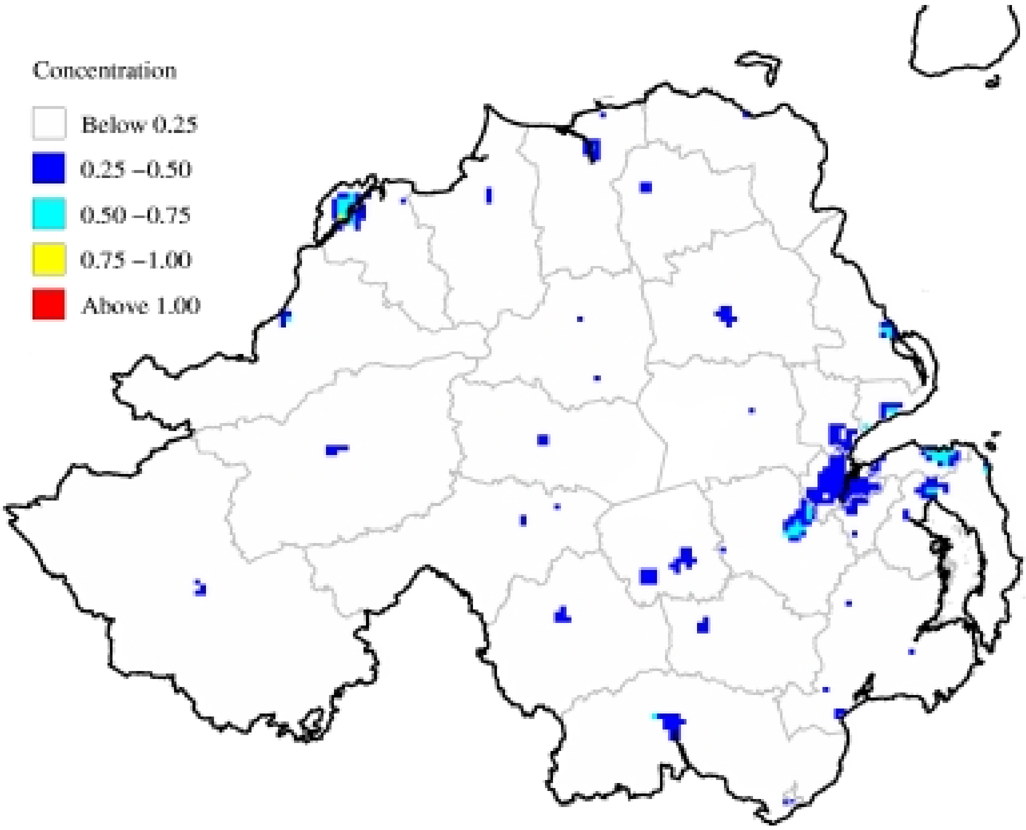
Evaluation of the Costs and Benefits of Achieving Air Quality Targets for PAHs in Northern Ireland



December 2003

Title	Evaluation of the Costs and Benefits of Achieving Air Quality Targets for PAHs in Northern Ireland
Customer	Department of Environment, Northern Ireland
Customer reference	EPG 1/3/154
Confidentiality, copyright and reproduction	
File reference	ED47047308
Report number	AEAT/ENV/R/1620
Report status	Issue 3

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Executive Summary

The purpose of this work is to prepare an analysis of the cost and health related benefits specific to Northern Ireland of the policy measures which might be required to meet either 0.25, 0.5 or 1 ng/m^3 as an annual average benzo[*a*]pyrene (B[a]P) concentration in 2010. The lower value, 0.25 ng/m^3, has been accepted as a national air quality objective by England, Scotland and Wales. The higher value, 1 ng/m^3, is the target value given in the draft European 4th air quality daughter directive.

The report builds on an earlier study that predicted B[a]P concentrations in 2010 throughout Northern Ireland and showed that B[a]P emissions from domestic heating was the dominant emission source. Several scenarios were investigated. The scenario which led to the lowest concentrations involved two actions by Government;

- The Northern Ireland Housing Executive has a replacement programme of solid fuel heating appliances by either gas fuelled heating if natural gas is available or if not then by oil burning appliances. This programme is due to complete in 2010. The study assumed this programme would be completed.
- The other major influence on domestic fuel use in Northern Ireland since the earlier report is the issuing of licences for two gas pipelines which were included as a possible scenario. These gas pipelines are likely to lead to a further take up of natural gas substituting for solid fuel use in towns and new developments along the routes of the pipelines. The study assumed a degree of take up from towns on the pipeline route.

The impact of these measures is to reduce the predicted BaP concentration so that the study identified no locations at which concentrations of B[a]P were predicted to be greater than 0.5 or 1.0 ng/m^3 in 2010. 96 500m by 500m squares were identified in which 0.25 ng/m^3 were exceeded.

This study looks at a number of measures to abate B[a]P emissions in those squares which were predicted to exceed the threshold of 0.25 ng/m^3 in 2010. The principal measure is the application of smoke control orders which would reduce the usage of bituminous coal or would lead to it being burnt more cleanly in exempt appliances. This measure was found to lead to compliance with the 0.25 ng/m^3 EPAQS objective.

The benefits arising from the implementation of this measure in reduced cancer deaths were calculated based on the ‘Value of Statistical Life’ approach. The provided an estimate of the benefits from this measure as being £32,100 per year with a possible range from £18,900 to £107,000 per year

The costs of smoke control implementation were calculated. While the implementation of smoke control leads to lower operating costs for domestic heating these costs are outweighed by the capital costs of new appliances which may be required. As such it was estimated that the annualised costs of smoke control in these 96 squares would be between £287,000 and £446,000.

A range of scenarios were investigated in which instead of switching to a cleaner solid fuel or exempt solid fuel appliance 25%, 50% or 80% of residents in the affected areas installed gas or oil central heating. While this leads to lower B[a]P emissions and hence a small improvement in the benefits, the extra capital costs make this measure more expensive still.

The costs calculated above are those that would fall directly on householders, local and central government. If smoke control was put in place this would have an impact on the solid fuel distribution companies in the areas affected. It proved not possible to quantify this effect as it is uncertain whether residents would change to premium solid fuels in which case profitability may increase or as appears more likely to change fuels to oil or gas in which case trade may diminish.

The relationship of solid fuel use with areas of deprivation was investigated. It was found that the most deprived communities in Northern Ireland are in areas which tend to have the highest B[a]P concentrations. It was also predicted that the most significant decreases in exposure between 2000 and 2010 are in the most deprived communities. It was also thought that the most significant decreases in B[a]P are likely to occur in the most deprived communities while improving air quality across the whole range of deprivation values.

The table below summaries the best estimate of the costs and benefits in financial terms of achieving the three limit values which have been examined.

Possible Air Quality Objective Annual Mean concentration ng b[a]P/m^3	Annualised Benefits £/year	Annualised Costs £/year
0.25	32,100	287,000-446,000
0.5	0	0
1.0	0	0

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1 Introduction

1.1 BACKGROUND

PAHs are a large group of compounds with a similar structure comprising two or more aromatic hydrocarbon rings. They are formed through incomplete combustion of carbon compounds. PAHs vary with respect to sources, and chemical and physical characteristics and they may be present in the atmosphere either in the gas phase or bound to particles.

Concern over PAH emissions relates to their health effects. The earliest relevant observations were made by Sir Percival Potts in London as early as 1775, regarding the incidence of scrotal cancers among chimney sweeps' apprentices. However, it took many years before specific carcinogens were identified, the first of these being benzo[*a*]pyrene (B[a]P), extracted from coal tar in 1933.

Human exposure to PAH compounds principally occurs through inhalation of contaminated air, dermal contact and ingestion. The principal effect from exposure via the ambient air is regarded as lung cancer, though there are also links to skin cancers and bladder cancer. In 1999, the UK Government's Expert Panel on Air Quality Standards (EPAQS) recommended an air quality standard for PAH of 0.25 ng/m^3 (0.25 nanograms per cubic metre) as an annual average, based on B[a]P as a marker for the total mixture of PAH in the UK.

In addition, the European Commission has proposed as part of the draft 4th Air Quality Daughter Directive a non-mandatory target of 1ng/m^3 based on a maximum annual average concentration of B[a]P, as a marker, for PAH to be achieved by 2010.

1.2 OBJECTIVE

The objective of this study is to prepare an analysis of the costs and health related benefits specific to Northern Ireland of the policy measures which might be required to meet either 0.25, 0.5 or 1 ng/m^3 as an annual average Benzo[a]pyrene (B[a]P) concentration as an air quality objective in 2010.

This study builds upon work reported by Netcen[1] mapping concentrations of B[a]P in Northern Ireland arising from domestic solid fuel use and an earlier economic evaluation of air quality targets for PAHs reported to the European Commission in 2001[2].

1.3 SCOPE

The main sources of B[a]P emissions in the UK are domestic coal combustion (15%), domestic wood combustion (13%), industry (49%), transport (9%) and creosote use (6%). Industrial sector emissions are dominated by aluminium production, with coke works and sinter plant at integrated iron and steel works making a significant contribution. Coke production for other applications (e.g. smokeless fuel) is also significant. There are no aluminium smelting or coking plants in Northern Ireland at present. However the earlier study established that in parts of Northern Ireland domestic

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[1] Netcen 2003. Determining the impact of domestic solid fuel burning on concentrations of PAHs and sulphur dioxide in northern Ireland. Report produced for the Department for Environment, Food and Rural Affairs et al. AEAT/ENV/R/1498, June 2003.

[2] AEA Technology, 2001. Economic Evaluation of Air Quality targets for PAHs. Report produced for the European Commission, Directorate General Environment. AEAT/ENV/R0593, March 2001.

solid fuel combustion is a particularly significant source. In the areas identified as being likely to exceed the air quality objective domestic solid fuel combustion is the principal source. Accordingly, this study focuses upon an evaluation of policy measures to reduce PAH emissions from domestic solid fuel use.

1.4 OVERVIEW OF THE METHODOLOGY

The methodology for this study is outlined in Figure 1.1. The main analysis carried through the chapters of this report concentrates on the development of best estimates of emissions, future concentrations, and the costs and benefits of meeting the possible targets under assessment. At each stage of the analysis uncertainties are identified, and an indication of their potential magnitude provided.

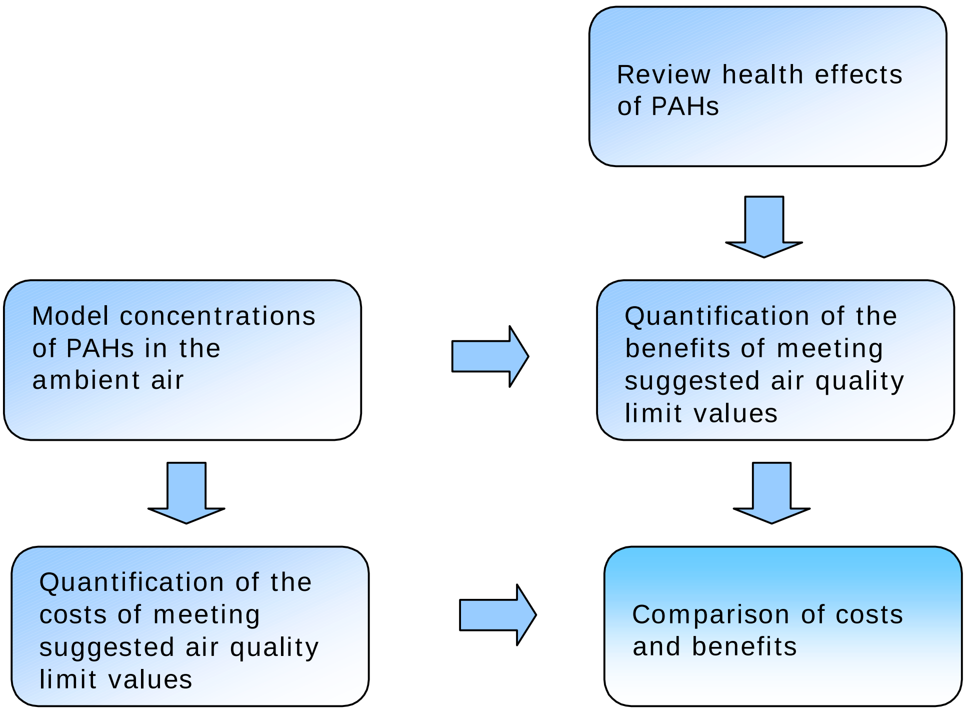

Figure 1.1 Principal stages of the cost-benefit analysis

The overall format for the uncertainty analysis is:

- Identify sources of uncertainty
- Identify which uncertainties are likely to have the most important impact on the results of the study
- Assign ranges to the main uncertainties
- Apply ranges through the analysis to establish potential error in the results.

1.5 B[A]P CONCENTRATIONS IN 2010

The base case scenario in 2010 predicted that there were no locations which exceeded 0.5 ng/m^3 and therefore also no squares with concentrations greater than 1ng/m^3. Hence there were no costs or health benefits associated with adopting these limit values. However it was predicted that there would be 96, 500 m x 500 m squares which exceed the concentration threshold of 0.25 ng/m^3. The locations of these 96 squares are shown in Figure 2.1. A list of the grid references of these squares is given in Appendix 1.

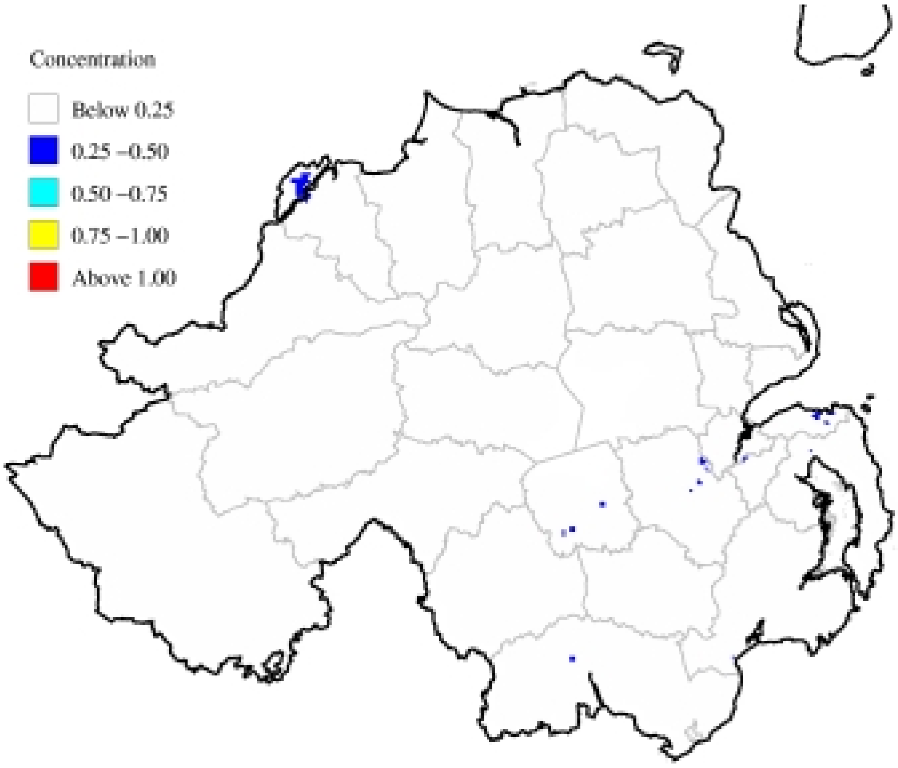

Figure 1.2 Location of grid squares which exceed the concentration threshold of 0.25 ng/m^3 for the 2010 base case scenario.

1.6 SCENARIO DEVELOPMENT

The existing powers of central government to affect domestic emissions are through the provisions of the Clean Air Order or through alterations to the Building Regulations.

The Clean Air Order allows the Department of Environment to encourage local authorities to declare smoke control areas (SCAs) in which only certain authorised fuels specified by the Department can be used or other exempt combustion appliances which use specified non-authorised fuels but which have been shown to burn cleanly. The implementation of Smoke Control Orders under the Clean Air Order can take place over several years but will affect domestic combustion in all premises within their geographical extent.

The Building Regulations affect the specification of new or significantly altered buildings. As such while they can lead to significant improvements in insulation or combustion appliance performance and hence reduce fuel use and emissions they can take several decades to improve the housing stock.

Hence the Scenarios developed within this study address the implementation of Smoke Control Areas in those 96 500m by 500m squares which were identified from the previous study as exceeding the possible 0.25 ng /m^3 B[a]P concentration air quality objective.

In implementing smoke control, residents presently burning solid fuel have two principal choices; to burn an authorised smokeless fuel in their existing appliance or to fit a new appliance and burning the fuel or fuels for which the appliance is exempted. It was felt that a proportion of households would choose to replace the existing appliance with a oil or gas appliance depending on the availability of these fuels. This would further reduce the emissions of PAHs beyond the minimum reduction implied by the implementation of smoke control and hence lead to enhanced benefits.

The proposed scenarios for mapping are as follows:

1. Smoke control area (SCA) coverage applied to all 96 grid cells exceeding 0.25ng/m^3 in 2010
2. Scenario 1 plus an 80% reduction in solid fuel use excluding coal
3. Scenario 1 plus a 50% reduction in solid fuel use excluding coal
4. Scenario 1 plus a 25% reduction in solid fuel use excluding coal

These scenarios are mapped on the basis of the 2010 baseline which assumes the full implementation of the NIHE conversion programme and the construction of two gas pipelines (for which licenses have now been granted) which was labelled Scenario 2 in the earlier report.

Scenario 1

Scenario 1 has been constructed by applying SCA areas over the 96 grid squares that are predicted to exceed 0.25 ng/m^3. The implementation of SCAs will lead to the cessation of bituminous coal use in these areas except in suitable exempt appliances . Where bituminous coal is used in open fires as a backup fuel then costs for substitution with solid smokeless fuel a solid fuel reduction factor has been calculated based on the impact that a SCA is considered to have on B[a]P concentrations. All grid squares are either located in the Greater Belfast (but not in Belfast) area or elsewhere in Northern Ireland. None of the grid squares are located in current SCAs.

This reduction factor due to a SCA is determined by levels of non-compliance. We can apply the following factors according to where the SCA is:

Location	Reduction Factor
Belfast	77.0%
Greater Belfast	65.9%
Elsewhere	54.8%

i.e. Belfast squares have their emission reduced by 77% after an SCA regulation is implemented (with limited non-compliance of 10%). Outside of Belfast lower levels of compliance mean that SCAs will have less impact on PAH emissions and hence concentrations.

Having applied these reduction factors, total emission from the resulting emissions grid for scenario 1 is 277.3 kg (Baseline map totals 286.17).

Scenarios 2-4

Scenarios 2, 3 and 4 have been constructed to reflect a decrease in the use of solid fuel excluding coal use (which is dealt with under scenario 1). Differing levels of reduction in solid fuel use have been considered under these three scenarios.

The scenario 1 map has simply had different levels of reduction applied to the solid fuel consumption in the identified 96 grid squares. The resulting emission totals illustrate the small impact that scenarios 2 to 4 have on the overall emission total, and the specific grid squares.

Scenario	Northern Ireland B[a]P Emissions in 2010 Kg $Year^{-1}$
1	277.29
2	276.95
3	277.08
4	277.19

2 Options for abatement and costs

2.1 METHODOLOGY

The scenarios that are considered for the cost assessment and the number of households likely to be affected by the different scheme specification are presented in this section. We then give an overview of the costs arising from the implementation of the scheme. These costs as presented below are:

- Maintenance costs
- Capital costs which are costs of purchasing a new boiler/gas fire and its installation.
- Annual cost of space heating
- Cost of enforcement and administration

2.2 SCENARIOS

Four scenarios have been investigated, based on the effectiveness of reducing PAH in Northern Ireland. The number of households affected varies with respect to each scenario. In the air quality analysis, there are two types of households: households using solid fuel (SF), here coal, as primary heating fuel and households using SF as a supplementary heating fuel. On average, the first group consumes 3.5 tonnes per year of coal while the second group consumes 0.9 tonnes per year. The table below gives a description of scenarios with the number of households affected:

Table 1 – Households affected under each scenario

Scenarios	Description	Number of household using coal as primary fuel	Number of household using coal as supplementary fuel
1	Smoke control area to all grid cells	940	5836
2	Scenario 1 plus 80% reduction in SF	940 + 571	5836 + 1318
3	Scenario 1 plus 50% reduction in SF	940 + 357	5836 + 824
4	Scenario 1 plus 25% reduction in SF	940 + 179	5836 + 412

The distinction between primary users of coal and supplementary users has also implications on how many households need to be considered in the cost analysis, particularly for the costs of enforcement.

In scenario 1, which corresponds to a switch from coal to an alternative, cleaner, SF, we assume that the switch will occur to only the first group of household. We estimate that a total of 940 households would be affected by scenario 1. We also assume all household are inspected by local officers for both surveys and inspection of the installation done. Scenarios 2, 3 and 4 corresponds to schemes where households have to switch form anthracite to an oil or gas appliance in addition to the first group of household having switched from coal to a cleaner SF (i.e. the one in scenario 1). We assume for scenario 2,3 and 4 that installation of replacement appliances will proceed at an annual rate of 10% of the households using solid fuel within the smoke control area from 2004 to 2007 and then at an annual rate of 20% from 2008 to 2010. It being assumed the implementation of Smoke Control would be phased to ensure full effectiveness for 2010.

The above scenarios are based on the objective of reducing PAH levels to compliance by 2010. Householders would off course have freedom to decide how they would comply with the regulations. In reality, different householders would make different decisions. For this analysis, we have assumed the following for each scenario:

Scenario 1: Switch to a cleaner SF: we assume a 100% switch from coal to anthracite nuts.
Scenario 2, 3 and 4: solid fuel heating is replaced by gas for all affected households or oil for all affected households. These alternative assumptions provide a range that should include the likely responses of households.

2.3 COSTS OF HOUSEHOLD HEATING SYSTEM

The cost of space and water heating for a house is made of capital costs, maintenance costs and fuel costs. Capital costs are considered if households change their heating systems.

2.4 MAINTENANCE COSTS AND SPACE AND WATER HEATING COSTS

We have used data from Salkent Ltd. who undertake a six monthly survey on household heating costs in Northern Ireland. Due to copyright, these cost data cannot be disclosed in the present report though are included in the analysis that follows. The different fuels considered in the cost analysis are:

- Solid fuel: coal, anthracite nuts
- Gas
- Oil

Maintenance costs vary with respect to the fuel used. Salkent Ltd provide data for the cost of space and water heating for 2, 3 and 4 bedroom houses. Because of the lack of data on types of houses for the current affected households, we have used the cost data for 3-bedroom houses.

2.5 CAPITAL COSTS

We assume the capital costs are composed of two elements: the purchase of a boiler or of a gas fire, and its installation in the house. There is a wide range of boilers and gas fires in the market and the cost of installation of these varies substantially with respect to the setting of the house. Newtownabbey Borough Council has estimated the cost of installing solid fuel appliance and gas/oil central heating system for different types of houses. We have used the following values for our cost assessment:

- Installation of oil central heating in semi detached property with 9 radiators: £1974 including VAT. This is for the smoke control area 15
- Installation of gas central heating in large detached property with 7 radiators: £1995 including VAT. This is for the smoke control area 16.
- Installation of solid fuel appliance: Representative approved cost for boiler £600 and installation £200. Total: £800.

2.6 ENFORCEMENT COSTS

To implement scenario 1 and 2, local authorities have to check that the installation occurs. This will entail some enforcement costs such inspection of houses by local officers and administration costs. To include such costs in the analysis, we have used enforcement cost data supplied by Newtownabbey Borough Council. The Council spent £23,764 for inspecting 1982 properties. We use an average unit cost per inspected household to derive the survey and inspection costs for scenario 1 and 2. This is £12 per house inspected.

2.7 RESULTS

For the cost assessment, we have calculated the net present values (NPV) and the annualised costs for each scenario. The period considered is 2004-2010 as 2010 corresponds to the date of compliance. We applied a 3.5% discount rate as recommended by HM Treasury.

The implementation of Scenario 1 which is a switch from coal to anthracite nuts, will lead to a negative NPV of £1,526,638 and of an annualised cost of £286,502.

Table 2 shows results of Net Present Value (NPV) and annualised costs for scenario 2, 3 and 4. The first set of results is based on gas appliance as an alternative fuel and the second set are based on oil appliances.

Table 2: Net Present Value and Annualised cost for Scenario 2, 3 and 4

Summary results	Oil appliance		Gas appliance	
	NPV	Annualised cost	NPV	Annualised cost
Sc2: sc1 + 80% reduction in solid fuel use (legislative)	£2,181,552	£409,408	£2,376,178	£445,933
Sc3: sc1 + 50% reduction in solid fuel use (voluntary)	£1,917,468	£359,848	£2,045,668	£383,907
Sc4: sc1 + 25% reduction in solid fuel use (voluntary)	£1,690,452	£317,244	£1,782,921	£334,598

Results shows that scenario 1 is the least expensive scenario with an annualised cost of £286502. The main explanation is that although alternative cleaner solid fuels are more expensive to buy than coal (generally 5 to 10% more expensive for a 25kg bag), annual costs of space and water heating for a house are lower because of differences in energy content of the different fuels.

On the other hand, Scenario 2, which corresponds to an 80% reduction in anthracite use by switching to gas in addition to scenario1, is the most expensive scenario with a £445,933 annualised cost.

By switching to new cleaner appliances, households are able to make substantial saving regarding their annual costs of space and water heating compared to current house coal. However, they have to bear the up-front capital costs of installing a new heating system which is the principal cost for Scenario 2.

2.8 COSTS TO THE COAL TRADE IN NORTHERN IRELAND

An indirect cost of the implementation of smoke control in the areas discussed above is the possible reduction in turnover of the coal trade in Northern Ireland.

The impact on the coal trade depends on the choices made by householders. If the option of changing to an authorised fuel on an open fire is attractive then it is possible that the turnover of the coal trade could increase as a result of the higher price of these fuels. This increase in value per tonne may to some extent be balanced by the higher heating value of SSFs leading to a reduced tonnage demand. However if an anthracite is burnt in an exempt closed appliance then volume will decrease significantly as a result of the higher efficiency of these appliances.

The other options open to householders of fuel switching to oil or gas will inevitably lead to a reduction in solid fuel sales. While in some cases oil sales and bottled gas may be handled by the same companies this will tend to lead to a decrease in turnover for the coal trade. It is not possible to quantify the economic impact of the measures in this indirect manner.

3 Benefits assessment for PAHs in Northern Ireland

3.1 STRUCTURE OF THE ANALYSIS

The basic model for quantifying the benefits of reducing emissions of PAHs is:

Total benefit = People x PAH concentration x Cancer risk factor x Value of a cancer

3.2 EFFECTS LINKED TO PAH EXPOSURE

The main effects linked to human exposure to PAHs are:

- Lung cancer through inhalation, and thus the effect most closely related to air pollution. Mortality rates within 5 years of diagnosis are high for lung cancer, at 90%. The severity of lung cancer is partly a result of the fact that it is hard to diagnose in its early stages.
- Bladder cancer, which appears to result from a combination of ingestion and inhalation, and is hence contributed to by air pollution. Clear inhalation concentration - response relationships are not available, through there being only limited records in the literature, though excess cases of bladder cancer have been detected in some occupational health studies of workers exposed to PAHs. The workers concerned appear likely to have been exposed to other agents known to cause bladder cancer, such as aromatic amines, as well as PAHs.

A variety of other cancers (skin, pancreatic, kidney) have been linked to PAH exposure, though evidence for them is relatively weak. A review by WHO found in favour of a relationship with lung cancer, but not bladder cancer, regarding the information available to be insufficient. Some subsequent analysis has strengthened the case for bladder cancers and weakened it for lung cancers, though there is still consensus that the link with lung cancer is causal. Recent analysis by Armstrong *et al* (2003) seems to agree that there is a case for including bladder cancers in a risk model. Their results suggest a stronger link with bladder cancer than lung cancer, though given that the incidence of lung cancer is much higher this will have a limited effect on the analysis. Also, lung cancer is almost invariably fatal, whereas only about one third of people who develop bladder cancer die of the disease.

3.3 METHODS AND DATA INPUTS FOR BENEFITS ANALYSIS

3.3.1 Population and PAH concentration data

The population of Northern Ireland is taken here to be 1,664,167. Information on population distribution and pollution data have been combined to give the exposure statistics in Table 3. The first column of this table shows the average PAH concentration to which the people of Northern Ireland are exposed from the ambient air. The second column multiplies this figure by total population to quantify overall exposure. The third column shows the difference between overall exposure in each 2010 scenario compared to the 2010 baseline.

Table 3 - Population weighted concentration data for each scenario (based on a population in Northern Ireland of 1,664,167).

Scenario	Population weighted concentration ng/m^3	Population exposure people.ng/m^3	Incremental Decrease in exposure vs 2010 base case, people.ng/m^3
1999	0.25021	416,391	-
2010 base case	0.09074	151,007	-
2010 scenario 1	0.08296	138,059	12,947
2010 scenario 2	0.08266	137,560	13,446
2010 scenario 3	0.08278	137,760	13,247
2010 scenario 4	0.08287	137,910	13,097

The following should be noted from this table in the context of the benefits analysis:

1. There is a significant decline in exposure (>50%) between 1999 and 2010.
2. However, there is very little difference in the exposures across the different scenarios for 2010.
3. Concentrations are reported in ng (10^{-9}g) / m^3, whereas those experienced occupationally are reported in µg (10^{-6}g)/ m^3. Occupational exposures are therefore much higher than those affecting the general public.

3.3.2 Selection of concentration-response function

Quantifiable risk data are available from studies on animal and human subjects, though for the purposes of this report it is only the latter that are considered. Overall, the animal data are of a similar magnitude to the human risk data, though the observed range is wider, particularly at the lower end. The following formed the core data used by the European Commission's Working Group on PAHs in consideration of probable risk factors during development of the EU's 4th Daughter Directive on Ambient Air Quality (Table 4) (see AEA Technology, 2001).

Table 4 - Summary of lifetime Unit Risk Estimates for PAH per ng/m^3 of B[a]P (taken from the summary given in the EC PAH Working Group).

Basis for calculation	Unit Risk	Reference
US coke oven workers	87×10^{-6}	WHO, 1987; 2000[1]
US coke oven workers	23×10^{-6}	Muller *et al*, 1997
US coke oven workers	50×10^{-6}	Pott, 1985
UK gas workers	430×10^{-6}	Pike, 1983
Smoky coal indoors in China	67×10^{-6}	RIVM, 1989
"Most appropriate" estimate	100×10^{-6}	RIVM, 1989[1]
Aluminium smelters	90×10^{-6}	Armstrong *et al*, 1994, converted from workplace exposure to continuous life-time exposure

[1]The WHO and RIVM "most appropriate" estimates are based on reviews, which include some of the other papers listed.

The risk factor recommended by the European Commission's Working Group, and used here for the best estimate, is that derived from the WHO (1987, 2000) studies on coke oven workers. The other studies shown suggest a range for the risk factor roughly a factor 4 higher and lower, and this is carried through to the sensitivity analysis shown in Appendix 1.

As noted elsewhere, the risk factors shown are expressed against B[a]P concentrations, where B[a]P is used as an indicator of PAH concentration. There is thus no need to take separate account of each individual PAH compound.

The UK's Health and Safety Executive have recently commissioned a paper from the London School of Hygiene and Tropical Medicine to carry out a meta-analysis of PAH risk data (Armstrong *et al*, 2003). In producing the present report there has not been sufficient time to take full account of this new work which appears to provide a more conservative view (i.e. would calculate a smaller number of cases) than if the WHO position were followed. For reasons that will become apparent it is reasonable for this analysis to retain the WHO estimate.

3.3.3 How many types of cancer are linked to PAH, and how can they be accounted for?

Although PAHs have been linked to a variety of cancers (lung, bladder, skin, pancreas, kidney) the only quantitative response data available relate to lung cancers. Quantification of lung cancers alone may therefore lead to an underestimate of total benefits, making it necessary to ask whether there is a logic for quantifying for the other cancers also. It may be expected that the link between PAH levels in the air and these other cancers is not so strong as it is for lung cancers, otherwise one would expect that functions would be available through the same epidemiological studies of workers that generate the function for lung cancer. On this basis it seems reasonable to say that if other cancers are generated none of them are as numerous as lung cancers. Given that several possible cancers have been linked to PAH it seems appropriate to double the benefits in terms of the fall in the number of lung cancers quantified to estimate the total effect on cancer incidence.

3.3.4 Reference point for effects in Northern Ireland

In Northern Ireland as a whole there are roughly 800 deaths per year from lung and throat cancer according to National Statistics (total lung cancer deaths over the period 1991-1998 were relatively steady between 752 and 816, with no trend in either direction). This represents a rate of 5% of all deaths. Most of these cases will of course be linked to smoking. We are unaware of any other analysis in Northern Ireland specific to PAHs. 90% of people die within 5 years of being diagnosed with lung cancer.

3.3.5 Selection of valuation data

There are two elements to the valuation of lung cancers linked to PAH exposure. The first concerns the period of morbidity prior to cure or death and the second, death itself. In November 2000 DG ENV convened a workshop with experts from Europe and the USA to consider valuation of mortality and morbidity relating to air pollution (see AEA Technology, 2001a). A best estimate and range for the value of statistical life (VOSL) was identified, together with a series of factors for adapting these values to specific problems, in this case. The following process was applied to derive values specific to lung cancer death and recovery:

The starting point was a best estimate for the value of statistical life amongst the elderly of €1 million, in a range of €0.65 million to 2.5 million, converted at an exchange rate of 1.44 € :£1 this gives a best estimate of £0.69 million and a range of from £0.45 million to £ 1.74 million.

Willingness to pay to avoid cancers was estimated at 0.5 times the VOSL. This figure, the 'cancer premium', forms the basis for valuation of the proportion of cases likely to lead to recovery (in the case of lung cancers this is only 10%, EstEve *et al*, 1993). For fatal cases the cancer premium is added to the VOSL.

There are strong theoretical and empirical grounds for believing that the value for preventing a fatality declines with age. Based on the results of research on valuation, the deaths of those aged less than 65 are given a value 1.43 times higher than those aged 65 years or older. Data on lung cancers shows 69% occur in the over 65s, and 31% in those younger than 65. Combining this information leads to a factor of 1.13 to correct for age.

The next factor concerns the lag between exposure and effect. Data on trends in smoking and lung cancer incidence suggest a 20 year lag. Discounting over this period at HM Treasury's recommended rate of 3.5% introduces a factor of 0.503. To calculate the lower estimate we have used the European Commission's recommended discount rate of 4% giving a 20 year factor of 0.456. Discounting at a rate of 2% introduces a factor of 0.673, and this figure is used to provide the upper estimate for the VOSL.

On this basis the VOSL relevant to the present case is calculated as:
(*baseline estimate* + *cancer premium*) x *age factor* x *discount factor*
where the cancer premium = 0.5 x baseline estimate

The average value of a lung cancer is adjusted down to account for the 10% of cases that lead to recovery, and which are valued as:
cancer premium x *age factor* x *discount factor*

Final values are shown in Table 5.

Table 5 - Valuation of cancers related to air pollution, £M. The first block deals with fatal cancers, and the second block, non-fatal cancers. The final block averages these results in accordance with the proportion of cancers that will lead to death.

VOSL	**Baseline estimate**	**Add cancer premium**	**Correct for age**	**Apply discount rate**
Low (4% discount rate)	0.45	0.68	0.77	0.35
Best (3.5% discount rate)	0.69	1.0	1.2	0.59
High (2% discount rate)	1.74	2.6	3.0	2.0

Willingness to Pay (WTP) for avoidance of non-fatal cancers	**Baseline estimate**	**Calculation of cancer premium**	**Correct for age**	**Apply discount rate**
Low (4% discount rate)	0.45	0.23	0.26	0.12
Best (3.5% discount rate)	0.69	0.35	0.39	0.20
High (2% discount rate)	1.74	0.87	0.98	0.66

Average WTP for avoidance of lung cancers	**Average assuming 90% of cases are fatal and 10% are recoverable**
Low (4% discount rate)	0.33
Best (3.5% discount rate)	0.55
High (2% discount rate)	1.9

There has been debate as to whether the VOSL approach is correct in the context of valuation of the impacts of air pollution. In relation to non-carcinogenic pollutants it alternative methods and values are emerging. However, application of the VOSL in the context of carcinogenic pollutants has not been questioned, and certainly deals with a situation that is more in keeping with the approach used to derive the VOSL.

The Department for Transport recommends a different starting value for assessment of the VOSL, of around £1.25 million in 2003 prices. Applying the same procedures as above to adjust for age, likelihood of recovery, treatment costs prior to death or recovery, etc. provides a best estimate of £1.0 million in a range of £0.59 to £3.3 million per case. The values based on the DfT VOSL will be taken forward.

3.4 RESULTS FOR THE BENEFITS ASSESSMENT

This section reports the best estimates of benefits in terms of reducing PAH exposure of the population of Northern Ireland. A more complete sensitivity analysis is presented in Appendix 1, drawing on the discussion of ranges given above.

Change in the incidence of lung cancer for the different scenarios is shown in Table 6, together with estimated total cancers (calculated simply by doubling the number of lung cancers as explained above). The table shows both the total number of lung cancers that would be anticipated were the concentrations given in Table 3 to be experienced for a period of 70 years, roughly corresponding to a lifetime, and the effects of just one year of exposure. According to these results the damages decline by almost two thirds in the period 1999 to 2010 assuming no further action.

Table 7 then summarises the change in the number of lung cancers for the 2010 scenarios against the 2010 base case. Finally, impacts are expressed in monetary terms in Table 8, on an annual basis to permit comparison with the annualised costs data.

Table 6 – Best estimates of lung cancers and total cancers attributed to exposure to ambient levels of PAHs at the concentrations described across Northern Ireland in 1999 and 2010. The top half of the table shows the number of cancers were these concentrations to be maintained for lifetime exposure. The lower half shows the effect of emissions for one year only.

Calculating the incidence of lung cancers linked to PAHs for sustained lifetime exposure		
	Lung cancers	**Total cancers**
1999	36.23	72.46
2010 base case	13.14	26.18
2010 scenario 1	12.01	24.02
2010 scenario 2	11.97	23.94
2010 scenario 3	11.99	23.98
2010 scenario 4	12.00	24.00

Calculating the incidence of lung cancers linked to PAHs for 1 year exposure		
	Lung cancers	**Total cancers**
1999	0.52	1.04
2010 base case	0.19	0.38
2010 scenario1	0.17	0.34
2010 scenario2	0.17	0.34
2010 scenario3	0.17	0.34
2010 scenario4	0.17	0.34

Table 7 – Best estimates of the reduction in lung cancers and total cancers for each scenario compared to 2010 base case

Sustained lifetime exposure		
	Lung cancers	**Total cancers**
2010 base case	-	-
2010 scenario 1	1.13	2.25
2010 scenario 2	1.17	2.34
2010 scenario 3	1.15	2.30
2010 scenario 4	1.14	2.28

1 year exposure		
	Lung cancers	**Total cancers**
2010 base case	-	-
2010 scenario 1	0.0161	0.0322
2010 scenario 2	0.0167	0.0334
2010 scenario 3	0.0165	0.0329
2010 scenario 4	0.0163	0.0326

Table 8 – Benefits according to the best estimate of the change in cancer incidence through reducing PAH exposures in Northern Ireland.

Valuation of total cancers, 1 year exposure	
2010 base case	-
2010 scenario 1	£32,078
2010 scenario 2	£33,315
2011 scenario 3	£32,820
2011 scenario 4	£32,449

3.5 DISCUSSION

Before considering the results of the benefits analysis it is necessary to ask whether the boundaries for the study have been defined correctly, in particular, whether the analysis should have included consideration of health impacts from risks other than exposure to ambient air.

3.5.1 Should the analysis have considered impacts of other emissions to the atmosphere?

The measures identified in this report for controlling domestic PAH emissions will be beneficial not just in terms of reducing PAH emissions, but also in reducing emissions of particles, and in most cases greenhouse gases. Based on past analyses, it is to be anticipated that these benefits would greatly outweigh the benefits of reduced PAH emissions. There may also be some disbenefits. For example, production of smokeless solid fuels can be a highly polluting process, though production in most of Europe will now be subject to tight environmental controls.

Whilst these secondary effects clearly need to be identified, we do not believe that it is appropriate to factor them into this analysis. The question that has been asked is simply whether it is appropriate to invest to meet objectives for PAH exposure. On this basis the analysis must concentrate solely on PAH effects.

The inclusion of other effects may well generate results that appear to justify action that (coincidentally) meets the PAH target. However, there may be ways of reducing particle and greenhouse gas emissions that are far more cost-effective than those that would be adopted for compliance with PAH objectives. If this is the case, then expenditure on the measures identified here would represent an inefficient use of the resources available.

Equally, of course, the measures identified for reducing PAH emissions may be a cost-effective approach for particle and greenhouse gas control, but that has not been investigated here. Some relevant data on the cost-effectiveness of particle control from the domestic sector relative to particle controls for other sectors are available in a report to DEFRA (AEA Technology, 2001b).

3.5.2 Should the analysis have considered impacts on indoor air quality?

Switching to alternative fuels and/or more modern appliances will reduce indoor as well as outdoor concentrations of combustion pollutants, including PAHs. It is possible that indoor exposure in many houses could be far worse than exposure to PAH in the outdoor air. However, the standard that is the subject of this investigation applies only to outdoor concentrations, so indoor exposures are not considered relevant to the CBA of the outdoor standard. Again, however, were the question to be asked different, such exposure may become relevant to a CBA.

3.5.3 The role of PAHs in the ambient air in determining lung cancer incidence in Northern Ireland

Against an annual incidence rate of 800 lung cancer deaths per year the benefits of controlling PAH emissions are small (considerably less than 0.1, or one case in every 10 years). Here, as elsewhere, it is smoking that is the primary determinant of lung cancer incidence. It would appear logical to ask whether investment should be made on other approaches to reducing cancer incidence.

It is worth noting, however, that whilst the benefits of reducing PAH emissions are relatively low, the benefits of controlling particle concentrations that follow from the measures described in this report are likely to be considerably larger.

3.5.4 If PAHs are a threat to health, why is the estimated number of cancers so small?

Cumulative occupational exposures in the studies reviewed by Armstrong et al (2003) ranged from 0.75 to 805 $\mu g/m^3$ years. This is equivalent to a concentration in air of 0.040 to 40 $\mu g/m^3$. Ambient concentrations on the other hand, are very much lower, so much so that they are reported in ng/m^3 ($10^{-9} g/m^3$) instead of $\mu g/m^3$ (10^{-6} g/m^3), a difference in unit of a factor of 1000. For the purposes of illustration, *maximum* ambient concentrations for Northern Ireland of around 0.5 ng/m^3 are a factor 80 to 80,000 less than the conditions examined in the epidemiological studies. On this basis it is not surprising that there is a marked difference between the likelihood of cancer being induced in those exposed in the workplace compared to those exposed only to PAH in ambient air.

The fact that a risk appears small is not a good reason for ignoring it. It is logical from an economic perspective at least to invest in measures that are most cost-effective in reducing risk, whether that risk affects a large number of people or not.

3.5.5 Results of the sensitivity analysis on benefits

The sensitivity analysis (Appendix 1) shows a very large range in the benefits of reducing PAH emissions. The reason for this lies in the way that the analysis was done, providing absolute high and low estimates.

3.6 COMPARISON OF COSTS AND BENEFITS

The table below summaries the best estimate of the costs and benefits in financial terms of achieving the three limit values which have been examined.

It can be seen that there is a large disparity between the costs of implementing smoke control and the benefits calculated from the willingness to pay to reduced cancer incidence of around one order of magnitude. While there is significant uncertainty in both of these figures it is unlikely that the decision on implementing smoke control in the 96 squares likely to exceed 0.25 ng/m^3 B[a]P in 2010 can be justified on solely economic grounds

Possible Air Quality Objective Annual Mean concentration ng b[a]P/m^3	Annualised Benefits £/year	Annualised Costs £/year
0.25	32,100	287,000-446,000
0.5	0	0
1.0	0	0

4 Targeting social needs

The Government has a duty, under the Targeting Social Needs (TSN) agenda, to ensure that its policies do not exacerbate the problems of social exclusion and enhance social need. The TSN strategy has been put in place to identify people and areas with social needs and high rates of social exclusion, and ensure that Government policy and programmes are more effective in helping address such needs.

As part of this work, it has been recognised that measures proposed need to be considered with respect to the communities that they will affect. We have undertaken some basic analysis to consider what the benefits might be, in terms of reduction in pollutant concentrations, for communities with differing levels of deprivation. We also note that while considering the benefits, we also need to consider the costs of such measures, and the impact on the communities who might have to pay.

We have undertaken some analysis to assess concentrations of B[a]P in enumeration districts across Northern Ireland. Enumeration districts (EDs) have been classified in different ranges, based on their score of economic deprivation. Scores of economic deprivation have been compiled by the Social Disadvantage Research Centre at Oxford University on behalf of NISRA (2001)). The 2001 deprivation score has been used for both 200 and 2010.

Firstly, we have considered the Northern Ireland situation as a whole, comparing average B[a]P concentrations in 2000 and 2010 for each enumeration district with deprivation levels. Figure 4.1 shows the trends for the 2000 and 2010 baseline situation, and the 2010 scenario 1.

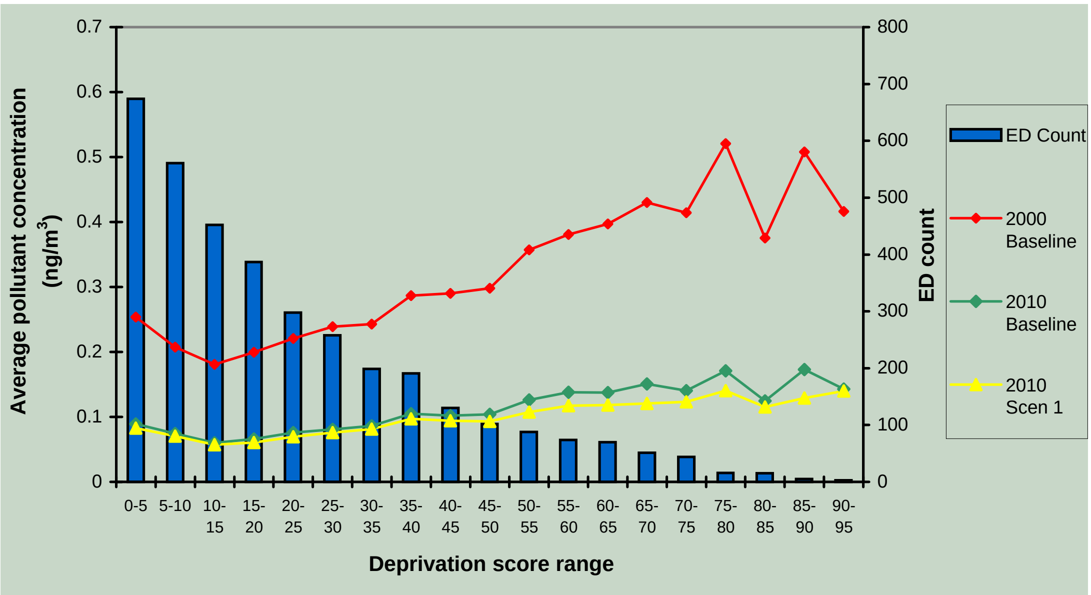

Figure 4.1. A comparison of average B[a]P concentrations in 2000 and 2010 (trend lines) with the deprivation levels for all enumeration district (bar graph) in Northern Ireland.

From Figure 4.1, it appears that B[a]P concentrations (for all trend lines) are highest in enumeration districts where levels of deprivation are highest. By 2010, this trend is much flatter, indicating that the most significant reductions will occur in enumeration districts where deprivation levels are the highest. This may indicate that policies to reduce B[a]P levels are also reducing the level of disparity in air quality terms between affluent and poorer communities.

The measures that we are considering in this study to ensure that there are no exceedances of 0.25 ng/m^3 of B[a]P in 2010 include introduction of SCA regulations across 96 grid cells that are predicted to exceed this limit. This is represented in Figure 4.1 as scenario 1. Above the bin 40-45 range, there appears to be a much more significant reduction in concentrations, again illustrating greater reductions in the more deprived enumeration districts.

Figure 4.2 reflects the above analysis but only for the 96 grid cells that have been identified as exceeding 0.25 ng/m^3 under the 2010 baseline. Each grid cell has been allocated a deprivation score according to its ward location. The grid cells have then been binned in ranges, and compared to their concentration values.

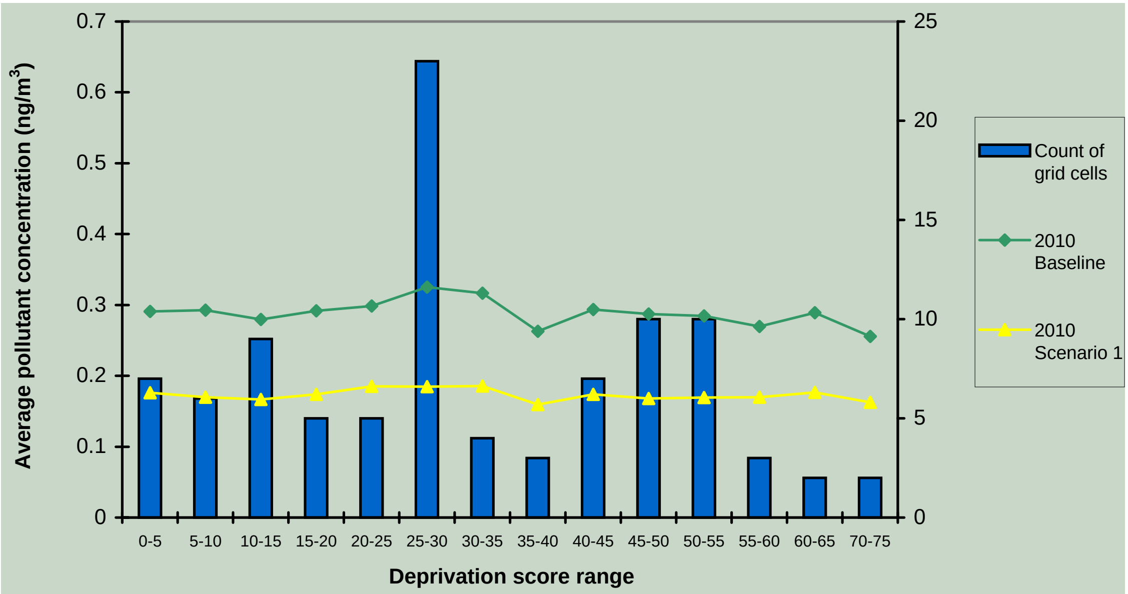

Figure 4.2. A comparison of average B[a]P concentrations in 2010 (trend lines) with the deprivation levels for only those 96 500 m x 500 m squares to which abatement measures were applied (bar graph).

Figure 4.2 reflects the above analysis but only for the 96 grid cells that have been identified as exceeding 0.25 ng/m^3 under the 2010 baseline. Figure 4.2 shows that for the area considered for additional measures, there is a wide range of deprivation scores. However, more grid cells are located in wards with higher deprivation, particularly in the 25-30, and 45-55 ranges. The trend in Figure 4.1 is not reflected in this analysis, with the trend in concentration values relatively flat. Given that we are assessing concentrations only in EDs with predicted 2010 benzo[*a*]pyrene concentrations above 0.25ng/m^3, this trend is be expected.

From the above analysis, the following observations can be made:

- Figure 4.1 illustrates that more deprived communities appear to have higher B[a]P concentrations under all three scenarios.
- The most significant reductions between 2000 and 2010 occur in the most deprived communities.

- The most significant reductions between 2010 baseline and 2010 scenario 1 appear to occur in the most deprived communities.
- Figure 4.2 indicates that concentrations above 0.25ng/m^3 occur across the whole ranges of deprivation values. However, most exceedances of this concentration limit occur in the more deprived ranges.

It is important that the proposed measures will be benefiting the most deprived communities. However, it is also important to note that these benefits are going to be realised at a given cost. Such cost implications mean that policies need to be introduced in such a way that they don’t impact unfairly on more deprived communities.

5 References

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WHO (1987) World Health Organisation. *Air Quality Guidelines for Europe*. WHO Regional Publications, European Series No.23, Copenhagen, WHO Regional Office for Europe.

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Appendices

CONTENTS

Appendix 1 Location of Exceedances

CONTENTS

The modelling study identified ninety six 500m by 500m squares which were predicted under the baseline case of this report to have concentrations of benzo[a]pyrene in 2010 exceeding 0.25 ng/m^3. There are significant uncertainties in the emission projections, the dispersion modelling and the meteorological conditions which will prevail six years in the future. However for completeness the individual squares are identified in Table A1.1 below.

The Easting and Northing in the table have been converted from Ordnance Survey of Great Britain to the Ordnance Survey of Northern Ireland (OS NI) grids and represent the centre of the original squares. The benzo[*a*]pyrene concentration is given at the precision provided by the model which is unrealistically accurate. Place Names have been obtained from OS NI 1:50000 maps and hence may not be accurate reflect of local names. The Local Government District given is that in which the centre of the square is estimated to sit.

Table A1.1 The Grid References of the centres of the 500m by 500m squares which are estimated in the baseline to have benzo[a]pyrene annual average concentrations in 2010 in excess of 0.25 ng/m^3.

no	Easting	Northing	Predicted 2010 Baseline Benzo[a]pyrene Concentration	Place Name (approx)	Local Government District
1	242575	420612	0.2871107	Lower Galliagh	Derry
2	243072	420655	0.2957753	Shantallow	Derry
3	243570	420698	0.2909006	Shantallow	Derry
4	244068	420741	0.2749823	Shantallow	Derry
5	242618	420115	0.3084131	Shantallow	Derry
6	243115	420158	0.3143950	Shantallow	Derry
7	243613	420200	0.2633209	Shantallow	Derry
8	240670	419446	0.3182378	Ballymagroty	Derry
9	241167	419489	0.3496906	Ballymagroty	Derry
10	241665	419531	0.3554524	Ballymagroty	Derry
11	242163	419574	0.3528278	Springtown	Derry
12	242660	419617	0.3127931	Springtown	Derry
13	243158	419660	0.3122872	Pennyburn	Derry
14	243656	419703	0.2996980	Shantallow	Derry
15	240713	418948	0.3205785	Ballymagroty	Derry
16	241210	418991	0.3592217	Ballymagroty	Derry
17	241708	419034	0.4541478	Ballymagroty	Derry
18	242206	419077	0.3596702	Springtown	Derry
19	242703	419119	0.3244881	Springtown	Derry
20	243201	419162	0.3293409	Pennyburn	Derry
21	243699	419205	0.3116391	Pennyburn	Derry
22	244196	419248	0.2829795	Pennyburn	Derry
23	241751	418536	0.3089302	Springtown	Derry
24	242248	418579	0.3074688	Springtown	Derry
25	242746	418622	0.2792636	Springtown	Derry
26	243244	418665	0.2594680	Pennyburn	Derry
27	241794	418038	0.3767660	Creggan	Derry
28	242291	418081	0.3020282	Springtown	Derry
29	242789	418124	0.2651410	Pennyburn	Derry

30	241836	417541	0.3718889	Creggan	Derry
31	242334	417584	0.2969931	Creggan	Derry
32	242832	417626	0.3029727	Rosemount	Derry
33	243329	417669	0.2925836	Rosemount	Derry
34	241879	417043	0.2508247	Creggan	Derry
35	242377	417086	0.2775907	Rosemount	Derry
36	242875	417129	0.2752969	Rosemount	Derry
37	243372	417172	0.2961154	Rosemount	Derry
38	241922	416545	0.2652173	Rosemount	Derry
39	242420	416588	0.2921071	Rosemount	Derry
40	242917	416631	0.2533959	Rosemount	Derry
41	243415	416674	0.2957074	Rosemount	Derry
42	243913	416717	0.3159564	Waterside	Derry
43	244410	416760	0.3017234	Waterside	Derry
44	242463	416091	0.2575093	Rosemount	Derry
45	243458	416176	0.2815357	Waterside	Derry
46	243956	416219	0.2930451	Waterside	Derry
47	244453	416262	0.2918754	Waterside	Derry
48	243998	415721	0.2506068	Waterside	Derry
49	244041	415224	0.3042389	Gobnascale	Derry
50	349249	381622	0.2579693	Bangor	North Down
51	349747	381664	0.2531536	Bangor	North Down
52	351740	381835	0.2973126	Bangor	North Down
53	352238	381878	0.3099859	Bangor	North Down
54	352736	381920	0.2890732	Bangor	North Down
55	348794	381081	0.2994586	Bangor	North Down
56	349292	381123	0.2707432	Bangor	North Down
57	349790	381166	0.2635382	Bangor	North Down
58	349335	380625	0.2632023	Bangor	North Down
59	349833	380668	0.2926315	Bangor	North Down
60	351370	380298	0.2736435	Bangor	North Down
61	351413	379800	0.2837285	Bangor	North Down
62	351911	379842	0.2653672	Bangor	North Down
63	348893	374064	0.2747332	Bangor	North Down
64	336027	371959	0.3217054	Cregah	Castlereagh
65	327104	370694	0.2772663	Poleglass	Lisburn
66	328100	370779	0.2574378	Poleglass	Lisburn
67	335571	371418	0.4247975	Ballynafeigh	Castlereagh
68	336069	371461	0.2866618	Cregah	Castlereagh
69	327146	370196	0.2884396	Poleglass	Lisburn
70	327644	370238	0.2575093	Poleglass	Lisburn
71	328142	370281	0.2637466	Twinbrook	Lisburn
72	335614	370920	0.3222575	Cregah	Castlereagh
73	327189	369698	0.2576763	Poleglass	Lisburn
74	327687	369740	0.2674443	Twinbrook	Lisburn
75	328270	368787	0.2916553	Dunmurry	Lisburn
76	328811	368331	0.2588387	Dunmurry	Lisburn
77	326989	366169	0.2647513	Lambeg	Lisburn Borough
78	327032	365671	0.3285557	Lambeg	Lisburn Borough
79	327530	365713	0.2586318	Lambeg	Lisburn Borough
80	325665	364049	0.2998861	Lisburn	Lisburn Borough
81	307950	360026	0.3146969	Lurgantarry	Craigavon
82	308448	360068	0.2586522	Lurgantarry	Craigavon
83	307992	359528	0.3213569	Lurgan	Craigavon
84	308490	359570	0.2726944	Lurgan	Craigavon
85	302400	354536	0.2918592	Portadown	Craigavon

86	302898	354578	0.2733066	Portadown	Craigavon
87	300948	353910	0.3396546	Portadown	Craigavon
88	302442	354038	0.2519263	Portadown	Craigavon
89	302940	354080	0.2685515	Portadown	Craigavon
90	300991	353412	0.3144377	Portadown	Craigavon
91	301034	352914	0.2855025	Portadown	Craigavon
92	304609	328642	0.3354131	Bessbrook	Newry and Mourne
93	305107	328685	0.3296476	Bessbrook	Newry and Mourne
94	336981	331400	0.2592230	Newcastle	Down
95	304651	328144	0.3130762	Bessbrook	Newry and Mourne
96	305149	328187	0.2568646	Bessbrook	Newry and Mourne

Appendix 2 Sensitivity Analysis on Benefits

CONTENTS

A2.1 Introduction

There are a series of uncertainties in the quantification of the health risks and costs associated with PAHs which need to be taken into account in the analysis. This Appendix describes what we perceive to be the main uncertainties and the approaches that have been used to factor them into the assessment.

A2.2 Sources of Uncertainty

A2.2.1 Accounting for uncertainty in the risk factor

As noted earlier, there is roughly a factor of four variation in published estimates of the risk factors for PAH exposure. This variation is carried through into the sensitivity analysis.

Sensitivity analysis 1: Apply factor 4 variation in the risk factor.

A2.2.2 Reliability of B[a]P as a marker for PAHs

The original risk analysis used by EPAQS and risk analysis by the European Commission and others suggested that B[a]P was responsible for 40% of the total carcinogenicity of PAH mixtures, and so was a reasonable choice as marker.

Subsequent work has assessed the carcinogenicity of individual PAHs in more detail. One recent estimate attributed 97% of PAH carcinogenicity to dibenzo[*al*]pyrene, with B[a]P contributing only about 1% (McGaughey and Coleman 2003). Cost Benefit Analysis work for the European Commission carried out during development of the 4th Daughter Directive includes sensitivity analysis that suggests that B[a]P contributes between 5% and 41% of the total carcinogenicity of PAH mixtures as monitored around the UK (AEA Technology, 2001a).

However, despite this, observations on the link between PAH as monitored in terms of B[a]P and lung cancers indicate that B[a]P while perhaps only providing a small fraction of the total carcinog3enicity correlates strongly with the total carcinogenicity and so is an appropriate marker compound. It is proposed that no account is taken of analysis that B[a]P is a less potent component of PAH mixtures than previously suspected on the grounds that the analysis simply expresses risk relative to B[a]P.

A2.2.3 The types of cancer associated with PAH inhalation

Although PAHs have been linked to a variety of cancers (lung, bladder, skin, pancreas, kidney) the only quantitative response data available relate to lung cancers. However quantification of lung cancers alone may lead to an underestimate of total benefits, making it necessary to ask whether there is a logic for quantifying for the other cancers also. It may be expected that the link between PAH levels in the air and these other cancers is not so strong as it is for lung cancers, otherwise one would expect that functions would be available through the same epidemiological studies of workers that generate the function for lung cancer. On this basis it seems reasonable to say that if other cancers are generated none of them are as numerous as lung cancers.

Given that several possible cancers have been linked to PAH it seems appropriate to double the benefits in terms of the fall in the number of lung cancers quantified to estimate the total effect on cancer incidence.

Sensitivity analysis 2: Double the benefits of reductions in lung cancer to account for total cancers.

A2.2.4 Accounting for uncertainty in valuation data

This part of the sensitivity analysis uses the range quantified earlier in the report.

Sensitivity analysis 3: Quantify benefits using low, best and high estimates of cancer valuations of £0.59, 1.0 and 3.3 million.

Note that this takes account of the estimated 10% of lung cancers that are non-fatal. However, it is likely to overvalue non-lung cancers as they respond better to treatment.

A2.3 Results

The Tables in this section are similar to those in the main text, though here they include high and low estimates in addition to the best estimates seen before.

Total lung cancers for the different scenarios are quantified in Table 9 which includes results also applying the first sensitivity analysis, the use of a factor of four to show uncertainty in the risk factor. The table shows both the total number of lung cancers that would be anticipated were the concentrations given in Table 3 to be experienced for a lifetime, and the effects of just one year of exposure. According to these results the damages decline by almost two thirds in the period 1999 to 2010 assuming no further action. Table 10 then summarises the change in the number of lung cancers for the 2010 scenarios against the 2010 base case. Sensitivity analysis 2, accounting for other cancers (bladder, kidney, etc.) is factored into Table 11 by doubling the best and high estimates. The low estimate is left unchanged on the assumption that PAH is only linked to lung cancer.

Finally, benefits of control are monetised in Table 12, using the range of values described above under sensitivity analysis 3.

Table 9 – Total lung cancers attributed to exposure to ambient levels of PAHs at the concentrations described across Northern Ireland in 1999 and 2010. The top half of the table shows the number of cancers were these concentrations to be maintained for lifetime exposure. The lower half shows the effect of emissions for one year only.

Calculating the incidence of lung cancers linked to PAHs for sustained lifetime exposure			
	WHO (1987, 2000)	**Low**	**High**
Lifetime Risk /ng/m^3	**8.70E-05**	**2.18E-05**	**3.48E-04**
1999	36.23	9.06	145
2010 base case	13.14	3.28	52.6
2010 scenario 1	12.01	3.00	48.0
2010 scenario 2	11.97	2.99	47.9
2010 scenario 3	11.99	3.00	47.9
2010 scenario 4	12.00	3.00	48.0

Calculating the incidence of lung cancers linked to PAHs for 1 year exposure			
	WHO (1987, 2000)	**Low**	**High**
Lifetime Risk /ng/m^3	**8.70E-05**	**2.18E-05**	**3.48E-04**
1999	0.52	0.13	2.1
2010 base case	0.19	0.05	0.75
2010 scenario1	0.17	0.04	0.69
2010 scenario2	0.17	0.04	0.68
2010 scenario3	0.17	0.04	0.69
2010 scenario4	0.17	0.04	0.69

Table 10 – Reduction in lung cancers for each scenario compared to 2010 base case

Sustained lifetime exposure	WHO (1987, 2000)	Low	High
2010 base case	-	-	-
2010 scenario 1	1.13	0.282	4.51
2010 scenario 2	1.17	0.292	4.68
2010 scenario 3	1.15	0.288	4.61
2010 scenario 4	1.14	0.285	4.56

1 year exposure	WHO (1987, 2000)	Low	High
2010 base case	-	-	-
2010 scenario 1	0.0161	0.00402	0.064
2010 scenario 2	0.0167	0.00418	0.067
2010 scenario 3	0.0165	0.00412	0.066
2010 scenario 4	0.0163	0.00407	0.065

Table11– Estimating total cancers (lung, bladder, etc.). WHO estimates and High estimates for lung cancers are doubled. Low estimate is left unchanged on the assumption that other cancers are not linked to PAH exposure.

Total cancers, sustained lifetime exposure	WHO (1987, 2000)	Low	High
2010 base case	-	-	-
2010 scenario 1	2.25	0.282	9.01
2010 scenario 2	2.34	0.292	9.36
2010 scenario 3	2.30	0.288	9.22
2010 scenario 4	2.28	0.285	9.12

Total cancers, 1 year exposure	WHO (1987, 2000)	Low	High
2010 base case	-	-	-
2010 scenario 1	0.0322	0.00402	0.1287
2010 scenario 2	0.0334	0.00418	0.1337
2010 scenario 3	0.0329	0.00412	0.1317
2010 scenario 4	0.0326	0.00407	0.1302

Table 12 – Valuation of the best estimate based on WHO (1987, 2000) and low and high estimates of the change in cancer incidence.

Valuation of total cancers, 1 year exposure			
Value	**WHO (1987, 2000) £1,000,000**	**Low £590,000**	**High £3,300,000**
2010 base case	-	-	-
2010 scenario 1	£32,078	£18,935	£107,386
2010 scenario 2	£33,315	£19,665	£111,527
2010 scenario 3	£32,820	£19,373	£109,870
2010 scenario 4	£32,449	£19,154	£108,628