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Impact pathway guidance for valuing changes in air quality

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Executive Summary

The quality of the air impacts people's health and the environment. Air pollution is estimated to reduce life expectancy of people in the UK by 6 months on average, imposing a cost of around £16 billion per year[1]. Despite substantial improvements that have reduced pollution levels, air quality in some locations remains a notable concern. Minimum air quality standards in some areas are not being delivered, in particular the NO_2 annual mean limit of 40µg.m^{-3} which was breached in 40 out of 43 zones in 2010.

This guidance provides an overview of the impact pathway methodology, which is the central methodology for valuing changes in air quality. It values the air quality impacts of proposed decisions by estimating how changes in the ambient concentrations of air pollutants affect a range of health and environmental outcomes.

The impact pathway approach has been developed by Defra with support from the Interdepartmental Group on Costs and Benefits (IGCB), a Defra-led group of government analysts that provides advice relating to the quantification and valuation of local environmental impacts.

A full impact pathway analysis is generally recommended when estimated air quality impacts are valued at more than £50m using damage costs, or when air quality is the main objective of the proposal. Damage costs have been developed from the impact pathway approach to facilitate proportionate analysis of air quality impacts[2]. This guidance provides an overview of how full impact pathway analysis is conducted.

Air quality impacts are separated into four broad types: health; amenity; productivity and ecosystems impacts. The objective is to quantify and value all of these types of impact. At present the evidence on health impacts is the most developed and so the methodology is most advanced for valuing these. Work is ongoing to quantify the impacts on productivity and ecosystems, while amenity impacts are unlikely to be significant as pollution is generally not detectable in ambient concentrations.

The impact pathway approach starts with the source of emissions and finishes by quantifying and valuing the impacts where possible. First, emissions in the baseline and with the proposed measure or policy are quantified. Next dispersion modelling converts

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[1] http://archive.defra.gov.uk/environment/quality/air/airquality/panels/igcb/documents/100303-aq-valuing-impacts.pdf

[2] Damage cost guidance is available from: www.gov.uk/air-quality-economic-analysis#damage-costs-approach

these emissions into population weighted concentrations. This quantifies the exposure of people, the environment and buildings to air quality changes. Finally health and non-health impacts of the change in exposure are estimated. Where possible these are monetised to estimate the value of the change in air pollution. This guidance details the main steps of an impact pathway analysis and highlights the associated uncertainties to consider.

1. Introduction

1. Air pollution harms human health and the environment. It is estimated that particulate air pollution reduces average life expectancy in the UK by around six months, worth £16 billion a year[3]. Therefore it is important that wherever possible air quality impacts are reflected in decision-making.

2. To facilitate the inclusion of air quality impacts a range of approaches have been developed to value changes in air quality. One of these is the impact-pathway methodology, which is recommended for use on all changes in air quality, where they do not impact on compliance with legally binding obligations.

3. This paper outlines the impact-pathway approach, identifies relevant sources of information and highlights the uncertainties related to each step of the approach. It is intended to provide analysts or policy leads with an overview of how the air quality impacts of their policy would be valued using the impact-pathway approach.

4. To evaluate the benefits of the local environment and the impacts of any changes affecting it, the methodologies that are recommended estimate and value all associated outcomes. These have been separated into four broad impacts[4]:
    - Health – this includes both mortality and morbidity.
    - Amenity – reflects conscious changes in consumers' satisfaction.
    - Productivity – through detriment to both human and natural capital.
    - Ecosystems – considers the effects on the environment.

5. The objective is to quantify and value all these impact end points for each of the different aspects of local environmental quality. However practical constraints on evidence, resources and time mean that achieving this objective for all aspects of local environmental quality is only possible in the long term.

6. This guidance sets out best practice appraisal methodologies for all projects, programmes and policies. Appraisal guidance on the local environment published by Defra informed by the work of the Interdepartmental Group on Costs and Benefits (IGCB). The IGCB is a Defra-led group of government analysts that provides analysis and advice relating to the quantification and valuation of local environmental impacts.

7. While the impact pathway approach and end points are common across the range of local environmental quality appraisal, this paper focuses on the specific approach that is recommended for air quality.

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[3] http://archive.defra.gov.uk/environment/quality/air/airquality/panels/igcb/documents/100303-aq-valuing-impacts.pdf

[4] This separation is not intended to suggest that these impacts are necessarily independent. It is rather intended as a clear framework in which the impacts can be presented. Care should be taken to avoid potential double counting of impacts.

1.1 Overview of approaches for valuing changes in air quality

8. There are different methods for valuing changes in air quality depending on the nature of the changes. Figure 1 sets out how to determine the appropriate method.

9. This paper focuses on the impact pathway approach (IPA) methodology, which will be used to value air quality in the majority of cases. It applies to situations where total air quality impacts are expected to exceed £50m and when a breach of the prescribed minimum standards is not an issue. More information on this methodology and its sensitivities is provided in 'Economic Analysis to inform the Air Quality Strategy – Volume 3'[5].

Damage costs

10. Where a breach of standards is not expected but total air quality impacts are expected to be less than £50m, damage costs can be used. Damage costs are derived from representative impact pathway modelling to provide a less resource intensive, albeit more approximate approach. Since they are approximations it is recommended they should be reported only when they are less than £50m and when air quality is not the main objective of the policy decision. Current damage cost values are available from Defra at www.gov.uk/air-quality-economic-analysis.

11. Damage costs can also be used to identify circumstances when an impact pathway assessment should be considered. If the air quality impact, estimated by applying damage costs, is greater than £50m then an impact pathway assessment might be suitable and you should contact igcb@defra.gsi.gov.uk for advice. This guidance provides an outline of how such an analysis works.

12. A Damage Cost Calculator is available which provides a convenient means of converting emissions into monetary values over time and can model a range of changes in different pollutants. The Calculator and supporting guidance providing further detail on damage costs can be found online at: http://uk-air.defra.gov.uk/library/reports?section_id=19

The impact pathway approach

13. The location of emissions has a substantial effect upon the scale of air quality impacts, particularly for health impacts. Impacts in highly populated areas will be much larger when compared with sparsely populated areas. Also, areas with sensitive ecosystems will face greater environmental impacts.

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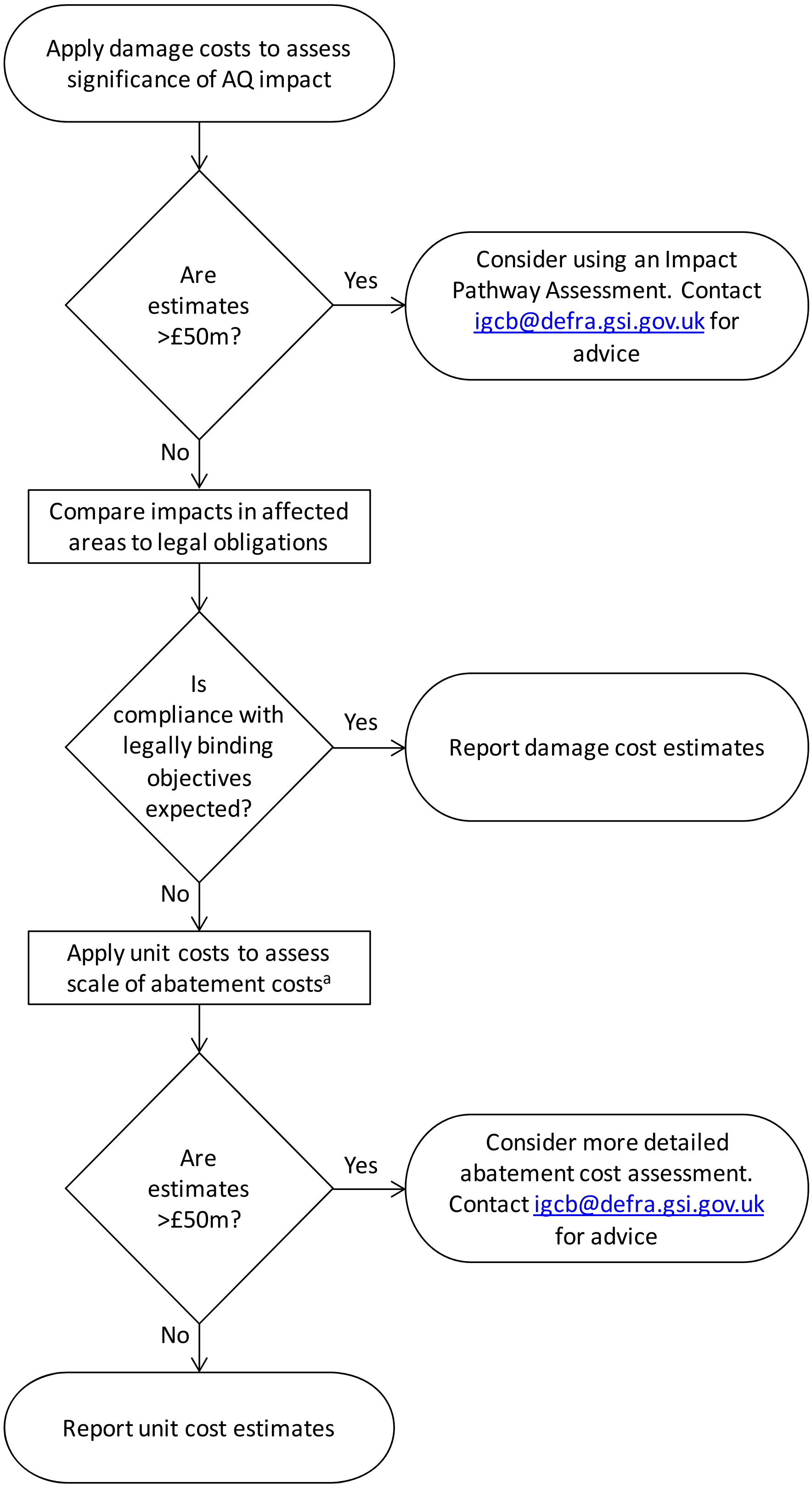
[5] Available from www.gov.uk/government/publications/an-economic-analysis-to-inform-the-air-quality-strategy

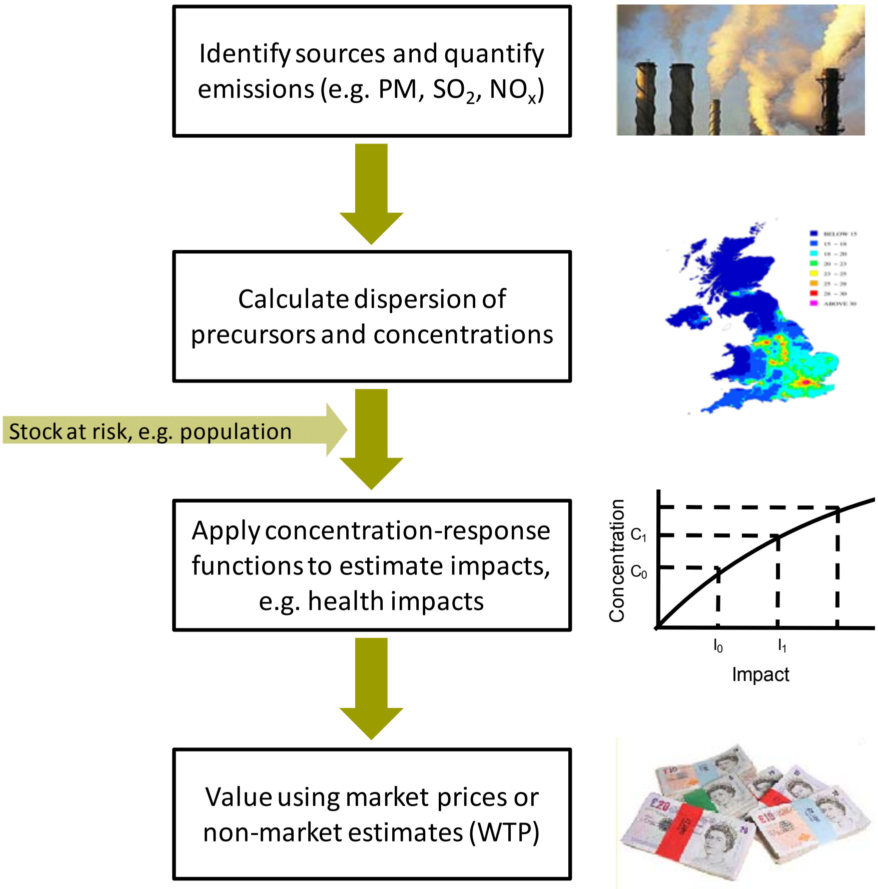
Figure 1: Overview of air quality valuation process



[a] Only emissions that occur above the legal obligation should be valued using unit costs. Emissions below this level should be valued using damage costs.

14. The impact pathway approach recognises the importance of geographical location. The approach follows a logical progression from locating the source of the emissions through to identifying the range of impacts that can then be valued. It is illustrated in Figure 2 below.

Figure 2: The impact pathway approach



15. The steps in Figure 2 broadly entail the following:

- Emissions - quantification of emissions, for the baseline and additional measures;
- Dispersion - conversion of projected emissions into population weighted concentrations for the baseline and differing policy scenarios. This quantifies the exposure of people, the environment and buildings to changes in air quality;
- Impact - quantification of health and non-health impacts associated with the change in pollutants, for example, using concentration-response functions that estimate the relationship between changes in air pollutants and changes in health outcomes;
- Valuation - monetisation of health and non-health impacts.

16. A large volume of information is needed to complete an impact pathway assessment fully. This guidance describes the sources of the information underpinning the analysis and highlights the uncertainties surrounding each step.

Abatement costs

17. There are limited circumstances where the IPA does not provide the most appropriate information to inform decisions. Where policy decisions affect compliance with a legally binding obligation (whether causing, avoiding or changing the extent of non-compliance) the IPA will not capture the full value of the change in air quality. This is because when obligations are breeched additional abatement of emissions is required, the cost of which is not captured by an IPA. The abatement cost approach captures these costs and is the appropriate method to reflect the true impact of the policy decision.

18. A guidance paper explaining the abatement cost methodology and when it should be used can be found at www.gov.uk/air-quality-economic-analysis.

1.2 Social cost benefit analysis

19. Social cost benefit analysis (SCBA) provides a framework to compare different policies. In its simplest form, the social costs and benefits of each policy are quantified and valued in monetary terms. The costs are subtracted from the benefits and if there is a positive net benefit it provides support for an intervention. Alternative options can be ranked and policies with a higher net benefit are considered preferable to those with a lower net benefit or a net cost.

20. A monetised net cost does not automatically mean a measure is not worthwhile, and similarly a monetised net benefit may not mean a measure is worthwhile. Not all concerns can be captured by the quantified costs and benefits, such as distributional considerations and non-monetised impacts. These should also inform the decision however.

21. An advantage of SCBA is that costs and benefits are presented in the same metric (money) as far as possible. Different impacts, such as the effects of different pollutants, can be compared within a particular measure, and across different measures. More broadly, monetised impacts of measures in different policy areas can be compared to assess where limited resources might be used best.

22. Not all costs and benefits can be monetised. Often supplementary qualitative assessments are needed where monetary values are unavailable. Uncertainties surrounding the quantification and valuation of costs and benefits also need to be considered when results are interpreted. These uncertainties are explored in more detail in the final section of this document.

23. A SCBA focuses on the overall societal impact of any decision. Financial transfers between groups or individuals (such as payments or tax liabilities) are not included because they would count as both a benefit and a cost, having no net social impact. Any distributional impacts should still be reflected in the wider consideration of any policy.

2. Emissions and dispersion

24. The first stage in any assessment of the impacts of changes in air quality is to estimate the changes in both the level of different pollutants emitted and the resulting change in the ambient concentration. This chapter sets out how such calculations are undertaken.

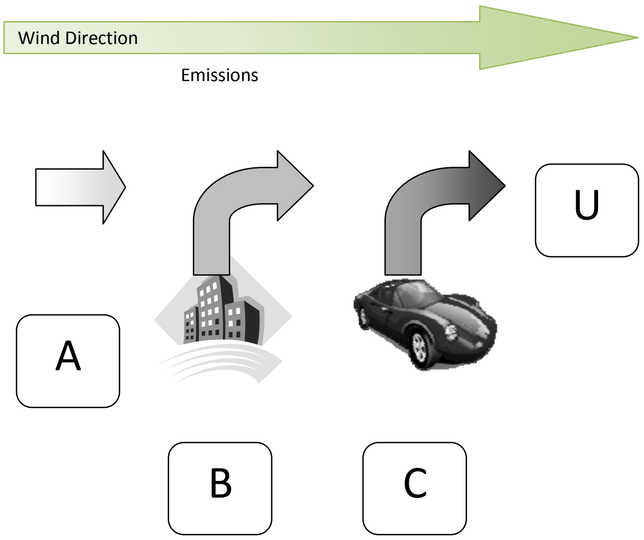
2.1 Assessing current air quality

25. Current air quality is assessed using a combination of measurement and modelling. Defra and the devolved administrations manage a national network of air quality monitoring sites that measure concentrations of air pollutants. Measurements from these sites are published at www.airquality.co.uk

26. It is impossible to measure air quality everywhere, so the measurement network is supplemented by national air quality modelling. This estimates concentrations of air pollutants nearly everywhere in the United Kingdom, with the exception of non-urban roads.

27. Figure 2 gives a stylized representation of how air quality modelling estimates pollutant concentrations. The model estimates the concentration at point or area U (for example, an urban background location near a busy road).

Figure 2: Summary of air quality modelling



U: area that concentrations are being estimated for
A: concentration of the pollutant outside the urban area
B: emissions of the pollutant from all the sources in the urban area
C: emissions from the road traffic near to U

28. To predict the concentration at U most models use information or assumptions about:

- Concentration of the pollutant outside the urban area (A);
- Emissions of the pollutant from all the sources in the urban area (B);
- Emissions from the road traffic near to U (C); and
- Meteorological conditions

29. Although this appears relatively straight forward, it is actually a challenging process because of the complexity of chemical reactions and physical processes in the atmosphere and the diversity and complexity of emissions sources and emissions rates. While it is not practical to measure actual emissions from all sources, using modelling estimates instead introduces uncertainties that need to be understood.

2.2 Projecting future air quality

30. In addition to assessing current and historic air quality, we need to estimate future air quality. This allows us to predict the impact of current and potential future measures on future air quality. There are a range of methods to project future air quality and air pollutant emissions. These involve 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, ozone, nitrogen dioxide, and sulphur dioxide.

31. UK-wide maps are also produced of annual mean benzene, 1,3-butadiene, nitrogen dioxide, PM_{10} and $PM_{2.5}$ concentrations at background locations for both current and future years. These maps are based on estimates of emissions provided by the National Atmospheric Emissions Inventory (NAEI). A series of reports describes in detail the methodologies for the national modelling of air quality[6].

2.3 Comparison with the baseline

32. All potential measures should be assessed against the relevant baseline. The baseline takes account of the expected changes in air pollution as a result of current policies and agreed future polices. The general principle is to include existing policies or those on which agreement has been reached, even if the full administrative and legal procedures have not been finalised.

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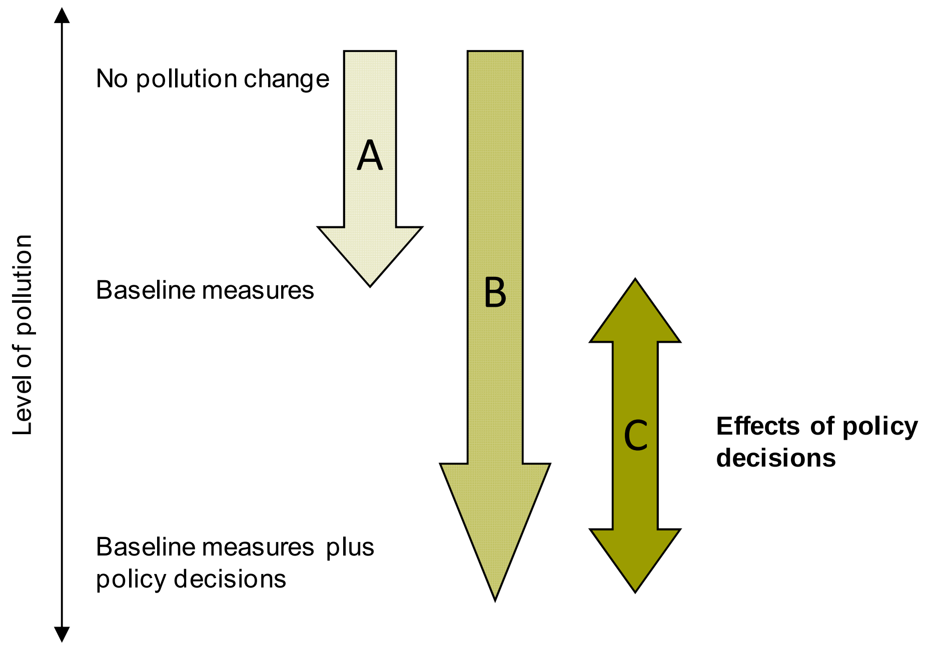
[6] Stedman et al (2006) 'Projections of Air Quality in the UK for Additional Measures Scenarios for the 2006 Review of the Air Quality Strategy', National Atmospheric Emissions Inventory, AEA Technology, National Environmental Technology Centre. Report AEAT/ENV/R/1986. Grice et al (2006) 'Baseline Projections of Air Quality in the UK for the 2006 Review of the Air Quality Strategy', National Atmospheric Emissions Inventory, AEA Technology, National Environmental Technology Centre. Report AEAT/ENV/R/1936.

33. Figure 3 shows that policy appraisal should only consider the level of pollution which is being affected by the given policy – arrow C in the figure below. Anticipated changes in air quality which are attributable to other factors – arrow A in Figure 3 – are part of the baseline position.

Figure 3: The effects of policy decisions in a single area



3. Quantification of impacts

34. Air pollution has a range of impacts, which are grouped into the four broad areas of health, amenity, productivity and ecosystems. Evidence is most developed for health effects, which have been the focus of research historically. Work is ongoing to quantify the impacts on productivity and ecosystems, which at present are usually expressed qualitatively. There is unlikely to be a significant amenity impact at prevailing levels of air pollution as it is generally not detectable in ambient concentrations.

3.1 Method for calculating health impacts

35. Air pollutants have a range of effects on health that have been considered in detail in publications from both the Advisory Group on the Medical Aspects of Air Pollution Episodes (MAAPE)[7] and the Committee on the Medical Effects of Air Pollutants (COMEAP)[8].

36. The following sections outline the evidence on the health impacts of air pollution that underpins the air quality valuation methodology. The methodology applies recommendations made by COMEAP about quantifying health impacts. As the evidence of links between air quality and health is continually developing this methodology may be changed in light of the latest evidence and accordance with new recommendations.

Quantification methodology: short term exposure

Concentration-response coefficients – effects of short term exposure

37. Exposure modelling is used to calculate the effects on health of exposure to pollutants. It takes into account variations in pollutant concentrations and population density across the UK. The literature on the effects of air pollutants on health is extensive. Reports by COMEAP use the relevant evidence to recommend a series of coefficients linking concentrations of the major pollutants to effects on health. The coefficients used in this analysis are presented in Table A. A coefficient of +0.6% per 10µgm^{-3} means that for every 10µgm^{-3} increase in the concentration of that pollutant there is an associated 0.6% increase in incidence of the particular health outcome.

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[7] Department of Health (1991; 1992; 1993; 1995a)

[8] COMEAP (2009; 2010); Department of Health (1995b; 1995c; 2006a). The COMEAP website can be found at www.comeap.org.uk

Table A: Concentration response coefficients

Pollutant	Health outcome	Concentration-response coefficient
$PM_{2.5}$	Loss of life expectancy (long term exposure)	See following section 'Quantification methodology: long term exposure to particles and mortality'
PM_{10}	Respiratory hospital admissions Cardiovascular hospital admissions	+ 0.80% per 10μgm^{-3} (24 hour mean) + 0.80% per 10μgm^{-3} (24 hour mean)
Sulphur dioxide	Death brought forward (all causes) Respiratory hospital admissions	+ 0.60% per 10μgm^{-3} (24 hour mean) + 0.50% per 10μgm^{-3} (24 hour mean)
Ozone	Deaths brought forward (all causes) Respiratory hospital admissions	+ 0.60% per 10μgm^{-3} (8 hour mean) + 0.70% per 10μgm^{-3} (8 hour mean)
Nitrogen dioxide[a]	Respiratory hospital admissions	+ 0.50% per 10μgm^{-3} (8 hour mean)

[a] Used in sensitivity analysis only.

38. Concentration response coefficients are specified for particulate matter, ozone and sulphur dioxide in Table A. COMEAP also recommend a coefficient of 0.5% per 10μgm^{-3} for respiratory hospital admissions from the short-term effects of nitrogen dioxide. The evidence for this association was considered less robust than the associations of the other pollutants. As such it is suggested that the effects of nitrogen dioxide are quantified for sensitivity analysis only and not for central estimates.

Method of calculation – effects of short term exposure

39. In calculating the effects of pollutants on health the following sequence of steps has been adopted. These steps are described in more detail in a report by COMEAP quantifying short-term effects of elevated levels of air pollution (COMEAP, 1998)[9], the EAHEAP report (Department of Health, 1999)[10] and a report from Netcen[11].

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[9] COMEAP (1998) 'Quantification of the Effects of Air Pollution on Health in the UK'

[10] Department of Health (1999) 'Economic Appraisal of the Health Effects of Air Pollution', Ad-Hoc Group on the Economic Appraisal of the Health Effects of Air Pollution, London: The Stationery Office.

[11] Stedman et al (2002) 'Quantification of the Health Effects of Air Pollution in the UK for Revised PM_{10} Objective Analysis', a report produced for the Department for Environment, Food and Rural Affairs, Welsh Assembly Government, The Scottish Executive and the Department of the Environment in Northern Ireland. Contract Number EPG 1/3/146

a) The country is divided into 1km grid squares and estimates of pollutant concentrations and the resident population are produced for each. Baseline concentrations are derived from the national mapping of the UK pollution climate and populations are from census data. The data is used to calculate population-weighted mean concentrations either by region or for the whole of the UK.

b) A baseline level of health-related and pollution-affected events (eg daily deaths, hospital admissions to treat respiratory diseases, and annual deaths) is obtained from national statistics.

c) The 'with measure' scenario is developed to estimate the change in pollutant concentrations as a result of the measure. Pollution concentrations with the measure are estimated and compared to the baseline estimated in (a) to generate the change in concentrations.

d) Finally, the size of the expected health effects is estimated by first combining the concentration response coefficients with the estimated change in emissions to give the change in risk of each health outcome. Applying this percentage to the health outcomes data from (b) produces an estimate of the expected health impacts.

Quantification methodology: long term exposure to particles and mortality

40. Studies in the United States (Pope et al 2002[12], Dockery et al 1993[13]; Pope et al 1995[14]) have shown that those living in less polluted cities live longer than those living in more polluted cities. This association between levels of fine particles ($PM_{2.5}$) and life expectancy held after controlling for other factors.

41. COMEAP published a report confirming that long-term exposure to air pollution has a significant impact on mortality (COMEAP 2009[15]). A 10 μgm^{-3} increase in fine particles ($PM_{2.5}$) is associated with a 6% increase in risk of death from all-causes (see Section 5 for the uncertainties around this). COMEAP published another report in 2010[16] with calculations of the potential impact on mortality and life expectancy in the UK of specified reductions in air pollutant concentrations using the coefficients from their 2009 report.

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[12] Pope, C. Burnett, R. Thun, M. Calle, E. Krewski, D. Ito, K. Thurston G. (2002) ' Lung cancer, cardiopulmonary mortalitry, and long-term exposure to fine particulate air pollution'.

[13] Dockery, D. W. Pope, C. A. Xu, X. Spengler, J. D. Ware, J. H. Fay, M. E. Ferris, B. G. And Speizer, F. E. (1993) 'An Association Between Air Pollution and Mortality in Six US Cities', New England Journal of Medicine, 329, pp.1753-1759

[14] Pope, C. Thun, M. Namboodiri, M. Dockery, D. Evans, J. Speizer, F. and Heath, C. (1995) 'Particulate Air Pollution as a Predictor of Mortality in a Prospective Study of US Adults', American Journal of Respiratory and Critical Care Medicine, 151, pp.669-74

[15] COMEAP (2009), 'Long-term exposure to air pollution: effect on mortality', available from www.comeap.org.uk/documents/reports/

[16] COMEAP (2010), 'The mortality effects of particulate air pollution', available from www.comeap.org.uk/documents/reports/

Calculating the impact of long-term exposure to particulate air pollution on population survival time

42. Long-term exposure to particulate air pollution has an effect on mortality and so reduces life expectancy. Any change in such exposure will lead to a change in life expectancy for the affected population. This impact can be calculated as follows:

    a) Obtain information on current mortality rates.

    b) Predict future mortality using current rates and life tables (see discussion below) and assumptions about future demography, in the absence of air pollution changes. This is the baseline scenario that estimates what would happen without the policy.

    c) Create an alternative scenario that captures the change in pollution expected due to the measures under consideration. This is done by adjusting mortality rates based on evidence about the effect of long-term exposure to air pollution on mortality, while leaving other baseline assumptions unchanged.

    d) Compare the predicted life expectancy (or some other appropriate summary measure) between the baseline scenario without pollution changes and the alternative scenario, to estimate the effect of the change in pollution.

    e) Examine sensitivity of estimates to changes in the underlying assumptions.

43. More information on the use of this methodology is available in the COMEAP report 'The Mortality Effects of Long-Term Exposure to Particulate Air Pollution in the United Kingdom' (2010)[17]. This draws upon the methodology used in an IOM report, published in 2000, and a subsequent publication on life table methods[18].

44. Life table calculations give the total life years lived for the (predicted) population of England and Wales for a 106 year period, including all new births during that time. This long follow-up and inclusion of new births ensures that long-term effects are captured and benefits to all those affected are included. There is understood to be a lag between the change in air quality and the resultant impact on mortality. This is incorporated using life tables that phase in the change in the risk of death over time[19].

45. Section 5 identifies some of the key uncertainties related to the health impacts that should be addressed through sensitivity testing.

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[17] See Footnote 15.

[18] Institute of Occupational Medicine, (2000); 'Towards assessing and costing the health impacts of ambient particulate air pollution in the UK'; Miller, B.G. and Hurley, J.F., (2003) 'Life table methods for quantitative impact assessments in chronic mortality', *Journal of Epidemiology and Community Health 57(3)*

[19] The default lag applied by COMEAP (2010) is that used by the US Environmental Protection Agency, which assumes that 80% of the risk reduction occurs in the first five years, and that the total reduction occurs by 20 years after the change in air pollution.

3.2 Method for calculating non-health impacts

46. There are a number of non-health impacts that should be quantified and valued as part of a monetary appraisal. The effects which should be reflected are:

    - Carbon price: Many air quality measures also impact on emissions of pollutants with climate change potential. These impacts should be valued in accordance with the latest guidance from the Department for Energy and Climate Change[20].
    - Direct effect on crop yields: Ozone is recognised as the most serious regional air pollution problem for the agricultural and horticultural sectors. Changes in crop yields are estimated and valued using international crop prices. Estimation of the changes in crop yield is informed by the Integrated Cooperative Programme (ICP) on Vegetation and ICP/MM (Mapping and Modelling)[21].
    - Material damage from ozone: Ozone is a major determinant of the lifetime of many rubber materials. Ozone damage to rubber goods from ozone exposure should be valued at £3.7 million per year based on a population weighted 1 part-per-billion (ppb) change in ozone exposure.
    - Material damage from SO_2: Acid damage from SO_2, H^+ and NO_2 damage natural stone and zinc coated materials. Changes in material damage resulting from changes in these pollutants should be valued following the Air Quality Strategy Evaluation study[22].
    - PM building soiling: Soiling of buildings by particles is one of the most obvious signs of pollution in urban areas. Cleaning costs are used to quantify soiling costs in the absence of willingness to pay values.

47. The long term objective of the IGCB(A) is to develop methodologies that enable a comprehensive reflection of all air pollution impacts in analysis. Work is continuing to incorporate environmental impacts through the application of the ecosystems services approach to value such impacts. This will be incorporated into IGCB guidance in due course. In the meantime an overview of the ecosystems services approach can be found here: www.gov.uk/government/policies/protecting-biodiversity-and-ecosystems-at-home-and-abroad/supporting-pages/valuing-the-benefits-we-get-from-nature

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[20] www.decc.gov.uk/en/content/cms/about/ec_social_res/iag_guidance/iag_guidance.aspx

[21] See http://www.icpmapping.org/

[22] Available from http://archive.defra.gov.uk/environment/quality/air/airquality/publications/stratevaluation/

4. Valuation of impacts

4.1 Valuation of health impacts

48. Values for a range of health endpoints have been agreed, following recommendations by the IGCB. The full paper discussing the recommendations is found at Annex 2 of 'An economic analysis to inform the air quality strategy review consultation'[23].

49. The IGCB recommendations draw upon research in the area of air quality health impact valuation, particularly the study by Chilton et al (2004). This study had been commissioned by Defra to provide empirical evidence on the willingness to pay to reduce the health impacts associated with air pollution.

50. Following the publication of the Chilton et al (2004) study, Defra held a workshop for expert economists and epidemiologists to discuss the results of this study and one by Markandya et al (2004) which assessed the willingness to pay for reducing mortality risks associated with air pollution.

51. The recommendations on valuation of mortality effects associated with air pollution are based on evidence drawn mainly from these two studies. For the valuation of morbidity effects, the recommendations are drawn from the Chilton et al (2004)[24] study and a study carried out by Pearce et al (1998). The recommendations are summarised in Table F below.

52. It is recommended that the health values are uplifted by 2% per year for analyses spanning a number of years[25]. This recognises the fact that willingness to pay tends to increase with income, so as people's incomes rise over time it is expected that their willingness to pay to reduce health risks associated with air pollution will also increase.

53. There are a number of uncertainties surrounding the values that need to be taken into account when interpreting the results of the analysis. In particular, there are uncertainties surrounding:

    - The amount of life expectancy lost due to the acute effects of air pollution;
    - The quality of the life expectancy lost due to the acute effects of air pollution;
    - The quality of the life expectancy lost due to the chronic effects of air pollution;

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[23] Available at http://archive.defra.gov.uk/environment/quality/air/airquality/publications/stratreview-analysis/index.htm

[24] Chilton et al (2004), 'Valuation of the health benefits associated with reductions in air pollution', available at http://archive.defra.gov.uk/environment/quality/air/airquality/publications/healthbenefits/index.htm

[25] This follows the approach taken by the Department of Health. See for instance Department of Health (2004), 'Policy appraisal and health: a guide from the Department of Health'.

- The ability of respondents within the contingent valuation study to accurately value losses of life expectancy in poor health; and
- The accuracy with which study respondents valued morbidity effects.

Table F: IGCB(A) recommended health values, 2012 prices[a]

Health effect	Form of measurement valuations apply to	Central value	Sensitivity
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	£18,000	10% and 15% of life years valued at £35,000 instead of £18,000 (to account for the avoidance of sudden cardiac deaths in those in apparently good health).
Chronic mortality	Number of years of life lost due to air pollution. Life expectancy losses assumed to be in normal health.	£35,000	£26,300 – £43,800 (sensitivity around the 95% confidence interval)
Respiratory hospital admissions	Case of a hospital admission, of average duration 8 days	£2,600 – £10,700	
Cardiovascular hospital admissions	Case of a hospital admission, of average duration 9 days	£3,000 – £9,900	

[a] Source: Defra (2006), 'An economic analysis to information the Air Quality Strategy Review consultation', available at http://archive.defra.gov.uk/environment/quality/air/airquality/publications/stratreview-analysis/index.htm . See also Chilton et al (2004), 'Valuation of the health benefits associated with reductions in air pollution', available at http://archive.defra.gov.uk/environment/quality/air/airquality/publications/healthbenefits/index.htm. Figures have been updated to 2012 prices and hospital admissions costs updated to 2010/11 costs.

4.2 Valuation of non-health impacts

54. Section 3.2 identifies the key non-health impacts that can be quantified and valued. Work is ongoing to develop the impact pathway methodology to reflect all air pollution impacts in analysis using the ecosystem services approach.

5. Uncertainties

55. There are uncertainties along each step of the impact pathway approach. These are described below. Assumptions, both for central modelling and sensitivity analysis, should be set out clearly to ensure that results can be interpreted correctly.

5.1 Emissions and dispersions uncertainties

56. The main uncertainties here are around the sources of ambient pollutants and the reactions between pollutants in the atmosphere. At high concentrations the reactions between pollutants can be very different than at low concentrations.

57. Many policy decisions are based in the future; this means that emissions and dispersions often need to be projected into the future. There are clearly large uncertainties when making future projections.

58. It is recommended generally that these uncertainties are reflected as modelling uncertainties rather than in the monetary valuation. One exception is the impact of changes in national air pollution levels on our international neighbours through trans-boundary pollution. To reflect this potential externality the air quality costs may be increased by 20% (based on estimates of trans-boundary sources).

5.2 Health impact uncertainties

59. There are a wide range of uncertainties in this area. The main uncertainty that should be included in any Social Cost Benefit Analysis is that related to the appropriate size of the coefficient for the long term effects of particles. The COMEAP recommendation is to provide a sensitivity using a range of between 1% - 12% per 10 μgm^{-3} [26,27].

60. Additionally the impact on respiratory hospital admissions from changes in NO_2 should be included as a sensitivity (see Table A for the relevant coefficient), and different assumptions about the coefficients and the lags could also be applied[28]. Not all uncertainties will be resolvable. They are discussed in more detail in Chapter 5 of Volume 3 of the Air Quality Strategy, available from www.gov.uk/government/publications/an-economic-analysis-to-inform-the-air-quality-strategy

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[26] To approximate the impact of this sensitivity the chronic mortality impact of exposure to PM can be linearly altered from the central 6% value. Therefore a 2% value is approximately a third of the 6% value and 12% is double the 6% value.

[27] In addition a wider uncertainty range of 0% - 15% should be reported.

[28] If the phased lag introduced by the EPA for the long term effects of particles is not being used then it may be appropriate to include a sensitivity range around the appropriate lag time, of between 0 and 40 years.

5.3 Valuation uncertainties

61. There is considerable uncertainty surrounding the valuation of changes in outcomes. Two key areas are the value of the health outcomes and changes in technology costs. Table F in section 4 presents the recommended sensitivities for the health values.

62. 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 of accuracy. The evaluation of the air quality strategy (2005) 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[29]. This would suggest that regulation can spur innovation, and that the SCBA may not adequately predict the impact of innovation on costs. To reflect this evidence the IGCB recommend upper and lower bounds on abatement technologies of 50% of the best estimate to 120% of the best estimate to reflect innovation.

Alternate valuation of air quality

63. Given the range of uncertainties the IGCB also recommend the use of alternate methodologies which may reflect a range of differing assumptions across the impact pathway methodology. In particular it is recommended that the Clean Air for Europe (CAFE) values also be applied as a sensitivity particularly when the policy would occur across the EU. So as not to impose a disproportionate cost it is recommended that the CAFE damage costs be applied based on the modelled emissions. Further information on these values and their derivation is available from http://www.cafe-cba.org/reports-on-analyses-using-the-cba-framework/.

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[29] Available from www.defra.gov.uk/evidence/economics/igcb/

6. Glossary

Concentration	The level of pollutants in the atmosphere; usually expressed in μgm^{-3} on an annual average basis.
Concentration response coefficient	Shows the percentage change in an outcome (e.g. deaths or hospital admissions brought forward) for a given change in pollution concentration.
Discount rate	Discounting is a technique used to compare costs and benefits that occur in different time periods. It is based on the principle that, generally, people prefer to receive goods and services now rather than later, known as ‘time preference’. The discount rate is used to convert all costs and benefits to ‘present values’, so that they can be compared. The HM Treasury Green Book recommended discount rate is 3.5% for the first 30 years, 3.0% for years 31-75 and 2.5% for years 76-125.
Emissions	The release of pollutants into the atmosphere; usually expressed in tonnes.
Hazard rate	The probability of dying at a given point in time; conditional on having survived until then.
Impact-pathway approach	Traces the origins of the pollutant through to the location/population that it affects.
Life table	A life table is a technique used to summarise the patterns of survival in populations. It uses age-specific death rates, derived from numbers of deaths in each age group and mid-year population sizes for each age group. Standard life table calculations compute survival rates at different ages, either from birth or from a specific achieved age. From these, the total numbers of life years lived at each age can be derived, as can average life expectancy.
Monetised health impact uplift	This is an uplift of 2% applied to the value of health benefits each year. It is included to recognise that willingness to pay is likely to increase over time in line with increases in wealth.
Population weighted mean concentration	This is estimated average exposure to different pollutants, weighted by population so that concentration data in more populated areas are given a higher weight than those in less populated areas.