate peak levels (exceedences of the UK objective).

163. There are a number of drivers that have affected O_3 concentrations and the distribution of O_3 concentrations over the last 15 years:

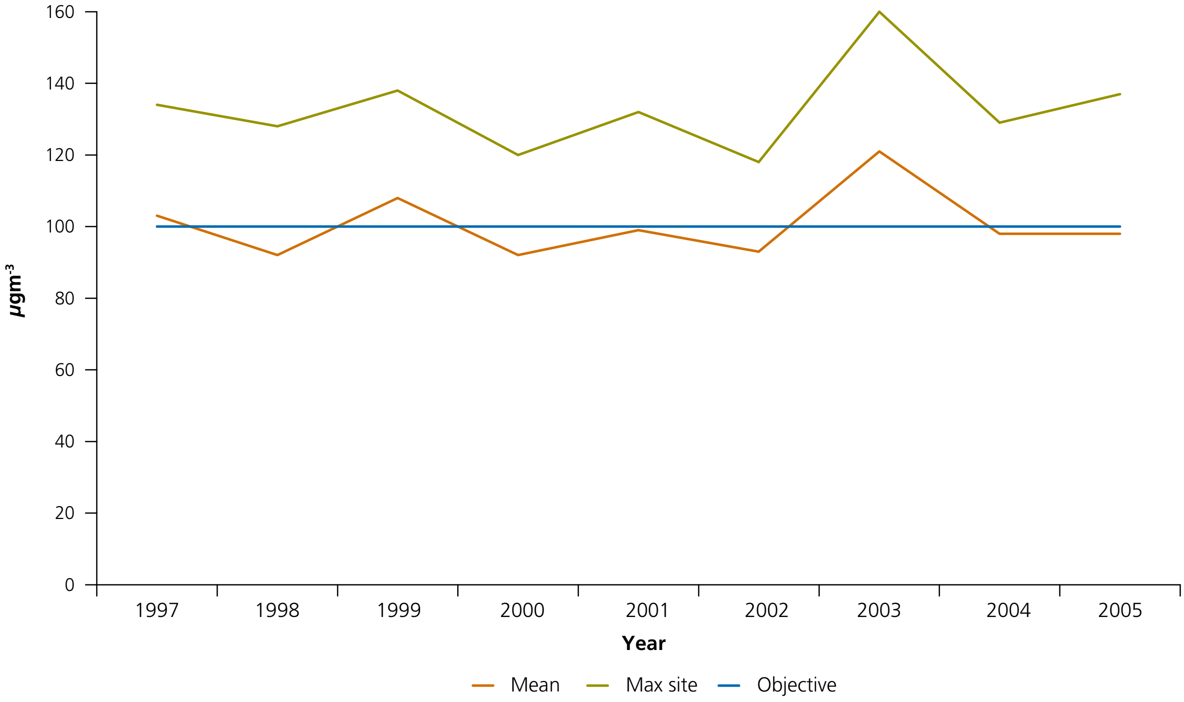
- regional (European Union) controls on NO_X and VOC emissions, reducing maximum peak O_3 concentrations (i.e., **reduced photochemical O_3 production);**
- **reduction in NO_X emissions,** especially in urban areas, as a result of the control of local NO_X emissions, leading to increased average O_3 concentrations in urban areas; and
- an **increasing background concentration** arising from global changes in atmospheric composition and hemispheric circulation.

164. The following sections summarise recent trends for two different O_3 metrics: daily maximum (reflecting elevated O_3 episodes), and; annual average of daily maximum (similar to an annual average). Both metrics are associated with health impacts.

1.3.5.4.1 Daily maximum ozone

165. The Strategy's O_3 objective for the protection of human health is 100 $\mu g.m^{-3}$ not to be exceeded more than ten times a year, measured as a daily maximum of a running 8-hour mean. Figure 1.42 shows the measured 97th percentile of daily maximum running 8-hour mean O_3 concentrations of all the national monitoring sites and the highest site. The 97th percentile equates to exceedences on up to ten calendar days per year. The mean of all 80 O_3 national sites in 2005 was 98 $\mu g.m^{-3}$. Thirty-five sites exceeded the Strategy's objective in 2005. This metric shows no discernable trend since 1997. There is however a decline in peaks of O_3 over 120 $\mu g.m^{-3}$ (the EU Limit Value) since the early 1990s.

Figure 1.42: Measured 97th percentile[58] of daily maximum running 8-hour mean ozone concentrations in the UK (mean of all sites and highest site and 2005 Strategy objective)



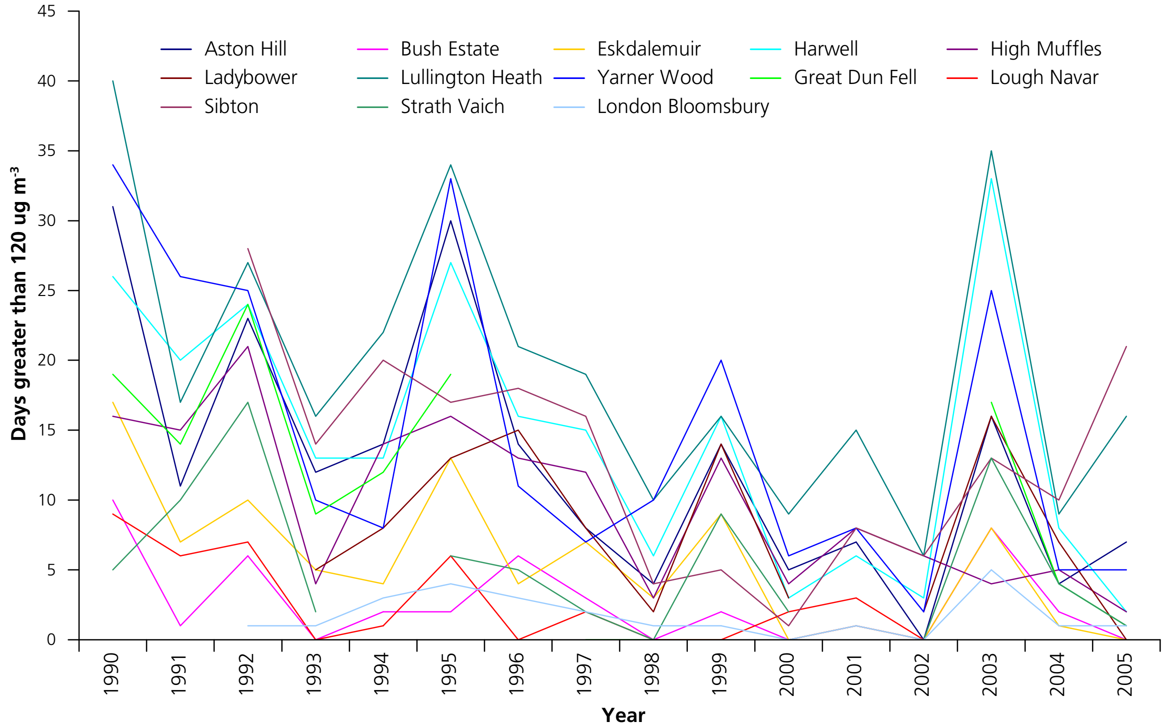
1.3.5.4.2 Long-term reduction in high peak levels

166. The frequency distributions of the hourly mean O_3 concentrations observed at rural UK O_3 monitoring sites, during each year, have changed throughout the period over which monitoring has been carried out. Some years show a greater frequency and intensity of summertime O_3 episodes and wintertime depletion events, compared with others.

167. Despite this variability, episodic peak O_3 levels have been decreasing at rural sites at about 4-6 µg.m^{-3} per year during the 1990s, and by about 100-300 µg.m^{-3} from the early 1970s to the late 1990s. The decreasing intensity of the regional O_3 pollution episodes can be illustrated using the annual trends in the maximum 8-hour mean O_3 concentrations monitored during each year at a selection of long-running rural UK O_3 monitoring sites (Figure 1.43). The majority of the rural sites show statistically significant downward trends in the number of exceedences of maximum 8-hour mean O_3 concentrations. This reflects the influence of the Europe-wide controls on O_3 precursor emissions of VOCs and NO_X through the introduction during the 1990s of three-way exhaust gas catalysts to petrol-engined motor vehicles and of canisters to reduce petrol evaporation emissions. The effect of the heatwave in 2003 on the number of exceedences can clearly be seen.

[60] see footnote 3 for explanation of how to calculate a percentile.

Figure 1.43: No. of daily 8-hour running mean ozone concentrations exceeding 120 μg.m⁻³



1.3.5.4.3 Long-term increase in average ozone levels

168. Figure 1.44 shows that O_3 levels for a selection of urban monitoring sites are experiencing a slow rise. Although urban O_3 levels are generally much lower than rural areas, the trend indicates a slow rise towards the levels experienced in rural areas. This is further illustrated in Figure 1.45 which, for the same metric, compares the mean London concentration with the mean obtained from the rural network. It quite clearly shows a rising trend for London in contrast to the less obvious trend for the rural network.

169. There is little discernable trend on annual average concentrations in rural areas whereas concentrations in urban areas are increasing slowly. Three-way exhaust gas catalysts and measures to reduce NO_X emissions from diesel traffic have also reduced the extent of O_3 scavenging by the NO_X emissions from road traffic. As a result, O_3 levels in towns and cities have begun to rise back towards the levels found in the surrounding countryside. Wintertime O_3 depletion events have become less severe. There has been a tendency, therefore, for levels to rise during much of the year whilst episodic peak levels during summertime have fallen.

Figure 1.44: Annual mean of daily max 8-hour mean ozone concentrations at urban sites

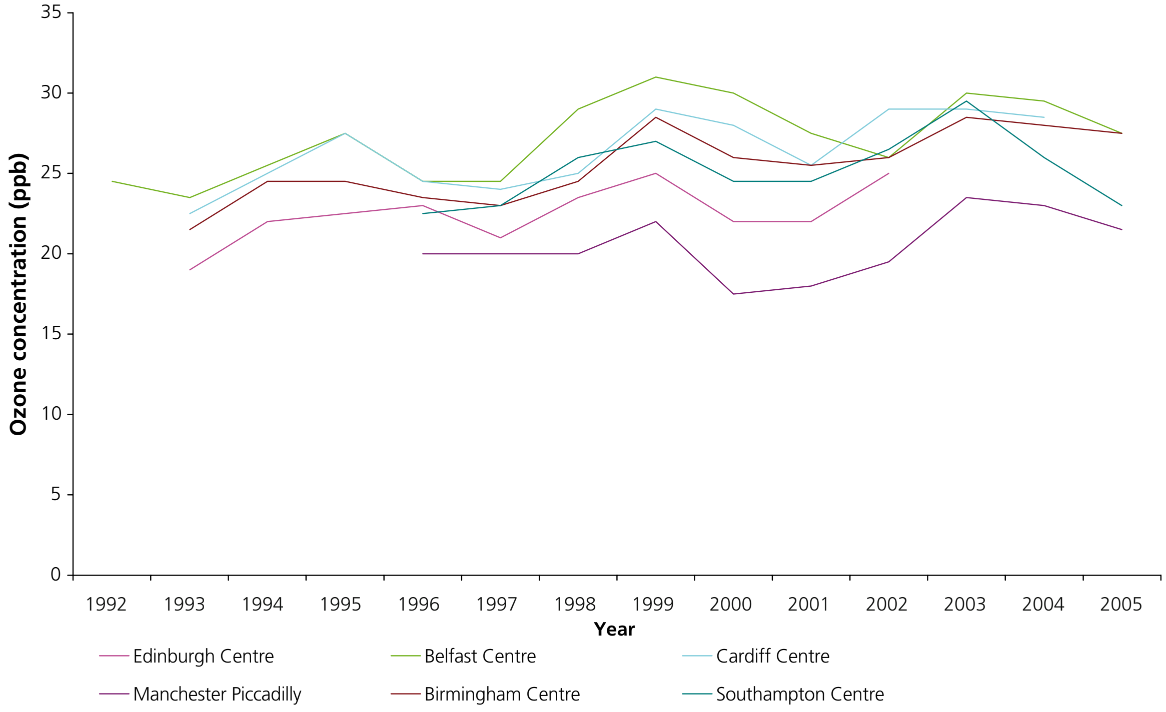
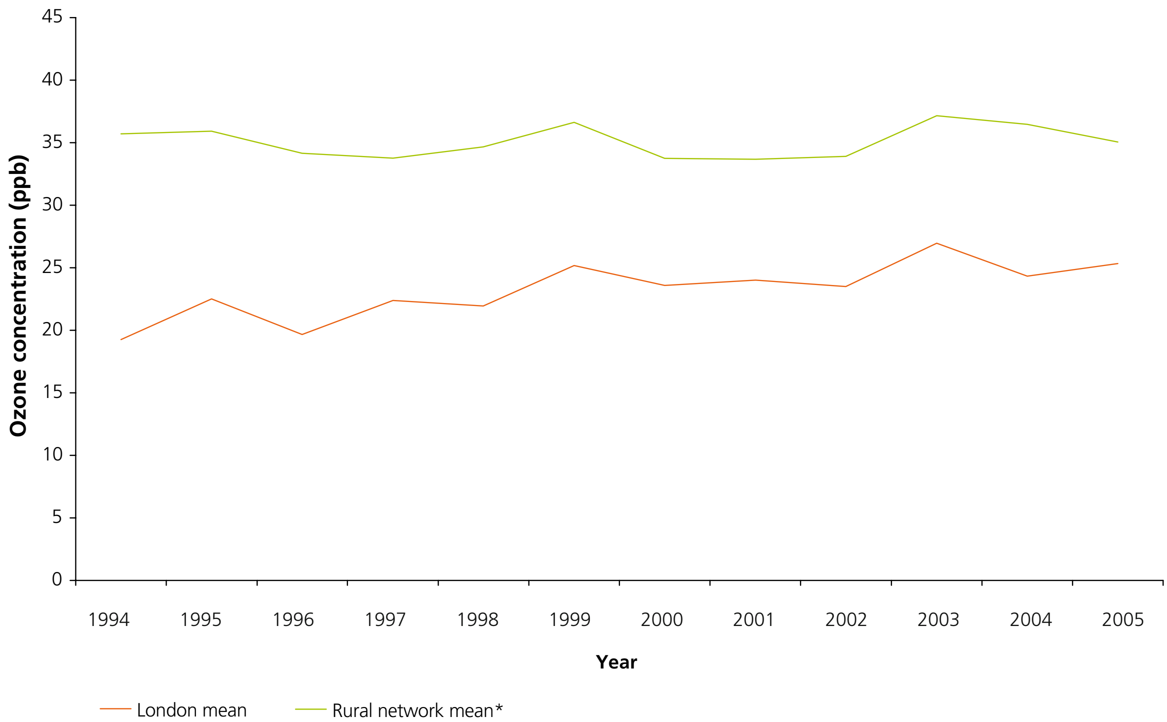


Figure A1.45: Annual mean of daily max 8-hour mean ozone concentrations



*Rural network mean also includes sites classified as 'remote'

1.3.5.5 Baseline modelling

170. The analysis for the O_3 work was undertaken using the Ozone Source Receptor model (OSRM). A description of the model is set out in box 1.2.

171. Analyses were completed for the years 2010, 2015 and 2020 at a horizontal spatial resolution of 10km by 10km (Hayman *et al*, 2006[61]). The latest emission projections from the NAEI developed for this review were used along with the Clean Air for Europe (CAFE) projected national emission totals[62]. An attempt was made to allow for the expected change in atmospheric composition due to climate change. There were eight O_3 and NO_2 metrics calculated during these runs. They included the following health based metrics:

- annual mean of the maximum daily running 8-hour average O_3 concentration with
  - – no cut-off;
  - – a 70 µg.m^{-3} (or 35ppb) cut off;
  - – a 100 µg.m^{-3} (or 50ppb) cut off;
- number of days when the maximum of the 24 possible 8-hour running mean concentration in each day exceeds 100 µg.m^{-3} (the UK Air Quality Strategy metric); and
- annual mean NO_2 concentration.

Box 1.2 The Ozone Source Receptor Model (OSRM)

The OSRM is a recently developed Lagrangian source-receptor model which is capable of describing the UK O_3 climate in more detail than most Lagrangian models (Hayman *et al*., 2002[62], 2004[63]; 2005[64]).

The OSRM uses global Met Office meteorological datasets to deriving 96-hour back trajectories centred on specific receptor sites (UK/EMEP monitoring sites which equate to a 10km by 10km grid over the UK. A finer resolution grid of 5, 2 or 1km can also be used to investigate the impact of local NO_X emissions in major urban areas). The meteorological data are provided as three dimensional fields of wind speed and direction, temperature, pressure cloud cover and relative humidity.

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61 Hayman, G., (2006) Ozone Modelling for the Review of the Air Quality Strategy AEA Technology plc netcen AEAT/ENV/R/2092 http://www.airquality.co.uk/archive/reports/cat16/0604031524_ED47154_OSRM_Modelling_for_AQS_Issue1.pdf

62 the IIASA RAINS scenario (official national energy projections with climate change policies included), the NECD for the EU member states (except for the UK) and the Gothenburg Protocol for the other UN ECE countries.

63 Hayman, G.D., Jenkin, M.E., Pilling, M.J. and Derwent, R.G. (2002) Modelling of Tropospheric Ozone Formation. A Final Project Report for Defra and the Devolved administrations under contract EPG 1/3/143.

64 Hayman, G.D., Bush, A., Kent, A., Derwent, R.G., Jenkin, M.E., Pilling, M.J. and Abbott, J. (2004) Modelling of Tropospheric Ozone. First Annual Report for Defra and the Devolved administrations under contract EPG1/3/200.

65 Hayman, G.D., Abbott, J., Thomson, C., Bush, T., Kent, A. Derwent, R.G., Jenkin, M.E. Pilling, M. J., Rickard, A. and Whitehead, L. (2005) Modelling of Tropospheric Ozone. Second Annual Report for Defra and the Devolved administrations under contract EPG1/3/200.

Box 1.2 The Ozone Source Receptor Model (OSRM) *(continued)*

The chemical schemes used in the model are based on those used in the Stochastic Chemistry model (STOCHEM – Collins *et al.*, 1997[65], 2000[66]) operated by the Met Office. The mechanism includes approximately 73 chemical species involved in approximately 180 thermal and photochemical reactions. Ten species of VOCs are used to represent the regional scale formation of O_3. The emission inventories use EMEP data but can include the NAEI to represent UK emissions. Temporal profiles were developed for certain emission sectors to simulate the varying emissions with time of day, day of week and month of year.

The OSRM simulates the chemical development of species in an air parcel as it moves along an air mass trajectory which the model derives from the met dataset wind fields. The model will also simulate the dry deposition of O_3 and other relevant compounds to the Earth's surface. Important factors relating to O_3 deposition such as the strong diurnal cycle (deposition being more efficient within a shallow night-time boundary layer) are fully represented in the model.

The OSRM is capable of calculating a range of ozone exposure metrics across the UK at high spatial resolution with sufficient turnaround time to allow for appropriate policy-related questions to be answered in a reasonable timeframe.

172. They also included the following non-health based metrics:

- annual mean O_3 concentration;
- AOT40[68] for crops; and
- AOT40 for forests.

173. In addition to the metrics mentioned above, population-weighted means were also derived for the human health effects metrics and/or area-weighted means for the non-health effects metrics. These were determined for Scotland, Wales, Northern Ireland, Central London, Outer London, the rest of England and the whole UK.

174. The following figures illustrate the results for the annual mean of the daily maximum 8-hourly O_3 concentrations (Figure 1.46), the number of days with running 8-hourly O_3 concentrations greater than 100 $\mu g.m^{-3}$ (Figure 1.47) and the appropriate metric for damage to crops, the AOT40 – Crops (Figure 1.48). Although various emission projections were modelled, in the interests of clarity only the emissions incorporating the latest NAEI with the CAFE projections have been illustrated in the graphs. The overall trends however remain the same.

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[66] Collins, W.J., Stevenson, D.S., Johnson, C.E., Derwent, R.G. (1997) Tropospheric Ozone in a Global-scale Three-dimensional Lagrangian model and its Response to NO_x Emission Controls. Journal of Atmospheric Chemistry, **26**, 223-274.

[67] Collins, W.J., Stevenson, D.S., Johnson, C.E., Derwent, R.G. (2000) The European Regional Ozone Distribution and its Links with the Global Scale for the Years 1992 and 2015. Atmospheric Environment, **34**, 255-267.

[68] Accumulated dose over a threshold of 40 ppb; AOT40 is the sum of the differences between the hourly mean surface ozone concentration (in ppb) for each hour when the concentration exceeds 40 ppb, accumulated during daylight hours.

175. Generally for each of the metrics there is an overall progressive increase in O_3 concentrations from the current year to 2010 and beyond. Figure A1.46 illustrates the annual mean of the daily maximum running 8-hourly O_3 concentration ($\mu g.m^{-3}$) for the various UK regions. Although the largest absolute values are expected to be in the countryside, the greatest increases in annual O_3 (from 2003) are in urban areas.

Figure 1.46: Annual mean of daily max running 8-hourly ozone concentrations, 2003 to 2020

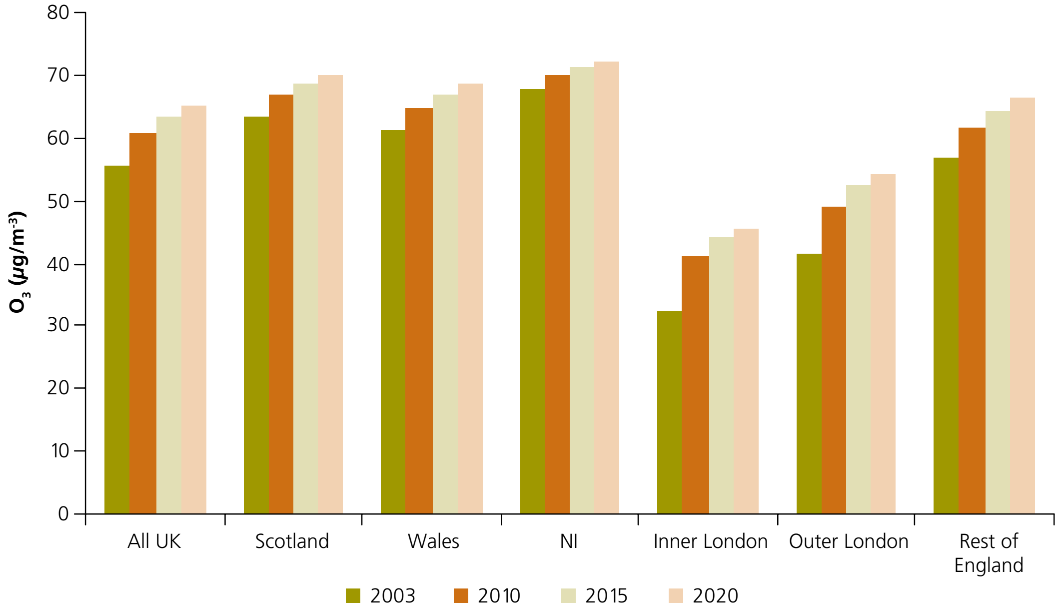


Figure 1.47: No. of days with running 8-hourly ozone concentrations > 100µg.m-3, 2003 to 2020

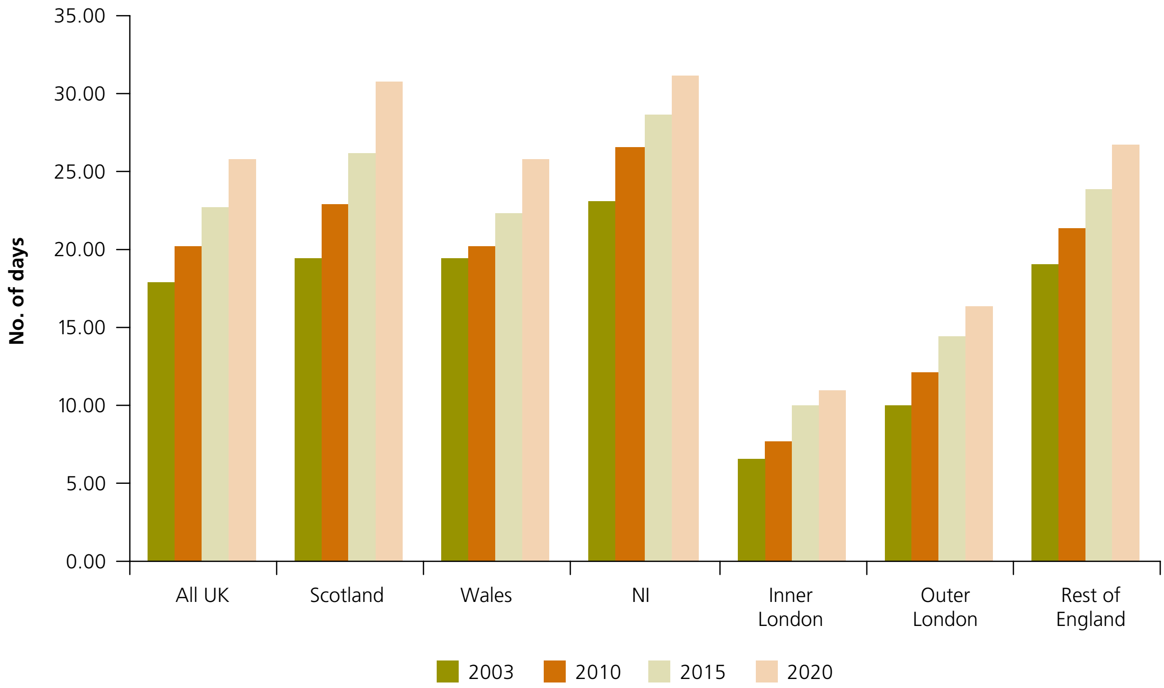
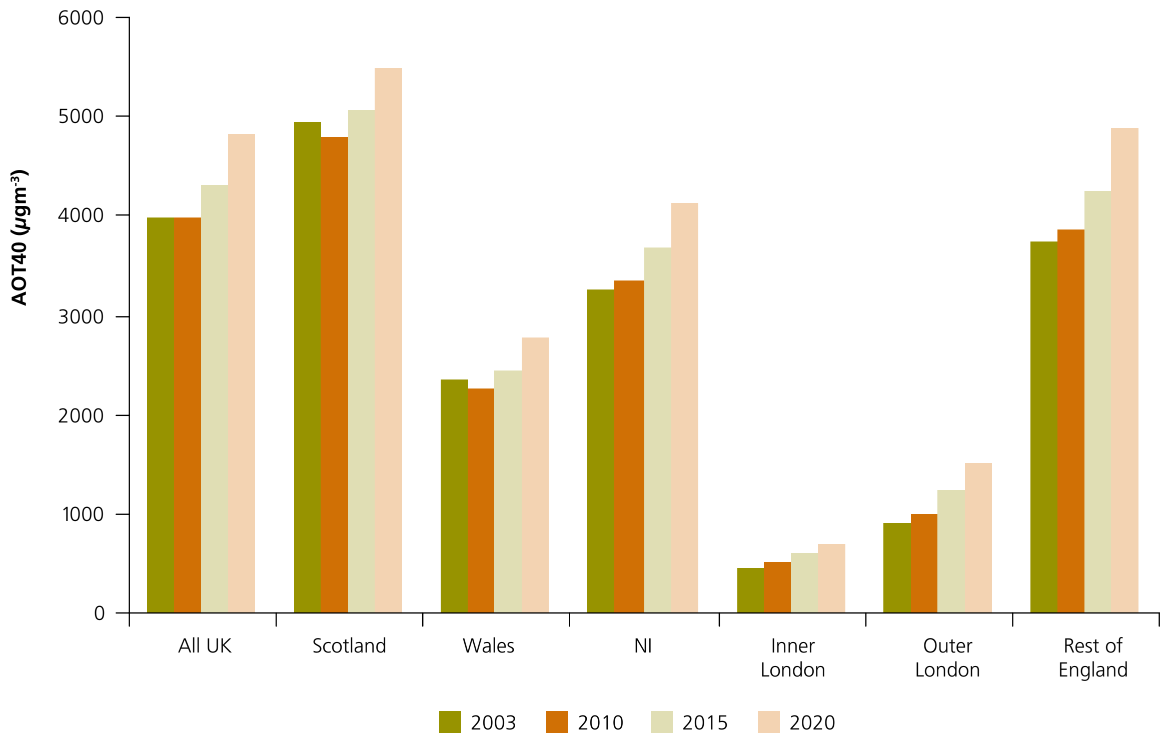


Figure 1.48: AOT40 – Crops, 2003 to 2020



176. In the base case run, UK emission projections out to 2020 show a greater decrease in NO_X emissions than VOC emissions. Projections for the rest of Europe show comparable reductions for both NO_X and VOC emissions. Overall therefore there is a proportionately greater reduction in NO_X than VOCs suggesting a smaller NO_X quenching effect and so leading to poorer O_3 air quality.

177. The expected change in atmospheric composition due to climate change is the main reason for the modelled increase in O_3 concentrations in rural areas. Model results using the same emissions projections but an unchanged atmosphere show lower O_3 concentrations.

178. Modelling of future O_3 concentrations suggests that, without additional measures, there is likely to be a gradual deterioration in O_3 air quality for both average levels and exceedences of the objective (episodes). Concentrations will still exceed the Strategy's objective in 2020. Average levels are likely to rise in urban and rural areas.

179. There are two main reasons for the projected increase:

- in addition to the role of NO_X emissions in O_3 production, lower NO_X emissions reduce the chemical quenching[69] effect, most notably in urban areas. This causes O_3 levels to increase towards the higher concentrations in surrounding rural areas; and
- the long-term increase in hemispheric background concentration.

[69] Where concentrations of traffic gases may be high, NO from exhaust emissions may react with O_3 to form NO_2, reducing for "quenching" O_3 concentrations. This is known as titration. Reducing NO_x emissions reduces this quenching of ozone in urban areas.

180. The nature of regional O_3 formation and the magnitude of the exceedence of the Strategy's objective means that only concerted action on an international scale can be effective. The O_3 modelling in Chapter 3 shows that UK action alone on VOC emissions could bring some small additional benefits, but levels are still expected to exceed the objective in large areas of southern Britain.

1.3.5.6 Uncertainties in ozone modelling

181. Like most air quality models, OSRM is subject to uncertainties in much of the input data including emissions (of O_3 precursors), meteorology and the chemical reaction schemes used. Ozone is particularly sensitive to the prevailing weather conditions, resulting in considerable year to year variability, so OSRM investigated the effects of five different met years (1999–2003)[70]. The O_3 metrics were found to be more sensitive to the meteorology than to emission changes in the runs between 2000 and 2010.

182. The comparison of the model results with observed measurements varied depending on location, metric considered and met year used for the analysis. For some years the model slightly over-predicted O_3 levels compared to observations and for other years it slightly under-predicted. For example, the maximum hourly urban and rural O_3 concentration was slightly over-predicted for all years (within a 2:1 ratio of modelled vs observed). In modelling the number of days with exceedences of 100 $\mu g.m^{-3}$ OSRM slightly under-estimated when compared with observed for urban locations in 2003 but slightly over-estimated for other years and gave a broader spread of results for rural areas with most years showing an over-estimate. With one or two exceptions the majority of the OSRM results were usually within ±50% of that observed.

1.3.5.7 Uncertainties in inventories

183. Uncertainties in the NO_X inventory are discussed in Section 1.3.4.4.4. The non-methane volatile organic compounds (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.

1.3.6 Sulphur Dioxide (SO_2)

184. There are three objectives[71] for SO_2:

- **15 minute mean concentration of 266 $\mu g.m^{-3}$ not be exceeded more than 35 times a year by 31 December 2005;**
- **one hour mean concentration of 350 $\mu g.m^{-3}$ not be exceeded more than 24 times a year by 31 December 2004; and**
- **24 hour mean concentration of 125 $\mu g.m^{-3}$ not to be exceeded more than three times a year by 31 December 2004.**

[70] Hayman, G., (2006) Modelling of tropospheric ozone. AEA Technology, National Environment Technology Centre. Report AEAT/ENV/R/210.

[71] Table 2 of Volume 1 Chapter 1 shows the EU limit values for all pollutants.

185. There were no exceedence of any of the three objectives relating to SO_2 measured at AURN monitoring sites in 2005. Some exceedences were measured at monitoring sites outside the AURN not run by Defra and the devolved administrations. Exceedences are predicted to be almost eliminated by 2010.

186. Modelled exceedences of the 1-hour and 24-hour objectives are limited to the vicinity of one industrial plant. Further work will be undertaken in conjunction with the Environment Agency to assess the likelihood of the objectives being met at this location.

1.3.6.1 Health effects

187. Sulphur dioxide is an irritant gas that, in high concentrations[72], provokes broncho-constriction: i.e. narrowing of the airways. Epidemiological studies, including some from the UK, have shown, as in the case of particles, that day to day variations in concentrations of SO_2 are associated with the number of deaths occurring each day and also with admissions to hospital for the treatment of respiratory diseases[73]. There is also evidence linking concentrations of SO_2 with chest symptoms and with the use of bronchodilator therapies[74].

188. There is evidence from the USA[75] that long term exposure to SO_2 itself may be linked to losses in life expectancy. The same studies also indicated that sulphate particles, produced by oxidation of SO_2, may increase the risk of death.

1.3.6.2 Sources

189. Sulphur dioxide is mainly emitted as a by-product of burning fuels containing sulphur. The main source of emissions in the UK is from electricity generation fuelled by coal, dominated by the electricity generation sector. Emissions of SO_2 are expected to continue to decrease under current legislation (Figure 1.5).

1.3.6.3 Current and historic ambient concentrations

1.3.6.3.1 Measurements

190. Sulphur dioxide concentrations for all averaging periods have been declining at many sites for a considerable number of years. This is mainly due to large emission reductions in solid fuel and fuel oil use and a reduction in the sulphur content of diesel used in cars and lorries and gas oil.

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[72] Bronchoconstriction has been shown at concentrations down to around 200ppb in mild asthmatics (see Footnote 72, DoE EPAQS SO_2 report). Severe asthmatics have not been examined in volunteer studies.

[73] Department of Health (1998) Committee on the Medical Effects of Air Pollutants. *Quantification of the Effects of Air Pollution on Health in the United Kingdom.* London: The Stationery Office. Available at (accessed April 2007): http://www.advisorybodies.doh.gov.uk/comeap/statementsreports/airpol7.htm
WHO (2006) Air Quality Guidelines – Global update 2005 http://www.euro.who.int/Document/E90038.pdf

[74] Department of the Environment (1995) Expert Panel on Air Quality Standards. *Sulphur Dioxide.* London. HMSO. Department of Health (1992) Advisory Group on the Medical Aspects of Air Pollution Episodes. Sulphur Dioxide, Acid Aerosols and Particulates. London. HMSO. Department of Health (1998) Committee on the Medical Effects of Air Pollutants. *Quantification of the Effects of Air Pollution on Health in the United Kingdom.* London: The Stationery Office. Available at (accessed April 2007): http://www.advisorybodies.doh.gov.uk/comeap/statementsreports/airpol7.htm
WHO (2006) Air Quality Guidelines – Global update 2005 http://www.euro.who.int/Document/E90038.pdf

[75] Pope CA, Thun MJ, Namboodiri MM, Dockery DW, Evans JS, Speizer FE, Heath CW. (1995) Particulate air pollution as a predictor of mortality in a prospective study of US adults. *Am J Resp Crit Care Med;* **151**: 669-674;
Health Effects Institute (2000) Reanalysis of the Harvard Six-Cities Study and American Cancer Study of air pollution and mortality: a special report of the Institute's Particle Epidemiology Reanalysis Project. Health Effects Institute, Cambridge, USA;
Pope *et al* (2002) Lung cancer, cardiopulmonary mortality and long-term exposure to fine particulate air pollution. *JAMA* **287**, 1132-1141.

191. Progress compared to the 15-minute mean SO_2 objective is shown in Figure 1.49. This objective allows no more than 35 exceedences of 266 µg.m^{-3} SO_2 as a 15-minute mean in any year and to be met by 31 December 2005. This is the most stringent of the objectives relating to SO_2. The metric used in Figure 1.49 expresses the concentration as the 99.9th percentile. This is the 15-minute average concentration to avoid more than 35 exceedences of the objective. The figure shows the mean measurement of all sites in the AURN and the site with highest concentration.

192. Measured concentrations from all sites in the national network were reported below the 15-minute objective. Some exceedences were measured at local authority monitoring sites outside the AURN.

193. The other objectives relating to SO_2 are currently being achieved at all AURN sites. Figure 1.50 and Figure 1.51 show the 99.73th percentile (equal to 24 exceedences) of 1-hour mean and 99.18th percentile (equal to 3 exceedences) of the 24-hour mean SO_2 concentrations, respectively.

Figure 1.49: Measured 99.9th percentile of UK 15-minute mean sulphur dioxide concentrations

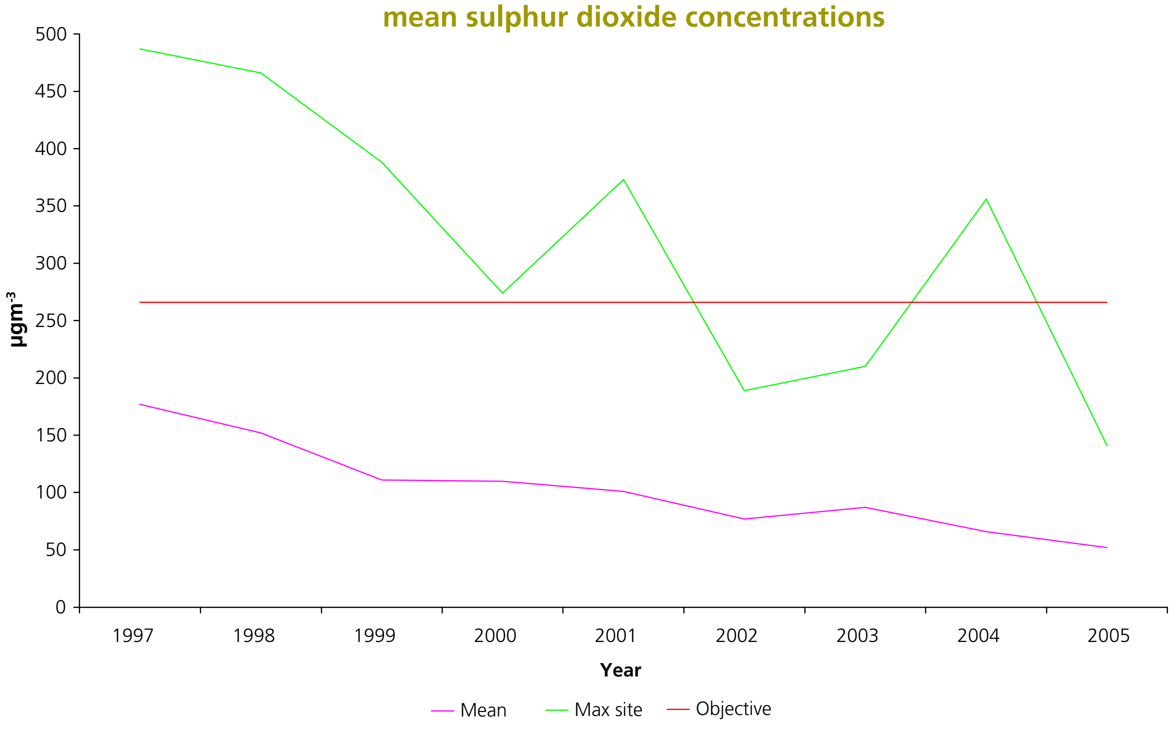


Figure 1.50: Measured 99.73th percentile of UK 1-hour mean sulphur dioxide concentrations

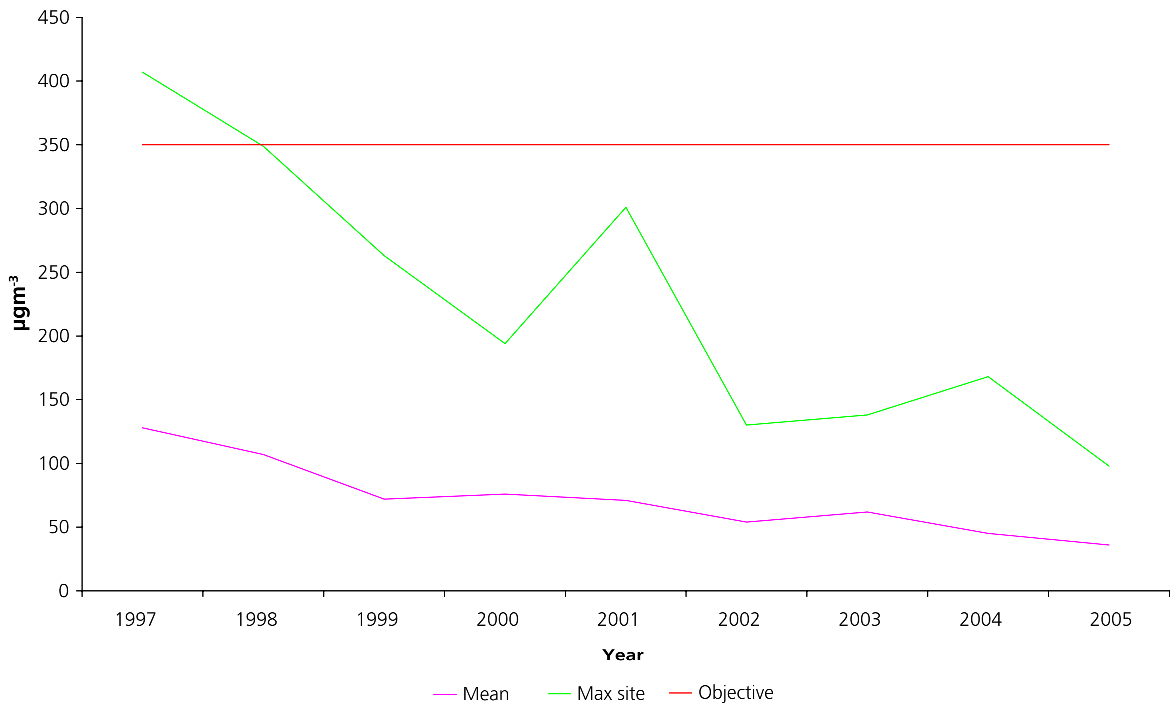
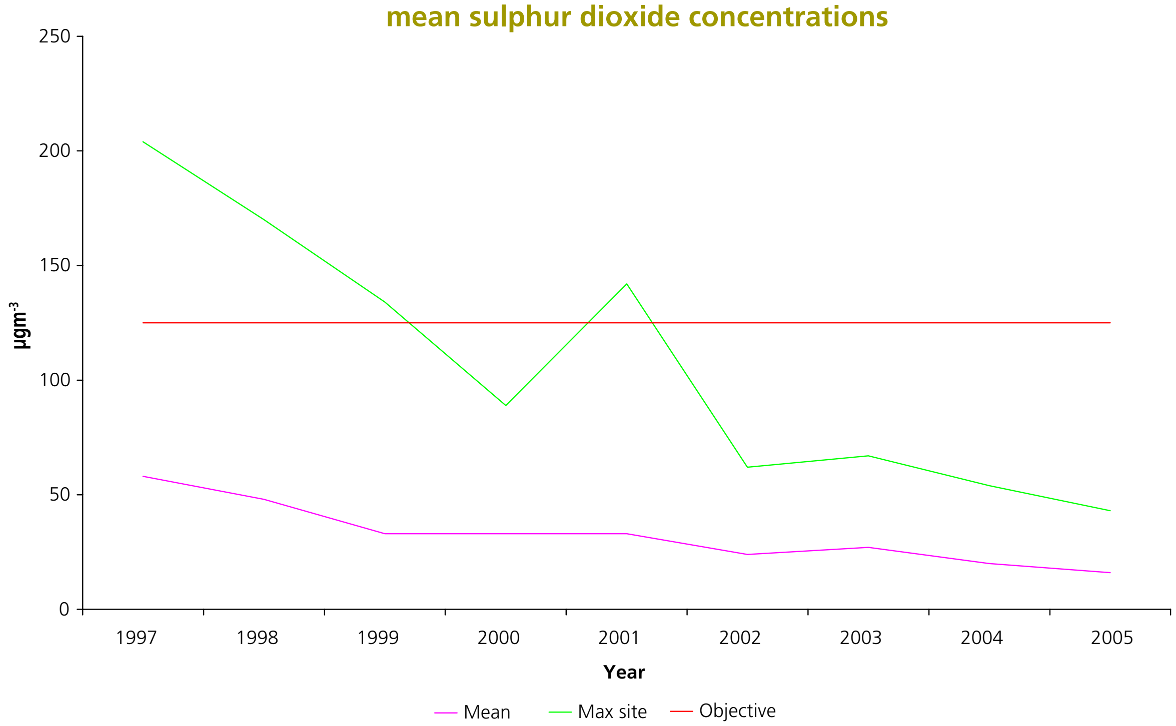


Figure 1.51: Measured 99.18th percentile of UK 24-hour mean sulphur dioxide concentrations



1.3.6.4 Model results and projections

194. We have estimated average SO_2 concentrations for 2003, 2005, 2010 and 2020. As with the other pollutants, this modelling is based on a 2003 base year and model and UEP12. These results do not differ significantly from those results given later on the detailed analysis for the 15-minute mean objective based on 2004 base year and model and UEP26.

195. Less than 1% of the total UK area currently exceeds the objectives and this drops significantly after 2005. The number of people exposed to SO_2 concentrations above the Strategy's objectives is forecast to increase from 2003 to 2005, reflecting that the predicted exceedence will occur in a more densely populated area in 2005 than that in 2003. After 2005 the number of people exposed to concentrations exceeding the objectives decreases significantly. Modelled exceedences of objectives in 2010 and beyond are limited to the vicinity of one industrial plant. Further work will be undertaken to assess the likelihood of the objectives being met at this location. In practice there should not be any exceedences at this plant because its Pollution Prevention and Control (PPC) permit requires the plant to achieve the 15-minute mean objective by the end of 2008.

196. Sulphur dioxide emissions can be estimated with 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.

197. Measurements only tell us about concentrations at certain locations. For a wide geographic coverage, we rely on models. Average SO_2 concentrations have been estimated for future years using a mapping model developed by Abbott and Vincent (1999)[76]. The methodology involved modelling emissions from point and area sources separately using a dispersion model and compared the modelled concentrations to measured concentrations at sampling sites located throughout the UK. At each sampling site the modelled concentrations were subtracted from the measured concentrations and the resulting values interpolated to produce a map of residual values. A fitting, or calibration, procedure was also used to ensure that the predicted concentration at a measurement site corresponded to the measured concentration. Sulphur dioxide concentration maps for 2003, 2005, 2010, 2015 and 2020 were produced for each of the 24-hour, 1-hour and 15-minute objectives.

198. Concentrations for future years were predicted using the same calibration factors, meteorological data and concentration residual maps as used for the EU 1st Air Quality Daughter Directive limit value reporting assessment (Stedman *et al.*, 2005a[77]). The only input parameter to change was the emission from power stations; emissions from all other point sources and area sources were assumed to remain constant. The dispersion model was then rerun for each of the forecast years.

199. This modelling (Stedman *et al*, 2005a) showed that there was only one 5 km x 5 km area of the United Kingdom that experienced an exceedence of the short-term EU limit values. However, the Environment Agency has now set permit conditions under IPPC requiring the plant to achieve these by the end of 2008.

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[76] Abbot, J. and Vincent, K. (1999). Annual average sulphur dioxide concentration maps derived by dispersion modelling. AEA Technology, National Environmental Technology Centre. Report AEAT – 4629 http://www.aeat.co.uk/netcen/airqual/reports/kvann1/so2ann.html.

[77] See footnote 13.

200. Table 1.15 presents the area of the UK forecast to exceed both the short term Air Quality Strategy objective and EU limit values for 2003, 2005, 2010 and 2020. As discussed above there is no change to the extent of exceedence of the EU limit values after 2003. For the Strategy's short-term objective, the area of exceedence decreases slightly from 2003 to 2005. After 2005 the area of exceedence drops significantly reflecting the large projected reduction in emissions.

201. Table 1.16 shows the number of people exposed to both the short term Air Quality Strategy objective and EU limit values for 2003, 2005, 2010 and 2020. The number of people exposed to SO_2 concentrations above the Strategy's objective is forecast to increase from 2003 to 2005 reflecting that the predicted exceedence will occur in a more densely populated area. After 2005 the number of people exposed to short-term concentrations exceeding the objective decreased significantly. It is recognised that some modelling undertaken for LAQM purposes has shown background areas and populations exceeding the short-term objectives for SO_2 in some local authorities, which is not reflected in the national modelling.

Table 1.15: Area (km^2) exceeding the short term sulphur dioxide Air Quality Strategy objectives and EU limit values

	Region	2003	2005	2010	2015	2020
AQS objective (15-minute)	London	0	0	0	0	0
	Rest of England (not London)	1566	1102	25	25	15
	Scotland	0	0	0	0	0
	Wales	0	0	0	0	0
	Northern Ireland	0	0	0	0	0
	Total	**1566**	**1102**	**25**	**25**	**25**
	% of UK	0.65	0.46	0.01	0.01	0.01
EU limit values and AQS objectives (Daily and Hourly)	London	0	0	0	0	0
	Rest of England (not London)	25	25	25	25	15
	Scotland	0	0	0	0	0
	Wales	0	0	0	0	0
	Northern Ireland	0	0	0	0	0
	Total	**25**	**25**	**25**	**25**	**15**
	% of UK	0.01	0.01	0.01	0.01	0.01

Table 1.16: Number of people ($x10^3$) exposed to concentrations exceeding the short term sulphur dioxide Air Quality Strategy objectives and EU limit values.

	Region	2003	2005	2010	2015	2020
AQS objective (15-minute)	London	0	0	0	0	0
	Rest of England (not London)	383	682	4	4	4
	Scotland	0	0	0	0	0
	Wales	0	0	0	0	0
	Northern Ireland	0	0	0	0	0
	Total	**383**	**682**	**4**	**4**	**4**
	% of UK population	0.66	1.17	0.01	0.01	0.01
EU limit values and AQS objectives (Daily and Hourly)	London	0	0	0	0	0
	Rest of England (not London)	4	4	4	4	4
	Scotland	0	0	0	0	0
	Wales	0	0	0	0	0
	Northern Ireland	0	0	0	0	0
	Total	**4**	**4**	**4**	**4**	**4**
	% of UK population	0.01	0.01	0.01	0.01	0.01

1.3.6.5 Assessment of the UK 15 minute Sulphur Dioxide Objective

1.3.6.5.1 Summary

202. In response to concerns raised during the 2006 consultation on the review of Air Quality Strategy and elsewhere, this section considers the costs and benefits of removing the Strategy's existing 15 minute objective on SO_2. If the objective were to be removed, some installations could potentially increase their emissions while maintaining compliance with other regulatory SO_2 constraints. The costs industry could save by doing that have been compared with the estimated monetised health disbenefits arising from the resulting additional sulphur emissions using assessment methodologies consistent with the rest of the Air Quality Strategy review evidence base.

203. The main effects of the removal of the objective would be felt in the power generation and refinery sectors, and the assessment focuses on these. Integrated Pollution Prevention and Control regulators have had regard to the objective in their deliberations on BAT, but there is no legal requirement to meet the objective. We are considering amending the IPPC guidance in England and Wales to make this clearer.

204. It is recognised that industry have incurred large costs in controlling SO_2 over the years, but we have evaluated only the additional costs of meeting the 15 minute mean objective that might be avoided by its removal. Only the health disbenefits of the resulting potential additional emissions have been calculated to maintain internal consistency.

205. The results of this analysis suggest the removal of the SO_2 15 minute mean objective would provide a net disbenefit of **£3m – £41m per annum** for the period up to 2015. The health disbenefits included in this calculation cover only those associated with chronic effects. Other effects which would increase this disbenefit have also been described and quantified (e.g. acute affects on sensitive individuals), but are not included in this estimate as they are either less certain or difficult to monetise.

1.3.6.5.2. Issue

206. The 1997 UK National Air Quality Strategy adopted an air quality objective based on a 15 minute averaging period to guard against the short term effects of SO_2. This objective has no direct equivalent in European legislation. It is more stringent than the 1st European Air Quality Daughter Directive (1999/30/EC), which sets Limit Values for SO_2 with averaging periods of 1 hour and 24 hours.

207. In recent years, some UK industries have suggested the 15 minute SO_2 objective is an example of 'gold plating'. This section sets out work undertaken by Defra, the devolved administrations and the Health Protection Agency to consider whether the objective should be retained.

1.3.6.5.3. Background

208. Directive 1999/30/EC sets two air quality limit values for SO_2 for the protection of human health to be achieved from January 2005: the 1 hour mean of 350 $\mu g.m^{-3}$, which is not to be exceeded more than 24 times per year; and the 24 hour mean of 125 $\mu g.m^{-3}$, not to be exceeded more than 3 times per year. The UK Air Quality Strategy has set an additional objective for SO_2 of a 15 min mean of 266 $\mu g.m^{-3}$ (100 ppb), not to be exceeded more than 35 times per year. This is derived from a standard recommended by EPAQS in 1995 (set at the same concentration and averaging time, but without any exceedences).

209. The EPAQS concluded that a short averaging time was desirable as the effects of SO_2 on the lung's airways could occur very rapidly (over a period of a few minutes). The EPAQS felt that it was unlikely that significant effects will occur in the majority of people with asthma exposed to concentrations below 200 ppb in ambient air. A 15 minute averaging time was decided upon as a sensible compromise between the desire to match the response time for sensitive individuals and the practicality of measurement. They agreed that a more easily measured 15 minute average could conceal short lived peaks. They recommended a lowering of the 200 ppb figure by a factor of two to allow for the possibility of shorter peaks being concealed within the 15 minute period[78], as well as the need to ensure an adequate margin of safety for individuals more severely affected with asthma.

210. The WHO has also produced a short-term guideline for SO_2 of 500 $\mu g.m^{-3}$ over a ten minute averaging time (with no exceedences). Their rationale, based on a rapid response to short term exposures, was similar to EPAQS. However they did not consider the possibility of short lived peaks within the averaging period in the same detail as EPAQS. The WHO guidelines are, like EPAQS standards, the result of risk assessment, rather than risk management – in other words the difficulty or otherwise of their attainment is not a determining consideration. It is worth noting that while the EPAQS 15 minute *standard* is likely to be more stringent than the WHO ten minute guideline, the 15 minute *objective* is likely to be less stringent than the WHO ten minute guideline.

[78] This factor was derived from monitoring data from areas where exceedences were likely. In those days monitors tended to incorporate chart recorders, so they could actually look at the occurrence of peak levels within the 15 min means to validate this assumption.

211. The WHO have recently recommended a new guideline for SO_2 of 20 µg.m^{-3} averaged over 24 hours. A preliminary analysis of the relative stringency of the different guidelines, standards and objectives has been carried out by examining monitoring data for 2005 from the national monitoring networks. This analysis suggests that WHO's new guideline of 20 µg.m^{-3} over 24 hours is considerably more stringent than the UK 15 minute standard (no exceedences of 266 µg.m^{-3}) and objective (no more than 35 exceedences of 266 µg.m^{-3}). The WHO also proposed two interim 24 hr guidelines of 50 µg.m^{-3} and 125 µg.m^{-3}. The higher of these interim guidelines is roughly equivalent to the 15 minute objective; the lower is roughly equivalent to the 15 minute EPAQS standard. So an important consideration in the debate on the objective is that there is a general international move amongst health professionals towards tighter SO_2 standards.

212. The EC legislation has been derived from the recommendations of the WHO using a one hour limit value for SO_2 derived from the ten minute short term guideline (although by including 24 allowed exceedences the limit value is in fact far less stringent). An averaging time of one hour will conceal exceedences and potential effects which may occur over shorter periods.

213. There are other legislative constraints on sulphur emissions within the UK, such as the National Emission Ceilings Directive (NECD), the IPPC Directive and the LCPD. Sulphur emissions may also be relevant to the requirements of other Directives.

214. It is important to recognise that there are very few remaining exceedences of the 15 minute objective within the UK. By 2006, 15 Air Quality Management Areas (AQMAs) had been declared based on failure of the 15 minute SO_2 objective. Of these, two are related to refineries, eight to industrial installations, one to shipping, one to a steam railway and three to domestic coal burning. Some of these sources are controlled under IPPC, others as part of LAQM. The IPPC regulators must have regard to the objective in their deliberations on BAT. Local Air Quality Management Action Plans must pursue the achievement of the objective. But there is no legal requirement to meet the objective in either case and we are considering amending the IPPC guidance in England and Wales to make this clearer.

1.3.6.5.4 Approach

215. In order to carry out this analysis, an assessment has been carried out of the effects on health of **removing** this objective. This assumes that industry would only need to comply with the one hour and 24 hour objectives for SO_2 and some installations, in particular those using lower sulphur fuels to meet the 15 minute objective, could therefore theoretically increase their emissions. The impact on health of this increase in emissions can be quantified, both in terms of the effects of SO_2 and secondary PM (which is partially derived from atmospheric reactions involving SO_2). These health effects can be monetised and compared with the financial benefits of removing the objective.

216. We have focused on the two industry sectors where we believe the removal of the objective would have the largest effect in terms of both health benefits foregone and industry costs saved – coal fired power stations and oil refineries.

217. The following scenarios have been modelled using a base year of 2004 and projections to 2010, 2015 and 2020 were produced:

(a) DTI UEP21 energy baseline with the current 15 minute SO_2 objective in place (2004 and 2010 only);

(b) DTI UEP21 energy baseline without the current 15 minute SO_2 objective in place (2004 and 2010 only);

(c) DTI UEP26 energy baseline with the current 15 minute SO_2 objective in place;

(d) DTI UEP26 energy baseline without the current 15 minute SO_2 objective in place.

1.3.6.5.5 Assumptions

218. A number of assumptions have been made in this modelling:

- The emissions for scenario (a) were projected based on site specific information prepared by DTI for UEP12 and adjusted by the projected emissions for the electricity supply industry for UEP21. At the start of the work to review the 15 minute SO_2 objective, this was the current set of energy projections published by DTI. UEP21 has now been superseded by UEP26.
- For scenario (b) site specific corrections were made for power stations based on their flue gas desulphurisation (FGD) and LCPD status. The emissions from power stations with FGD and within the National Emission Reduction Plan (NERP) were kept constant. This is based on two conservative assumptions: that the operation of a plant at less than optimum abatement conditions is not BAT and therefore unlikely to be allowed by the permit, and; that within the NERP the increase in emissions by one source would be cancelled by the decrease in emissions from another source. Hence the annual total emissions would remain constant.[79]
- Annual emissions from 'opted out' coal fired power stations were increased by a factor of 1.5 (based upon the lower end of factors arising from modelling results from the Environment Agency – see Box 1.3).
- Virtually all LCPD sources in the refinery sector have opted into the NERP. So, even if their emissions increase individually under trading, there will be no overall increase in emissions since the NERP in effect has a fixed maximum "bubble". The refinery emissions from non-LCPD sources (currently 60% of the sector total) were increased by a factor of 1.5 giving an overall 30% increase. Further detail can be found in Box 1.3.
- While smaller operators in other sectors may also be impacted by the removal of the objective possibly allowing the increase in emissions this was considered insignificant on a national scale compared to the uncertainties in the emission projections which are of the order of 20%.
- Emissions estimates for scenario (b) were only calculated for 2010. Following advice from the Environment Agency it was assumed that the opted out power stations would be unlikely to emit in 2015 and this scenario would therefore be identical to scenario (a).

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[79] There is limited capacity within the NERP for one of the major sources to increase their emissions significantly as the majority of operators within the NERP have relatively small emissions to trade. If the 15 minute objective were removed, operators which are part of the NERP would need to decide whether it was cost-effective to purchase additional SO_2 quota to enable an increase in site specific emissions whilst complying with the requirements of the reduction plan.

- Site specific information was obtained from DTI for UEP26 for coal fired power stations. This was used for a UEP26 baseline (c) for each year. UEP26 predicts more power stations with FGD than UEP21. As a result SO_2 emissions are lower, despite a greater use of coal, and both the costs and benefits of removing the objective are reduced.
- As the DTI UEP26 estimates show opted out power stations continuing to operate in 2015 (the last year in which they are able to) and non-LCPD sources at refineries operating through to 2020, emissions for scenario (d) were calculated for 2010, 2015 and 2020 using the assumptions described above.

Box 1.3 Modelling Assumptions

Potential increase in annual emissions from 'opted out' coal fired power stations

Opted out power stations will be able to manage their emissions by altering the proportion and times at which they buy lower sulphur coal. The operating hours used are based on DTI estimates of behaviour and clearly are subject to the commercial decisions of individual operators.

Within scenario (b) annual emissions from 'opted out' coal fired power stations were increased by 50%. No physical abatement equipment is assumed to be fitted in any of the scenarios. This factor arises from three concurrent studies; analysis based on plume dispersion theory suggests that a plant emitting sufficient to exactly meet the 15 minute objective could increase its emission by between 100% and 300% if allowed to increase its emissions until it just meets the one hour objective.

Reanalysis of measurement data from sites impacted by plumes from major point sources suggested that an increase of between 30% and 450% in emissions would be allowed depending on the meteorological conditions and the relative location of other sources.

Ground level concentrations are linearly related to emissions. Modelling carried out for a generic power station with and without FGD shows that, in the absence of the 15 minute objective, emissions could be increased by 80% before meeting the next regulatory constraint (the one hour EU Directive Limit Value). Further work on a range of generic sources gave increases of 52% for a refinery, 64% for a municipal waste incinerator, 50% for a hazardous waste incinerator and 57% for a cement works using the dry process and burning 25% tyres.

Hence 50% was a conservative value to take into account that operators are cautious in approaching regulatory limits since they may be subject to action for breach of permit if they were to exceed an objective. If necessary, the resulting emission was constrained to the station specific limit ('A' limits in England and Wales, a bubble for Longannet and Cockenzie in Scotland).

Box 1.3 Modelling Assumptions *(continued)*

Potential increase in refinery emissions from non-LCPD sources

The 60% of refinery emissions from non-LCPD sources are presently permitted based on the attainment of the 15 minute objective. In the absence of this objective, the regulator would no longer be able to take into account the short term health effects of SO_2 in permit determinations. It is therefore assumed that removal of the objective will lead to operators applying for revised permits.

In scenarios (b) and (d) it is assumed that operators will seek the most economic approach to emission management which would be to increase emissions from these sources. This could involve moving releases from LPCD sources on site and hence making available the possibility of a trading gain for the operator. This would lead to an increase in the national total. These non-LCPD sources were increased by a factor of 1.5 for the reasons given above leading to an overall 30% increase at refineries.

1.3.6.5.6 Air Quality modelling results

219. The monetisable benefits for this analysis focus on the chronic health effects arising from the assumed additional SO_2 emissions. These are calculated on the basis of changes in the annual average population weighted concentrations described in the tables below. Other effects which would increase this benefit have also been described and quantified (e.g. acute affects on sensitive individuals), but are not included in the main estimate as they are either less certain or difficult to monetise.

220. Table 1.17 shows a summary of the key results of this modelling assessment. Key results of the health impact assessment are shown in Table 1.18.

Table 1.17: Predicted UK population weighted mean concentrations

	a	b	difference
SO_2 2010 (μg.m^{-3})	2.755	3.010	0.255
PM_{10} 2010 (μg.m^{-3}, gravimetric)	18.233	18.353	0.120

	c	d	difference
SO_2 2010 (μg.m^{-3})	2.495	2.632	0.138
SO_2 2015 (μg.m^{-3})	2.359	2.469	0.110
SO_2 2020 (μg.m^{-3})	2.224	2.297	0.073
PM_{10} 2010 (μg.m^{-3}, gravimetric)	18.163	18.214	0.051
PM_{10} 2015 (μg.m^{-3}, gravimetric)	17.453	17.496	0.043
PM_{10} 2020 (μg.m^{-3}, gravimetric)	16.880	16.900	0.020

221. The GIS-based air dispersion models used in this assessment were of the same type as those in the April 2006 Air Quality Strategy review consultation. The health impact assessment of the resulting changes in SO_2 and PM_{10} concentrations were calculated

using methods fully consistent with the Third Report of the IGCB[80]. The assessment of the change in life expectancy due to the long-term effect of PM has been based on a five year change in concentration, with the impact of this change followed for 100 years.

Table 1.18: Results of the health impact assessment

	Deaths brought forward	Additional respiratory hospital admissions	Additional cardiovascular hospital admissions
SO_2 2010 (b – a)	88	73	–
PM_{10} 2010 (b – a)	40	42	42

	Deaths brought forward	Additional respiratory hospital admissions	Additional cardiovascular hospital admissions
SO_2 2010 (d-c)	48	39	–
SO_2 2015 (d-c)	38	31	–
SO_2 2020 (d-c)	25	21	–
PM_{10} 2010 (d-c)	17	18	18
PM_{10} 2015 (d-c)	14	15	15
PM_{10} 2020 (d-c)	7	7	7

222. The lifetable calculations carried out for the Air Quality Strategy review used changes in concentration for 5, 20 or 100 years and five years is the most appropriate for the assessment of the combined impact of the increases in emissions from power stations and refineries between 2010 and 2015. After 2015 the emissions from power stations for scenario (d) are the same as for scenario (c) (the UEP26 baseline). The emissions from refineries are, however, predicted to remain higher for scenario d than for scenario c for the foreseeable future. However, for the main analysis we have focused on the five year impact. We have also separately assessed the impact of the change in emissions (and therefore ambient concentrations) over a 100-year period.

223. The number of additional life years lost due to the long term effect of PM is estimated to be 25,310 (no lag) to 26,779 (40 year lag) or approximately 0.1 days per person for the difference between scenarios (a) and (b) (UEP21) in 2010 (five-year change in concentrations). For the difference between scenarios (c) and (d) (UEP26) in 2010 the number of additional life years lost is 10,775 – 11,401 (five-year change in concentrations). A coefficient of 6.0% per 10 $\mu g.m^{-3}$ change in PM has been used in these calculations.

[80] 'An Economic Analysis to Inform the Air Quality Strategy Review Consultation'. Defra (2006). Available at http://www.defra.gov.uk/environment/airquality/strategy/igcb/index.htm

1.3.6.5.7 Cost-Benefit analysis

224. This section sets out the assumptions and results of the cost-benefit analysis carried out to assess the impacts of the SO_2 15 minute objective.

Benefits

Monetisable benefits arising from avoided chronic effects

225. Quantified benefits of the SO_2 15 minute objective have been based on the agreed IGCB methodology and on expert advice from the COMEAP who recommended a 6% reduction in hazard rate (per 10 µg.m^{-3}) for $PM_{2.5}$ health effects. The COMEAP also stated that the 6% coefficient should apply equally to all components of $PM_{2.5}$, including sulphate. This has been applied to the secondary particulate benefits of this objective, on the basis that virtually all the sulphate created by the extra SO_2 emissions will be in the finer size fraction. Table 1.19 sets out the quantified health benefits of the SO_2 15 minute mean based on UEP21 (scenarios a and b) and UEP26 (scenarios c and d).

Table 1.19: Quantified health impacts of sulphur dioxide 15 minute mean objective in the UK

	PM life years saved ('000s) – 6% (2010–2109[79])	PM – RHA[80] (2010, p.a.)	PM – CHA[81] (2010, p.a.)	SO_2 as gas – mortality (2010, p.a.)	SO_2 as gas – RHA (2010, p.a.)
Scenario (b-a)	25 – 27	42	42	88	73
Scenario (d-c)	11	18	18	48	39

226. These values have been discounted to generate a Present Value (PV) in 2005 prices of the different impacts and then annualised. The results are presented in Table 1.20.

Table 1.20: Annual present value of health impacts of sulphur dioxide 15 min objective in the UK

	PM life years saved – 6%	PM – RHA[3]	PM – CHA[4]	SO_2 as gas – mortality	SO_2 as gas – RHA
Scenario (b-a)	£86-127m	£0.1-0.4m	£0.1-0.4m	£1.3m	£0.1-0.7m
Scenario (d-c)	£37-54m	£0.2m	£0.2 m	£0.7m	£0.1-0.4m

227. The main analysis therefore suggests an annualised benefit of **£38m – £56m per annum** from the retention of the 15 minute mean SO_2 objective for the period to 2015.

Other benefits not included in main analysis

228. We have also estimated the additional benefits derived from changes in concentrations arising from additional refinery emissions beyond 2015. These are more uncertain because of the difficulty in making assumptions about abatement in the longer term. Initial estimates suggest these additional impacts are likely to exceed an annualised

[81] These long term changes in health outcomes only relate to changes in concentrations over a five year period.

[82] RHA – Respiratory Hospital Admissions saved.

[83] CHA – Cardiovascular Hospital Admissions saved.

benefit of £10m.

229. Chamber studies indicate SO_2 also acts to irritate the airways and exposure can lead to breathing difficulties through bronchoconstriction. Given the reduction in population-weighted mean concentrations of SO_2 (set out in Table 1.17) evidence suggests the 15 minute mean objective is likely to generate some benefits in reduced occurrences of breathing difficulties, particularly among sensitive groups of the population such as asthmatics. However current studies are insufficient at present to allow formal monetised quantification of these avoided impacts to take place. This effect is therefore not included in the main analysis, even though there is strong evidence of its existence.

230. A formal quantification is not currently possible because of the absence of an established cost-benefit approach for this health endpoint. In the absence of such a method, the following steps can be used to derive the 'worst-case' number of additional episodes of bronchoconstriction:

- Determine the number of exceedences of the 100 ppb 15 minute averages per year for each emission scenario;
- Determine the population size in each 1km grid square;
- Make an assumption about the proportion of the population who are asthmatics;
- Make a further assumption that asthmatic symptoms (i.e. bronchoconstriction) will be produced in the proportion of asthmatics (previous step) once an exceedence of the 100 ppb 15 minute average has occurred; and
- Calculate the possible impact in terms of the number of episodes of bronchoconstriction using the different emission scenarios.

231. This is a very crude means of calculating the possible impact and we acknowledge the debatable intrinsic assumptions. Using this method, we have estimated the number of episodes of bronchoconstriction at 90,000 for scenario (c) and 160,000 for scenario (d). This implies a worst case estimate of 70,000 additional episodes of bronchoconstriction could be associated with the removal of the objective.

232. A reduction in SO_2 concentrations is also expected to lead to a reduction in damage to materials and ecosystems through acidic deposition as set out in the Third Report of IGCB. This benefit has not been quantified or monetised although it is likely to be small.[84]

Costs

233. The assumptions used in the cost analysis are presented below. The analysis focuses on those costs borne by both coal-fired power stations and oil refineries in meeting the 15 minute mean that would be avoidable in its absence. These costs capture the estimated incremental cost of meeting the 15 minute mean (as opposed to the one hour limit value) and assumptions used are based on discussions with both Environment Agency and industry stakeholders. Costs have been modelled over a five year period (2005-2009) for coal-fired power stations[85] and oil refineries on a consistent basis with the benefits

[84] The benefits of a reduction in SO_2 on materials and crops is discussed in section 2.6 and section 4.11 (respectively) of the IGCB third report. Analysis carried out for Air Quality Strategy measures that lead to a reduction in SO_2 emissions suggest that these monetised benefits are small compared to the health benefits (as shown in Table 1.19). Available at http://www.defra.gov.uk/environment/airquality/publications/stratreview-analysis/index.htm

[85] Only non-FGD coal-fired power stations have been considered in this cost analysis. Our assessment of remaining plants indicates that plants were either already fitted with (or commissioned) FGD before the introduction of the SO_2 15 minute mean in 2000, or are currently planning or in the process of fitting FGD in time for 2008 (to meet the requirements of LCPD).

modelling above.

Non-FGD equipped coal-fired power stations

234. The Environment Agency have looked at coal power stations on a case-by-case basis and estimated the level of sulphur content in coal that would be required to achieve compliance with the SO_2 15 minute objective (as opposed to the next most stringent Air Quality Strategy objective) assuming the 2005 level of electricity generation. This is based on the current average sulphur content of fuel, load factors and estimates of the sulphur content of coal power stations could use in order to individually achieve the Strategy's objectives. This can then be used to estimate the additional low sulphur coal required to meet the 15 minute mean only. Based on these assessments, this equates to an additional estimated 10Mt p.a. of low sulphur coal being used between 2005-2007 and an estimated 4Mt p.a. between 2008-2009 (the amount in the former period is higher as it includes the additional low sulphur coal used by plants that will be fitting FGD to meet the LCPD requirements in 2008).[86]

235. The cost of coal is based on DTI figures (estimated to be between £30 – £37 per tonne, 2005 prices) with a 3% – 7% premium applied to account for extra cost of low-sulphur content coal (based on International Energy Agency (IEA) findings).[87] When these cost assumptions are applied to the additional estimates above, results suggest additional annualised costs of **£15m – £20m per annum** for coal-fired power stations to meet the SO_2 15 minute mean.

Oil refineries

236. The cost estimate from UKPIA suggested that costs, per refinery, could be up to £10m p.a. in order to switch to sweeter (lower sulphur grade) crude oil. Current cost assumptions pro-rata this according to refining capacity across the nine refineries. The Environment Agency has suggested the sulphur issue could be better (and more cost-effectively) dealt with by fitting abatement equipment to the refinery – allowing them to continue using current crude supplies – as opposed to restricting crude oil choice.

237. A significant proportion of SO_2 releases on a refinery can be from the Fluid Catalytic Cracker unit (FCCU). Other sources are the Sulphur Recovery unit (SRU) as well as the onsite combustion plant (that are covered by the requirements of the LCPD). It is possible to fit scrubbers to the FCCU or SRU in order to reduce SO_2 emissions and comply with the 15 minute mean. The Environment Agency estimates that achieving a 30% reduction in SO_2 released from this sector in England and Wales would be an annualised cost of **£5m p.a.** This is based on information provided by the operators in this sector as part of their PPC applications.

238. The situation in Scotland is more complex for the refinery at Grangemouth. So it has been assumed that the cost to meet the 15 minute SO_2 objective will be in the order of **£10m p.a.**, based on the indicative figure from UKPIA.

[86] The range in estimated additional low sulphur coal needed is driven by the lack of data of available data to estimate the additional coal usage for the Scottish power stations (Cockenzie and Longannet). The range assumes additional low sulphur coal needed to meet the 15 min mean at these power stations is between 0 tonnes (0%) and the total individual coal usage at each station (100%).

[87] Evidence is mixed on the presence of a low sulphur premium. For the purposes of this analysis we have taken a conservative estimate of 7% premium, based on the high end estimate of the premium range suggested by IEA.

239. The PPC sector guidance note shows FCCU and SRU gas scrubbing as candidate BAT techniques and this will be assessed for each refinery during the PPC determination. It is therefore possible that scrubbing would have to be fitted irrespective of the 15-minute mean. In this case there may be no additional cost incurred in meeting the 15-minute mean.

240. In light of this the additional cost borne per refinery by the 15 minute mean is estimated at between **£0m per annum** (assuming all refineries are required to fit scrubbing under BAT) and **£15m per annum**[88] (assuming that scrubbing is fitted at the refineries in England and Wales that are most likely to cause a breach of the 15 minute mean and that the Scottish refinery would incur the cost of using sweeter crudes; Table 1.21).

Table 1.21: Annual present value of costs to non-flue gas desulphurisation coal-fired power stations and oil refineries

Cost to non-FGD coal power stations	Cost to oil refineries
£15-20m	£0-15m

Summary of costs and benefits

241. The analysis of benefits and costs set out above suggest that removal of the SO_2 15 minute mean objective would provide a net disbenefit of **£3m – £41m per annum** until 2015. This is based on the more recent UEP26 scenario (scenario (c-d)) results.

242. This is a conservative analysis. There would be other effects resulting from a removal of the objective, although their magnitude is less certain. An illustrative calculation suggests that removal of the objective could result in 70,000 additional episodes of bronchoconstriction as a result of increased SO_2 concentrations.

1.3.7 Polycyclic Aromatic Hydrocarbons (PAHs)

1.3.7.1 Objective attainment/status

- **for the whole of the UK, annual average concentration of 0.25 μg.m^{-3} based on benzo[a]pyrene to be met by 31 December 2010**

243. The objective was exceeded at five urban background or industrial sites in the AURN in 2005. Modelling of PAHs is highly uncertain because of a highly uncertain emissions inventory. Indications are that the objective will be difficult to achieve in some areas due to domestic space heating and increased activity projected in the use of coal, anthracite and solid smokeless fuels.

1.3.7.2 Health Effects

244. Studies of occupational exposure to PAHs have shown an increased incidence of tumours of the lung, skin and possibly bladder and other sites. Lung cancer is most obviously linked to exposure to PAHs through inhaled air. In its report, published in 1999[89], EPAQS recommended an air quality standard for PAHs of 0.25 ng.m^{-3} as an annual average, based on benzo[a]pyrene (B[a]P) as a marker for the total mixture of PAHs in the UK. This

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[88] For the analysis of the longer term impact of additional refinery emissions we have made the conservative assumption that these costs will be maintained beyond 2015.

[89] *Expert Panel on Air Quality Standards. Polycyclic Aromatic Hydrocarbons*. 1999. The Stationery Office Ltd.

recommendation is intended to reduce any risk to the population from exposure to PAHs to one which the Panel believes would be so small as to be undetectable. The Panel also commented that it does not necessarily follow that all exposure above this standard carries a significant risk, in view of the effective application of an additional tenfold safety factor in deriving the standard.

1.3.7.3. Sources

245. The main sources of PAHs in the UK are domestic coal and wood burning, fires (e.g. accidental fires (building/vehicle), bonfires, forest fires, etc.), anode baking, coke production, aluminium production and road transport. Available data indicates a substantial decline in emissions in the UK. Emissions of B[a]P are expected to decline to 2010. Emissions projections are however highly uncertain beyond 2010 (Figure 1.9).

246. The recent production of the 2005 NAEI has reduced the total B[a]P emissions in 2005 from 11,463 kilograms in the 2004 NAEI to 6766 kilograms in the 2005 NAEI. The 2005 NAEI has seen a number of revisions to the methodology for estimating emissions of B[a]P, following a short internal review of the NAEI methodology for POPs. Most of the revisions have made a small impact relative to UK emissions as a whole. However, changes have been made in three areas which do have a significant impact on the UK emission total for B[a]P. These areas are:

- a more realistic handling of burning of treated wood. This is no longer fixed at 1Mtonne per year. Separate estimates are now made of the wood treated with i) creosote, which produces large amounts of B[a]P, ii) pentachlorophenol (PCP) and iii) lindane;
- revisions to the emission factors for coal combustion; and
- increased use of the Pollution inventory data for coke ovens, sinter plant, coal tar distillers and cement works.

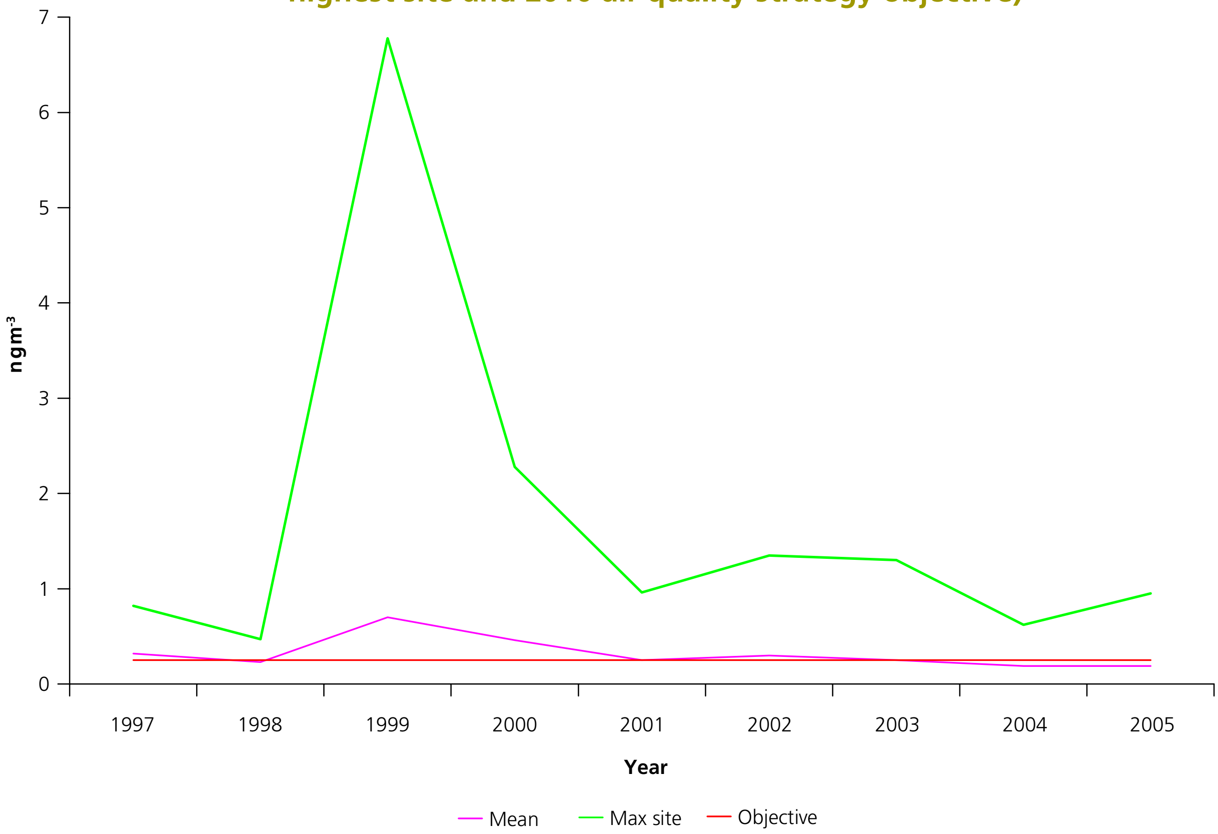
247. These revised emissions have not been modelled over the UK, since the gridded emission maps were not available. It is therefore likely that the modelled concentrations and exceedence estimates contained here are overestimates in some areas and this is likely to be a worst case. Further modelling will be carried out towards the end of 2007 using the 2005 NAEI and will be repeated each subsequent year. Uncertainties on the B[a]P emissions inventory remain high.

1.3.7.4 Current and historic ambient concentrations

1.3.7.4.1 Measurements

248. Benzo[a]pyrene is used as a surrogate for total PAHs. There has been a significant increase in the number of monitoring stations measuring B[a]P concentrations recently – there are now twenty-four sampling sites. This increase is required as the UK implements the monitoring requirements of the 4th Daughter Directive. Benzo[a]pyrene concentrations in 2005 ranged from less than 0.02 ng.m^{-3} at the semi-rural site at Hazelrigg in Lancashire to 0.95 ng.m^{-3} at an urban industrial monitoring site at Scunthorpe. The mean of all 24 B[a]P national sites was 0.19 ng.m^{-3}. Figure 1.52 shows the annual mean B[a]P concentrations of all the national sites and the highest site.

Figure 1.52: Measured annual mean benzo[a]pyrene concentrations in the UK (mean of all 24 sites and highest site and 2010 air quality strategy objective)



1.3.7.4.2 Baseline Modelling

249. In 2004, total UK emissions were about 11.5 tonnes with about 7% of the total arising from point sources. The remaining emissions were from area sources – domestic space heating (33%), and natural fires (22 %) being the main sources (Figure 1.9). As reported in the earlier national assessment[90], the emission inventory for B[a]P is significantly uncertain. This is because few emission measurements have been made both nationally and internationally and the relevant activity statistics in some cases are not collected regularly. Consequently the model results are highly uncertain.

250. The modelling method can however predict the measured concentrations, at all but one site, according to the data quality modelling objectives of ± 60%.

251. The emissions modelled from the area, point and background sources (0.05 ng.m^{-3}) were combined to produce B[a]P concentration maps for both 2005, 2010, 2015 and 2020[91]. The updated modelling was undertaken using a revised domestic combustion emissions grid.

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[90] Coleman, P., Bush T., Conolly C., Irons S., Murrells T., Vincent K., Watterson J., (2001) Assessment of benzo[a]pyrene atmospheric concentrations in the UK to support the establishment of a national PAH objective. AEA Technology, National Environmental Technology Centre. Report AEAT/ENV/R/0620 http://www.aeat.co.uk/netcen/airqual/reports/naqs2001/aeat-env-r-0620.pdf

[91] Vincent, K J. Bush, T. Coleman, P. (2007) Assessment of Benzo[a]pyrene concentrations in the UK. AEA Energy and Environment. Report AEA/ENV/R/2373

252. Modelled maps of B[a]P concentrations in 2005 and 2010 are presented in Figure 1.53 and Figure 1.54 and show areas of the UK estimated to exceed the B[a]P objective of 0.25 ng.m^{-3}. Where exceedences of 0.25 ng.m^{-3} are modelled, the overwhelming majority of 1 km squares do not exceed 0.4 ng.m^{-3}.

Figure 1.53: Benzo[a]Pyrene concentrations in 2005

Figure 1.54: Benzo[a]Pyrene concentrations in 2010

253. Nationally, the number of people exposed to B[a]P above the air quality objective concentration of 0.25 ng.m^{-3} decreases from 1.0 million in 2005 to 0.88 million by 2010 (Table 1.22).

254. A considerable amount of the area (and hence population) estimated to exceed the objective is believed to be due to the very uncertain emissions from uncontrolled waste treatment and disposal and natural fires. These emission sources include demolition, garden and accidental (building and vehicle) fires and are generally distributed on a population basis. Activity statistics are very difficult to obtain for these sources. Monitoring data for London suggest that, even at roadside, concentrations are below the objective.

Table 1.22: Background area, and population in the background area exceeding the Benzo[a]pyrene objective of 0.25 $ng.m^{-3}$ in 2005, 2010, 2015 and 2020 by region

		2005		2010		2015		2020	
	area assessed (km^2)	area (km^2)	No of people ($x10^3$)	area (km^2)	No of people ($x10^3$)	area (km^2)	No of people ($x10^3$)	area (km^2)	No of people ($x10^3$)
London	**1,629**	0	0	0	0	0	0	0	0
Rest of England	**128,547**	480	480	409	419	412	413	448	460
Scotland	**77,473**	4	11	2	8	2	8	3	9
Wales	**20,665**	9	9	6	5	6	5	7	6
Northern Ireland	**13,724**	258	508	216	451	217	453	233	472
Total UK	**242,038**	**751**	**1,008**	**633**	**883**	**637**	**879**	**691**	**947**

Population-weighted mean B[a]P concentrations ($ng.m^{-3}$)				
	2005	**2010**	**2015**	**2020**
Inner London	0.111	0.106	0.104	0.103
Outer London	0.109	0.108	0.106	0.106
Rest of England	0.112	0.112	0.111	0.112
Scotland	0.105	0.103	0.102	0.104
Wales	0.110	0.105	0.105	0.107
Northern Ireland	0.228	0.209	0.210	0.218
UK	**0.115**	**0.113**	**0.112**	**0.113**

1.3.7.4.3 Uncertainties in inventories

255. Inventories for POPs such as B[a]P are more uncertain than those for gaseous pollutants, PM_{10} 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. Those estimates relating to uncontrolled burning i.e. accidental fires in buildings, small-scale waste burning, agricultural waste burning, bonfire night, and natural fires are particularly uncertain. Estimated emissions from these sources are about 3,800 kg in the 2004 NAEI but actual emissions could conceivably be very much higher or lower.

1.3.8. Benzene

256. There are three objectives for benzene:

- **for the whole of the UK, a running annual mean concentration of 16.25 $\mu g.m^{-3}$ to be met by 31 December 2003.**

257. Measurements show that this is being met by a wide margin.

- **for England and Wales, an annual average concentration of 5 μg.m^{-3} by 31 December 2010;**
- **for Scotland and Northern Ireland, a running annual mean concentration of 3.25 μg.m^{-3} to be met by 31 December 2010.**

258. All objectives related to benzene were met everywhere in 2005. Modelled projections show that the objective is expected to be met at all background and roadside locations in 2010.

1.3.8.1 Health Effects

259. Benzene is a recognised genotoxic human carcinogen. Studies of industrial workers exposed in the past to high levels of benzene have demonstrated an excess risk of leukaemia which increased in relation to their working lifetime exposure. Benzene is not considered to affect childhood leukaemia[92]. Because it is a genotoxic carcinogen, no absolutely safe level can be specified for ambient air concentrations of benzene. In their 1994 report, EPAQS considered the advice of the Committee on Carcinogenicity of Chemicals in Food, Consumer Products and the Environment (COC) that exposure to benzene should be kept as low as practicable, and recommended a target of 3.25 μg.m^{-3}, also as a running annual mean.

1.3.8.2 Sources

260. Benzene has a wide variety of sources, mainly road vehicles, domestic combustion of coal and wood for heating and industrial processes. Benzene emissions are expected to continue to decline until around 2015, but are likely to increase after that without further measures (Figure 1.7). This is due to increases in the use of coal and wood for domestic fuel, as well as natural gas, to satisfy demand after 2010. There is also a predicted increase in the activity of the chemical industry in later years.

1.3.8.3 Current and historic ambient concentrations

261. Figure 1.55 shows the maximum running annual mean benzene concentrations of all the national sites and the highest site. The mean of all 39 benzene national sites was 1.64 μg.m^{-3}. Figure 1.56 shows the annual mean benzene concentrations in England and Wales and the highest site. The mean of all 34 benzene sites was 1.62 μg.m^{-3}. Figure 1.57 shows the maximum running annual mean benzene concentrations in Scotland and Northern Ireland and the highest site. The mean of all 6 benzene sites was 1.47 μg.m^{-3}. No sites exceeded any of the 2003 or 2010 AQS objectives for benzene in 2005. Benzene concentrations at both background and roadside sites have fallen sharply due to reductions in the benzene content of petrol and the introduction of cars equipped with catalytic converters. Monitoring site numbers have changed drastically between 2000 and 2004. The current network of 41 is a mixture of gas chromatographs (2), BTEX monitors (3) and non-automatic pumped tubes[93] (36).

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92 Committee on Carcinogenicity of Chemicals in Food, Consumer Products and the Environment, (COC) Statement on the review of the possible associations between childhood leukaemia and residence near sources of traffic exhausts and petrol fumes. Available at http://www.advisorybodies.doh.gov.uk/coc/childleukaemia.htm.

93 the maximum running annual mean was assumed to be equal to the annual mean for the pumped tube measurements. Maximum running annual means have been calculated for the automatic measurements.

Figure 1.55: Measured maximum running annual mean Benzene concentrations in the UK (mean of all 39 sites and highest site and 2003 Air Quality Strategy objective)

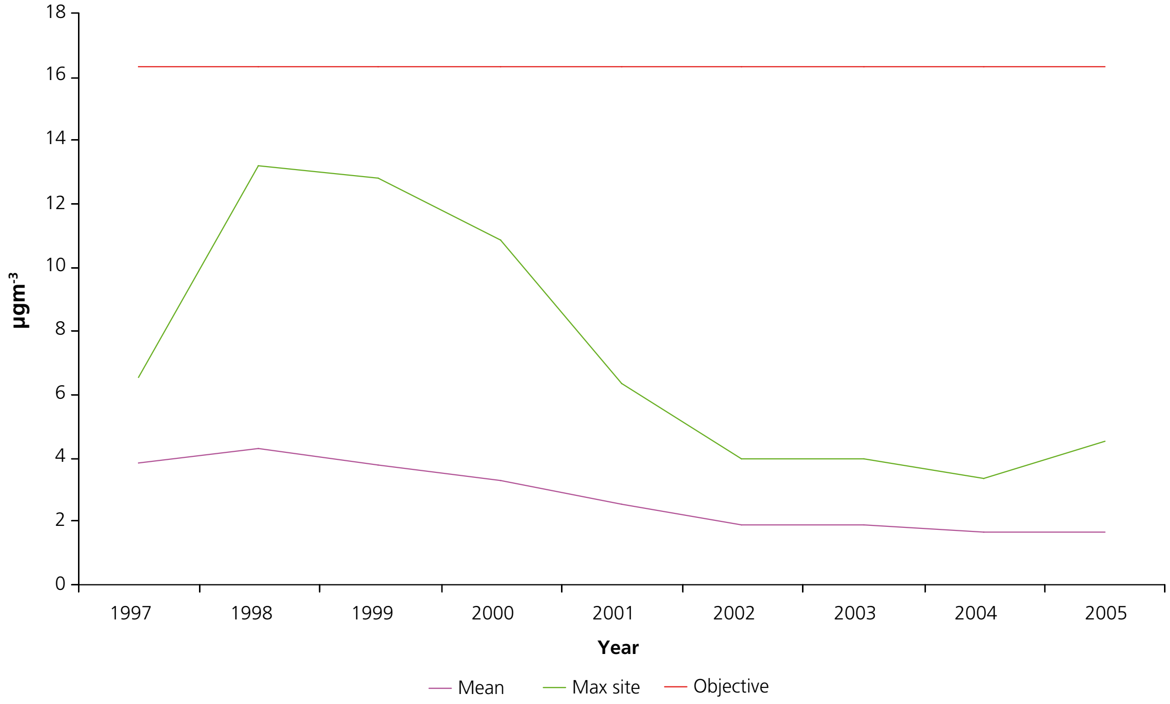


Figure 1.56: Measured annual mean Benzene concentrations in England and Wales (mean of all 34 sites and highest site and 2010 Air Quality Strategy objective)

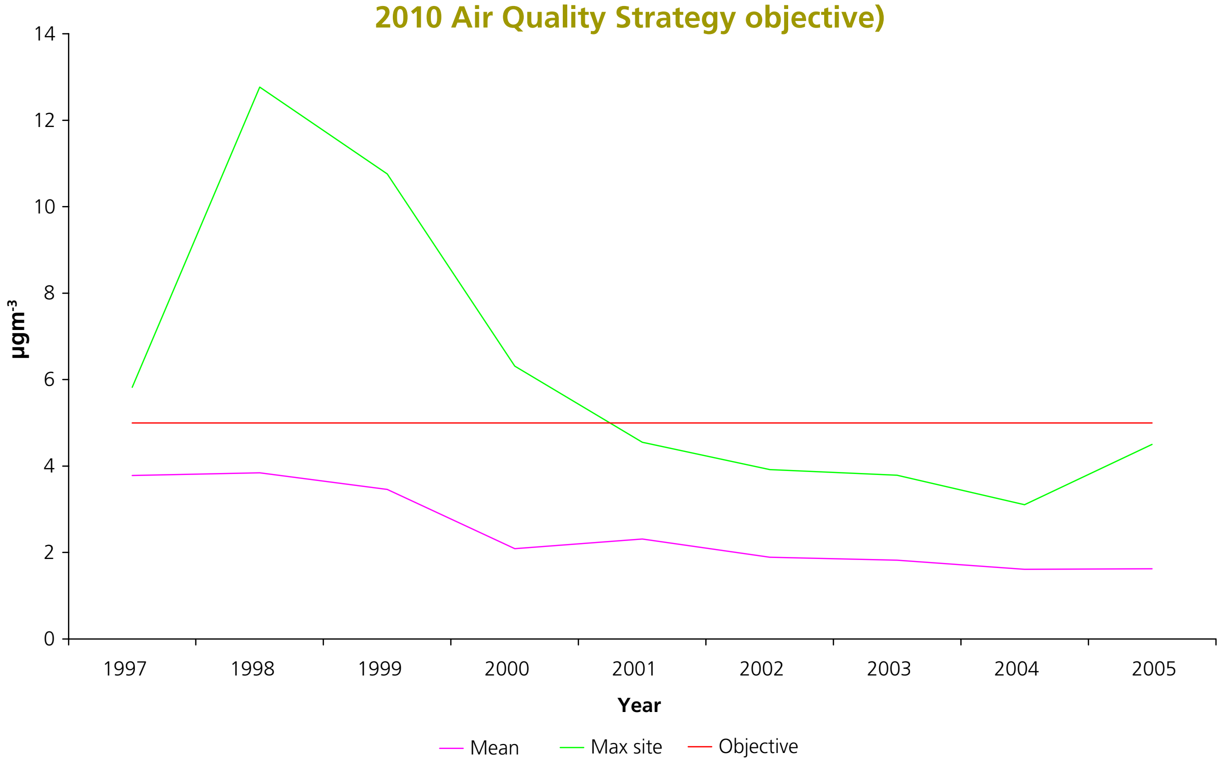
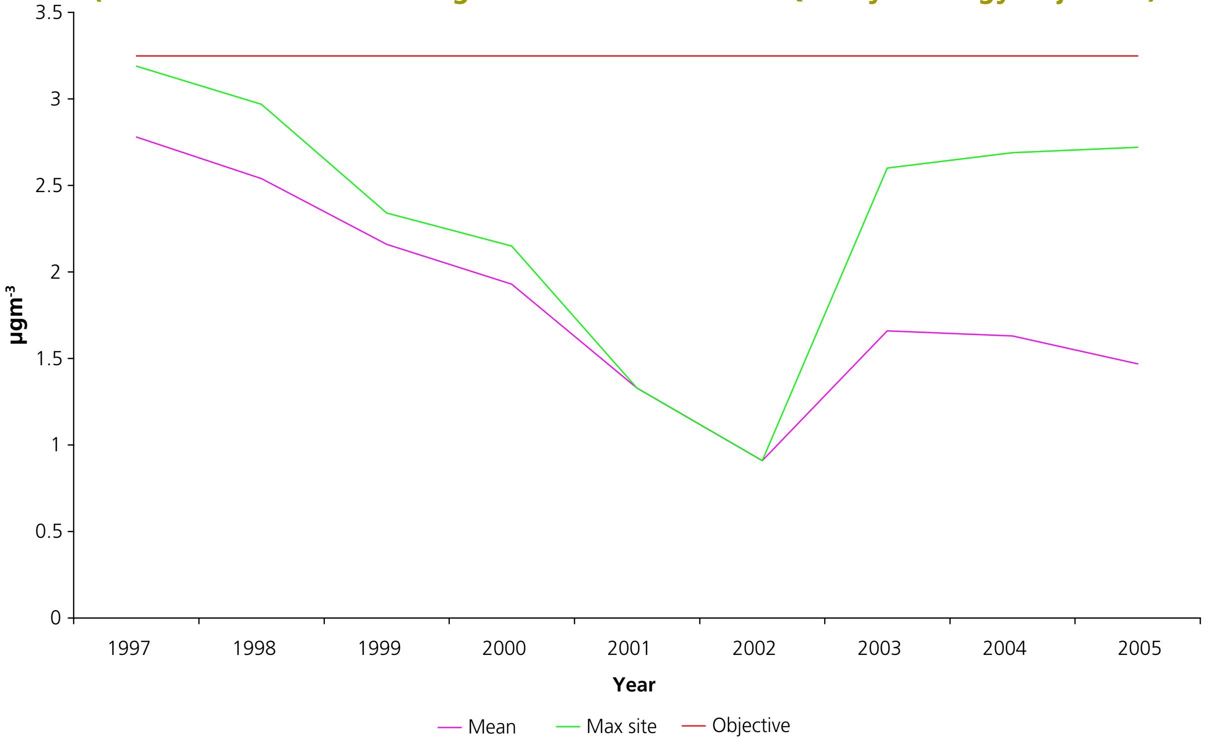


Figure 1.57: Measured maximum running annual mean Benzene concentrations in Scotland and Northern Ireland (mean of all 6 sites and highest site and 2010 Air Quality Strategy objective)



1.3.8.4. Baseline modelling

262. The Strategy's 2010 objective in England and Wales is 5 µg.m^{-3} annual mean (the same as the EU limit value). The objective in Scotland and Northern Ireland is 3.25 µg.m^{-3} measured as the maximum running annual mean. The GIS-based modelling does not predict any exceedences of these objectives in 2003 (Figure 1.58 and Figure 1.59) or 2010.

263. Maps of mean projected benzene concentrations at background and roadside locations for 2010 are presented in Figure 1.60 and Figure 1.61. The modelling method used in estimating projected annual mean concentrations in these years closely follows the method used to estimate concentrations in 2003 for benzene as described in Stedman *et al* (2005)[94].

[94] See footnote 14.

Figure 1.58: Annual mean background benzene concentration, 2003 (µg.m^{-3})

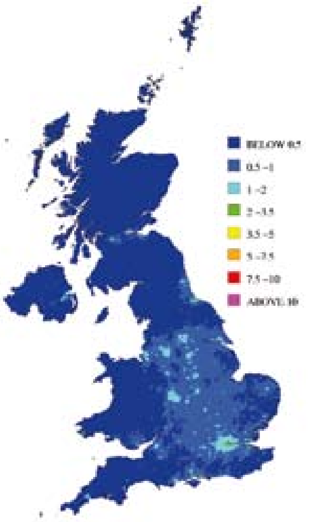


Figure 1.59: Urban major roads, annual mean roadside benzene concentration, 2003 (µg.m^{-3})

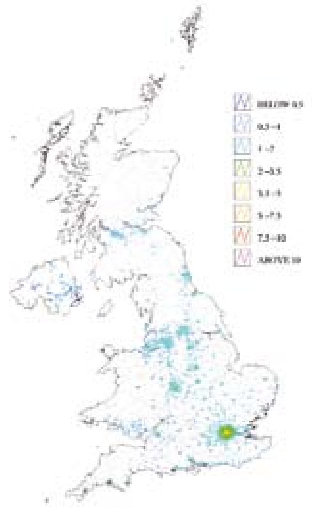
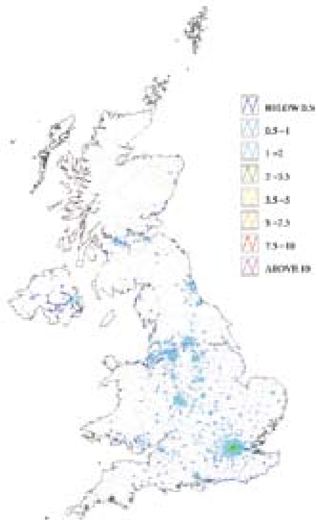


Figure 1.60: Annual mean background benzene concentration, 2010 (µg.m^{-3})

Figure 1.61: Urban major roads, annual mean roadside benzene concentration, 2003 (µg.m^{-3})



264. The modelling results for 2010 are summarised in Table 1.23. As with the 2003 results (see Stedman *et al*, 2005), estimates of area and population exposed have only been derived from the background maps. No attempt has been made to derive estimates using maps of roadside concentrations as these maps will only apply within approximately 10 metres from the road kerb.

Table 1.23: Summary statistics for UK baseline benzene projections using a 2003 base year

Total major road length (km) exceeding the annual mean limit value of 5 µg.m^{-3}			
	Total assessed	**2003**	**2010**
London	1,886	71.4	0.0
Rest of England (not London)	9,430	0	0
Scotland	1,085	0	0
Wales	640	0	0
Northern Ireland	1,044	0	0
Total	**14,084**	**71.4**	**0**
percentage > 5 µg.m^{-3}		**1%**	**0%**
Total background area (km^2) exceeding the annual mean limit value of 5 µg.m^{-3}			
	Total assessed	**2003**	**2010**
London	1,624	0	0
Rest of England (not London)	128,770	0	0
Scotland	77,791	0	0
Wales	20,745	0	0
Northern Ireland	13,318	0	0
Total	**242,248**	**0**	**0**
percentage > 5 µg.m^{-3}		**0%**	**0%**
Total population (x10^3) in area exceeding the annual mean limit value of 5 µg.m^{-3}			
	Total assessed	**2003**	**2010**
London	7,730	0	0
Rest of England (not London)	41,011	0	0
Scotland	4,945	0	0
Wales	2,851	0	0
Northern Ireland	1,623	0	0
Total	**58,160**	**0**	**0**
percentage > 5 µg.m^{-3}		**0%**	**0%**

265. Modelled concentrations in background locations were below the limit value of 5 µg.m^{-3} across the whole of the UK in 2003 and this threshold was only exceeded at a small number of roadside locations in London. A continued decline in emissions from road traffic sources is expected between 2003 and 2010. Thus no exceedences of 5 µg.m^{-3} are predicted for 2010.

1.3.8.4.1 Uncertainties in inventories

266. There has been much improvement in the benzene emission estimates in recent years. Information gained in speciating the emissions of NMVOC has helped the generation of more robust emission inventories for benzene. However, due in particular to the uncertainty in the levels of benzene in NMVOC emissions from road transport and other combustion processes, the uncertainty is much higher than that in the NMVOC inventory.

1.3.9 1,3-Butadiene

- **for the whole of the UK, a running annual mean concentration of 2.25 µg.m^{-3} to be met by 31 December 2003.**

267. No AURN monitoring sites recorded exceedences in 2005. Moreover, modelling of 1,3-butadiene for 2003 showed no predicted exceedences of the objective. Therefore projections have not been produced because emissions are expected to decline in the future. The objective is expected to continue to be met.

1.3.9.1 Health Effects

268. The health effect which is of most concern in relation to 1,3-butadiene exposure is the induction of cancers of the lymphoid system and blood-forming tissues, lymphomas and leukaemias. Like benzene, 1,3-butadiene is a genotoxic carcinogen, and so no absolutely safe level can be defined. The EPAQS nevertheless believed that a standard could be set at which any risks to the health of the population are exceedingly small. In their 1994 report EPAQS recommended an air quality standard of 2.25 µg.m^{-3} as a running annual mean and this was confirmed in a subsequent report in 2002.

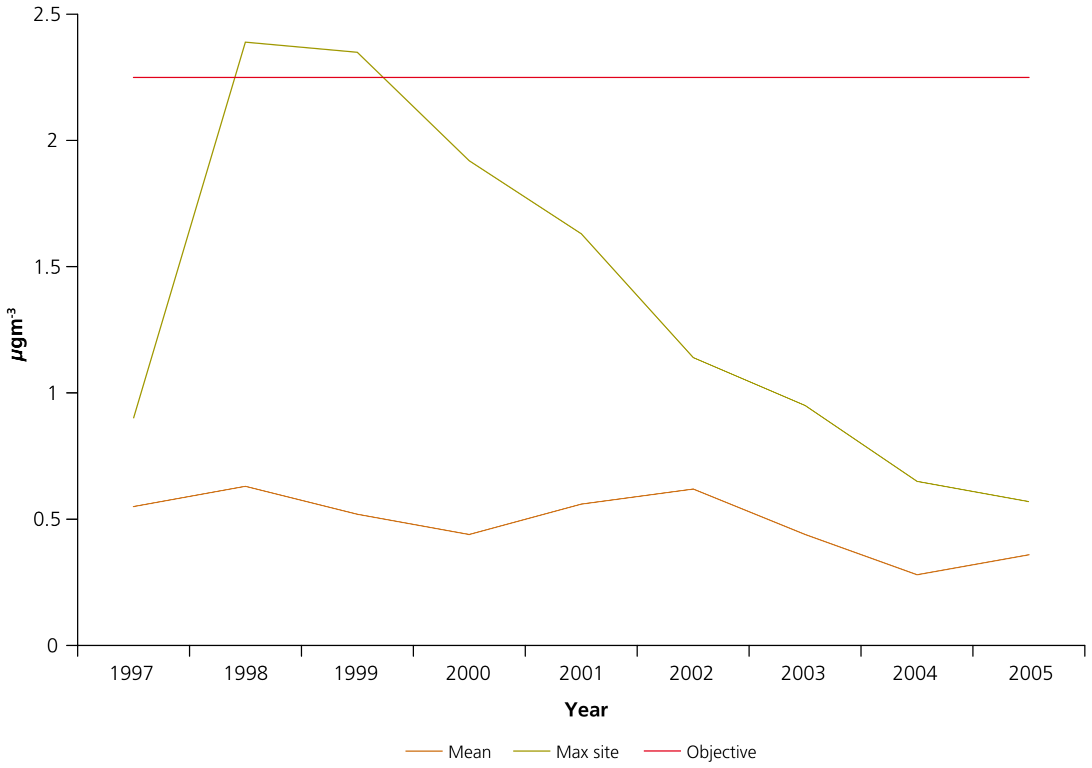
1.3.9.1 Sources

269. 1,3-Butadiene in air derives solely from human activity. It is an important industrial chemical, although fugitive emissions from its manufacture and use in the chemical industry are small and the majority of 1,3-butadiene in ambient air comes from combustion sources. The dominant combustion sources are associated with road transport, particularly petrol-engined vehicles but with a small contribution from diesel-fuelled vehicles. The introduction of catalytic converters in 1991 has had a significant impact on the emissions from the road transport sector due to their efficient removal of 1,3-butadiene. Emissions from other significant combustion sources, such as other transportation and machinery, have not changed significantly in recent years.

1.3.9.3 Measurements

270. Figure 1.62 shows the annual mean 1,3-butadiene concentrations of all the national sites and the highest site. The mean of all four 1,3-butadiene national sites was 0.28 µg.m^{-3} in 2005. 1,3-butadiene concentrations are well below the objective and have been declining in both metrics. As with benzene, this is mainly due to the introduction of cars equipped with catalytic converters.

Figure 1.62: Measured maximum running annual mean 1,3-butadiene concentrations in the UK (mean of all sites and highest site and 2003 Air Quality Strategy objective)



1.3.9.4 Baseline modelling

1.3.9.4.1 Model results

271. Maps of 2003 annual mean 1,3-butadiene at background and roadside locations are presented in Figure 1.63 and Figure 1.64. 1,3-butadiene concentrations have been calculated using a similar approach to that adopted for benzene described in Stedman *et al* (2005)[95].

272. There are no modelled background or roadside exceedences for this pollutant for 2003. Projections have not been produced for 1,3-butadiene. This is because there are no exceedences of the Strategy's objective for 2003, emissions are expected to decline in the future therefore modelled exceedences in future years are unlikely.

[95] See footnote 14.

Figure 1.63: Annual mean background 1,3-butadiene concentration, 2003 (µg.m^{-3})

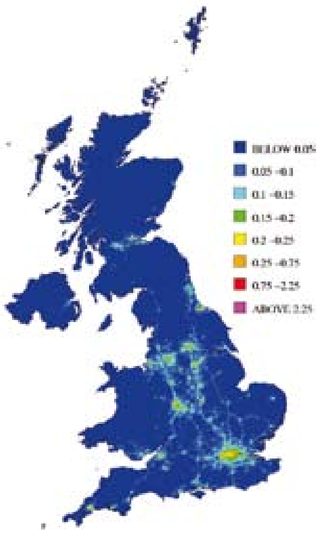
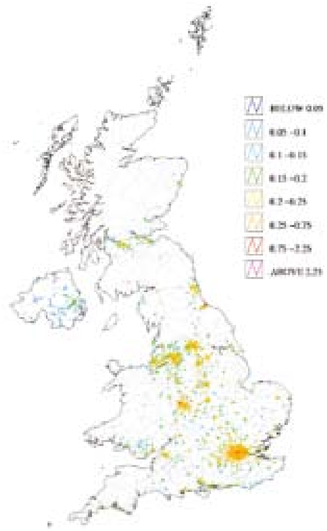


Figure 1.64: Urban major roads, annual mean roadside 1,3-butadiene concentration, 2003 (µg.m^{-3})



1.3.9.4.2 Uncertainties in inventories

273. There has been much improvement in the 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 1,3-butadiene. However, due in particular to the uncertainty in the levels of 1,3-butadiene in NMVOC emissions from road transport and other combustion processes, the uncertainty is much higher than that in the NMVOC inventory.

1.3.10 Carbon monoxide (CO)

- **for the whole of the UK, maximum daily running eight hour mean (running eight hour mean in Scotland) concentration of 10 mg.m^{-3} by 31 December 2003.**

274. No measurements in the AURN exceeded this objective in 2005. No CO projections have been produced for comparison with the objective. This is because there were no modelled or measured exceedences in 2005 and emissions from the main sources of CO are expected to decrease. Therefore no exceedences of CO are expected in future years and the objective is expected to continue to be met.

1.3.10.1 Health Effects

275. The main threats to human health from exposure to CO are the formation of carboxyhaemoglobin, which substantially reduces the capacity of the blood to carry oxygen and deliver it to the tissues, and blockage of important biochemical reactions in cells. People who have an existing disease which affects the delivery of oxygen to the heart or brain (e.g. coronary artery disease (angina)) are likely to be at particular risk if these delivery systems are further impaired by carbon monoxide. In their 1994 report EPAQS recommended an air quality standard of 11.6 mg.m^{-3} as a running eight hour

mean. The EPAQS recommendation is intended to limit the exposure of the population, including susceptible individuals, and specifies levels at which harm is unlikely to occur.

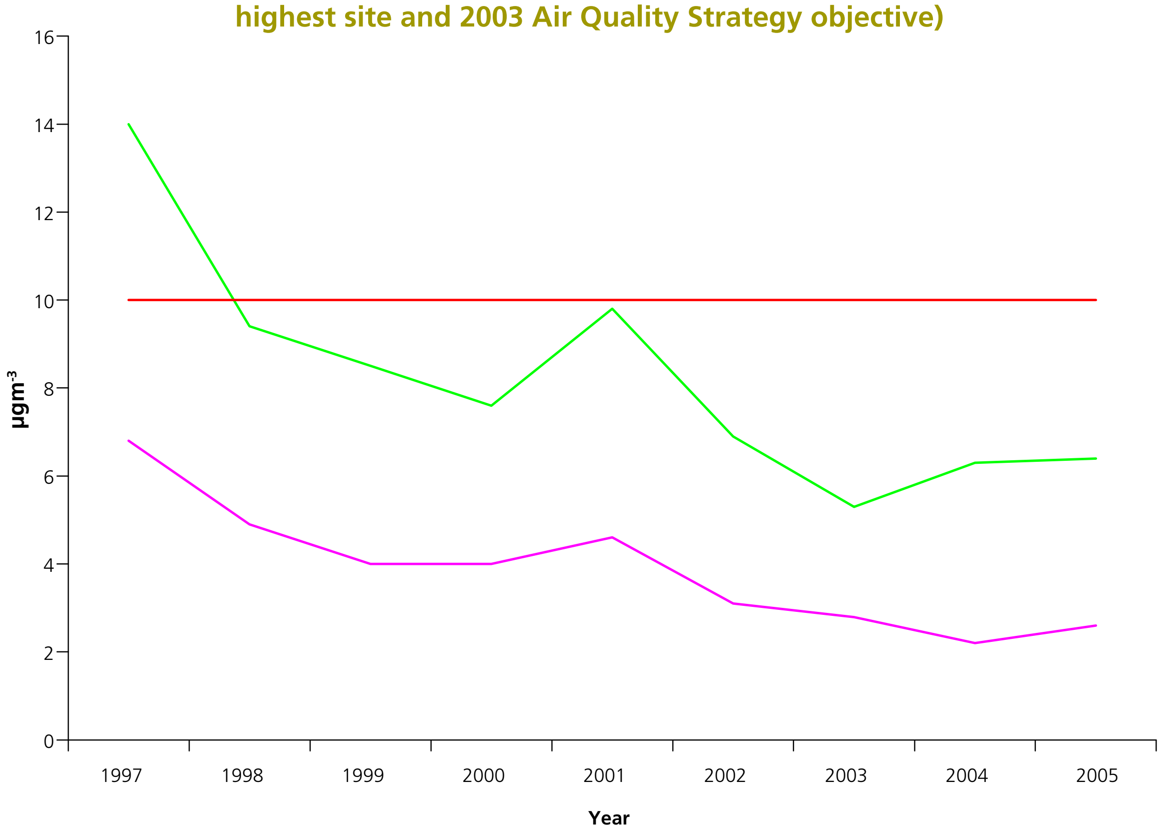
1.3.10.2 Sources

276. Carbon monoxide arises from incomplete fuel-combustion. Total UK emissions are dominated by those from road transport, particularly those from petrol engined vehicles and vehicles travelling at low speeds on urban or minor roads.

1.3.10.3 Measurements

277. Figure 1.65 shows the maximum 8-hour mean CO concentrations of all the national sites and the highest site. The mean of all 67 CO national sites was 2.6 mg.m^{-3}. CO concentrations have been declining since the early 1990's. This is due to significant reductions in emissions from road transport because of the introduction of catalytic converters, the ban on agricultural field burning of stubble and the switch from coal to gas and electricity in the domestic sector.

Figure 1.65: Measured maximum 8-hour mean CO concentrations in the UK (mean of all sites and highest site and 2003 Air Quality Strategy objective)



1.3.10.4 Model results

278. No projections have been produced for this pollutant. This is because the 2003 modelling (Figure 1.66 and Figure 1.67; Stedman *et al*, 2005a) and measurements showed that there were no exceedences of the Strategy's objective for 2003 (the same as the EU limit value for 2005). This has been confirmed by further modelling for the reporting requirements under the 2nd Air Quality Daughter Directive (report[96]). Emissions projections for future years (Grice *et al*, 2005[97]) show that the main source of CO, road traffic emissions, are likely to continue to decline, despite an underlying increase in traffic activity, and so exceedences in future years are unlikely.

1.3.10.4.1 Uncertainties in inventories

279. 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.

Figure 1.66: Maximum 8-hour mean background carbon monoxide concentration, 2003 (mg.m^{-3})

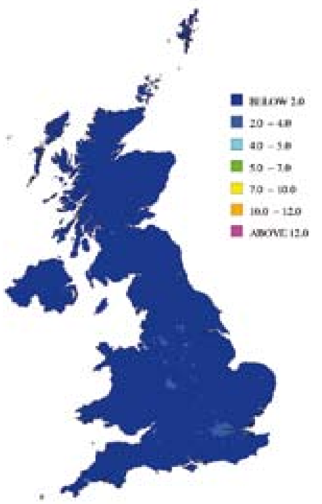
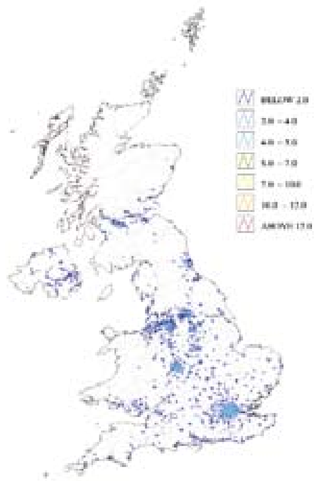


Figure 1.67: Urban major roads, maximum 8-hour mean roadside carbon monoxide concentration, 2003 (mg.m^{-3})



[96] Stedman, J. R., Bush, T. J., Grice S., Kent, A. J., Vincent K. J., Abbott J., Derwent, R. (2005). UK air quality modelling for annual reporting 2004 on ambient air quality assessment under Council Directives 96/62/EC, 1999/30/EC and 2000/69/EC. AEA Technology, National Environmental Technology Centre. Report AEAT/ENV/R/2052.

[97] See Footnote 17

1.3.11 Lead

- **for the whole of the UK, annual mean concentration of 0.5 µg.m^{-3} to be met by 31 December 2004; and**
- **annual mean concentration of 0.25 µg.m^{-3} to be met by 31 December 2008.**

280. The 2008 lead objective is predicted to be met everywhere based on current levels in the monitoring network and hence no projections have been carried out.

1.3.11.1 Health Effects

281. Lead is known to damage the developing nervous system and blood lead concentrations have been shown to be inversely related to IQ. There is no apparent threshold for this effect. Blood lead concentrations have been shown to be related to air lead concentrations. There is also evidence to suggest that raised blood lead concentrations are related to increased blood pressure. The data are not sufficient to allow quantification of the effects of outdoor air lead concentrations on health in the UK.

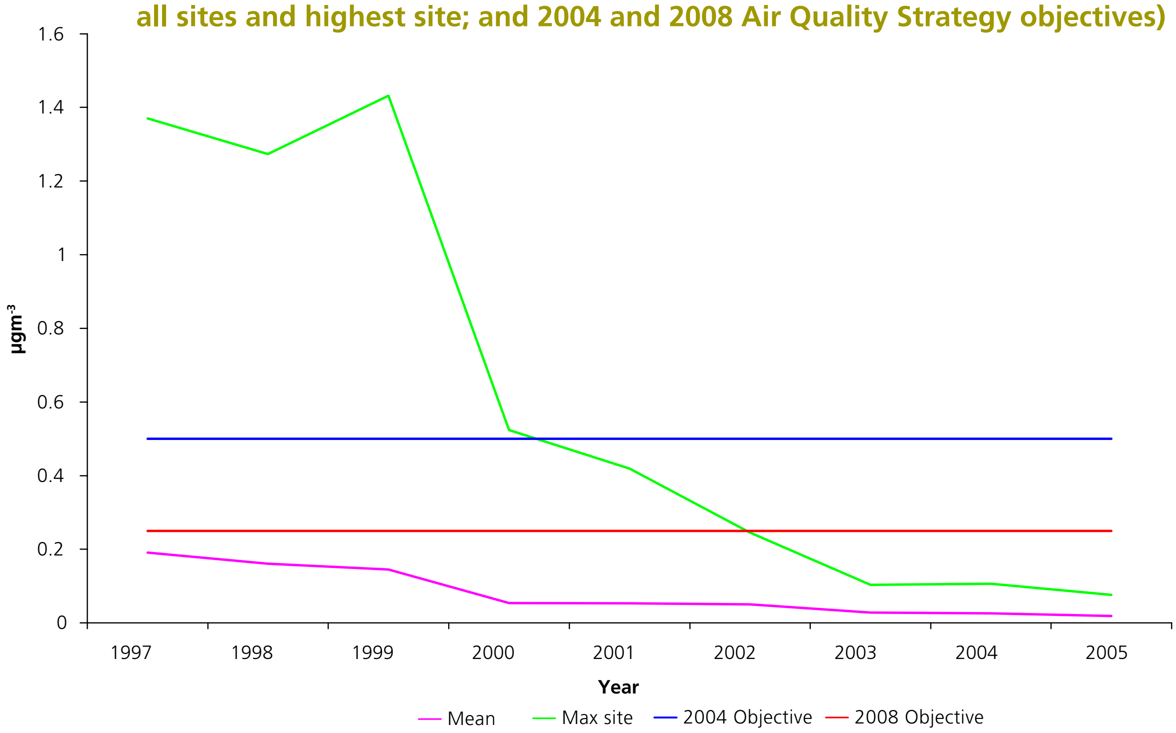
1.3.11.2 Sources

282. Historically, the principle source of lead was anti-knock lead additives in petrol. This was phased out from general sale at the end of 1999, resulting in a large decline in lead emissions from road transport. Other major sources are combustion in industry, including iron and steel combustion and non-ferrous metals.

1.3.11.3 Measurements

283. Figure 1.68 shows the annual mean lead concentrations of all the national sites and the highest site. The mean of all 17 lead national sites was 0.019 µg.m^{-3} in 2005. No sites exceed either the 2004 or 2008 AQS objectives. Lead concentrations have declined over recent years due to the increase in use of unleaded petrol and the phase out of leaded petrol from 1999. There have also been reductions in emissions due to improved abatement measures on iron and steel production processes and decreasing use of coal in that sector, reduction in emissions from non-ferrous metal industries and improved controls on municipal solid waste incinerators.

Figure 1.68: Measured annual mean Lead concentrations in the UK (mean of all sites and highest site; and 2004 and 2008 Air Quality Strategy objectives)



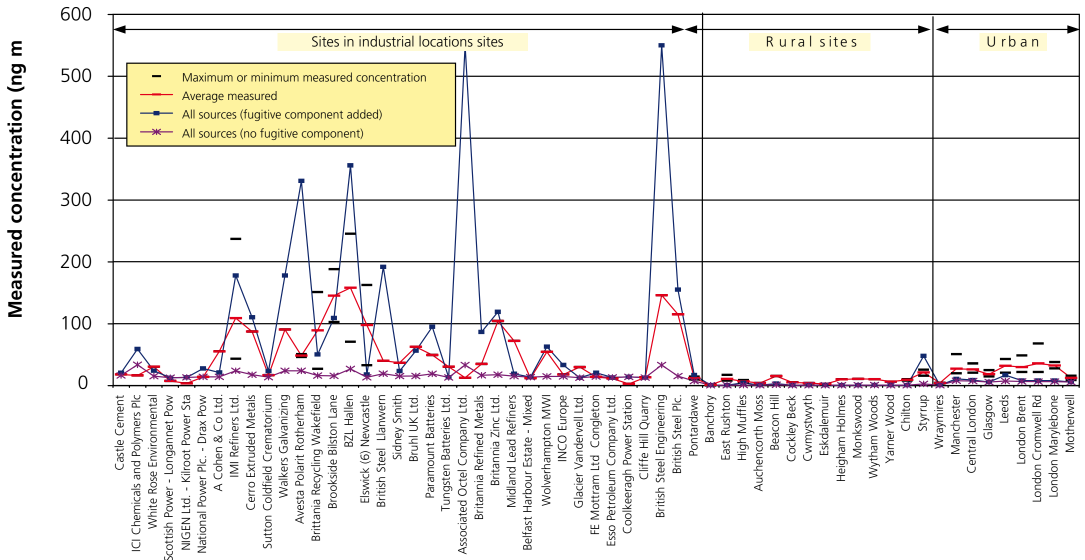
1.3.11.4 Baseline Modelling

284. Modelling of lead concentrations has been carried out for 2003 and a comparison carried out with the small number of the monitoring sites available during that year[98]. Modelling used a similar approach to that used for SO_2 and B[a]P and assumed a large contribution from fugitive emissions from point sources (approximately 3x the stack emissions from any one plant) and a natural component from soil. The model both over and under predicts concentrations at industrial plant and significantly under predicts concentrations at the urban sites (Figure 1.69, which includes the range of monitoring data from 1999 to 2003). Modelled concentrations and measurements were well below the Strategy's objectives at all locations except the vicinity of certain industrial plant, where possible modelled exceedences were not confirmed by the measurements.

285. Projections have not been modelled. There were no measured exceedences of the Strategy's two objectives or the EU's limit value in 2003. Emissions of lead are not expected to increase and future exceedences are highly unlikely.

[98] Vincent, K. J., Passant, N., Coleman, P., Stedman, J. R. (2006a) Assessment of heavy metal concentrations in the UK. AEA Technology, National Environmental Technology Centre. Report AEAT/ENV/R/2013. www.airquality.co.uk/archive/aqsreview2006.php

Figure 1.69 Comparison of modelled and measured lead concentrations in the UK.



1.3.12 Ammonia (NH_3)

286. There are currently no objectives for ammonia although we have agreed, at EU and UNECE level, national emission ceilings (for details see Volume 1, section 1.4.1).

1.3.12.1 Health Effects

287. Ammonia is a highly reactive gas and can be transformed by chemical reactions with other airborne pollutants. The most common reactions are with sulphur and NO_x to form sulphate and nitrate aerosols. Ammonium aerosols form a major component within the secondary PM, which as discussed in Section 1.3.1.1, are thought to have a significant impacts on health.

1.3.12.2 Sources

288. Emissions of NH_3 were estimated to be 337 kilotonnes in 2004[99]. Agricultural emissions account for more than 80% of emissions, with cattle alone accounting for 44% of the total. The main activities from which NH_3 emissions arise are the collection, storage and use (e.g. field application) of farmyard manures, slurries and other livestock excreta.

289. Ammonia emissions from non-agricultural sources account for the remainder of the total NH_3 emission from the UK. These arise primarily from a large number of small sources, including sewage treatment works, fertiliser manufacture, vehicles fitted with catalytic converters, pets, wild mammals and seabirds. Waste (sewage sludge processing and application to land) and transport account for 24 and 20% of the total from non-agricultural sources, respectively. The estimate for these two sources is highly uncertain, however, because of a lack of measurement data.

[99] Dore C. J., Watterson, J. D., Murrells J. P., Passant N. R., Hobson M. M. , Baggott S. L., Thistlethwaite G., *et al* (2006) UK Emissions of Air Pollutants 1970 to 2004. AEA Technology, National Environmental Technology Centre. Report AEAT/ENV/R/2359 http://www.airquality.co.uk/archive/reports/cat07/0701221151_Full_Report_NAEI_2004.pdf

1.3.12.3 Current and historic ambient concentrations

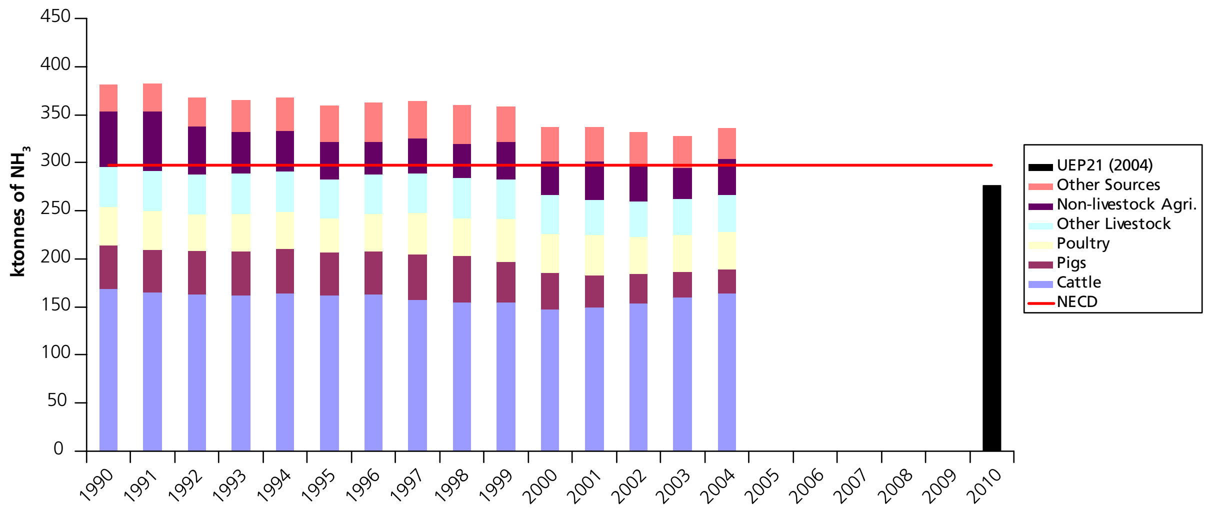
1.3.12.3.1 Model results and projections

290. Ammonia emissions from agricultural sources have been, until recently, compiled for a number of years using the UK Ammonia Emission Inventory (UKAEI), which combines emission factors, specific to livestock categories and management practices, with detailed activity data (derived from surveys and expert opinion). More recently a mass-conservative nitrogen-flow model has been developed, the NARSES model (National Ammonia Reduction Strategy Evaluation System), with emission factors expressed as a proportion of the ammoniacal-N available at each emission stage. This model has the advantage that emission sources are linked through the manure management chain, such that changes to the emission at one stage (e.g. livestock housing) will impact on the mass of available nitrogen flowing to later emission stages (e.g. manure storage and land application). In addition, NARSES enables emission estimates to be spatially (10 km grid) and temporally (monthly) disaggregated. This model is therefore more suited to scenario testing in assessing potential mitigation strategies.

291. Non-agricultural emissions of NH_3 fall into one of several different source categories including stationary combustion, production processes, road transport and natural emissions and are complied using various methodologies detailed at www.airquality.co.uk/archive/reports/cat07/0606231101_NAEIMappingMethodReport2003Final.pdf

292. There has been a steady decline in NH_3 emissions over the last 15 years, with emissions in 2004 representing a decrease of 12% on 1990 emissions (Figure 1.70).

Figure 1.70: Estimates of ammonia emission in the UK



1.3.12.3.2 Measurements

293. Defra and the devolved administrations also support an NH_3 monitoring network which consists of 94 sites across the UK with either denuder or passive (or both) samplers giving monthly mean atmospheric NH_3 concentrations (and ammonium (NH_4^+) at some sites)[100]. Data generated by this network support development of baselines against which trends can be assessed and for model validation. Nine years of gaseous NH_3 data and seven years of aerosol NH_4^+ data (since 1999) have been analysed.

294. At background sites and in cattle dominated areas, there appears to be a slight increase in NH_3 concentrations over the monitoring period, even though emissions are not estimated to have increased. This may be a feature of the reduction in SO_2 emissions over the same period, leading to a longer atmospheric lifetime of NH_3, thereby increasing NH_3 concentrations in remote areas. In contrast, in sheep, and in pig and poultry dominated areas, there is a slight (non-significant) reduction in NH_3 concentrations. The reasons for this need to be investigated further. In relation to aerosol NH_4^+ concentrations, there are currently no detectable trends, indicating that a longer measurement period is needed before trends can be detected.

1.3.12.3.3 Baseline projections

295. Projected annual mean concentrations of NH_3 have been modelled for 2005, 2010, 2015 and 2020. NARSES is used for modelling changes from agriculture, utilising information from business as usual (BAU) study[101] to underpin estimates of changes in the farming industry including changes in livestock numbers. Methodology for non-agricultural sources is detailed at www.naei.org.uk/report_link.php?report_id=407.

296. The estimates to date indicate that although we are likely to meet our emission ceiling targets by 2010, it will be by the narrowest of margins (see Table 1.24). Any unforeseen changes to and/or by the agricultural industry and other activities and industries that lead to greater emissions will almost certainly lead to exceedence of the target.

Table 1.24: ammonia emissions from the UK (ktonnes of NH_3)

Year	1990	2004	2010	2015	2020
Total (kT)	381.5	336.4	276.5	273.2	272

1.3.12.4 Uncertainties in inventories

297. 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. Emission estimates for non-agricultural sources such as wild animals are also highly uncertain. Unlike the case

100 http://www.airquality.co.uk/archive/monitoring_networks.php?n=nh3

101 'Business as Usual' Phase I & II & 'WFD River Basin Characterisation: information to improve baseline risk assessment': Final reports at: http://www.environment-agency.gov.uk/aboutus/512398/516810/516841/578627/?version=1&lang=_e; http://www.environment-agency.gov.uk/business/444217/444663/955573/; http://www.environment-agency.gov.uk/business/444217/444663/955573/

of NO_X and NMVOC, a few sources dominate the inventory and there is limited potential for error compensation.

1.4 Ecosystems and Vegetation Objectives

1.4.1 Air Quality Objectives

298. The principal legislative drivers for the reduction of transboundary air pollution are the NECD and the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP Gothenburg Protocol). Both set annual emission ceilings for 2010 for four pollutants: sulphur, NO_x, VOCs and NH_3. The ceilings set for the UK are:

- SO_2: 585kT
- NO_x: 1,167kT
- VOCs: 1,200kT
- NH_3: 297kT

299. The European Union's 6th Community Environment Action Programme[102] set as a target the development of a thematic strategy (adopted in 2005[103]) to strengthen a coherent and integrated policy on air pollution, with a view to "reach the long term objective of no-exceedence of critical loads and levels". The UK Government and the devolved administrations do not currently have a specific target for critical load (and level) exceedences.

300. The Air Quality Strategy sets objectives for the protection of vegetation and ecosystems based on a *critical levels* approach, i.e. concentrations of pollutants in air above which damage to sensitive plants may occur. In addition, critical loads have been used for the Strategy to assess the risks to habitats from acidification and eutrophication (see summary box 1.4 for details).

301. In relation to the protection of vegetation and ecosystems of high conservation value, the International and national agreements which identify conservation sites are:

- the EC Habitats Directive and the EC Birds Directive establish Special Areas of Conservation (SACs) and Special Protection Areas (SPAs), respectively. The SACs and SPAs are included in an EU-wide network of protected areas called Natura 2000 sites;
- the Convention on Wetlands of International Importance establishes Ramsar Sites;
- 1981 Wildlife and Countryside Act establishes Areas of Special Scientific Interest (ASSI) in Northern Ireland and Sites of Special Scientific Interest (SSSI) in Great Britain; and
- in England, Defra has a challenging PSA target to get 95% of SSSIs into a favourable condition by 2010.

302. These are therefore, also key drivers for action to reduce impacts, and thus emissions of SO_2, NO_X, NH_3 and O_3.

102 http://europa.eu.int/comm/environment/newprg/index.htm

103 http://europa.eu.int/comm/environment/air/cafe/index.htm

Box 1.4: Critical Loads

Critical loads are usually defined as "a quantitative estimate of exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge"[105]. Critical loads refer to the deposition of pollutants to land or water, while critical levels refer to gaseous concentrations of pollutants which usually have direct effects on vegetation or human health. When pollutant loads (or concentrations) exceed the critical load (or critical level) it is considered that there may be a risk of harmful effects. The excess deposition over the critical load (or concentration above the critical level) has been termed the exceedence. A larger exceedence is often considered to pose a greater risk of damage. In the UK, and at European and UNECE level, critical loads have been developed to address the issues of acidification and eutrophication.

Acidification: Critical loads of acidity represent the acid deposition load that will not lead to harmful effects. The key acidifying pollutants are oxides of sulphur and nitrogen. In addition, reduced nitrogen species (NH_3, NH_4^+) can also contribute to acidification. To incorporate both sulphur and nitrogen compounds, critical loads are expressed in kilo equivalents of hydrogen ions per hectare per year (keq/ha/yr). Two methods are used for calculating acidity critical loads for terrestrial habitats in the UK: an empirical approach based mainly on the mineralogy and weathering rate of the soils is applied to non-woodland habitats, and the simple mass balance (SMB) equation is applied to both managed and unmanaged woodland habitats. The acidity critical load for an ecosystem is therefore largely dependant on the ability of the underlying soils and geology to buffer or neutralise the incoming acid deposition. For example, a soil based on chalk has a high acid buffering capacity and therefore a higher critical load, whereas a soil dominated by minerals such as quartz will have a lower critical load. For freshwater ecosystems, the catchment-based First-order Acidity Balance (FAB) model is used to calculate acidity critical loads.

104 1999 Protocol to Abate Acidification, Eutrophication, and Ground-level Ozone (protocol to the UNECE 1979 Convention on Long-range Transboundary Air Pollution); United Nations; Geneva; 1999.

Box A1.4: Critical Loads *(continued)*

Eutrophication: Eutrophication refers to an increase in the primary production of any ecosystem and is caused by the increase of chemical nutrients, typically compounds containing nitrogen or phosphorus. It may occur on land or in water. Enhanced nitrogen deposition (oxidised (NO_X) and reduced (NH_y)) to terrestrial and freshwater ecosystems can result in eutrophication. This can have major impacts on plant communities leading to changes in species composition and the sensitivity of vegetation to environmental stresses, such as drought, frost or insect predation. Therefore methods have been developed to set critical loads to protect against these adverse effects. Critical loads for eutrophication (or nutrient nitrogen) are also expressed in kilo equivalents of hydrogen ions per hectare per year (keq/ha/yr) for consistency and comparison with acidity data. However, they can alternatively be expressed in kilograms of nitrogen per hectare per year (kg N/ha/yr).Two approaches are currently in use: empirical and mass balance. Empirical critical loads are based on observed changes in the structure or function of ecosystems as reported in the refereed literature from the results of experimental or field studies. This method has been applied to unmanaged coniferous and broadleaved woodlands, grassland (acid and calcareous), dwarf shrub heath, bog, montane and some coastal habitats. Mass balance critical loads for nutrient nitrogen are based on an equation that balances all the significant long term inputs and outputs of nitrogen for terrestrial ecosystems. In the UK this method has been applied to managed woodland habitats only.

It should be noted that the critical loads data are derived from empirical or steady-state mass balance methods, which are used to define **long-term** critical loads for systems at **steady-state**. Therefore exceedence of critical loads is an indication of the potential for harmful effects to systems at steady-state. This means that current exceedence does not necessarily equate with damage and achievement of non-exceedence of critical loads does not mean the ecosystems have recovered. Chemical recovery will not necessarily be accompanied by biological recovery; and the timescales for both chemical and biological recovery could be very long, particularly for the most sensitive ecosystems.

While being extremely useful for assessing potential damage to ecosystems, it should be remembered that critical loads are based on a number of assumptions and that there are uncertainties in the data used for both the calculation of critical loads and exceedences. Further information can be found on the website of the UK National Focal Centre for Critical Loads Modelling and Mapping http://critloads.ceh.ac.uk.

1.4.2 Objectives for sulphur dioxide and oxides of nitrogen for protection of ecosystems

303. The 1st EU Air Quality Daughter Directive set limit values for NO_X and SO_2 to protect vegetation and ecosystems. The Air Quality Strategy 2000 adopted these as UK air quality objectives, to be achieved by the end of 2000.

304. The current objective for the protection of vegetation and ecosystems for NO_x is based on a critical level (the point at which damage occurs from exposure to gaseous pollutants) of 30 $\mu g.m^{-3}$, as an annual average.

305. The critical levels for the protection of vegetation and ecosystems for SO_2 are 10 to 30 $\mu g.m^{-3}$, depending on vegetation type. The 2000 Strategy set two objectives:

- 20 µg.m^{-3} measured as an annual average; and
- 20 µg.m^{-3} measured as a winter months average (reflecting the additional sensitivity of plants during cold weather conditions).

306. The areas where the UK vegetation and ecosystem air quality objectives apply are based on the monitoring criteria for the vegetation and ecosystems limit values set under the 1st Air Quality Directive:

- more than 20km from an agglomeration (i.e. an area with a population of more than 250,000);
- more than 5km away from industrial sources regulated under Part A of the Environment Act 1990 (and/or Part A1 sites under the PPC regulations);
- more than 5km away from motorways; and
- more than 5km away from built up areas of more than 5,000 people.

307. The Directive allows for compliance to be demonstrated through a modelling approach which effectively simulates results from static continuous monitoring equipment. This is the approach which the UK has adopted. The base data used is the same as that used for the baseline assessments for SO_2 and NO_2. However, these data need to be modified in order to replicate the Directive requirements.

308. The first step is to define the areas in which the objectives apply and overlay these on maps showing 1 x 1 km grid square annual or winter average concentrations for SO_2 and NO_2. The concentration data are then aggregated to form 30 x 30 km grid squares (equivalent to 900km^2 which is required in the 1st Daughter Directive[105]), excluding concentrations from within the "exclusion" areas. This latter step is necessary in order to avoid averages from the 1 x 1 km squares within the exclusion areas falsely skewing the results for those areas where the objectives apply. The results for this assessment are shown in Table 1.25, Figure 1.71 and Figure 1.72 below.

Table 1.25: Compliance modelling results for vegetation and ecosystems objectives.

Objective	Model outcomes for 2004, µg.m^{-3}			Result
	minimum value	maximum value	mean value	
SO_2 annual mean	0.6	7.0	1.4	No exceedences
SO_2 winter mean	0.7	9.2	1.8	No exceedences
NO_X annual average	0.7	26.9	5.6	No exceedences

105 99/30/EC

Figure 1.71 Annual mean sulphur dioxide concentration, 2004 (mg m^{-3}) in ecosystem areas

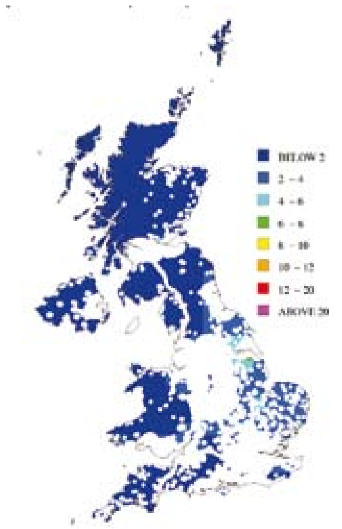
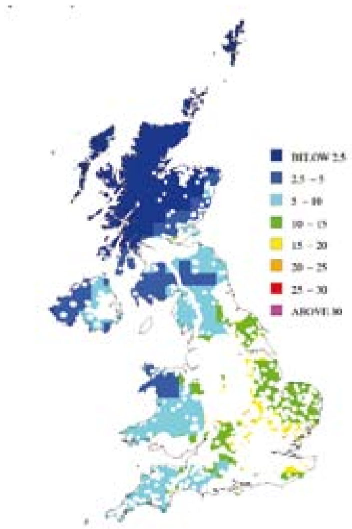


Figure 1.72 Annual mean oxides of nitrogen concentration, 2004 (mg m^{-3} as nitrogen dioxide) in ecosystem areas



309. The UK is currently meeting the Strategy's air quality objectives for NO_x and SO_2, and on a BAU scenario this will remain unchanged.

310. The 2000 Strategy did not seek to address air quality at sites specially designated for conservation purposes as described above these to include SSSIs in Great Britain, and ASSI in Northern Ireland; SACs, SPAs (collectively described as Natura 2000 sites) and Ramsar sites in the UK.

311. Currently, some 37% of SSSIs (and ASSIs) and 53% of Natura 2000 sites and Ramsar sites lie within the exclusion area defined above and are therefore not protected by the objectives.

312. Analysis based on modelling has shown that it would be possible to achieve the NO_x objective at 99% of all sites, by area, by 2010 through baseline policies with the Air Quality Strategy. Therefore the extension of the proposed objectives would generate no additional costs.

313. In the case of SO_2, substantial scientific evidence, reviewed by WHO in its Air Quality Guidelines for Europe[106], suggests that 10μg.m^{-3} is a more appropriate critical level for the protection of sensitive species, notably some lichen and bryophyte species. Policies already included in the baseline assessment, will result in achieving annual average concentrations of 10μg.m^{-3} SO_2 at 100% of all sensitive sites by 2010[107].

[106] http://www.euro.who.int/document/e71922.pdf

[107] This assessment uses the same modelling approach as that used to show compliance with the First Daughter Directive Limit Values for the protection of ecosystems i.e. averages based on 30x30 km grid squares.

1.4.2.1 Results of baseline exceedence modelling

314. In order to determine the risks to habitats from acidification and eutrophication, critical load exceedences are calculated and mapped by the UK National Focal Centre. Emission and deposition data (averaged over three year periods to allow for inter-annual variability) are used with the critical loads data to produce critical load exceedence statistics and maps.

315. The FRAME model[108] was used to calculate total oxidised sulphur, NO_X and total reduced nitrogen deposition for the BAU scenario (with no additional abatement measures implemented) projected to 2020.

316. The process of depositing pollutants onto ecosystems can be split into three pathways. Dry deposition is the direct removal of the pollutant gas to vegetation, soils or other surfaces. Wet deposition is incorporation of the pollutant into water droplets and then removal from the atmosphere in rain or snow. Cloud droplet or particulate aerosol deposition occurs when either small water droplets or particles are removed by landing directly on surfaces. The combination of these processes provides the total deposition of the pollutant to the ecosystem. Dry deposition occurs in the vicinity of the major sources (road transport for total reactive oxides of nitrogen (NO_y) and industrial regions and power stations for oxides of sulphur (SO_x)). Wet deposition is associated with the longer range transport of aerosols and is larger in upland regions where annual precipitation is highest.

317. The exceedences of the critical loads of acidity and nutrient nitrogen for the UK were based on the deposition modelling carried out by C-BED[109] and FRAME. The results of trends, the current situation 2001-2003 and the BAU scenario in 2010 have been tabulated and can be seen in Table 1.26.

Table 1.26: Trends in the percentage area of natural and semi-natural habitat critical load exceedence for 1995 to 2010

	Percentage area of habitats exceeded in:		
	1995-97	**2001-2003**	**2010**
Exceedence of acidity critical loads	73	55	47
Exceedences of nutrient nitrogen critical loads	65	60	49

318. Data on emissions trends and the expected impact of current policies can also be used to produce forward projection maps, to give estimates of the effectiveness of policies (in this case single years are used). Figure 1.73 and Figure 1.74 show the exceedences of critical loads for both acid and nitrogen deposition, mapped for the UK, for the periods 1995-1997, 2001-2003, and for 2010.

319. The projections indicate that significant number of habitats will still be at risk from both acidification and eutrophication in 2010, despite significant reduction in air pollution emissions.

[108] See http://www.frame.ceh.ac.uk for details of the FRAME model.

[109] For further information see http://www.nbu.ac.uk/negtap/

Figure 1.73: Exceedence of critical loads for acid deposition, 1995-1997, 2001-2003, 2010

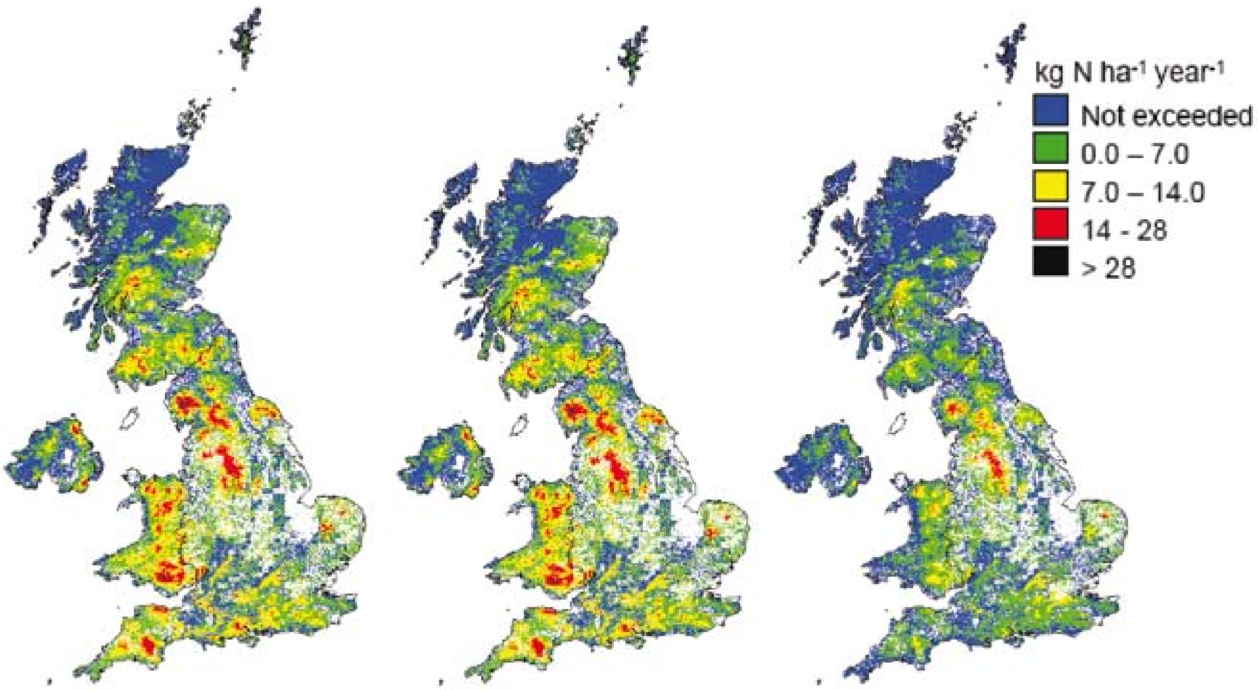
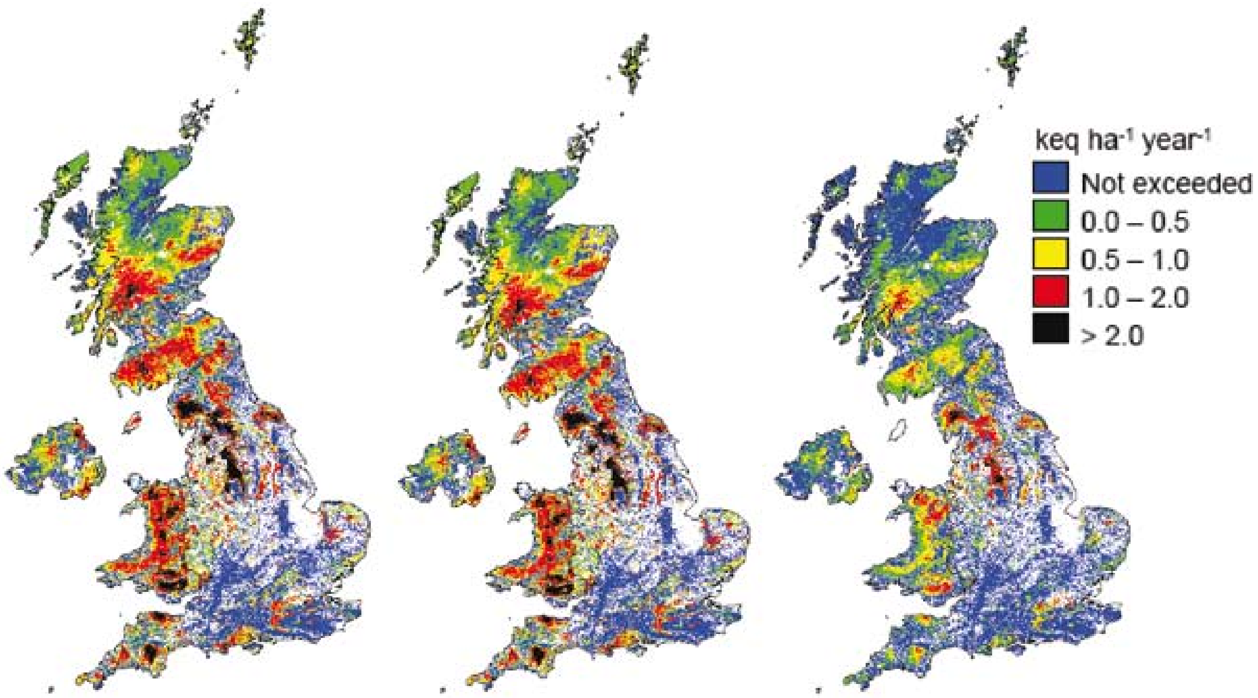


Figure 1.74: Exceedence of critical loads for nitrogen deposition, 1995-1997, 2001-2003, 2010



320. Data analysis has shown two important issues which will need to be addressed as part of the ongoing process of reducing critical loads exceedences. Firstly, the rate of reduction in nitrogen deposition critical load exceedences is smaller than that for acidity critical load exceedences. This is mainly due to the relatively low rate of reduction in NH_3 emissions. Ammonia is now the dominant factor in driving nitrogen deposition in many parts of Europe.

321. The second issue is the apparent "non-linearity" between reductions in SO_x and NO_x emissions, and reductions in acid deposition. There has been relatively good agreement between these in some parts of the UK, mainly the south and east. Recent work by Centre for Ecology and Hydrology in Edinburgh on behalf the UK Government and the devolved administrations involved analysis of the changes in ion concentrations in precipitation at national monitoring sites across the UK since 1986. This has shown that reductions in deposition decrease towards the north and west, resulting in a zero trend in the extreme west. Furthermore, an increasing trend in the deposition velocity of SO_2 was proposed. This lack of a reduction in deposition rates is hampering efforts to reduce critical load exceedences. While the reasons for such non-linearity between emission and deposition are not fully clear, it is likely that two causes feature prominently:

- lower levels of NH_3 emission reduction relative to SO_x and NO_x from land based sources have caused increased SO_2 deposition velocities close to sources because the SO_2:NH_3 ratio has decreased; and
- gradual increase in sulphur emissions from international shipping, which are carried into the UK on prevailing south westerly winds and deposited mainly on high ground in the west. As sulphur has been removed from road fuels, its proportion in marine "bunker" fuels has increased from an already high level; international shipping traffic has also increased.

322. The reduction of NH_3 emission and emissions of SO_x and NO_x from shipping have both been identified as priority areas by the European Commission. The UK Government will work with its European and international partners to reduce shipping emissions. This issue is the subject of additional policy Measure N (discussed in the Strategy and Chapter 2) which analysis shows has one of the greatest potential benefits for ecosystem protection.

1.4.2.2 Ozone

323. Ground level O_3 is a major air pollutant that, at current concentrations in the UK and Europe, adversely affects forest growth, agricultural production and the composition of semi-natural ecosystems. However, despite this, there is currently no O_3 objective for protection of vegetation and ecosystems. This is primarily due to difficulties in developing and identifying robust, measurable metric which adequately reflects damage to vegetation by O_3 under different climatic and other conditions. Work is, however, ongoing both in the UK and in the UNECE.

324. The EU (through EU/CAFE process) suggested and agreed a new target of 18,000 µg m^{-3} h^{-1} of O_3 averaged over 5 years based on AOT40 (to be calculated from I hr values from May to July) for protection of vegetation and ecosystems.

325. Figure 1.48 shows that this objective is achievable within the UK without imposing further burdens (regulatory or otherwise) on emission sources.

1.4.2.3 Direct impacts of ammonia

326. In addition to contributing to acidification, eutrophication and particle levels, NH_3 can also have a direct effect on vegetation. UK ammonia concentrations were derived from both 2004 data from the NH_3 monitoring network and also from FRAME modelling using emission inventory estimates[110].

327. In both cases concentrations were found to be below 8 $\mu g.m^{-3}$ over the whole country, save for a single 1 x 1 km square in East Anglia in the modelled map (believed to be a modelling artefact). The square in question does not contain any sites designated for nature protection.

1.5 Uncertainties and sensitivity analysis

328. There are uncertainties associated with the assessment. The weather in any future year will have a large influence on the extent of any exceedence of objectives. Furthermore, there are significant uncertainties associated with future emissions of air pollutants and the effectiveness of mitigation measures at further reducing concentrations of problem pollutants.

329. This section includes a discussion of the uncertainties associated with the air quality assessment and projections. It explores the sensitivity of the conclusions drawn from the analysis to uncertainty in assumptions and understanding of pollutant characteristics and behaviour.

330. Uncertainty associated with health impacts of air pollution is discussed in the accompanying IGCB report.

331. The air quality assessment presented in this document is too complex and has too many inputs to allow a practical single estimate of uncertainty associated with the results. We have therefore carried out sensitivity analyses on important assumptions and inputs that influence the outcome and consequently conclusions drawn in this document.

1.5.1 Choice of base year

332. 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 the next 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. Oxides of nitrogen and primary PM_{10} emissions changed little between 2002 and 2003 but there were large differences in air pollution climate.

[110] See http://www.frame.ceh.ac.uk for details of the FRAME model.

333. The UK 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.

334. 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 is important to look at a few years' worth of air quality data to draw conclusions on trends.

335. The air quality modelling presented in section 1.3 uses 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.

336. 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 for PM_{10} and NO_2 starting from 2002, a relatively typical year for air quality in recent years. We have also carried out a sensitivity using 2004 as a base year for the basecase and Measure Q. Modelling the base case for these three years should provide an estimate of the likely range of future air quality outcomes that are influenced by the weather.

337. Table 1.27 shows results for model outputs for PM_{10} projections starting in 2002 or 2003[111]. 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.

338. Population weighted mean concentrations are about 10% higher in 2010 and 2020 when projected from 2003 compared to 2002. Calculated health impacts of PM_{10} scale linearly with population weighted mean concentration. Consequently the base case health impact assessment that uses 2003 as the base year is approximately 10% greater than a comparable assessment using 2002 as the base year.

[111] See Footnote 17.

Table 1.27: Model outputs for PM_{10} projections starting in 2002 or 2003

Model output	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
% total road length exceeding an PM_{10} annual average of 31.5 $\mu g.m^{-3}$, gravimetric*	0.1	2.1	0	0.3
% total background area exceeding a PM_{10} annual mean value of 31.5 $\mu g.m^{-3}$, gravimetric	0	0	0	0
% population in area exceeding a PM_{10} annual mean value of 31.5 $\mu g.m^{-3}$, gravimetric	0	0	0	0
% total road length exceeding an PM_{10} annual average of 20 $\mu g.m^{-3}$, gravimetric**	46.5	77.6	27.5	60.5
% 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
% 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

339. Table 1.28 shows results for model outputs for NO_2 projections starting in 2002 or 2003. It 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.

Table 1.28: Results for model outputs for nitrogen dioxide projections starting in 2002 or 2003

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

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

340. 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 in 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.

341. We have compared results for Measures P and Q using a 2002 and 2003 base year[112]. These 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. Consequently the choice of base year is unlikely to change the conclusions arising from the cost benefit assessment in Chapter 2.

1.5.2 Uncertainty associated with projected air quality – projected emissions

342. Projected air quality depends fundamentally on assumptions about projected emissions of air pollutants. We have tested the sensitivity of projected estimates of PM_{10} and $PM_{2.5}$ population weighted 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.

343. This differs to the sensitivity discussed in section 1.5.4, where the sensitivity of assumptions about PM source apportionment was tested, i.e. the contribution of precursor gases to PM concentration. Total emissions were unchanged.

344. 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.

345. Table 1.29 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 25% 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 burned in 2020 than currently forecast.

Table 1.29: Effect on projected population weighted PM_{10} and $PM_{2.5}$ concentrations of changes to future estimates of sulphur dioxide and oxides of nitrogen emissions

	UK population weighted PM_{10} concentration 2020	% difference	UK population weighted $PM_{2.5}$ concentration 2020	% 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%

[112] See footnote 18.

346. 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}.

347. 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.

1.5.2.1 Sensitivity of key assumptions in model inputs

348. 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.

349. 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 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 stationery or from road transport sources by 25%;
- residual PM_{10}. The assumption that residual PM_{10} (mainly coarse fraction PM_{10}-$PM_{2.5}$) material contributes one third of measured PM_{10} in all projected years. What if this assumption is significantly incorrect?; and
- secondary PM_{10}. The assumption that secondary particulates contribute approximately one third of measured PM_{10} on average in 2003. What if this assumption is significantly incorrect?

350. Table 1.30 compares the impact of changing other inputs on key model outputs. In all cases these changes represent changes in the source apportionment of 2003 concentrations because the model has been calibrated using 2003 measurements.

Table 1.30: 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 exceeding 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%

351. 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.

352. 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.

353. 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.

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

1.5.3 Change in Nitrogen Dioxide outputs in 2010

355. For NO_2 (Table 1.31) 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 O_3 by 9%;
- increasing primary NO_2 emissions by 78%;and
- a combination of increases in background O_3 and primary NO_2.

Table 1.31: Change in nitrogen dioxide outputs in 2010

Model output	Model input varied					
	Stationary source NO_X emissions +25%	Road transport NO_X emissions +25%	Rural background NO_X emissions +25%	Regional oxidant +9%	Local oxidant +78%	Regional oxidant +9%, local oxidant +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%

356. Table 1.31 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.

357. Using a combination of 2002 meteorological data and 2002 AURN measurement data has a significant effect on the modelled concentrations. 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.

358. Table 1.31 does, however, show that the NO_2 model is sensitive to changes in both the regional and local oxidant (OX[113]) availability. Oxidant converts emitted NO to NO_2 in the atmosphere. In these sensitivity tests, the regional OX field has been increased by approximately 9% (up to a maximum of 40 ppb of OX) and the local OX increased by 78% (up to a maximum of 25% of NO_X 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 an indication of the likely effect of individual and combined increases in hemispheric O_3 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 NO_X emitted as primary NO_2. The contribution of local OX could be greater at higher percentages of primary NO_2.

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

1.5.3.1 Primary nitrogen dioxide

360. In August 2006, AQEG released a draft report *Trends in Primary Nitrogen Dioxide in the UK*. In that report the primary NO_2 fraction in London is predicted to increase from 13% in 2002 to 19% in 2010. In order to assess the impact of these changes on NO_2 and O_3 concentrations ADMS-urban modelling was carried out using primary NO_2 fractions of 15% and 20% to compare with the base case of 10%[114]. The changes significantly impact on NO_2 concentrations, for example, in 2010 with 20% primary NO_2:

- the population-weighted mean concentration increases from 35.0μg.m^{-3} for the base case to 38.1μg.m^{-3} with the increased primary NO_2 fraction;
- the area exceeding 40μg.m^{-3} increases from 13% to 22% of London;
- exceedences of the short-term NO_2 objective are predicted at roadside sites;
- the population weighted mean O_3 concentration is predicted to increase from 36.9μg.m^{-3} to 39.0μg.m^{-3}; and
- the percentage area of London with more than 10 exceedences of 100μg.m^{-3} by the 8-hour mean O_3 concentrations is predicted to increase from 81% to 86%.

1.5.3.1.1 An analysis of oxides of nitrogen and nitrogen dioxide emissions from road transport in urban areas.

361. Data in the NAEI has been used to assess NO_X and NO_2 emissions from road transport in urban areas. A similar approach has been followed and the same NO_2:NO_X ratios used for different vehicle classes to that in AQEG, 2006[115].

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[113] OX = O_3 + NO_2.

[114] Carruthers, D., Williams, M., Johnson, K., Lad, C., (2007) Dispersion modelling of air pollution in urban areas in the UK (Phase 2). Contract CPEA 22: Final report. www.airquality.co.uk/archive/aqs2007.php

[115] See Footnote 33.

362. Annual NO_X and NO_2 emissions have been calculated for the years 2002 to 2010 for road transport in urban areas by vehicle type (See Figure 1.75 and Figure 1.76 below).

Figure 1.75: Annual oxides of nitrogen road transport emissions in urban areas by vehicle type for the years 2002 to 2010

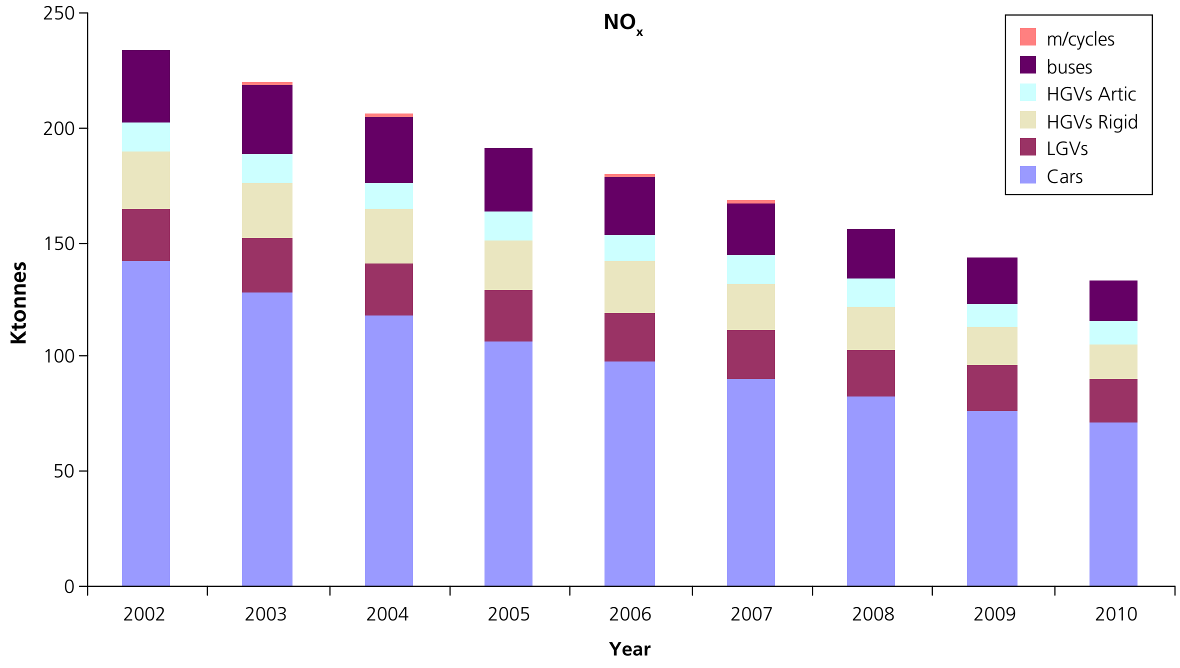
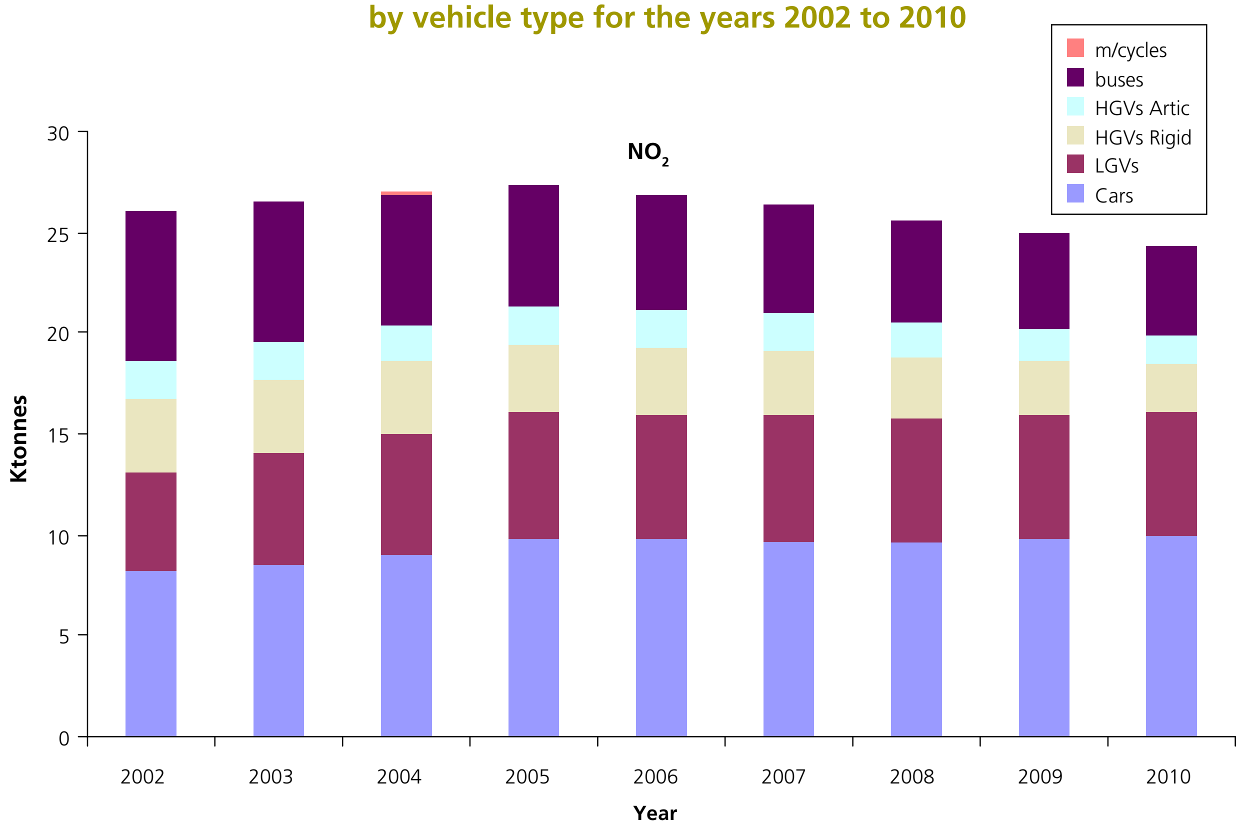


Figure 1.76: Annual nitrogen dioxide road transport emissions in urban areas by vehicle type for the years 2002 to 2010



363. The NAEI uses traffic forecasts from DfT's FORGE model which takes into account the Ten Year Plan for Transport. The rate at which new vehicles penetrate the fleet and old ones are taken out are calculated by a fleet turnover model based on average survival rates and figures from DfT's Vehicle Market Model (VMM) on new car sales. The survival rates are based on averages of historical survival rates over the last 10 years. It has been assumed that diesel car sales will grow to 42% by 2010.

364. The emission calculations show that in urban areas, road transport NO_x emissions show a decline from 233 Ktonnes to 133 Ktonnes between 2002 and 2010 respectively (Figure 1.75). In contrast, NO_2 emissions are predicted to increase between 2002 and 2005. Following this, they are predicted to fall (Figure 1.76). This decline in NO_2 emissions post 2005 was also predicted by AQEG (2006) for London road transport emissions. This trend is, as identified by AQEG, as a result of an increasing NO_2:NO_X emission ratio (see Figure 1.77) in combination with declining NO_x emissions from all vehicles.

365. In 2002, the NO_2:NO_X emissions ratio from all vehicles combined (Figure 1.77) was approximately 11% and this is predicted to increase to 18% by 2010. In London a similar increase is predicted over this period.

366. Figure 1.78 shows the proportion that each vehicle type contributes to the total NO_2 emissions in urban areas. The analysis shows that cars and light goods vehicles (LGVs) will contribute proportionately greater amounts of NO_2 in the future. This is as a result of the increasing numbers of diesel cars and increasing numbers of both cars and LGVs conforming to Euro III and Euro IV emission standards. The analysis has showed that HGVs and buses are of less importance as their contribution to total NO_2 emissions in urban areas is predicted to fall over time. This is because the NAEI forecasts at present assume that there is no widespread use of particulate traps on Euro IV and IV+ vehicles. This assumption obviously has large implications on the total NO_2 emissions predicted in urban areas.

Figure 1.77: The percentage nitrogen dioxide to oxides of nitrogen ratio for all vehicle types for 2002 to 2010

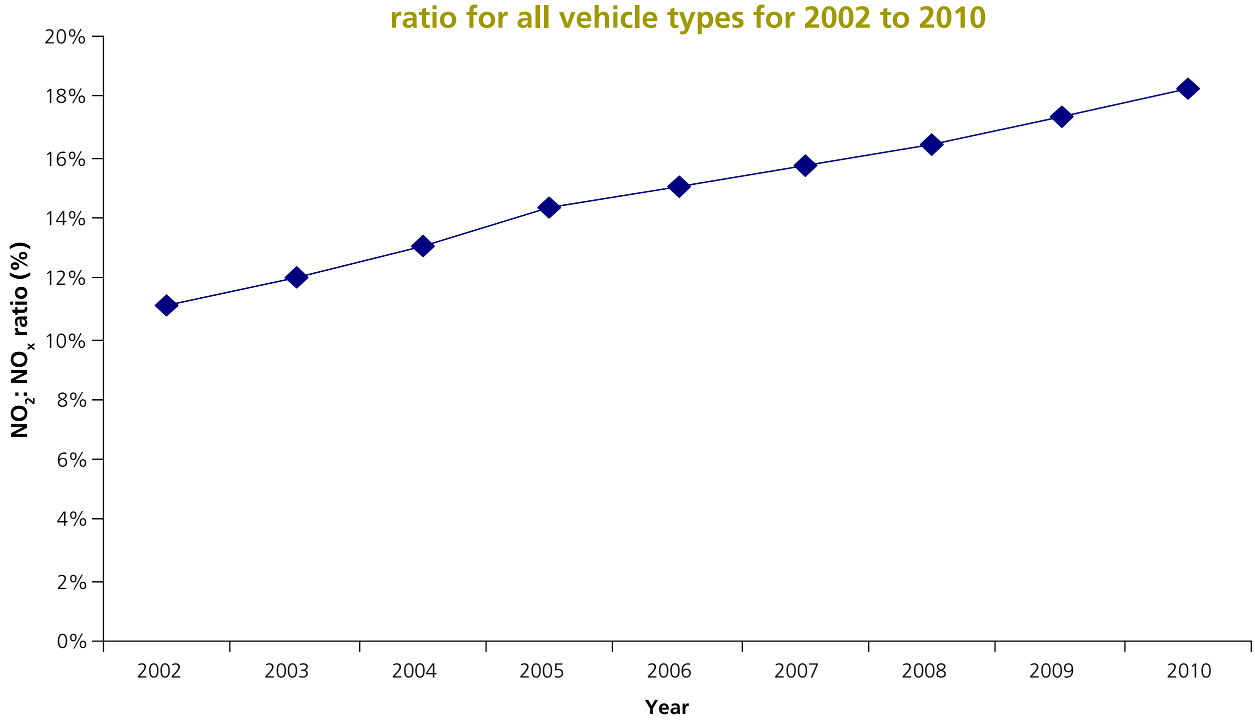
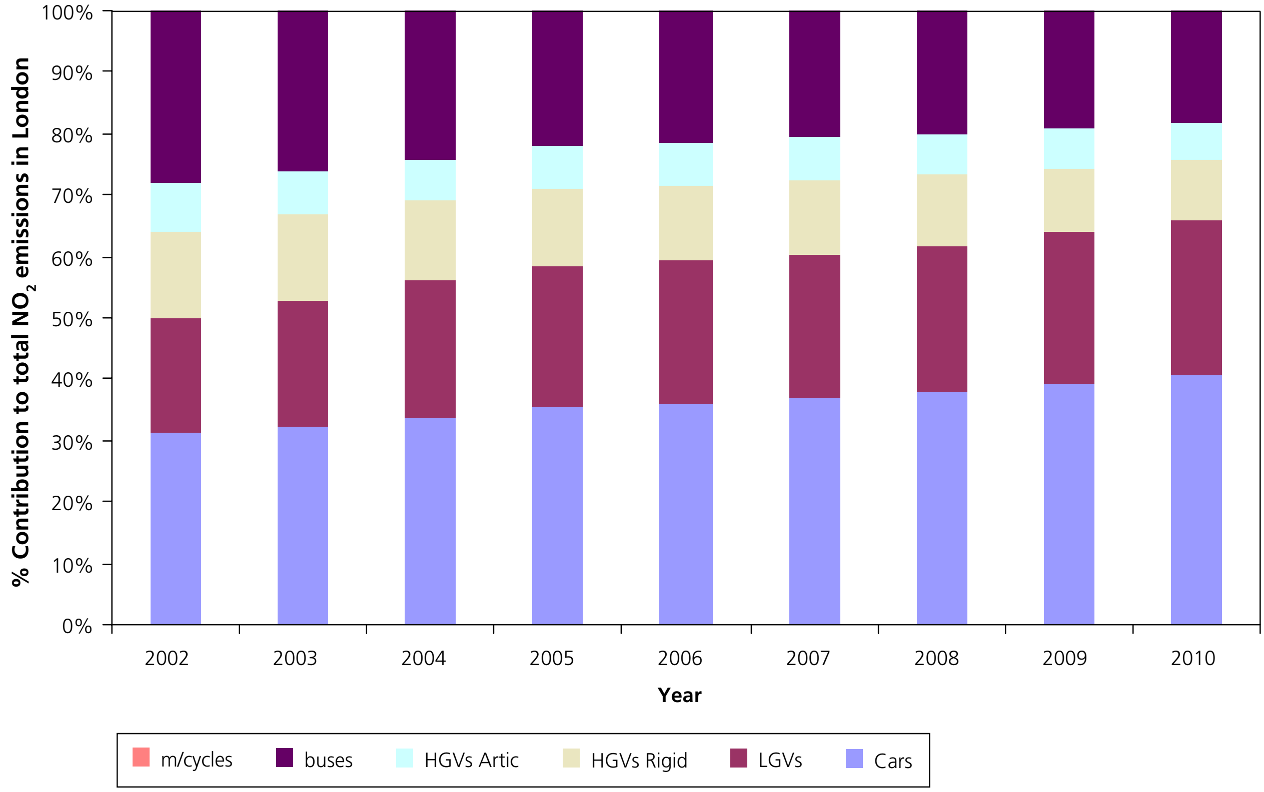


Figure 1.78: Percentage contribution to total London nitrogen dioxide emission by vehicle type for 2002 to 2010



367. Predictions of annual mean NO_2 concentrations at roadside have been calculated for a range of sensitivity analyses for comparison with the baseline calculations, in which no change in the fraction of NO_X emitted as primary NO_2 (f-NO_2, expressed as a percentage) has been assumed in the projections. The impact of changes in f-NO_2 for traffic emissions in background concentrations has not been assessed but is expected to be much smaller than at the roadside.

1.5.3.1.2 Sensitivity analyses

368. All of the sensitivity analyses have been calculated for a base year of 2004 using emission projections derived from UEP21. Table 1.32 lists the different scenarios modelled. The implied values of f-NO_2 for Marylebone Road are illustrated.

Table 1.32: Sensitivity analyses for f-NO_2 at Marylebone Road (%)

	baseline	prim_inv	prim_norm	prim_link
2004	13.7	13.1	13.7	15.9
2010	13.7	18.3	19.1	20.6
2015	13.7	21.9	22.9	23.9
2020	13.7	22.6	23.6	23.5

- **baseline** this is the projections from a base year of 2004 using energy projections UEP21 and no change in f-NO_2 between 2004 and 2020. The f-NO_2 varies for different parts of the country and with NO_X concentration, this variation has been derived from analysis of ambient monitoring data.
- **prim_inv** single values of f-NO_2 for UK urban road traffic emissions have been estimated for each year from 2002 to 2020 by the NAEI. Thus f-NO_2 in 2004 is different from that assumed in the baseline.
- **prim_norm** a spatially varying f-NO_2 for 2010, 2015 and 2020 has been calculated from the values used in the 2004 baseline calculations by scaling these values according to the proportional change in f-NO_2 implied by the prim_inv scenario.
- **prim_link** link specific values of f-NO_2 have been calculated for 2004, 2010, 2015 and 2020 by applying values of f-NO_2 for each vehicle class (cars, buses, LGV etc.) in each year provided by the NAEI to projections of NO_X emissions for each link by vehicle class.

1.5.3.1.3 Results

369. Table 1.33 shows the results of the sensitivity analyses for Marylebone Road.

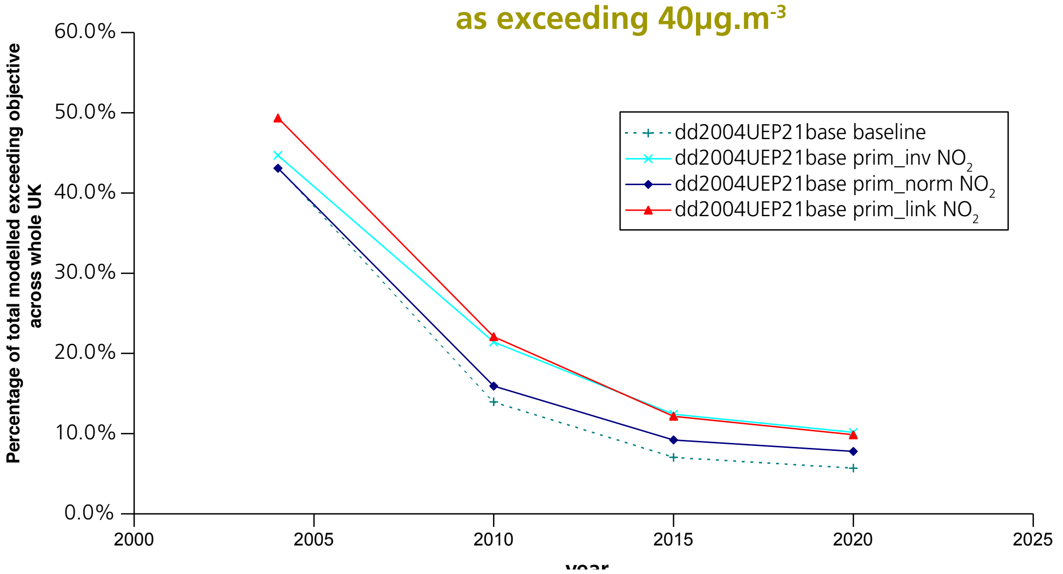
Table 1.33: Modelled oxides of nitrogen and nitrogen dioxide concentrations at Marylebone Road (µg.m^{-3}, as nitrogen dioxide)

	Meas NO_x	Mod NO_x	Meas NO_2	Modelled NO_2			
				baseline	prim_inv	prim_norm	prim_link
2004	309	284.1	110	86.1	84.7	86.1	91.2
2010	–	181.5	–	67.8	73.9	75.0	76.9
2015	–	146.3	–	59.5	67.6	68.7	68.7
2020	–	137.8	–	57.5	65.6	66.6	66.5

370. All of the calculations under-predict NO_2 in 2004 at Marylebone Road. This is because the baseline and normalised calculations and the NAEI UK-urban inventory and link specific calculations are based on UK national fleet characteristics. The predicted NO_2 concentrations for 2010, 2015 and 2020 are higher than the baseline for all of the scenarios with increasing f-NO_2.

371. Figure 1.79 shows how the road length modelled to exceed an annual mean NO_2 concentration of 40 µg.m^{-3} varies with year of the different sensitivity analyses. The prim_norm calculations are the same as the baseline in 2004 but show a greater percentage of road length exceeding in 2010, 2015 and 2020. The prim_inv calculations show slightly more excedeence than the baseline in 2004 and considerably more in 2010, 2015 and 2020. The prim_inv calculations typically have a lower assumed f-NO_2 in 2004 at some of busier roads and a higher f-NO_2 at some of the less busy roads than the baseline calculations. The prim_link calculations show the highest percentage of exceedence in 2004 but very similar extents of exceedence in 2010, 2015 and 2020 to the prim_inv scenario.

Figure 1.79: Nitrogen dioxide road length modelled as exceeding 40µg.m^{-3}



1.5.3.1.4 Conclusions

372. Overall the predicted extents of exceedence in 2004 are very similar considering that the baseline values of f-NO_2 have been derived from an examination of monitoring data and the for the prim_inv and prim_link values of f-NO_2 have been derived from vehicle emissions measurements and emission inventories.

373. The increase in percentage of major road length exceeding 2020 for the various treatments of primary NO_2 relative to the baseline calculations is of similar magnitude to the reduction delivered by scenario Q (from 5.7% to 1.5%). If, however f-NO_2 is thought to be greater for Euro 5 Light Duty Vehicle (LDVs) and Euro 6 HDVs than for the Euro 4 LDVs and Euro 5 HDVs then an estimate of the reduction in exceedences delivered by scenario Q relative to these various primary NO_2 scenarios might be smaller.

374. These analyses suggest that the impact in terms of the length of road exceeding 40 mg m^{-3} of reductions in total NO_X emissions will be much greater than the impact of increases in f-NO_2 in the period from 2004 to 2020. However these analyses also suggest that increases in f-NO_2 should be included in future baseline and scenario assessments and there are various ways in which the pcm models can be adapted to achieve this (Kent et al 2007[116]).

1.5.4 Response of particulate matter concentrations to changes in emissions of precursor gases

375. 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 change in response to changes in emissions of SO_2? This issue is important for the assessment of the impacts of the Strategy's additional policy measures because most of the monetised benefits derive from changes to PM_{10} concentrations. Secondary PM_{10} is thought to contribute around one third to total PM_{10} concentrations, so the estimated health benefits are sensitive to responses of secondary PM_{10} concentrations to changes in precursor emissions.

376. The AQEG[117] 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[118].

377. 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 national model assumes for the base case the same relationship between emissions and concentration

116 Kent, A. J. , Grice, S., Stedman, J. R., Bush, T. J., Vincent K. J., Abbott, J., Derwent, R. G., Hobson, M. (2007) UK air quality modelling for annual reporting 2005 on ambient air quality assessment under Council directives 96/62/EC, 1999/30/EC and 2000/69/EC. AEA Energy & Environment Report ED48208 www.airquality.co.uk/archive/reports/reports.php?action=category&section_id=9

117 AQEG (2005), Particulate Matter in the United Kingdom. ISBN 0-85521-143-1

118 This is described in detail in the AQEG report on air quality and climate change. Consultation on draft AQEG report: Air quality and climate change: a UK perspective http://defraweb/corporate/consult/airqual-climatechange/index.htm

as assumed by the EMEP assessment for Europe[119]. 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.

378. 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.

379. 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 O_3 concentrations (see section on O_3 in this Chapter). 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.

380. Consequently we have carried out a sensitivity analysis of the relationship between precursor emissions (both SO_2 and NO_X) and PM concentrations. There are two uncertainties that this sensitivity analysis addresses: those in the base case and those associated with the impact of measures.

381. The following sensitivity tests have been carried out:

- **SENSITIVITY 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.
- **SENSITIVITY 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.
- **SENSITIVITY 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.

382. The following section presents a summary of the impact of these sensitivities on the exposure reduction estimates for $PM_{2.5}$ in Section 2 of Volume 1 and the population-weighted concentration changes in Section 1.3.1.

[119] Convention on Long Range Transboundary Pollution. Cooperative programme for monitoring and evaluation of the long-range transmissions of air pollutants in Europe. http://www.emep.int/index_assessment.html

1.5.4.1 Exposure

383. Table 1.34 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.

Table 1.34: 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
SENSITIVITY A: 50% response of secondary PM to additional measures: measure Q	-14.9	-10.1
SENSITIVITY B: 25% response of secondary PM for the baseline	-5.7	-3.1
SENSITIVITY C: 25% response of secondary PM to additional measures: measure Q	-8.4	-6.1

384. 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 SO_2 to particulate sulphate is increased, then the effectiveness of measures will be reduced.

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

386. 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.

387. The impact of the Strategy's additional policy 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 is safer to assume the same relationship applies to additional measures as those included in the basecase. This is Sensitivity A in the above table.

388. For Measure Q, the percentage reduction for PM_{10} is 6.1 to 10.7% reduction between 2010 and 2020; and 8.4 to 16.1% for $PM_{2.5}$. The reduction would be 15%, 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.

1.5.4.2 Exceedences

389. The predicted extent of exceedences is also dependent on the relationship between precursor emissions and PM concentrations. Table 1.35 below shows the percentage of UK urban major roads predicted to exceed 20 µg.m^{-3}, gravimetric in 2020.

Table 1.35: Percentage exceedence of 20 µg.m^{-3}, gravimetric in 2020

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

1.5.4.3 Benefits of measures

390. Table 1.36, Table 1.37 and Table 1.38 show the changes in UK population-weighted mean PM concentrations for measures Q and N 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.

391. Measure Q has reductions in both primary and secondary PM; measure N has reductions in secondary PM only.

Table 1.36: Changes in population-weighted mean $PM_{2.5}$ concentrations for measure Q (µg.m^{-3}, gravimetric)

Year	Standard	SENSITIVITY A	% difference A – Standard	SENSITIVITY C	% difference C – Standard
2010	–0.106	–0.082	–23%	–0.076	–28%
2020	–0.571	–0.406	–29%	–0.347	–39%

Table 1.37: Changes in population–weighted mean PM_{10} concentrations for measure Q (µg.m^{-3}, gravimetric)

Year	Standard	SENSITIVITY A	% difference A – Standard	SENSITIVITY C	% difference C – Standard
2010	–0.167	–0.145	–23%	–0.139	–27%
2020	–0.803	–0.648	–19%	–0.594	–26%

Table 1.38: Changes in population–weighted mean PM_{10} concentrations for measure N (µg.m^{-3}, gravimetric)

Year	Standard	SENSITIVITY A	% difference A – Standard	SENSITIVITY C	% difference C – Standard
2010	–0.378	–0.194	–49%	–0.118	–69%
2020	–0.541	–0.272	–51%	–0.175	–68%

392. 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.

393. 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 1.36). The change to population-weighted PM_{10} concentration is smaller (-19% in 2020, Table 1.37) because secondary PM contributes a smaller proportion to PM_{10} concentrations than $PM_{2.5}$.

394. New calculations are presented in Volume 2 Chapter 2 and new IGCB report for all measures using an analysis consistent with sensitivity A.

1.5.4.4 Conclusions

395. The assessment presented in this document represents our best estimate of current and future air quality. There are uncertainties associated with many aspects of the assessment. The sensitivity of the assessment results to some of these uncertainties has been tested.

396. It is not practical to combine all the uncertainties and sensitivities to arrive at an estimate of total uncertainty associated with the analysis for the review of the Air Quality Strategy. It is possible however to identify the key uncertainties that effect the main conclusions of the analysis, i.e. which pollutants are likely to exceed objectives in the future and the effectiveness of additional policies on future concentrations and improving public health.

397. Table 1.39 and 1.40 summarise the results of the key sensitivity analyses on the baseline and measure Q and R for NO_2 and PM_{10}. For NO_2, the most recent available energy projection, UEP26[120], generally give a slightly higher concentration for the baseline and measures in 2010, 2015 and 2020, when compared to UEP21 and UEP12. The 2003 model and meteorology generally produces much higher baseline concentrations than either 2002 or 2004. The 2004 model also appears to produce a slightly smaller response to the measures that the 2003 model.

398. For PM_{10}, UEP26 has a more variable effect on the baseline and measures than those for NO_2 in the different years. Again the 2003 model and meteorology produced a much higher baseline concentration than either 2002 and 2004. A number of different factors gave rise to a high number of PM_{10} episodes in 2003. These included secondary

[120] At the time of publication, UEP30 had been published. However, this was not available in time to inform the analysis supporting the Air Quality Strategy.

particulate associated with continental air masses, Saharan dust episodes and Russian forest/peat/agricultural fires, all of which were superimposed on the normal baseline pollution levels. The 2004 model produces a slightly increased response to the measures than the 2003 model.

399. An indication of the effect on urban $PM_{2.5}$ exposure reduction are also shown in Table 1.40, utilising total UK PM_{10} exposure reduction. A reduction of around 7.3% is expected from the baseline alone with a further 3.25% from measure Q or 4.6-5.4% from measure R depending on the energy projection and year.

400. Overall the meteorological year chosen produces the largest effect on the future concentrations, resulting in differences of around 10%. The different energy projections, measures and model produce much smaller effects on future concentrations.

Table 1.39: Effects of changing the base year (2002, 2003, 2004), energy projections (UEP 12, 21 and 26) and model (2003, 2004) on nitrogen dioxide concentrations in 2005, 2010, 2015 and 2020 for the baseline, Measure Q and Measure R.

		2002, 2003, 2004	2005	2010	2015	2020
2002, UEP12	**Baseline**	21.35	19.46	16.57	15.00	14.31
	Measure Q			16.39 (1.1)	14.01 (6.6)	12.81 (10.5)
2003, UEP12	**Baseline**	24.45	23.02	19.52	17.61	16.78
	Measure Q			19.31 (1.1)	16.42 (6.7)	14.98 (10.7)
	Measure R			19.25 (1.4)	16.3 (7.4)	14.55 (13.3)
2003, UEP21	**Baseline**	24.45		19.54	17.92	16.77
	Measure Q			19.33 (1.1)	16.78 (6.3)	15.02 10.5)
2004, UEP21	**Baseline**	19.12		15.80	14.36	13.78
	Measure Q			15.65 (1)	13.5 (6)	12.48 (9.5)
2003, UEP26	**Baseline**	24.45		19.74	18.10	16.94
	Measure Q			19.53 (1.1)	16.97 (6.2)	15.19 (10.3)
2004, UEP26	**Baseline**	19.12		15.86	14.40	13.83
	Measure Q			15.7 (1)	13.66 (5.1)	12.66 (8.5)
	Measure R			15.64 (1.4)	13.35 (7.3)	11.98 (13.4)

Table 1.40: Effects of changing the base year (2002, 2003, 2004), energy projections (UEP 12, 21 and 26) and model (2003, 2004) on PM_{10} concentrations in 2005, 2010, 2015 and 2020 for the baseline, Measure Q and Measure R and the percentage UK PM_{10} exposure reduction. All at 50% response in secondary particulate matter to changes in sulphur dioxide/nitrogen dioxide emissions unless otherwise stated (see section 1.5.4 for further details)

		2002, 2003, 2004	2005	2010	2015	2020	% UK PM_{10} Exposure Reduction
2002, UEP12	**Baseline**	19.90	18.87	17.59	17.00	16.69	5.12
	Measure Q			17.43 (0.9)	16.57 (2.5)	16.09 (3.6)	8.61
2003, UEP12	**Baseline**	22.42	21.55	19.88	19.08	18.54	6.72
	Measure Q			19.74 (0.7)	18.62 (2.5)	17.89 (3.5)	9.98
	Measure R			19.59 (1.4)	18.42 (3.5)	17.62 (5)	11.38
2003, UEP21	**Baseline**	22.42		19.84	19.03	18.25	8.04
	Measure Q			19.7 (0.7)	18.57 (2.4)	17.6 (3.6)	11.30
2004, UEP21	**Baseline**	20.21		18.23	17.46	16.85	7.57
	Measure Q			18.05 (1)	16.9 (3.2)	16.06 (4.7)	10.98
2003, UEP26	**Baseline**	22.42		19.82	19.10	18.38	7.26
	Measure Q			19.67 (0.8)	18.65 (2.4)	17.74 (3.5)	10.50
2004, UEP26	**Baseline**	20.21		18.25	17.48	16.91	7.34
	Measure Q			18.06 (1)	16.93 (3.2)	16.12 (4.7)	11.65
	Measure R			17.99 (1.4)	16.8 (3.9)	15.91 (5.9)	12.79
2003, UEP12	**Baseline 50% response**	22.42	21.55	19.88	19.08	18.54	6.72
	Measure Q 100% response			19.71 (0.8)	18.51 (3)	17.74 (4.3)	10.76
2003, UEP12	**Baseline 25% response**			20.82	20.37	20.19	3.07
	Measure Q 25% response			20.69 (0.7)	19.95 (2)	19.59 (2.9)	5.92

1.5.5 Future concentrations

1.5.5.1 Nitrogen dioxide

401. 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.

402. Furthermore, AQEG 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 O_3.

403. C onsequently 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[121].

404. The 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".

1.5.5.2 Particulate matter PM_{10}

405. For PM_{10}, the sensitivity analysis indicates that we can be confident that limited exceedences of the Strategy's 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.

406. There is highly likely to be widespread exceedence of an annual average concentration of 20 $\mu g.m^{-3}$ 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 20 $\mu g.m^{-3}$ in future years.

407. The AQEG independently drew similar conclusions that the EU annual mean 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 50$\mu g.m^{-3}$, especially in London[122]. AQEG also concluded there is likely to be substantial exceedences of 20 $\mu g.m^{-3}$ near to major roads in 2010.

121 Air Quality Expert Group (2004) Nitrogen Dioxide in the United Kingdom. www.defra.gov.uk/environment/airquality/aqeg/nitrogen-dioxide/index.htm

122 Air Quality Expert Group (2005) Particulate Matter in the United Kingdom www.defra.gov.uk/environment/airquality/aqeg/particulate-matter/index.htm

1.5.5.3 Ozone

408. The O_3 modelling presented in Volume 2 estimates that there will be extensive exceedence of the objective in future years. Measurements show background O_3 levels are slowly increasing and that measures to reduce NO_X emissions will increase O_3 concentrations in urban areas (Chapter 3). Consequently there is a large margin for error in the assessment of future concentrations and we are confident that O_3 concentrations will exceed the objective in 2010 and 2020.

1.5.5.4 Polycyclic aromatic hydrocarbons

409. Modelling of PAHs presented in Volume 2 is highly uncertain because of a highly uncertain emissions inventory. Indications from the monitoring and modelling are that the objective will be difficult to achieve in some areas due to domestic space heating and increased activity projected in the use of coal, anthracite and solid smokeless fuels.

1.5.5.5 Future particulate matter concentrations and health impacts

410. Quantification of health impacts of air pollution is dominated by the impact on mortality of chronic exposure to PM (see updated Third Report of the IGCB). Calculation of this impact is based on population-weighted concentration of PM. Hence the sensitivity of population weighted concentration to input assumptions is a good indicator of the sensitivity of the estimate of health impacts to the same assumptions.

411. 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.

412. 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.

1.5.6 Effectiveness of measures in the base case and additional measures

413. There is a significant risk that the effectiveness of measures in the base case and additional measures will 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 (1) the composition of the atmosphere in the future and the responsiveness of PM concentrations to changes in precursor gas emissions (see Table 1.29) and (2) apportionment of sources of PM (see Table 1.30). This is potentially important because of the influence that changes to population-weighted concentration have on estimates of health impact in Chapter 2.

414. In summary, there are three elements that contribute the greatest uncertainty to the main conclusions drawn in this review for the key pollutants, NO_2, PM_{10} and O_3. 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.

415. 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 in respect of the cost and benefits assessment and in particular for the compliance with objectives assessment, 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 model may underestimate the impact on air quality of measures at the local scale.

1.5.7 Intercomparision between national model, ADMS-URBAN and UKIAM

416. A comparison of the results of three air quality modelling studies has been carried out. The 2006 review of the Air Quality Strategy for England, Scotland, Wales and Northern Ireland was focussed on measures to reduce concentrations of PM_{10} and NO_2. The air quality modelling results presented in the review were carried out by netcen using national scale GIS-based models (known as the PCM model). Modelling studies were also carried out by CERC using the ADMS-Urban model and Imperial College using the UKIAM model specifically to provide a comparison with the results of the PCM model.

417. Full details of the intercomparison are contained in Stedman *et al*, (2007)[123]. This report provides a summary of the key results from the three modelling studies and some discussion of the main reasons for some of the similarities and differences between the models. There are several distinct areas to consider when comparing the results of the different models:

- the representation of base year concentrations: this should be reasonable for all the models, within the limitations of spatial scale. The information on the verification of the models by comparison with ambient monitoring data is provided in the individual modelling reports;
- trends in predicted concentrations for the baseline from the base year to 2020.;
- Impact of measure Q in 2010 and 2020 in terms of the change in predicted concentrations; and
- the implications of key assumptions in the design and use of each model, including the spatial resolution, PM/NO_X background concentrations, source apportionment, imported contributions and chemical transformations etc.

418. The source apportionment of base year concentrations and the assumptions on the impact of the changes in emissions represented by the baseline and additional measures to reduce concentrations on the different components are key to understanding the differences between the different models. The changes in population-weighted mean PM concentrations are probably the most important statistics since the impact of changes in long-term PM concentrations dominate the health benefits of the predicted reductions in concentrations.

[123] Stedman, J., Grice, S., Carruthers, D., Williams, M., ApSimon, H., Oxley, T., Cooke, S., (2007) Model comparison report for AQSR. AEAT/ENV/R/2456 http://www.airquality.co.uk/archive/reports/list.php

419. Some of the main differences between the different models considered in the report are listed in Table 1.41. The impact of Measure Q on predicted population-weighted mean concentrations in 2020 for each of the models is summarised in Table 1.42. This table summarises model input and model methodology and gives comments on the impacts of the differences as appropriate. The different approaches arise partly from the different purposes for which the models were designed. Of definite significance for the model comparisons are the base year utilised, the modelling methodology and spatial resolution of the model, the method of calculating NO_2 from NO_X and the specification of background concentrations and their future projections. It is not clear from this study whether the different emission inventories utilised have any significant impact on the comparisons.

Table 1.41: Summary of main differences between the models

Feature	PCM	ADMS-Urban	UKIAM	Comments/Impacts of differences
Area covered in study	UK	London	UK	
Emission inventory	NAEI	LAEI	NAEI	The effect of the inventory is unclear from this study since in PCM concentrations calculated from emissions are adjusted empirically, whilst ADMS-Urban and UKIAM are difficult to compare because of the large difference in spatial resolution.
Base year	2003	2001	2000	Background PM concentrations are higher for 2003 meteorology due to higher secondary PM production and enhanced photochemical activity.
Model methodology	Based on dispersion modelling with empirical adjustment plus simple valued roadside increment for each road segment. Regional background from annual measurements	Dispersion modelling for each hour; Sources treated explicitly. Regional background from rural measurements for each hour.	Source receptor model on 5km x 5km grid.	These differences are reflected in the modelled concentrations and output for each model.

Table 1.41: Summary of main differences between the models *(continued)*

Spatial resolution of output	1km x 1km grid plus roadside increments	10m – 100m includes concentration gradients near roads	5km x 5km grid	A coarser spatial resolution generally leads to lower estimates of population-weighted mean concentrations and reduced sensitivity to local emission reduction measures.
Temporal resolution	annual	hourly	annual	Uncertain and difficult to test. Difference may be greater in 'atypical' years.
Method used to predict NO_2 from NO_X	Empirically based partitioning model for annual averages	Explicit NO_X, O_3 chemistry; simplified chemistry for VOCs. Hourly.	Annual empirical relationship for annual averages.	There are differences in the response of NO_2 to changes in NOx at the roadside and in background locations. The ratio of NO_2:NO_x increases more in future years for ADMS-Urban when NO_x concentrations are lower than either PCM or UKIAM.
Source apportionment of regional NO_x (percentage from UK sources)	100%	100%	50%	Assuming 100% of regional NO_x is due to UK sources may overestimate the impact of UK measures on concentrations. Actual source apportionment may be somewhere between 100 and 50%
Response of UK secondary PM concentrations to changes in precursor emissions	linear	linear	based on the EMEP model	The observed response is non-linear so a non-linear response may be an improvement depending on its formulation.

Table 1.42: The impact of Measure Q on population-weighted means (μg.m^{-3}, gravimetric)

	PCM	AMDS-Urban	UKIAM
NO_2 London	–2.26	–1.40	–1.83
NO_2 UK	–1.80	–	–1.18
PM_{10} London	–1.34	–0.96	–0.66
PM_{10} UK	–0.80	–	–0.28
$PM_{2.5}$ London	–0.84	–0.84	–
$PM_{2.5}$ UK	–0.57	–	–

420. The source apportionment of base year concentrations and the assumptions on the impact of the changes in emissions represented by the baseline and additional measures to reduce concentrations on the different components are key to understanding the differences between the different models. The changes in population-weighted mean PM concentrations between the baseline and Measure Q are probably the most important statistics since the impact of changes in long-term PM concentrations dominate the health benefits of the predicted reductions in concentrations. The extent of exceedences predicted by the models are also of interest in terms of the development of air quality policy, although the formal cost benefit analyses are dominated by the changes in population-weighted means.

421. In addition to differences in data on emissions the models also make different assumptions about the contributions imported into the areas modelled, including the contribution from outside the UK. These include contributions to NO_x emissions from shipping, which are steadily increasing over time, as well as from other European countries; and also contributions to nitrate and sulphate from North America and outside Europe. Uncertainties arise as to how these contributions will change over time, and the models make different assumptions – UKIAM being more pessimistic than PCM and ADMS.

1.5.7.1 Nitrogen dioxide

422. The predicted impacts of Measure Q in 2020 in terms of the population-weighted mean NO_2 are listed in Table 1.42. The largest changes are predicted by the PCM model. A smaller impact predicted by ADMS-Urban model and this is likely to be as a result of the finer spatial scale and chemical scheme adopted, which takes explicit account of concentrations in the vicinity, but not adjacent to, the roadside. Smaller changes are also predicted by the UKIAM model and this is likely to be due to a combination of an assumed unchanging imported component of regional NO_X concentrations and the larger spatial resolution of the model. The direct health impacts of NO_2 do not make a large contribution to the quantified health impacts in the cost benefit analysis although the contribution of NO_2 to secondary particle formation may form a more significant proportion of the result.

423. The predicted extents of excedence of $40μg.m^{-3}$ at background and roadside locations predicted for 2010 and 2020 by the different models are reasonably consistent.

1.5.7.2 Particulate matter PM_{10}

424. The PCM model predicts the larger impact of Measure Q on population-weighted mean PM_{10} concentration in 2020 than the UKIAM model (Table 1.42). This is likely to be due to a combination of different assumptions about the response of secondary PM to changes in precursor emissions, the source apportionment of regional background concentrations (UKIAM has rather less secondary PM overall), the base year and the spatial scale of the models. The impact predicted by ADMS-Urban is also somewhat lower and this is likely to have been due to differing source apportionment of the local contribution to ambient PM_{10} with the PCM model having a somewhat larger contribution from road traffic sources. These differences also have implications for the predicted percentage of exposure reduction between 2010 and 2020 for which the PCM model predicts the largest reductions.

425. The comparison of the model assumptions and results for PM_{10} suggests that it is more likely that the PCM modelling (which informed the consultation document on the review of the Air Quality Strategy) would have over-predicted the impact of Measure Q on ambient PM concentrations, and thus the benefits of these reductions, rather than underestimated.

426. The predicted extent of exceedences for PM_{10} has also informed the review of the Air Quality Strategy and the results of this inter-comparison clearly show that the predicted extent of exceedences is highly variable between the different models. This confirms the results of the sensitivity analyses presented by Stedman *et al* (2006a) and Defra (2006b) that showed that the predictions of annual mean PM_{10} concentrations are subject to considerable uncertainty. The accuracy of predictions of exceedences of threshold concentrations are 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 and uncertainties about the source apportionment of PM. The predicted extent of exceedence is known to be particularly uncertain (AQEG, 2005). The analysis presented here confirms that the predicted extent of exceedences is subject to more uncertainty than predictions of the marginal changes in PM concentrations likely to result from current or possible future policy measures. This is a useful insight since it is the marginal changes in concentrations that dominate the cost-benefit analyses, rather than the predicted extent of exceedences.

1.5.7.3 Particulate matter $PM_{2.5}$

427. The modelling of $PM_{2.5}$ concentrations is subject to greater uncertainty than the modelling of PM_{10} due to the much smaller amount of monitoring data available for model verification and development. The population-weighted mean concentrations predicted by the PCM and ADMS-Urban are in very good agreement for $PM_{2.5}$, as are the predicted changes in concentration for measure Q. The differences in the source apportionment suggest that this very good agreement is partly fortuitous and the uncertainties associated with the modelling of ambient $PM_{2.5}$ remain high. Remember, also, that both the PCM and ADMS models assumed a linear response of secondary PM to changes in precursor emissions. The predicted exposure reduction between 2010 and 2020 is somewhat greater for the PCM modelling. This is likely to be due to the differing source apportionment between the two models, the PCM model has a larger contribution from nitrate and a smaller contribution from primary PM. The ADMS-Urban modelling is more consistent between PM_{10} and $PM_{2.5}$ than the PCM modelling for which the source apportionment of PM_{10} and $PM_{2.5}$ is less consistent.

428. The relatively close agreement between PCM and ADMS-Urban for $PM_{2.5}$ is not consistent with the differences in PM_{10} due to the different base years utilised and may be due to the fact that the relationship between primary emissions and concentrations is not fully consistene for PM_{10} and $PM_{2.5}$ within the 2003 base year PCM modelling.

1.5.7.4 Policy implications

429. Each of the models compared in the report have associated with them uncertainties arising from their various different features and modelling methodologies (for example see Table 5.1) which in this case for PCM show the considerable uncertainty in annual mean concentrations of PM_{10}. However the comparison exercise has revealed some

consistency and therefore robustness in the differences in the models which do have clear policy implications. PCM generally gives a more optimistic picture then either ADMS-Urban or UKIAM. It predicts the largest reductions in both absolute and percentage terms in both PM_{10} and $PM_{2.5}$ for both UK and London even though in these cases it predicts higher concentrations because of the base year considered. In the case of NO_2 it is more 'optimistic' then either ADMS-Urban or UKIAM in London and predicts a greater impact of measure Q on the population-weighted means than UKIAM across the UK. These differences may partly be explained by differences in the forward projection of background concentrations (which in future studies could be harmonised between the models), however the other differences arising mainly from differences in model resolution (spatial and temporal), the differences in the chemical conversion schemes for NO_X to NO_2 and the extent to which monitoring data are used directly in the models are not easily addressed because of inherent differences in the model methodologies.

1.5.7.5 Additional modelling work

430. Additional PCM modelling work has been carried out to support the Air Quality Strategy review since the publication of the consultation documents (Defra *et al*, 2006a[124], 2006b[125]). This additional modelling work includes the following:

- revised energy projections UEP21 (the previous modelling used UEP12);
- revised energy projections UEP26; and
- revised packages of additional measures (measures A2, C2 and combined measure R; see section 2.2).

431. This additional modelling (Stedman *et al*, 2007a[126]) has incorporated a number of changes to the PCM models to take account of some of the key results of this model comparison, in order to improve the confidence with which the results can be used within the cost benefit analyses. These changes include:

- additional modelling for the 2004 base year (to provide estimates for an additional base year with less unusual meteorological conditions);
- a revised source apportionment of regional rural NO_X concentrations to take account of the contributions from shipping and sources in continental Europe;
- incorporation of a 50% response function, to represent the apparent non-linearity in the impact of changes in precursor emissions on secondary PM; and
- a more consistent source apportionment of PM_{10} and $PM_{2.5}$ concentrations (Stedman *et al,* 2007b[127])

[124] DEFRA *et al* (2006a). Department for Environment, Food and Rural Affairs, The Scottish Executive, Welsh Assembly Government and The Department of the Environment for Northern Ireland. The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. Volume 1: A consultation document on options for further improvements in air quality

[125] DEFRA *et al* (2006b). Department for Environment, Food and Rural Affairs, The Scottish Executive, Welsh Assembly Government and The Department of the Environment for Northern Ireland. The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. Volume 2: Technical Annex and Regulatory Impact Assessment

[126] Stedman, J.R., *et al* (2007a) Report on additional projections of air quality in the UK for additional measures scenarios for the 2007 review of the air quality strategy. Report to be prepared. http://www.airquality.co.uk/archive/reports/list.php

[127] Stedman, J. R., Kent , A. J., Grice, S., Bush, T. J. and Derwent, R. G. (2007b). A consistent method for modelling PM_{10} and $PM_{2.5}$ concentrations across the United Kingdom in 2004 for air quality assessment. *Atmospheric Environment*, **41**, 161-172.

1.6 Climate change programme air quality modelling assessment

432. The links between climate change and air quality are currently generating great interest and these links have recently been reviewed by AQEG[128] and the Royal Society will also be examining them during 2007. To make an assessment of the potential effects of climate change on the measures included in this strategy, two evaluations were carried out at a local and national level. The local air quality impacts of climate change uses Met Office climate predictions to input into a dispersion model for London and Glasgow. The national air quality impacts were considered using the effect of not implementing the Climate Change Programme (2000)[129] and the effect of implementing new policies from the Climate Change Programme (2006)[130] fully.

1.6.1 Local Impacts of Climate Change on Air Quality

433. CERC and the Met Office carried out a study to investigate the impact of climate change on air quality in London and Glasgow[131].

434. Initially climate simulations were conducted by the Met Office to predict changes between the current climate (1970-1990) and a future climate in the period 2070 – 2090. The main impacts on meteorology at London and Glasgow were as follows:

- an increase in temperature of order 2-4°C;
- an increase in wind speed in winter and reduction in summer;
- a tendency in London for more westerlies in winter and a shift from south-westerlies to north-westerlies in summer. A tendency in Glasgow for wind directions to become much more concentrated in the WSW direction;
- a small reduction in cloud cover in summer and a modest consequential increase in incoming solar radiation and surface heat flux;
- a modest increase in mean boundary layer depth in London (to approximately 50m) and a very small mean increase in Glasgow (approximately 10m);
- a decrease in precipitation in summer and an increase in winter;
- an increase in mean sea level pressure in summer and a decrease in winter, suggesting an increase in blocking circulation patterns in summer and in mobile westerly patterns in winter; and
- an increase in specific humidity.

435. In order to assess the impact of the changes in meteorology on dispersion from single sources, modelling was carried out for a variety of representative sources: a small source with a low stack; a small power station; a large power station; and a road source.

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128 AQEG (2007) Air Quality and Climate Change: A UK Perspective. TSO ISBN 0-85521-172-5.

129 The Local Impact of Climate Change on Air Quality; Carruthers D. *et al*; Defra; 2005; http://www.airquality.co.uk/archive/reports/cat16/0608041526_Report_25-10-05.pdf

130 Defra (2006) Climate change. The UK Programme 2006. TSO ISBN 0-10-167642-5.

131 Reference to CERC CC/AQ report.

436. With the London meteorological data, only the large power station showed significant differences with a 13% increase in the maximum of the annual average and 98th percentile concentrations by approximately 2080.

437. For Glasgow the effects were larger with increases in the range 25-39% for the maximum annual average for all three non-road sources and for the 98th percentile for the power station source. This reflected the increased tendency for the wind to be from a WSW direction.

438. Subsequently an assessment was made using the meteorological datasets to model impacts of climate change on urban air quality in London and Glasgow i.e. the meteorology was changed but not the emissions. CERC's rural predictor, a statistical model based on correlation of O_3 and NO_x with temperature, wind direction and time of day, was used to calculate the change in the background concentration. These background concentrations were used in conjunction with ADMS-Urban to calculate pollutant concentration in London and Glasgow.

439. The rural predictor showed large increases in O_3 and decreases in NO_X in the London area, but only small impacts in the Glasgow area.

440. Long-term average concentrations in London calculated at roadside and background receptor points showed an average fall in NO_X of 6.1ppb and an average rise in ozone of 4ppb, with only a small change in PM_{10} and NO_2. The increase in O_3 was associated both with the rise in background O_3 predicted by the rural predictor and the decrease in NO_X concentrations.

441. In Glasgow, the predicted changes in concentrations of NO_X, NO_2, O_3 and PM_{10} are predicted to be small.

442. Calculations from the Met Office Stochem model which included climate change and projected emission changes also showed large increases is O_3 in both London and Glasgow areas, however the impacts are even larger when only the emission changes are considered without their impact on climate.

1.6.2 National Impacts of Climate Change Programme on Air Quality

443. Two sets of scenario calculations were carried out to assess the impact of the climate change programme on ambient air quality. These scenarios have been compared with the baseline assessment within the 2006 Air Quality Strategy Review (UEP12, 2003 base year for concentrations). Concentrations of PM_{10}, NO_2 and O_3 have been estimated for two scenarios:

- **Counter factual scenario** (CFS): the emissions and concentrations have been estimated without the **existing** policies within the climate change programme (CCP)[132]. This is what would have happened without these policies, which in fact have happened. Concentrations have been calculated for 2003, 2010, 2015 and 2020; and
- **New policies** (new): a scenario including the existing and proposed new policies from the climate change programme. 2010, 2015 and 2020.

[132] Climate Change The UK Programme 2006; TSO (The Stationary Office); 2006; www.tsoshop.co.uk

1.6.2.1 Emissions scenarios

1.6.2.1.1 Climate Change Programme 2000 (existing policies)

444. The policies and programmes within the CCP have a significant impact on air quality, now and in the future.

445. Almost all policies make a positive contribution towards air quality, by reducing emissions of pollutants relative to the baseline emissions level.

446. The business and domestic policies together offer substantial air quality benefits, while the transport policies lead to reductions in air quality:

- in the **domestic sector**, the largest benefits accrue from the Fuel Poverty Schemes that have an important influence upon emissions of PM. The Building Regulations and the Energy Efficiency Commitment are also associated with a large emissions saving;
- **transport policies** cause an increase in emissions of air pollutants. This is the case with the Voluntary Agreement package, which results in both an increase in vehicle mileage (other things being equal), as well as a switch to diesel fuel;
- in the **energy supply** sector, the Renewables Obligation is projected to increase emissions of NO_X, SO_X and PM_{10} in both 2010 and 2020. The increase in NO_X is attributed to increased generation from landfill gas, whereas emissions of PM_{10} increase largely as a result of the increase in biomass combustion. All emissions are relative to emissions from combined-cycle gas-turbine power generation; and
- the air quality impacts of the policies and measures in the **agriculture and forestry sector** are insignificant.

1.6.2.1.2 Climate Change Programme 2006 (new policies)

447. Almost all policies make a positive contribution towards air quality, by reducing emissions of pollutants relative to the baseline emissions level;

- in the **domestic sector**, the expansions to the Energy Efficiency Commitment and to Warm Front will both result in reduction in air quality emissions by 2010. In 2020, Better Billing and Metering contributes the largest NO_X savings, due to the assumed reduction in natural gas use that results;
- emissions reduction will also arise from policies targeting **energy efficiency** in the business sector;
- the greatest overall air quality benefit is generated by the **EU ETS** (EU Emission Trading Scheme). However, the precise impacts upon air quality emissions will be strongly affected by the market conditions, the price of carbon in the trading scheme, the emissions cap applied to the sector, and the level of fuel switching that is induced;
- in the **transport sector**, the Renewable Transport Fuel Obligation (RTFO) is expected to reduce emissions of particulate matter relative to the situation without the RTFO in place. However, this may be offset by emissions from the increased vehicle mileage that might be associated with a future voluntary agreements package; and

- the air quality impacts of the **strategy for non-food crops** has not been quantified, although it is acknowledged that the policy has the potential to impact negatively upon air quality emissions.

1.6.2.2 Exceedence analysis

448. For both PM_{10} and NO_2 the results of the analysis suggest that there would have been more exceedences in the CFS than in the baseline. Similarly the analysis suggests that there will be fewer exceedences for the new policies than for the baseline. So both the existing and proposed new policies are beneficial for PM_{10} and NO_2 air quality in terms of exceedences.

1.6.2.3 Population-weighted means

449. Both the existing and proposed new policies are also beneficial for PM_{10} and NO_2 air quality in terms of population-weighted mean concentrations. The differences in population-weighted mean are illustrated in Table 1.43. They are presented as the scenario concentration minus the baseline. The changes are positive for the CFS because the baseline includes the existing policies. The results for O_3 are presented for thresholds of zero, 70 and 100µg.m^{-3}. Note that in all instances the sign is the opposite for O_3. Thus both the existing and new policies have a detrimental effect on ozone air quality in terms of these metrics.

Table 1.43: The change in UK Population weighted-mean concentrations implied by the climate change programme scenarios

PM_{10} (µg.m^{-3}, gravimetric)				
	2003	**2010**	**2015**	**2020**
CFS	0.202	0.462	0.362	0.403
New	–	–0.157	–0.105	–0.079
NO_2 (µg.m^{-3})				
	2003	**2010**	**2015**	**2020**
CFS	0.565	0.998	0.521	0.726
New	–	–0.241	–0.190	–0.163
Ozone (µg.m^{-3})				
No threshold	**2003**	**2010**	**2015**	**2020**
CFS	–0.292	–0.434	–0.220	–0.328
New	–	0.178	0.107	0.085
70 µg.m^{-3}	**2003**	**2010**	**2015**	**2020**
CFS	–0.202	–0.182	–0.096	–0.154
New	–	0.080	0.051	0.042
100 µg.m^{-3}	**2003**	**2010**	**2015**	**2020**
CFS	–0.100	–0.042	–0.023	–0.039
New	–	0.025	0.015	0.012

1.6.3 Health impact assessment

450. Key results from the health impact assessment are shown in Table 1.44. The methods used are consistent with those adopted for the 2006 Air Quality Strategy review. In all cases the marginal change relative to the baseline is presented.

451. A coefficient of 6.0% per 10µg.m^{-3} change in $PM_{2.5}$ has been used in the calculations of the long term effect of PM. The lifetable calculations carried out for the review used changes in concentration for 5, 20 or 100 years. One hundred years is probably the most appropriate for this assessment. Figure 1.80 shows how the impact of the CFS and new policies on emissions vary between 2000 and 2020. For both the CFS and new policies, NO_x emissions are reduced most in the period up to about 2010 and then the change is smaller. The change in emissions is more consistent for PM_{10} out to 2020. The most important policy for the new scenario is the EU ETS, for which the impact stops after 2012. It is likely, however, that it will be replaced by something similar. Thus it is probably most realistic to assume that the impact of the climate change policies will continue for a long time. Results are shown for zero lag and a 40-year lag of the effect of the change in concentrations.

452. The tables show that there would have been additional deaths brought forward, hospital admissions and life years lost from PM if existing climate change policies had not been in place. For O_3, there would have been fewer deaths brought forward and hospital admissions.

453. Implementing new climate change policies is predicted to decrease deaths brought forward, hospital admissions and life years lost from PM but increase deaths brought forward and hospital admissions from O_3.

Table 1.44: Health impact assessment: results for the UK

PM_{10} Deaths brought forward per year				
	2003	**2010**	**2015**	**2020**
CFS	67	154	120	134
New	–	–52	–35	–26
PM_{10} Respiratory hospital admissions per year				
	2003	**2010**	**2015**	**2020**
CFS	71	162	127	142
New	–	–55	–37	–28
PM_{10} Cardiovascular hospital admissions per year				
	2003	**2010**	**2015**	**2020**
CFS	71	163	127	142
New	–	–55	–37	–28
NO_2 Respiratory hospital admissions per year				
	2003	**2010**	**2015**	**2020**
CFS	161	285	149	207
New	–	–69	–54	–46

Ozone Deaths brought forward per year (coefficient 0.6%)				
No threshold	**2003**	**2010**	**2015**	**2020**
CFS	–101	–150	–76	–114
New	–	62	37	30
70 μg.m^{-3}	**2003**	**2010**	**2015**	**2020**
CFS	–70	–63	–33	–53
New	–	28	18	15
100 μg.m^{-3}	**2003**	**2010**	**2015**	**2020**
CFS	–34	–14	–8	–14
New	–	9	5	4
Ozone Respiratory hospital admissions per year				
No threshold	**2003**	**2010**	**2015**	**2020**
CFS	–117	–173	–88	–131
New	–	71	43	34
70 μg.m^{-3}	**2003**	**2010**	**2015**	**2020**
CFS	–81	–73	–38	–62
New	–	32	20	17
100 μg.m^{-3}	**2003**	**2010**	**2015**	**2020**
CFS	–40	–17	–9	–16
New	–	10	6	5

Long term impact of PM_{10} CFS (Additional life years lost)						
Change in concentration (years)	**2010**	**40 year lag**	**2015**	**40 year lag**	**2020**	**40 year lag**
5	97,569	103,234	76,401	80,837	85,066	90,005
20	413,784	396,685	324,011	310,621	360,758	345,850
100	1,868,711	979,133	1,463,281	766,704	1,629,239	853,659
Long term impact of PM_{10} New (Additional life years lost)						
Change in concentration (years)	**2010**	**40 year lag**	**2015**	**40 year lag**	**2020**	**40 year lag**
5	–33,114	–35,037	–22,094	–23,376	–16,611	–17,575
20	–140,435	–134,632	–93,697	–89,825	–70,445	–67,534
100	–634,227	–332,311	–423,151	–221,715	–318,139	–166, 693

Figure 1.80: Counter factural scenario oxides of nitrogen emissions saved in different sectorsdue to policies affecting these sectors

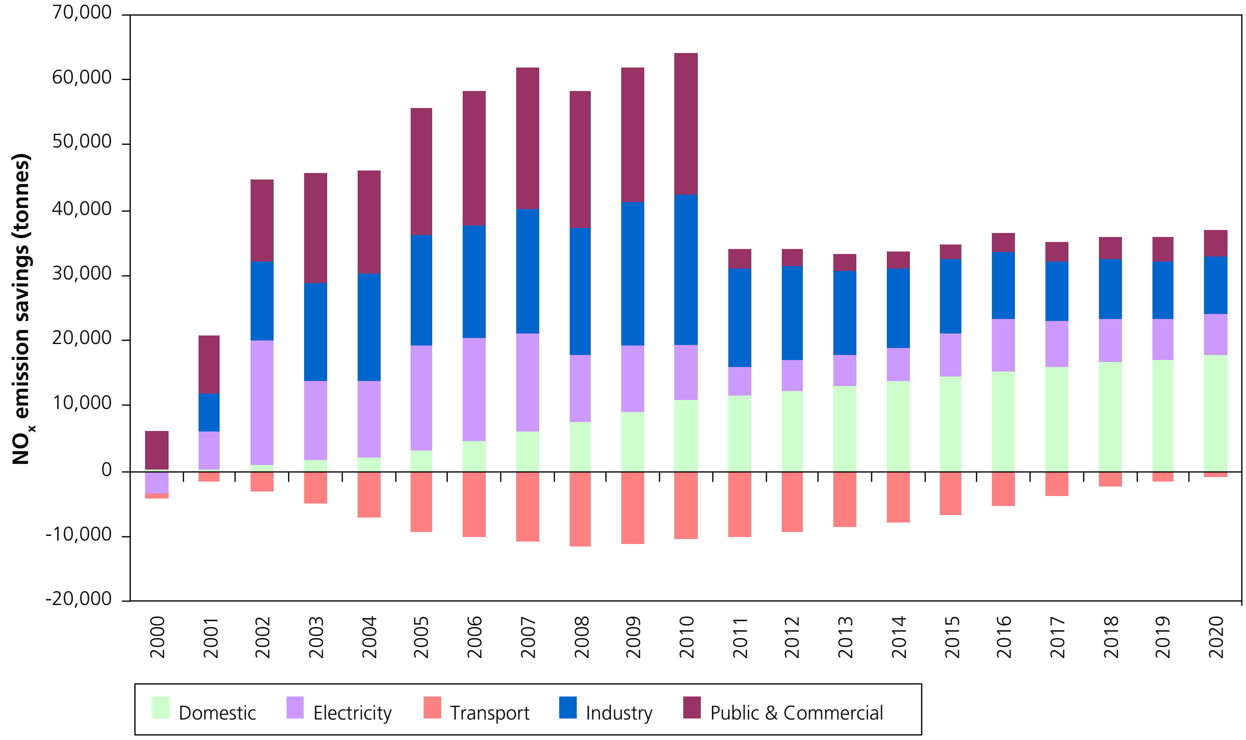


Figure 1.81: Counter factual scenario particulate matter PM_{10} emissions saved in different sectors due to policies affecting these sectors

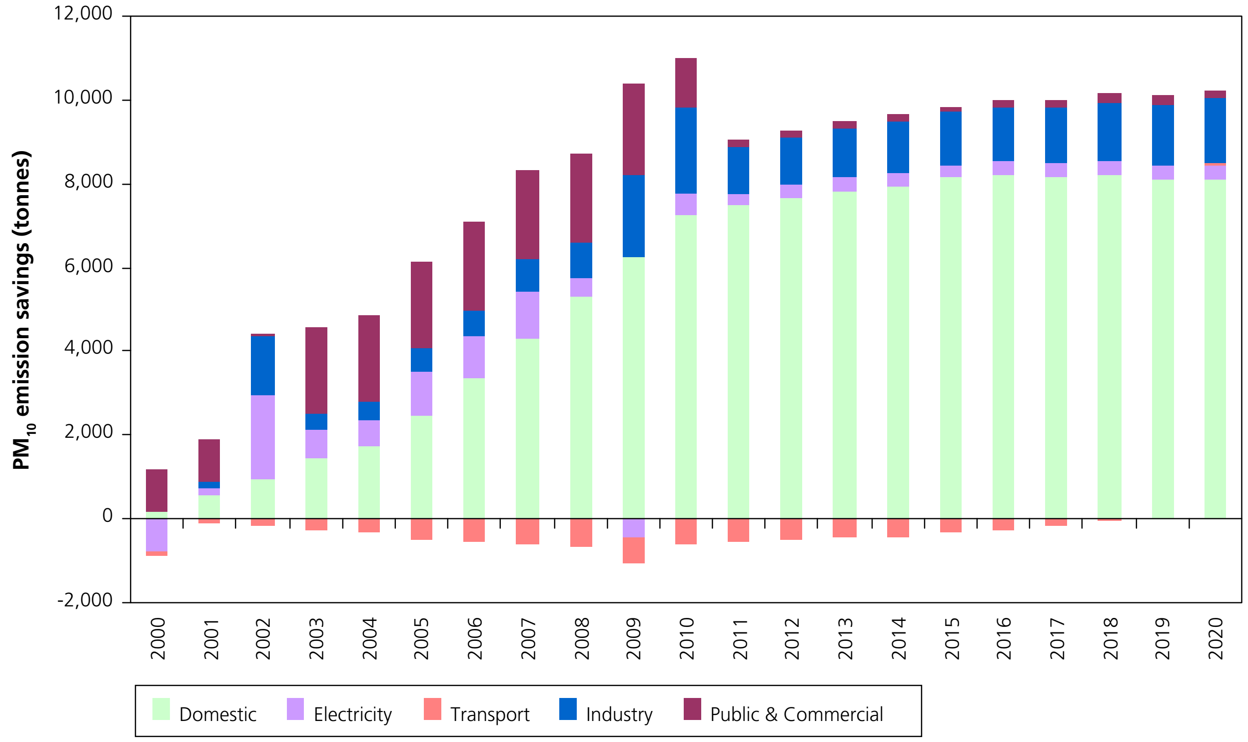


Figure 1.82: New – oxides of nitrogen emissions saved in different sectors due to policies affecting these sectors

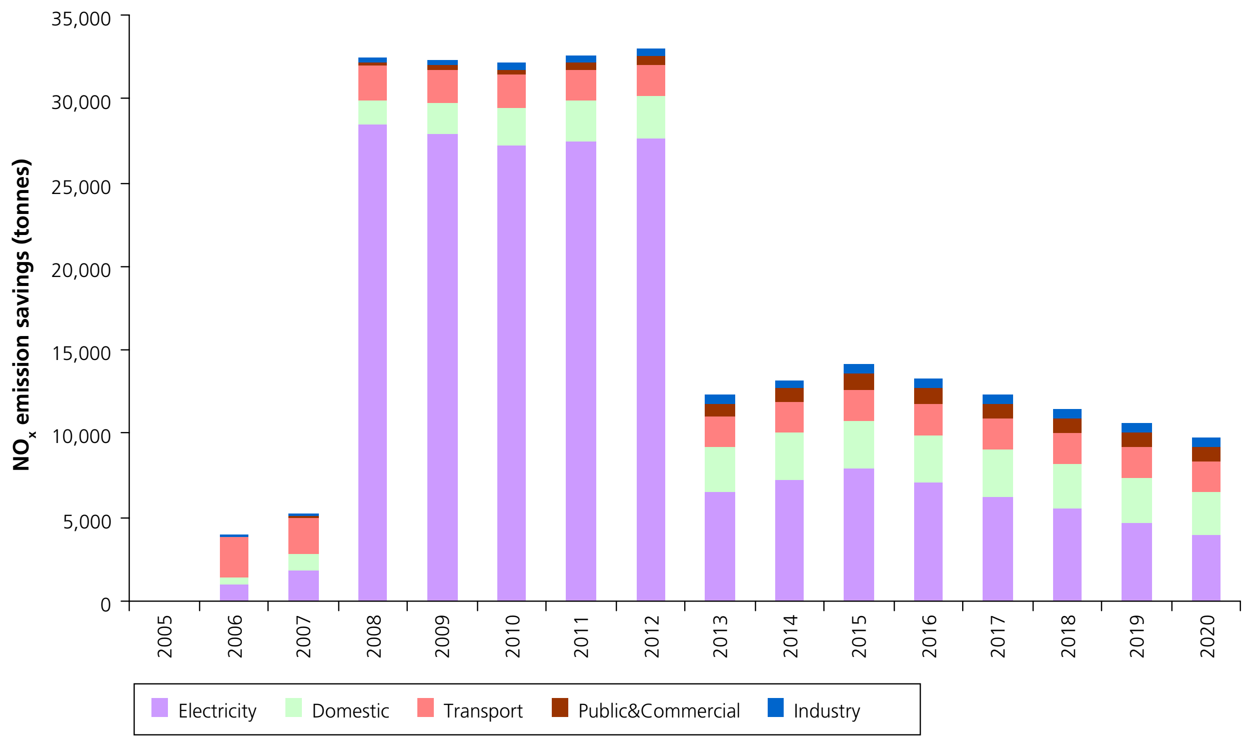
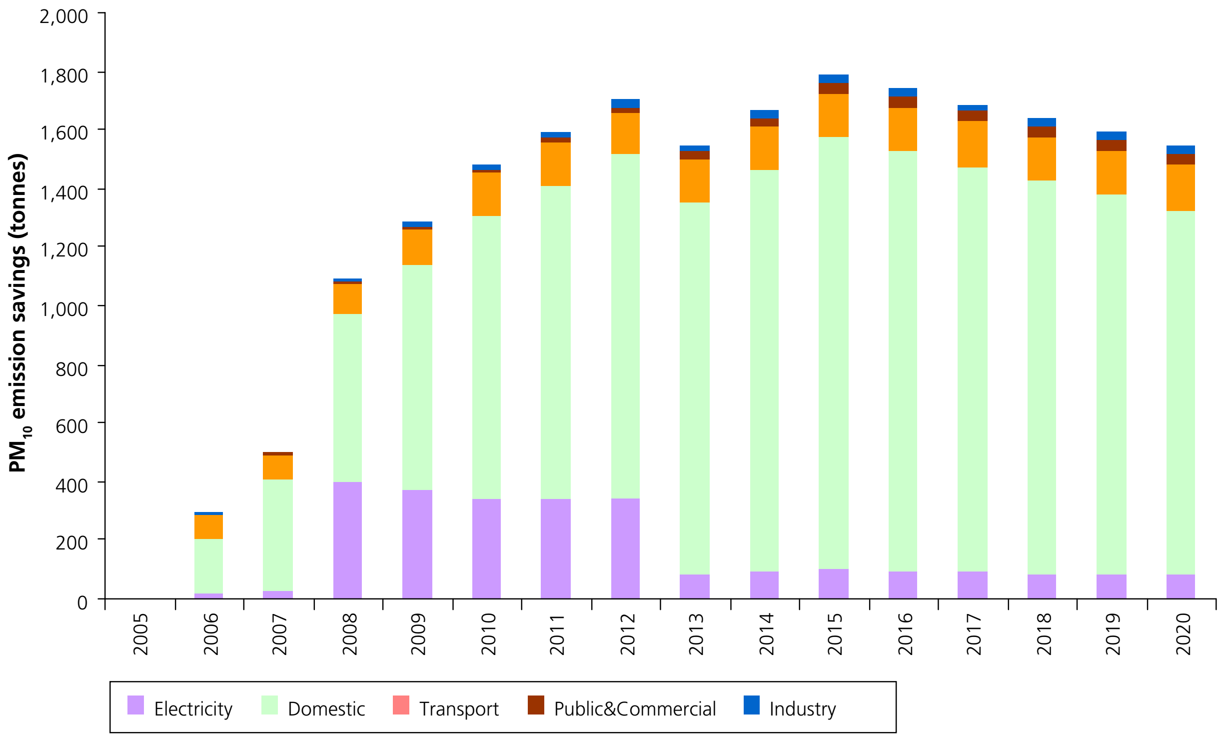


Figure 1.83: New – particulate matter emissions saved in different sectors due to policies affecting these sectors



1.7 Challenging objectives

454. GIS-based modelling predictions of air quality using baseline conditions (i.e. under current policies) have been produced for SO_2, NO_X and NO_2, PM_{10}, benzene, CO, $PM_{2.5}$ and 1,3-butadiene for a range of years. A summary of the percentage of modelled exceedences of relevant EU limit values/Air Quality Strategy objectives/ thresholds for each pollutant is presented in Table 1.45 for a 2003 base year. A comparison of modelling results and EU limit values for NO_2 and PM_{10} for a 2002 base year (Grice *et al*, 2005) showed significantly fewer exceedences for projections derived from this base year. Measurement data are summarised in Figure 1.84.

455. Overall, some of the Strategy's objectives are, and will remain, very challenging even with the new measures. These include 2010 annual mean PM_{10}, 2010 PM_{10} 24-hour mean, 2010 B[a]P annual mean, 2005 NO_2 annual mean and 2005 O_3 daily maximum 8-hour mean. Other objectives, including the SO_2 (nearly everywhere), benzene, 1,3-butadiene, CO and lead objectives, are being met or are more likely to be met by their target dates.

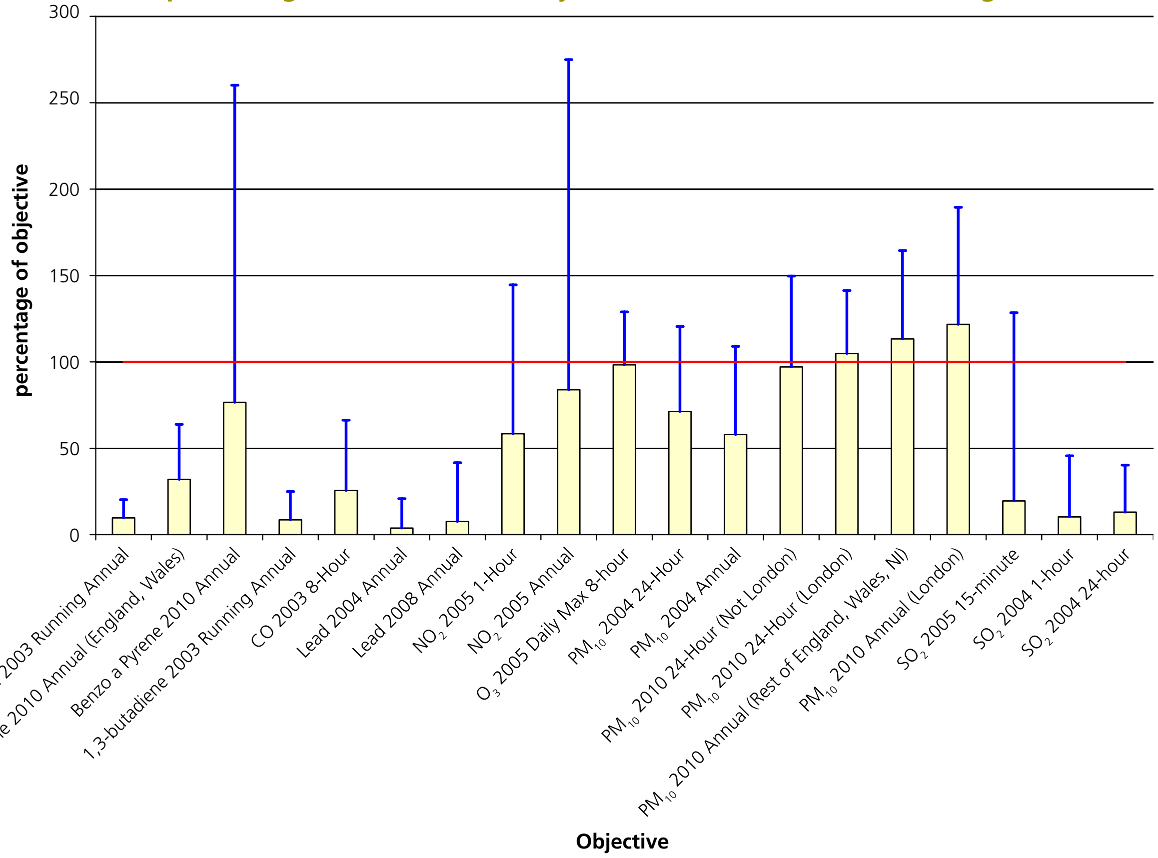
Table 1.45: Summary of modelled total percentage exceedences using a 2003 base year (ozone not included because assessment & metrics are not appropriate for this table)

Percentage of total urban major road length exceeding (road length assessed 14,084 km)						
Pollutant	**Threshold**	**2003**	**2005**	**2010**	**2015**	**2020**
SO_2	15 minute mean	N/A	N/A	N/A	N/A	N/A
	1 hour and 24 hour	N/A	N/A	N/A	N/A	N/A
NO_2	Annual mean >40 µg.m^{-3}	52.5	41.3	18.2	10.0	8.5
PM_{10}	Annual mean >31.5 µg.m^{-3}	16	10	2	0.5	0.3
	Annual mean >20 µg.m^{-3} (England (not London) 2010 objective)	98	97	89	76	67
	Annual mean >20 µg.m^{-3} (Wales 2010 objective)	94	88	53	30	22
	Annual mean >20 µg.m^{-3} (NI 2010 objective)	54	36	14	11	14
	Annual mean >18 µg.m^{-3} (Scotland 2010 objective)	84	76	49	28	23
	Annual mean >23 µg.m^{-3} (London 2010 objective)	100	100	92	87	72
$PM_{2.5}$	Annual mean >20 µg.m^{-3}	9.0	4.3	0.2	0.0	0.0
	Annual mean >16 µg.m^{-3}	53.1	42.3	10.9	2.3	0.9
	Annual mean >12 µg.m^{-3}	85.0	82.7	72.3	58.6	46.7
Benzene	Annual mean > 5 µg.m^{-3}	1.0	0.0			
CO	8-hour mean > 10 mg.m^{-3}	0.0	N/A	N/A	N/A	N/A
1-3, butadiene	Annual mean > 2.25 µg.m^{-3}	0.0	N/A	N/A	N/A	N/A
Percentage of total background area exceeding (total UK area assessed 242,248 km^2)						
Pollutant	**Threshold**	**2003**	**2005**	**2010**	**2015**	**2020**
SO_2	15 minute mean	0.65	0.46	0.01	0.01	0.01
	1 hour and 24 hour	0.01	0.01	0.01	0.01	0.01
NO_2	Annual mean >40 µg.m^{-3}	0.2	0.1	0.0	0.0	0.0
PM_{10}	Annual mean >31.5 µg.m^{-3}	0	0	0	0	0
	Annual mean >20 µg.m^{-3} (England (not London) 2010 objective)	60	50	13	6	4
	Annual mean >20 µg.m^{-3} (Wales 2010 objective)	8	5	1	1	1
	Annual mean >20 µg.m^{-3} (NI 2010 objective)	2	1	1	0.1	1
	Annual mean >18 µg.m^{-3} (Scotland 2010 objective)	1	0.6	0.1	0.1	0.1
	Annual mean >23 µg.m^{-3} (London 2010 objective)	97	93	35	10	4

Table 1.45: Summary of modelled total percentage exceedences using a 2003 base year (ozone not included because assessment & metrics are not appropriate for this table) *(continued)*

Percentage of total background area exceeding (total UK area assessed 242,248 km^2)						
$PM_{2.5}$	Annual mean >20 µg.m^{-3}	0.0	0.0	0.0	0.0	0.0
	Annual mean >16 µg.m^{-3}	2.2	0.8	0.0	0.0	0.0
	Annual mean >12 µg.m^{-3}	44.1	37.8	24.5	9.7	2.1
Benzene	Annual mean > 5 µg.m^{-3}	0.0	0.0			
CO	8-hour mean > 10 mg.m^{-3}	0.0	N/A	N/A	N/A	N/A
1-3, butadiene	Annual mean > 2.25 µg.m^{-3}	0.0	N/A	N/A	N/A	N/A
B[a]P	Annual mean > 0.5 ng.m^{-3}	0.003		0.002		
Percentage of total population in the area exceeding (total population assessed 58,160,071)						
Pollutant	**Threshold**	**2003**	**2005**	**2010**	**2015**	**2020**
SO_2	15 minute mean	0.66	1.17	0.01	0.01	0.01
	1 hour and 24 hour	0.01	0.01	0.01	0.01	0.01
NO_2	Annual mean >40 µg.m^{-3}	4.0	2.3	0.6	0.3	0.3
PM_{10}	Annual mean >31.5 µg.m^{-3}	0.1	0.1	0	0	0
	Annual mean >20 µg.m^{-3} (England (not London) 2010 objective)	88	81	51	32	20
	Annual mean >20 µg.m^{-3} (Wales 2010 objective)	55	37	12	6	5
	Annual mean >20 µg.m^{-3} (NI 2010 objective)	40	2	4	2	7
	Annual mean >18 µg.m^{-3} (Scotland 2010 objective)	19	19	4	2	2
	Annual mean >23 µg.m^{-3} (London 2010 objective)	99	97	46	13	4
$PM_{2.5}$	Annual mean >20 µg.m^{-3}	0.0	0.0	0.0	0.0	0.0
	Annual mean >16 µg.m^{-3}	23.4	12.1	0.1	0.0	0.0
	Annual mean >12 µg.m^{-3}	81.9	77.5	56.6	43.0	23.3
Benzene	Annual mean > 5 µg.m^{-3}	0.0	0.0			
CO	8-hour mean > 10 mg.m^{-3}	0.0	N/A	N/A	N/A	N/A
1-3, butadiene	Annual mean > 2.25 µg.m^{-3}	0.0	N/A	N/A	N/A	N/A
B[a]P	Annual mean > 0.5ng.m^{-3}	0.4		0.03		

Figure 1.84: Measured concentrations of pollutants in the UK in 2005 as a percentage of the relevant objectives (mean of all sites and highest site)



2.1 Key Points

- This chapter describes the assumptions used in the modelling for each of the new measures to be considered, the different analyses applied to them, and the results of these analyses.
- It also describes the measures which require additional development work and those which are no longer under immediate consideration, and why they have been categorised as such (see sections 2.3 and 2.4).
- The assumptions used for the measures may differ from the measures themselves once their implementation plans are developed; the final form a number of the measures will take is beyond the control of the Government and Devolved Administrations[133,134].
- The analysis used looks at the emissions change the measures produce; their monetised costs and benefits; their impact on exceedences of air quality objectives and limit values; changes in the air pollution impacts on ecosystems; and a number of other qualitative assessments. Each of these methodologies is described (see section 2.5).
- Based on the results of these assessments, the measures are given a red, amber or green (RAG) status for ease of reference. The RAG parameters are described in section 2.5.6.
- Due to the iterative nature of the strategy, the definition of some of the measures changed over time, as did the some aspects of the assessment model, reflecting an improved scientific understanding. Therefore, while the basis for the assessment has been made as consistent as possible, there are some subtle differences in the assessment of the measures. However, prior to implementation, a formal Impact Assessment will be undertaken, which will re-analyse their costs and benefits using the most up to date energy and transport projections, and modelling assumptions (see section 2.6.1).

2.2 New Measures to be Considered

456. Volume 1, section 3d of this strategy sets out the measures which will be considered further. This section sets out the assumptions used as a basis for the modelling and analysis of the measures, using the methodologies described in section 2.5, below. All of the measures in this section have been shown to be cost beneficial based on these assumptions.

[133] For example, measures A2 and C2 are based on European emissions standards which have yet to reach final agreement, and measure N on shipping will require action through the International Maritime Organisation (IMO).

[134] It is not the UK Government and Devolved Administrations' intention that the measures assessed in this strategy will receive funding beyond that which has already been or will be provided.

Table 2.1: Assumptions used for measures to be considered

Measure: A2 – Euro 5/6 and Euro VI vehicle emission standards	
Modelling basis	• Modified version of previous Measure A – Euro 5/6 and Euro VI vehicle emission standards, low intensity). • This measure models a **12.5% reduction in NO_X, 32% reduction in VOC** from all new petrol LDVs from 2010 (Euro 5), **28% reduction in NO_X** from new diesel LDVs from 2010 (Euro 5), and 72% reduction in NO_X from all new LDVs from 2015 (Euro 6). It also models a **90% reduction** in PM emissions from all new LDV from 2010 (Euro 5). Durability at 160,000km. • This measure models a **50% reduction in NO_X** from new diesel HDVs (Euro VI)[134].
Assumed timescales	The initial reduction in NO_X for LDVs is to apply from 2010, the tighter NO_X for LDVs is due to apply from 2015. The measure is introduced in 2013 for HDVs
Area of application	This measure applies to all EU countries
Measure: C2 – Incentivising the early uptake of new Euro standards	

Modelling basis	• Modified version of previous Measure C, to reflect changes in measure A2, above.
	• This measure has been modelled assuming the level of early uptake of Euro 5/6 and Euro VI vehicles as follows:
	  • 2007 0% Euro 5 petrol LDVs, 0% Euro 5 diesel cars, 0% Euro 5 diesel LGVs, 15% Euro V HDVs
	  • 2008 33% Euro 5 petrol LDVs, 33% Euro 5 diesel cars, 0% Euro 5 diesel LGVs, 47.5% Euro V HDVs
	  • 2009 66% Euro 5 petrol LDVs, 66% Euro 5 diesel cars, 33% Euro 5 diesel LGVs, 100% Euro V HDVs
	  • 2010 100% Euro 5 petrol LDVs, 100% Euro 5 diesel cars, 66% Euro 5 diesel LGVs, 25% Euro VI HDVs
	  • 2011 100% Euro 5 petrol LDVs, 100% Euro 5 diesel cars, 100% Euro 5 diesel LGVs, 50% Euro VI HDVs
	  • 2012 100% Euro 5 petrol LDVs, 100% Euro 5 diesel cars, 100% Euro 5 diesel LGVs, 75% Euro VI HDVs
	  • 2013 100% Euro 5 petrol LDVs, 33% Euro 6 diesel cars, 100% Euro 5 diesel LGVs, 100% Euro VI HDVs
	  • 2014 100% Euro 5 petrol LDVs, 66% Euro 6 diesel cars, 33% Euro 6 diesel LGVs, 100% Euro VI HDVs
	  • 2015 100% Euro 5 petrol LDVs, 100% Euro 6 diesel cars, 66% Euro 6 diesel LGVs, 100% Euro VI HDVs
	  • 2016+ 100% Euro 5 petrol LDVs, 100% Euro 6 diesel cars, 100% Euro 6 diesel LGVs, 100% Euro VI HDVs

Assumed timescales	The measure has been introduced in 2006 for LDVs (Euro 5) and will be 2010 for HDVs (Euro VI)
Area of application	This measure applies to UK

Measure: E – Increased uptake of low emission vehicles (LEV)	
Modelling basis	• Petrol LEVs assumed to deliver 38% reduction in NO_X and 34% reduction in CO_2 compared to Euro IV petrol cars. Penetration of petrol LEVs 10% by 2010, 25% by 2020 • Diesel LEVs assumed to deliver 80% reduction in NO_X, 92% reduction in PM_{10} and 29% reduction in CO_2 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
Assumed timescales	Currently undertaking additional analysis[135]
Area of application	This measure applies to the UK
Measure: N – Reducing emissions from ships	
Modelling basis	Requirements on global fleet (for all ships > 100 tonnes) to: • Use 1% rather than 1.5% Sulphur fuel from 2010 in waters surrounding the UK (applies to old and new vessels from 2010); and to • Reduce NO_X emissions by 25% from new ships from 2010. The introduction rate of new ships is assumed to be 1/30th of fleet per year.
Assumed timescales	2010. Full implementation can only be achieved through the International Maritime Organisation (IMO). This measure represents only one of several possible courses of action that the IMO might choose to pursue and does not necessarily represent the UK's preferred option, although the UK will push for challenging targets in reducing emissions.
Area of application	This measure applies to UK and all maritime
Measure: Combined Scenario R	
Modelling basis	A combination of measures C2, E and N, above.
Assumed timescales	N/A
Area of application	N/A

[135] This is likely to be a conservative estimate of the emission reductions required by Euro VI for HDV engines, although proposals for this are not due to be published by the European Commission until Autumn, 2007.

2.3 Measures requiring additional development work

457. Volume 1, section 3d of this strategy sets out the measures which will require additional development work prior to being considered for implementation, or coordination with other policy measures which are yet to be implemented. This section sets out the assumptions used as a basis for the modelling and analysis of the measures, using the methodologies described in section 2.5, below, and the individual reasons for their status.

Table 2.2: Measures requiring additional work

Measure: F – Impact of hypothetical national road pricing scheme on air quality	
Modelling basis	A hypothetical national road pricing scheme could take a variety of different forms and this analysis considers only one possible variant for illustrative purposes only, in order to give an indication of the potential impacts. The measure is based on the work that was done for the Road User Pricing Feasibility study. Emissions based on the analytical work that assumed marginal social cost pricing, using 10 charges capped at 80p per km. The emissions from the modelling have then been used as a basis for projections from 2015.
Assumed timescales	The scenario has been modelled as being implemented in the middle of the next decade.
Area of application	Under the scenario modelled, this measure would apply to GB
Reason for "further development" status	The option considers the impact of a hypothetical national pricing scheme on air quality based on the work that was done for the Road Pricing Feasibility study[136]. Although the primary objective of such a scheme is to reduce the externality of congestion, air quality benefits could potentially be produced. A national road pricing scheme could take a variety of different forms and this analysis considers only one possible variant for illustrative purposes only in order to give an indication of the potential impacts. No decisions have been taken on whether or not hypothetical national road pricing would be introduced, what form it might take, or how it might operate. It is highly unlikely that any 'real world' scheme would reflect the scenario that has been used for this assessment. This option will use the impacts from emission modelling in the above study as a basis for projections from 2015. It should be noted that there is a particularly high degree of uncertainty surrounding the costs and benefits of this measure. This reflects the fact that it is unlikely to be feasible before the middle of the next decade at the earliest, and the inherent uncertainties surrounding future technological developments and movements in technology-related costs.

136 Original modelling based on assumption of 2006 start date.

Measure: G2 – Low Emission Zones in London and 7 largest urban areas	
Modelling basis	Measures for London: • 2007: HDVs adopt Euro II + Reduced Pollution Certificate (RPC) • 2010 HDVs adopt Euro III + RPC Measures for other seven urban areas • 2010: HDVs adopt Euro II + RPC • 2013: HDVs adopt Euro III + RPC
Assumed timescales	2007 for London, 2010 for other seven urban areas
Area of application	London plus seven largest cities outside London
Reason for "further development" status	This measure clearly has great potential to reduce exceedences of statutory Air Quality Limit Values in urban Areas, even though, under the assumptions detailed above, it comes out as non cost beneficial. The London scheme however, is different from Defra's theoretical scheme and under the EU CAFE methodology used by Transport for London (TfL), will offer net benefits. On 9th May 2007, the Mayor of London confirmed the London Low Emissions Zone (LEZ) scheme, and announced that the LLEZ would commence operation in February 2008. From the theoretical assumptions above, we propose to wait until the final basis and implementation approaches for the London scheme are in place before moving to implementation elsewhere. Low Emissions Zones are localised measures and development of LEZ's is the decision of Local Authorities. Government remains committed to improving air quality, and achieving the UK's air quality targets.
Measure: H – Retrofit Diesel Particulate Filters (DPF) on HDV and captive fleets (buses and coaches)	
Modelling basis	• Emissions modelling only is done for these measures. There are three versions of this scenario. • Scenario 1: 65% pre-Euro I to Euro IV HDVs retrofitted with DPFs + Fuel Borne Catalysts (FBCs) by 2010 • Scenario 2: 20% pre-Euro I to Euro IV HDVs retrofitted with platinum (Pt) coated DPFs by 2010. • Scenario 3: 35% pre-Euro I to Euro IV HDVs retrofitted with Pt coated DPFs by 2010
Assumed timescales	2006
Area of application	This measure applies to UK

Reason for "further development" status	This measure currently has high implementation costs associated with its introduction. However, following input by consultees, this cost base has been reduced, although not to the extent that the measure becomes wholly cost beneficial. This measure, in common with the other measures proposed in the consultation document, was analysed on a national basis. However, there are some indications that it may be more cost effective when analysed and implemented on a more localised basis. This has to be balanced against the possible market change and economies of scale which could result from a wider geographical base, or a high number of schemes. Further work is therefore needed to assess the sensitivity of the costs and benefits of the measure to: • the initial assumptions • the geographical scale of implementation • future technology costs.
Measure: L – Small combustion plant measure	
Modelling basis	• 50% reduction in NO_2 and SO_2 in small combustion plants (20-50 MWth). 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.
Assumed timescales	2013
Area of application	This measure applies to EU

Reason for "further development" status	The cost beneficial status of this measure indicates the potential for cost effective emissions reduction in this sector. The original measure was based on proposals by the European Commission in its Thematic Strategy for Air Quality[137], and implemented either through a stand alone Directive, or through an extension of the IPPC Directive, which is currently under review by the Commission. However, no firm proposals have been published by the Commission, and these are unlikely to emerge, if at all, before the end of 2007 at the earliest. In the UK, unaggregated combustion plant rated in the range 20-50 MWth are already regulated through Local Authority Pollution Prevention and Control (LAPPC), while others come under IPPC by virtue of being part of a Part A Installation. These must therefore operate using BAT, and so the potential for further emissions reduction from currently regulated plant is limited. In addition, the resolution of the NAEI at this level is not high. Therefore, it is difficult to determine, with any great certainty, the actual emission reductions which could be attained through a measure which only addressed the 20-50 MWth range. As a result of policies to improve energy efficiency and reduce carbon emissions, there is a great deal of interest and activity in the installation of high efficiency small combustion plant (below the 20-50 MWth range), and in particular, combined heat and power plant. There is also the possibility that such plant could be fuelled by biomass, rather than conventional fossil fuels, and the Government is currently developing a biomass strategy to take such possibilities into account. Given that there is considerable activity within the sub 20 MWth range, this measure will need to be re-designed to take this into account. It will also need to be aligned with any proposals from the European Commission on small combustion plant, the Government's biomass strategy, and more broadly, policies to improve the efficiency of energy generation. Both the feasibility of this measure and its cost effectiveness could be greatly improved by: • expanding the scope of the measure to include the 500KWth to 20MWth range, within which existing regulatory levers are limited in nature; • aligning the measure with the implementation plans for the recently published Energy White Paper and Biomass Strategy; • waiting for the conclusions to the review of the PPC Directive, expected at the end of 2007 or later. It would therefore be premature to develop and implement firm proposals at this stage.

2.4 Measures no longer under immediate consideration

458. Volume 1, section 3d of this strategy set out the measures which are no longer under immediate consideration. This section sets out the assumptions used as a basis for the modelling and analysis of the measures, using the methodologies described in section 2.5, below. Implementation costs for measures D, I, J, K and M were found, in the analysis carried out for the review of the Air Quality Strategy, to be disproportionately high in comparison with the air quality and other benefits gained. Therefore, under current cost estimates, these measures are not currently being considered for implementation.

[137] Feasibility Study of Road Pricing in the UK', Department for Transport (2004). Available at http://www.dft.gov.uk/stellent/groups/dft_roads/documents/divisionhomepage/029798.hcsp

[138] http://ec.europa.eu/environment/air/cafe/index.htm

However, this will be reviewed should there be a significant drop in such costs. The assumptions used for measure B have been superseded by the outcome of negotiations between the European Commission, Council and Parliament on the timing and content of the Euro 5 and 6 emission standards. Combined measures O, P and Q are partially made up from measures which require further development, or which have been modified substantially. Subsequent analysis has used the new combined measure R.

Table 2.3: Measures no longer under immediate consideration

Measure: B – New Euro 5/6/VI vehicle emissions standard (High intensity)	
Modelling basis	• This measure proposes a **50% reduction in NO_X** from all new petrol LDVs from 2010 (Euro V), **40% reduction in NO_X** from new diesel LDVs from 2010 (Euro V, stage 1), and **68% reduction in NO_X** from all new LDVs from 2015 (Euro V, stage 2). **75% reduction in NO_X** from new HDVs from 2013 (Euro VI). • The measure **proposes a 90% reduction in PM emissions** in all new diesel vehicles (HDVs + LDVs) (Euro V). Durability at 100,000km • With allowance for increased NO_x emissions from a proportion of stage 2 diesel LDVs with catalyst systems failing at a rate of 5% pa
Assumed timescales	The dates for introduction are 2010 for cars and LDVs and 2013 for HDVs.
Area of application	This measure applies to all EU countries
Measure: D – Programme to phase out the most polluting vehicles (e.g. pre-Euro)	
Modelling basis	• This measure models scrappage of all pre Euro and Euro-I cars (concentrations modelling) • All pre-Euro and Euro-I passenger cars are assumed to be scrapped at rates of: 25% by 2007, 50% by 2008 and 100% by 2009 and replaced by Euro IV
Assumed timescales	2007
Area of application	This measure applies to UK
Measure: I – Domestic combustion: switch from coal to natural gas or oil	
Modelling basis	• 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
Assumed timescales	2006 (fully implemented by 2010)
Area of application	This measure applies to UK
Measure: J – Domestic combustion: Product standards for gas fired appliances which require tighter NO_X emission standards	
Modelling basis	• 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 NO_X' boilers.

Assumed timescales	2008
Area of application	This measure applies to EU
Measure: K2 – Large combustion plant measure	
Modelling basis	• Selective Catalytic Reduction (SCR) controls for NO_X on gas fired power stations, iron and steel plants and petrol refineries by 2010.
Assumed timescales	2010
Area of application	This measure applies to UK
Measure: M – Reducing national VOC emissions by 10%	
Modelling basis	• The various measures used to achieve this target are: • Petrol stations Stage II controls > 3000m^3 throughput • chemical and man made fibre production - thermal oxidation (TO) • chemical and man made fibre production - road tanker vapour recovery • chemical and man made fibre production - storage tank replacement programme (TRP) • chemical and man made fibre production - leak detection & repair (LDAR) • chemical and man made fibre production - second stage vapour recovery unit (VRU) • chemical and man made fibre production - cryogenic condensation (CC) • offshore loading of crude oil - modification to shuttle tankers (MST) • offshore loading of crude oil - modification to floating production, storage & off-take vessels (MFPSO) • offshore loading of crude oil - vapour recovery unit (from ship loading)
Assumed timescales	2010
Area of application	This measure applies to UK
Measure: Combined Scenario O	
Modelling basis	A combination of measures C (early Euro low) and E (LEV)
Assumed timescales	N/A
Area of application	N/A
Measure: Combined Scenario P	
Modelling basis	A combination of measures C (early Euro low) and L (small combustion plant)
Assumed timescales	N/A
Area of application	N/A

Measure: Combined Scenario Q	
Modelling basis	A combination of measures C (early Euro low), E (LEV), and L (small combustion plant)
Assumed timescales	N/A
Area of application	N/A

2.5 Assessment Methodologies

2.5.1 Emissions and Concentrations

459. The methodology for calculating future emissions and concentrations, both for the base line and possible additional measures, is addressed in section 1.2 of Chapter 1 of this Volume. The outcome of the emissions assessment for each of the measures being taken forward is presented in section 2.6 below.

2.5.2 Monetary Cost Benefit Analysis

460. The monetary cost benefit assessment follows the impact-pathway approach: mapping and dispersion models have been used to convert projected emissions into concentrations, concentration-response functions have been used to link concentrations to various physical effects and monetary values have then been assigned.

General methodological issues

461. Different additional policy measures have impacts over differing timescales. Those policies expected to result in a sustained improvement in air pollution (new Euro standards (Measures A2 and C2) have been assessed over a 100 year timeframe. Policies expected to have a shorter term improvement in air quality have been assessed over periods ranging from 5 to 15 years, depending on the individual proposed measure.

462. To facilitate comparison between all the measures, costs and benefits need to be assessed on a consistent basis. All the additional measures have been assessed against a common baseline that takes account of what would have happened 'anyway' (as described in section 1.2 of Chapter 1 of this Volume). In addition, future costs and benefits have been discounted, using 2005 as the base year, in line with current HM Treasury Green Book guidance i.e. 3.5%, declining after 30 years.

463. Both health and non-health benefits have been quantified and valued as part of the cost benefit analysis. The policy measures have been assessed using the full impact-pathway approach, following the steps of emissions, dispersion and exposure modelling through to quantification and monetisation of physical impacts.

2.5.2.1 Quantification of health benefits

464. The health effects that have been quantified as part of the analysis include both mortality and morbidity effects (such as hospital admissions) for a variety of pollutants. In terms of mortality, there is a distinction between acute (short term) effects and chronic (long term) effects.

465. The impacts included in the central analysis for this review are shown in Table 2.4. This table also shows the relevant concentration-response coefficients that have been used to quantify health impacts i.e. the expected change in the health impacts as a result of the change in the specified pollutant. The concentration-response coefficients used throughout the analysis are based on recommendations from the COMEAP in 1998, 2001, 2006 and 2007[139] and WHO/UNECE Task Force on the Health Aspects of Air Pollution (2003)[140].

Table 2.4: Health impacts included in central analysis

Pollutant	Health outcome	Concentration-response coefficient
$PM_{2.5}$ (as marginal change in PM_{10})	Loss of life expectancy	6.0% per 10 µg.m^{-3} (annual average)
PM_{10}	RHA	0.8% per 10µg.m^{-3} (24 hour mean)
PM_{10}	CHA	0.8% per 10µg.m^{-3} (24 hour mean)
O_3	Deaths brought forward	0.6% per 10µg.m^{-3} (daily 8 hour maximum O_3)
O_3	RHA	0.7% per 10µg.m^{-3} (daily 8 hour maximum O_3)
SO_2	Deaths brought forward	0.6% per 10µg.m^{-3} (24 hour mean)
SO_2	RHA	0.5% per 10µg.m^{-3} (24 hour mean)

COMEAP did not consider that the evidence on nitrogen dioxide was sufficiently robust for quantification (due to uncertainties over possible overlaps with the effect of particles) but did give a coefficient of 0.5% per 10µg.m^{-3}. This has been included in sensitivity analysis – see 3rd Report by IGCB.

466. There is a degree of uncertainty regarding the appropriate concentration-response coefficients that should be applied to the relevant change in pollutant concentration. Although there is general consensus that there is sufficient evidence of a link between mortality and long-term exposure to particles so that the chronic effects should be quantified, there is some uncertainty over the size of the effect. The most recent report from COMEAP[141] has recommended 0.6% per µg.m^{-3} $PM_{2.5}$ as the preferred estimate. A probability distribution for a range of coefficients has been defined for use in Monte

[139] 'Quantification of the effects of air pollution on health in the UK' (1998), 'Statement on long-term effects of particles on mortality' (2001a), 'Statement on short term association between ambient particles and admissions to hospital for cardiovascular disorders' (2001b). COMEAP, An interim statement on the Quantification of the Effects of Air Pollutants on Health in the UK (2006) updating the 2001 report. Long-term Exposure to Air Pollution: Effect on Mortality' Draft report for technical comment (2007). All available at: www.advisorybodies.doh.gov.uk/comeap/state.htm

[140] UNECE/WHO Joint Task Force on Health Aspects of Air Pollution (2003) Modelling Assessment of Health Impact of Particulate Matter and Ozone. http://www.unece.org/env/documents/2003/eb/wg1/eb.air.wg1.2003.11.pdf

[141] http://www.advisorybodies.doh.gov.uk/comeap/statementsreports/longtermeffectsmort2007.pdf

Carlo analysis, if possible. If not, a 'typical low' and 'typical high' sensitivity of 0.1% and 1.2% per $\mu g.m^{-3}$ $PM_{2.5}$ was suggested (the 12.5th and 87.5th percentile of the distribution. These uncertainties are discussed in more detail in the updated Third Report of the Interdepartmental Group on Costs and Benefits.

467. At international level, the WHO/UNECE Task Force on the Health Aspects of Air Pollution (2003) has recommended a concentration-response function for estimating the impact of long term exposure to $PM_{2.5}$ derived from the American Cancer Society studies of Pope *et al* (2002). The recommendation is equivalent to a 0.6% change in hazard rate per $\mu g.m^{-3}$ $PM_{2.5}$. This has been used within the core analysis of the CAFE Thematic Strategy Cost Benefit Analysis.

468. The analysis here has applied the $PM_{2.5}$ concentration response functions directly to the marginal change in PM_{10} concentrations; this approach is acceptable as most of the policies assessed will primarily lead to changes in the $PM_{2.5}$ fraction of PM_{10} concentrations.

469. There are a number of other uncertainties that have been incorporated into the central results:

- given the inconclusive evidence as to the exact lag time between the changes in PM concentrations and chronic health impacts, the results have therefore been modelled assuming both a 0-year lag and a 40-year lag. Neither no-lag nor a 40-year lag for the whole of the effect is considered likely but these assumptions define the outer ends of the range. The COMEAP considered that a noteworthy proportion of the effect occurs in the years soon after the pollution reduction rather than later.
- There is also uncertainty as to the appropriate threshold to apply to O_3 effects. The COMEAP (1998) recommended the use of both a zero threshold and a threshold of 50ppb for O_3 effects, due to the uncertainty as to the appropriate threshold to apply. The results using both these thresholds are presented in section 2.6 below.

2.5.2.2 Valuation of health effects

470. In previous appraisals of air quality policy proposals, it has not been possible to value health impacts due to a lack of empirical evidence as to the appropriate values. A major step change in the analysis accompanying this strategy review, compared to previous work by the IGCB, is that health outcomes have now been valued, following recommendations by the IGCB. These recommendations drew upon recent research in the area, particularly the Defra-led study by Chilton *et al* (2004)[142] which aimed to identify the willingness to pay to reduce the health impacts associated with air pollution, using a survey-style contingent valuation approach. Further detail on the derivation of the values used in this analysis is provided in the updated Third Report of the IGCB.

471. The main values used in the analysis are shown in Table 2.5 below:

[142] Chilton et al (2004) 'Valuation of Health Benefits Associated with Reductions in Air Pollution'. Available at http://www.defra.gov.uk/environment/airquality/valuation/index.htm

Table 2.5: Main monetary values of health impacts

Health effect	Form of measurement to which the valuations apply	Central value (2004 prices)
Acute Mortality	Number of years of life lost due to air pollution, assuming 2-6 months loss of life expectancy for every death brought forward. Life-expectancy losses assumed to be in poor health	£15,000
Chronic Mortality	Number of years of life lost due to air pollution. Life expectancy losses assumed to be in normal health	£29,000
Respiratory hospital admissions	Case of a hospital admission, of average duration 8 days	£1,900 – £9,100
Cardiovascular hospital admissions	Case of a hospital admission, of average duration 9 days	£2,000 – £9,800

472. While the ability to value the health impacts represents a major step forward in the ability to use cost benefit analysis to assess air quality policy options, there are a number of uncertainties surrounding the values that have been used. These are elaborated upon in the updated Third Report of the IGCB.

473. These agreed values have been used to monetise the health impacts presented in this Chapter. The values have been converted to 2005 prices (assuming an inflation rate of 2.5%). In subsequent years, the values have been uplifted by 2%. This reflects the assumption that willingness to pay will rise in line with economic growth.

474. For comparison with the individual additional measures considered later in this chapter, the effect of baseline measures already agreed for implementation by 2020 (compared with 2005 concentrations) is a saving of 6.4 to 12.2 million life years across the UK, followed up over a 100 year period. This equates to a monetary value attributable to the changes in the baseline by 2020 of between £2,701m and £6,347m p.a.

2.5.2.3 Quantification and valuation of non-health benefits

475. A summary of the non-health benefits that have been incorporated on a monetary basis is provided in Table 2.6, below. Further detail is provided in the updated Third Report of the IGCB.

Table 2.6: Summary of non-health benefits

Effect	Summary of methodology
Direct effects of O_3 on crop yields	Quantification of changes in UK crop yields, based on work by the Integrated Cooperative Programme on Vegetation and ICP/MM (Mapping and Modelling).[143] Valuation based on world market prices published by the UN's Food and Agriculture Organisations
Materials damage from SO_2	The benefits in reducing material damage as a result of reductions in SO_2 have been estimated using pollution benefits from previous analysis as part of the Air Quality Evaluation study.
Materials damage from ozone	An estimate of ozone damage to rubber products has been made based on work by Holland *et al* 1998.[144] This estimated the effect of a population weighted 1ppb change in O_3 at £3.7m p.a.
PM buildings soiling	Soiling damage estimated based on cleaning costs, using Rabl *et al's* 1998[145] work.
Social cost of carbon	Carbon emissions have been assessed where possible and valued according to current interdepartmental guidance. The central value is equivalent to £70 in 2000, uplifted by £1 per year thereafter.

2.5.2.4 Assessment of costs

476. Many of the assumptions on costs are specific to the individual measures. These are presented and discussed in detail in the updated Third Report of the IGCB. This section focuses on general methodological issues with regards to costs.

477. Costs have been presented in terms of the impact to society as a whole and therefore do not take account of transfers between different sectors (e.g. taxes and subsidies) or accounting costs such as depreciation.

478. For industrial, shipping and domestic-related measures, both capital costs, such as those associated with the fitting of pollution abatement technologies, and changes to operating costs are included. The assessment of transport-related costs takes account of the costs of new technology, the resource costs due to a change in fuel use and the welfare effect due to any change in kilometres travelled. Therefore, as far as possible, the costs include both financial costs and wider welfare impacts.

479. All costs are presented in 2005 prices. As far as possible, costs have been assessed over the same timeframes as the benefits and have been discounted in the same way i.e. using a discount rate of 3.5%, declining after 30 years.

480. There is considerable uncertainty surrounding the cost estimates. New technology, new processes and structural changes to the economy may all impact the future costs of policy implementation. In most instances, it is impossible to predict such changes with any level

143 ICP/MM (2004) Mapping Manual Revision. United Nations Economic Commission for Europe, ICP Mapping and Modelling. http://www.oekodata.com/icpmapping/html/manual.html

144 Holland, M.R., Haydock, H.,Lee, D.S., Espenhahn, S., Cape, J.N., Leith, I.D., Derwent, R.G., Lewis, P.M., Falla, N.A.R. and Mower, K.G. (1998) The effects of ozone on materials. Contract report for Department of the Environment, Transport and the Regions.

145 Rabl, A., Curtiss, P. and Pons (1998). Air Pollution and Buildings: An Estimate of Damage Costs in France. Environmental Impact Assessment Review.

of accuracy. In the recent evaluation of past air quality policies, it was found that, in the majority of cases, actual costs associated with the implementation of air quality policies, were lower than costs that had been predicted prior to implementation. This would suggest that regulation can spur innovation, and that the cost benefit analysis may not adequately predict the impact of innovation on costs. For some measures, a range of costs has been used reflecting different underlying assumptions about the costs and these are presented in this analysis. For other measures, where there is a higher level of uncertainty about the costs, sensitivity analysis has been presented in updated Third Report of the IGCB. This also demonstrates the sensitivity of the overall cost benefit analysis results to changes in costs more generally.

2.5.3 Exceedences

481. The national GIS based modelling methodology has been used to estimate the geographic extent of exceedences of objectives for PM_{10} and NO_2 in the basecase. Section 1.2 of Chapter 1 of this Volume includes a description of the methods used and the results for the baseline. The model has also been used to estimate the change in the extent of exceedences resulting from additional policy measures. Estimates of the impacts on exceedences for each additional policy measure are included in the summary tables in section 2.6 below.

2.5.4 Ecosystems

482. The potential benefit offered by the selected additional measures to the protection of ecosystems was assessed through their impact on exceedence of critical loads. Further details on the importance of critical loads as a policy tool, including details on the current situation, are discussed in section 1.4 of Chapter 1 of this Volume.

483. Measures A2, C2, E, N and R, alongside the baseline 2020 were modelled using the Fine Resolution Atmospheric Multi-pollutant Exchange (FRAME) model. Further details on the FRAME model can be found at http://www.frame.ceh.ac.uk/index.html. Maps of wet and dry deposition of oxidised sulphur, oxidised nitrogen and reduced nitrogen were generated at a 5km resolution for three vegetation types: moorland, forest and grid-averaged deposition by the FRAME model and these were used as input for the calculation of critical load exceedences.

484. The assessment of the impact of additional scenarios on critical loads exceedences is based on a comparison of maps of critical loads and deposition loads. Deposition maps from the Concentration-Based Estimated Deposition (CBED) model were generated to reflect the historic picture, whereas the FRAME model was used for future scenarios. The CBED model generates UK maps of wet and dry deposition, wet deposition and direct cloud droplet/aerosol deposition from site measurements of gas concentrations and deposition. Meteorology from 2001-2003 was used to model the current situation as the use of three year averaged meteorological data can minimise inter-annual variations. Further details on the methodology used for the generation of UK critical load maps can be found at http://www.critloads.ceh.ac.uk.

485. The results were calculated for both the reduction in the area over which the critical load is exceeded and the magnitude of these exceedences. The problem with only comparing the measures by area (or percentage area) exceeded is that the differences between the

measures tend not to be very great and there is therefore little difference across the range of measures. When summing up the areas exceeded, the area is included whether the critical load is only just exceeded, or exceeded by a large amount. Two measures could give the same area exceeded, but the magnitude of exceedence (and therefore the deposition values, and deposition reductions required) could be very different.

486. Accumulated exceedence (AE) can be calculated in order to integrate the area exceeded with the magnitude of exceedence, and so can be a more useful measure for comparing the results. However, large areas with a small exceedence could lead to the same AE value as a smaller area with a larger exceedence. For example (AE = exceeded area * exceedence):

Exceeded habitat area (ha)	Exceedence (keq/ha/yr)	AE (keq/yr)
1000	0.1	100
100	1	100

487. Not all large habitat areas will have small exceedences or all small habitat areas have large exceedences. The results could therefore be:

Exceeded habitat area (ha)	Exceedence (keq/ha/yr)	AE (keq/yr)
1000	1	1000
100	0.1	10

488. In the assessment, both area exceeded and AE are used to assess the magnitude of the benefit which could be expected from each scenario. The differences in area exceeded (rather than percentage area) are important, deposition could go up or down and the area exceeded not change. Accumulated exceedence is useful in taking into account the magnitude of the exceedence, especially where the area exceeded may be the same or similar.

2.5.5 Qualitative

489. A summary of the qualitative assessments that have been considered is provided in Table 2.7 below. Fuller detail can be obtained in the updated Third Report of the IGCB.

Table 2.7: Summary of qualitative assessment

Effect	Comments
Acid damage to cultural heritage	Difficult to quantify and value cultural heritage because of lack of data in terms of stock at risk and valuation. Those policies that have the greatest impact on SO_2 have been highlighted as this is expected to have the most impact on cultural heritage.
Noise	Noise impacts expected to be extremely small in relation to other benefits. Certain transport measures may impact noise levels to some extent; these have been highlighted where relevant
Visibility	Visibility is not considered to be a major issue across Europe, in part because of significant improvements in the past. The impact of additional measures on visibility has therefore not been conducted within this analysis.
Material damage from NO_X	The role of atmospheric NO_2 in material damage is not yet clear. Although a strong synergistic effect with SO_2 has been observed in laboratory studies, this has not yet been observed in the field. Material corrosion does occur from wet deposition (from secondary pollutants formed from NO_x emissions). However, the importance of this pollutant is now considered much less than the effect of dry deposition of $SO_{2.}$ Consequently, these effects have not been assessed here.
Crop damage from SO_2 and NO_X	Ozone is considered to have the greatest effect on crops. Some potential effects are possible from other pollutants but are not as important. At very high concentrations, SO_2 can damage crops, but previous analysis as part of the appraisal of the Air Quality Strategy has shown that in monetary terms, such effects are negligible at current concentrations. They have not been assessed here. Direct effects of NO_2 on crops have been reported, but not at the concentrations found in the UK. Accordingly, such effects are not considered here.
Ozone damage to forests	The effect of O_3 on forests provides an area where there is potential for future quantification. Karlsson *et al* (2004) investigated the response of a forest stand in Sweden to predicted O_3 concentrations and generate monetary estimates. It has not been possible to apply this approach in this review, though the original study provides some guide to the potential magnitude of the effect.
Distributional analysis	The existing evidence linking air quality and distributional (i.e. social and socio-economic) effects has been assessed and used as the basis of a qualitative assessment of the measures included within this review.
Other health impacts	In some cases there is a clear consensus that a particular health impact is linked with a relevant pollutant however the health impact has not been quantified. In such cases these health impacts are noted qualitatively. Impacts on carcinogenic air pollutants such as benzene, 1,3-butadiene and PAHs are considered qualitatively. There are a few measures which have impacts on these pollutants they are highlighted below.
Competition analysis and impacts on small businesses	The competition assessment of the additional measures has been undertaken through applying the 'competition filter' set out in the Office of Fair Trading's Guidelines. For the small business impact, a qualitative assessment has been made based on the expected market impacts.

2.5.6 Traffic light assessment for measures

490. To further aid comparison of different measures under different assessment a traffic light assessment (or RAG Status) of red, amber, green or white is provided for the CBA ("Annual net present value" table), exceedences and ecosystems assessment under each of the additional policy measures assessed. Table 2.8 explains the criteria utilised to allocate a traffic light assessment.

Table 2.8: Red-Amber-Green categorisation

RAG Status		Cost Benefit Analysis	Exceedences assessment	Ecosystem assessment
Green		The range of the annual net present value is positive, assuming the health coefficient considered most likely by the WHO and COMEAP. 6%	Measures that reduce roadside exceedences in 2010 or 2020 of an NO_2 or PM_{10} objective by 50% or more compared to the base case.	Measures that generate significant (above 2%) reduction in critical loads exceedence and/or accumulated exceedence for either Acidity or Nutrient Nitrogen.
Amber		The range of the annual net present value spans positive and negative, assuming the health coefficient considered most likely by the WHO and COMEAP. (6%).	Measures that reduce roadside exceedences in 2010 or 2020 of an NO_2 or PM_{10} objective by between 5 and 49%, compared to the base case.	Measures that generate little (between 0.5-2%) reduction in critical loads exceedence and/or accumulated exceedence for either Acidity or Nutrient Nitrogen.
Red	**White**	The range of the annual net present value is negative, assuming the health coefficient considered most likely by the WHO and COMEAP (6%).	(White) Measures that reduce roadside exceedences in 2010 or 2020 of an NO_2 or PM_{10} objective by 5% or less, compared to the base case.	(White) Measures that generate insignificant or no (less that 0.5%) reduction in critical loads exceedence and accumulated exceedence for Acidity and Nutrient Nitrogen. Also for measures that have not been assessed.
Qualitative assessment				
SI = social impacts; N = noise; H = additional health outcomes; C = competition; SB = small businesses;				+ = positive impacts expected; - = negative impacts expected

2.6 Assessment data for measures to be considered

2.6.1 Assessment basis for measures A2, C2, E, N and R

491. This section will present the assessment results for those measures presented in section 2.2 above. Due to the iterative nature of this strategy, the definition of some of the measures changed over time, as did the some aspects of the assessment model, reflecting an improved scientific understanding. Therefore, while the basis for the assessment has been made as consistent as possible, there are some subtle differences in the assessment of the measures. The differences in the baseline assumptions, the energy projections used and the relevant met year have been discussed in Chapter 1, section 1.5 of this Volume.

492. The basis on which the measures A2, C2, E, N and R have been assessed is as follows:

- Measures E and N were assessed on the basis of UEP12, with a 2003 met year and a 100% SO_2 and NO_2 to secondary PM conversion factor. This reflects the fact that their underlying assumptions have not changed since the analysis undertaken for the consultation document. However, in order to obtain a consistent basis for comparison, the health impact and NPV calculations have been corrected to give the equivalent of a 50% SO_2 and NO_2 to secondary PM conversion factor.
- Measures A2, C2 and combined measure R have been modelled using UEP12, 2003 met year and a 50% SO_2 to secondary PM conversion factor. This reflects the fact that, as transport measures, the changes in the different UEPs have relatively little effect on them.

493. Section 1.5 of Chapter 1 of this Volume discusses the differences each of these analytical bases make to the modelling outputs, using the former combined measure Q as an example. **It is also important to note that prior to implementation of any of these measures, a formal Impact Assessment will be undertaken, which will re-analyse their costs and benefits using the most up to date energy and transport projections, modelling assumptions, and met year.**

2.6.2 Measure A2: New Euro 5/6 and Euro VI vehicle emission standards

Table 2.9: UK Emission reductions over baseline (ktonnes yr^{-1})

Measure A2	PM_{10} emissions relative to baseline (2020)	NO_X emissions relative to baseline (2020)
New Euro 5/6 and Euro VI vehicle emission standards	8.7	100.1

Table 2.10: Population weighted concentration impacts ($\mu g.m^{-3}$)*

Measure A2	PM_{10} concentrations relative to baseline (2020)	O_3 concentrations relative to baseline (2020)		NO_2 concentrations relative to baseline (2020)
		No threshold effect	Threshold effect at 50ppb [100$\mu g.m^{-3}$]	
New Euro 5/6 and Euro VI vehicle emission standards	(0.622)	1.059	0.032	(1.844)

*Data presented in the table in brackets represents a positive impact, therefore a reduction in population weighted concentrations.

Table 2.11: Major health impacts*

Measure A2	PM life years saved ('000s) (2010 – 2109)	PM – RHA (2020)	PM – CHA (2020)	O_3 mortality (2020)	O_3 RHA (2020)
New Euro 5/6 and Euro VI vehicle emission standards	1,319-2,518	219	219	(366) – (11)	(423) – (13)

*Data presented in the table in brackets represent a negative impact – for O_3 impacts this reflects the increase in population weighted O_3 concentrations presented in the previous table.

Table 2.12: Annual net present value results (£millions)

Measure A2	NPV	RAG STATUS
New Euro 5/6 and Euro VI vehicle emission standards	(264) – 539	Amber

Table 2.13: Impacts on Exceedences

Measure A2	Percentage exceedences of NO_2 40µg.m^{-3} annual mean (baseline in brackets)			
New Euro 5/6 and Euro VI vehicle emission standards	Impact on exceedences in 2010		Impact on exceedences in 2020	
	Background	Urban Roadside	Background	Urban Roadside
	0 (0)	17.9 (18.2)	0 (0)	3.3 (8.5)
	Percentage exceedences of PM_{10} <31.5µg.m^{-3} annual mean (equivalent to the 24 hour PM_{10} 2004 objective) (basecase in brackets)			
	Impact on exceedences in 2010		Impact on exceedences in 2020	
	Background	Urban Roadside	Background	Urban Roadside
	0 (0)	2.0 (2.1)	0 (0)	0 (0.3)
	Percentage exceedences of PM_{10} <20µg.m^{-3} annual mean (indicative Stage 2 EU limit value) (basecase in brackets)			
	Impact on exceedences in 2010		Impact on exceedences in 2020	
	Background	Urban Roadside	Background	Urban Roadside
	7.8 (7.9)	77.1 (77.6)	1.5 (2.6)	32.5 (60.5)
	RAG STATUS Criterion			
	Green		Percentage exceedences of NO_2 40 µg.m^{-3} annual average. 61% reduction in urban roadside exceedences in 2020. Percentage exceedences of PM_{10} <31.5 µg.m^{-3} annual mean (equivalent to the 24 hour PM_{10} 2004 objective). Removal of all urban roadside exceedences in 2020.	

Table 2.14: Impacts on ecosystems

Measure A2: Acidity			
Area exceeded for critical loads ($km^2 \times 10^3$)	**% reduction against baseline**	**accumulated exceedence of critical load ($Meq.yr^{-1}$)**	**% reduction against baseline**
31.0	2.8	1,607	7.6
RAG Status	**Green**		
Measure A2: Nutrient Nitrogen			
Area exceeded for critical loads ($km^2 \times 10^3$)	**% reduction against baseline**	**accumulated exceedence of critical load ($Meq.yr^{-1}$)**	**reduction against baseline**
34.3	3.4	2,391	7.3
RAG Status	**Green**		

Table 2.15: qualitative impacts

Deprivation and other social impacts	**Noise**	**Health Impacts**	**Competition**	**Small businesses**
SI+	N/A	N/A	N/A	N/A

2.6.3 Measure C2: Incentivising the early uptake of new Euro standards

Table 2.16: UK Emission reductions over baseline (ktonnes yr^{-1})

Measure C2	**PM_{10} emissions relative to baseline (2020)**	**NO_X emissions relative to baseline (2020)**
Incentivising the early uptake of new Euro standards	9.1	106.8

Table 2.17: Population weighted concentration impacts ($\mu g.m^{-3}$)*

Measure C2	PM_{10} concentrations relative to baseline (2020)	O_3 concentrations relative to baseline (2020)		NO_2 concentrations relative to baseline (2020)
		No threshold effect	Threshold effect at 50ppb [100$\mu g.m^{-3}$]	
Incentivising the early uptake of new Euro standards	(0.653)	1.128	0.031	(1.968)

*Data presented in the table in brackets represents a positive impact, therefore a reduction in population weighted concentrations.

Table 2.18: Major health impacts*

Measure C2	PM life years saved ('000s) (2010 – 2109)	PM – RHA (2020)	PM – CHA (2020)	O_3 mortality (2020)	O_3 RHA (2020)
Incentivising the early uptake of new Euro standards	1,445-2,701	230	230	(390) – (11)	(451) – (12)

*Data presented in the table in brackets represent a negative impact – for O_3 impacts this reflects the increase in population weighted ozone concentrations presented in the previous table.

Table 2.19: Annual net present value results (£millions)

Measure C2	NPV	RAG STATUS
Incentivising the early uptake of new Euro standards	(246) – 595	**Amber**

Table 2.20: Impacts on Exceedences

Measure C2	Percentage exceedences of NO_2 40µg.m^{-3} annual mean (baseline in brackets)			
Incentivising the early uptake of new Euro standards	Impact on exceedences in 2010		Impact on exceedences in 2020	
	Background	Urban Roadside	Background	Urban Roadside
	0 (0)	17.2 (19.2)	0 (0)	3.0 (8.5)
	Percentage exceedences of PM_{10} <31.5µg.m^{-3} annual mean (equivalent to the 24 hour PM_{10} 2004 objective) (basecase in brackets)			
	Impact on exceedences in 2010		Impact on exceedences in 2020	
	Background	Urban Roadside	Background	Urban Roadside
	0 (0)	1.6 (2.1)	0 (0)	0 (0.3)
	Percentage exceedences of PM_{10} <20µg.m^{-3} annual mean (indicative Stage 2 EU limit value) (basecase in brackets)			
	Impact on exceedences in 2010		Impact on exceedences in 2020	
	Background	Urban Roadside	Background	Urban Roadside
	7.4 (7.9)	76.1 (77.6)	1.4 (2.6)	31.3 (60.5)
	RAG STATUS Criterion			
	Green		Percentage exceedences of NO_2 40 µg.m^{-3} annual average. 65% reduction in urban roadside exceedences in 2020. Percentage exceedences of PM_{10} <31.5 µg.m^{-3} annual mean (equivalent to the 24 hour PM_{10} 2004 objective). Removal of all urban roadside exceedences in 2020.	

Table 2.21: Impacts on ecosystems

Measure C2: Acidity			
Area exceeded for critical loads ($km^2 \times 10^3$)	% reduction against baseline	accumulated exceedence of critical load ($Meq.yr^{-1}$)	% reduction against baseline
30.9	3.1	1,598	8.1
RAG Status	Green		
Measure C2: Nutrient Nitrogen			
Area exceeded for critical loads ($km^2 \times 10^3$)	% reduction against baseline	accumulated exceedence of critical load ($Meq.yr^{-1}$)	reduction against baseline
34.2	3.7	2,379	7.8
RAG Status	Green		

Table 2.22: qualitative impacts

Deprivation and other social impacts	Noise	Health Impacts	Competition	Small businesses
SI+	N/A	N/A	N/A	N/A

2.6.4 Measure E: Increased uptake of low emission vehicles

Table 2.23: UK Emission reductions over baseline (ktonnes yr^{-1})

Measure E	PM_{10} emissions relative to baseline (2020)	NO_X emissions relative to baseline (2020)
Incentives to increase penetration of LEV	0.5	11.2

Table 2.24: Population weighted concentration impacts (μg.m^{-3})*

Measure E	PM_{10} concentrations relative to baseline (2020)	O_3 concentrations relative to baseline (2020)		NO_2 concentrations relative to baseline (2020)
		No threshold effect	Threshold effect at 50ppb [100μg.m^{-3}]	
Incentives to increase penetration of LEV	(0.039)	0.121	0.021	(0.228)

*Data presented in the table in brackets represents a positive impact, therefore a reduction in population weighted concentrations.

Table 2.25: Major health impacts*

Measure E	PM life years saved ('000s) (2010 – 2109)	PM – RHA (2020)	PM – CHA (2020)	O_3 mortality (2020)	O_3 RHA (2020)
Incentives to increase penetration of LEV	87 – 157[146]	14	14	(42) – (7)	(48) – (8)

*Data presented in the table in brackets represent a negative impact – for O_3 impacts this reflects the increase in population weighted O_3 concentrations presented in the previous table.

Table 2.26: Annual net present value results (£millions)

Measure E	NPV	RAG STATUS
Incentives to increase penetration of LEV	63 – 112[147]	**Green**

[146] Scaled to give a figure equivalent to a 50% SO_2 to secondary PM conversion factor.

Table 2.27: Impacts on Exceedences

Measure E	Percentage exceedences of NO_2 40µg.m^{-3} annual mean (baseline in brackets)			
Incentives to increase penetration of LEV	Impact on exceedences in 2010		Impact on exceedences in 2020	
	Background	Urban Roadside	Background	Urban Roadside
	0 (0)	18.1 (18.2)	0 (0)	7.7 (8.5)
	Percentage exceedences of PM_{10} <31.5µg.m^{-3} annual mean (equivalent to the 24 hour PM_{10} 2004 objective) (basecase in brackets)			
	Impact on exceedences in 2010		Impact on exceedences in 2020	
	Background	Urban Roadside	Background	Urban Roadside
	0 (0)	2.1 (2.1)	0 (0)	0 (0.3)
	Percentage exceedences of PM_{10} <20µg.m^{-3} annual mean (indicative Stage 2 EU limit value) (basecase in brackets)			
	Impact on exceedences in 2010		Impact on exceedences in 2020	
	Background	Urban Roadside	Background	Urban Roadside
	7.2 (7.9)	77.5 (77.6)	2.6 (2.6)	58.9 (60.5)
	RAG STATUS Criterion			
	Amber		Percentage exceedences of PM_{10} <40 µg.m^{-3} annual mean. 9% reduction of exceedences at urban roadside in 2020.	

Impacts on ecosystems. Measure E was assessed as having no potentially significant impact on critical loads exceedences for either acidity or nutrient nitrogen. It was not subject to a full assessment and its RAG status is white.

Table 2.28: qualitative impacts

Deprivation and other social impacts	Noise	Health Impacts	Competition	Small businesses
SI+	N/A	N/A	N/A	N/A

2.6.5 Measure N: Shipping measure

Table 2.29 UK Emission reductions over baseline (ktonnes yr^{-1})

Measure N	PM_{10} emissions relative to baseline (2020)	NO_x emissions relative to baseline (2020)
Shipping measure through IMO	0	1.0

Table 2.30: Population weighted concentration impacts ($\mu g.m^{-3}$)*

Measure N	PM_{10} concentrations relative to baseline (2020)	NO_x concentrations relative to baseline (2020)
Shipping measure through IMO[147]	(0.272)	(0.127)

*Data presented in the table in brackets represents a positive impact, therefore a reduction in population weighted concentrations.

Table 2.31: Major health impacts*

Measure N	PM life years saved ('000s) (2010 – 2109)	PM – RHA (2020)	PM – CHA (2020)	SO_2 mortality (2020)	SO_2 RHA (2020)
Shipping measure through IMO	576 – 1,100	95	96	1	1

* Data presented in the table in brackets represent a negative impact – for ozone impacts this reflects the increase in population weighted ozone concentrations presented in the previous table.

Table 2.32: Annual net present value results (£millions)

Measure E	NPV	RAG STATUS
Shipping measure through IMO	245–576[148]	**Green**

[147] The impact of reducing shipping emissions on UK air quality is relatively large. However, as the emissions are not UK land based, the impact of the measure on emissions as assessed here is small.

[148] Scaled to give a figure equivalent to a 50% SO_2 to secondary PM conversion factor.

Table 2.33: Impacts on Exceedences

Measure N	Percentage exceedences of NO_2 40µg.m^{-3} annual mean (baseline in brackets)			
Shipping measure through IMO	Impact on exceedences in 2010		Impact on exceedences in 2020	
	Background	Urban Roadside	Background	Urban Roadside
	0 (0)	18.2 (18.2)	0 (0)	8.4 (8.5)
	Percentage exceedences of PM_{10} <31.5µg.m^{-3} annual mean (equivalent to the 24 hour PM_{10} 2004 objective) (basecase in brackets)			
	Impact on exceedences in 2010		Impact on exceedences in 2020	
	Background	Urban Roadside	Background	Urban Roadside
	0 (0)	1.7 (2.1)	0 (0)	0.2 (0.3)
	Percentage exceedences of PM_{10} <20µg.m^{-3} annual mean (indicative Stage 2 EU limit value) (basecase in brackets)			
	Impact on exceedences in 2010		Impact on exceedences in 2020	
	Background	Urban Roadside	Background	Urban Roadside
	5.7 (7.9)	75.2 (77.6)	1.6 (2.6)	52.3 (60.5)
	RAG STATUS Criterion			
	Amber		Percentage exceedences of PM_{10} <31.5µg.m^{-3} annual mean (equivalent to the 24 hour PM_{10} 2004 objective. 19% reduction in urban roadside exceedences in 2010. 33% reduction in urban roadside exceedences in 2020. Percentage exceedences of PM_{10} <20µg.m^{-3} annual mean. 28% reduction in background exceedences in 2010. 38% reduction in background exceedences in 2020. 14% reduction in urban roadside exceedences in 2020.	

[149] Scaled to give a figure equivalent to a 50% SO_2 to secondary PM conversion factor.

Table 2.34: Impacts on ecosystems

Measure N: Acidity			
Area exceeded for critical loads (km^2 x 10^3)	**% reduction against baseline**	**accumulated exceedence of critical load (Meq.yr^{-1})**	**% reduction against baseline**
30	2.3	1,820	3.2
RAG Status	**Green**		
Measure N: Nutrient Nitrogen			
Area exceeded for critical loads (km^2 x 10^3)	**% reduction against baseline**	**accumulated exceedence of critical load (Meq.yr^{-1})**	**reduction against baseline**
35.6	0.6	2,750	0.6
RAG Status	**Amber**		

There were no major impacts identified for any of the qualitative assessments for Measure N.

2.6.6 Measure R: Combined scenario R

Table 2.35: UK Emission reductions over baseline (ktonnes yr^{-1})

Measure R	PM_{10} emissions relative to baseline (2020)	NO_X emissions relative to baseline (2020)
Combined scenario R	9.1	112.7

Table 2.36: Population weighted concentration impacts (μg.m^{-3})*

Measure E	PM_{10} concentrations relative to baseline (2020)	O_3 concentrations relative to baseline (2020)		NO_2 concentrations relative to baseline (2020)
		No threshold effect	**Threshold effect at 50ppb [100μg.m^{-3}]**	
Combined scenario R	(0.926)	1.053	(0.017)	(2.228)

*Data presented in the table in brackets represents a positive impact, therefore a reduction in population weighted concentrations.

Table 2.37: Major health impacts*

Measure R	PM life years saved ('000s) (2010 – 2109)	PM – RHA (2020)	PM – CHA (2020)	O_3 mortality (2020)	O_3 RHA (2020)
Combined scenario R	2,020 – 3,806	325	326	(364) – 6	(421) – 7

*Data presented in the table in brackets represent a negative impact – for O_3 impacts this reflects the increase in population weighted ozone concentrations presented in the previous table.

Table 2.38: Annual net present value results (£millions)

Measure R	NPV	RAG STATUS
Combined scenario R	33 – 1,211	**Green**

Table 2.39: Impacts on Exceedences

Measure R	**Percentage exceedences of NO_2 40µg.m^{-3} annual mean (baseline in brackets)**			
Combined scenario R	**Impact on exceedences in 2010**		**Impact on exceedences in 2020**	
	Background	**Urban Roadside**	**Background**	**Urban Roadside**
	0 (0)	17.1 (18.2)	0 (0)	2.6 (8.5)
	Percentage exceedences of PM_{10} <31.5µg.m^{-3} annual mean (equivalent to the 24 hour PM_{10} 2004 objective) (basecase in brackets)			
	Impact on exceedences in 2010		**Impact on exceedences in 2020**	
	Background	**Urban Roadside**	**Background**	**Urban Roadside**
	0 (0)	1.4 (2.1)	0 (0)	0 (0.3)
	Percentage exceedences of PM_{10} <20µg.m^{-3} annual mean (indicative Stage 2 EU limit value) (basecase in brackets)			
	Impact on exceedences in 2010		**Impact on exceedences in 2020**	
	Background	**Urban Roadside**	**Background**	**Urban Roadside**
	6.4 (7.9)	74.7 (77.6)	1.1 (2.6)	26.5 (60.5)
	RAG STATUS **Criterion**			
	Green		Percentage exceedences of NO_2 40 µg.m^{-3} annual average. 69% reduction in urban roadside exceedences in 2020. Percentage exceedences of PM_{10} <31.5 µg.m^{-3} annual mean (equivalent to the 24 hour PM_{10} 2004 objective). Removal of all urban roadside exceedences in 2020. Percentage exceedences of PM_{10} <20µg.m^{-3} annual mean. 58% reduction in background exceedences in 2020. 56% reduction in urban roadside exceedences in 2020.	

Table 2.40: Impacts on ecosystems

Measure R: Acidity			
Area exceeded for critical loads ($km^2 \times 10^3$)	**% reduction against baseline**	**accumulated exceedence of critical load ($Meq.yr^{-1}$)**	**% reduction against baseline**
30.1	5.6	1,530	12.0
RAG Status	**Green**		
Measure R: Nutrient Nitrogen			
Area exceeded for critical loads ($km^2 \times 10^3$)	**% reduction against baseline**	**accumulated exceedence of critical load ($Meq.yr^{-1}$)**	**reduction against baseline**
33.8	4.8	2,347	9.0
RAG Status	**Green**		

Table 2.41: qualitative impacts

Deprivation and other social impacts	**Noise**	**Health Impacts**	**Competition**	**Small businesses**
SI+	N+	N/A	N/A	N/A

3.1 Key Points

- The evidence requirements to improve our understanding of the remaining challenges on air pollution are discussed in this Chapter.

- These needs are informed by the views of stakeholders, in particular the recommendations of independent expert groups set up to advise the UK Government and the devolved administrations on air quality matters.

- The journey to developing a complete understanding of the sources, effects and effective abatement options for air pollutants is a long one. Much progress has been made, and the work described here will improve our ability to deliver cost effective policies to reduce effects still further, but long term investment in the evidence base will need to continue for the foreseeable future to ensure air quality policies continue to become ever more efficiently targeted.

- The main focus of the evidence and innovation programme is on pollutants presenting the largest policy challenges, i.e. PM, O_3, NO_X and NH_3.

Much of the work on improving understanding of the mechanisms and quantification of how these pollutants cause adverse effects will require international collaboration.

3.2 Introduction

494. The aim of this Chapter is to set an agenda for longer term actions to improve our understanding of air pollutants and their impact on human health and the environment. It describes the further evidence necessary to answer some of the questions we have been unable to address in this Strategy.

495. National and international policies agreed over the last few years will take us a significant way towards reducing the adverse impacts of air pollution, but even so there is more to be done, both in terms of scientific understanding of air pollution and its impacts, and in determining the appropriate policy response.

496. Reducing the risks posed to the UK population and environment by air pollution is likely to involve difficult decisions across Government affecting how we travel and generate our energy. In this there are obvious links to the climate change policy, and it will be important for us to continue to develop our understanding of how these different issues interact. Much of our air pollution has a significant transboundary component, necessitating close cooperation with partners in Europe and beyond. Improving the evidence base on air quality will be crucial to future sound decision making on these issues.

3.3 The Evidence and Innovation Strategy

497. Objectives for the air quality evidence and innovation programme are:

- **Statutory** – meeting the measurement and reporting requirements in existing and forthcoming national legislation, EU Directives and UNECE Protocols. These are specified in detail and include measurement of airborne concentrations and deposition of a wide variety of pollutants, emissions reporting, mapping and modelling of exposures to humans and ecosystems, contributions to international research efforts, and public dissemination of information. Investments to meet statutory commitments represents over 70% of the total current air quality evidence and innovation programme budget;

- **Policy support** – a range of projects that do not meet statutory requirements but are still essential to formulate a robust UK policy. This includes strategic research that delivers greater understanding of the spatial and temporal effects of air pollution on health and the environment in the UK to assess the long term effects of past and current policies, determine the need for further improvements, and best way of achieving them.

498. Evidence needs for pollutants evolves as the policy on them matures. Thus, where successful emission reduction policies have been instigated (e.g. SO_2 or benzene) the objective is largely to monitor the effects of existing policies. Currently the main focus of the evidence and innovation programme is on the pollutants that present the largest policy challenges, i.e. PM, O_3, NO_X and NH_3. The objectives are to:

- quantify the current and projected exposure of human populations and/or ecosystems to pollutants through measurement and modelling (henceforth referred to as *quantifying exposure*);
- assess the relative contributions to these exposures from source sectors both in the UK and elsewhere (*source attribution*);
- assess the impact of air pollution (*assessing impacts*);
- assess policy options and their delivery (*assessing policy options*); and
- provide effective strategies and communication to positively impact behaviour to improve air quality (*influencing behaviour*).

499. Overarching these objectives is work to link the evidence base on air quality with that on climate change to ensure potential synergies and trade-offs between the two policy areas are identified.

3.3.1 The role of the air quality evidence programme and other organisations/interests

500. The air quality evidence programme is jointly owned by the UK Government and the devolved administrations. Air pollution is an issue for a wide variety of organisations across different geographic scales. Policy and delivery occur at local, national and international levels, and the programme needs to engage and inform a variety of other bodies – local authorities, environment agencies, policy departments (notably DfT and DTI) and international bodies (the EU and UNECE) are all key. There are important links with policy areas on both a sectoral (e.g. transport, energy and industry) and environmental (e.g. natural resource protection and climate change) basis.

501. We need to make use of the outputs from these organisations and programmes together with those from the research councils. Our programme focuses on gathering evidence essential to policy development, but there will be synergies with work elsewhere that needs to be actively sought and pursued.

3.3.2 What we have done previously to establish our evidence and innovation needs

502. Other Government and agency stakeholders are consulted on an annual basis on the priorities for funding through the Research Requirements Committee. Further input is provided by the reports from the formally constituted expert groups advising Defra and the devolved administrations. These groups, their predecessors, and bodies reporting to other organisations have a long history of providing Government with independent advice from recognised experts. They summarise the current state of knowledge from evidence gathered in the UK and elsewhere to inform both current policy development and future evidence needs. Wider consultation has also been carried out as part of Defra's Evidence and Innovation Strategy (2005).

503. We ensure that outputs from the evidence programme are of a suitable quality. Data in the statutory monitoring networks are subjected to rigorous quality assurance and quality control checks. Researchers are encouraged to publish their results in peer reviewed journals wherever possible, and independent expert advisory groups review data and compare the outputs of models as part of their studies. Many research proposals are subject to peer review, as are many of the outputs not covered by other procedures.

3.3.3 Future work of advisory groups

504. There are a number of advisory Non-Departmental Public Bodies (NDPBs) and other groups advising the UK Government and the devolved administrations on aspects of air pollution. All appointments to NDPBs are made following the Nolan Principles[150] and in accordance with the rules laid down in the Office of the Commissioner for Public Appointments' Code of Practice.

505. These groups provide independent advice to Government on a range of air quality issues. They also provide a useful role in helping to assure the quality of the data used to underpin policy development. In many cases the current groups have built upon the reviews carried out by earlier expert groups, such as the Photochemical Oxidant Review Group (PORG), the Airborne Particles Expert Group (APEG) and the Review Group on Acid Rain (RGAR).

3.3.3.1 Air Quality Expert Group (AQEG)

506. The Group was set up in 2001 to provide independent scientific advice on the levels of pollution in the atmosphere, in particular those addressed in the Air Quality Strategy and EU Directives. Members of the Group are drawn from those with a proven track record in the fields of air pollution research and practice. In line with the latest guidance on best practice for Government bodies, a lay member is currently being sought to reflect the views and interests of the general public in the work of the Group.

[150] The Seven Principles of Public Life set out by the Committee on Standards in Public Life, see http://www.public-standards.gov.uk/about_us/the_seven_principles_of_life.aspx

507. The group's main functions are to:

- give advice on levels, sources and characteristics of air pollutants in the UK;
- assess the extent of exceedences of Air Quality Strategy's objectives, EU limit values and proposed or possible objectives and limit values, where monitoring data is not available;
- analyse trends in pollutant concentrations;
- assess current and future ambient concentrations of air pollutants in the UK; and
- suggest potential priority areas for future research aimed at providing a better understanding of the issues to be addressed in setting air quality objectives.

508. AQEG has already published detailed assessments of NO_2 in the UK, PM in the UK, Air Quality and Climate Change: A UK Perspective, and a short study on direct emissions of nitrogen dioxide (NO_2)[151]. Their research and monitoring recommendations are discussed in section 3.3.

509. We plan to review AQEG and its work programme during 2007 ensuring the Group's output continues to address our policy needs. In the meantime the Group will undertake a study on O_3 with a focus on trends in urban areas.

3.3.3.2 Committee on the Medical Effects of Air Pollutants (COMEAP)

510. The Committee is an advisory committee of independent experts sponsored by the Department of Health. It provides advice to Government departments and agencies on the potential toxicity and effects upon health of air pollutants.

511. The Committee's terms of reference are: to advise the UK Health Departments on the effects on health of both outdoor and indoor air pollutants on the basis of data currently available; to assess the need for further research; and to liaise as necessary with other Government bodies to assess the effects of exposure and associated risks to human health.

512. COMEAP has recently published a report on Cardiovascular Disease and Air Pollution[152]. The Committee is currently giving advice on the quantification of the long term effects of air pollution on mortality in the UK. A short interim statement outlining their thinking and a draft report for technical comment is now available[153]. COMEAP is also working on a report on the health implications of O_3 in the UK.

513. The role of COMEAP will be incorporating that of EPAQS (see below). A new sub-group is being formed within COMEAP to provide independent scientific advice on specifying, interpreting and using air quality standards to the UK Government and devolved administrations. The enlarged body will retain the COMEAP name, structure and work programme.

151 See http://www.defra.gov.uk/environment/airquality/panels/aqeg/publications/index.htm

152 See http://www.advisorybodies.doh.gov.uk/comeap/statementsreports/CardioDisease.pdf

153 See http://www.advisorybodies.doh.gov.uk/comeap/statementsreports/longtermeffectsmort2007.pdf

3.2.3.3 Expert Panel on Air Quality Standards (EPAQS)

514. The Panel was set up in 1991 to provide independent advice on appropriate ambient air quality standards. The Panel's recommendations have previously been adopted as the benchmark standards in the Air Quality Strategy.

515. The Panel advised on non-occupational ambient air quality standards, with particular reference to the levels of airborne pollutants at which no or minimal effects on human health are likely to occur, taking account of the best available evidence. This was done without reference to the practicality of abatement or mitigation measures, the economic costs and economic benefits of pollution control measures or other factors related to the management rather than the assessment of risk. Where appropriate the Panel has recommended exposure-response relationships or other information the UK Government and the devolved administrations might use to set policy objectives. The Panel also identified gaps in the knowledge needed for standard setting and suggested potential priority areas for future research.

516. Following an independent review[154], the Government has decided to transfer the work of EPAQS to COMEAP, creating a sub-group of COMEAP to address future needs for advice on appropriate standards.

3.2.3.4 National Expert Group on Transboundary Air Pollution (NEGTAP)

517. The group was formed in 1999 to advise on past, current and projected deposition of transboundary air pollutants. They reviewed current knowledge on biological and chemical trends in the UK environment and the prospects for recovery. The group published its report[155] in 2001, and has since been dissolved. However Defra and the devolved administrations have commissioned an update, to be completed in 2008, to take account of new research findings. Such an update will inform the need for, and feasibility of, introducing new policy targets on ecosystem protection in future reviews of the Air Quality Strategy, e.g. on critical loads exceedences or NH_3 emissions.

3.2.3.5 Project for the Sustainable Development of Heathrow (Project Heathrow)

518. Project Heathrow is led by the Department for Transport and takes forward the commitment made in the Government's White Paper The Future of Air Transport to examine how to make best use of Heathrow's existing two runways, and how a third runway could be added, whilst complying with strict conditions on air quality, noise and improved public transport access. The project aims to reach a view about whether further development is likely to be consistent with the environmental conditions laid down in the White Paper.

519. The work will consider how best to represent current air quality impacts at Heathrow through measurement and modelling work and to define means by which future air quality concentrations can be predicted for the period up to 2020. The work will need to take account of emissions from all sources contributing to concentrations of NO_2 and other relevant pollutants, including road traffic emissions. It will also inform work on noise, surface access and air traffic management.

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[154] Available at http://www.defra.gov.uk/environment/airquality/aqs/index.htm

[155] See http://www.edinburgh.ceh.ac.uk/negtap/finalreport.htm

520. Panels of independent experts have been established to examine dispersion modelling, ambient measurement, and emissions source data. Progress will be reported to a wider range of stakeholders from time to time and there will be an independent review process of the work of the panels.

3.4 Challenges for the evidence base

521. A large proportion of the work currently funded by the our air quality evidence programmes needs to continue for the foreseeable future. Monitoring networks and emission inventories are tightly specified in legislation, but also provide the fundamental information to quantify exposure, attribute sources and identify trends on which the rest of the evidence base depends. Modelling is essential to extend this data spatially and temporally. But effective policy making in the future will also depend on improving our understanding of what adverse effects are caused by pollution, where they occur and how. We will combine these developments in our scientific understanding with a more sophisticated assessment of the likely outcomes of possible policy measures for environmental, social and economic impacts. We will also monitor and evaluate the delivery performance of current and new policies. One of the key challenges for the evidence base will be to develop our understanding of the links between air pollution and climate change (policies, pollutants and effects). Another will be to develop a social science capability to better understand societal drivers.

3.4.1 Quantifying exposure

3.4.1.1 Monitoring networks

522. All the data from the UK's extensive air quality monitoring networks are publicly available through a fully searchable online database[156]. The database includes measurements from the last 50 years as well as hourly updates from the current AURN. We will continue to review and refine our monitoring networks to ensure effective and efficient delivery of high quality and representative monitoring data to underpin the air quality evidence base. This section provides information on some of the issues which will affect our monitoring networks.

523. **New Air Quality Directive:** The European Air Quality Framework Directive, the first three Daughter Directives and the Exchange of Information Decision place a number of obligations on Member States on monitoring NO_2, SO_2, PM, lead, CO, benzene and O_3. Negotiations are underway on a new Directive[157] which aims to merge these requirements and substantially revise the existing provisions to incorporate the latest health and scientific developments and Member States' experiences. The proposal also introduces a new approach to control $PM_{2.5}$. This will greatly increase the amount of $PM_{2.5}$ monitoring.

524. Member States are currently allowed to use a mix of monitoring and modelling to show compliance with the air quality limit values, target values, etc. The proposal alters the number and distribution of sites required where modelling is available. There is also a maximum ratio of 2:1 between roadside and background sites.

156 See http://www.airquality.co.uk/archive/index.php

157 See http://ec.europa.eu/environment/air/directive.htm

525. Clearly, the new Directive will significantly alter the size, location and make up of a number of the components of the UK national air quality monitoring networks. The networks will be reviewed once the outcome of the negotiations becomes clear. The review will include consideration the degree to which more local authority data could be integrated into national assessments.

3.4.1.2 Modelling issues

526. We currently use a variety of models to help predict current and future levels of air pollutants, depending on the pollutant and geographic scale of interest. Each is considered fit for purpose and has provided valuable insights into individual issues, but the results between models are not necessarily consistent.

527. Atmospheric dispersion models are an integral part of air quality management, complementing information received from monitoring networks and assumptions made about emissions to provide predictions of air quality at other points and/or times.

528. As well as making predictions, models can be used to check the quality of input data, such as emissions. Observed data can also be used to calibrate and improve the models. Besides the ambient pollutant concentrations, models can describe emissions, transport and chemical transformations in air, and eventual removal from the atmosphere. Consequently the models must cover a range of scales (global to national to local) and specialised features, such as describing wind flow patterns around buildings, or the inclusion of complex chemical reaction mechanisms. No single model is currently capable of addressing the full range of complexities demanded by policy makers. Our approach is therefore 'horses for courses' rather than a 'one size fits all'.

529. There is often a trade-off between the time available to provide the answers and the sophistication of the model used, particularly if many scenarios need to be analysed. Where possible more than one modelling approach is used to check the robustness of the outputs.

530. We are assessing the feasibility of using nested models (i.e. linked monitoring approaches used at different levels of detail in a single model) to ensure greater consistency of approach between the various scales, but this is likely to be a long term process dependent on the availability of additional resources for development and testing.

531. Modelling techniques are continually improving their 'real world' representation, largely due to the growth in available computing power. So we will keep our use of models under review, learning from experiences within the UK and elsewhere, and investigating potential improvements and new approaches.

3.4.1.3 Nitrogen dioxide

532. Aside from the generic monitoring and modelling issues detailed above, there are also a number of issues which impact on the exposure quantification approaches for specific pollutants. In their report on 'Nitrogen Dioxide in the UK'[158] AQEG made a number of research recommendations to better quantify exposure including: improvements to the

[158] See http://www.defra.gov.uk/environment/airquality/publications/nitrogen-dioxide/index.htm

current models, with further comparisons of the national empirical model and dispersion models; investigations into the effects of increasing primary NO_2 emissions; and the temporal and spatial characteristics of NO_2 concentrations away from roads during episodes.

533. It is clear that NO_2 should not be considered in isolation from other pollutants when considering the development of pollution control strategies. For instance, a notable source of NO_x originates from road traffic along with other pollutants such as PM. An additional complication can be found in the relationship between NO_x and the formation and destruction of O_3. There is a need to better understand this relationship and how it varies spatially and temporally. The currently accepted empirical relationship between NO_x and NO_2 assumes that the oxidation of nitric oxide (NO) by O_3 along with the direct emissions of NO_2 are the two main sources of urban NO_2. Therefore the observed changes in background O_3 levels are not taken into account by the models.

3.4.1.4 Ozone

534. Research suggests that the level of commitment to emission reductions required to make a difference for the UK cannot be made at national level alone. Reductions in O_3 levels must be addressed at international level.

535. Controls on O_3 precursor pollutant emissions affect O_3 levels at different spatial and temporal scales. Recent opinion suggests that as the global climate warms and the reactive nature of the atmosphere changes, we can expect increases in reactive species such as the hydroxyl radical which is particularly good at stimulating O_3 production. This is expected to occur near regions of strong NO_x production (i.e. cities etc). However, in the more remote regions, such as over the oceans, the same increase in reactive species will prevent the formation of O_3.

536. Natural biogenic emissions of isoprene and terpenes from vegetation contribute to O_3 formation. Climate change is predicted to increase these emissions, increasing O_3 levels. Future research will be needed to investigate this response.

3.4.1.5 Particulate matter

537. There are a number of important gaps in our current understanding of atmospheric particles. AQEG has reviewed the state of current knowledge on exposure to particles and made a number of recommendations on the monitoring of PM and its constituents.

538. We have considered their recommendations and a number of work streams are in place, or are being developed, to implement the key proposals. One overall aim is to increase rural PM_{10} and $PM_{2.5}$, nitrate, sulphate, elemental and organic carbon monitoring in the future at linked triplet sites involving rural, urban background and urban roadside locations, within the context of the requirements of the new EU Air Quality Directive. Plans are also in place to improve our monitoring capability to allow better understanding of source attribution.

539. There remain a number of potentially more intractable questions on particulates which are yet to be resolved, largely concerning the mechanisms by which they cause or initiate adverse health effects. These are discussed further in section 3.3.3.1. A question

remains as to the measurement metric or metrics, e.g. size fraction, component number, which most closely represents such health effects. Resolving this issue will allow the UK Government and the devolved administrations' modelling and monitoring efforts to be better targeted, and improve the efficiency of our control strategies.

3.4.1.6 Equivalence study

540. The UK Government and the devolved administrations routinely measure PM in ambient air using automatic continuous monitors known as TEOMs. We use this method because it provides quick, reliable, hourly data on PM which cannot be done using the EU reference method. These data are published within one hour of measurement on the air quality archive. The data include a correction factor to try to make them equivalent to the reference method.

541. A recent study has shown that the TEOM does not meet the equivalence criteria required by the Directive. This raises a number of interesting policy issues for the UK and other member states. It is not considered that this information invalidates all the TEOM measurements in the UK national network, since they show that there are elevated levels of PM in some places; and we know that particles pose a large public health risk across the UK. The differences between TEOM and 'actual' levels are not significant to any policy decision on whether to take action. They are, however, significant in assessing strict compliance with EU Limit Values. TEOMs will continue to be useful to local authorities for use in the review and assessment process. We also remain committed to providing near real-time data to the public and only automatic monitors can do that.

542. Defra and the devolved administrations will upgrade the national network to achieve equivalence for the first Daughter Directive. We will also take the findings into account when we expand our $PM_{2.5}$ network.

3.4.1.7 Polycyclic aromatic hydrocarbons and metals

543. The 4th Daughter Directive (2004/107/EC) requires measurement of the PM_{10} fraction of particle bound B[a]P and other PAHs, whereas the current PAH monitoring network measures a different size fraction (approximately PM_{14}), and is therefore non-compliant. Compliant equipment will be installed in time to start monitoring from January 2008. The network will be expanded to include additional ambient monitors as well as two new rural sites to monitor PAH deposition. As a research requirement, more needs to be understood about the correlation between B[a]P and other potent PAHs.

544. Current concentrations of the metals addressed by the Directive (arsenic, cadmium, mercury and nickel) are extremely low, except around certain industrial processes. It is unlikely that further sites will be required either for ambient or for deposition monitoring, except where the up/downwind concentrations around industrial plant are unknown.

3.4.1.8 Pollutants causing environmental effects

545. The UK already has an extensive series of networks measuring deposition of a wide range of pollutant species. However, these networks have generally developed independently of one another and the agreement of a new monitoring strategy in EMEP (the European Monitoring and Evaluation Programme under the auspices of the UNECE Convention on

Long Range Transboundary Air Pollution) provides the opportunity to review the networks with a view to better coordinating and updating our data collection.

546. Most of the sites with long time series of data will continue as before, providing high spatial and low temporal resolution data helping to determine long term trends in the rural pollution climate. However, two supersites will be created to meet the EMEP Level 2 requirements. The first of these at Auchencorth Moss in the Southern Uplands of Scotland came on-line early in 2006, while the second at Harwell in Oxfordshire will follow in 2008. These sites will provide much higher resolution data on a wider range of species. This will be used to contribute to European efforts to provide a high quality database of rural background measurement of sufficient temporal resolution to underpin models that can accurately reproduce episodic pollution. This will lead to a more sophisticated understanding of transboundary pollution, especially the origins of secondary PM and O_3. The sites will also contribute to the UK Government and the devolved administrations' plans to implement the recommendations arising from the AQEG report on Particulate Matter in the UK.

3.4.2 Source attribution

3.4.2.1 Nitrogen dioxide

547. In their reports on 'Nitrogen dioxide in the UK' and 'Trends in primary nitrogen dioxide in the UK', AQEG made a number of research recommendations on source attribution. We need to develop a better understanding of vehicle behaviour and emissions from all parts of the drive cycle. There is also a need for more robust NO_x emission factors for all transport and the fraction of NO_x emitted as primary NO_2.

548. It is acknowledged that some differences exist between estimates of vehicle emissions derived from drive-cycle tests and real world emissions. Future improvements in this area will need to concentrate on a more accurate representation of how vehicle emission characteristics vary for a range of driving situations. These results will inform the emission factors used by research modellers and help reduce current uncertainties.

3.4.2.2 Particles

549. In addition to their recommendation on monitoring (see Table 3.1) AQEG[159] suggested a number of other research recommendations on particles, including:

- developing a better understanding of non-exhaust traffic emissions;
- the provision of more robust PM emission factors for emission inventories;
- improvements to, and refinement of, current models for PM source apportionment;
- improved understanding of the impact of road characteristics such as traffic induced turbulence, vehicle exhaust height, etc. on PM concentrations measured near roads;
- improved PM monitoring and characterisation in support of epidemiological studies;
- development of comprehensive aerosol modelling capability;

[159] See http://www.defra.gov.uk/environment/airquality/publications/particulate-matter/index.htm

- model development for the coarse component of PM to handle both direct and re-suspended emissions at urban background and traffic levels; and
- modelling of $PM_{2.5}$ in anticipation of potential new air quality targets.

550. A priority is the ability to make reasonably accurate predictions of future PM levels to inform policy. At present the source apportionment model which contributes to this task employs a combination of ambient measurement data and dispersion modelling to assist with the future predictions. The accurate description of source categories via their emission factors is crucial to the dispersion modelling. The techniques, used to estimate these factors (for some sources), are considered insufficiently robust and require some refinement.

551. The source apportionment model is also acknowledged to be incomplete in the light of recent research findings. Categories such as secondary organic particles are not accounted for. The model also treats the other mainly coarse particles category as constant. This is now accepted as being incorrect as the category, which includes soil, road dust and sea salt, is known to be both spatially and temporally variable.

552. Ultimately Defra and the devolved administrations will be looking to improve our understanding of the size distribution and chemical composition of both primary and secondary PM so that the abatement strategy can be better focused.

3.4.2.3 Interactions between pollutants

553. We already have a relatively sophisticated understanding of the interactions between some pollutants. The Master Chemical Mechanism, developed in the UK, is the world's most detailed description of photochemical reactions in the atmosphere leading to tropospheric O_3 production. Nevertheless, our models can only approximate the true complexity of the behaviour of pollutants in the atmosphere and can sometimes fail to predict the full consequences of changes in the pollution climate.

554. In some cases this is because of an imperfect understanding of the effects of measures to reduce any one pollutant on other emissions. For instance, reductions in agricultural NH_3 could lead to an increase in other nitrogen based pollution, such as nitrates in groundwater or nitrous oxide (a potent greenhouse gas) emissions to the atmosphere. Ideally we need a more holistic understanding of the nitrogen cycle in animal husbandry.

555. We have also observed non-linearities in the response of pollutant levels to changes in emissions. For example, while sulphur emissions have decreased dramatically over the last few decades, only SO_2 levels have mirrored that trend. Wet deposition of sulphur has decreased much more slowly. In effect the benefits of reduced sulphur emissions have been in terms of human health and those areas most affected by critical level exceedences (predominantly in the heavily populated and drier locations of the south and east). On the other hand, the uplands to the north and west which are most at risk from acid deposition have seen smaller improvements. The reason for this non-linear response is suspected to be two-fold – atmospheric chemistry (efficient conversion of SO_2 to sulphate aerosol as a consequence of excess atmospheric NH_3) and an under-acknowledged source of sulphur emissions from shipping. Much of the current work in this area requires close collaboration with other European groups (particularly EMEP) whose current models

do not describe atmospheric and deposition processes to a sufficient detail for UK applications. Future research will concentrate on smaller scale processes which more accurately describe UK measurements.

556. Ozone levels can also react in counter-intuitive ways to emission reductions as a result of a number of competing effects. In addition to helping to form O_3, reactions with NO_x will also act as an effective removal mechanism. Under calm conditions NO_x emissions from vehicles can efficiently remove O_3 from the atmosphere. So O_3 levels are invariably lower in urban/inner-city locations. Ozone will quite readily react with NO to form NO_2, which in turn can generate additional O_3 further downwind. Generally, the concentration of NO_x in rural areas is not high enough to continue the O_3 destruction, therefore O_3 is usually higher in rural areas.

557. This is an important consideration because efforts to drive down emissions of NO_x (for compliance with the Air Quality Strategy) result in less NO_x to scavenge O_3 in urban areas leading to an increase in O_3 levels within cities. In the short to medium term the benefits of NO_x reductions (in terms of reduced health effects from particles and NO_2 and ecosystem effects from nitrogen deposition) will therefore come at the expense of poorer urban O_3 air quality. Urban O_3 levels will tend to approach the higher concentrations normally recorded in rural areas.

558. The reduction in NO_2 emissions has not yet made much difference to regional O_3 formation. Instead, controls on VOC emissions have driven down rural concentrations. Counteracting this rural decline is the steady rise in hemispheric O_3. Increased emissions of precursor gases from North America and Asia have led to a rise of about 10 $\mu g.m^{-3}$ per decade in the hemispheric background level of O_3.

559. We therefore have a situation where controls on O_3 precursor emissions will have different effects at different spatial and temporal scales. More research is needed to investigate the relationships between the rising hemispheric background O_3 and regional and local levels in the light of continued VOC and NO_x reductions. If there is no reasonable health threshold for O_3 future research will need to investigate the complex O_3 chemistry at all temporal and spatial scales.

3.4.3 Assessing impacts

3.4.3.1 Human health effects evidence needs

560. A key challenge will be improving quantification of air pollution effects through the use of health impact assessments. These will play a key role in assessing the potential health benefits of mitigation measures, providing an evidence base for policy decisions.

561. Evidence on the relationship between exposure to different air pollutants and health effects has increased significantly over the past few years. Nonetheless, there are still large uncertainties and gaps in knowledge that can only be addressed by targeted research and monitoring. A number of areas have been identified in which further research would increase our understanding of the impacts of individual pollutants on human health. These are discussed in more depth in the IGCB report accompanying this document. They include:

- the toxicity of PM from different sources, in particular combustion, to identify the chemical components primarily responsible for the different effects on health;
- associations between different indices of PM, (e.g. coarse, fine and ultrafine particles and particle number) and effects on health;
- improving understanding of the appropriate size of the coefficient for the long term effects of particles;
- improving understanding of windows of exposure and lag time to effect for the long term effects of particles;
- further development of the lifetable methodology, e.g. to incorporate the above improvements in understanding;
- the mechanisms by which inhaled pollution leads to adverse health effects;
- the relationship between long term exposure to low levels of other pollutants, such as O_3, and effects on health, including chronic morbidity;
- the effects of different components of traffic-generated air pollutants, particularly the significance of NO_2 as a pollutant with direct impacts on human health;
- potentially susceptible groups of the population; and
- developing ways to incorporate the effects of air pollution on health outcomes other than death and hospital admissions (including increasing the robustness of the underlying evidence).

562. As well as investigating the impacts of individual pollutants, a further goal will be to determine whether there are particular synergies between the effects caused by combinations of air pollutants, or individual air pollutants and other environmental factors. This will not be an easy task given the potentially huge number of associations to be investigated and the problems with differentiating between association and cause.

563. A number of these research requirements need to be supported by better characterisation of the pollutants themselves, most notably particulate matter. Further information on the chemical composition of PM, particularly from combustion sources, together with monitoring of additional PM metrics including $PM_{2.5}$, $PM_{1.0}$ and particle number is needed. These data could be used in time-series studies designed to look at associations between these indices and adverse health outcomes. Defra already has an extensive monitoring programme and further improvements to the monitoring network are planned, as outlined in section 3.3.1.

564. Research in the areas outlined above will provide important evidence for the establishment of exposure-response relationships for different health end-points associated with individual pollutants and their components. A key area in which improvements are expected in the coming years is the developing science of meta-analysis. This is a statistical technique for combining the results from a number of studies and was used by the WHO[160] in 2004 to update risk coefficients in relation to ambient exposure to PM and O_3. It is likely that the necessary statistical power to derive robust relationships will only be possible by combining UK studies with others carried out elsewhere, particularly in Europe.

[160] http://www.euro.who.int/document/e82792.pdf

565. The exposure of the population to pollution needs to be assessed to quantify the health benefits of different emission reduction scenarios and the health impact of pollutants in particular micro-environments such as roadsides. This information will come not only from ambient monitoring and modelling programmes, but also from knowledge of where people spend their time and the pollution levels that exist in these micro-environments.

3.4.3.2 Ecosystem effects evidence needs

566. There are extremely complex interactions between atmospheric pollutants and ecosystems, the chemistry and behaviour of pollutants prior to deposition, and their fate within ecosystems following deposition. Despite many years of research, we are only just beginning to understand how, for example, NH_3 is deposited, transported, transformed, utilised and removed from different ecosystem types, and how those ecosystems are impacted by its presence. As analytical tools become more sophisticated, so further complexities are uncovered. The development of dynamic simulation models to show how ecosystems operate and interact with pollutants is at an early stage, and the demand for ever more detailed real-world information on ecosystems to support such models is increasing.

567. For acidification and nitrogen deposition, the main evidence needs are:

- the causes of the apparent non-linearities between reductions in emissions and lesser reductions in wet deposition (see section 3.3.2.3);
- historic trends, to allow the simulation of pre-industrial (low deposition) ecosystems;
- more data on the real-world effects of acid and nitrogen deposition, in particular the fate of nitrogen species within ecosystems, and the mechanisms which operate when an ecosystem becomes nitrogen saturated;
- how eutrophication changes the defining characteristics of different ecosystems types (e.g. species change, species reduction);
- the prospects and timescales for recovery by acidified and eutrophic ecosystems following reductions in deposition; and
- the development of dynamic simulation models, and the data to support them.

568. As in other areas of pollution control policy, there is a need to develop measurement metrics which relate closely to the effects a given pollutant has on a particular ecosystem. Metrics currently in use, such as empirical or steady state critical loads for acid and nitrogen deposition or AOT levels for O_3, are relatively simple to develop, but will still only approximate real-world situations. But ecosystems are not static – their responses to pollutants change under different environmental conditions.

569. Stomatal flux modelling seeks to simulate how plants take up O_3 through their stomata under different conditions, e.g. in hot, dry weather leaf stomata close up to avoid water loss, and therefore take up less O_3. Dynamic modelling also seeks to simulate real world conditions, focusing on the fate of acid and nitrogen species in different soil types in order to predict their impacts. While such complex modelling approaches may in time represent real world conditions better than to steady state critical loads or AOT limits, they have the disadvantage of being complex, data intensive and difficult for non-specialists to comprehend and utilise.

570. Further research is therefore needed to develop and refine all of these approaches, and to find ways in which they may usefully be integrated in policy development.

571. The increasing importance of NH_3 as a pollutant gives rise to additional evidence needs, including:

- refined NH_3 emissions inventories and projections;
- the effectiveness and practicability of NH_3 control measures and techniques;
- quantification of the ecosystem, human health and climate impacts of NH_3, and the apportionment of these effects to emission sources; and
- effects of gaseous NH_3 on vegetation, and setting appropriate critical levels.

572. The current evidence base already addresses many of these ecosystem effects evidence needs, but further efforts will be required to underpin decisions on the need for, and the character of, further effective and efficient control strategies.

573. To inform this evidence base, Defra and the devolved administrations operate a number of networks designed to monitor the ecosystem effects of air pollution. The largest and longest running of these is the UK Acid Waters Monitoring Network, which has monitored the water chemistry and species composition of a range of biological groups from 22 acid-sensitive lakes and streams since 1988. The results show that some chemical recovery is underway, with the first signs of biological recovery also evident[161].

574. Effects monitoring is also routinely carried out as part of Defra and the devolved administrations' four 'umbrella' research programmes, on terrestrial and freshwater effects[162], on O_3, and on dynamic modelling. The terrestrial effects work includes a number of experimental plots across the UK (manipulation plots and roof experiments), while the freshwater umbrella includes the use of isotope tracking to better understand the transmission and fate of pollutants in the environment. The programme also includes a regular moss survey of the UK, under the UNECE International Cooperative Programme on vegetation effects, to better calibrate heavy metals deposition mapping and support the development of critical loads for heavy metals.

3.4.4 Assessing policy options

575. This category covers work which synthesises the outputs from the previous three sections, combining it with economic assessments of costs and benefits to provide further input to decisions on new policies. It also includes the provision of guidance on the effective delivery of existing measures.

3.4.4.1 Providing guidance on the most effective policies

576. There are a number of ways in which the evidence base can guide policymakers towards more effective policies. Alternative means of setting air quality targets, such as the exposure reduction approach, can be investigated. The potential of a variety of

[161] See Environmental Pollution (volume 137 (1), 2005). Detailed reports at http://www.ukawmn.ucl.ac.uk

[162] See http://www.bangor.ceh.ac.uk/terrestrial-umbrella

abatement measures can be compared, as can their relative costs. Evidence from previous policy implementations (i.e. ex-post studies) can also help to inform decisions on future policy options. Such an analysis was published in January 2005[163].

577. Integrated assessment modelling seeks the most cost efficient combination of measures to achieve a given environmental outcome. In doing so it takes information on the size and location of sources and predicts the resulting levels of pollution at receptor sites. It then seeks out the cheapest method of achieving the environmental targets using cost curves derived from the relative costs and efficiencies of available measures. Such an approach was used to inform the development of the NECD and the UNECE Gothenburg Protocol. In doing so it sought to meet ecosystem protection targets for acidification and eutrophication on a relatively coarse geographical scale, and focused on technological abatement measures, such as switching to cleaner fuels and end of pipe technologies.

578. The modelling underpinning the European Commission's Thematic Strategy on Air Pollution, subsequently picked up in the current preparations for the revision of the NECD, marked several developments in the approach. Finer scale modelling allowed the model to be driven by improvements in health effects. In the future it is hoped that models can be further developed to allow the incorporation of a broader range of abatement measures, including non-technical measures such as demand management. This would make it easier to compare the effectiveness of different combinations of policies, such as transport demand management and technological solutions.

579. It may also be possible for integrated assessment models to accommodate finer scale models nested within a pan-European grid to allow a more robust assessment of health effects and benefits. The UK is currently working with the UNECE Meteorological Synthesising Centre on such a model for the UK within the main EMEP Eulerian model. We are also working on a similarly nested integrated assessment model that could help to develop cost efficient national or regional strategies within the UK.

3.4.4.2 Assessing costs and benefits

580. As can be seen from the report of the IGCB accompanying this consultation document, there is already much we can do to help quantify the costs and benefits of policy measures. Government policy requires all new policy proposals – both national and international – to be accompanied by a Regulatory Impact Assessment. Likewise all European legislative proposals from the European Commission are now to be accompanied by a comprehensive Impact Assessment – a good example being the Commission's Thematic Strategy[164].

581. Nevertheless, there are still impacts that are difficult to monetise, either because of problems quantifying the precise environmental impact (such as ecosystem damage resulting from critical load exceedence) or in placing a monetary value on the stock at risk (for instance the value of a loss of biodiversity over and above its amenity value).

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[163] See http://www.defra.gov.uk/environment/airquality/publications/stratevaluation/index.htm

[164] See http://ec.europa.eu/environment/air/cafe/index.htm

582. Areas where further research specific to air quality is needed include:

- further willingness to pay studies to validate/improve existing health valuation;
- extension of health impacts that are assessed e.g. quantification and valuation of additional morbidity endpoints (restricted activity days, respiratory medication use etc), identification and valuation of differing categories[165] of deaths brought forward;
- further understanding of the health effects of secondary particles;
- improved understanding of the impact of legislation on costs (e.g. providing a spur to innovation);
- improved data on local air quality policies and the localised impacts of transport schemes;
- improved quantification and valuation of non-health impacts e.g. effects on cultural heritage and ecosystems; and
- greater understanding of distributional impacts of air quality policies.

3.4.4.3 Input to the delivery of existing policies

583. Once policies have been agreed there is still important work to do to ensure they are efficiently implemented and their effectiveness evaluated to inform initiatives under the Government's Better Regulation agenda. So we will continue to review reports generated by local authorities under the LAQM regime, and carry out periodic statistical and performance reviews of the Local Authority Pollution Control regime. We will also continue to provide advice to local authorities on monitoring and dispersion modelling to help them discharge their responsibilities efficiently and effectively. In addition, we will undertake periodic evaluations of both national and local air quality policies.

3.4.4.4 Evaluating the links between policies

584. Evaluating policies has to go wider than an assessment of the direct costs and benefits of individual measures. Often there are links to other policy goals in the form of synergies or trade-offs which need to be understood at a scientific level before they can be effectively integrated into policy.

585. Another example is the potential for work on the effects of deposition on ecosystems to provide useful inputs to site specific habitat protection policies. At present limitations on the resolution of effects assessments make it difficult to relate the national or regional picture to specific ecosystems of conservation value. Further developments in deposition modelling and dose response relationships will provide the opportunity to include deposition impacts in assessments carried out under the Habitats Directive.

586. Other less obvious examples also provide challenges to the evidence base and policy. For instance, as described by AQEG, certain types of particle trap technology fitted to heavy duty vehicles can have an adverse effect on NO_2 levels. The traps deliver an order of magnitude reduction in particle emissions from these vehicles, and are therefore considered to have a large potential to reduce adverse health effects. While total NO_x

[165] For example, sudden cardiac death might be valued differently from a death from chronic obstructive pulmonary disease.

emissions are unaffected by the traps, a larger proportion than before is emitted as NO_2, hindering achievement of the objectives for this pollutant. Fitting particle traps still delivers a large overall health benefit as current health advice suggests ambient particle levels pose a much greater risk to health than levels of NO_2, but nevertheless provides an unforeseen policy conundrum. There may be a need to investigate the feasibility of setting a limit on primary NO_2 emissions as well as total NO_x, and considering the extent to which technologies could respond should such a limit to be specified in European standards.

3.4.5 Influencing behaviour

587. In the past, work under this heading has tended to focus on dissemination of air quality information. For many years now predictions of the next few days' air quality have been regularly updated on freephone, Teletext and the UK Government and the devolved administrations' website allowing members of the public who are sensitive to air pollution to plan their medication or activities accordingly.

588. Vast quantities of data are generated by the evidence and innovation programme. The Air Quality Archive[166] is the prime route for dissemination of these data. This site, maintained under the evidence and innovation programme, gives a large user community in academia, local authorities, and industry access not only to reports produced by the programme, but also to a huge range of raw data, accessed via a fully-relational database. It contains every data point measured by our extensive monitoring networks over the last 50 years (over 150 million measurements), with new data being added from the AURN within an hour of its measurement. The archive also contains detailed breakdowns of emission data.

589. We will maintain these services, seeking where possible to improve their user-friendliness by taking advantage of new techniques in web design. To help us do this, we will periodically consult users of the information for feedback and suggestions. More broadly we hope to review the effectiveness of our communication of the evidence base seeking greater transparency and stakeholder awareness.

3.4.5.1 Improving the effectiveness of policies

590. Along with the environment agencies we will continue to investigate the potential of new technologies to lead to reduced emissions and lead to improvements in air quality through the updating of BAT. However progress on pollution issues increasingly depends on policies that aim to change behaviour in industry, commerce and public life.

591. One of the challenges for the evidence base across environmental policy is to develop a broader appreciation of what social science can contribute to the development of effective policies. The Evidence and Innovation Strategy recognises that more work is needed in this field.

592. A new project aimed at articulating public values on air quality represents a step forward in this regard. This has used deliberative techniques to engage with selected members of the public to help gain an insight into what influences people's opinions on air quality and their willingness to contribute to its improvement. Our longer term goal is to develop

[166] See http://www.airquality.co.uk/archive/index.php

a social research programme that provides a focal centre for innovative, inclusive and interactive consultation techniques, in order that policies may become more responsive to the needs and expectations of the public and stakeholder groups. Some social science evidence needs are likely to be best served by generic research equally applicable in other policy areas (e.g. sustainable development, transport, climate change, etc), so this programme may need to be coordinated with others.

593. Such research might investigate: stakeholders and communication techniques; the use of innovative participatory methods to resolve conflicts in public desires; the social and technical barriers to innovative delivery of environmental policies; and the up-stream drivers of air pollution (e.g. consumer demand).

3.4.6 Air pollution and climate change

594. There is a growing awareness of the need to take a more holistic view on air quality and climate change in terms of both scientific research and policy thinking. The key driving forces behind climate change and poor air quality are similar, e.g. economic growth, consumption and production processes and demography. They share many emission sources, so any abatement strategy will impact on both. They have transboundary considerations requiring a co-ordinated approach incorporating a wide range of policies and stakeholder involvement.

595. AQEG has examined the linkages between air quality and climate change[167], considering the scientific background to interactions focusing on the next 10-15 years and also to comment on the decades starting 2030 and 2050. The focus was on the UK and Europe and on likely rather than catastrophic future events.

596. Research into climate change and air pollution has developed along mainly independent routes over the last 30 years or so. The gases normally associated with climate change have a long residence time in the atmosphere so are well mixed and impact at a global scale. Pollutants normally associated with poor air quality were traditionally thought of as short lived, impacting mainly on the local, national and continental scales although in recent years the global impacts of some have begun to be recognised. Poor air quality impacts directly on human health and ecosystems. Climate change indirectly affects a wider range of endpoints – including global sea levels, socio-economics, demographics, agricultural output and water availability. In developed countries air pollutant emissions are mainly decreasing, unlike the more stable CO_2 emissions.

597. These factors mean that abatement strategies to combat climate change require agreements made through multilateral political and scientific approaches on a global basis. The more immediate nature of pollutants responsible for poor air quality meant that these can be abated through a more local and regional approach.

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[167] AQEG (2007). Air Quality and Climate Change: A UK Perspective. Report prepared by the Air Quality Expert Group for the Department for Environment, Food and Rural Affairs; Scottish Executive; Welsh Assembly Government; and Department of the Environment in Northern Ireland. PB12489 ISBN 0-85521-172-5 [http://www.defra.gov.uk/environment/airquality/publications/airqual-climatechange/].

598. Exploring synergies between climate change and air quality may prove beneficial for both technological and policy outcomes. Often when the two policy areas are considered together, a suitable technology can be developed that addresses both local air quality and climate change problems. Energy efficiency is an example of a climate change mitigation measure that results in benefits for air quality from reduced fossil fuel consumption. On other occasions there may be a trade-off between the two issues, e.g. fitting particle traps to diesel vehicles is a very effective way to reduce particle emissions, but results in a small increase in CO_2 emissions (although this is at least partially offset by the reduction in climate forcing black carbon emissions). We will continue to develop our understanding of these synergies and trade-offs to better inform policy decisions.

599. Given the close link between weather, climate change and air quality, it is logical to assume that changing weather patterns resulting from climate change will change the nature and frequency of pollution episodes. We are investigating this as part of the project on dispersion modelling in urban areas. Predictions of future climate conditions were obtained from the regional climate model runs of the Met Office's Hadley Centre. Each parameter was analysed for current climate conditions and those expected towards the end of the century (see Table 3.1). There could be significant changes in a future climate for some of the meteorological parameters analysed. These will have different influences on air quality.

Table 3.1: Summary of analysis results and likely impact on air quality[168]

Weather parameter	Future change	Possible influence on air quality
Wind speed	Summer – lower	Less dispersion – higher pollution levels from local emissions
	Winter – higher	Greater disperson – lower pollution levels from local sources
Wind direction	Summer – slightly more northern with less westerly	Little effect
	Winter – slightly more westerly than easterly	Lower air pollution (less pollution sources to the west)
Heat flux	Summer – slightly higher	Slight changes in local pollution – higher concentrations from elevated sources but lower impact from surface sources
	Winter – no obvious change	None
Boundary layer depth	Summer – more depths greater than 1500m	Lower pollution due to larger dilution and mixing (but very small effect)
	Winter – no obvious change	None
Cloud cover	Summer – slightly less	Lower local pollution due to greater turbulence, but turbulence may influence plume grounding. Greater sunlight may increase photochemical reactions leading to higher O_3
	Winter – no obvious change	None
Incoming solar radiation	Summer – slightly greater	Lower local pollution due to greater turbulence, but turbulence may influence plume grounding. Greater sunlight may increase photochemical reactions leading to higher O_3
	Winter – no obvious change	None
Temperature	Summer – higher with more frequent heat waves	More high O_3 pollution episodes
	Winter – higher	Unclear
Precipitation	More dry spells	Higher pollution – precipitation cleans the air
Pressure (mean sea level)	Summer – high pressure more prevalent	Higher pollution due to anti-cyclonic conditions circulating pollutants from continental Europe. Also high pressure systems associated with high O_3 concentrations
	Winter – low pressure	Lower pollution due to more turbulent conditions

600. AQEG examined the scientific background to these interactions and identified synergies, where measures to improve air quality can help to ameliorate climate change, and trade-offs where policy measures in the two areas pull in different directions. The main

[168] See http://www.airquality.co.uk/archive/reports/cat16/0608041526_Report_25-10-05.pdf

recommendations from the report are reproduced in Box 3.1[169]. We will consider these recommendations and further develop the methods for assessing the links between climate change and air quality policy as appropriate.

3.4.6.1 Air quality synergies with climate change in the longer term

601. In the longer term, policies to address both climate change and air pollutant emissions can potentially deliver significant improvements in air quality and public health. We have made a speculative assessment of what urban air quality might be in the UK around the year 2050.[170] The discussion in this assessment is intended neither to be a statement of government policy, nor to give any signals that the ambitions or goals might form part of policy over and above those already agreed and published.

602. The intention was not to make our best quantified projections of future emissions and air quality in a specific year, as in the other parts of this review, but rather to give a more impressionistic feel for the magnitude of air pollutant concentrations one might envisage over that timescale if many of the ambitions in the fields of energy, transport and environment were realised. Possible developments in transport technology and in energy generation are of particular interest here. These improvements would go beyond the measures discussed in earlier chapters of this review.

603. The assessment suggests that levels of fine particles ($PM_{2.5}$) in London could be reduced by up to 55% compared with current levels at urban background locations and 63% beside the most polluted roads. Levels of NO_2 could be reduced by approximately 55% and 70% at background and roadside locations respectively in London.

604. The reduction of O_3 concentrations in the UK will need co-operation on European, northern hemisphere and even global scales. Reductions in NO_x and VOCs would be necessary to halt the projected increase in the hemispheric background ozone level and reduce the damage from 'summer smog' episodes.

605. As emissions are progressively controlled in the UK and the rest of the EU and UNECE Europe, contributions to pollution levels from elsewhere in the northern hemisphere become more important and the policy process will need to take this into account, for example, building on the work of the Task Force on the Hemispheric Transport of Air Pollution within the UNECE Convention on Long Range Transboundary Air Pollution.

[169] For a more detailed discussion of the recommendations see http://www.defra.gov.uk/environment/airquality/publications/airqual-climatechange/pdf/chapter06.pdf

[170] Williams, M.L., UK Air Quality in 2050 – Synergies with Climate Change Policies, Environ. Sci. Policy (Volume 10, Issue 2, April 2007, pages 169-175)

Box 3.1: AQEG main recommendations

1. Impact analysis of policies or specific developments, whether for industry, transport, housing etc., should take account of the interlinkages of emissions of air quality and climate change pollutants. In particular measures at the national level designed to improve local air quality or to abate greenhouse warming should not be implemented without prior consideration of all types of impact on the atmosphere and other environmental media.

2. Detailed consideration should be given to appropriate policy drivers and legislation that could be introduced to ensure that the reduction of greenhouse gas emissions is properly incorporated into regional and local government planning decisions.

3. Detailed consideration should be given to developing better means of expressing the influence of air quality pollutants on climate, and for inter-comparing the benefits of abatement strategies in respect of air quality and of climate change.

4. The relationship between local radiative forcing and local temperature response has not been sufficiently investigated. This may be particularly important for spatially inhomogeneous radiative forcing agents such as aerosol (direct and indirect effects) and tropospheric O_3 and needs further research.

5. Research is needed on the extent to which policies for large-scale tree planting within the United Kingdom and elsewhere within Europe would influence air quality in high temperature summer pollution episodes. Wider impacts of land use change upon both air quality and global pollutants also need to be considered.

6. Consideration should be given to promoting measures which result in benefits both for air quality and climate. These might include incentives for domestic energy conservation, improved industrial process efficiency and measures designed to modify the behaviour of individuals so as to reduce the impact of their activities on the atmosphere. Given the significant influence of transport emissions, measures which reduced the use of road vehicles, shipping and aircraft would be highly beneficial.

7. A comprehensive life cycle analysis should be conducted comparing the environmental implications of electric and hybrid vehicles with each other and with conventionally-fuelled vehicles, to inform policy on incentivising their use. A detailed fuel-cycle analysis is required to consider the air quality and greenhouse gas emission implications for the production, supply and consumption of biofuels for transport.

8. The full fuel cycle environmental implications of non-fossil fuel means of electricity generation (i.e. wind, tidal, nuclear, etc) should be evaluated, as part of the development of future energy supply policies. This should include the implications of large-scale biofuel and bioenergy production for land-surface exchange of both air pollutants and greenhouse gases.

9. The development of well informed European policy on O_3 precursors would benefit greatly from a more global view of emissions, trends and abatement issues.

10. Future climate change policy should consider extending the basket of radiative forcing agents included in the development of climate change policies.

4.1 Title of proposal

606. The Air Quality Strategy for England, Scotland, Wales and Northern Ireland, 2007.

4.2 Purpose and intended effect

607. The purpose of the Air Quality Strategy is to set out a clear long-term vision for improving air quality in the UK. It also identifies a package of measures to reduce the risk to health and the environment from air pollution and help achieve our national and international commitments.

608. The new Air Quality Strategy develops and takes forward the previous achievements of the 2000 Air Quality Strategy for England, Scotland, Wales and Northern Ireland with new scientific information and economic methods. This Regulatory Impact Assessment (RIA), along with accompanying volumes of the Air Quality Strategy (2007) and the updated IGCB report, is intended to set out our current thinking and assessment of the current policy options available to us to meet our air quality objectives, helping inform decisions on which policy measures are best candidates for implementation. More detailed RIAs will be produced for individual policy measures taken forward at a later stage.

4.2.1 Background

609. The UK Government and devolved administrations' Air Quality Strategy for England, Scotland, Wales and Northern Ireland, published in 2000, and its Addendum issued in 2003, set objectives for the protection of human health and the environment to be achieved for nine key air pollutants between 2003 and 2010.

610. Both the Strategy and the Addendum stated that the Air Quality Strategy would be kept under regular review to take account of the latest information on the health and other effects of air pollution and technological and policy developments, such as need to implement EU directives relating to measures aimed at improving air quality (Directives relating to the Air Quality Strategy are discussed in Box 4.1 below). The Strategy and the Addendum also indicated that the next review would focus less on the air quality objectives themselves, but more on assessing potential additional policy options needed to deliver them. These options are presented in this RIA, which accompanies the consultation document and in the updated IGCB report, which sets out the technical detail of the cost-benefit analysis.

611. The Air Quality Strategy is among the Government's key objectives in its strategy for sustainable development, *Securing the Future*, published in March 2005. The aim of sustainable development is to enable all people throughout the world to satisfy their basic needs and enjoy a better quality of life, without compromising the quality of life of future generations. For air quality, the Government's sustainable development strategy reported that it is often those living in the deprived areas that suffer the higher levels of pollution and that the Government's aim is to tackle this and improve air quality, in particular through the new Air Quality Strategy.

Box 4.1 EU directives relating to the Air Quality Strategy Review

One of the main purposes of the Air Quality Strategy is to identify potential additional policy options that can deliver the air quality objectives in light of recent policy developments, and as such several of the policy options presented in this RIA involve taking forward current EU directive proposals.

There have been several developments in European air quality policy since the last full review of the Air Quality Strategy in 2000. At that point the Air Quality Framework Directive (96/62/EC) had been adopted and the 1st Daughter Directive (1999/30/EC), which set mandatory limit values for SO_2, NO_2, PM_{10}, NO_x and lead, took effect in 2001. Since then three more Daughter Directives have been agreed. The 2nd Daughter Directive (2000/69/EC) sets limit values for benzene and CO; the 3rd (2002/2/EC) sets a target value – that is a non-mandatory obligation – for O_3; and the 4th Daughter Directive (2004/107/EC) sets target values for arsenic, cadmium, mercury, nickel, and PAH.

Clean Air for Europe (CAFE) The Commission has announced proposals for a new Directive, which is currently being considered by Council and Parliament. The new Directive would set out new measures to control emissions from road transport, shipping, 'small' combustion plants and from domestic combustion, which are similar to those measures considered by the AQSR. CAFE also intends to take forward the better regulation agenda, as far as streamlining of several air quality regulations is concerned. The new Directive would consolidate and repeal four existing Directives: the Air Quality Framework Directive, and the 1st, 2nd, and 3rd Daughter Directives. The need for better regulation, and how it is taken forward by the review, is discussed further in section 5 of the RIA.

Euro Standards (1-4/I-IV) Since the early 1990s, Euro standards for cars, LDVs and HDVs have been applied limiting emissions for all newly manufactured vehicles sold in the European Union, with each subsequent Euro Standard setting more stringent emissions limits. The Euro 1/I Standard was phased in from 1992, Euro 2/II from 1996 and Euro 3/III from 2000, and Euro 4/IV standards will apply from 2006. These existing standards form part of Options D, G and H.

Euro Standards (5-6/V-VI) These standards will go further than there predecessors in setting tighter emissions limits for cars, LDVs and HDVs and proposals for these standards were published in December 2005 (Euro 5 will apply to cars and LDVs and Euro VI will apply to HDVs). The implementation dates for Euro 5/V are set at 2010 for cars and LDVs and 2011 for HGV. For Euro VI HGVs, the implementation date is set at 2013. The proposed implementation date of these standards are considered by Options A, A2, B, C and C2 and in combined options O, P, Q and R.

Box 4.1 EU directives relating to the Air Quality Strategy Review *(continued)*

Large Combustion Plants Directive (LCPD) The revised Large Combustion Plants Directive (2001/80/EC) aims to control emissions of SO_2, NO_x and PM_{10} from large combustion plants with a thermal output greater than 50MW and replaces the original LCPD adopted in 1988. These include plants in power stations, petroleum refineries, steelworks and other industrial processes running on solid, liquid or gaseous fuel. The proposed early implementation of this Directive is considered by Option K.

Small Combustion Plants Directive (SCPD) The proposed SCPD aims to control the emissions SO_2 and NO_x for combustion plants with a capacity of 20-50MW not captured by the LCPD. It is anticipated that this Directive will be introduced in 2008 and take effect in 2013. The proposed implementation of this Directive is considered by Option L.

4.2.2 Rationale for government intervention

612. While it is clear that the Government will meet many of the Strategy's existing objectives in most parts of the UK, projections show that in some parts of the country, particularly in some of our major urban areas and by busy roads, meeting the Strategy's remaining objectives will be challenging in the absence of additional policy measures. In particular we expect to miss objectives on three of the nine pollutants. These pollutants can cause significant harm to human health from respiratory and cardiovascular problems. In 2003, air pollution also led to over half of the UK's designated conservation sites being at risk or in unfavourable condition due to receiving harmful levels of acidity and/or nitrogen.

613. Specifically the objectives for PM_{10} annual and 24-hour mean values are expected to continue to exceed their specified limits well after their target achievement date at the end of 2010, and meeting objectives for the NO_2 annual mean and O_3 8-hour daily maximum mean, by 2005, will also be very challenging. Table 4.1 below sets out the existing air quality objectives, as agreed in the 2000 Air Quality Strategy and 2003 Addendum, in addition to EU limit values, and discusses the progress made in achieving them.

Table 4.1 – Air Quality Strategy objectives and progress so far

Pollutant	Objective*	To be achieved by (and maintained thereafter)	European obligations	To be achieved by (and maintained thereafter)	Progress so far in achieving AQS objectives and potential improvements by 2020
Nitrogen dioxide	$200\mu g.m^{-3}$ (105ppb) 1hr mean not to be exceeded more than 18 times a year	31 December 2005	Equivalent to AQS objective	1 January 2010	A great deal of progress has been achieved since 1990 with emissions and concentrations falling significantly. The national model indicates that 99.9% of background locations, about 98% of the population and about 60% of urban roads of the country expected to comply with the objective by 2005.[171] However current objectives have proven very challenging to achieve across the whole country.
	$40\mu g.m^{-3}$ (21ppb) annual mean	31 December 2005	Equivalent to AQS objective	1 January 2010	
Ozone	$100\mu g.m^{-3}$ (50ppb) 8hr mean not to be exceeded more than 10 times a year	31 December 2005	$100\mu g.m^{-3}$ not to be exceeded more than 25 times/yr over 3 yrs	1 January 2010	There has been progress in reducing peak ozone episodes. Monitoring information shows a decline in the number of times the daily 8 hour running mean exceeded $120\mu gm^{-3}$

[171] The national model is explained in Vol. 2, Ch. 1 of the Air Quality Strategy document.

Pollutant	Objective*	To be achieved by (and maintained thereafter)	European obligations	To be achieved by (and maintained thereafter)	Progress so far in achieving AQS objectives and potential improvements by 2020
Particles (PM_{10})	50µg.m^{-3} 24hr mean not to be exceeded more than 35 times a year	31 December 2004	Equivalent to AQS objective	1 January 2005	A great deal of progress has been achieved with emissions and concentrations falling significantly over the past few decades. The national model indicates that in 2003 about 99.9% of the area of England containing 99% of the population met the 24 hour objective for PM_{10}. Around 84% of urban roads in England also met the objective in 2003. Full compliance is expected at background locations in the UK by 2010, although around 0.3% of urban road length in the UK is still not expected not to comply by 2020. Under the 2010 objectives, it is estimated that only about 92% of background locations, 57% of population and about 20% of roads across in England will comply with the 2010 annual mean objectives by 2010. Full compliance of the objectives across the whole country is not expected even after 2020.
	40µg.m^{-3} annual mean	31 December 2004	Equivalent to AQS objective	1 January 2005	
	50µg.m^{-3} 24hr mean not to be exceeded more than 7 times a year for UK (apart from London)	31 December 2010	–	–	
	50µg.m^{-3} 24hr mean not to be exceeded more than 10 times a year for London	31 December 2010	–	–	
	20µg.m^{-3} annual mean for England (apart from London). Wales and N. Ireland	31 December 2010	–	–	
	23µg.m^{-3} annual mean for London	31 December 2010	–	–	
	18µg.m^{-3} annual mean for Scotland	31 December 2010	–	–	

Pollutant	Objective*	To be achieved by (and maintained thereafter)	European obligations	To be achieved by (and maintained thereafter)	Progress so far in achieving AQS objectives and potential improvements by 2020
Benzene	16.25µg.m^{-3} (5ppb) running annual mean	31 December 2003	–	–	We are on track or have met all these objectives
	5µg.m^{-3} (1.54ppb) annual average for England & Wales	31 December 2010	Equivalent to AQS objective	1 January 2010	
	3.25µg.m^{-3} (1ppb) running annual mean for Scotland & NI	31 December 2010	–	–	
1,3-Butadiene	2.25µg.m^{-3} (1ppb) running annual mean	31 December 2003	–	–	
Carbon monoxide	10mg.m^{3} (8.6ppm) max. daily running 8-hour annual mean	31 December 2003	Equivalent to AQS objective	1 January 2005	
Lead	0.5µg.m^{3} annual mean	31 December 2004	Equivalent to AQS objective	1 January 2005	We are on track or have met both these objectives
	0.25µg.m^{3} annual mean	31 December 2008	–	–	

Pollutant	Objective*	To be achieved by (and maintained thereafter)	European obligations	To be achieved by (and maintained thereafter)	Progress so far in achieving AQS objectives and potential improvements by 2020
Polycyclic Aromatic Hydro-carbons	0.25ng.m^{-3} B[a]P annual average	31 December 2010	1ng.m^{-3}	31 December 2012	There has been around a 75% reduction in total emissions of PAH since 1990. However, based on the latest baseline assessment we do not expect to meet this objective across the whole country.
Sulphur dioxide	350µg.m^{-3} (132ppb) 1hr mean not to be exceeded more than 24 times a year	31 December 2004	Equivalent to AQS objective	1 January 2005	We are on track or have met all these objectives. However a very small number of Local Authorities have declared Air Quality Management Areas for sulphur dioxide and, together with the relevant Regulators (such and the Environment Agency and SEPA), are working to improve the situation.
	125µg.m^{-3} (47ppb) 24hr mean not to be exceeded more than 3 times a year	31 December 2004	Equivalent to AQS objective	1 January 2005	
	266µg.m^{-3} (100ppb) 15mins mean not to be exceeded more than 35 times a year	31 December 2005	–	–	

* Objective applies to the UK unless otherwise indicated

614. Although it is important that any new policy measures identified for implementation help to meet those objectives that are currently not being achieved, it is also prudent to regard air pollution, caused by pollutants with no evidence of a threshold effect (such as PM), as having a significant impact on people's health in the UK even in areas that have already met the objectives set out in the table above. The initial assessments carried out for the Air Quality Strategy Review indicate that there are a number of policy options that, in addition to helping to meet the Air Quality Strategy objectives, might generate significant net benefits to the UK and contribute significantly to improving people's health and the environment in the UK.

615. There is no single measure to improve air quality and a package of measures needs to be deployed. Additional policy options can be defined at the international level (at the EU level, such as new Euro Standards for vehicle emissions, and beyond) and national and local levels. Such options can include regulatory approaches (i.e. emission standards for vehicle emissions and industrial and domestic combustion) as well as options designed to change behaviours (i.e. traffic management options or incentives for cleaner vehicles and road pricing). The options considered for the Air Quality Strategy are discussed in more detail in Chapter 4.4 of this RIA.

4.3 Consultation

4.3.1 Within government

616. Defra and the devolved administrations have set up an officials level interdepartmental group (IDG) to consider the air quality proposals for inclusion in the Air Quality Strategy, which includes representatives from Defra, devolved administrations, Department of Health, HM Treasury, Cabinet Office, DfT and DTI. This group has also worked closely with the IGCB, who have worked to produce in depth economic analysis on the proposed options. The IGCB report is published alongside the Air Quality Strategy.

4.3.2 Public consultation

617. Defra and the devolved administrations issued a consultation document, as part of the Air Quality Strategy Review process in April 2006, with the aim of securing stakeholders' comments on the review and, in particular, on additional policy options that have been assessed and could contribute to the further improvement of air quality. The responses from the consultation have been assessed and as a result, improvements have been made to the strategy. A summary of the responses to this consultation is available online[173].

618. During the formal consultation period Defra and the devolved administrations hosted a workshop in May 2006 to provide further information to stakeholders on the Review, and the opportunity to put forward and discuss their opinions on the proposed options ahead of their final response.

619. The review of the Strategy has also been developed and discussed with the Air Quality Forum of stakeholders from the initial stage. The Air Quality Forum (AQF) was established in 1998 to act as a mechanism for stakeholders to put their views to the Government on the review of the National Air Quality Strategy. The Forum, chaired by Defra, consists of representatives from around 30 external organisations and meets 3-4 times a year; representatives from government departments attend as observers. Minutes of the Forum and papers are online: http://www.defra.gov.uk/environment/airquality/panels/forum/index.htm.

4.4 Air Quality Objectives

620. The strategy does not propose withdrawing any objectives apart from replacing PM_{10} with the Exposure Reduction approach, as discussed below. The UK Government and devolved administrations have reviewed the case for retaining and introducing objectives, and the supporting evidence is set out in Volume 2, Chapter 1 of the Air Quality Strategy.

[173] Available from www.defra.gov.uk/corporate/consult/airqualstrat-review/responses-summary.pdf

They are also still justified as the UK Government and the devolved administrations would not want to see retrograde steps in human health and environmental protection. Further discussion of the objectives can be found in the Air Quality Strategy.

621. The objective for PM_{10} has been replaced in light of the evidence that using a limit value for non-threshold pollutants (i.e. those for which there is no safe level, such as particles) makes those policy objectives less likely to be cost-effective and less likely to maximise public health improvements. As Chapter 1 of this Volume of the Air Quality Strategy has indicated there are very few areas of exceedence of particles objective across the country. These tend to concentrate around busy roads where not many people are actually exposed to annual averaging periods. Current efforts to improve air quality are therefore focusing around these few areas rather than improving air quality everywhere, particularly in heavily populated areas which are already below the objective/limit value.

622. The exposure reduction approach moves away from the current objective/limit to focus on reducing people's exposure to pollutants. The two core components of this approach are:

- that air quality objectives/limit values are in place to ensure some basic level or quality of air for the entire population; and
- an objective based on reducing average exposures across the most heavily populated areas of the country, in order to produce further public health improvements.

623. The approach seeks the most effective and efficient way to maximise health benefits for non-threshold pollutants and ensure an overall reduction in exposure of the general population, irrespective of the concentrations at specific hotspots, which is instead the basis for the current limit value approach. Box 4.2 compares the costs and benefits of the two approaches and shows that the exposure reduction approach, rather than focussing on exceedences, can deliver health benefits in a more cost-effective manner.

Box 4. 2 Comparing the exposure reduction approach with the current objective/limit value approach[174]

As a practical way to illustrate and compare the two approaches, let us consider two alternative options: Option R, defined as a package of additional policy measures designed to reduce exposure in line with the exposure reduction approach (this option is presented along with the other policy options in section 4.5 of this RIA), and hypothetical scenario Z, that eliminates background exceedences across the whole of the UK by reducing all PM_{10} concentrations in areas above 20 $\mu g.m^{-3}$ down to 20 $\mu g.m^{-3}$. Table 4.1 below presents the impact on the baseline of both Option R and Scenario Z.

Table 4.2 – Comparing the exposure reduction approach with the existing approach

	Percentage of UK population above 20µg.m^{-3} (background areas only) in 2020[a]	Public health improvements, expressed as additional life years saved compared to baseline in 2020	Percentage exposure reduction in urban areas between 2010-2020, PM_{10}[b]	Percentage exposure reduction in urban areas between 2010-2020, $PM_{2.5}$[b]
Baseline	26.7%	0	6.7%	11.5%
Option R[c]	10.6%	3,744,942[d]	12.2%	17.7%
Scenario Z	0%	1,574,365	10.1%	13.4%

[a] Percentage of UK population leaving in areas above 20mg.m3 PM_{10} in 2020 (base year 2003)

[b] Urban areas above 100,000 residents

[c] For option R, it is noted that 2020 results can only be achieved from 2010 R results, not the 2010 baseline. In this case it reduces the exposure reduction from 17.7% to 16.3%. The 17.7% value is retained for easier comparison with scenario Z.

[d] For comparison with Scenario Z, the early incentivisation 20 year add on for Option R is not included in this table, which explains the discrepancy with Chapter 6 of this RIA. The results are for the no lag scenario.

The table above shows that Option R generates more than double the additional health benefits generated by Scenario Z (both compared to the baseline). However although Option R is expected to reduce exceedences of the 20µg.m^{-3} objective in 2020 from 26.7 per cent to 11.9 per cent, Scenario Z is expected to eliminate all background exceedences by 2020. Clearly we need to look at the relative balance of cost and benefits of each approach to help determine which is the more cost effective policy framework to improve public health. Table 4.3 below presents the estimated annual present value of additional cost and benefits for Option R and scenario Z when compared to the baseline.

Table 4.3 – Estimated annual cost and benefits of the two approaches

	Estimated Annual Present Value of Additional Benefits (£m)	Estimated Annual Present Value of Additional Costs (£m)
Baseline	0	0
Option R	831 – 1952	878 – 885
Scenario Z	349 – 820	Difficult to estimate in detail but likely to be very high (i.e. much higher than £885m) both in economic and social terms

Box 4.2 Comparing the exposure reduction approach with the current objective/limit value approach[174] *(Continued)*

For direct comparison with Scenario Z, the 20 year add-on early incentivisation assumption is not included in the benefits of Option R.

As indicated in the table above it is difficult to estimate the cost of Scenario Z since reducing exceedences at particular hotspot areas across the UK involves, by its own nature, very specific localised measures that are difficult to cost in details. It is anticipated, however, that costs would be very high since Scenario Z would involve actions such as:

- preventing road vehicles access to the city centres of major urban areas such as London;
- closing down certain roads in many urban areas and market towns, with significant wider economic impacts on businesses and employment;
- finding a way to reduce emissions from brake and tyre wear on road vehicles; and
- additional measures to address emissions from domestic and commercial heating, construction processes and non-road mobile machinery.

Therefore adopting an exposure reduction approach, rather than focussing on eliminating exceedences, may be able to deliver health benefits in a more cost-effective manner.

4.5 Options

624. Following consultation and discussions, the Air Quality Forum, IDG and IGCB agreed a short list of potential new measures that should be taken forward for analysis by the Air Quality Strategy Review in 2006. The short list of measures was based on a preliminary assessment of a longer list of possible additional measures, looking at the impact on air quality and initial assessment of costs and benefits, and on indications of measures the European Commission is considering, in particular what is expected to come out of CAFE (see Box 4.1). A balance was also sought, when short listing measures, between those policy options that adopt a more regulatory approach, such as implementing new Euro standards for vehicle emissions and the EU Directive on large combustion plants, as well as options designed to change behaviours, such as incentives for less polluting vehicles. Options presented in this RIA are based on new proposals or expected EU directives and as such do not involve the need to transpose any agreed EU legislation.

625. The short list of measures provides the basis for the options considered in this RIA that will help us achieve the Air Quality Strategy objectives and our legally binding EU pollutant limit values (see Table 4.1).

[174] Scenario Z has been calculated using a 100% formation rate for secondary PM and therefore is not consistent with the other estimated benefits in this RIA, this however means that the figures presented overestimate its relative benefit.

626. The options considered by this RIA are presented below. To avoid confusion with the way the options have been presented in the consultation document and IGCB report the baseline option is referred to as Option Ø to allow the lettering of the policy options to follow the manner used elsewhere.

627. The options considered in the Air Quality Strategy have been modelled in order to prioritise areas for further consideration. Areas taken forward will be subject to a full evaluation including detailed assessment across different implementation options. As a result the values provided by this modelling should be considered as indicative and may subsequently change as the result of further analysis.

Option Ø: Do nothing – the baseline

628. This option consists of the current measures, and future measures already set in legislation, deployed to help meet the air quality objectives set out in the 2000 Air Quality Strategy. This includes measures agreed and set by the European Union, such as Euro 4 standards for LDVs, the original LCPD and the Solvent Emission Directive (SED), and includes the review of energy projections, the latest traffic data published in the Future of Transport White Paper (2004) and the 2003 Air Transport White Paper.

Option A: New Euro standard 5/VI – low intensity

629. This option is based on the expected proposals for Euro 5 and VI vehicle standards. It proposes a 20% reduction in NO_x from all new diesel LDVs (Euro 5), a 90% reduction in PM from all new LDVs (Euro 5), and a 50% reduction in NO_x from new diesel HDVs (Euro VI). Based on current European Commission proposals, the implementation of new Euro standards will occur in line with expected implementation dates – 2010 for cars and LDVs (including cars) and 2013 for HDVs, after which the standards are expected to be mandatory for all new vehicles.

Option A2: Updated New Euro standard 5/VI – low intensity

630. This updated option is a new measure modelled to reflect later European Parliament proposals for new vehicle standards. The restrictions on emissions are tighter, calling for a 28% reduction in NO_x emissions from all new diesel LDVs in 2010 (Euro 5) and a 72% reduction from all new diesel LDVs in 2015 (Euro 6). In addition, all new petrol LDVs must reduce their NO_x emissions by 12.5% by 2010 and all new diesel HDVs must reduce NO_x emissions by 50% (Euro VI). All new diesel vehicles are also required to have 90% reduced PM emissions by 2010.

Option B: New Euro standard 5/6/VI – high intensity

631. This option is based on a more high intensity scenario for the expected proposals for Euro 5 and VI vehicle standards than option A. It proposes a 50% reduction in NO_x from all new petrol LDVs from 2010 (Euro 5), a 40% reduction in NO_x from new diesel LDVs from 2010 (Euro 5), and a 68% reduction in NO_x from all new LDVs from 2015 (Euro 6). The option also proposes a 75% reduction in NO_x from new HDVs from 2013 (Euro VI) and a 90% reduction in PM_{10} from all new diesel vehicles (HDVs + LDVs) (Euro 5/VI). The proposed dates of implementations of these standards are assumed to be the expected Commission implementation dates after which it is mandatory for all vehicles.

Option C: Programme of incentives for early uptake of Euro 5/V/VI standards

632. This option assumes that a programme of incentives is introduced for early introduction of Euro 5/V/VI to help achieve EU limit values; similar to policies implemented other EU countries such as Germany and Austria. This option would be implemented based on Option A (i.e. the policy reverts back to Option A after the incentives have taken effect). The uptake rates of these incentives are:

- 2007 25% Euro 5 LDVs, 15% Euro V HDVs
- 2008 50% Euro 5 LDVs, 23% Euro V HDVs
- 2009 75% Euro 5 LDVs (Euro V now mandatory for HDVs)
- 2010 25% Euro VI HDVs (Euro 5 now mandatory for LDVs)
- 2011 50% Euro VI HDVs
- 2012 75% Euro VI HDVs
- 2013 (Euro VI now mandatory for HDVs)

Option C2: Programme of incentives for early uptake of Euro 5/V/VI (revised scenario)

633. Option C2 is a new measure proposing a programme of incentives, based on the new Option A2 to introduce the Euro standards 5/V/VI for all diesel vehicles. In this scenario the impacts of this option revert back to Option A2 after the new standards become mandatory. The uptake rates of this option are as follows:

- 2007 0% Euro 5 LDVs, 15% Euro V HDVs
- 2008 33% Euro 5 LDVs, 47.5% Euro V HDVs
- 2009 66% Euro 5 LDVs (Euro V now mandatory for HDVs)
- 2010 25% Euro VI HDVs (Euro 5 now mandatory for LDVs)
- 2011 50% Euro VI HDVs
- 2012 75% Euro VI HDVs
- 2013 33% Euro 6 LDVs (Euro VI now mandatory for HDVs)
- 2014 66% Euro 6 LDVs
- 2015 Euro 6 now mandatory for LDVs

Option D: Programme of incentives to phase out the most polluting vehicles

634. Under this option, two options are considered:

- **Option D1:** This option models incentivising the scrappage of all pre-Euro cars (emissions only modelled)
- **Option D2:** This option models incentisiving the scrappage of all pre Euro and Euro-I cars (concentrations modelling)

635. This option would be introduced in 2007. All pre-Euro cars in scenarios D1 & D2 and the Euro-I passenger cars in scenario D2 are assumed to be scrapped at rates of: 25% by 2007, 50% by 2008 and 100% by 2009.

Option E: Updated programme of incentives to increase penetration of low emission vehicles (LEVs)

636. This option proposes an updated programme of incentives to increase penetration of petrol LEVs to 10% by 2010 and 25% by 2020, and increase penetration of diesel LEVs to 5% by 2010 and 20% by 2020. In the context of this option, LEVs are defined as any vehicles meeting emission standards better than those set by Euro 4 for NO_X and PM_{10} and below the current industry voluntary agreement for carbon. This option was modelled to introduced from 2006 and is assumed to apply to new cars only.

Option F: Impact of national road pricing scheme on air quality

637. The option considers the impact of a hypothetical national pricing scheme on air quality based on the work that was done for the Road Pricing Feasibility study[175]. Although the primary objective of such a scheme is to reduce the externality of congestion, air quality benefits could also be produced. A national road pricing scheme could take a variety of different forms and this analysis considers only one possible variant for illustrative purposes only in order to give an indication of the potential impacts. No decisions have been taken on whether or not national road pricing would be introduced, what form it might take, or how it might operate. It is highly unlikely that any 'real world' scheme would reflect the scenario that has been used for this assessment. This option will use the impacts from emission modelling in the above study as a basis for projections from 2015.

Option G: A London Low Emissions Zone (LEZ) for Greater London and replicating in the seven largest UK urban areas

638. Under this option, three options are considered:

- **Option G1**: The proposed London LEZ first phase (2007), which is planning to introduce a Euro II + Reduced Pollution Certificate (RPC) standard for all HGVs and coaches (all buses are assumed to comply under the mayoral strategy).
- **Option G2**: Phase 2 of the proposed London LEZ, which is planning to introduce a Euro III + RPC standard for all HGVs, coaches and buses in 2010.
- **Option G3**: An equivalent scheme Euro II + RPC standard (equivalent to the London first phase) introduced in 2010 in seven other major areas (applied to the central areas of Glasgow, Manchester, Liverpool, Sheffield, Newcastle, Birmingham, and Leeds)

Option H: Retrofit diesel particulate filters (DPFs) on HGVs and captive fleets (buses and coaches)

639. Under this option, three options are considered:

- **Option H1**: 65% of pre-Euro I to Euro IV HDVs are retrofitted with DPFs with Fuel Borne Catalysts (FBCs) by 2010
- **Option H2**: 20% of pre-Euro I to Euro IV HDVs are retrofitted with DPFs by 2010

175 Feasibility Study of Road Pricing in the UK', Department for Transport (2004). Available at http://www.dft.gov.uk/stellent/groups/dft_roads/documents/divisionhomepage/029798.hcsp

- **Option H3**: 35% of pre-Euro I to Euro IV HDVs are retrofitted with DPFs by 2010.

640. This option is modelled based on an introduction in 2006.

Option I: Domestic Combustion – Switch from coal to natural gas or oil

641. This option assumes a switch from coal to natural gas (70% in Great Britain) or to oil (30% in Great Britain). In Northern Ireland, this option assumes a larger switch from coal to oil (70%) and smaller switch to gas (30%) is assumed. This option would be introduced and fully implemented in 2010.

Option J: Domestic combustion – Product standards for gas fired appliances which require tighter NOx emission standards

642. This option proposes that new gas fired appliances fitted after 2008 are fitted to at least the CEN 483 Class 4 standard[176]. The option assumes a replacement rate of 5% of the boilers assumed per year and as such assumes a 20 year lifespan of existing older 'high NO_x' boilers.

Option K: Large combustion plant option

643. Under this option, two options are considered:

- **Option K1**: This option would bring forward by six years, to 2010, the requirement of the revised LCPD to implement selective catalytic reduction (SCR) on coal fired power stations with thermal generating capacities of more than 300 MW. Including this option allows us to assess the benefit of bringing forward the implementation of the revised LCPD and whether it would help us meet legally binding EU limit values that we are current failing.

- **Option K2**: This option assumes SCR implementation on gas fired power stations with thermal generating facilities of more than 300MW, iron and steel plants and petrol refineries by 2010.

Option L: Small combustion plant option

644. This option proposes a 50% reduction in NO_X and SO_2 emissions in small combustion plants (with a thermal generating capacity of between 20-50 MW) by 2008. The 50% reduction in SO_2 is achieved by the use of low sulphur fuels. The 50% in NO_x is achieved through combustion modifications. This option is due to be applied in 2008, following a possible EU Small Combustion Plant Directive or a revision to the existing IPPC or LCPD Directive, and take effect by 2013.

Option M: Reduce national volatile organic compounds (VOC) emissions by around 10 per cent

645. This option proposes a reduction of national VOC emissions by 10% by 2010, based on the following options:

- Petrol Vapour Recovery (Stage II controls) for station with throughput >3,000m³

[176] Information on CEN standards can be found on www.cen.eu

- Chemical and man made fibre production
  - Thermal oxidation
  - Road tanker vapour recovery
  - Storage tank replacement programme
  - Leak detection and repair
  - Second stage vapour recovery unit
  - Cryogenic condensation
- Offshore loading of crude oil
  - Modification to shuttle tankers
  - Modification to floating production, storage and off-take vessels
  - Vapour recovery unit (from ship loading)

Option N: Reducing emissions from shipping

646. The modelling for this option is based on an assumption that there would be a requirement on all ships (greater than 100 tonnes) from 2010, to reduce sulphur emissions from both old and new vessels (it assumes a move in waters surrounding the UK to 1% sulphur fuel from the current standard of 1.5% sulphur fuel)[177] and a reduction in NO_X emissions by 25% from new ships. The introduction rate of new ships is assumed to be $1/30^{th}$ of the fleet per year. This option represents only one of a number of options that are currently on the table for discussion at the International Maritime Organisation (IMO) and does not necessarily represent the UK's preferred position.

4.5.1 Combined measures

647. A number of packages of the potential additional policy measures have also been assessed, and separately modelled, in order to provide information on the impacts and costs and benefits of implementing more than one of the additional measure in combination.

Option O: Combined Option C + E

648. This option combines Options C and E discussed above.

Option P: Combined Option C + L

649. This option combines Options C and L discussed above.

Option Q: Combined Option C + E + L

650. This option combines Options C, E and L discussed above.

Option R: Combined measure C2 + E + N

651. This option combines Options C, E and N discussed above.

652. The following options (Options S, T and U) are also being considered by the Air Quality Strategy for their potential air quality benefits based on existing work carried out for the Climate Change Programme Review in 2006. However due to time and resource

177 The assumption of the baseline figure of 1.5% sulphur fuel is derived from the current Sulphur Emission Control Area (SECA) system that is applicable in the majority of the waters surrounding the UK. However the real average sulphur content is likely to be higher as the current global limit of 4.5% sulphur fuel applies in wider waters.

constraints and the difficulty in modelling these measures at a national level, these measures have not been subject to full national assessments.

Option S: Smarter Choices

653. This option refers to measures that balance the need to travel with the aim of improving quality of life. These 'Smarter Choices' can offer a variety of alternative travel modes that can result in a reduction in car usage – for example by providing better public transport information, personalised travel planning, car sharing schemes, teleworking and teleconferencing. The fundamental objective is to influence people's travel behaviour to more sustainable options thus reducing car dependency and thereby achieving lower traffic levels.

Option T: Sustainable Distribution

654. This option would target freight movements and attempt to reduce their impact on the environment, other road users, and to improve safety by extending the provision of road haulage schemes which offer drivers best practice advice on fuel saving measures and promote safer and more fuel efficient driving or by securing the shift of freight from road to rail or water transport.

Option U: Traffic Speed Changes

655. This option attempts to realise the potential fuel efficiency benefits from limiting the speed at which vehicles travel, with related benefits on carbon and air quality pollutant emissions. Therefore two potential additional measures were assessed: a) reducing 70mph speed limits to 60mph, and; b) better enforcement of the 70mph speed limits.

4.6 Costs and benefits

656. The options that have been subject to a full assessment (i.e. Options A-R) have been assessed using a common assessment framework, in order that they can be more easily compared, and assessed against a common baseline (Option Ø) to account for what would have happened anyway. The framework for assessment has been agreed within the IGCB and the methodology is set out in detail in the IGCB report that accompanies this document. Options S-U have not been subject to full national assessment or cost benefit analysis in this document.

Box 4.3 Simplification of air quality policy

Air quality regulations are estimated to account to account for approximately £10.8m per annum in administrative burden, or around 3.5% of Defra's total estimated burden[178]. Table 4.4 below disaggregates the total cost by regulation and source based on the PriceWaterhouseCoopers (PWC) baseline exercise.

Table 4.4 – Administrative burden by regulation and source

Regulation	Source		Total estimated administrative burden (£m per annum)
	International	Domestic	
Pollution Prevention and Control Regulations 2000	12.7482	9.5367	22.2849
Code of Good Agricultural Practice for the protection of air	0.0000	1.2007	1.2007
Environmental Protection Act 1990	0.0000	0.0327	0.0327
Waste Incineration 2002	0.0400	0.0000	0.0400
Large Combustion Plants Directive	0.0006	0.0000	0.0006
Total	**12.78**	**10.77**	**23.56**

The table above shows how effective the application of this legislation has been in avoiding imposing unnecessary administrative burdens. Only five air quality regulations were identified as imposing an administrative burden on business. Within these two regulations, the Pollution Prevention and Control Regulations 2000 (PPC) and the Code of Good Agricultural Practice for the protection of air (COGAP(air)), together account for over 99% of the burden.

[178] Estimated from the Admin Burdens Measurement Exercise. Available from www.cabinet-office.gov.uk/regulation

Box 4.3 Simplification of air quality policy *(Continued)*

Simplification of the PPC regulations is being considered under the Environmental Permitting Programme (EPP) and the Better Regulation Review of Part B activities. Proposals under the current EPP consultation identify potential savings of £72m over 10 years. In addition a Better Regulation Review is underway on the 4,000 processes regulated by Local Authorities. The substantive analysis of the sectors involved is now in progress, and a second consultation with detailed proposals and a RIA will be issued late in 2007. Their holistic review is also being undertaken of the Codes of Good Agricultural Practice in respect to Air, Water and Soil. This review is looking to consolidate these codes in order to reduce overlap and minimise any unnecessary burden on businesses.

We are also undertaking a range of simplification measures on regulations that are not identified in the baseline as having a significant burden on business which include:

- Stage 2 petrol vapour recovery
- 4th Air Quality Daughter Directive
- Ambient Air Quality Directive
- Clean Air for Europe Programme
- Promotion of Clean Vehicles
- Smoke Control Exempted Fireplaces Order
- Review the Sulphur Content of Liquid Fuels Directive
- Review of the National Emissions Ceiling Directive
- Review of the UNECE Gothenburg Protocol
- Emissions from Shipping
- Euro Standards
- Fuel Quality Directive
- Aviation

657. The assessment of these proposals has been undertaken in a way that is fully consistent with the better regulation agenda. Proposals identified for implementation will be subject to full regulatory scrutiny prior to introduction including detailed Impact Assessments. The key better regulation change being the introduction of the exposure reduction approach as discussed in Chapter 4.4 of this RIA. Box 4.3 outlines the work currently underway to simplify and offset any new regulatory burdens from the new measures.

658. Each option subject to a full assessment has been assessed against a number of criteria:

- Monetary cost benefit analysis;
- Exceedences of agreed limit values;
- Impact on ecosystems and vegetations; and
- Qualitative assessments, e.g. noise, additional health impacts.

659. Each of the assessments undertaken has uncertainties associated with it and it is important that the results from each assessment are considered as a whole. The following provides a brief outline of the different assessments undertaken:

4.6.1 Cost benefit analysis

660. There are a range of health and non-health impacts that have been assessed as part of the CBA:

- The chronic mortality impacts of changes in PM_{10} concentrations in terms of the number of life years saved.
- The impact on respiratory hospital admissions as a result of changes in PM_{10} concentrations (PM – RHA).
- The impact on cardiovascular hospital admissions as a result of change in PM_{10} concentrations (PM – CHA).
- The acute mortality impacts of changes in O_3 concentrations.
- The impact on respiratory hospital admissions as a result of changes in O_3 concentrations (O_3 RHA).
- The acute mortality impacts of changes in SO_2 concentrations (where applicable).
- The impact on respiratory hospital admissions as a result of changes in SO_2 concentrations (SO_2 RHA) (where applicable).
- The social cost of the change in carbon emissions.
- The direct effects of O_3 on crop yields.
- Building soiling caused by PM_{10} and materials damage from O_3 and SO_2.

661. Health and non-health impacts have been valued in accordance with the methodology set out in the IGCB report that accompanies this document. These values have then been annualised and discounted, using 2005 as the base year, in line with current HM Treasury Green Book guidance of a 3.5% discount rate, declining after 30 years. Numbers presented in brackets represent a disbenefit created by the impact concerned.

662. There are two main types of uncertainty that arise when calculating expected health impacts from a change in pollutant levels. First, there is uncertainty associated with the relationship between air pollution and health outcomes, such as whether air pollution causes chronic and/or acute health effects. Second, there is uncertainty associated with the quantification of such health impacts. To try and address this issue the analysis has used a different approach for different pollutants (the rationale and evidence for these approaches are discussed in Chapter 2 of the IGCB report):

- Particulate matter health impact, annual present values and the overall Net Present Value (NPV) results have been presented using a 6% hazard rates as recommended by the Department of Health's Committee on the Medical Effects of Air Pollutants (COMEAP). Hazard rates, or concentration-response coefficients, reflect the assumed change in health impacts resulting from a change in pollutant. The 6% hazard rate therefore assumes a 6% change in life years lost per 10µg.m^{-3} change in PM. There is however significant uncertainty surrounding this co-efficient that are reflected in the sensitivity analysis within the IGCB report.[179]

- Particulate matter health impacts and annual present values (PVs) have been presented as a range assuming a 0-year lag and a 40-year lag, given inconclusive evidence as to the exact lag time between the changes in PM_{10} concentrations and chronic health impacts. Although the evidence is limited, recent expert judgement from COMEAP tends towards a greater proportion of the effect occurring in the years soon after a pollution reduction rather than later. This suggests that more weight should be given to results towards the 0-year lag end of the 0-40 year lag range given in each life years column in the forthcoming tables.[180]
- Ozone effects have been presented as a range using both a zero threshold and a 50ppb threshold due to the uncertainty as to the appropriate threshold to apply.

663. Costs have been presented in terms of the impact to society as a whole and in 2005 prices. As far as possible, costs have been assessed over the same timeframes as the benefits and have been discounted in the same way, i.e. using a discount rate of 3.5%, declining after 30 years.

664. There is considerable uncertainty surrounding the cost estimates. For example, new technology and innovation may impact on the future costs of policy implementation making it difficult for CBA to adequately predict actual costs.[181] For some options, a range of costs has been used reflecting different underlying assumptions about the costs and these are presented in this analysis. For further details see: Chapter 3 of the IGCB report that discusses this issue in more detail; Chapter 5 which provides sensitivity analyses for each of the options considered in the review; and Annex 7 provides a Monte Carlo analysis combining the key sensitivities, in line with Treasury Green Book guidance.

4.6.2 Exceedences

665. The exceedences assessment analyses the impact that each of the options may have in terms of moving us closer to reducing and/or eliminating the existing gaps in meeting our air quality objectives. It estimates the change in exceedences, compared to the baseline (Option Ø), of objectives for PM_{10} and NO_2, resulting from the additional measures. The assessment considers the following objectives as a percentage of both the total background area and total road length (urban roadside):

- Percentage exceeding a NO_2 annual mean value of 40µg.m^{-3}
- Percentage exceeding a PM_{10} annual average of 31.5µg.m^{-3}, gravimetric (equivalent to 36 exceedences of the a 24 hour average of 50µg.m^{-3})

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[179] Hazard rates (also referred to as dose-response coefficients) are based on the latest recommendations from the Department of Health's COMEAP (published on 18 January 2006) recommend a 6% hazard rate as the best estimate with an interim uncertainty range of 2% to 11%. A 6% hazard rate has been proposed by the WHO/UNECE Task Force on Health Aspects of Air Pollution and adopted by the EC CAFE programme. Further details can be found in IGCB Chapter 2.

[180] The probabilities of the different lag times is discussed further in the Monte Carlo analysis presented in Annex 7 of the IGCB report. This analysis uses the conservative assumption that 30% of the damage occurs between up to 5 years after exposure.

[181] The Evaluation of the Air Quality Strategy, carried out in 2004, found that, in the majority of cases, actual costs associated with the implementation of air quality policies, were lower than costs that had been predicted prior to implementation. The report can be found at http://www.defra.gov.uk/environment/airquality/strategy/evaluation/report-index.htm.

- Percentage of total road length exceeding an PM_{10} annual average of $20\mu g.m^{-3}$, gravimetric (annual average objective for England in 2010, not including London)

666. Results are presented for the impacts on exceedences as a percentage reduction from the baseline projections and are presented in the summary table, for each option, which shows the range of exceedence reductions that are expected to be achieved by the option (i.e. a range from the objective showing the smallest reduction to the objective showing the greatest reduction). Full results for the exceedences assessment can be found in Volume 2, Chapter 2 of the Air Quality Strategy.

667. Owing to changes in the modelling assumptions following the Air Quality Strategy Review Consultation, the exceedences estimates for PM can not directly be compared between the measures to be taken forward in the strategy (A2, C2, E, N and R) and the other measures. While this has been addressed in the monetary CBA it has not been possible to undertake this analysis again for all the measures. The exceedence values therefore should only be considered to be indicative for the measures "requiring additional development work" or "no longer under immediate consideration".

4.6.3 Ecosystems and vegetation

668. The impact of each option on ecosystems and vegetation has been assessed through their impact on the exceedence of critical loads.[182] Following an initial assessment, options that are expected to lead to a reduction in critical loads exceedence of more than 2% have been modelled using the FRAME model to determine the quantified impacts on ecosystems. For these options, the following impacts are presented in this RIA for both acidity and nutrient nitrogen deposition:

- percentage reduction in exceeded area – this is the additional reduction, beyond the BAU case, in the areas of ecosystems exceeding critical loads, expressed in percentage terms
- percentage reduction in accumulated exceedence – this is the additional reduction, beyond BAU case, of the accumulated exceedence of critical loads (a combination of area exceeded and magnitude of exceedence), expressed in percentage terms

669. The results are also presented in the summary tables for each policy option with those options generating an above 2% reduction in critical loads exceedence *and* accumulated exceedence defined as a 'significant positive impact' on critical loads and other options generating little or no impact. Further discussion of the model and methodology used for this analysis can be found in Volume 2, Chapter 2 of the Air Quality Strategy.

[182] The 'critical load' of a specified pollutant represents the maximum pollutant deposition that can occur without any significant harmful effects on the environment. As such, an exceedence of the critical load would represent a negative impact, which is qualitatively assessed according to methodology set out in Chapter 4 of the IGCB report.

4.6.4 Qualitative assessment

670. For some impacts, it has been concluded that valuation is not possible at this time. It is important that the non-valued impacts are taken into account when assessing the different policy options, rather than conclusions being drawn solely from the monetary CBA and other quantified impacts. The following impacts have been subject to qualitative assessment where applicable:

- Social impacts (SI) – The existing evidence linking air quality and distributional (i.e. social and socio-economic) effects has been assessed and used as the basis of a qualitative assessment of the options discussed. Chapter 4 of the IGCB report provides more analysis and discussion of these results but an indication of the likely social impact of each option is presented in the summary table for each option in the RIA, with SI+ indicating a positive impact and SI– indicating a negative impact.
- Noise (N) – Noise affects amenity and numerous surveys have shown it to be a major nuisance. It may also lead to a number of health impacts through a variety of direct and indirect effects, though there is considerable debate on the reliability of the evidence. The expected impacts of noise are discussed, where applicable, and an indication of the likely impact on noise levels of each option is presented in each summary table, with N+ indicating a positive impact and N- indicating a negative impact.
- Additional health impacts (H) – In addition to the health impacts quantified and monetised in the cost-benefit analysis, further health impacts have been qualitatively assessed. This includes the assessment of specific health impacts of additional pollutants, such as benzene and 1,3-butadiene, where there is consensus that a particular health impact is linked to the relevant pollutant (although the health impacts are likely to be small given that the options considered were not designed to tackle the specific health effects of these pollutants). Chapter 4 of the IGCB discusses these assessments in more detail. An indication of the likely additional health impacts of each option is also presented in each summary table, where applicable, with H+ indicating a positive impact and H- indicating a negative impact.
- Competition and small business (C) (SB) – This assessment is carried out separately under Chapters 4.7 and 4.8 of this RIA although an indication of the likely impact of each option is presented in each summary table, with C+ or SB+ indicating a positive impact on competition or small business respectively and C- or SB- indicating a negative impact.

671. An initial assessment of the potential rural impacts of the proposed options has also been made but found none of the proposed options are likely to adversely affect rural areas. This issue will be reconsidered, as part of further assessments, when more detailed Impact Assessments are drawn up for those options that are taken forward, to ensure rural circumstances and needs are properly accounted for.

Option Ø: Do nothing

672. This option consists of the current measures, and future measures already set in legislation, deployed to help meet the air quality objectives set out in the 2000 Air Quality Strategy only. Modelling has estimated the impacts of the 'do nothing' option on health, exceedences of air quality objectives and impacts on ecosystems through exceedences of critical loads. These baseline figures provide the basis for the comparison and assessment of the impact of the additional measures detailed in Options A – R.

673. Table 4.5 below sets out the estimated monetised health impacts of the 'do nothing' option, as discussed in CBA methodology at beginning of this section and based on the changes in baseline pollutant concentrations between 2003 and 2020. It should be noted that the present values of the health impacts presented for the additional policy options in this RIA are incremental to the baseline valuations presented below.

Table 4.5 – Annual present value of health impacts of Option Ø (£ million)

PM life years saved – 6%	PM – RHA	PM – CHA	O_3 Mortality*	O_3 RHA*
3,482 – 8,181	5 – 23	5 – 23	(44) – (2)	(62) – (1)

*Ozone valuations based on concentration changes relative to 2003 not 2005 (2005 not modelled)

674. Further details of all the health impacts assessed in this table can be found at the beginning of Chapter 4.6 of this RIA.

675. As Table 4.1 shows, some of the Strategy's objectives are, and will remain, very challenging without further measures. Therefore under the 'do nothing' option, the following exceedences of air quality objectives are expected in 2020:

- 7.1% exceedence of NO_2 urban roadside and no exceedence of NO_2 background annual average (40µg.m^{-3} annual average).
- 0.3% exceedence of PM_{10} urban roadside and no exceedence of PM_{10} background annual average (<31.5µg.m^{-3} annual mean).
- 60.5% exceedence of PM_{10} urban roadside and 2.6% exceedence of PM_{10} background annual average (<20µg.m^{-3} annual mean).

676. The impacts of the policy options discussed below represent a percentage reduction in these baseline figures.

677. In addition, under the do nothing option, the baseline impact on ecosystems is expected to show an exceedence of critical loads for the following total areas:

- For acidity levels, 30,742 km² of ecosystems area are expected to exceed critical loads in 2020 with an accumulated exceedence of 1,875,050 keq/yr by 2020.[183]
- For nutrient nitrogen deposition, 35,789 km² of ecosystems area are expected to exceed critical loads in 2020 with an accumulated exceedence of 2,771,792 keq/yr by 2020.

678. The impacts of the policy options discussed below represent a percentage reduction in these baseline figures.

[183] 'Keq/yr' denotes kilograms equivalent per year.

Option A: New Euro standard 5/VI – low intensity

679. Option A is a long–term measure aimed at the transport sector and primarily affecting vehicle and engine manufacturers/suppliers; manufacturers and suppliers of exhaust after treatment systems; and owners/operators of vehicles. Costs and benefits have been analysed over a period of 100 years from 2010 in accordance with the methodology set out in Chapter 2 of the IGCB report.

Benefits

680. Tables 4.6 and 4.7 set out the estimated monetised health and non-health impacts of Option A, based on pollutant concentrations data. In addition Option A is expected to have the following impact on exceedences by 2020:

- 44% reduction in urban roadside exceedences of NO_2 (40µg.m^{-3} annual average).
- The removal of all urban roadside exceedences of PM_{10} (<31.5µg.m^{-3} annual mean).
- 50% reduction in background exceedences and 49 percent reduction in urban roadside exceedences of PM_{10} (<20µg.m^{-3} annual mean).

681. Option A is also expected to lead to a reduction in ecosystem areas where critical loads have been exceeded by 2.7% nutrient nitrogen and 1.8% for acidity, and reductions in accumulated exceedence of critical loads by 3.8% and 4.1% respectively. For social impacts, Option A would create benefits from reducing road-side concentrations of pollutants and probably greater benefits for more deprived areas by reducing high concentrations of pollution.

Table 4.6 – Annual present value of health impacts of implementing Option A (£ million)

PM life years saved	PM – RHA	PM – CHA	O_3 Mortality	O_3 RHA
518 – 1,219	1 – 3	1 – 3	(4) – (0.12)	(5) – (0.09)

Table 4.7 – Annual present value of non-health impacts of implementing Option A

	(£ million)
Annualised social cost of carbon	(46)
Annualised PV of impact on crop yields	2
Annualised PV of impact on buildings and materials	2

Costs

682. The costs of this option are driven primarily by the resource costs of the incremental technologies (beyond Euro 4/V) that have to be implemented to achieve the required emission reductions. The other costs of this option include the impacts of the changes in fuel economies of vehicles compared to Euro 4/V vehicles, which include the changes in resource costs of fuel, as well as the welfare impacts of changes in the vehicle kilometres travelled due to changes in fuel efficiency. It is expected that vehicle manufacturers will bear the additional technologies costs under this option and vehicle operators/owners will bear the resource and welfare costs, although it is anticipated that manufacturers will

pass on (as far as relative competitiveness impacts allow) the technology costs to the end user through higher prices. The total costs of the implementation of this option in the UK are presented in Table 4.8 below. The costs are presented as a range due to different assumptions regarding technology costs.

Table 4.8 – Costs of implementing Option A in the UK (2005 prices)

	(£ million)
Annualised technology costs	262 – 268
Annualised resource cost of extra fuel consumed	119 – 120
Annualised welfare impact due to rebound effect	1
Annualised present value of costs	382 - 389

Summary

683. The summary costs and benefits for Option A2 are presented in Table 4.9 below, including the annualised net present value (NPV) figures, which represent the difference between annualised benefits and annualised costs. The results show that this option could potentially achieve quantifiable net benefits of £801 million.

Table 4.9 – Costs and benefits of implementing Option A in the UK (£ million)

Annual PV of Costs	Annual NPV	Exceedences assessment[184]	Ecosystems assessment	Qualitative assessments
382 – 389	80 – 801	Between 44% and 100% reduction for individual objectives	Significant positive impact on critical loads	SI+

Option A2: Updated Euro 5/6/VI measure

684. Option A2 is a long–term measure aimed at the transport sector and primarily affecting vehicle and engine manufacturers/suppliers; manufacturers and suppliers of exhaust after treatment systems; and owners/operators of vehicles. Costs and benefits have been analysed over a period of 100 years from 2010 in accordance with the methodology set out in Chapter 2 of the IGCB report.

Benefits

685. Tables 4.10 and 4.11 set out the estimated monetised health and non-health impacts of Option A2, based on pollutant concentrations data. In addition Option A2 is expected to have the following impact on exceedences by 2020:

- 61% reduction in urban roadside exceedences of NO_2 (40µg.m^{-3} annual average).
- The removal of all urban roadside exceedences of PM_{10} (<31.5µg.m^{-3} annual mean).
- 42 per cent reduction in background exceedences and 46% reduction in urban roadside exceedences of PM_{10} (<20µg.m^{3} annual mean).

[184] This summary shows the lowest and highest expected impact by 2020 on baseline exceedences across all objectives and does not represent a range for individual objectives

686. Option A2 is also expected to lead to a reduction in ecosystem areas where critical loads have been exceeded by 3.4% for nutrient nitrogen and 2.8% for acidity, and reductions in accumulated exceedence of critical loads by 7.3% and 7.6% respectively. For social impacts, Option A2 would create benefits from reducing road-side concentrations of pollutants and probably greater benefits for more deprived areas by reducing high concentrations of pollution.

Table 4.10 – Annual present value of health impacts of implementing Option A2 (£ million)

PM life years saved	PM – RHA	PM – CHA	O_3 Mortality	O_3 RHA
584 – 1,366	1 – 4	1 – 4	(5) – (0.05)	(5) – (0.05)

Table 4.11 – Annual present value of non-health impacts of implementing Option A2

	(£ million)
Annualised social cost of carbon	(51)
Annualised PV of impact on crop yields	2
Annualised PV of impact on buildings and materials	2

Costs

687. The costs of this option are driven primarily by the resource costs of the incremental technologies (beyond Euro 4/V) that have to be implemented to achieve the required emission reductions. The other costs of this option include the impacts of the changes in fuel economies of vehicles compared to Euro 4/V vehicles, which include the changes in resource costs of fuel, as well as the welfare impacts of changes in the vehicle kilometres travelled due to changes in fuel efficiency. It is expected that vehicle manufacturers will bear the additional technologies costs under this option and vehicle operators/owners will bear the resource and welfare costs, although it is anticipated that manufacturers will pass on (as far as relative competitiveness impacts allow) the technology costs to the end user through higher prices. The total costs of the implementation of this option in the UK are presented in Table 4.12 below. The costs are presented as a range due to different assumptions regarding technology costs.

Table 4.12 – Costs of implementing Option A2 in the UK (2005 prices)

	(£ million)
Annualised technology costs	648 – 652
Annualised resource cost of extra fuel consumed	139 – 140
Annualised welfare impact due to rebound effect	1
Annualised present value of costs	788 – 793

Summary

688. The summary costs and benefits for Option A2 are presented in Table 4.13 below, including the annualised NPV figures, which represent the difference between annualised benefits and annualised costs. The option could potentially achieve quantifiable net benefits of £539 million though at the low end potential net costs of £264 million are observed.

Table 4.13 – Costs and benefits of implementing Option A2 in the UK (£ million)

Annual PV of Costs	Annual NPV	Exceedences assessment[185]	Ecosystems assessment	Qualitative assessments
788 – 793	(264) – 539	Between 46% and 100% reduction for individual objectives	Significant positive impact on critical loads	SI+

Option B: New Euro standard 5/6/VI – high intensity

689. Option B is a long–term measure aimed at the transport sector and primarily affecting engine manufacturers/suppliers; manufacturers and suppliers of exhaust after treatment systems; and owners/operators of vehicles. Costs and benefits have been analysed over a period of 100 years from 2010 in accordance with the methodology set out in Chapter 2 of the IGCB report.

Benefits

690. Tables 4.14 and 4.15 set out the estimated monetised health and non-health impacts of Option B, based on pollutant concentrations data. In addition Option B is expected to have the following impact on exceedences by 2020:

- 89% reduction in urban roadside exceedences of NO_2 (40µg.m^{-3} annual average).
- The removal of all urban roadside exceedences of PM_{10} (<31.5µg.m^{-3} annual mean).
- 62% reduction in background exceedences and 64% reduction in urban roadside exceedences of PM_{10} (<20µg.m^{-3} annual mean).

691. Option B is also expected to lead to a reduction in ecosystem areas where critical loads have been exceeded by 5.3% for nutrient nitrogen and 3.8% for acidity, and reductions in accumulated exceedence of critical loads by 8.2% and 8.9% respectively. For social impacts, Option B would create benefits from reducing road-side concentrations of pollutants and probably greater benefits for more deprived areas by reducing high concentrations of pollution.

Table 4.14 – Annual present value of health impacts of implementing Option B (£ million)

PM life years saved	PM – RHA	PM – CHA	O_3 Mortality	O_3 RHA
669 – 1,571	1 – 4	1 – 4	(8) – (0.21)	(10) – (0.17)

[185] This summary shows the lowest and highest expected impact by 2020 on baseline exceedences across all objectives and does not represent a range for individual objectives

Table 4.15 – Annual present value of non-health impacts of implementing Option B

	(£ million)
Annualised social cost of carbon	(86)
Annualised PV of impact on crop yields	2
Annualised PV of impact on buildings and materials	2

Costs

692. Similar to Option A, the costs of this option are driven primarily by the resource costs of the incremental technologies (beyond Euro 4/V) that have to be implemented to achieve the required emission reductions. Since the emission requirements are more stringent for this Option, the technology required is more expensive. The other costs of this option include the impacts of the changes in fuel efficiencies of vehicles compared to Euro 4/V vehicles, which include the changes in resource costs of fuel, as well as the welfare impacts of changes in the vehicle kilometres travelled due to changes in fuel efficiency. It is expected that vehicle manufacturers will bear the additional technologies costs under this option and vehicle operators/owners will bear the resource and welfare costs, although it is anticipated that manufacturers will pass on, as far as is possible, the technology costs to the end user through higher prices. The total costs of the implementation of this option in the UK are presented in Table 4.16 below. The costs are presented as a range due to different assumptions regarding technology costs.

Table 4.16 – Costs of implementing Option B in the UK (2005 prices)

	(£ million)
Annualised technology costs	731 – 751
Annualised resource cost of extra fuel consumed	250
Annualised welfare impact due to rebound effect	2
Annualised present value of costs	983 – 1,003

Summary

693. The summary costs and benefits for Option B are presented in Table 4.17 below, including the annualised NPV figures, which represent the difference between annualised benefits and annualised costs for the 6% hazard rate. The option could potentially achieve quantifiable net benefits of £514 million, though at the low end, the option could potentially create net costs of £432 million.

Table 4.17 – Costs and benefits of implementing Option B in the UK (£ million)

Annual PV of Costs	Annual NPV	Exceedences assessment[186]	Ecosystems assessment	Qualitative assessments
983 – 1,003	(432) – 514	Between 62% and 100% reduction for individual objectives	Significant positive impact on critical loads	SI+

Option C: Incentivising early uptake of new Euro Standards

694. Option C is a long–term measure aimed at the transport sector and primarily affecting vehicle and engine manufacturers/suppliers; manufacturers and suppliers of exhaust after treatment systems; and owners/operators of vehicles. Costs and benefits have been analysed over a period of 100 years from 2010 in accordance with the methodology set out in Chapter 2 of the IGCB report.

Benefits

695. Tables 4.18 and 4.19 set out the estimated monetised health and non-health impacts of Option C, based on pollutant concentrations data. In addition Option C is expected to have the following impact on exceedences by 2020:

- 51% reduction in urban roadside exceedences of NO_2 (40µg.m^{-3} annual average).
- The removal of all urban roadside exceedences of PM_{10} (<31.5µg.m^{-3} annual mean).
- 50% reduction in background exceedences and 52% reduction in urban roadside exceedences of PM_{10} (<20µg.m^{-3} annual mean).

696. Option C is also expected to lead to a reduction in ecosystem areas where critical loads have been exceeded by 2.9% for nutrient nitrogen and 1.8% for acidity, and reductions in accumulated exceedence of critical loads by 4.0% and 4.3% respectively. For social impacts, Option C would create benefits from reducing road-side concentrations of pollutants and probably greater benefits for more deprived areas by reducing high concentrations of pollution.

Table 4.18 – Annual present value of health impacts of implementing Option C (£ million)

PM life years saved	PM – RHA	PM – CHA	O_3 Mortality	O_3 RHA
618 – 1,396	1 – 3	1 – 3	(4) – (0.14)	(5) – (0.11)

[186] This summary shows the lowest and highest expected impact by 2020 on baseline exceedences across all objectives and does not represent a range for individual objectives

Table 4.19 – Annual present value of non-health impacts of implementing Option C

	(£ million)
Annualised social cost of carbon	(50)
Annualised PV of impact on crop yields	2
Annualised PV of impact on buildings and materials	2

Costs

697. The costs of Option C are similar to that of Option A, the only difference being that they apply earlier due to the incentive effect. The costs of Option C are modelled over the period 2010 to 2029 and then added to the costs of Option A and are shown in Table 4.20 below. The value of the incentive itself is not considered as part of the costs of the option as it is not a resource cost; it is a transfer payment between the person providing the incentive and the person receiving it. As with Options A & B, it is expected that vehicle manufacturers will bear the additional technologies costs under this option and vehicle operators/owners will bear the resource and welfare costs, although it is anticipated, as far as is possible, that manufacturers will pass on the technology costs to the end user through higher prices. The costs are presented as a range due to different assumptions regarding technology costs.

Table 4.20 – Costs of implementing Option C in the UK (2005 prices)

	(£ million)
Annualised technology costs	276 – 284
Annualised resource cost of extra fuel consumed	132
Annualised welfare impact due to rebound effect	1
Annualised present value of costs	409 – 417

Summary

698. The summary costs and benefits for Option C are presented in Table 4.21 below, including the annualised NPV figures, which represent the difference between annualised benefits and annualised costs. The option could potentially achieve quantifiable net benefits of £947 million. The early uptake of Euro 5/V/VI standards therefore generates additional benefits compared to the NPVs for Option A (which would be implemented based on EU proposed dates) of up to £146 million.

Table 4.21 – Costs and benefits of implementing Option C in the UK (£ million)

Annual PV of Costs	Annual NPV	Exceedences assessment[187]	Ecosystems assessment	Qualitative assessments
409 – 417	148 – 947	Between 50% and 100% reduction for individual objectives	Significant positive impact on critical loads	SI+

187 This summary shows the lowest and highest expected impact by 2020 on baseline exceedances across all objectives and does not represent a range for individual objectives.”

Option C2: Incentivising early uptake of new Euro Standards (revised scenario)

699. Option C2 is a long-term measure proposing a programme of incentives, based on the new Measure A2 to introduce the Euro standards 5/V/VI for all diesel vehicles (both LDVs and HDVs) earlier than the proposed dates of implementation. Costs and benefits have been analysed over a period of 100 years from 2010 in accordance with the methodology set out in Chapter 2 of the IGCB report. This measure forms part of the proposed package of measures in the Air Quality Strategy and part of the new combined Measure R.

Benefits

700. Tables 4.22 and 4.23 set out the estimated monetised health and non-health impacts of Option C2, based on pollutant concentrations data. In addition Option C2 is expected to have the following impact on exceedences by 2020:

- 65% reduction in urban roadside exceedences of NO_2 (40µg.m^{-3} annual average).
- The removal of all urban roadside exceedences of PM_{10} (<31.5µg.m^{-3} annual mean).
- 42% reduction in background exceedences and 48% reduction in urban roadside exceedences of PM_{10} (<20µg.m^{-3} annual mean).

701. Option C2 is also expected to lead to a reduction in ecosystem areas where critical loads have been exceeded by 3.7% for nutrient nitrogen and 3.1% for acidity, and reductions in accumulated exceedence of critical loads by 7.8% and 8.1% respectively. For social impacts, Option C2 would create benefits from reducing road-side concentrations of pollutants and probably greater benefits for more deprived areas by reducing high concentrations of pollution.

Table 4.22 – Annual present value of health impacts of implementing Option C2 (£ million)

PM life years saved	PM – RHA	PM – CHA	O_3 Mortality	O_3 RHA
637 – 1,454	1 – 4	1 – 4	(5) – (0.05)	(6) – (0.05)

Table 4.23 – Annual present value of non-health impacts of implementing Option C2

	(£ million)
Annualised social cost of carbon	(55)
Annualised PV of impact on crop yields	2
Annualised PV of impact on buildings and materials	2

Costs

702. The costs of Option C2 are similar to that of Option A2, the only difference being that they apply earlier due to the incentive effect. The costs of Option C2 are modelled over the period 2010 to 2029 and then added to the costs of Option A2 and are shown in Table 4.24 below. The value of the incentive itself is not considered as part of the costs of the option as it is not a resource cost; it is a transfer payment between the person providing the incentive and the person receiving it. As with Options A & B, it is expected that vehicle manufacturers will bear the additional technologies costs under this option

and vehicle operators/owners will bear the resource and welfare costs, although it is anticipated, as far as is possible, that manufacturers will pass on the technology costs to the end user through higher prices. The costs are presented as a range due to different assumptions regarding technology costs.

Table 4.24 – Costs of implementing Option C2 in the UK (2005 prices)

	(£ million)
Annualised technology costs	671 – 677
Annualised resource cost of extra fuel consumed	144 – 145
Annualised welfare impact due to rebound effect	1
Annualised present value of costs	816 – 823

Summary

703. The summary costs and benefits for Option C2 are presented in Table 4.25 below, including the annualised NPV figures, which represent the difference between annualised benefits and annualised costs for the 6% hazard rate. The option could potentially achieve quantifiable net benefits of £595 million, though it is possible that the option could also produce net costs of £246 million.

Table 4.25 – Costs and benefits of implementing Option C2 in the UK (£ million)

Annual PV of Costs	Annual NPV	Exceedences assessment[188]	Ecosystems assessment	Qualitative assessments
816 – 823	(246) – 595	Between 48% and 100% reduction for individual objectives	Significant positive impact on critical loads	SI+

Option D: Programme of incentives to phase out the most polluting vehicles

704. Option D is divided into two short–term measures primarily affecting owners and operators of existing vehicles. Costs and benefits have been analysed over a period of five years from 2010 for D1 and over a period of ten years from 2010 for D2, in accordance with the methodology set out in Chapter 2 of the IGCB report.

Benefits

705. Tables 4.26 and 4.27 set out the estimated monetised health and non-health impacts of Options D1 and D2, based on marginal damage cost estimates (D1) and pollutant concentrations data (D2). In addition Option D2 is expected to have the following impact on exceedences by 2010:

- 8% reduction in urban roadside exceedences of NO_2 (40µg.m^{-3} annual average).
- 5% reduction in urban roadside exceedences of PM_{10} (<31.5µg.m^{-3} annual mean).

[188] This summary shows the lowest and highest expected impact by 2020 on baseline exceedences across all objectives and does not represent a range for individual objectives

- 3% reduction in background exceedences and 0.4% reduction in urban roadside exceedences of PM_{10} (<20µg.m^{-3} annual mean).

706. For social impacts Option D, in addition to the distributional benefits described under Option A, is expected to create wider distributional benefits as lower income groups tend to drive older cars. This option is also expected to lead to a reduction in noise since older vehicles have much higher engine noise than modern vehicles, and may lead to additional health benefits from reductions in levels of benzene and 1,3-butadiene causing a possible small reduced risk of leukaemia (and lymphoma for 1,3-butadiene).

Table 4.26 – Annual present value of health impacts of implementing Option D (£ million)

	PM life years saved	PM – RHA	PM – CHA
Option D1	0.94 – 1.36	0 – 0.001	0 – 0.001
Option D2	11 – 15	0.001 – 0.002	0.001 – 0.002

Table 4.27 – Annual present value of non-health impacts of implementing Option D

	(£ million)	
	Option D1	**Option D2**
Annualised social cost of carbon	0.36	4
Annualised PV of impact on buildings and materials	–	0.11

Costs

707. Table 4.28 sets out the anticipated costs of both Options D1 and D2 all of which are anticipated to be borne by the owners and operators of existing cars that would benefit from this programme of incentives. The key driver of the costs of Option D is the fact that useful resources (cars) are being destroyed. This cost is estimated by calculating the market value of the cars in the year that they are scrapped. It is an estimate of the value of the service that the car would have provided for the rest of its lifetime, had it not been scrapped. In addition, reductions in theft that can arise due to the implementation of this scheme. The reduction in cost per theft assumes that total car crime is reduced as a result of a newer fleet, rather than simply being displaced. Thus this avoided cost is likely to be a maximum value and may be an overestimate of the impacts of the option. Wider impacts such as improvements in safety from the introduction of newer vehicles in the fleet, administrative costs from running the scheme and distortions that may arise in the car markets caused by Option D have not been estimated.

Table 4.28 – Costs of implementing Option D in the UK (2005 prices)

	(£ million)	
	Option D1	**Option D2**
Annualised cost of reduced fuel cost	(1)	(12)
Annualised cost of reduced car theft	(0.27)	(1)
Annualised capital cost	6	125
Annualised present value of costs	5	112

Summary

708. The summary costs and benefits for Options D1 and D2 are presented in Table 4.29 below, annualised NPV figures, which represent the difference between annualised benefits and annualised costs. However, both options are likely to create benefits based on impacts considered in the qualitative assessments.

Table 4.29 – Costs and benefits of implementing Option D in the UK (£ million)

	Annual PV of Costs	**Annual NPV**	**Exceedences assessment***	**Ecosystems assessment**	**Qualitative assessments**
D1	5	(4) – (3)			SI+, N+, H+
D2	112	(97) – (93)	Between 0.4% and 8% reduction for individual objectives	No or insignificant effects	

*This summary shows the lowest and highest expected impact by 2010 on baseline exceedences across all objectives and does not represent a range for individual objectives

Option E: Updated programme of incentives to increase penetration of low emission vehicles (LEVs)

709. Option E is a long–term measure aimed at vehicle owners and operators and the manufacturers/suppliers of vehicles and engines. Costs and benefits have been analysed over a period of 100 years from 2010 in accordance with the methodology set out in Chapter 2 of the IGCB report.

Benefits

710. Tables 4.30 and 4.31 set out the estimated monetised health and non-health impacts of Option E, based on pollutant concentrations data. In addition Option E is expected to have the following impact on exceedences by 2020:

- 9% reduction in urban roadside exceedences of NO_2 (40µg.m^{-3} annual average).
- The removal of all urban roadside exceedences of PM_{10} (<31.5µg.m^{-3} annual mean).
- 8% reduction in background exceedences and 3% reduction in urban roadside exceedences of PM_{10} (<20µg.m^{-3} annual mean).

711. For social impacts, Option E would create benefits from reducing road-side concentrations of pollutants and probably greater benefits for more deprived areas by reducing high concentrations of pollution. This option is also expected to lead to a reduction in noise since some low emission vehicles may have lower noise emissions.

Table 4.30 – Annual present value of health impacts of implementing Option E (£ million)

PM life years saved	PM – RHA	PM – CHA	O_3 Mortality	O_3 RHA
35 – 82	0.05 – 0.23	0.05 – 0.23	(1) – (0.03)	(1) – (0.03)

Table 4.31 – Annual present value of non-health impacts of implementing Option E

	(£ million)
Annualised social cost of carbon	91
Annualised PV of impact on crop yields	(0.20)
Annualised PV of impact on buildings and materials	0.03

Costs

712. The costs of this option are driven primarily by the resource costs of the technologies that have to be implemented in order that vehicles meet the LEV emissions specified in this option. As LEVs have higher levels of fuel efficiency, this option also incorporates the reductions in resource costs of the reduced fuel consumed as well as the welfare impacts of changes in the vehicle kilometres travelled due to changes in fuel efficiency. It is expected that vehicle manufacturers will bear the additional technologies costs under this option and vehicle operators/owners will bear the resource and welfare costs, although it is anticipated that manufacturers will pass on, as far as is possible, the technology costs to the end user through higher prices. The total costs of the implementation of this option in the UK are presented in Table 4.32 below.

Table 4.32 – Costs of implementing Option E in the UK (2005 prices)

	(£ million)
Annualised technology costs	295
Annualised resource cost of extra fuel consumed	(227)
Annualised welfare impact due to rebound effect	(7)
Annualised present value of costs	61

Summary

713. The summary costs and benefits for Option E are presented in Table 4.33 below, including the annualised NPV figures, which represent the difference between annualised benefits and annualised costs. The results show that the option could create a net benefit of up to £112 million.

Table 4.33 – Costs and benefits of implementing Option E in the UK (£ million)

Annual PV of Costs	Annual NPV	Exceedences assessment*	Ecosystems assessment	Qualitative assessments
61	63 – 112	Between 3% and 100% reduction for individual objectives	No or insignificant effects	SI+, N+

*This summary shows the lowest and highest expected impact by 2020 on baseline exceedences across all objectives and does not represent a range for individual objectives

Option F: Impact of national road pricing scheme on air quality

714. Option F is a long–term measure aimed at the transport sector and primarily affecting the owners and operators of vehicles. Costs and benefits for a hypothetical national road pricing scheme have been analysed over a period of 100 years from 2010 in accordance with the methodology set out in Chapter 2 of the IGCB report.

Benefits

715. Tables 4.34 and 4.35 set out the estimated monetised health and non-health impacts of Option F, based on pollutant concentrations data. In addition Option F could potentially have the following impact on exceedences by 2020:

- 16% reduction in urban roadside exceedences of NO_2 (40µg.m^{-3} annual average).
- 67% reduction in urban roadside exceedences of PM_{10} (<31.5µg.m^{-3} annual mean).
- 8% reduction in background exceedences and 3% reduction in urban roadside exceedences of PM_{10} (<20µg.m^{-3} annual mean).

716. For social impacts, Option F could create benefits from reducing road-side concentrations of pollutants and probably greater benefits for more deprived areas by reducing high concentrations of pollution. This option could also be expected to lead to a reduction in noise since the number of vehicles is expected to reduce but vehicle speeds may increase with consequent negative noise impact, as surface-tyre noise is higher at increase speeds. Modelling undertaken for the Road Pricing Feasibility Study, for the scenario considered by Option F, suggested noise benefits equivalent to less than 1% of total benefits. These benefits are included in the total monetary estimates shown for this option in the monetary CBA.

Table 4.34 – Annual present value of health impacts of implementing Option F (£ million)

PM life years saved	PM – RHA	PM – CHA
83 – 195	0.11 – 1	0.11 – 0.11

Table 4.35 – Annual present value of non-health impacts of implementing Option F

	(£ million)
Annualised PV of impact on buildings and materials	0.13

Costs

717. Costs for this option have been taken from the Cost Model Report published as part of the Department for Transport's Road User Charging Feasibility Implementation Workstream[189], based on the scenario that assumed that there would be a national framework for road pricing and that on-board units would be mandatory. The work done for the Feasibility Study suggested that the costs for such a scheme would be substantial, but are very uncertain. Any estimates are unlikely to reflect actual costs of any scheme given the rapidly developing nature of technology in this area.

Summary

718. In view of the degree of uncertainty surrounding the likely costs and benefits of this potential future measure, it is not possible to generate meaningful estimates of its NPV. The Government is undertaking further work which will help inform future decisions on whether such a scheme would yield overall net benefits.

Option G: Extend the London Low Emissions Zone (LEZ) to Greater London and the seven largest UK urban areas

719. Option G is a short–term measure primarily affecting fleet operators of vehicles who operate in the urban areas covered by the LEZ option. It considers three scenarios: Option G1, relating to the proposed London LEZ first phase in 2007; Option G2, relating to phase 2 of the proposed London LEZ in 2010; and Option G3, relating to the introduction of LEZ schemes (equivalent to London Phase 1) in seven other major urban areas in 2010. This analysis of costs and benefits for Option G1 has been analysed over a period of eight years, from 2007; Option G2 has been analysed over a period of five years, from 2010 and Option G3 has been analysed over a period of eight years, from 2010, in accordance with the methodology set out in Chapter 2 of the IGCB report.

720. On 13 November 2006 TfL opened a consultation on detailed proposals for a London Low Emission Zone in the form of a scheme order[190]. These proposals are substantially different from the phase II feasibility study on which Measures G1-G3 are based. It has not been possible to update these measures to reflect this new information.

[189] Available at http://www.dft.gov.uk/stellent/groups/dft_roads/documents/page/dft_roads_029770.pdf

[190] http://www.tfl.gov.uk/tfl/low-emission-zone/consultation.asp]

Benefits

721. Tables 4.36 and 4.37 set out the estimated monetised health impacts and possible additional benefits of Option G. In addition Option G is expected to have the following impact on exceedences by 2010:

- 2% reduction in urban roadside exceedences of NO_2 (40µg.m^{-3} annual average).
- 33% reduction in urban roadside exceedences of PM_{10} (<31.5µg.m^{-3} annual mean).
- No reduction in background exceedences and a 0.3% reduction in urban roadside exceedences of PM_{10} (<20µg.m^{-3} annual mean).

722. For social impacts Option G, in addition to the distributional benefits described under Option A, is expected to create greater benefits in more deprived areas, given that the option targets urban centres. This option is also expected to have the same effect on noise as Option D although the impact is not expected to be as pronounced.

Table 4.36 – Annual present value of health impacts of implementing Option G (£ million)

	PM life years saved	PM – RHA	PM – CHA
Option G1	8 – 12	0.01 – 0.03	0.01 – 0.04
Option G2	17 – 25	0.02 – 0.08	0.02 – 0.08
Option G3	5 – 7	0.004 – 0.02	0.004 – 0.02

Table 4.37 – Annual present value of possible additional benefits of Option G

	(£ million)		
	Option G1	**Option G2**	**Option G3**
Annualised additional benefits outside the LEZ	1 – 5	1 – 5	– [b]
Annualised noise benefits	1	– [a]	– [b]

[a] Option G2 is not expected to create additional noise benefits as noisier vehicles will have already been excluded under Phase I.
[b] It has not been possible to quantify any additional benefits that may be generated by Option G3.

Costs

723. Table 4.38 below sets out the costs associated with Options G1, G2 and G3. These are split into the costs of implementing and operating the scheme (excluding any potential revenues from the scheme, as there a transfer) and the costs to operators from enforced changes to comply with the zone. The set-up and operational costs of the scheme also depend on the enforcement method chosen: either manual or automatic enforcement. For Option G1, it is estimated a manual enforcement scheme targeting heavy vehicles would have start-up costs of £2.8 million and annual running costs of £4.2 million per year. If this scheme were implemented using automatic enforcement, then costs would rise to a start-up cost of £8.9 million and annual running costs of £4.0 million per year. The costs of the scheme also depend on the costs to operators, which depend on the response of the operators with non-compliant vehicles which enter London each year. The costs to operators have been calculated using estimated replacement, or abatement

equipment costs, combined with estimates of the number of vehicles operating in London. This analysis takes the natural retirement of vehicles in the fleet into account. For Option G2 the scheme costs and operating costs will follow from the costs of G1 outlined above (although in practice, the operating costs will change due to the number of vehicles in the scheme). Costs of Option G2 to operators have been calculated with a new baseline of vehicles, adjusted for the operator response to phase 1 of the scheme. When phase II is introduced in London, the costs of this measure are added to the costs of the phase 1 considered above. Finally, the costs for Option G3 the start-up costs are estimated to be £25 million, with annual operating costs of £7 million (based on fixed plus mobile camera scheme). This includes some shared facilities with the London scheme (e.g. on registering vehicles), which improves the cost-effectiveness of these schemes relative to London alone. For all three options the costs are shown assuming an eight-year lifetime, consistent with the benefits above.

Table 4.38 – Possible costs of implementing Option G (£ million, 2005 prices)

	(£ million)		
	Option G1	Option G2	Option G3
Annualised PV of scheme costs	4 – 5	–	9
Annualised PV of costs to operators	14 – 40	33 – 88	10
Annualised present value of costs	18 – 45	33 – 88	19

Summary

724. The summary costs and benefits for Options G1, G2, and G3 are presented in Table 4.39 below, annualised NPV figures, which represent the difference between annualised benefits and annualised costs at the 6% hazard rate. The results show that the costs outweigh the benefits for all the options although the they are likely to have positive distributional and noise impacts.

Table 4.39 – Costs and benefits of implementing Option G in the UK (£ million)

	Annual PV of Costs	Annual NPV	Exceedences assessment*	Ecosystems assessment	Qualitative assessments
G1	18 – 45	(33) – (1)			SI+, N+, C–, SB–
G2	33 – 88	(67) – (2)	Between 0% and 33% reduction for individual objectives	No or insignificant effects	
G3	19	(14) – (12)			

*This summary shows the lowest and highest expected impact by 2010 on baseline exceedences across all objectives and does not represent a range for individual objectives

Option H: Retrofit diesel particulate filters (DPFs) on heavy goods vehicles (HGVs) and captive fleets (buses and coaches)

725. Option H is divided into three short–term measures aimed at the transport sector and primarily affecting suppliers of abatement equipment and owners/operators of vehicles. Costs and benefits have been analysed over a period of 13 years from 2010 in accordance with the methodology set out in Chapter 2 of the IGCB report.

Benefits

726. Table 4.40 sets out the estimated monetised health impacts of Options H1, H2 and H3, based on marginal damage cost estimates. For social impacts, Option H would create benefits from reducing road-side concentrations of pollutants and probably greater benefits for more deprived areas by reducing high concentrations of pollution.

Table 4.40 – Annual present value of health impacts of implementing Option H (£ million)

	PM life years saved	PM – RHA	PM – CHA
Option H1	35 – 51	0.03 – 0.15	0.03 – 0.16
Option H2	10 – 14	0.01 – 0.04	0.01 – 0.04
Option H3	18 – 26	0.02 – 0.08	0.02 – 0.08

Costs

727. The costs of this option are driven by the unit costs of the DPF technology and the operational costs for retrofitting the various vehicles included in the option. It is expected that vehicle operators and owners will bear the costs associated with this option which are presented in Table 4.41 below.

Table 4.41 – Costs of implementing Option H in the UK (2005 prices)

	(£ million)		
	Option H1	**Option H2**	**Option H3**
Annualised technology costs	24	7	13
Annualised operating costs	44	7	12
Annualised present value of costs	68	14	25

Summary

728. The summary costs and benefits for Options H1, H2, and H3 are presented in Table 4.42 below, annualised NPV figures, which represent the difference between annualised benefits and annualised costs at 6% hazard rate. The results show that the costs outweigh the benefits for all options, assuming a 40 year lag, although Option H3 suggests a small annual net benefit of £2m could be achieved. For all three options, it is observed that there are social benefits associated with the implementation of this scheme.

Table 4.42 – Costs and benefits of implementing Option H in the UK (£ million)

	Annual PV of Costs	Annual NPV	Exceedences assessment*	Ecosystems assessment	Qualitative assessments
H1	68	(33) – (17)	Not modelled	No or insignificant effects	SI+
H2	14	(5) – 0	Not modelled	No or insignificant effects	SI+
H3	25	(7) – 2	Not modelled	No or insignificant effects	SI+

Option I: Domestic Combustion – Switch from coal to natural gas or oil

729. Option I is a short–term measure primarily affecting the domestic fuel supply market. Costs and benefits have been analysed over a period of 15 years from 2010 in accordance with the methodology set out in Chapter 2 of the IGCB report.

Benefits

730. Tables 4.43 and 4.44 set out the estimated monetised health and non-health impacts of Option I, based on marginal damage cost estimates. This option may also lead to additional health benefits from reductions in the level of PAH causing a possible small reduced risk of lung cancer. For social impacts Option I is likely to have very strong distributional benefits (especially in Northern Ireland).

Table 4.43 – Annual present value of health impacts of implementing Option I (£ million)

PM life years saved	PM – RHA	PM – CHA	SO_2 Mortality	SO_2 RHA
18 – 26	0.02 – 0.09	0.02 – 0.09	0.01 – 0.02	0.01 – 0.02

Table 4.44 – Annual present value of non-health impacts of implementing Option I

	(£ million)
Annualised social cost of carbon	2
Annualised PV of impact on buildings and materials	0.26

Costs

731. Table 4.45 sets out the costs associated with implementing Option I. The capital costs of this option are based on the additional costs of domestic appliances. As of 1st April 2005 the boiler provisions in the revised Building Regulations for England and Wales require boilers to be replaced by boilers with a SEDBUK A or B rating. Hence, it is assumed for this measure that replacement boilers will be new condensing boilers with an assumed average cost of £800 and an assumed installation cost of £1,000 per boiler. Oil boilers are assumed to incur the same cost. No net change in fuel costs is assumed, so incremental operating costs are zero (in practice, the new boilers are more fuel efficient but there was insufficient information to cost the fuel saving). The additional infrastructure costs (such as new gas pipelines) of increasing the availability of natural gas and oil to those

households currently using solid fuel boilers has not been included.

Table 4.45 – Costs of implementing Option I in the UK – 15 yrs lifetime of technology (2005 prices)

	(£ million)
Capital cost	610
Operating cost	0
Annualised present value of costs	43

Summary

732. The summary costs and benefits for Option I are presented in Table 4.46 below, including the annualised NPV figures, which represent the difference between annualised benefits and annualised costs. The results show that there are net costs of implementing this measure and there are mixed results of the qualitative assessments.

Table 4.46 – Costs and benefits of implementing Option I in the UK (£ million)

Annual PV of Costs	Annual NPV	Exceedences assessment	Ecosystems assessment	Qualitative assessments
43	(23) – (15)	Not modelled	No or insignificant effects	SI+, C–, SB–, H+

Option J: Domestic combustion – Product standards for gas fired appliances which require tighter oxides of nitrogen emission standards

733. Option J is a long–term measure applicable across the UK and is also assumed to apply across the EU. Costs and benefits have been analysed over a period of 100 years from 2010 in accordance with the methodology set out in Chapter 2 of the IGCB report.

Benefits

734. Tables 4.47 and 4.48 set out the estimated monetised health and non-health impacts of Option J, based on pollutant concentrations data. In addition Option J is expected to have the following impact on exceedences by 2020:

- 5% reduction in urban roadside exceedences of NO_2 (40µg.m^{-3} annual average).
- No reduction in urban roadside exceedences of PM_{10} (<31.5µg.m^{-3} annual mean).
- 4% in background exceedences and 1% reduction in urban roadside exceedences of PM_{10} (<20µg.m^{-3} annual mean).

735. For social impacts Option J is expected to create greater benefits in more deprived areas, as the measure has more effect in urban areas.

Table 4.47 – Annual present value of health impacts of implementing Option J (£ million)

PM life years saved	PM – RHA	PM – CHA	O_3 Mortality	O_3 RHA
20 – 48	0.03 – 0.12	0.03 – 0.12	(1) – (0.04)	(1) – (0.03)

Table 4.48 – Annual present value of non-health impacts of implementing Option J

	(£ million)
Annualised PV of impact on crop yields	(0.20)
Annualised PV of impact on buildings and materials	(0.40)

Costs

736. Table 4.49 sets out the costs associated with implementing Option J. It is assumed that the capital costs are based on the cost differential between an average size new boiler that meets the tighter NO_X standards and an average size boiler that meets the minimum standards. These costs are incurred each time household boilers need renewing: that is the capital costs are incurred by households every 20 years, which is the assumed lifetime of household boilers. The differential operating costs are assumed to be zero (as the scale of the energy efficiency gains are currently not clear), so it is only the capital costs that are repeated every 20 years over the period 2008 – 2109.

Table 4.49 – Costs of implementing Option J in the UK – 20 yr lifetime of technology (2005 prices)

	(£ million)
Capital cost	216
Operating cost	0
Annualised present value of costs	196

Summary

737. The summary costs and benefits for Option J are presented in Table 4.50 below, including the annualised NPV figures, which represent the difference between annualised benefits and annualised costs. The results show that the option is expected to create net costs, although the option is expected to generate some positive distributional impacts.

Table 4.50 – Costs and benefits of implementing Option J in the UK (£ million)

Annual PV of Costs	Annual NPV	Exceedences assessment*	Ecosystems assessment	Qualitative assessments
196	(179) – (148)	Between 0% and 5% reduction for individual objectives	No or insignificant effects	SI+

*This summary shows the lowest and highest expected impact by 2020 on baseline exceedences across all objectives and does not represent a range for individual objectives

Option K: Large combustion plant option

738. Option K is divided into two measures. K1 is a short–term measure, and costs and benefits have been analysed over a period of six years from 2010 in accordance with the methodology set out in Chapter 2 of the IGCB report. K2 is a long–term measure, and as such costs and benefits have been analysed over a period of 100 years from 2010.

Benefits

739. Tables 4.51 and 4.52 set out the estimated monetised health and non-health impacts of Options K1 and K2. In addition Option K2 is expected to have the following impact on exceedences in 2020:

- 2% reduction in urban roadside exceedences of NO_2 (40µg.m^{-3} annual average) in 2010 and 2% reduction in 2020.
- 19% reduction in urban roadside exceedences of PM_{10} (<31.5µg.m^{-3} annual mean) in 2010 and no reduction in 2020.
- 28% reduction in background exceedences of PM_{10} (<20µg.m^{-3} annual mean) in 2010 and 15% reduction in 2020.
- 3% reduction in urban roadside exceedences of PM_{10} (<20µg.m^{-3} annual mean) in both 2010 and 2020.

740. Option K2 is also expected to lead to a reduction in ecosystem areas where critical loads have been exceeded by 4.9% for nutrient nitrogen and 3.2% for acidity, and reductions in accumulated exceedence of critical loads by 5.6% and 6.6% respectively.

Table 4.51 – Annual present value of health impacts of implementing Option K (£ million)

	PM life years saved	PM – RHA	PM – CHA	O_3 Mortality	O_3 RHA
Option K1	111 – 162	0.1 – 0.5	0.1 – 0.5	–	–
Option K2	64 – 151	0.12 – 0.5	0.12 – 0.5	(2) – (0.10)	(3) – (0.11)

Table 4.52 – Annual present value of non-health impacts of implementing Option K

	(£ million)	
	Option K1	**Option K2**
Annualised social cost of carbon	(12)	(16)
Annualised PV of impact on crop yields		(1)
Annualised PV of impact on buildings and materials		(1)

Costs

741. Table 4.53 sets out the costs associated with Options K1 and K2. The costs for Option K1 are presented as a range to reflect two different methodologies used to estimate the costs of bringing forward the introduction of SCR to the coal-fired power stations included under Option K1. The first methodology includes the costs to large combustion plants of bringing forward investment in SCR by six years from 2016 to 2010 for those

plants planning to fit SCR under BAU in 2016. The second methodology also includes the costs to those plants not planning to fit SCR under BAU (that is those that will opt-out and only operate for a limited lifetime under LCPD regulations; although this also means that these plants will close down by the end of 2015). To match the timeframe over which the benefits are being analysed, the capital costs of K1 were included in 2010, operating costs were added each year from 2011-2016, and then the capital costs were subtracted in 2016, as they would have become BAU at this point. For Option K2, the capital costs of SCR were included in 2010, followed by 14 years of operating costs. This cost profile was then repeated every 15 years until 2109.

Table 4.53 – Costs of implementing Option K in the UK (2005 prices)

	(£ million)	
	Option K1	**Option K2**
Capital cost	1,148 – 1,589	2,844
Operating cost	101 – 126	94
Annualised present value of costs	118 – 206	273

Summary

742. The summary costs and benefits for Options K1 and K2 are presented in Table 4.54 below, annualised NPV figures, which represent the difference between annualised benefits and annualised costs. The results show that the schemes are expected to create net costs to society.

Table 4.54 – Costs and benefits of implementing Option K in the UK (£ million)

	Annual PV of Costs	**Annual NPV**	**Exceedences assessment***	**Ecosystems assessment**	**Qualitative assessments**
K1	118 – 206	(107) – 33	Between 3% and 33% reduction for individual objectives	Significant positive impact on critical loads	C–
K2	273	(232) – (139)	Between 0% and 15% reduction for individual objectives	Significant positive impact on critical loads	C–

*This summary shows the lowest and highest expected impact by 2010 (K1) and 2020 (K2) on baseline exceedences across all objectives and does not represent a range for individual objectives

Option L: Small combustion plant Option

743. Option L is a long–term measure, with costs and benefits analysed over a period of 100 years from 2010 in accordance with the methodology set out in Chapter 2 of the IGCB report.

Benefits

744. Tables 4.55 and 4.56 set out the estimated monetised health and non-health impacts of Option L, based on pollutant concentrations data. In addition Option L is expected to have the following impact on exceedences by 2020:

- 4% reduction in urban roadside exceedences of NO_2 (40µg.m^{-3} annual average).
- No reduction in urban roadside exceedences of PM_{10} (<31.5µg.m^{-3} annual mean).
- 8% in background exceedences and 1% reduction in urban roadside exceedences of PM_{10} (<20µg.m^{-3} annual mean).

745. For social impacts Option L is expected to create greater benefits in more deprived areas, as the option has more effect in urban areas.

Table 4.55 – Annual present value of health impacts of implementing Option L (£ million)

PM life years saved	PM – RHA	PM – CHA	O_3 Mortality	O_3 RHA	SO_2 mortality	SO_2 RHA
28 – 65	0.04 – 0.18	0.04 – 0.18	(0.46) – (0.03)	(1) – (0.02)	0.08 – 0.23	0.05 – 0.23

Table 4.56 – Annual present value of non-health impacts of implementing Option L

	(£ million)
Annualised PV of impact on crop yields	(1)
Annualised PV of impact on buildings and materials	1

Costs

746. Table 4.57 sets out the costs of implementing Option L. The one-off capital costs to small combustion plants of using low sulphur fuels range between £310,000 and £3,000,000 for each entire sector being considered. The range reflects the different abatement costs associated with different sectors complying with the requirements of Option L. The capital costs of SCPs range between £400,000 and £61,000,000 for each entire sector and again the range reflects the difference in abatement costs across sectors. No change in operating costs from fitting these technologies is assumed (given that this will depend on the abatement technology that will be put into place to comply with the possible directive). It was not possible to calculate any potential change in energy efficiency due to Option L. Any change in the amount of fuel consumed and the costs of these fuel penalties or savings have not been quantified. Hence, no change in operating costs from fitting these technologies is assumed.

Table 4.57 – Costs of implementing Option L in the UK (2005 prices)

	(£ million)
Capital cost	96
Operating cost	5
Annualised present value of costs	9

Summary

747. The summary costs and benefits for Option L are presented in Table 4.58 below, including the annualised NPV figures, which represent the difference between annualised benefits and annualised costs. The results show that the scheme could potentially create net benefits of £57 million.

Table 4.58 – Costs and benefits of implementing Option L in the UK (£ million)

Annual PV of Costs	Annual NPV	Exceedences assessment*	Ecosystems assessment	Qualitative assessments
9	18 – 57	Between 0% and 8% reduction for individual objectives	No or insignificant effects	SI+, SB–

*This summary shows the lowest and highest expected impact by 2020 on baseline exceedences across all objectives and does not represent a range for individual objectives

Option M: Reduce national volatile organic compounds (VOC) emissions by 10%

748. Option M is a long–term measure combining many options for reducing national VOC emissions. Costs and benefits have been analysed over a period of 100 years from 2010 in accordance with the methodology set out in Chapter 2 of the IGCB report.

Benefits

749. Tables 4.59 and 4.60 set out the estimated monetised health and non-health impacts of Option M, based on pollutant concentrations data.

Table 4.59 – Annual present value of health impacts of implementing Option M (£ million)

O_3 Mortality	O_3 RHA
0.02 – 0.14	0.02 – 0.20

Table 4.60 – Annual present value of non-health impacts of implementing Option M

	(£ million)
Annualised PV of impact on crop yields	0.25
Annualised PV of impact on buildings and materials	0.04

Costs

750. The total capital and operating costs for the VOC abatement techniques under Option M are listed in Table 4.61 below. The costs for PVR Stage II controls assume an economic lifetime of 15 years for the equipment. A 15 year lifetime was used in the cost results below and was considered to be consistent with the methodology used to calculate the emission reductions.

Table 4.61 – Costs of implementing Option M in the UK (2005 prices)

	(£ million)
Capital cost	2,599
Operating cost	77
Annualised present value of costs	249

Summary

751. The summary costs and benefits for Option M are presented in Table 4.62 below, including the annualised NPV figures, which represent the difference between annualised benefits and annualised costs at the 6% hazard rate. The results suggest that the costs outweigh the benefits for Option M and could potentially create a disbenefit of £249 million.

Table 4.62 – Costs and benefits of implementing Option M in the UK (£ million)

Annual PV of Costs	Annual NPV	Exceedences assessment	Ecosystems assessment
249	(249) – (248)	Not modelled	No or insignificant effects

Option N: Shipping Option through International Maritime Organisation (IMO)

752. Option N is a long–term measure aimed at the shipping sector and primarily affecting petroleum refineries producing fuel for shipping, bunker suppliers, shipping operators, as well as ship and abatement technology manufacturers/suppliers. Costs and benefits have been analysed over a period of 100 years from 2010 in accordance with the methodology set out in Chapter 2 of the IGCB report.

Benefits

753. Tables 4.63 and 4.64 set out the estimated monetised health and non-health impacts of Option N, based on pollutant concentrations data. In addition Option N is expected to have the following impact on exceedences by 2020:

- 1% reduction in urban roadside exceedences of NO_2 (40µg.m^{-3} annual average).
- 33% reduction in urban roadside exceedences of PM_{10} (<31.5µg.m^{-3} annual mean).
- 38% in background exceedences and 14% reduction in urban roadside exceedences of PM_{10} (<20µg.m^{-3} annual mean).

754. Option N is also expected to lead to a reduction in ecosystem areas where critical loads have been exceeded by 0.6% for nutrient nitrogen and 2.3% for acidity, and reductions in accumulated exceedence of critical loads by 0.6% and 3.2% respectively.

Table 4.63 – Annual present value of health impacts of implementing Option N (£ million)

PM life years saved	PM – RHA	PM – CHA	SO_2 Mortality	SO_2 RHA
244 – 573	1 – 2	1 – 2	0.002 – 0.005	0.05 – 0.23

Table 4.64 – Annual present value of non-health impacts of implementing Option N

	(£ million)
Annualised PV of impact on buildings and materials	0.09

Costs

755. The costs of Option N are presented in Table 4.65 but only include those costs due to the impact on the UK fleet. The advanced IEM solution to achieving the target reduction in NO_X emissions is more consistent with the definition of Option N since it is estimated to achieve around a 30% improvement in NO_X emissions. The assumed lifetime of the advanced IEM technology is 25 years; the capital costs have therefore been replicated every 25 years over the period 2010 to 2109.

Table 4.65 – Costs of implementing Option N in the UK (2005 prices)

	(£ million)
Capital cost	0.5
Operating cost	0.8
Annualised present value of costs	1

Summary

756. The summary costs and benefits for Option N are presented in Table 4.66 below, including the annualised NPV figures, which represent the difference between annualised benefits and annualised costs at the 6% hazard rate. The results show that the annualised benefits outweigh the annualised costs and the option could produce net benefits £576 million.

Table 4.66 – Costs and benefits of implementing Option N in the UK (£ million)

Annual PV of Costs	Annual NPV	Exceedences assessment*	Ecosystems assessment	Qualitative assessments
1	245 – 576	Between 1% and 38% reduction for individual objectives	Significant positive impact on critical loads	

*This summary shows the lowest and highest expected impact by 2020 on baseline exceedences across all objectives and does not represent a range for individual objectives

Option O: Combined Option C + E

757. Option O is a combined measure incorporating Options C and E. Costs and benefits have been analysed over a period of 100 years from 2010 in accordance with the methodology set out in Chapter 2 of the IGCB report.

Benefits

758. Tables 4.67 and 4.68 set out the estimated monetised health and non-health impacts of Option O, based on pollutant concentrations data. In Option O is expected to have the following impact on exceedences by 2020:

- 55% reduction in urban roadside exceedences of NO_2 (40µg.m^{-3} annual average).
- the removal of all urban roadside exceedences of PM_{10} (<31.5µg.m^{-3} annual mean).
- 50% reduction in background exceedences and 53% reduction in urban roadside exceedences of PM_{10} (<20µg.m^{-3} annual mean).

759. Option O is also expected to lead to a reduction in ecosystem areas where critical loads have been exceeded by 3.4% for nutrient nitrogen and 2.1% for acidity, and reductions in accumulated exceedence of critical loads by 4.7% and 5.1% respectively. For social impacts, Option O would create benefits from reducing road-side concentrations of pollutants and probably greater benefits for more deprived areas by reducing high concentrations of pollution.

Table 4.67 – Annual present value of health impacts of implementing Option O (£ million)

PM life years saved	PM – RHA	PM – CHA	O_3 Mortality	O_3 RHA
627 – 1,396	1 – 3	1 – 3	(5) – (0.17)	(6) – (0.13)

Table 4.68 – Annual present value of non-health impacts of implementing Option O

	(£ million)
Annualised social cost of carbon	42
Annualised PV of impact on crop yields	2
Annualised PV of impact on buildings and materials	2

Costs

760. Table 4.69 sets out the costs of Option O, which combines Options C and E. Costs are presented as a range due to different assumptions regarding technology costs under Option C.

Table 4.69 – Costs of implementing Option O in the UK (2005 prices)

	(£ million)
Annualised technology costs	571 – 579
Annualised resource cost of extra fuel consumed	(95)
Annualised welfare impact due to rebound effect	(6)
Annualised present value of costs	470 – 478

Summary

761. The summary costs and benefits for Option O are presented in Table 4.70 below, including the annualised NPV figures, which represent the difference between annualised benefits and annualised costs at the 6% hazard rate. The results show that the option potentially could create net benefits of £978 million at the high assumption.

Table 4.70 – Costs and benefits of implementing Option O in the UK (£ million)

Annual PV of Costs	Annual NPV	Exceedences assessment*	Ecosystems assessment	Qualitative assessments
470 – 478	186 – 978	Between 50% and 100% reduction for individual objectives	Significant positive impact on critical loads	SI+, N+

*This summary shows the lowest and highest expected impact by 2020 on baseline exceedences across all objectives and does not represent a range for individual objectives

Option P: Combined Option C + L

762. Option P is a combined measure incorporating Options C and L. Costs and benefits have been analysed over a period of 100 years from 2010 in accordance with the methodology set out in Chapter 2 of the IGCB report.

Benefits

763. Tables 4.71 and 4.72 set out the estimated monetised health and non-health impacts of Option P, based on pollutant concentrations data. In addition Option P is expected to have the following impact on exceedences by 2020:

- 52% reduction in urban roadside exceedences of NO_2 (40μg.m^{-3} annual average).
- the removal of all urban roadside exceedences of PM_{10} (<31.5μg.m^{-3} annual mean).
- 54% reduction in background exceedences and 53% reduction in urban roadside exceedences of PM_{10} (<20μg.m^{-3} annual mean).

764. Option P is also expected to lead to a reduction in ecosystem areas where critical loads have been exceeded by 3.3% for nutrient nitrogen and 2.4% for acidity, and reductions in accumulated exceedence of critical loads by 4.6% and 5.7% respectively. For social impacts, Option P would create benefits from reducing road-side concentrations of pollutants and greater benefits for more deprived areas, particularly as Option L has a greater effect in urban areas.

Table 4.71 – Annual present value of health impacts of implementing Option P (£ million)

PM life years saved	PM – RHA	PM – CHA	O_3 Mortality	O_3 RHA	SO_2 mortality	SO_2 RHA
644 – 1,458	1 – 3	1 – 3	(5) – (0.17)	(6) – (0.13)	0.08 – 0.23	0.05 – 0.23

Table 4.72 – Annual present value of non-health impacts of implementing Option P

	(£ million)
Annualised social cost of carbon	(50)
Annualised PV of impact on crop yields	1
Annualised PV of impact on buildings and materials	3

Costs

765. Table 4.73 sets out the costs of Option P, which combines Options C and L. Costs are presented as a range due to different assumptions regarding technology costs under Option C.

Table 4.73 – Costs of implementing Option P in the UK (2005 prices)

	(£ million)
Annualised technology costs	276 – 284
Annualised resource cost of extra fuel consumed	132
Annualised welfare impact due to rebound effect	1
Capital cost	96
Operating cost	5
Annualised present value of costs	418 – 426

Summary

766. The summary costs and benefits for Option P are presented in Table 4.74 below, including the annualised NPV figures, which represent the difference between annualised benefits and annualised costs at the 6% hazard rate. The results show that the option could potentially create net benefits of £1,000 million at the high end.

Table 4.74 – Costs and benefits of implementing Option P in the UK (£ million)

Annual PV of Costs	Annual NPV	Exceedences assessment*	Ecosystems assessment	Qualitative assessments
418 – 426	163 – 1,000	Between 52% and 100% reduction for individual objectives	Significant positive impact on critical loads	SI+, SB–

*This summary shows the lowest and highest expected impact by 2020 on baseline exceedences across all objectives and does not represent a range for individual objectives

Option Q: Combined Option C + E + L

767. Option Q is a combined measure incorporating Options C, E and L. Costs and benefits have been analysed over a period of 100 years from 2010 in accordance with the methodology set out in Chapter 2 of the IGCB report.

Benefits

768. Tables 4.75 and 4.76 set out the estimated monetised health and non-health impacts of Option Q, based on pollutant concentrations data. In addition Option Q is expected to have the following impact on exceedences by 2020:

- 59% reduction in urban roadside exceedences of NO_2 (40µg.m^{-3} annual average).
- the removal of all urban roadside exceedences of PM_{10} (<31.5µg.m^{-3} annual mean).
- 54% reduction in background exceedences and 55% reduction in urban roadside exceedences of PM_{10} (<20µg.m^{-3} annual mean).

769. Option Q is also expected to lead to a reduction in ecosystem areas where critical loads have been exceeded by 3.7% for nutrient nitrogen and 2.7% for acidity, and reductions in accumulated exceedence of critical loads by 5.3% and 6.4% respectively. For social impacts, Option Q would create benefits from reducing road-side concentrations of pollutants and greater benefits for more deprived areas, particularly as Option L has a greater effect in urban areas.

Table 4.75 – Annual present value of health impacts of implementing Option Q (£ million)

PM life years saved	PM – RHA	PM – CHA	O_3 Mortality	O_3 RHA	SO_2 mortality	SO_2 RHA
653 – 1,480	1 – 3	1 – 3	(5) – (0.19)	(6) – (0.15)	0.08 – 0.23	0.05 – 0.23

Table 4.76 – Annual present value of non-health impacts of implementing Option Q

	(£ million)
Annualised social cost of carbon	42
Annualised PV of impact on crop yields	1
Annualised PV of impact on buildings and materials	3

Costs

770. Table 4.77 sets out the costs of Option Q, which combines Options C, E, and L. Costs are presented as a range due to different assumptions regarding technology costs under Option C.

Table 4.77 – Costs of implementing Option Q in the UK (2005 prices)

	(£ million)
Annualised technology costs	571 – 579
Annualised resource cost of extra fuel consumed	(95)
Annualised welfare impact due to rebound effect	(6)
Capital cost	96
Operating cost	5
Annualised present value of costs	479 – 487

Summary

771. The summary costs and benefits for Option Q are presented in Table 4.78 below, including the annualised NPV figures, which represent the difference between annualised benefits and annualised costs at the 6% hazard rate. The results show that the implementation of this option could potentially create net benefits of £1,053 million.

Table 4.78 – Costs and benefits of implementing Option Q in the UK (£ million)

Annual PV of Costs	Annual NPV	Exceedences assessment*	Ecosystems assessment	Qualitative assessments
479 – 487	203 – 1,053	Between 54% and 100% reduction for individual objectives	Significant positive impact on critical loads	SI+, N+, SB–

*This summary shows the lowest and highest expected impact by 2020 on baseline exceedences across all objectives and does not represent a range for individual objectives

Measure R: Combined option C + E + N

772. Measure R is a new combined measure comprising the proposed measures being taken forward by the new Air Quality Strategy, This is a combination of Measure C2 (programme of incentives for the early uptake of Euro 5/6/V/VI standards), Measure E (incentives to increase the uptake of LEVs) and Measure N (Shipping measure).

Table 4.79 – Annual present value of health impacts of implementing Option R (£ million)

PM life years saved	PM – RHA	PM – CHA	O_3 Mortality	O_3 RHA	SO_2 mortality	SO_2 RHA
886 – 2,039	1 – 5	1 – 5	(5) – 0.02	(5) – 0.02	0.002 – 0.005	0.05 – 0.23

Table 4.80 – Annual present value of non-health impacts of implementing Option R

	(£ million)
Annualised social cost of carbon	36
Annualised PV of impact on crop yields	2
Annualised PV of impact on buildings and materials	2

Costs

773. Table 4.81 sets out the costs of Option R, which combines Options C2, E, and N. Costs are presented as a range due to different assumptions regarding technology costs under Option C2.

Table 4.81 – Costs of implementing Option R in the UK (2005 prices)

	(£ million)
Annualised technology costs	966 – 972
Annualised resource cost of extra fuel consumed	(83) – (82)
Annualised welfare impact due to rebound effect	(6)
Capital cost	0.5
Operating cost	0.8
Annualised present value of costs	878 – 885

Summary

774. The summary costs and benefits for Option R are presented in Table 4.82 below, including the annualised NPV figures, which represent the difference between annualised benefits and annualised costs at the 6% hazard rate. The results show that the implementation of the scheme could potentially create net benefits of £1,211 million.

Table 4.82 – Costs and benefits of implementing Option R in the UK (£ million)

Annual PV of Costs	Annual NPV	Exceedences assessment*	Ecosystems assessment	Qualitative assessments
878 – 885	33 – 1,211	Between 56% and 100% reduction for individual objectives	Significant positive impact on critical loads	SI+, N+, SB–

*This summary shows the lowest and highest expected impact by 2020 on baseline exceedences across all objectives and does not represent a range for individual objectives

775. The following options are also being considered by the review although have not had full national assessments or cost benefit analyses carried out. However a number of work-strands within the Air Quality Strategy have gathered information and results about the impact of these additional measures, based on Climate Change Programme Review and these assessments are presented below.

Option S: Smarter Choices

776. 'Smarter Choice' measures balance the need to travel with the aim of improving quality of life. Smarter Choices can offer a variety of alternative travel modes that can result in a reduction in car usage. Emphasis is placed on persuasion rather than technical or fiscal measures to better inform the road-user of the alternative, more sustainable, modes of transport available thus reducing car dependency and thereby achieving lower traffic levels.

777. The original report on Smarter Choices[191] looked at 24 case studies of areas within the UK in which soft policies have been implemented. The report estimated that significant reductions in road journeys could be achieved by implementing Smarter Choices policies at an average cost for implementation of 1.5p per car kilometre saved. The report also estimates the benefits to be ten times this, at 15p per car kilometre saved.

[191] Department for Transport, July 2004.'Smarter Choices – Changing the Way We Travel'. http://www.dft.gov.uk/sustainable/smarterchoices

778. Further appraisal of Smarter Choices has been undertaken for the Climate Change Programme Review (CCPR). This modelled two scenarios over the period 2006-2020: a) a 'low' scenario assuming a sustained continuation of current Smarter Choice funding on a national scale and; b) a 'high' scenario assuming greater expenditure, hence increased implementation of Smarter Choices. The high scenario modelled assumes a maximum percentage traffic reduction of around 4.5% in 2010, whereas for the low scenario a reduction of 1.3% is assumed. Costs in the analysis are assumed constant at 1.5 pence per car kilometre removed over the full 15 year period.

779. Table 4.83 below outlines the emissions reductions of NO_X and PM_{10} that could be achieved for each scenario and the annualised present values of the air quality benefits generated by these emission reductions over the period 2006-2020. The analysis also considers the public expenditure necessary to fund the schemes presented as the annualised present value of costs. From the figures in Table 4.83 it can be seen that the air quality impact only form a small proportion (3%) of the annual net benefit of the two scenarios. The benefits are instead dominated by the reductions in congestion.

Table 4.83 Results of the appraisal of Smarter Choices measures[a]

	High scenario	Low scenario
Total NO_X saved over the period 2006-2020 (tonnes)	96,412	29,512
Total PM_{10} saved over the period 2006-2020 (tonnes)	4,288	1,286
Annual Present Value of air quality benefits (low) – £million	£4	£1
Annual Present Value of air quality benefits (high) – £million	£27	£6
Annual Present Value of costs – £million	£356	£107
Annual NPV (low) – £million	£573	£84
Annual NPV (high) – £million	£595	£89
Max proportion of total benefits that are due to air quality impacts	3%	3%

*These estimates should be regarded as optimistic since the modelling was based on evidence from case studies and it is uncertain whether these policies could be scaled up to a national level. In addition, the delivery of these benefits may be dependant on other policies in order to lock in the benefits.

780. From the results above it is clear that there are significant benefits to be gained by increasing the take-up of Smarter Choices measures, if the take up levels underlying the above results is reached.

Option T: Sustainable Distribution

781. This option focuses on freight movements and attempts to reduce their impact on the environment, other road users, and to improve safety. The appraisal carried out looked at extending the provision of road haulage schemes (RHS), which offer drivers best practice advice on fuel saving measures and promote safer and more fuel efficient driving.

782. The model looks at a sustainable distribution policy implemented over the period 2006-2020. The model was set up to look at the costs of increasing carbon savings by an arbitrary 0.4MtC to 0.5MtC in 2010, including the costs of the investment in fuel saving measures (e.g. fuel economic technology, driver training). The benefits include the carbon savings, the savings in fuel and the air quality benefits.

783. Table 4.84 below outlines the emissions reductions of NO_x and PM_{10} that could be achieved by the RHS and the annualised present values of the air quality benefits generated by these emission reductions over the period 2006-2020.

Table 4.84 Results of the appraisal of Sustainable Distribution measures

	Road Haulage Scheme
Total NO_X saved over the period 2006-2020 (tonnes)	60,894
Total PM_{10} saved over the period 2006-2020 (tonnes)	913
Annual Present Value of air quality benefits (low) – £million	£1
Annual Present Value of air quality benefits (high) – £million	£9
Annual Present Value of costs – £million	£17
Annual NPV (low) – £million	£93
Annual NPV (high) – £million	£100
Max proportion of total benefits that are due to air quality impacts	11%

784. The results indicate that the road haulage industry could realise large benefits by implementing fuel saving technologies and driver training. The most likely reason that these gains are not being realised in the absence of RHS is a lack of information and knowledge within the haulage industry about these gains.

Option U: Traffic Speed Changes

785. There are potential fuel efficiency benefits from limiting the speeds at which vehicles travel, with related benefits for carbon and air quality pollutant emissions. Appraisal of traffic speed changes has been undertaken for the CCPR. This modelled reducing 70mph speed limits to 60mph.

786. The model assumes that there is a constant traffic flow and no move to or from alternative roads or modes occurs as a result of the new speed limits. In addition, only the proportion of travel done on major roads is considered, as the data for minor roads is limited. The scheme is assessed over the period 2008-2020.

787. Table 4.85 below outlines the emissions reductions of NO_X and PM_{10} that could be achieved by the two schemes and the annualised present values of the air quality benefits generated by these emission reductions over the period 2006-2020.

Table 4.85 Results of the Appraisal of Speed Changes

	70mph to 60mph
Total NO_x saved over the period 2008-2020 (tonnes)	310,886
Total PM_{10} saved over the period 2008-2020 (tonnes)	10,938
Annual Present Value of air quality benefits (low) – £million	£10
Annual Present Value of air quality benefits (high) – £million	£109
Total annual NPV (low) – £million	(£1,475) – (£1,375)

The scheme has a negative NPV, in spite of the air quality and carbon benefits, as the scheme incurs an overall cost due to impacts on travel time.

4.7 Small Firms Impact Test

788. Following discussion with the Small Business Service and, for some options, initial comments from the relevant trade bodies, the following options have been highlighted as having specific impacts on small businesses:

Options A, A2, B, C and C2: New Euro standards

789. While the burden upon smaller manufacturers may be proportionately larger, it is envisaged that the EU vehicle type approval framework directive could be employed, in order to limit the effects of measures on manufacturers whose world-wide production is less than 500 units per annum. This assumption does not change with the inclusion of the new Euro standards measures

Option G: Extend the London Low Emissions Zone (LEZ) to Greater London and the seven largest UK urban areas

790. The LEZ measure could have a disproportionate effect on small businesses. The views of small businesses were assessed as part of Transport for London's Strategic Review of the Feasibility Study for London's LEZ[192]. The concerns of small businesses included:

- increased financial burden due to the cost of retrofit equipment or the need to purchase new/newer, compliant vehicles;
- increased administrative burden, depending on how certification was handled; and
- the effect on the second hand vehicle market e.g. a reduced residual value for those wishing to sell vehicles and/or constraints on the ability to purchase second hand vehicles

[192] Available at http://www.tfl.gov.uk/tfl/low-emission-zone/feasibility-study.asp

Option I: Domestic Combustion – Switch from coal to natural gas or oil

791. This option has the potential to have a disproportionate effect on small coal suppliers that supply domestic coal although the way in which this option is intended to be implemented has not yet been defined. The Small Business Service indicate that, in 2004, there were approximately 40 companies undertaking mining and agglomeration of hard coal in the UK, of which 75% were classified as either micro or small businesses.[193] Given that domestic coal supplies have higher profit margins than industrial supplies, any shift away from domestic supplies could have the effect of lowering profit margins. In addition, there is a possible impact on the anthracite industry as a result of this measure and there may also be significant impacts on the downstream distributors and sellers of coal, and distributors of gas (which may benefit asymmetrically). This impact will have to be looked at in more detail if the measure is taken forward.

Option L: Small combustion plant measure

792. This option has the potential to have a disproportionate effect on small businesses. However, given the range of plants/sectors that the measure effects, a detailed view of this has not been possible at this stage. There are a wide array of businesses and linked businesses involved in this measure, and a more detailed assessment would be produced if this measure is taken forward.

4.8 Competition assessment

793. An initial assessment of the possible competition effects of each option has been carried out and is presented below. This preliminary assessment has highlighted Option G (Low Emission Zones), Option I (Domestic combustion switch from coal) and Option K (Large Combustion Plants) as having competition issues that may warrant further investigation although without a detailed understanding of the implementation options it is difficult to clearly assess these effects. As none of these measures have been selected for immediate implementation a full competition assessment will be undertaken when and if policy in these areas is proposed.

794. Further policy developments, at an international level, may actually occur independently of the introduction of any additional options. For example, the proposed Euro Standards (relating to Options A & B) will be implemented at an EU level, and the SCPD (relating to Option L) and shipping measure (relating to Option N) are likely to be implemented at an EU (directive) and global (via the IMO) level, respectively. It is currently not clear whether the policy options presented in this review will be completely consistent with the implementation plans for these developments (as they have yet to be agreed), however it may be possible that the competition assessments outlined below incorporate elements that could occur independently of the outcomes of this review.

Options A, A2 & B: New Euro standards

795. The option would mainly affect vehicle and engine manufacturers/suppliers; manufacturers and suppliers of exhaust after treatment systems; and owners/operators of vehicles. These options would not be expected to alter market structures in general, although

[193] The SBS statistics define micro businesses as operating with 1-9 employees, with small businesses operating with 10-49 employees. Statistics are available at http://www.sbs.gov.uk/SBS_Gov_files/researchandstats/

if the standards necessitate particular technologies, those producing alternative abatement techniques may be excluded from the market. The strength of competition among manufacturers/suppliers could also be potentially affected, depending upon the technologies required. No significant effects on innovation would be expected: innovation by UK and EU firms may in fact be stimulated by the requirements.

Options C & C2: Programme of incentives for early uptake of new Euro standards

796. These option would affect similar markets to Options A, A2 and B. It is unlikely such incentives would alter the current vehicle and engine manufacture/supply market structure given that all suppliers would be subject to the same incentive mechanisms. While such early incentives have the potential to create disparities between the UK and other countries, it is understood that German, Austrian and Dutch governments have already tabled plans for such fiscal incentives, with France and Sweden having expressed an interest.

797. The potential competition effects are as follows, although they are all expected to be small:

- Manufacturers may have to produce a greater range of models to satisfy both markets with and without incentives for vehicles meeting the standards (with potentially significant costs and higher unit costs due to smaller production runs). It may also prove difficult to pass on cost increases to (non-EU) markets that are not subject to the same requirements.
- In terms of suppliers of abatement equipment, firms that manufacture the required technologies will have a competitive advantage over those that do not and could gain a greater market share potentially reducing competition.
- Firms owning/operating vehicles that are able to take advantage of these incentives (e.g. in fleet renewal) may gain an advantage over those that are required to purchase vehicles after the incentivisation period has ended (this might also mean slightly higher start-up costs for new-entrants to the market, in the short-term at least).

Option D: Programme of incentives to phase out the most polluting vehicles

798. This option is not expected to impact on competition as the option proposes incentives to owners or operators of existing vehicles only and as such it is unlikely such incentives would alter the current vehicle manufacture and supply market structure. In addition, only a small number of vehicles will be affected by this option.

Option E: Updated programme of incentives to increase penetration of low emission vehicles

799. This option incentivises the replacement of certain petrol and diesel cars with low emission vehicles and as such would affect manufacturers/suppliers of vehicles/engines, as well as vehicle owners and operators. In the short-term, this measure may favour the small number of companies currently supplying LEVs to the UK market (though several other manufacturers are currently developing their own models). In the longer term however, the number of firms manufacturing and supplying LEVs should increase thus increasing the strength of competition, improving customer choice and encouraging innovation.

Option F: Impact of national road pricing scheme on air quality

800. This option would primarily affect the owners and operators of vehicles. The road pricing feasibility study[194] estimated considerable net benefits to businesses, with the results of the study suggesting that, in aggregate, the value of time savings for freight and business car travellers would exceed the amount they would have to pay in charges as those people travelling on behalf of their employer tend to value their time more highly. The impacts would depend on the details of any scheme, such as where and when it might apply, and which vehicles it might apply to. As no decisions have been taken on national road pricing, it is not possible to make a more detailed assessment of the potential competition impacts at the current time.

Option G: Extend the London Low Emissions Zone (LEZ) to Greater London and the seven largest UK urban areas

801. The impact on competition for this option was assessed as part of Transport for London's Strategic Review of the Feasibility Study for London's LEZ.[195] This option is expected to affect fleet operators of vehicles who operate predominately or solely in the urban areas covered by the LEZ option and also disproportionately impact fleet operators of specialist vehicles (specialist vehicles are more expensive than conventional fleet vehicles and therefore tend to have longer replacement cycles). This measure could also affect the structure of the second hand vehicle market as the presence of a LEZ would reduce the re-sale value of older vehicles (i.e. that do not meet the emissions criteria for the LEZ), affecting both operators and leasing companies. In addition, this measure could benefits suppliers of equipment such as DPFs, and provide a spur to innovation in emission-reducing equipment. Further investigation of the competition impacts may be needed although without a more detailed understanding of the implementation options it is difficult to clearly assess the effects.

Option H: Retrofit diesel particulate filters on heavy goods vehicles and captive fleets (buses and coaches)

802. This option will mainly affect suppliers of abatement equipment and owners/operators of vehicles. Although this option could potentially exclude suppliers of alternative abatement technologies from the market, it should not reduce the strength of competition between vehicle operators/owners, provided that the option is implemented through a voluntary scheme.

Option I: Domestic Combustion – Switch from coal to natural gas or oil

803. This option might change the structure of the domestic fuel supply market through the replacement of coal with natural gas or oil for domestic use, and has been identified by the competition filter as requiring more detailed assessment.

- The option will affect producers and suppliers of natural gas, oil and coal for domestic use. Manufacturers and suppliers of boilers, stoves and fireplaces would also be indirectly affected by the proposed measure as it should lead to an increased demand for new gas (or oil where applicable) appliances and reduced demand for coal fireplaces or stoves.

[194] Available at http://www.dft.gov.uk/stellent/groups/dft_roads/documents/divisionhomepage/029709.hcsp

[195] Available at http://www.tfl.gov.uk/tfl/low-emission-zone/feasibility-study.asp

- There are over 1,100 approved coal merchants in the UK and eight main coal producers.[196] The Small Business Service indicate that, in 2004, there were approximately 40 companies undertaking mining and agglomeration of hard coal in the UK, of which 75% were classified as either micro or small businesses.[197] The largest supplier of coal to domestic markets, RJB mining, is estimated to supply just under 30% of domestic coal and domestic coal use represents around 2% of total UK demand for coal and around 6% of UK coal supply,[198] since the majority of coal is imported. The main final gas supplier in the UK held over 67% of the market share with respect to domestic supply and consumption of gas in 2002.[199]
- The switch in domestic combustion from coal to gas (or oil where applicable) would reduce the number of domestic coal producers and suppliers in the market to those who already supply (or begin to supply) domestic gas leading to a more concentrated market structure overall, although the way in which this measure is intended to be implemented has not yet been defined. There may be a danger of larger suppliers being affected, and could cause more widespread impact on the coal sector and the UK's ability to meet its electricity security of supply. The domestic gas market, which is already dominated by one firm (see above), would therefore grow to accommodate the resulting new customers, though other suppliers would be able to enter the market leading to a growth in competition. This switch from coal to gas (or oil where applicable) could reduce the incentive for investment in clean coal technologies (for example, low sulphur coal), although it would not restrict innovation in the gas market.
- However, this switch should be seen in the context of an ongoing BAU increase in the proportion of gas in the UK's domestic combustion fuel mix (although the volatility of gas prices would suggest that this option could be costly to small households and businesses). Furthermore, domestic sales represent only a small proportion of total coal sales, with many of the larger companies supplying coal to other uses. Companies with a higher than average share of domestic coal sales therefore will be the most affected.

Option J: Domestic combustion – Product standards for gas fired appliances which require tighter NOx emission standards

804. The market for gas boilers appears to be relatively uniform across the EU, and a regulation that would affect all of these installations simultaneously would be assumed to impact little on the competitive outcomes on the intra-EU competitiveness front. However, there is a need to assess the structure of the gas boiler market within each geographical area in order to establish whether there are any significant impacts arising from this measure. It has not been possible to conduct this analysis at the detailed level required to ensure that no significant adverse impacts will follow. There are also related markets in maintenance services that may need to be considered. An additional issue relates to existing boilers, the manner in which they would be phased out, and how the market for these boilers would be affected by the new regulation.

196 Based on the number of members of the Confederation of UK Coal Producers, see www.coalpro.co.uk.

197 The SBS statistics define micro businesses as operating with 1-9 employees, with small businesses operating with 10-49 employees. Statistics are available at http://www.sbs.gov.uk/SBS_Gov_files/researchandstats/

198 Based on http://www.dti.gov.uk/energy/inform/energy_stats/coal/dukes05_2_7.xls and www.rjb.co.uk

199 Ofgem (2002): Competition in Gas and Electricity Supply, Separating Fact from Fiction.

Option K: Large combustion plant measure

805. The UK has a proportionately greater reliance on coal-fired electricity generation than other countries. If UK installations have to fit SCR and other countries do not, this will impact on the relative profitability of these installations relative to those which fall outside the scope of this measure. For the Option K2, the plants in the non-electricity generating sector, refining, iron and steel might be allowed to operate under a cap and trade scheme, in which case the industry will adopt a cost-effective means of implementing this measure. It is difficult to model the impact of these alternative outcomes, given it is too early to say what the final implementation route might be. A full assessment of the competitiveness impact would look at all the installations affected and how this measure will be implemented. If all the plants have to individually fit abatement equipment (SCR) then there is likelihood that the manufacturing sector (iron and steel and refineries) would face more competitiveness issues than their electricity-sector counterparts (since extra costs could be easily passed onto final electricity consumers).

Option L: Small combustion plant measure

806. This option would affect a range of markets and installations (such as power generation, autogenerators, various industrial sources, public services and others), and the market for alternative abatement technologies, so it has not been possible to define individual markets in any detail. The measure (introduced through a future directive) should affect market structures equally across Europe, but the national implications would only be understood with a more detailed assessment of the composition of plants affected and how these differ between Member States. In the best case scenarios, all EU-based firms would be equally affected - though non-EU firms would not be affected. An additional issue that would need consideration is that those installations below the minimum threshold for inclusion (<20MW) might gain an advantage over those above the threshold.

Option M: Reduce national volatile organic compounds emissions by 10%

807. This option proposes a reduction in national VOC emissions based on a range of different measures and as such it is difficult to present an overall assessment of the competition impacts of this option.

808. For one component measure of the option – the Petrol Vapour Recovery (Stage II) controls – an assessment of the competitiveness impacts of the measure is presented in its RIA.[200] The assessment states there is unlikely to be an impact on competitiveness as capital costs associated with the controls are not likely to be passed on to consumers, given limited flexibility in price setting due to the strength of competition in the petrol retail market. Although competition between stations is less intense in certain areas, for example remote rural areas, the size of the station considered by this component measure of Option M is rather larger than the majority of such rural petrol stations.

Option N: Shipping measure through International Maritime Organisation

809. This option would affect petroleum refineries producing fuel for shipping, bunker suppliers, shipping operators, as well as ship and abatement technology manufacturers/ suppliers. However, it would affect all ships globally, that are above the specified size

[200] AEA Technology (2005) 'Regulatory Impact Assessment, Stage II Petrol Vapour Recovery', prepared for Defra, June 2005

threshold, and would not be expected to affect market structure significantly, nor create significant barriers to entering/exiting the market (though new firms may face higher initial capital outlay).

Option O: Combined Option C + E

810. This option would affect competition in line with the competition effects discussed above for Options C and E.

Option P: Combined Option C + L

811. This option would affect competition in line with the competition effects discussed above for Options C and L.

Option Q: Combined Option C + E + L

812. This option would affect competition in line with the competition effects discussed above for Options C, E and L.

Option R: Combined Option C2 + E + N

813. This option would affect competition in line with the competition effects discussed above for Options C2, E and N.

4.9 Enforcement, sanctions and monitoring

814. The focus of the review is to assess the policy options that might be taken forward, in order to help move towards achieving Air Quality Strategy objectives. Any option that is taken forward would need to have a detailed implementation plan developed and would be subject to a full Impact Assessment, which would detail the issues surrounding the enforcement, sanctions and monitoring of the option.

4.10 Implementation and Delivery Plan

815. The process for implementing the measures being taken forward as set out in the strategy should be started from the time of the Strategy's publication. The Delivery Plan and dates of implementation will take place as is in the text for each individual measure.

816. The Department will also take account of changes to EU policy or scientific developments and this will in turn affect the date of the next review of the Strategy.

817. The Department has consulted industry and other stakeholders throughout the process of drawing up the new Air Quality Strategy, and as such comments on the proposed implementation route and delivery plan have been taken into account for the final production.

4.11 Post-Implementation Review

818. Reviews taken after publication of the Strategy will base on changes in international policy (directives soon to be reassessed include the new EU Air Quality Directive expected in Summer 2007, there are proposals to revise the IPPC Directive at the end of 2007 and the Gothenburg Protocol is expected to be reviewed during 2007) and also to developments in the evidence base through the UK Air Quality Evidence and Innovation Programme, which is managed by Defra. This will look to quantify exposures, assessing impacts of air pollution, assess policy options and produce effective strategies.

4.12 Summary and recommendation

819. Table 4.86 below summarises the costs and benefits of the options presented in this RIA.

Table 4.86 Summary of costs and benefits for all options

AQS Option	Annual NPV	Exceedance Assessment	Ecosystems Assessment
Ø	–	–	–
A	80 – 801	Between 44% and 100% reduction for individual objectives	Significant positive impact
A2	(264) – 539	Between 46% and 100% reduction for individual objectives	Significant positive impact
B	(432) – 514	Between 62% and 100% reduction for individual objectives	Significant positive impact
C	148 – 947	Between 47% and 100% reduction for individual objectives	Significant positive impact
C2	(246) – 595	Between 48% and 100% reduction for individual objectives	Significant positive impact
D1	(4) – (3)	Not modelled	No/insignificant impact
D2	(97) – (93)	Between 0.4% and 5% reduction for individual objectives	No/insignificant impact
E	63 – 112	Between 3% and 9% reduction for individual objectives	No/insignificant impact
F	–	Between 3% and 67% reduction for individual objectives	No/insignificant impact
G1	(33) – (1)	Not modelled	No/insignificant impact
G2	(67) – (2)	Between 0% and 33% reduction for individual objectives	No/insignificant impact
G3	(14) – (12)		No/insignificant impact
H1	(33) – (17)	Not modelled	No/insignificant impact

AQS Option	Annual NPV	Exceedance Assessment	Ecosystems Assessment
H2	(5) – (0)	Not modelled	No/insignificant impact
H3	(7) – 2	Not modelled	No/insignificant impact
I	(23) – (15)	Not modelled	No/insignificant impact
J	(179) – (148)	Between 0% and 5% reduction for individual objectives	No/insignificant impact
K1	(107) – 33	Not modelled	No/insignificant impact
K2	(232) – (139)	Between 0% and 15% reduction for individual objectives	Significant positive impact
L	18 – 57	Between 0% and 8% reduction for individual objectives	No/insignificant impact
M	(249) – (248)	Not modelled	No/insignificant impact
N	245 – 576	Between 1% and 38% for reduction for individual objectives	Significant positive impact
O	186 – 978	Between 50% and 100% for reduction for individual objectives	Significant positive impact
P	163 – 1,000	Between 52% and 100% for reduction for individual objectives	Significant positive impact
Q	203 – 1,053	Between 52% and 100% for reduction for individual objectives	Significant positive impact
R	33 – 1,211	Between 56% and 100% reduction for individual objectives	Significant positive impact

820. It is recommended that Measure R, the combined package of measures C2, E and N, is taken forward for further consideration as a result of the cost benefit analysis. Also Measures F, G1-G3, H and L are being kept under review for future work. The remaining measures are not being taken forward at this time.

Declaration and publication

I have read the Regulatory Impact Assessment and I am satisfied that the benefits justify the costs.

Signed by the responsible Minister

Ben Bradshaw

Signed: ______________________________

Date: ________________________________

List of abbreviations

$\mu g.m^{-3}$	micrograms per cubic metre
AE	Accumulated exceedence
AOT	accumulation over threshold
APEG	Airborne Particles Expert Group
AQF	Air Quality Forum
AQMA	Air Quality Management Areas
AQS	Air Quality Strategy for England, Scotland, Wales and Northern Ireland
ASSI	Areas of Special Scientific Interest
AURN	Automatic Urban and Rural Network
B[a]P	Benzo[a]pyrene
BAT	best available techniques
BAU	Business as usual scenario (based on the measures already in place)
BLH	boundary layer height
CAFE	Clean Air for Europe programme, which sets out the European Commission's draft strategy on the future of air quality
CBA	Cost Benefit Analysis
CBED	Concentration-Based Estimated Deposition
CC	cryogenic condensation
CCP	climate change programme
CCPR	climate change programme review
CFS	Counter factual scenario
CHA	Cardiovascular hospital admissions
CLRTAP	Convention on Long-Range Transboundary Air Pollution
CO	carbon monoxide
CO_2	Carbon dioxide
COC	Committee on Carcinogenicity of Chemicals in Food, Consumer Products and the Environment

COGAP(air)	Code of Good Agricultural Practice for the protection of air
COMEAP	UK Department of Health's Committee on the Medical Effects of Air Pollutants
DPF	Diesel Particulate Filter
EEP	Environmental Permitting Programme
ELV	Emission Limit Value
EMEP	European Monitoring and Evaluation Programme – a Cooperative Programme under CLRTAP
EPAQS	Expert Panel on Air Quality Standards
EU ETS	EU Emission Trading Scheme
FAB	First-order Acidity Balance
FBC	Fuel borne catalyst
FCCU	Fluid Catalytic Cracker unit
FGD	flue gas desulphurisation
f-NO_2	fraction of NO_X emitted as primary NO_2
FRAME	Fine Resolution Atmospheric Multi-pollutant Exchange
HDV	Heavy Duty Vehicle (including articulated and rigid heavy goods vehicles)
HGV	Heavy Goods Vehicle
IDG	interdepartmental group
IEA	International Energy Agency
IGCB	Interdepartmental Group on Costs and Benefits
IPPC	Integrated Pollution Prevention and Control Directive
IMO	International Maritime Organisation
LAEI	London Atmospheric Emission Inventory
LAPPC	Local Authority Pollution Prevention and Control
LAQM	Local Air Quality Management
LCPD	Large Combustion Plant Directive

LDAR	leak detection and repair
LDV	Light Duty Vehicle (including cars and light goods vehicles)
LEV	Low Emission Vehicle
LEZ	Low Emission Zone
LGV	Light Goods Vehicle (such as commercial vans)
MFPSO	modification to floating production, storage and off-take vessels
MST	modification to shuttle tankers
NAEI	National Atmospheric Emissions Inventory
NARSES	National Ammonia Reduction Strategy Evaluation System
NDPB	Non-Departmental Public Bodies
NECD	National Emission Ceilings Directive
NERP	National Emission Reduction Plan
NH_3	ammonia
NH_4^+	ammonium
NMVOC	non-methane volatile organic compounds
NO	nitric oxide
NO_2	nitrogen dioxide
NO_x	oxides of nitrogen
NO_y	total reactive oxides of nitrogen
NPV	Net Present Value
O_3	ozone
OFT	Office of Fair Trading
OSRM	Ozone Source Receptor Model
OX	oxidant
PAH	polycyclic aromatic hydrocarbons

PCP	pentachlorophenol
PM_{10}	Particulate matter less than 10μm aerodynamic diameter
$PM_{2.5}$	Particulate matter less than 2.5μm aerodynamic diameter
POPs	persistent organic pollutants
PORG	Photochemical Oxidant Review Group
PPC	Pollution Prevention and Control Regulations 2000
PV	Present Value
RAG	Red, amber or green
RGAR	Review Group on Acid Rain
RHA	Respiratory hospital admissions
RHS	road haulage scheme
RIA	Regulatory Impact Assessment
RPC	Reduced Pollution Certificate
RTFO	Renewable Transport Fuel Obligation
SAC	Special Areas of Conservation
SCPD	Small Combustion Plant Directive
SCR	Selective Catalytic Reduction
SMB	simple mass balance
SO_2	Sulphur dioxide
SO_x	oxides of sulphur
SPA	Special Protection Areas
SRU	Sulphur Recovery unit
SSSI	Sites of Special Scientific Interest
TEOM	Tapered Element Oscillating Microbalance
TfL	Transport for London

TO	thermal oxidation
TRP	storage tank replacement programme
UEP	Updated Energy Projection
UKAEI	UK Ammonia Emission Inventory
UKIAM	UK Integrated Assessment Model
UKPIA	UK Petroleum Industries Association
UNECE	United Nations Economic Commission for Europe
VMM	Vehicle Market Model
VOCs	Volatile Organic Compounds
VRU	vapour recovery unit
WHO	World Health Organisation

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