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Book

Clean air policy in Great Britain: problem displacement as best practicable means

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Helmut Weidner

**Clean Air Policy
in Great Britain**

Problem Displacement
as Best Practicable Means



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FOREWORD

Air pollution control policy in the United Kingdom (UK) began to gather momentum in 1986. After years of criticism by various continental European governments and many environmental organisations of Britain's continued export of SO₂ emissions from fossil fuelled power plants, the British government finally agreed to retrofit some of the country's main power stations with flue gas desulphurisation units and to fit all future plants with this technology. Although the UK had come close to achieving the goal set by the "30% Club", that is, to reducing its total annual SO₂ emissions (based upon 1980 emission levels) by 30% by 1993, the British government is still unwilling to join forces with other European countries in important areas of clean air policy such as automobile exhaust regulation, emission standards for power plants and industrial boilers.

The UK's obvious reluctance to cooperate in international measures designed to reduce air pollutants is a result not only of its special emissions problems, but also of its long-standing, deeply rooted pollution control philosophy. One of the aims of this book is to make this philosophy understandable to the United Kingdom's neighbours.

This book closely resembles an earlier publication by the same author, Air Pollution Control Strategies and Policies in the F. R. Germany, (edition sigma, rainer bohn verlag, Berlin 1986). It is particularly valuable, therefore, because it allows a detailed study and comparison of two countries, the UK and the FRG, each of which takes a distinctively different approach to the problem of air pollution and strategies for air pollution control.

Berlin, December 1987

Udo E. Simonis
Director, IIUG

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Berlin, December 1987

Helmut Weidner

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INTRODUCTION

Great Britain, as an early industrialised nation, has had a long history of concern for the control of air pollutants and improving air quality. In 1848 the Public Health Act was passed, followed by the passing of the first Alkali Act in 1863. These pieces of legislation were designed to protect public health and to control the emission of noxious gases from alkali works. Additional regulations requiring prior authorisation of certain industrial plants, as a measure to control emissions, have been in force since 1906.

The United Kingdom's achievements in improved air quality are no less impressive. Annual average urban concentrations of smoke have fallen by over 80% in the last 20-year period; average ground level concentrations of sulphur dioxide have fallen by more than 70% since 1960. The UK's total sulphur dioxide emissions have dropped from 6.12 million tonnes in 1970 to 3.58 million tonnes in 1985, representing a reduction of 42%. Nitrogen oxide emissions dropped from 2.03 million tonnes in 1970 to 1.84 million tonnes in 1985, representing a reduction of 10%. Furthermore, the British government has announced its aim to achieve a 30% reduction in sulphur dioxide and nitrogen oxide emissions (based upon 1980 emission levels) by the end of the 1990s.

Declining emissions and improved ground level concentrations have resulted in noticeable improvements in Britain's air quality, particularly in urban areas. For instance, smog episodes such as those occurring in London in the 1950s have been eliminated; visibility and level of sunshine in British cities have increased. London today, for example, enjoys 70% more December sunshine than it did in the late 1950s, and average winter daytime visibility has increased by 2.5 km to 6 km.

The striking decline in sulphur dioxide and, in particular, smoke concentration levels in British cities was due partly to measures taken by local authorities based on the Clean Air Act 1956. Since that time, some 6,000 smoke control areas covering nearly 9 million properties in urban areas were established. Improvements in Britain's air quality were also achieved through application of the principle of "best practicable means" (BPM) to control industrial emissions, including those from fossil fuelled power plants. BPM has been a central feature of British

industrial air pollution control since 1874. According to the Department of the Environment (December 1986), the essential elements of BPM are as follows.

- No emission can be tolerated which constitutes a recognised health hazard, either short-term or long-term.
- Emissions in terms of both concentration and mass must be reduced to the lowest practicable amount. When determining the BPM for any particular process, the control authorities in turn take into account the local conditions and circumstances, both of the works and of the environment; the current state of technical knowledge about control technology and the effects of substances on human health, flora and fauna, construction materials, amenity, etc.; the financial implications in relation to direct capital and revenue costs; and the means to be employed which includes, among other things, the design, installation, maintenance and manner and periods of operation of plant and machinery.
- Having secured the minimum practicable emission, the height of discharge must be arranged so that the residual emission is rendered harmless and inoffensive by dilution and dispersion.

Undoubtedly BPM, which allows the responsible authorities to take a flexible and pragmatic approach to air pollution, has had its merits in the control of industrial air pollution. However, with respect to sulphur dioxide in particular, and nitrogen oxide emissions arising from combustion processes as well, mandatory implementation of BPM has resulted in dispersal of pollutants by high chimney construction rather than emission reduction through chimney stack control. Until the present, no large-scale flue gas desulphurisation or denitrification units had been installed in fossil fuelled combustion plants. The majority of British sulphur dioxide emissions are still dispersed using high stacks, and it is a well-established fact that British sulphur dioxide emissions do indeed contribute significantly to the acidification of lakes and streams in Scandinavia. Although some European countries have also claimed that British sulphur dioxide emissions have contributed to the dying forests in continental Europe, hard scientific evidence in support of such claims is still a matter of dispute. Consequently, British air pollution control policy, particularly where this concerns pollutants from large combustion plants, has remained essentially a policy of "pollution

export". Therefore (and hence the subtitle of this volume), problem shifting is the real outcome of the application of the principle of "best practicable means".

Environment related problem shifting has various forms. These may be generally classified as follows.

- **Medial problem shifting.** Environmental problems are shifted from one medium to another—for example, from air to water or soil. Dust collectors, for instance, reduce air pollution at the expense of greater water or soil pollution when dusts are disposed of recklessly.
- **Spatial problem shifting.** One region is "cleaned up" at the expense of others. For example, air quality in urban agglomerations is improved through long-range dispersion of pollutants.
- **Temporal problem shifting.** Environmental problems are dispersed over a lengthy period of time. For instance, concentrations of pollutants in the ambient air are diluted so as to avoid immediate, acute injury to human health. While this may mitigate critical problem situations in the short run; continuous, long-term exposure to pollutants may impair health or induce chronic disease which becomes noticeable at a relatively later stage and is thus difficult to trace back to its actual cause.
- **Problem shifting caused by substitution measures.** Industrial processes, raw materials, fuels, etc. are substituted by others (sometimes in response to environmental policy decisions) which may pollute the environment to the same or even to a greater extent: for instance, switching from fossil fuels to nuclear power or substituting lead in petrol for aromatic hydrocarbons which are suspected carcinogens.

In Britain as in many other nations, we can find examples of all these forms of problem shifting. However, spatial problem shifting--the best known example of which refers to sulphur dioxide and "long-range transboundary air pollution"--is a typical element of British air pollution control policy which in turn is characterised by the following features, unique to Britain in terms of their extent and combination: the systematic application of high stack policy qua BPM; the export of most of its sulphur dioxide emissions outside Britain, supported by favourable prevailing winds; and, until recently, the strongest opposition to national or international policies directed towards reducing sulphur dioxide emissions from high stack sources to any significant degree, by

government and the Central Electricity Generating Board whose power stations are responsible for most of the pollution exports. Although the UK was a pioneer in industrial clean air policy nearly a century ago and a leader in domestic clean air policy nearly 30 years ago, in more recent years it has become the "problem child" among Western European countries, systematically blocking every attempt to develop a coordinated international or supranational system of measures to combat air pollution.

The decision in 1986 to retrofit some of Britain's existing power stations and to equip all new coal-fired power stations with flue gas desulphurisation (FGD) units or whatever better technology may become available, is probably essentially the result of compounding criticism from abroad over so many years and, more recently, mounting criticism at home of Britain's policy of problem shifting (Blowers, 1987; Macrory, 1987). By way of comparison, other European countries had long since undertaken such measures to control air pollution. For instance, by the end of 1986, in the Federal Republic of Germany (FRG) 12,000 megawatts of electric power were generated from power stations fitted with flue gas desulphurisation equipment; by the end of 1987, power stations representing a capacity of nearly 30,000 megawatts had been fitted with FGD and by mid-1988, 43,000 megawatts of electric power will be generated by FGD equipped power stations. As a result of these measures in the FRG, sulphur dioxide emissions from large combustion plants, which amounted to over 2 million tonnes in 1982, are expected to fall to 0.8 million tonnes by 1988 and to 0.5 million tonnes by 1993, representing a reduction of about 75%. To reduce nitrogen oxide emissions in the FRG, it is planned to equip West German power plants representing a generating capacity of between 30,000 and 33,000 megawatts with flue gas denitrification (denox) units. This means, according to official calculations, that nitrogen oxide emissions from West German power stations, which amounted to about 1 million tonnes in 1982, will be reduced by 70% by the early 1990s (Lange, 1987). Thus, compared to West German pollution control measures, British efforts represent only a very small first step. However, if one considers the UK context alone, recent measures undertaken by government do indeed represent a major step towards reducing emissions, in light of previous clean air policy in Britain.

In other areas as well, significant changes are occurring in the British air pollution control system. Existing power stations are to be retrofitted with low nitrogen oxide burners; efforts are being made to improve public access to information about air pollution control; local authorities will be granted powers of prior approval for certain stationary emissions sources and the Secretary of State for the Environment will be empowered to regulate pollution by setting air quality standards and emission limits. Fundamental reorganisation of the British air pollution control system had begun in April 1987. Government agencies specialised in different areas of pollution control, including the Industrial Air Pollution Inspectorate, were reorganised into a new, unified central agency, Her Majesty's Inspectorate of Pollution (HMIP), designed to scrutinise gaseous, liquid, and solid waste arising from industrial processes in a unified, consistent manner. "The move is intended to secure a co-ordinated approach to controls over industrial emissions and discharges into air, water and on land with a view to developing the 'best practicable environmental option' concept" (Clean Air, No. 3, 1986, p. 136). The "best practicable environmental option" concept was recommended in 1976 by the Royal Commission on Environmental Pollution.

"What initially brought the RCEP to expound the BPEO concept was evidence that cross-media pollution transfers had resulted from the decisions of one regulatory authority to tighten controls on the waste disposal route under its control without considering the consequences for other media or consulting with other authorities about them." (ENDS, No. 148, 1987, p. 8)

In general and in light of recent developments, what can be said about the British concept in air pollution control is that it is currently undergoing a process of fundamental change. If the British government's attempts to restructure the existing legislative and organisational bases of pollution control actually come to fruition, then the United Kingdom's approach to air pollution issues will become among the most modern in Europe. The coming few years will indeed reveal whether the new dynamics in policy formulation will really be followed up by implementation of measures and enforcement. Very recent developments do indicate, however, that the British government is still taking a rather dilatory approach to implementation despite the fact that by the end of 1987 it was well established that a significant proportion of British

forests had been severely damaged and, in part, to an even greater extent than forests in the FRG.

This book presents an overview of the essential features of the British air pollution control regime over many decades. In addition, it will examine the various legislative and organisational changes that have occurred in Britain, giving special attention to those of most recent origin. The main aim of this book is, on the one hand, to present a detailed set of facts such that the British experience--its approach to air pollution control, its problems and achievements--can be compared to those of other countries. On the other hand, the goal is to provide a springboard for research into the new and extremely interesting developments in British clean air policy since 1986.

1. BACKGROUND INFORMATION

1.1. Basic Data

With about 56 million inhabitants and a total land area of just a little over 244 square kilometers, Great Britain's population density equals approximately 229 inhabitants per square kilometer, but the population is very unevenly distributed. The change in volume of the UK's gross domestic product (GDP) of market price (index: 1980 = 100) developed as follows:

Year	Volume	Year	Volume
1970	82.9	1982	100.3
1975	92.1	1983	103.8
1979	102.4	1984	106.7
1980	100	1985	110.5
1981	98.7		

(Source: Annual Abstract of Statistics, HMSO, London, annual.)

Industrial production in the UK (index: 1980 = 100) developed as follows:

Year	Volume	Year	Volume
1970	90.1	1982	98.4
1975	92.2	1983	101.9
1980	100	1984	103.2
1981	96.6	1985	108.1

(Source: Annual Abstract of Statistics, HMSO, London, annual.)

Indigenous production of primary energy showed the following development, measured in million tonnes of oil equivalent (MTOE):

Year	Volume	Year	Volume
1970	103.4	1980	198.5
1975	116.7	1981	206.3
1976	127.3	1982	220.3
1977	155.0	1983	231.0
1978	169.7	1984	201.9
1979	193.5	1985	234.2

(Source: Digest of UK Energy Statistics, HMSO, London, annual.)

By 1980, the UK had become a net exporter of oil. Its total primary energy requirements from 1970 to 1985 (in MTOE) were:

Year	Volume	Year	Volume
1970	198.6	1980	193.3
1975	191.1	1981	186.6
1976	194.0	1982	183.5
1977	199.0	1983	184.0
1978	199.9	1984	183.7
1979	209.2	1985	192.3

(Source: Digest of UK Energy Statistics, HMSO, London, annual.)

Energy requirement statistics according to energy source show a decline in the demand for solid fuels and petroleum products, but an increase in the demand for gas and nuclear power from 1973 to 1985 (in MTOE):

Energy Source	1973	1983	1985
Solid fuels	78.2	65.6	62.0
Petroleum products	96.6	62.4	67.7
Natural gas	26.0	44.0	48.4
Nuclear/hydroelectric	7.1	12.0	14.3

In 1985, there were 11 nuclear power plants in operation in the UK, with a total capacity of 6.8 gigawatt (GW), representing 20% of the UK's total electricity supply. The UK's total energy requirements measured in gross domestic product (GDP) units decreased continuously from 1970 to 1984 (index: 1975 = 100). Its energy intensity (energy/GDP ratio) developed as follows:

Year	Energy Intensity	Year	Energy Intensity
1970	116	1982	88
1975	100	1983	85
1979	98	1984	83
1980	53	1985	84
1981	91		

The total final energy consumption decreased from 136 MTOE in 1970 to 132 MTOE by 1985, but this was not a smooth trend. Energy consumption peaks were reached in 1973 and 1979, and 1981/82 enjoyed an energy consumption minimum. The overall trend in energy consumption as well as the shifts in energy structure have led to improvements in air quality. However, as will be shown, this trend was not brought about by an active environmental protection policy. Table 1 provides an overview of fuel consumption in the UK.

These trends have been interpreted by the Department of the Environment (DOE) as follows:

"The decline in coal consumption outside the electricity generating industry, evident since the mid-1950s, has been due mainly to the introduction of smoke control areas and switches to cleaner, more convenient sources of energy, especially gas and electricity. Fluctuations around the downward trend reflect differences in weather from year to year. Power stations used an increasing volume of coal during the 1970s, except in years affected by industrial disputes, but consumption has fallen since the peak in 1980.

". . . Since 1979 demand for electricity has fallen, mainly because of the economic recession. This lower demand, coupled with increased thermal efficiency in power stations and the development of nuclear power is reflected in the lower consumption of coal by power stations.

"Consumption of petroleum products, with the exception of motor spirit, diesel fuel and petroleum gases, has fallen over the ten years to 1984; although this trend was reversed in 1984 due to the increased use of oil in power stations during the miners' dispute. By contrast, combined natural and town gas consumption increased by 44 per cent over the decade. Since the mid-1970s the usages of town gas has been insignificant compared with that of natural gas." (DOE, 1985, p. 11)

1.2. International Aspects

With an estimated output of 3.58 million tonnes per annum (1985), the UK remains the largest single emitter of sulphur dioxide (SO_2) in the European Community (EC) and possibly, with more than 1.8 million tonnes per annum (1985), the second largest emitter of nitrogen oxides (NO_x) after the Federal Republic of Germany (FRG). In terms of SO_2 emissions per capita, it ranks tenth in all of Europe. About one million tonnes of SO_2 are estimated as being exported to countries downwind, especially Norway and Sweden.

On the basis of information derived from a monitoring programme organised by the United Nations Economic Commission for Europe (ECE), EMEP, slightly more than 30% of UK SO_2 emissions are deposited in the UK itself; some 40% are deposited in neighbouring countries. UK SO_2 emissions deposited in the UK represent about 80% of the total SO_2 deposition in that country; only about 20% of the SO_2 deposited in the UK originates from other countries.

Table 1. Fuel consumption by type of fuel and consumer¹ (in million tonnes unless otherwise stated).

Fuel and Consumer	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Coal:											
Domestic 2	9.9	9.4	9.7	8.7	8.9	7.2	6.9	6.7	6.2	4.8	6.5
Industry, etc.	12.9	12.2	12.2	11.6	12.1	10.4	9.4	9.6	9.5	8.0	9.3
Power stations	74.6	77.8	80.0	80.6	88.8	89.6	87.2	80.2	81.6	53.4	73.9
Gas works ³	4.0	3.4	3.2	3.1	2.9	3.0	2.5	2.3	2.1	1.3	2.2
Solid smokeless fuels:											
Domestic 4	5.3	4.7	4.7	4.5	4.5	4.4	4.0	4.1	3.9	3.2	4.2
Industry, etc.	3.5	3.3	3.1	3.1	3.2	1.9	2.0	1.9	1.9	1.8	1.8
Petroleum:											
Motor spirit	16.1	16.9	17.3	18.3	18.7	19.1	18.7	19.2	19.6	20.2	20.4
Diesel fuel	5.4	5.6	5.7	5.9	6.1	5.9	5.5	5.7	6.2	6.8	7.1
Burning oil (kerosene)	2.6	2.6	2.6	2.7	2.7	2.1	1.9	1.7	1.7	1.7	1.9
Gas oil	12.0	11.8	12.8	12.5	12.6	10.7	10.0	9.5	9.0	9.9	8.7
Fuel oil:											
Power stations	12.9	10.1	10.2	11.1	10.7	6.3	4.8	6.3	3.8	19.8	9.8
Other uses	17.3	17.5	17.4	16.9	16.6	12.7	10.8	9.9	8.7	8.0	6.4
Refinery fuel	6.0	6.3	6.2	6.4	6.5	6.3	5.4	5.5	5.3	5.9	5.2
Liquefied petroleum gas⁵ (in million therms)⁶	575	603	609	608	669	591	555	676	825	912	725
Other petroleum gas⁵ (in million therms)	50	81	115	93	153	139	125	302	379	388	526
Coke oven gas⁷ (in million therms)	987	996	903	780	831	619	578	537	539	438	604
Blast furnace gas (in million therms)	772	875	770	686	775	352	503	442	481	486	517
Town gas (in million therms)	716	214	70	32	36	31	27	23	18	17	16
Natural gas⁸ (in million therms)	12,602	14,004	14,794	15,636	17,067	17,270	17,385	17,594	17,954	18,537	19,804

¹Includes only those fuels which are sources of air pollution for which estimated emissions are presented in later tables.

²Final energy users (i.e., industry other than fuel conversion industries); also includes public services, railways, agriculture, and miscellaneous.

³Includes low temperature carbonisation and patent fuel plants.

⁴Includes public services, railways, agriculture, and miscellaneous.

⁵Excludes gas already included under "refinery fuel" which is a mixture of gas and oil fuel.

⁶1 million therms is approximately equivalent to 4,000 tonnes of coal or 2,400 tonnes of petroleum.

⁷Unpurified.

⁸Includes substitute natural gas.

Source: Warren Spring Laboratory, Department of Trade and Industry, using Digest of United Kingdom Energy Statistics, published by the Department of Energy. Quoted in DOE (1986a).

The UK contributes approximately 10% and 5% respectively of the sulphur falling in Norway and Sweden. On the basis of these figures, however, the DOE concluded in 1985 that: ". . . even a large reduction in the UK's total emissions would make very little difference to the deposition burden in other countries" (Burgess, 1985, p. 5). According to one DOE official, the reasoning underlying this view was as follows:

"We (the UK) are not however the largest contributor to other countries' deposition--not only do four of the eastern countries exceed us in this respect but so does West Germany whose emissions contribute half as much again as ours to others' depositions. I think this shows that, purely in terms of reducing deposition in other countries, the effectiveness of measures to reduce UK emissions at a greater rate than they are already going down would be questionable." (Cited in Burgess, 1985, p. 6)

The cost of installing flue gas desulphurisation (FGD) at 12 major power stations in the UK was estimated (in 1983 prices) to amount to £1600 million; the new estimate is in excess of £2000 million. The cost-effectiveness ratio of massive reductions in emissions is seen to be highly unfavourable and has led to opposition by the British government to the proposed EC directive which would require EC member states to reduce SO₂, NO_x, and dust emissions from large power plants presently in operation by 60%, 40%, and 40% respectively. The directive would also require the imposition of strict quantitative emission limits for SO₂, NO_x, and dust on all new plants. Although modifications in the reduction percentages, to the benefit of countries like the UK which experienced a decline in emission reduction prior to 1980, were proposed during the Belgian and Danish Presidencies of the EC Council of Ministers, no agreement was reached until December 1987. In accordance with the compromise proposal made by Denmark in October 1987, the UK would be compelled to reduce its SO₂ emissions from large combustion plants (i.e., those over 50 MW) from 3.6 million tonnes (as of 1980) to 2.8 million tonnes by 1993, and 2.4 million tonnes by 1998.

Although the UK did ratify the Convention on Long-Range Transboundary Air Pollution in July 1982, it did not commit itself formally to the introduction of major legislation or clean air programmes, or to the initiation of a substantial number of new activities to reduce SO₂ emissions, until 1986 when the British government made a modest gesture by

announcing that it intended to retrofit three power plants with FGD equipment and to put FGD on all new plants. The DOE has also issued proposals to change the UK's clean air legislation to make it compatible with the EC framework directive on emissions from industrial plants.

The UK has not joined the "30% Club", i.e., the countries which have agreed to reduce their total SO₂ emissions by 30% (or more) on the basis of their 1980 national statistics. The British government has so far merely announced, without commitment, its intention to achieve a 30% reduction in both SO₂ and NO_x by the late 1990s.

UK SO₂ emissions in 1985 were 23% below the 1980 level; NO_x emissions for the same year were about 5% below the 1980 level. The British position that it does not intend to become committed to expensive emission controls, especially as long as uncertainty remains about the environmental benefits to be achieved in the UK and continental Europe, has been criticised by the British National Society for Clean Air (NSCA) as follows:

"This policy line seems to run counter to the principle, established in this country for many years, that the 'best practicable means' should be used to prevent emissions of noxious or offensive gases, even though environmental benefits may not be clearly recognisable." (NSCA, n.d)

A study of the British government's behaviour in international negotiations (including EC level negotiations) over emission reductions for stationary and mobile emission sources reveals that, in most cases, the UK has been reluctant to participate in concerted international actions aimed at reducing transboundary air pollution. The UK has thus become one of the "dirty outsiders" of the international ecology community. It has come under growing pressure not only from environmental groups in Britain as well as abroad, but also from foreign governments, especially of those countries which believe they suffer from exports of the UK's emissions.

2. AIR POLLUTION FROM MAJOR POLLUTANTS

2.1. Emissions and Emission Sources

Total emissions of SO₂ from fuel combustion in the UK increased during the 1950s but remained relatively stable throughout the 1960s and early 1970s, amounting to about 6 million tonnes per year. After 1973, annual emissions fell to about 5 million tonnes by 1976. They remained stable at 5 million tonnes during 1977 and 1978, and then dropped again to 4.67 million tonnes by 1980. Annual SO₂ emissions continued to decline steadily, falling to 3.54 million tonnes by 1984. In 1985, emissions began to rise again; the provisional figures for 1986 emissions amount to 3.74 million tonnes.

The British government has therefore insisted that present SO₂ emission figures should be compared with the statistics for emissions in the peak year of 1970 (6 million tonnes) and those for 1980 (4.67 million tonnes) which serves as the base year for the "30% Club" and the proposed EC directive on reductions in emissions from large plants. The British government argues that the choice of 1980 as a base year is arbitrary and unjustified because it does not reflect the enormous cut in emissions since 1970. While UK SO₂ emissions in 1985 were 23% below their 1980 level, on a long-term view, the UK, the British government claims, has already achieved substantial emission reductions not yet matched by other countries for whom a 30% reduction commitment (based on 1980 statistics) would be easier to achieve.

Table 2 and figure 1 present a statistical and graphical overview of the SO₂ emission trend in the UK. If one considers the separate contribution to SO₂ emissions from combustion by major class of emission source, then, comparing 1970 to 1985, a decline in absolute terms has occurred for all classes except road transport. However, if one looks at the relative contribution to total emissions, marked changes in the contributions from different classes of emission sources over time can be observed. The proportion contributed by domestic/commercial/public service sectors and industry dropped, whereas that contributed by power stations and road transport has increased.

In general, therefore, there has been progressive replacement of small and medium sized sources emitting at low heights by large sources

Table 2. SO₂ emissions from fuel combustion in million tonnes.

Year	SO ₂ emissions
1938	4.19*
1950	4.55
1955	5.03
1960	5.54
1965	5.61
1969	6.02
1970	6.12
1971	5.86
1972	5.65
1973	5.81
1974	5.35
1975	5.13
1976	4.98
1977	4.98
1978	5.02
1979	5.34
1980	4.67
1981	4.22
1982	4.01
1983	3.69
1984	3.54
1985	3.58

*Estimate by Parker in NSCA Yearbook 1976, table C, p. 72.

Source: Compiled from data supplied by the National Society for Clean Air, Sulphur Dioxide, 1974; DOE, Digest of Environmental Pollution and Water Statistics, 1980; P. Knoepfel and H. Weidner, Handbuch der SO₂-Luftreinhaltepolitik, Teil II, 1980; DOE, Digest of Environmental Pollution and Water Statistics, 1985; DOE, Digest of Environmental Pollution and Water Statistics, 1986.

SO₂ EMISSION
million tonnes

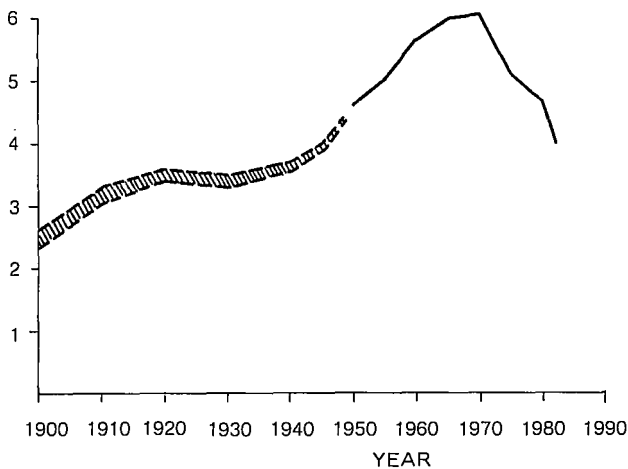


Figure 1. Sulphur dioxide emission from fuel combustion in the United Kingdom, 1900 to 1982. Retrospective estimates prior to 1950 are approximate only. Source: Clarke (n.d.).

emitting at high levels above ground. The shift to "tall chimney sources" has had a profound effect on the improvement of ambient air quality in the UK. Whilst emissions from low and medium height sources have nearly halved since 1960, those from tall sources have increased by more than half. The proportion of total SO₂ emissions from power plants and refineries amounted to 75% of the total in 1985, as compared to 52% in 1970 and 67% in 1980 (DOE, 1986a). Provisional figures submitted by the Warren Spring Laboratory (WSL) for SO₂ emissions in 1986 indicate a total of 3.74 million tonnes. Power plants emitting 2.60 million tonnes of SO₂ in 1986 contributed 90,000 tonnes to the increase over 1985 emission tonnage; oil refineries contributed 30,000 tonnes and other industrial sources a further 50,000 tonnes.

The largest increase in relative contributions to total SO₂ emissions has come from power plants. In 1960, power plants accounted for 33% of total emissions; in 1970, they accounted for 45%, and by 1985 their proportional contribution had climbed to 71%. There are no other EC member states in which power plants contribute to a comparable degree to total SO₂ emissions. Most of the UK's SO₂ emissions result from coal combustion, which accounted for 55% in 1970, 60% in 1980, and 76% in 1983. By 1984, this percentage had fallen to 55% because power stations substituted fuel oil for coal during the miners' strike in that year. (SO₂ emissions from fuel oil combustion increased from 0.53 million tonnes in 1983 to 1.27 million tonnes in 1984.) In 1985, the SO₂ emissions from coal combustion increased again to 2.53 million tonnes (71% of all sulphur emissions). SO₂ emissions from non-combustion sources are small, adding at most 2% to 3% to the total (Clark, n.d.). Table 3, table 4, and figure 2 provide an overview of SO₂ emissions from various classes of emitters, listed according to type of fuel.

Several factors have contributed to the changes in total SO₂ emissions and in the contributions made by different classes of emission source. These are: changes in fuel use, a lower demand for electricity for industrial purposes, and energy conservation, all of which were stimulated by the large increases in the price of oil after 1973. In particular, the rapid substitution of low sulphur natural gas for traditional fuels has significantly reduced SO₂ emissions.

It is estimated that this development has resulted in a reduction of over 25% of SO₂ emissions per unit of primary fuel in the UK during the

Table 3. Estimated sulphur dioxide emissions from fuel combustion by type of consumer and fuel,¹ 1970-1974 (in million tonnes).

Type of Consumer	1970	1971	1972	1973	1974
Domestic	0.52	0.46	0.37	0.36	0.35
Commercial/public service	0.39	0.34	0.31	0.29	0.26
Power stations	2.77	2.80	2.87	3.02	2.78
Refineries	0.24	0.25	0.26	0.29	0.30
Other industry ²	2.12	1.94	1.76	1.78	1.59
Rail transport	0.03	0.02	0.02	0.02	0.02
Road transport	0.04	0.05	0.06	0.05	0.05
All consumers (ground based) ³	6.12	5.86	5.65	5.81	5.36
Type of Fuel	1970	1971	1972	1973	1974
Coal	3.34	3.04	2.65	2.89	2.56
Solid, smokeless fuel	0.25	0.20	0.18	0.17	0.16
Motor spirit	0.01	0.02	0.02	0.02	0.01
Derv	0.03	0.03	0.04	0.03	0.04
Gas	0.16	0.16	0.20	0.20	0.17
Fuel oil	2.07	2.16	2.30	2.20	2.11
Refinery fuel	0.24	0.25	0.26	0.29	0.30
All petroleum fuels	2.52	2.62	2.83	2.75	2.64
All fuels ³	6.12	5.86	5.65	5.81	5.36

¹Excludes emissions from chemical and other fuels.

²Includes agriculture; excludes power stations and refineries.

³Excludes emissions from fuels used for water transport.

Source: Warren Spring Laboratory, Department of Trade and Industry.
Quoted in DOE, Digest of Environmental Pollution and Water Statistics, 1979.

Table 4. Sulphur dioxide: estimated emissions from fuel combustion by type of consumer and fuel¹ (in million tonnes).

(a) Type of Consumer		1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Percentage of Total in 1985
Domestic		0.30	0.28	0.29	0.26	0.26	0.22	0.21	0.20	0.20	0.16	0.20	6
Commercial/public service ²		0.24	0.24	0.24	0.23	0.24	0.20	0.18	0.17	0.14	0.14	0.12	3
Power stations		2.82	2.69	2.74	2.81	3.10	2.87	2.71	2.62	2.53	2.50	2.53	71
Refineries		0.26	0.28	0.27	0.29	0.29	0.28	0.22	0.21	0.16	0.15	0.14	4
Agriculture ³		0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	-
Other industry ³		1.40	1.39	1.34	1.33	1.34	1.03	0.83	0.74	0.61	0.52	0.53	15
Rail transport		0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	-	-
Road transport		0.05	0.05	0.05	0.05	0.06	0.04	0.05	0.05	0.04	0.04	0.04	1
All consumers ⁴ (ground based)		5.13	4.98	4.98	5.02	5.34	4.67	4.22	4.01	3.69	3.54	3.58	100
(b) Type of Fuel													
Coal		2.68	2.74	2.79	2.77	3.10	3.02	2.75	2.71	2.81	1.93	2.53	71
Solid, smokeless fuel		0.15	0.13	0.13	0.13	0.13	0.10	0.10	0.10	0.10	0.08	0.10	3
Petroleum:													
Motor spirit		0.01	0.02	0.02	0.02	0.02	0.01	0.03	0.02	0.02	0.02	0.02	1
Derv		0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	1
Gas		0.17	0.16	0.14	0.14	0.14	0.10	0.07	0.07	0.05	0.05	0.05	1
Fuel oil		1.82	1.61	1.58	1.64	1.62	1.13	0.86	0.83	0.53	1.27	0.71	20
Refinery fuel		0.26	0.28	0.27	0.29	0.29	0.28	0.22	0.21	0.16	0.15	0.14	4
All fuels ⁴		5.13	4.98	4.98	5.02	5.34	4.67	4.22	4.01	3.69	3.54	3.58	100

¹Excludes emissions from chemical and other processes, which probably amount to a few per cent of the emissions from fuel combustion.

²Includes miscellaneous consumers.

³Excludes power stations, refineries, and agriculture.

⁴Excludes emissions from fuels used for water transport.

Source: Warren Spring Laboratory, Department of Trade and Industry. Quoted in DOE (1986a).

- | | | |
|-----------------------|-----|--------------------|
| | I | Power stations |
| High level emitters | II | Refineries |
| Medium level emitters | III | Other industry |
| Low level emitters | IV | Other non-domestic |
| | V | Domestic |

Average urban concentration
CONCENTRATION INDEX
1981/82=100 ($50\mu\text{g}\text{m}^{-3}$)

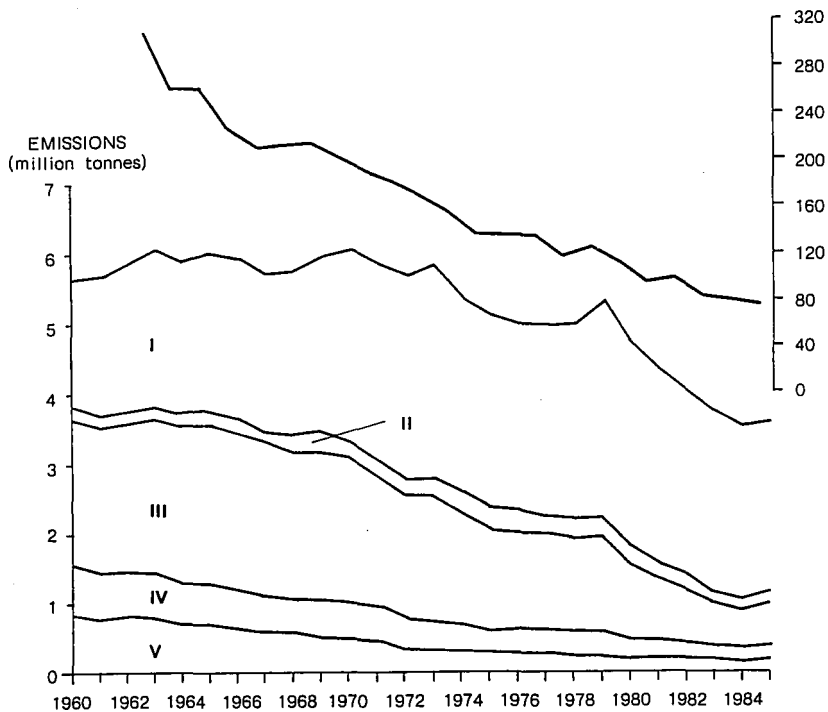


Figure 2. Sulphur dioxide emissions from fuel combustion and average urban concentrations. Emissions are from fuel combustion only. Emissions from chemical and other processes, which probably amount to a few per cent of total emissions from fuel combustion, have been excluded. Source: Warren Spring Laboratory, Department of Trade and Industry, quoted in DOE (1986a).

last decade (DOE, 1985, p. 14). To this, nuclear energy has made only a small contribution. The drop experienced in very recent years, however, is mainly a side-effect of economic recession (Knoepfel and Weidner, 1985; Clarke, n.d.). Correspondingly, British emissions of SO_2 and NO_x began to rise again significantly in 1986 as the UK economy revived. It is worth noting, therefore, that environmental policies had only a minor impact on emissions from industrial sources and power plants; whereas in the domestic (households) and the commercial and public services sectors, the policy effect was more significant. The decline in SO_2 emissions was partially a side-effect of the Clean Air Acts, which sought primarily to control smoke emission.

"The necessity for many households to change their heating appliances as a result of smoke control, induced a large proportion to change also from solid fuels to gas, domestic oil or electricity, with zero or very small emissions of (sulphur dioxide) at the point of use." (Clarke, n.d., p. 19)

As this trend had begun before the passing of the Clean Air Acts, it reflects in part a social preference for more comfortable means of domestic heating. The Clean Air Acts thus helped to accelerate and reinforce a trend already in motion. However, although this was a positive development, it in turn encouraged an increase in emissions from power plants through the substitution of electricity for coal and oil in domestic households (Knoepfel and Weidner, 1985).

Smoke is defined as an air pollutant consisting of suspended particulate matter (of an average grain size below 5 microns) arising from the incomplete combustion of fuel. Smoke is hazardous to human health because the particulate matter remains suspended in the air for long periods and can be inhaled easily. Smoke is not a problem where pulverised fuel boilers have been installed in power stations, or with very large industrial boilers. Power stations, therefore, will contribute very little to overall smoke emissions. Similarly, medium or small sized industrial or commercial units do not give rise to smoke when properly operated, except on limited occasions such as start-up. Domestic heating units almost always produce some smoke because of the difficulty of controlling combustion accurately. However, new units have been developed for burning bituminous coal relatively smoke-free (some 3% to 4% by weight of bituminous coal is emitted as smoke in open-fire burning) (Commission of Energy and the Environment, 1982).

Coal combustion is the main source of smoke in the UK (accounting for 70% of all smoke emissions in the late 1970s). However, smoke emissions from coal combustion have fallen by over 90% since 1958. Reduction in these emissions has been more gradual over the last few years and, in many areas of the UK, domestic coal burning is still the major source of smoke pollution (DOE, 1985). The large reduction in smoke emissions from coal combustion was mainly effected through implementation of the Clean Air Acts 1956 and 1968 (1964 in Northern Ireland), improved combustion efficiency in industry, and a shift away from coal to cleaner and more convenient fuels in the domestic sector. Smoke emission trends and the relative contributions from major sources since 1950 and 1958 respectively are shown in figures 3 and 4, and table 5.

As nitrogen oxides are a matter of more recent concern, no statistical data on NO_x emissions and concentrations comparable to those for smoke and SO_2 is available. On the basis of 1985 data, the UK appears to be the second largest emitter of NO_x in the EC. In 1985, the UK's NO_x emissions were estimated as about 1.837 million tonnes. Annual NO_x emissions estimates have not changed appreciably during the 10-year period up to 1985 (1975 NO_x emissions: 1.832 million tonnes). The figures presented in table 6 indicate that the contributions from other emissions sources than road transport remained roughly stable or showed slight reductions (see also figure 5). In 1985, power stations and road transport (particularly petrol-engined road vehicles) were the main sources of NO_x emissions; each contributed 40% to total NO_x emissions. NO_x emissions rose by 100,000 tonnes to reach 1.94 million tonnes in 1986 (provisional figures provided by the Warren Spring Laboratory), reflecting the upturn in electricity generation and increased road traffic. The major contributors to this increase were power plants, accounting for 48,000 tonnes, and vehicles, accounting for 44,000 tonnes. It is worth mentioning that the NO_x emission figures seem to be less reliable than those for SO_2 and smoke. The new vehicle emissions data, for example, are presumably based on emissions factors derived from a fleet of only 20 cars.

As shown in table 6, carbon monoxide (CO) emissions increased by 15% between 1975 and 1985. Emissions of hydrocarbons (HC) increased by 12% from 1975 to 1985. Figures for 1985 on the relative contributions of pollutants from different sources compared to total emissions indicate

SMOKE EMISSION
- million tonnes

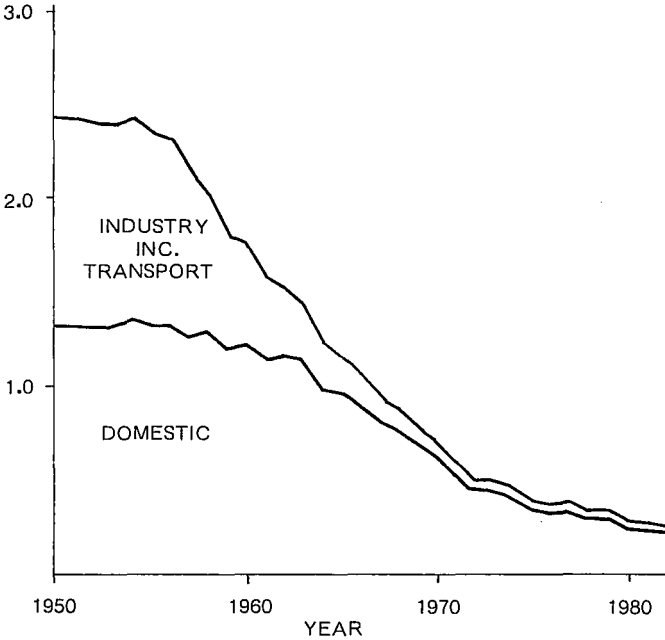


Figure 3. Smoke emission, United Kingdom 1950-1982. Source: Clarke (n.d.).

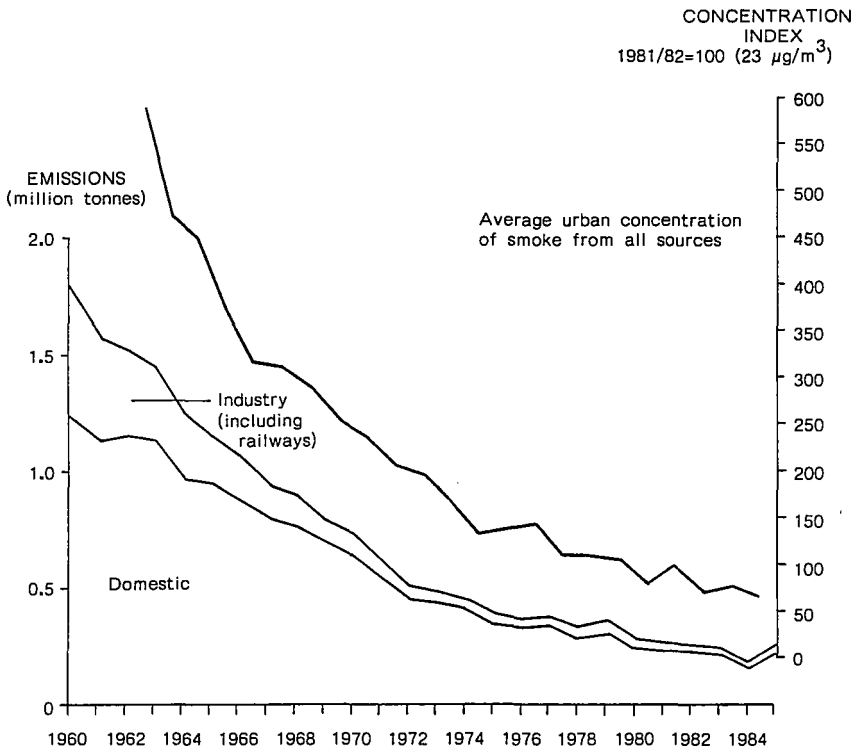


Figure 4. Smoke emissions from coal combustion and average urban concentrations 1960-1985. Source: Warren Spring Laboratory, Department of Trade and Industry, quoted in DOE (1986a).

Table 5. Smoke: trends in estimated emissions from coal combustion by source (in million tonnes).

Year	Domestic ¹	Industry etc. ²	Railways ³	All Sources
1960	1.21	0.35	0.19	1.75
1965	0.95	0.14	0.06	1.15
1970	0.64	0.08	-	0.72
1975	0.35	0.04	-	0.39
1976	0.33	0.04	-	0.37
1977	0.34	0.04	-	0.38
1978	0.30	0.03	-	0.34
1979	0.31	0.04	-	0.35
1980	0.25	0.03	-	0.29
1981	0.24	0.03	-	0.27
1982	0.24	0.03	-	0.26
1983	0.22	0.03	-	0.25
1984	0.16	0.02	-	0.19
1985	0.23	0.03	-	0.26

¹Domestic: Smoke is taken as 3.5 per cent of the weight of coal burned in domestic open fires.

²Industry etc.: Final energy users (i.e., energy other than fuel conversion industries); includes collieries, public services, agriculture, and miscellaneous. For 1958, smoke is taken as 0.97 per cent of the total weight of coal burned; for 1962 it is taken as 0.5 per cent, and 1971 and subsequent years, 0.3 per cent. For the intervening years, intermediate proportionate values are used.

³Railways: An estimate of 2 per cent of the weight of coal burned is used.

Source: Warren Spring Laboratory, Department of Trade and Industry. Quoted in DOE (1986a).

Table 6. Nitrogen oxides, carbon monoxide, and hydrocarbons: estimated emissions¹ by source, 1975-1985 (in thousand tonnes).

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Percentage of Total in 1985 ⁶
Nitrogen oxides ²												
Domestic	51	50	52	52	56	52	52	51	50	48	54	3
Commercial/public service ³	46	47	50	48	49	44	44	44	43	44	44	2
Power stations	766	774	795	805	876	851	819	767	763	621	735	40
Refineries	41	44	43	44	44	44	37	38	36	37	36	2
Agriculture (fuel use) ⁴	6	6	6	6	5	5	4	4	4	3	3	-
Other industry ⁴	283	286	280	271	278	214	203	193	185	173	176	10
Rail transport	45	42	42	43	42	41	39	36	38	35	37	2
Road transport ⁵	584 ^R	604 ^R	619 ^R	650 ^R	666 ^R	671 ^R	649 ^R	669 ^R	688	716	740	40
Incineration and agricultural burning	8	10	12	12	12	12	12	12	12	12	12	<1
All sources (ground based) ⁶	1,832 ^R	1,865 ^R	1,899 ^R	1,931 ^R	2,027 ^R	1,932 ^R	1,859 ^R	1,814 ^R	1,819	1,689	1,837	100
Carbon monoxide												
Domestic	686	641	656	599	611	532	496	493	463	370	490	9
Commercial/public service ³	13	13	14	13	13	12	11	12	11	11	16	-
Power stations	54	52	53	55	58	53	50	48	46	52	50	1
Refineries	4	4	4	4	4	4	4	4	4	4	4	-
Agriculture (fuel use) ⁴	1	1	1	1	1	1	1	1	1	-	1	-
Other industry ⁴	112	110	105	100	104	76	77	73	73	65	78	1
Rail transport	17	16	16	16	16	15	15	14	14	13	14	-
Road transport ⁵	3,585 ^R	3,725 ^R	3,829 ^R	4,045 ^R	4,122 ^R	4,209 ^R	4,108 ^R	4,225 ^R	4,437	4,456	4,521	83
Incineration and agricultural burning	218	223	223	223	224	224	220	220	220	220	220	4
All sources (ground based) ⁶	4,690 ^R	4,789 ^R	4,901 ^R	5,056 ^R	5,153 ^R	5,127 ^R	4,982 ^R	5,090 ^R	5,269	5,191	5,394	100

Cont/d . . .

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Percentage of Total ⁶ in 1985
Hydrocarbons												
Domestic	108	102	105	95	98	81	77	75	70	56	79	4
Commercial/public service ³	1	1	1	1	1	1	1	1	1	1	1	1
Power stations	12	13	13	13	14	14	14	13	12	10	12	1
Refineries	1	1	1	1	1	1	1	1	1	1	1	1
Other industry (fuel use) ⁴	5	5	5	5	5	4	4	4	4	3	4	1
Rail transport ^{5,7}	12	11	11	11	11	10	10	9	10	9	10	1
Road transport ^{5,7}	432 ^R	449 ^R	461 ^R	487 ^R	496 ^R	506 ^R	494 ^R	508 ^R	531	538	545	26
Incineration and agricultural burning	37	38	38	38	38	38	38	38	38	38	38	2
Gas leakage ⁸	280	295	314	343	344	349	349	367	366	384	419	20
Industrial processes and solvent evaporation ⁹	950 ^R	950 ^R	950 ^R	950 ^R	950 ^R	950 ^R	950 ^R	950 ^R	950 ^R	950 ^R	950	48
All sources (ground based) ⁶	1,838 ^R	1,865 ^R	1,899 ^R	1,944 ^R	1,958 ^R	1,954 ^R	1,938 ^R	1,965 ^R	1,983 ^R	1,990 ^R	2,059	100

¹For the main part of the table these figures are based on constant emission factors and do not take into account possible reductions in emission factors as a result of ECE regulations.

²Expressed as nitrogen dioxide equivalent.

³Includes miscellaneous fuel consumers.

⁴Excludes power stations, refineries, and agriculture.

⁵Estimates using revised emission factors for petrol-engined vehicles based on in-service performance.

⁶Excludes emissions from fuel used for water and air transport.

⁷Includes evaporative emissions from the petrol tank and carburetor of petrol-engined vehicles.

⁸Gas leakage is an estimate of losses during transmissions along the distribution system.

⁹Estimates using revised evaporation and process emission factors.

Source: Warren Spring Laboratory, Department of Trade and Industry. Quoted in DOE (1986a).

Index
(1975 = 100)

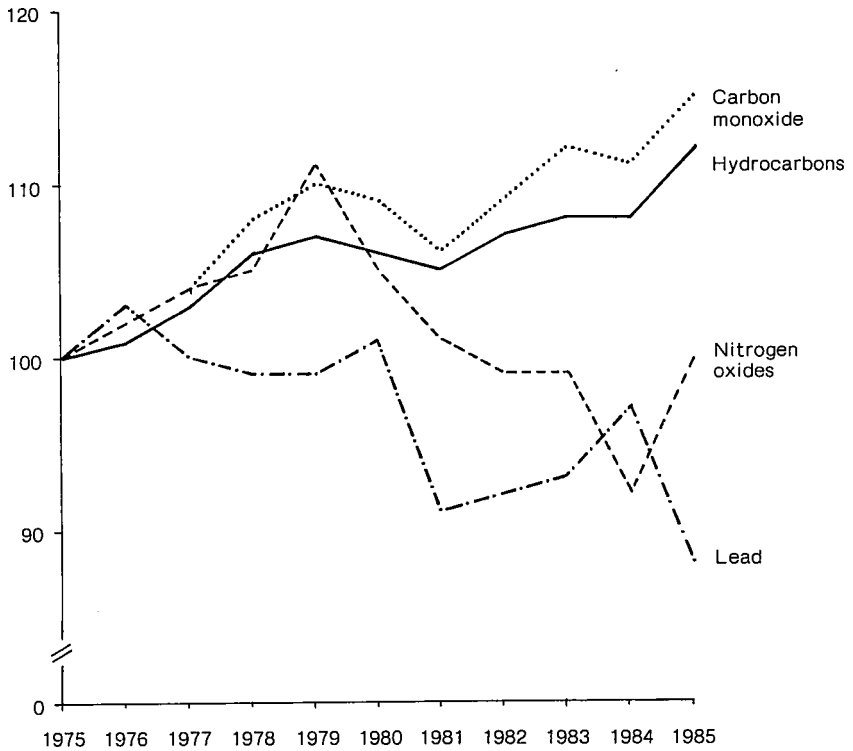


Figure 5. Estimated emissions of hydrocarbons, carbon monoxide, nitrogen oxides and lead. This chart is based on constant emission factors and does not take into account possible reductions in emission factors as a result of ECE regulations. Estimated lead emissions are from petrol-engined road vehicles only. Source: Warren Spring Laboratory, Department of Trade and Industry, quoted in DOE (1986a).

that motor vehicles emitted 83% of the total CO emitted and 36% of total HC value; gas leakages contributed 20% and industrial processes and solvent evaporation 48% respectively.

Lead emissions from petrol-engined vehicles (table 7) fell from a peak of 8.4 thousand tonnes in 1973 to 6.5 thousand tonnes by 1985, a fall of 23%. Recent data submitted by the Warren Spring Laboratory indicate that total lead emissions from vehicles dropped to 2,900 tonnes in 1986. Despite an increase in petrol consumption to about 20%, lead contamination dropped as a result of a reduction in the legally permitted lead content in petrol from 0.84 grams per litre in 1972, to 0.40 grams per litre in 1981, and again to 0.15 grams per litre by December 1985.

Information on other pollutants potentially hazardous to the environment and human health is sparse and, in most cases, insufficient for trend analysis.

2.2. Monitoring

The first coordinated National Survey of Air Pollution (SO₂ and smoke) was set up in 1961, following the Clean Air Act 1956. Initially, measurements of ambient air quality were made at some 500 monitoring stations in the UK (DOE, 1974). By 1966 the number of monitoring stations had increased to a total of about 1200 urban and rural sites, resulting in the UK's having the most extensive, close-knit monitoring network in Europe and possibly worldwide. Both smoke and SO₂ are monitored, with values recorded every 24 hours; however, not all monitoring stations have maintained a completely regular recording system (DOE, 1986a).

The achievement of this monitoring system reflects the underlying British philosophy that environmental monitoring is the first step in pollution control. That is, it is designed to discover the assimilative capacity of the environment, to determine that no unacceptable harm to the environment is being done, and to ensure that the "best environmental option" is chosen. The DOE described the UK approach to environmental monitoring as follows:

"Monitoring is undertaken in the UK to provide information about the state of the environment and to assist in planning

Table 7. Consumption of motor spirit and estimated emissions of lead from petrol-engined road vehicles.

Year	Consumption of Motor Spirit		Estimated Emissions of Lead From Petrol-engined Road Vehicles ¹	
	Million Tonnes	Index: 1975 = 100	Million Tonnes	Index: 1975 = 100 ²
1975	16.12	100	7.4	100
1976	16.88	105	7.6	103
1977	17.34	108	7.4	100
1978	18.35	114	7.3	99
1979	18.68	116	7.3	99
1980	19.15	119	7.5	101
1981	18.72	116	6.7	91
1982	19.25	119	6.8 ^R	92
1983	19.57	121	6.9 ^R	93
1984	20.22	125	7.2 ^R	97
1985	20.40	127	6.5	88

¹These figures are based on lead contents for motor spirit, published by the Institute of Petroleum. It has been assumed that only 70% of this lead in petrol is emitted from vehicle exhausts, the remainder being retained in lubricating oil and exhaust systems. Figures for 1980 onwards have been estimated on a slightly different basis to those for earlier years. This has led to minor revisions to the figures for 1982-84.

²Index rebased to 1975; previously the base year was 1973.

Sources: Department of Energy; Warren Spring Laboratory, Department of Trade and Industry. Quoted in DOE (1986a).

actions and policies for environmental protection. Monitoring may also serve to inform the public. . . . Where practicable, monitoring is concentrated on:

- a. the most significant emissions (sources);
- b. the highest concentrations in the environment (hot spots and sinks);
- c. the critical group most at risk (targets);
- d. the most important changes in the state of the environment.

"Monitoring of substances which, at the concentrations found, do not represent a risk has been discontinued where possible; or, where it has been necessary to maintain it, reduced to a minimum. There is still further scope for bringing monitoring into line with current and future policy requirements, but significant progress has been made." (DOE, 1986a, p. 62)

Ambient air quality monitoring is carried out, as a rule, by local UK authorities; central government provides policy guidance and the statutory framework. The Warren Spring Laboratory of the Department of Trade and Industry acts as coordinator and advises on methods of measurement and site selection. In 1982, the National Survey was reorganised into several smaller networks designed to meet more specific objectives. One of these smaller networks is the Basic Urban Network, consisting of 170 sites. It is supplemented by several other surveys designed to check the UK's compliance with the EC directive on smoke and SO₂ concentrations in the atmosphere. As a result, surveys are located in areas considered to be at risk of exceeding the mandatory maximum levels set by the EC directive. The number of monitoring instruments used in the survey to check compliance with EC Directive 80/779 included 572 non-continuous SO₂ monitors and 572 black smoke monitors (December 1982 data). In addition, a network of 20 sites supports an epidemiological survey.

According to the DOE, it is likely that a small rural network of monitoring stations will be established to complement the urban network. Previously, some 150 monitoring stations were operated in rural communities and the open countryside. It has been suggested by the Warren Spring Laboratory that in future only 50 or fewer rural sites will be needed for the baseline network. The Royal Commission on Environmental Pollution (RCEP) comments:

"We are concerned that the future structure of the baseline network for monitoring smoke and (sulphur dioxide) concentrations, which reflects the emphasis given to hazards for

human health, makes insufficient provision for rural areas where the effects of (sulphur dioxide) on crops and natural vegetation may be of considerable importance. The lack of monitoring data from rural areas has been a serious drawback for those engaged in research on the quantification of the effects of air pollutants on crop production." (RCEP, 1984, p. 116)

Concentrations of trace elements (e.g., zinc, arsenic, selenium, vanadium) are measured continuously only at some few sites. Concentrations of lead in air have been measured in a long-term monitoring programme at 21 sites. During the period from 1984 to 1987, lead concentrations were monitored at over 100 sites in 40 towns, villages, and remote rural locations (DOE, 1986a). The major air pollutant, NO_x , is monitored continuously at only about 25 sites. According to the DOE, a new network of stations monitoring NO_x and ozone (O_3) is currently being set up. Some local authorities have established monitoring sites for other pollutants. For example, during the 1970s, the then existing Greater London Council (GLC) recognised the need for a more diverse monitoring system than that provided by the National Survey. In particular, emissions from road vehicles were a cause for concern. New chemical and physical monitoring techniques were introduced to detect pollutants such as carbon monoxide, ozone, lead and other heavy metals, as well as SO_2 and smoke (Schwar and Ball, 1982).

The Warren Spring Laboratory also carries out monitoring for several other purposes. In 1983, the Acid Rain Review Group of the DOE recommended that the acid rain monitoring network be expanded. Further, it pointed out some serious shortcomings in the availability and quality of monitoring data. The DOE set up two networks in 1986 to monitor acid deposition at 10 primary and 60 secondary sites. "Wet only" collectors are used for the primary network; specially designed bulk collectors are used for the secondary network. The aim of the primary network is to provide high quality data on the composition of precipitation; the secondary network is intended to provide data on regional patterns of deposition over the whole of the UK. A main requirement of the secondary network is that the monitoring sites be in a rural environment and that they provide regionally representative data not influenced by local pollution sources (Olding, 1986). The first results from these new networks are scheduled to be published in 1987 (DOE, 1986a).

The reporting of monitoring data in the UK is sufficiently comprehensive, current, and easily understandable to the public. However, reporting was more comprehensive in former times when data were collected from about 1200 monitoring sites and published by some 500 local authorities.

The state of monitoring in the UK was reviewed by the Royal Commission on Environmental Pollution in its 10th Report:

". . . There is . . . a lack of systematic information on the concentrations of contaminant gases on a countrywide basis . . . (and) . . . there is a strong case for the baseline monitoring of gases such as nitrogen oxides and ozone, since these have been found to be more abundant than previously believed and may cause damage to vegetation at concentrations regularly detected even by the limited monitoring currently undertaken.

". . . We consider the present network for (nitrogen oxides) to be inadequate. We accept that the measurement of (nitrogen oxides) presents considerable technical problems and is expensive, and that a baseline network on the scale of that for (sulphur dioxide) and smoke would be both prohibitively expensive . . . and unnecessary. Nevertheless we believe that a baseline network of about 25 sites is desirable. . . .

"Ozone at present also has a baseline monitoring network restricted to three sites. . . . We consider that a baseline network of about ten sites is justified. Ozone is important as a pollutant affecting both man and plants . . . and it serves as an index of other photochemical oxidants. . . .

". . . We recommend that the Department of the Environment should give greater recognition to the importance of long-term monitoring as a basis for the action to improve air quality. We are concerned that not enough attention is being given to monitoring (sulphur dioxide) in remote and rural areas and we recommend that further consideration should be given to the size of the baseline rural network. . . . Finally we recommend that the number of sites in the baseline networks for the monitoring of nitrogen oxides and ozone should be increased substantially." (RCEP, 1984, pp. 117-118)

(The Royal Commission on Environmental Pollution is a group of experts appointed by the Queen for a 3-year period. It can select its own subject for investigation or be requested by ministries to investigate a particular subject. The RCEP was set up in 1970 and its task was "to advise on matters both national and international, concerning pollution of the environment; on the adequacy of research in this field;

and the future possibility of danger to the environment". Since its establishment, the RCEP has published several reports on various environmental issues.)

Monitoring of emissions in the UK is not nearly as comprehensive as the measurement of ambient air quality. Although the authority to measure emissions from stationary sources has been granted under the Clean Air Acts and the Control of Pollution Act 1974, this power has not so far been exercised to any great extent. Moreover, emissions of major pollutants (with the exception of smoke, dust, and grit) from stationary sources are calculated on the basis of fuel data (DOE, 1977).

According to the DOE, the assessment of emissions of sulphur, nitrogen compounds, and hydrocarbons from a number of identified source types is made annually for the UK on a 20 x 20 km grid square basis. In addition, national inventories of speciated hydrocarbons are being finalised. An emissions inventory for ammonia (England and Wales only) based on 10 x 10 km grid squares has just been completed (DOE, 1986b).

The RCEP commented on the collection of emissions data as follows:

"There are some atmospheric contaminants, now considered to be important, for which there are few data. This applies in particular to ozone and other photochemical oxidants which are formed in the atmosphere rather than emitted directly. Reliable data on rainfall acidity are also scarce. In these cases the conclusions which can be drawn from trends are greatly limited. Data on the emissions of atmospheric contaminants in the United Kingdom can thus be considered to fall into three categories. There are good data for smoke and (sulphur dioxide) while data for (nitrogen oxides), CO and hydrocarbons are available, but unfortunately, of low reliability. Data for most other contaminants are largely lacking. We must express our regret that we were unable to obtain any official figures in 1982." (RCEP, 1984, p. 11)

In the case of scheduled facilities, monitoring can be ordered or carried out by the responsible agency, the Industrial Air Pollution Inspectorate (IAPI). Where local authorities have responsibilities for monitoring, they may require industrial plant owners to measure their SO₂ emissions; however, the owner's consent to do so must be obtained. The publication of data on individual industrial plants by local authorities is severely restricted by law. Only in certain cases, where the

plant owner has granted his consent and no trade secrets are at stake, can data on individual facilities be made public.

Section 79 of the Control of Pollution Act 1974 gives local authorities the power to obtain, if they wish, information about the emission of pollutants and other substances into the air. However, if an authority chooses to exercise this power, it must consult all interested parties in order to determine to what extent and in what way any information gathered should be made available to the public. The DOE advised that this consultation should be carried out through local committees comprising council members, nominees of local industry, and suitably qualified local individuals. As this procedure is rather time consuming, local authorities have made almost no use of these discretionary powers (DOE, 1986b). The restricted public access to information on emissions from individual industrial plants has been the subject of criticism for quite some time by various environmental groups (see, for example, the Freedom of Information Campaign) and also by the RCEP.

2.3. Ambient Air Quality

2.3.1. Trends

Until the late 1960s, the main air quality problem in the UK was pollution by smoke produced from the burning of bituminous coal. The smoke problem had continued to escalate over the years until the occurrence of a major smog disaster in London in December 1952: some 4000 persons died probably as a result of severe smog pollution. Moreover, a recurrence of such episodes was not uncommon until 1962, although the resulting death tolls were lower. The air pollution legislation enacted in response to those smog episodes (the Clean Air Acts 1956 and 1968) as well as other developments (see section 2.1 above) led to considerable improvements in ambient air quality. The average urban concentration of smoke in 1983-84 was down to about 13% of that for 1962-63. The annual average urban smoke concentrations have fallen by more than 80% over the last 20 years. Considerable improvements have been achieved in London especially, and the obvious improvement in London's air quality since these smog episodes may have been attributed too readily to the success of the Clean Air Acts, as was explained by an

expert of the Scientific Services Branch of the former Greater London Council (GLC):

"Historical evidence, however, suggests that pollution by sulphur dioxide and smoke was at its worst in London in about the year 1900, and has been declining ever since. Evidently a number of factors have been involved, including, apart from the Acts themselves, underlying changes in fuel consumption patterns, especially the replacement of solid fuel by gas, oil and electricity. In addition there have been changes in the urban structure which would have influenced air quality. . . . This is not to say that the implementation of the Acts, which was particularly rapid in London, did not contribute in an important way to the rate of improvement of London's air." (Schwar and Ball, 1962, p. 16)

Since the 1960s the distribution and relative importance of various emission sources have changed; road vehicles (especially diesel-engined vehicles) are now the main source of black smoke in London. However, this change is not sufficiently reflected in the monitoring data on smoke concentrations in ambient air, because the monitoring stations were located according to other criteria (e.g., to monitor the progress of the Clean Air Act). Although the overall picture on smoke concentration in the UK appears favourable, there are still areas where smoke pollution is considerable. Smoke concentration met the limit values specified in the EC directive only by 1981, even in Greater London where 90% of the facilities involved are covered by the Smoke Control Orders. In 1982, some areas were still in danger of exceeding these standards (Schwar and Ball, 1982). The trend in average urban smoke concentrations is shown in tables 8 and 9.

Long-term developments in SO_2 concentrations clearly show a favourable trend. Average urban concentrations have fallen by over 70% since 1960, and from $84 \mu\text{g}/\text{m}^3$ to $42 \mu\text{g}/\text{m}^3$ in the decade to 1982-83. Longer records suggest that this downward trend began before 1950 when mean annual concentrations of around $250 \mu\text{g}/\text{m}^3$ were no rare occurrences in city centres. The reduction in urban SO_2 concentrations has been due primarily to the 75% drop in low-level emissions. Table 10 shows that average urban concentrations fell by half between 1974-75 and 1984-85. All this may well explain the relative (compared with West Germany, Austria, Switzerland, etc.) lack of concern about air pollution by the British public.

Table 8. Smoke concentration index 1974-1985.

Year	Concentration Index: 1981/82 = 100 (= 23 $\mu\text{g}/\text{m}^3$)
1974/75	136
1975/76	140
1976/77	145
1977/78	113
1978/79	113
1979/80	109
1980/81	83
1981/82	100
1982/83	74
1983/84	78
1984/85	67

Note: Smoke as given in this table is taken to be suspended matter collected on filter paper in accordance with British Standard 1747, Part 2.

Table 9. Smoke: daily concentrations at individual urban sites for the winter period,¹ by region and country UK.

Region/Country	Average Concentration in $\mu\text{g}/\text{m}^3$		Median Concentration ² in $\mu\text{g}/\text{m}^3$		Percentage of Sites with Winter Mean ³ Greater Than $45\mu\text{g}/\text{m}^3$		Percentage of Sites with Winter Mean ³ Greater Than $60\mu\text{g}/\text{m}^3$		Percentage of Sites with Winter Mean ³ Greater Than $80\mu\text{g}/\text{m}^3$			
	1974/75	1976/77	1978/79	1974/75	1976/77	1978/79	1974/75	1976/77	1978/79	1974/75	1976/77	1978/79
North	45	45	34	37	39	31	44	42	20	31	27	8
Yorkshire and Humberside	58	65	50	45	51	42	50	65	42	32	35	27
East Midlands	45	52	42	40	49	36	37	55	33	24	37	13
East Anglia	34	32	29	31	31	27	18	9	-	-	-	-
Greater London	35	37	30	32	34	29	18	20	8	8	3	3
South East (excluding Greater London)	24	25	23	22	25	21	2	4	2	<1	1	-
South West	24	25	21	26	23	23	-	3	-	-	-	-
West Midlands	45	47	29	37	39	35	36	40	30	16	23	9
North West	51	52	38	47	49	36	53	60	27	29	28	8
England	41	44	36	34	38	31	31	38	22	18	20	9
Wales	27	32	25	25	30	25	8	13	5	3	8	3
Scotland	39	48	34	39	45	34	33	50	19	11	26	5
Northern Ireland	44	99	50	39	72	48	33	73	50	11	60	39
United Kingdom	40	45	35	34	38	31	30	38	21	16	20	9

¹October to March.

²The median is that value above and below which half the observations lie.

Notes: The figures refer to concentrations in urban areas. They are obtained by averaging over all sites in urban areas for which valid winter averages were recorded. Since the regional figures are not based on precisely the same sites from winter to winter, the figures are not strictly comparable between winters. The ratio of the annual mean concentrations to the winter mean concentrations of all those sites in the UK recording both valid annual and winter means in 1978/79 (i.e., about 800 sites) was 0.74.

Source: Department of the Environment, Digest of United Kingdom Energy Statistics, 1980.

Table 10. Sulphur dioxide concentration index, 1974-1985.

Year	Concentration index: 1981/82 = 100 (= 50 $\mu\text{g}/\text{m}^3$)
1974/75	137
1975/76	135
1976/77	135
1977/78	118
1978/79	126
1979/80	114
1980/81	96
1981/82	100
1982/83	81
1983/84	79
1984/85	76

The daily concentrations of SO₂ at individual urban sites for the winter period are shown in table 11. Table 12 shows SO₂ concentrations in five British cities considered to be particularly polluted. It also indicates that there have been long-term improvements in pollution levels. However, some districts were plagued by extremely high levels of pollution in the late 1970s.

The Greater London area also shows a steady decline in SO₂ levels. Results from the 32 monitoring stations involved in the London Boroughs and Greater London Council Local Survey indicate that for winter 1984-85 the EC directive SO₂ limit values were not exceeded. However, on a number of occasions, short-term levels rose above 1000 µg/m³. In one episode, on 21 February 1985, the maximum hourly mean SO₂ concentration reached 1700 µg/m³ at the monitoring site at the County Hall, and 940 µg/m³ at the Hounslow site (London Environmental Bulletin, Vol. 3, No. 2, 1985).

In the absence of comprehensive, long-term monitoring of nitrogen oxides, only some rough estimates of NO_x concentrations are available. According to an expert from the Central Electricity Generating Board (CEGB):

"No estimate can be made of the trend in (nitrogen oxide) concentrations in UK urban areas as monitoring of this pollutant has been on a small, and generally local, scale only. . . . Neither these limited studies nor the emission trends . . . lead, however, to the conclusion that (nitrogen oxide) pollution levels are likely to have increased over the last decade." (Clarke, n.d., p. 24)

More recent data on NO_x concentrations in London show that this city may face difficulties in meeting the EC directive's air quality standard for NO_x. A major London-wide survey carried out by the GLC between 1980 and 1984 came to the conclusion that problems will be greatest alongside busy roads where the highest NO_x levels are found. According to the GLC's Scientific Services Branch, the measurements indicate strongly that emissions from vehicle exhausts are the main source of NO_x in London's air.

"This implies that additional controls on vehicle emissions are the most prudent way to bring about a reduction in (nitrogen oxide) levels, though traffic management schemes could be used to tackle local problems." (London Environmental Bulletin, Vol. 3, No. 2, 1985)

Table 11. Sulphur dioxide: daily concentrations at individual urban sites for the winter period,¹ by region and country UK.

Region/Country	Average Concentration in $\mu\text{g}/\text{m}^3$				Median ² Concentration in $\mu\text{g}/\text{m}^3$			
	1974/75	1976/77	1978/79	1979/80	1974/75	1976/77	1978/79	1979/80
	Percentage of Sites with Winter Mean > 50 $\mu\text{g}/\text{m}^3$	Percentage of Sites with Winter Mean > 50 $\mu\text{g}/\text{m}^3$	Percentage of Sites with Winter Mean > 75 $\mu\text{g}/\text{m}^3$	Percentage of Sites with Winter Mean > 75 $\mu\text{g}/\text{m}^3$	Percentage of Sites with Winter Mean > 100 $\mu\text{g}/\text{m}^3$	Percentage of Sites with Winter Mean > 100 $\mu\text{g}/\text{m}^3$	Percentage of Sites with Winter Mean > 150 $\mu\text{g}/\text{m}^3$	Percentage of Sites with Winter Mean > 150 $\mu\text{g}/\text{m}^3$
North	68	68	57	57	60	59	53	53
Yorkshire and Humberside	100	104	94	94	96	105	95	95
East Midlands	73	85	84	84	72	80	80	80
East Anglia	65	70	62	62	67	74	64	64
Greater London	117	110	100	100	107	106	94	94
South East (excluding Greater London)	62	59	59	59	64	56	56	56
South West	47	44	42	42	48	38	44	44
West Midlands	87	89	86	86	83	88	89	89
North West	96	109	91	91	95	108	71	71
England	86	97	80	80	82	83	76	76
Wales	56	50	50	50	56	51	57	57
Scotland	63	58	58	58	51	74	55	55
Northern Ireland	60	76	41	41	77	78	41	41
United Kingdom	82	84	76	76	78	78	72	72

Region/Country	Percentage of Sites with Winter Mean > 50 $\mu\text{g}/\text{m}^3$				Percentage of Sites with Winter Mean > 75 $\mu\text{g}/\text{m}^3$				Percentage of Sites with Winter Mean > 100 $\mu\text{g}/\text{m}^3$				Percentage of Sites with Winter Mean > 150 $\mu\text{g}/\text{m}^3$			
	1974/75	1976/77	1978/79	1979/80	1974/75	1976/77	1978/79	1979/80	1974/75	1976/77	1978/79	1979/80	1974/75	1976/77	1978/79	1979/80
	Percentage of Sites with Winter Mean > 50 $\mu\text{g}/\text{m}^3$	Percentage of Sites with Winter Mean > 50 $\mu\text{g}/\text{m}^3$	Percentage of Sites with Winter Mean > 75 $\mu\text{g}/\text{m}^3$	Percentage of Sites with Winter Mean > 75 $\mu\text{g}/\text{m}^3$	Percentage of Sites with Winter Mean > 100 $\mu\text{g}/\text{m}^3$	Percentage of Sites with Winter Mean > 100 $\mu\text{g}/\text{m}^3$	Percentage of Sites with Winter Mean > 150 $\mu\text{g}/\text{m}^3$	Percentage of Sites with Winter Mean > 150 $\mu\text{g}/\text{m}^3$	Percentage of Sites with Winter Mean > 100 $\mu\text{g}/\text{m}^3$	Percentage of Sites with Winter Mean > 100 $\mu\text{g}/\text{m}^3$	Percentage of Sites with Winter Mean > 150 $\mu\text{g}/\text{m}^3$	Percentage of Sites with Winter Mean > 150 $\mu\text{g}/\text{m}^3$	Percentage of Sites with Winter Mean > 100 $\mu\text{g}/\text{m}^3$	Percentage of Sites with Winter Mean > 100 $\mu\text{g}/\text{m}^3$	Percentage of Sites with Winter Mean > 150 $\mu\text{g}/\text{m}^3$	Percentage of Sites with Winter Mean > 150 $\mu\text{g}/\text{m}^3$
North	8	69	58	58	23	30	20	20	14	2	2	2	2	3	3	1
Yorkshire and Humberside	95	91	92	92	82	80	70	70	45	59	46	46	10	4	4	4
East Midlands	84	91	92	92	45	56	58	58	12	32	27	27	2	1	3	3
East Anglia	91	100	91	91	18	45	45	45	5	5	5	5	5	5	5	5
Greater London	99	98	97	97	90	84	84	84	57	53	42	42	22	18	9	9
South East (excluding Greater London)	68	63	72	72	26	24	20	20	4	4	4	4	4	4	4	4
South West	36	37	27	27	11	5	6	6	4	3	3	3	3	3	3	3
West Midlands	84	88	92	92	60	65	67	67	36	39	30	30	4	1	1	1
North West	95	95	96	96	79	78	70	70	43	60	38	38	5	14	3	3
England	85	82	84	84	58	57	52	52	30	36	26	26	6	7	3	3
Wales	63	50	59	59	24	13	18	18	3	3	3	3	3	3	3	3
Scotland	57	65	62	62	27	38	26	26	19	21	6	6	1	2	2	2
Northern Ireland	44	73	35	35	22	53	53	53	11	27	27	27	7	7	7	7
United Kingdom	80	79	79	79	53	53	47	47	27	33	22	22	5	6	6	6

¹ October to March.

² The median is that value above and below which half the observations lie.

Notes: The figures refer to concentrations in urban areas. They are obtained by averaging over all sites in urban areas for which valid winter averages were recorded. Since the regional figures are not based on precisely the same sites from winter to winter, the figures are not strictly comparable between winters. The ratio of the annual mean concentrations to the winter mean concentrations of all those sites in the UK recording both valid annual and winter means in 1978/79 was 0.82.

Source: Department of the Environment, *Digest of United Kingdom Energy Statistics, 1980*.

Table 12. Sulphur dioxide concentrations at individual urban sites in five highly polluted areas.

Year	Leeds 4			Leeds 18		
	W	S	HD	W	S	HD
1954/55	286	372	1230	-	-	-
1955/56	601	257	2402	-	-	-
1956/57	515	229	1745	-	-	-
1957/58	515	200	2774	400	172	2688
1958/59	596	205	3832	544	195	3403
1959/60	569	235	1939	331	181	1018
1960/61	549	272	1544	310	130	755
1961/62	541	244	1896	-	132	1679
1962/63	536	196	3970	511	173	3971
1963/64	438	214	1676	340	171	1423
1964/65	429	204	1562	311	168	967
1965/66	376	189	1079	338	163	1027
1966/67	344	193	731	318	197	877
1967/68	346	170	1519	314	198	973
1968/69	287	151	904	275	181	987
1969/70	284	151	962	247	158	771
1970/71	276	129	843	278	134	1028
1971/72	-	151	-	217	159	641
1972/73	203	112	637	215	154	640
1974/75	113	85	462	163	134	519
1975/76	-	81	739	187	145	879
1976/77	-	107	-	-	100	-
1977/78	97	67	287	118	73	288
1978/79	59	44	207	102	59	313
1979/80	66	55	230	-	72	421

Year	Liverpool 16			Liverpool 21		
	W	S	HD	W	S	HD
1962/63	501	170	1214	-	-	-
1963/64	510	220	1808	-	-	-
1964/65	-	-	-	-	-	-
1965/66	391	276	883	-	-	-
1966/67	261	207	728	-	-	-
1967/68	362	171	1108	-	-	-
1968/69	321	177	927	252	192	776
1969/70	234	153	648	-	101	466
1970/71	221	145	880	141	96	646
1971/72	203	151	697	148	-	835
1972/73	195	120	736	123	94	426
1973/74	-	-	488	163	-	397
1974/75	162	101	442	94	70	232
1975/76	147	95	324	79	73	518
1976/77	175	94	598	104	79	268
1977/78	139	93	336	83	67	336
1978/79	118	67	409	89	60	-

Year	Manchester 11			Manchester 19		
	W	S	HD	W	S	HD
1962/63	390	112	2491	-	-	-
1963/64	384	170	1425	-	-	-
1964/65	434	158	2473	-	-	-
1965/66	342	180	1006	304	-	1330
1966/67	345	163	1389	310	167	1748
1967/68	397	187	1530	318	162	1580
1968/69	360	194	1422	261	162	1220
1969/70	310	160	1346	225	135	1240
1970/71	306	139	1086	211	116	1133
1971/72	248	172	864	-	127	768
1972/73	232	138	723	190	-	629
1973/74	177	116	633	159	120	634
1974/75	167	104	504	145	110	448
1975/76	179	102	529	160	119	483
1976/77	199	111	552	160	117	513
1977/78	164	110	722	136	92	629
1978/79	152	81	583	129	78	499

Cont/d . . .

Table 12 continued . . .

Year	Newcastle-upon-Tyne					
	W	S	HD			
1962/63	189	121	957			
1963/64	182	100	782			
1964/65	177	106	716			
1965/66	169	94	468			
1966/67	162	110	639			
1967/68	222	107	719			
1968/69	191	106	456			
1969/70	196	106	604			
1970/71	232	96	528			
1971/72	188	120	557			
1972/73	207	142	559			
1973/74	172	108	543			
1974/75	165	113	503			
1975/76	-	122	-			
1976/77	171	112	344			
1977/78	191	132	401			
1978/79	-	100	446			
Year	St. Helens 7			St. Helens 12		
	W	S	HD	W	S	HD
1962/63	385	189	1431	-	230	2055
1963/64	300	180	1101	338	219	1277
1964/65	294	181	810	-	242	-
1965/66	208	165	729	219	-	699
1966/67	249	163	732	199	-	611
1967/68	-	144	-	200	177	987
1968/69	281	-	818	295	174	1063
1969/70	211	131	588	234	165	827
1970/71	-	162	-	222	174	840
1971/72	137	107	340	227	209	631
1972/73	127	85	347	158	169	823
1973/74	130	97	579	129	72	450
1974/75	154	108	445	118	99	464
1975/76	-	22	-	90	86	411
1976/77	-	-	-	-	85	448
1977/78	-	-	-	-	81	577
1978/79	-	-	-	154	87	456

Notes: W = winter average, S = summer average, HD = highest daily concentration. The figures for 1971/72 are of limited reliability because of technical problems at the monitoring sites during that period. In particular, figures for winter average concentrations in 1971/72 may be more favourable than conditions actually warrant.

Source: Warren Spring Laboratory. Quoted in Knoepfel and Weidner (1980).

The results of the survey are summarised in table 13.

Data on the emissions and concentrations of other atmospheric contaminants are less systematic and less reliable than those for smoke and SO₂. For example, concentrations of lead and other trace elements have been monitored on a long-term basis at only five urban and four non-urban sites. Concentrations of lead have fallen over time at all these monitoring stations (DOE, 1985). The results of lead-in-air measurements at 20 monitoring stations in 1986, reported by the Warren Spring Laboratory, show that airborne lead levels fell by an average of 53% across Britain following the reduction in maximum lead content of petrol to 0.15 g/l at the end of 1985 (WSL, 1987). According to a survey by the GLC, however, air and dust in London have excessive concentrations of lead; road sites and school playgrounds in the city had lead concentrations in excess of recommended safe levels. The GLC did point out that the reduction of lead in petrol will undoubtedly reduce lead pollution (London Environmental Bulletin, Vol. 3, No. 4, 1985). According to an air pollution survey by the Warren Spring Laboratory, lead concentrations in the atmosphere were increased by as much as tenfold above background levels, as a result of emissions from metal refining and processing works. But with the possible exception of a metal works in Walsall, none of the refineries emit so much lead as to cause a local breach of EC air quality regulations (compliance with the corresponding EC air quality standards must be achieved by 1981) (ENDS, No. 136, 1986).

When discussing photochemical smog in 1984, the Royal Commission on Environmental Pollution came to the conclusion that:

"The United Kingdom does not suffer from severe and long-lasting smogs of, for example, Los Angeles, but during stable anticyclonic weather in summer elevated concentrations of ozone, PAN and visibility-reducing aerosols are produced by photochemical reactions in air masses over northwest Europe and affect large areas of the United Kingdom.

". . . Monitoring of the lower atmosphere for ozone has been carried out in the United Kingdom for little more than a decade and elevated concentrations due to photochemical reactions were first detected in 1971. Concentrations above 200 µg (per cubic meter) are now found frequently and 800 µg (per cubic meter) were recorded in south-east England during the exceptional summer of 1976. The long, hot

Table 13. Nitrogen dioxide concentrations at fourteen sites in London.

Site	Period	Concentrations ($\mu\text{g}/\text{m}^3$ at 20°C)		Site	Period	Concentrations ($\mu\text{g}/\text{m}^3$ at 20°C)	
		50 Percentile	98 Percentile			50 Percentile	98 Percentile
<u>Roadside</u>				<u>Urban Background</u>			
Archway Rd, LB Haringey	Oct 83-Jul 83	63	174	Brent Cross, LB Barnet	Dec 82-Mar 83	63	26
E India Dock Road, LB Tower Hamlets	Jan 83-Feb 83	67	185	Bushy Park, LB Richmond/Thames	Jul 82-Sep 82	33	98
Elephant & Castle, LB Southwark	Jan 83-Sep 83	69	193	Kew Gardens, LB Richmond/Thames	Jan 80-Dec 80	27	80
Manor Rd, LB Newham	Mar 81-Sep 81	38	126	Maryland St, LB Newham	Jan 81-Apr 81	36	105
N Circular, LB Brent	Oct 83-Mar 84	92	187	Upminster Rd South, LB Havering	Nov 81-Jul 82	46	128
Orchard St, City of Westminster	Apr 82-Jun 82	134	272	County Hall, LB Lambeth	Jan 82-Mar 82	42	90
Ripple Rd, LB Barking & Dagenham	Feb 82-Jun 82	55	141		1978	44*	132*
York Road, County Hall, LB Lambeth	1978	63*	159*		1979	40*	86*
	1979	59	191		1980	44*	98*
	1980	54*	132*		1981	46*	140*
	1981	80*	205*		1982	50	132
	1982	92*	225*		1983	57	130
	1983	52*	119*		1984	55*	126*
	1984	82*	185*				

EC Air Quality Standards for Nitrogen Dioxide for Comparison

Standard	Expressed As	Concentration ($\mu\text{g}/\text{m}^3$ at 20°C)
Limit value	98 percentile	200
Guide value	98 percentile	135
Guide value	50 percentile	50

* Qualifies for comparison with Directive, as 75% data recovery in a year

Source: London Environmental Bulletin, Vol. 3, No. 2, Autumn 1985, pp. 10-11.

spells of summery weather in 1983 also favoured photochemical formation of ozone and in London the highest concentrations for several years were recorded.

". . . It has been suggested that ozone may have a substantial effect on crop yields in rural Britain, usually without visible symptoms on plants. . . . We recommend that the Research Councils should encourage continued research on secondary pollutants, particularly the photochemical oxidants in the United Kingdom." (RCEP, 1984, pp. 138-139)

Increasing concern over the acidity of rainwater because of its possible long-term detrimental environmental impacts on lakes, soils, forests, crops and buildings has led to an investigation by the Warren Spring Laboratory of the acidity of rainfall in the UK. Measurements were carried out at some 40 rural sites between 1978 and 1980:

"The sites were mainly located in Scotland, northern England and the East Midlands; there are large areas where no measurements of suitable quality were made. The annual average acidity of rain was found to be between pH 4.7 and pH 4.1 and, although it is inadvisable to draw too many detailed conclusion from the data, there appeared to be a trend of increasing acidity from west to east across Britain and, for northern Britain, a trend of increasing acidity from north-west to south-east.

". . . Bearing in mind that in the main the deposited acidity was not measured directly but was calculated on the basis of some simplifying assumptions, the chart suggests that the areas receiving the maximum input of acidity due to rain are parts of Cumbria in England and the West Central Highlands and Southern Uplands in Scotland, which are areas where rainfall is high. In these areas, the annual deposition is similar to the high levels experienced in parts of Scandinavia and North America. Maps of the wet deposition of nitrate and sulphate ions show a similar pattern to that of hydrogen ion deposition and reflect the influence of rainfall amount on that deposition." (DOE, 1985, p. 14)

The situation of ozone pollution in Britain has recently been assessed by Ball and Laxen (1987). On the basis of a review of major reports on this subject, they point, among other things, to the following:

- Elevated ozone levels have been observed at all monitoring stations in the UK from the south coast to Scotland.
- Ozone concentrations at both rural and urban sites exceed air quality standards used elsewhere for the protection of human health and crops.

- The movement of photochemically polluted continental air masses into the UK accounts for some of the ozone observed there.
- There is evidence that ozone concentrations of up to about 130 ppb have been generated throughout the whole United Kingdom.
- There is some evidence that ozone levels in general have doubled over the last 100 years (Ball and Laxen, 1987).

2.3.2. Highly Polluted Areas

Article 3 of EC Directive 80/779 states inter alia that each member state,

"where it considers that there is a likelihood that, despite the measures taken, the concentrations of sulphur dioxide and suspended particulates in the atmosphere might, after April 1983, exceed in certain zones the limit values given in Annex I, it shall inform the Commission thereof before 1 October 1982."

The UK notified the Commission that limit values were likely to be approached or exceeded in the following locations: Allerdale, Barnsley, Bassetlan, Blyth Valley, Bolsover, Bradford, Cannock Chase, Chesterfield, Copeland, Crew and Nantwich, Doncaster, Kirklees, Mansfield, Newark, Newcastle-under-Lyme, Nottingham, Rotherham, Staffordshire Moorlands, Sunderland, Wakefield, Wansbeck, Cunningham, Falkirk, Glasgow, Strathkelvin, Belfast, Londonderry, Newry, and Castle Morpeth.

3. AIR POLLUTION DAMAGE

3.1. Public Health

Several cases have been reported in the UK, where air pollutants have had negative impacts on human health. The effect of major air pollution episodes (such as the London smog episodes) on the human mortality rate is not disputed. However, there is no consensus among the scientific community as to the number of deaths which may have been attributable to particular pollutants or a combination of pollutants; that is, there is no consensus about causality, i.e., on linking emissions to concentrations of pollutants in the air to human health damage. In 1971, the National Society for Clean Air (NSCA) published a special report on SO₂ (NSCA, 1974), in which it is pointed out that only very few studies had been carried out on the harmful effects of SO₂ pollution. The NSCA concluded, inter alia:

"Further research is vitally needed on several aspects of (sulphur dioxide) pollution brought out in this report: the better definition of the levels of (sulphur dioxide) concentrations that are harmful to the public health, to crops and the decay of building materials; establishing the chemical reactions and life history of (sulphur dioxide) emitted to the atmosphere, particularly from high chimneys; the role of ambient (sulphur dioxide) concentrations in the nutrition of crops; and the search for cheaper ways of limiting (sulphur dioxide) emissions by the various means discussed." (NSCA, quoted in Knoepfel and Weidner, 1985, pp. 726-727)

A British medical expert on the health impacts of air pollution, regarded by the Department of Health and Social Security as the leading authority on this subject, takes the view that detrimental health impacts from SO₂ concentrations have been overestimated. During an interview conducted by the British team (M. Hill and P. Garrard) doing an international comparative study on air pollution policies (published in Knoepfel and Weidner, 1985), this expert stressed the insignificance of SO₂ as an issue, arguing that policy must reflect priorities and that one cannot legislate for rare, exceptional meteorological conditions. He stated:

"The energy required for gas washing would be equal to the whole energy requirement of the Indian sub-continent. . . . What will happen if you double the price of electricity or have to burn coalite is that, instead of people dying because

of smog, you'll have an epidemic of hypothermia--that is a daily cause of winter deaths. Old people die of cold because they can't afford electricity and are afraid to turn on their one-bar fires because of fear of the electricity bill. Or else, you have immigrant families using kerosene stoves, blocking up all the drafts and gassing themselves with carbon monoxide. With all this, one must preserve a sense of perspective. . . . I'm not really hedonistic, but I feel things have got out of hand. One of 'Lawther's Laws' is that concern about air pollution is in inverse relation to its concentration."

Another expert study of primary school children in Sheffield concluded that no ill effects in terms of symptoms or sickness could be detected when pollution concentrations fell below an annual average of $140 \mu\text{g}/\text{m}^3$ for smoke alone. But, if pollutant concentrations rose above an annual average level of $200 \mu\text{g}/\text{m}^3$ for smoke and SO_2 combined, then an effect on the human respiratory function or other symptoms of illness were evident (UN, 1984). The contrasting views given here may well illustrate the British tendency to judge air pollution in relation to other social issues which are more pressing; that is, to relate it, for instance, to the relative poverty of a growing number of people (Watts, 1987; Richardson and Watts, 1985).

The House of Commons Environmental Committee summarised their findings on research into health risks from air pollutants in the UK--which illustrate that the UK is no longer "at the top" in environmental research--as follows:

" . . . high concentrations of (sulphur dioxide) and (nitrogen oxides) as particulates in the atmosphere can kill . . . (and) . . . research has not gone on in this country into the health effects of lower concentrations of particulate sulphates and nitrates in the atmosphere. . . . We consider that the almost total absence of research in this field is too be deprecated. . . . We recommend that the Government should commission research in this country on all aspects of risk to human health to which US, Swedish and German research has drawn attention." (House of Commons Environmental Committee, 1984, p. xlix)

Much more research has been carried out on lead and its impacts on human health. Furthermore, lead pollution and its health effects have been an issue attracting considerable public attention in the UK, more so than pollution by SO_2 , NO_x , or smoke. In 1983, the Royal Commission on Environmental Pollution concluded in its 9th Report (RCEP, 1984) that levels of lead in the blood of UK residents were too high. The

RCEP made 29 recommendations for reducing these levels, including the removal of lead from petrol within a 7-year period. The Campaign for Lead-Free Air (CLEAR), which is seeking a total ban on leaded petrol, received support from a leading expert on child psychiatry and member of the so-called Lawther Committee which reported in 1980 on "Lead and Health". This expert claimed in 1983 that the Government's plans to reduce the lead content of petrol to 0.15 grams per litre by 1985 represented an unacceptable compromise. He had no doubts:

"We do not need any further research. No good can come from keeping lead in petrol and harm may result. The onus of proof in this issue needs to be placed on those who advocate no action, rather than the other way round." (International Environment Reporter, 4-13-83, p. 152)

The claim by a London-based study of CLEAR that lead pollution in the UK is much too high has been supported. It was reported inter alia that a large proportion of vegetables contained lead in excess of the statutory limit (London Environmental Bulletin, No. 3, 1983). More recent evidence indicates, however, that lead pollution had improved. Preliminary results from the 1984 survey of lead in blood, the fourth stage in a 4-year programme to monitor the effects of the 60% reduction of lead in petrol by the end of 1985, showed that lead concentrations in the blood of all 18 groups monitored were within the reference levels fixed in the EC 1977 directive (DOE, 1986a).

3.2. Forests and Plantlife

Only 7.4% of UK land use is devoted to "forestry and woodland" (EC average 21.6%). Until very recently air pollution was generally not considered a threat to British forests and woodlands. Evidence of acid rain damage to trees, however, is being discovered. Environmental protection groups in the UK have suspected for some time that in Britain, too, there has been a degree of forest dieback. In the summer of 1984, Friends of the Earth (FOE), Scotland, invited a German expert to "examine some tree specimens. Several instances of "tree stress" strongly resembling the ailment suffered by trees in West German forests were identified. Subsequent surveys initiated by FOE and sponsored by the World Wildlife Fund, concluded that half of the beech and yew trees in Britain were suffering from acid rain damage. Other trees, including

oak, fir, spruce, and pine, were also harmed. In North Wales and Central-South and South-West England, the worst affected trees were beech, while in North England yew was worst affected. On the basis of these findings, the FOE made the following recommendations to the DOE:

- that a nationwide survey of trees should be carried out in 1986 by government agencies other than the Forestry Commission and in cooperation with voluntary environmental groups and specialists;
- that a monitoring network capable of "reconstructing" pollution episodes on an hourly or daily basis, in order to correlate tree damage, be set up;
- that an immediate programme of controls be devised and put into effect to reduce emissions of SO_2 and NO_x from other power stations, including the installation of flue gas desulphurisation equipment in 12 large facilities, and that cars be fitted with catalytic converters and required to meet US emissions standards in order to reduce emissions of HC and NO_x (Acid News, No. 1, 1986; FOE, 1985).

In contrast to the FOE, studies by the Forestry Commission—a government agency—could not until recently find convincing evidence for significant forest damage from air pollutants. However, in 1985, the Commission scientists who had hitherto attributed most symptoms of damage to natural causes were beginning to modify their original conclusion, because they were unable to explain an unusually early yellowing of beech leaves (one of the primary "early warning" signals of forest decline in continental Europe) which had begun to appear in UK specimens in 1985. The Commission's plant pathologist conceded that air pollution could not be ruled out as a causal factor in the damage suffered by beech during the dry years since 1975 (ENDS, No. 128, 1985, pp. 5-6). Initially the government had promised to conduct a survey as proposed by FOE, but it later withdrew its support. The purported reason for so doing was that independent scientists considered the claims of both FOE and the Forestry Commission to be flawed and not representative. Government, therefore, called for a national forest health survey (ENDS, No. 139, 1986).

The 1987 forest health survey carried out by the Forestry Commission comprised 264 plots and included oak, beech, and older Sitka spruce for the first time. According to the findings, 45% of the Sitka spruce surveyed had lost 26% to 60% of their needles and thus fell into the

"moderate damage" category, while another 2% were classified under the "severe damage" category. The figures for trees older than 50 years indicated that they were substantially worse off. Of the Norway spruce surveyed, 41% fell into the "moderate damage" category, while another 3% were considered "severely damaged". Again, older trees were more seriously affected. Of the Scots pine surveyed, 41% were moderately damaged and 3% severely. Finally, the survey revealed that a high percentage of oaks and beeches suffered moderate damage.

A comparison of the 1987 survey with the survey conducted in 1986 shows a significant increase in damage among all three coniferous species. In contrast to statements made in previous years, the Forestry Commission now admits there has been remarkable deterioration in the health of conifers. Nevertheless, it still maintains that the cause of damage to British trees cannot be attributed to air pollution alone, although it accepts that air pollution is a likely contributing factor (Forestry Commission, 1987). On the other hand, it is well known that air pollutants have damaged trees in the UK in the past. For instance, attempts by the Forestry Commission over many years to establish spruce trees in the Southern Pennines have failed and high levels of SO₂ affecting the area were thought to have been a possible cause (Knoepfel and Weidner, 1985).

While the general effects of air pollution on crops and vegetation remain far from clear, according to the Commission on Energy and the Environment, nitrogen oxides, however,

"... have never reached concentrations which give cause for concern regarding their effects on animals and plants, even in inner city areas where emissions from motor vehicles are greater." (Coal and the Environment, 1982, p. 177)

The same source nevertheless admitted that estimated possible crop losses in the UK due to SO₂ pollution amounted to about £23 million per year under worst case conditions. There is also evidence that ozone may have adverse effects on the growth of a number of crops including clover, peas, spinach, radish, and barley (Ashmore, 1984). Contrary to the conclusion of the Commission on Energy and the Environment in 1982 on NO_x, a Lancaster University scientist reported in 1982 to a symposium organised by the National Society for Clean Air that nitrogen oxides are a growing threat to vegetation and could soon overtake sulphur dioxide

as the principle pollution hazard to plantlife (International Environment Review, 7-10-85, p. 228). A study by scientists at Imperial College provides evidence that ambient levels of air pollution (SO_2 , NO_x) in Britain do indeed reduce crop yields (ENDS, No. 108, 1984, p. 3). A report by the Cornwall Trust for Nature Conservation, based on its own surveys, warned that almost three dozen plant species native to Cornwall were facing the risk of extinction because of acid deposition. It also claimed that soil acidification since the early 1900s had already caused the extinction of a number of local plants (ENDS, No. 135, 1986, p. 7).

In 1983, a litigation, the first of its kind to reach the High Court, awarded £70,000 to a Yorkshire farmer for damages to crops and livestock from lime kiln emissions (dust fallout). The High Court ruling vindicated a 10-year long struggle in which the plaintiff's pleas for help from the pollution control authorities went, he claimed, almost unheeded.

In reviewing several reports and various sources of information on the effects of air pollutants on plants in the UK, the House of Commons Environment Committee reached the general conclusion that reduced levels of emissions would be of benefit to plants:

"Economically valueless plants have suffered, and the Nature Conservancy Council argued that it was likely that losses to plants other than the mosses and lichens which had been studied had occurred in much of the upland areas of the country, through wet and dry deposition and soil acidification. . . . In summary, there would be environmental and ecological benefits to plants from reduced emissions of (sulphur dioxide) and (nitrogen oxides)." (House of Commons Environment Committee, 1984, p. xlv)

3.3. Rivers and Lakes

In its 10th Report, the Royal Commission on Environmental Pollution pointed to increasing evidence of damage to fish from acidification, causing a higher mortality rate among fish and decline in fish stocks. The RCEP was also critical of the fact that, in general, UK data on freshwater acidification have been patchy and of varying quality for a long time, and that research on the relationship between acidity in

precipitation, afforestation and acidity in freshwater was started rather belatedly (RCEP, 1984, p. 12).

In 1985, a representative of the DOE argued that while acidification of freshwater does occur in the UK, damage similar to that experienced in southern Scandinavia appears to be very limited in extent in the UK, e.g., to Galloway (Burgess, 1985, p. 8). Losses of fish have been documented for several streams in Wales and the Lake District. The results of studies undertaken by members of the University College London on acid deposition also suggest strongly that air pollution is the most probable explanation for the acidification of two lochs in Galloway, south-west Scotland. Similar results are now beginning to emerge in other parts of Britain. However, absolute proof that acid deposition is the cause of acidification of the bodies of water investigated has not been provided (ENDS, No. 132, 1986, pp. 11-13). A recently published interim report from the DOE's Acid Waters Review Group concludes that sound evidence of surface water acidification is confined to six catchment areas in northern Britain (DOE, 1986a).

3.4. Materials

Although there is a lack of reliable data on the nature and cost of damage to materials from acid pollution, there is clear evidence that SO₂ and its acidic derivatives have caused serious damage to buildings, monuments, and other structures in the UK. Several examples of such damage from acid rain and dry deposition are given in the Fourth Report by the House of Commons Environment Committee, Acid Rain, Vol. 1 (1984, pp. xviiiiff). The National Society for Clean Air has also drawn attention to this problem:

"Concentrations of (sulphur dioxide) and other pollutants in major urban areas have fallen in recent years. This may have reduced the rate of building/materials damage but early results from studies carried out by the Building Research Establishment suggest that damage is still continuing." (NSCA, n.d.)

Corresponding to changes in the structure of emission source in the UK, it was plausible that the greatest damage to materials may stem from low-level sources and motor vehicle emissions. However, recent

preliminary reports on damage to Britain's buildings suggest that acid rain has more profound effects than may previously have been assumed:

"This finding spells trouble for the Central Electricity Generating Board, which is responsible for most of the acid input to the air over Britain, but which insists that local air pollution . . . is the dominant cause of damage to buildings." (Acid News, 1/86, p. 10)

As for the other categories of damage, no reliable or comprehensive data on damage costs arising from acid deposition are available. Not only are existing data highly uncertain with regards to economic assessment, there are also many theoretical constraints and methodological problems involved in expressing in monetary terms what value society attaches to the preservation of historic buildings, the preservation of forests, and the quality of ambient air.

4. AIR POLLUTION CONTROL POLICY

The United Kingdom includes three separate areas of jurisdiction: England and Wales, Scotland, and Northern Ireland. Statutory provisions for air pollution control generally apply to only one of these areas although a particular statute may expressly cover the whole of the United Kingdom. The administrative structures for the implementation of the laws in Scotland and Northern Ireland are quite different from those in England and Wales (see McLoughlin, 1982). In the following sections, only those laws, regulations, and organisational structures applicable to England and Wales are discussed.

4.1. Major Laws, Regulations, Standards and Objectives

This section provides an overview of the basic elements of the British (England and Wales) air pollution control regime (DOE, 1977, 1984; Garner and Crow, 1976; Knoepfel and Weidner, 1980; Macrory, 1984; McLoughlin, 1982). The principal statutes governing air pollution are as follows (Schwar and Ball, 1982).

The Alkali Etc. Works Regulation Act 1906. This Act allows specialist control of certain difficult processes registerable under the Act. It has been partly subsumed under the Health and Safety at Work Etc. Act 1974 and the Control of Pollution Act 1974. Enforcement of this Act is the responsibility of the Industrial Air Pollution Inspectorate (IAPI), formerly the Alkali and Clean Air Inspectorate. This authority operates on a regional basis, there being 12 such regions. (In 1987, after a hot debate lasting about three years, a reorganisation took place.)

The Health and Safety at Work Etc. Act 1974. This act enables regulations to be made to control emissions from prescribed premises by using the "best practicable means" (BPM) for preventing the emission of noxious or offensive substances into the atmosphere. (More recently there is growing reference by the DOE to the 'best practicable environmental option' principle, recommended by the RCEP already in 1976.)

The Public Health Acts 1936 and 1961, and the Public Health (Recurring Nuisances) Act 1969. These Acts provide a tool for tackling noxious or offensive emissions other than smoke, grit, and dust from premises not dealt with under specific legislation. Nuisances include any

dust or effluvia caused by any trade, business, manufacturer, or process, prejudicial to the health of, or nuisance to, the inhabitants of the district. Responsibility for enforcement of these Acts rests with the local authorities (in London, Borough Councils).

The Clean Air Acts 1956 and 1968. These Acts empower local authorities to issue Smoke Control Orders prohibiting the emission of smoke from buildings, including dwellings, in any part of their administrative area. A householder may claim a grant from the local authority amounting to 70% of the reasonable cost of installing suitable, smokeless domestic heating units. The local authorities are also empowered to control the height of new chimneys for furnaces greater than a given size to prevent emissions from becoming prejudicial to health or a nuisance. The procedure to be followed is outlined in the Chimney Heights Memorandum.

The Control of Pollution Act 1974. Part I supplements existing provisions by empowering the Secretary of State to limit or reduce air pollution through regulations governing the sulphur or lead content of oil fuel for furnaces or engines.

Road Traffic Acts 1972 and 1974. Regulations drawn up under these acts set emission limits for smoke from compression ignition (diesel) engined vehicles; and for carbon monoxide, nitrogen oxides, and hydrocarbons from positive ignition (petrol) engined vehicles. The annual testing of heavy goods vehicles is also carried out under this legislation.

There are also a number of regulations, circulars, and notes issued by central government or the IAPI which are relevant to air pollution control policy (see Knoepfel and Weidner, 1985). EC directives require central government to set up the appropriate machinery to meet EC pollution control legislation. Several Acts and regulations related to land use planning are also relevant in the context of the management and control of air pollution, especially the Town and Country Planning Act 1971 and the Town and Country Planning General Development Order 1977. These pieces of legislation require that planning permission be obtained from the local authority for any land development scheme. Completely new industrial plants or substantial modifications to existing plants would require full planning permission. Applications are normally processed within six weeks unless a planning inquiry is called.

Applicants for whom permission is refused, or granted subject to unacceptable conditions, may appeal to the Secretary of State for Environment (Commission on Energy and the Environment, 1982).

In addition to impacts from the formal air pollution control system, the electricity industry is affected by relevant sections of the Electric Lighting Act 1909 and the Electricity Act 1957. The Electric Lighting Act 1909 empowers the Secretary of State to impose conditions on new power stations. This authority has been used to require the Central Electricity Generating Board to leave sufficient space in new oil and coal-fired facilities for future retrofitting with flue gas desulphurisation equipment. The Electricity Act 1957, which established the CEGB, requires the CEGB to give due consideration to various environmental concerns in formulating its programmes.

4.1.1. Principles of British Pollution Control Legislation

According to an interdepartmental working party report published by the DOE, the broad objectives of environmental protection in the UK

". . . are the same in relation to all the sectors--air, land, sea, freshwater and the working environment. The most important is to maintain human life and health (now and in the future) and the life support systems necessary to sustain man. Other objectives, not in any order of priority include the need:

"(i) to safeguard plant and animal life of actual or potential use or value to man over and above basic life support requirements;

"(ii) to avoid disturbance of man's use of his environment, including interference with his recreation;

"(iii) to minimise permanent adverse effects on the natural environment.

"Thus, controlling the disposal of a pollutant to the environment is intended to prevent avoidable human injury and death and to protect the functional capacity of man's life-support system. . . .

". . . Although the identification of effects should logically precede the imposition of controls, it is not in practice always possible to wait for a definitive medical view before deciding to impose precautionary restrictions on the disposal of a pollutant. The decision when and how to control a pollutant that is potentially damaging to human health will

always require an element of subjective and political judgement, although it should be taken in the light of experience and based on the best possible medical and scientific advice and some estimate of the economic and social costs involved.

". . . (However,) simple cost comparisons, almost always incomplete, cannot determine the priorities which should be set for the control of disposals to the environment.

". . . At its simplest the principle behind the control applied is that it should ensure that the adverse effect on man is the lowest practicable, having regard to the costs involved. If the effect or threat is still unacceptably great, the process must be stopped altogether. The policy requires that careful consideration should be given not just to the seen and easily calculable costs of installing further equipment, or of changing products, processes, or treatment methods, so as to reduce the level of an emission, but to the costs in terms of damage to human health in allowing the pollutant to issue unabated, and to the benefits of control (including the benefits that can result (sic) from the stimulation of technological change).

". . . The approach both to setting of quality standards and to the standards by which those objectives can be met and enforced varies according to the receiving medium. . . . Given adequate knowledge of the emissions and prevailing weather conditions, the concentration can be roughly calculated, and this approach is of considerable use in the siting of chimneys and long term development plans for large scale industrial emissions.

". . . If the relationship between the concentration of a pollutant and its effect can be determined, then it is possible to develop quality objectives which can provide the measure of protection required. Once the quality objective has been defined, this helps to determine what restriction on emissions may be required--an emission standard for each type of emission or even for each individual emission." (DOE, 1977, pp. 9-13)

According to the DOE, it is not an aim of UK pollution control policy to eliminate discharges to the environment which are not likely to cause damage. Moreover, there are cases in which adverse environmental effects may need to be tolerated to a certain extent, for example, where the cost of eliminating the damage is unacceptably high (RCEP, 1984, p. 46). This seems to be a basic view on air pollution control policy by government, backed by tradition and approved by the scientific community, whose task it has been to define when effects by discharges are adverse, intolerable, etc.

4.1.2. Air Quality Standards, Etc.

Before EC Directive 80/779 came into effect, there were no mandatory air quality standards in the UK. The standards imposed by this directive refer to smoke and SO₂ and are intended to protect human health and the environment. The EC directives on lead in air and NO_x introduced further air quality standards. There are no national air quality standards other than those stemming from EC directives. Moreover, before these directives came into effect, no air quality objectives had been explicitly defined in the UK. The setting of environmental quality objectives (EQO) as basic guidelines for air pollution control policies was strongly recommended by the RCEP in its 5th Report, 1976. An EQO was defined as a statement of the quality to be aimed for. It may not be immediately attainable and will often be phrased in qualitative terms.

Another point worth noting is that until 1974 SO₂ arising from coal combustion was not even included among the many "noxious and offensive gases" defined by statute under the Alkali and Clean Air Acts, as a representative of the Central Electricity Generating Board pointed out in 1972:

"An important omission in the statutory list of offensive gases is sulphur dioxide arising solely from the combustion of coal which for reasons which may have been valid at the time was specifically excluded from the control of the Alkali Inspectorate" (now the Industrial Air Pollution Inspectorate). (Clarke, 1972, p. 2)

There are no presumptive limits for SO₂ in the IAPI's Notes on Best Practicable Means related to combustion processes. The same applies to NO_x emissions. However, the IAPI circulated a draft note on best practicable means (BPM) for large combustion plants in the middle of 1986, which did contain such presumptive limits. The more recent situation with regard to emission standards for sulphur and nitrogen was reported by the UK government to the United Nations Economic Commission for Europe (ECE) as follows:

"Major emitters of sulphur and nitrogen are subject to the requirement to use BPM to reduce pollution. . . . Under this system, the Inspectorates specify non-statutory emission limits on a national basis. Compliance with these limits is taken as prima facie evidence that the BPM are being properly applied and operated to control stack emissions. Limits

are laid down for sulphur and nitrogen emissions from chemical processes but have not hitherto been applied to such emissions from combustion plants since dispersal rather than stack control has been regarded as the practicable method of reducing pollution. However the Inspectorates now consider it practicable for any new large fossil fuel fired combustion plants to be equipped with means to limit (sulphur dioxide) and (nitrogen dioxide) emissions. . . ." (DOE, 1986b)

As of October 1987, there were no mandatory national standards for emissions from stationary sources.

The Alkali Etc. Works Regulation Act 1906 specified initial limits for only four chemical processes. Nevertheless, for the majority of the processes and pollutants controlled under UK legislation, numerical limits do apply to the allowable emissions to the atmosphere. These limits are fixed administratively by the IAPI on the basis of its interpretation of the "best practicable means" principle. These limits are non-statutory numerical standards; they are set at the discretion of a statutory body, the IAPI, to fix such limits on a case-by-case or industry-by-industry basis. This system seems to be the essence of the British air pollution control system for large stationary sources, and the fact that the EC air pollution control methods and principles challenge this very tradition might have been at the basis of Britain's opposition to nearly all EC directives.

The Inspectorate is required by law to ensure that scheduled processes (that is, processes carried out under the aegis of the IAPI) are operated using the

" . . . best practicable means for preventing emission into the atmosphere from the premises of noxious or offensive substances and for rendering harmless and inoffensive such substances as may be so emitted." (Health and Safety at Work Etc. Act 1974).

The Clean Air Act 1956 defines the term "practicable" as follows:

"'Practicable' means reasonably practicable having regard, among other things, to local conditions and circumstances, to the financial implications and to the current state of technical knowledge, and 'practicable means' includes the provision and maintenance of plant and the proper use thereof."

It is reasonable to assume that this definition is essentially the interpretation of "best practicable means" which is applied by the IAPI. The large area of discretion thus given to the IAPI in interpreting the law was highlighted in the RCEP's 5th Report:

"Although the law does not appear to say so explicitly, 'best practicable means' is generally interpreted as 'best practicable means to the satisfaction of the Alkali Inspectorate'." (RCEP, 1976, p. 23)

Emission limits for major air pollutants from power plants as required by the IAPI are given in table 14. Although there are no formal limits for SO₂ and NO_x, scheduled processes are required to use the best practicable means of control. A review of some 60 Notes on Best Practicable Means (including those notes for power plants and major industrial branches or processes), issued by the IAPI, reveals that no presumptive limits have been set for SO₂ and NO_x emissions from combustion processes (Knoepfel and Weidner, 1985). In fact, these pollutants are only controlled by the determination of specific chimney heights. To this end, various specifications and methods of control have been devised by the IAPI. They are given in Appendix V of the 1969 Annual Alkali Report and serve as basic guidelines. Considerable discretion is left to the IAPI in individual cases as the following example illustrates:

"New chimney heights shall be determined after discussion between the Alkali Inspectorate and the owner of works. The basis for determination shall be the sulphur dioxide emission rate at maximum continuous rating with adjustments for local topography, existing background pollution, and other nearby emissions." (Notes on Best Practicable Means for Electricity Works, 1975)

Control of emissions to the atmosphere from domestic sources and industrial sources not covered by the Alkali Acts is the responsibility of local authorities, that is, their environmental health officers. The DOE regulates emissions of grit and dust; the emission of dark smoke from any trade or industrial premises is prohibited by law. The local authorities may also draft Smoke Control Orders prohibiting the emission of smoke from any building in specified areas. Emissions other than smoke, grit, and dust from processes that are not scheduled are not regulated by emission standards. SO₂ and NO_x are indirectly regulated through the power granted to local authorities to approve the height of any new chimney constructed for furnaces other than domestic boilers with a given maximum heating capacity. The determination of chimney height, in turn, follows principles and methods set out in the Chimney Heights Memorandum issued by central government. These guidelines are

Table 14. Emission limits for UK power stations.

Pollutant	Source	Emission Limits	Approximate Equivalent in g/GJ
Particulates	industrial boilers (heat input 1.25-550 x 10 ⁶ Btu/hour	0.45-0.88 lbs/MBtu * statutory limits	192-380
	power stations (continuous maximum rating above 550 x 10 ⁶ Btu/hour) (greater than 131 MW)	a presumptive limit set by the IAPI	
	(pre-1958)	460 mg/m ³ **	192
NO _x	(1958-1974)	115 mg/m ³ ** (pro-rata to ash content above 20%)	48
	(after 1974)	115 mg/m ³	48
SO ₂		no specific limits	
		no specific limits	

* Sliding scale: limit decreases with increasing boiler heat input.

** Measured at 15°C. 1 Bar. 12% CO₂, wet gas.

Source: Clean Air Regulations, United Kingdom, 1971; OECD, 1984. Quoted in International Energy Agency, Coal Information 1986, Paris, 1986.

largely comparable to the chimney height specifications used by the IAPI.

The DOE is empowered to regulate the composition of fuels. The Secretary of State has used his authority under the Control of Pollution Act 1974 to limit the sulphur content of oil fuels and the composition of motor fuels including lead in petrol and sulphur in diesel fuel. The Oil Fuel (Sulphur Content of Gas Oil) Regulations 1976 have set the following limits for gas oil: 0.8% by weight from 1976 onwards; 0.5% by weight from October 1980 onwards. In addition, a special City of London (Various Powers) Act, sought by the Corporation of the City of London, was introduced in 1972 with the objective of phasing in a 1% limit on the sulphur content of fuels over a 15-year period. Although the Act applies to only three square kilometers of the City of London (0.2% of the area of Greater London), it was relatively successful in reducing SO₂ emissions. According to Schwar and Ball, this piece of legislation is important for two reasons:

"First, it tackled the area which, as a result of the intensive development of the land for commercial purposes, had the highest sulphur dioxide emission density in London at that time. Second, its successful implementation has demonstrated that this type of control, which is unique in the United Kingdom, is not associated with undue difficulties. . . . It is perhaps unfortunate that other local authorities in areas of high pollution (e.g. Westminster), who have requested similar legislation, have been discouraged." (Schwar and Ball, 1982, p. 16)

The lead content of petrol was reduced via central government regulation in several stages:

Year	Lead Concentration
1973	0.64 grams per litre (g/l)
1974	0.55 g/l
1976	0.50 g/l
1978	0.45 g/l
1981	0.40 g/l
1985	0.15 g/l

The Secretary of State for Transport is empowered under the Road Traffic Act 1972 to regulate vehicle emissions. Regulations have been drawn up to implement the various EC directives. General speed limits are also in force in the UK: on motorways and other divided roads, 112 km per

hour (kph); on roads outside built-up areas, 97 kph; and inside towns, 38 to 50 kph.

The British government was among those EC member states who successfully resisted the establishment of strict limits on vehicle emissions as proposed, for example, by the Federal Republic of Germany. The British government was opposed to stricter exhaust standards because of fears that the imposition of such standards would have serious implications for motoring costs (especially by worsening fuel efficiency) and the motoring industry. According to the DOE, the limits for medium sized cars can be met with lean burn engines fitted with an oxidation catalyst to control hydrocarbon emissions, at a total cost of £200 per car, although heavier vehicles in this range may require more sophisticated fuel injection systems, pushing the cost up to £450 (ENDS, No. 126, 1985).

4.2. Governmental Responsibilities and Organisational Structure

The Department of Housing and Local Government was renamed in 1970 to become the Department of the Environment, with general responsibility for coordination of pollution control policies. However, this is only one of many of the DOE's responsibilities; most of its work is related to the control of local authority funding. Day-to-day responsibility for policy is, in most cases, delegated to local government, other ministries, or expert agencies. Government departments with particular responsibilities in pollution policy include the Ministry for Agriculture, Fisheries and Food, the Department of Trade, and the Department of Energy as well as the Health and Safety Executive. Central government departments are generally not empowered to direct the day-to-day activities of local governments. Where reserve powers do exist, however, the practice of central government has been to allow local governments considerable leeway and discretion. Local authorities' room for manoeuvring can, however, be indirectly limited by the DOE's control of local authority finance, for example, by subsidies for smoke control areas. The principal local government bodies in England and Wales are 54 County Councils and 401 District and London Borough Councils. The function of the County Councils is not relevant to pollution control, but District Councils have extensive responsibilities, including air pollution control. Routine tasks

are carried out by Environmental Health Officers of which there are about 6000 in England and Wales. Environmental Health Officers have many other responsibilities as well, including nutrition, hygiene, and housing conditions.

In broad terms, therefore, air quality control in the UK (Ashby and Anderson, 1981) takes place at two levels:

- at the central level where legislation is enacted and responsibility for the enforcement of certain regulations rests. The enforcement agents are the Health and Safety Executive, to which the Industrial Air Pollution Inspectorate was responsible until 1987, dealing with the regulation of noxious or offensive emissions or emissions technically difficult to control; and the Department of Transport, responsible particularly for the regulation of pollution by motor vehicles.
- at the local level, where local authorities (Environmental Health Officers) are responsible for all other local air pollution control.

A major overhaul of air pollution control and a new Clean Air Act was first promised by the government in 1984. So far, the IAPI has been reorganised. It is now abolished and has been absorbed in the new HM Inspectorate for Pollution which began on 1 April 1987.

4.2.1. The Industrial Air Pollution Inspectorate

The division of responsibilities for implementation between the IAPI and local governments is not based on geographical considerations, but rather on classes of industrial processes. In general, the IAPI (Frankel, 1974; Hart, 1978; Rhodes, 1981) is responsible for those industrial processes thought to give rise to complex technical problems in pollution control. These processes are "scheduled" by regulations which are periodically revised. The latest major revision, for example, occurred in 1983 under Section 1 (1) (d) of the Health and Safety at Work Act; this meant an increase in the number of industrial premises scheduled. By the end of 1985, the IAPI controlled emissions from 3,367 "scheduled processes"—these processes are listed in Schedule 1 of the Health and Safety (Emissions into the Atmosphere) Regulations 1983—at 2,284 registered works. Registered works were those works which had the greatest potential for causing air pollution or which presented the greatest difficulties technologically for pollution abatement. Works

containing scheduled processes must be registered annually with the IAPI. Registration does not grant licence to emit a certain quantity of pollutants. A precondition for registration is that the industrial plant must have the facilities that the IAPI considers necessary for compliance in accordance with the principle of "best practicable means" (Nonhebel, 1975). The processes under IAPI surveillance include a large number of chemical processes, the more complex metal smelting processes, the production of electricity, the production of coke and smokeless fuels, oil refining and related processes, cement works, and aluminium works. All high-level emission sources fall within the aegis of the IAPI.

Registered works have a general obligation to use the "best practicable means". This key concept defies precise definition. It has a long history in the UK and is held to be a typically British idea which originated from attempts to curb air pollution during the early 19th century. It has enjoyed statutory force since the implementation of the Alkali Act 1874, whereas its predecessor (Alkali Etc. Works Regulation Act 1863) set only numerical emission standards for three classes of industrial processes.

With respect to SO₂ and NO_x emissions from stationary sources, the primary means of control was, and still is, to render the pollutants harmless by dispersion--that is, the use of chimney stacks--because of the IAPI's conviction that FGD (or any other technology) were not a BPM for SO₂ abatement. The IAPI officially changed its stance on this matter for the first time in 1982 when the Chief Inspector announced (June 1982) that desulphurisation equipment would be required for new fossil fuelled power stations (Wetstone and Rosencranz, 1983).

In its capacity as an implementation agency, the IAPI has established the so-called "presumptive (emission) standards", the official concretisation of the BPM principle. These standards may be made stricter by the respective District Inspectors according to local conditions. Whether and how the District Inspector uses his discretionary powers is difficult to surmise from the outside, because there are no binding rules placed on inspectors nor are they obliged to supply public information on their activities. The only obvious control are the nationally unified specifications for chimney heights. This technical guideline, however, includes not an explicit but a "hidden" ambient air quality standard, because the local ambient air situation is taken into account in the

calculation of chimney heights, and reference to different domestic and industrial structures may be involved. The concrete definition of the degree of air pollution is left largely to the inspectors. Nevertheless, the regulation of chimney height is important because it has contributed to generally favourable air quality with respect to SO₂. An additional "purification effect" of considerable importance are the favourable prevailing winds which carry a good part of the pollutants to other countries, especially Scandinavia. A "policy of tall stacks" thus became the core of British SO₂ and NO_x policy for stationary emission sources (Knoepfel and Weidner, 1982). (Tall stacks, to be fair, were also the policy of other European countries including the Federal Republic of Germany until the beginning of the 1980s.)

About 80% of the industrial SO₂ emissions stem from sources for which the IAPI is responsible. The IAPI belonged to the Health and Safety Executive, but could be regarded as a quasi-autonomous institution. The DOE generally refrained from active intervention in IAPI matters. The IAPI was formed originally as the Alkali Inspectorate in 1863 and became Her Majesty's Alkali and Clean Air Inspectorate in 1970. It reported directly to a ministerial office, later on the Secretary of State for Environment. In 1975, it was brought under the auspices of the Health and Safety Executive, a quasi-autonomous body responsible to the Health and Safety Commission. It became the IAPI in 1982 and was absorbed in the DOE's Inspectorate of Pollution in April 1987. The Inspectorate has a very long history marked by a number of achievements. Shortly after its formation (Macleod, 1965), IAPI was able to bring about a reduction in industrial emissions quickly and economically, because its regulations increased manufacturers' profits by turning waste hydrochloric acid into sellable bleach and hypochlorite.

"Hence, by a happy chance, which rarely again characterised emission control, the new regulatory agency was able to steer the regulatee into a profitable commercial venture while achieving the necessary abatement." (Hill, 1985, p. 85)

In terms of staffing and resources, the Inspectorate is a small, highly professional body consisting of around 47 inspectors, with a core of seven London-based inspectors providing central administration and the remainder based in several districts. The inspectors are supported by sampling teams (Technical Officers) and a limited number of other

supporting staff. Each inspector is responsible for one district. The District Inspector usually has one and sometimes two assistants, and is able to call upon the services of a team of Technical Officers (Hill, 1983). In 1985, the Inspectorate cut its number of control districts from 15 to 12 because, according to the Chief Inspector, the number of problems began to diminish as pollution issues were resolved. The general industrial recession also had its impact, as old "smokestack industries" were systematically closed down or replaced with modern, more efficient plants (International Environment Review, 2-13-85, p. 56).

By the end of 1983, 1,950 works and 2,772 processes were registered with the IAPI. Registration increased in 1984 as more premises became eligible under the new regulations, the Health and Safety (Emissions to Atmosphere) Regulations 1983. However, this involved no major increase in the number of plants covered.

From its humble beginnings until the present day, the IAPI, when compared to air pollution agencies abroad, has been a very small body with a broad area of responsibilities. Nevertheless, the IAPI staff was reduced in the 1980s. Because of low salaries, recruitment was poor and vacancies remained unfilled. As a result emission sampling fell significantly. The total number of tests conducted was 2,369, compared to 3,028 in 1982 and 4,095 in 1981. The number of inspections also fell from 13,399 in 1982 to 11,128 in 1983 (IAPI, 1983).

Although it is a small body, the IAPI plays the most important role in control of air pollution from stationary sources in Great Britain. Some of the basic features of the Inspectorate are described in Hill (1982). These are as follows.

Relationship between the Chief Inspector and the field staff. The picture is that of a professional organisation, combining autonomy with solidarity. In its 1973 Annual Report of the Inspectorate, this relationship was described as follows:

"The Chief Inspector, with the help of his deputies, lays down the broad national policies and provided they keep within their broad lines, inspectors in the field have plenty of flexibility to take into account local circumstances and make suitable decisions. They are given plenty of autonomy and are trained as a team of decision-takers with as much responsibility and authority as possible. Nonetheless, they keep the head office staff well informed about the works under their control, so that the information can be assessed, compared and disseminated as necessary. It helps to

formulate new policies, which are regularly discussed at the annual staff meetings when all the inspectors from the United Kingdom gather for a three-day meeting and exchange notes." (Hill, 1982, pp. 90-91)

Pattern of work. The 1973 Annual Report gave the following picture of the Inspectorate's routine tasks.

"In practice, inspectors make routine, unannounced visits to inspect registered processes and to carry out their own emission tests where necessary. At least two visits per year are made to even the smallest, least offensive works under the Inspectorate's control and at least eight visits per year to what are known as 'major potential offenders'. Usually far more visits than the minimum are carried out, many of a special nature to discuss developments and improvements with top management officials. All inspectors carry with them fairly simple sampling and analysing equipment which is used to check emissions to compare results with those of the works. . . ." (Hill, 1982, p. 91)

However, this data on inspections is rather outdated. In 1985, works were visited on average five times per year and some works were, for the first time ever, not visited at all.

Concept of "best practicable means". In a statement on BPM in the 1973 Annual Report, the Chief Inspector pointed out:

"I have often said, and been criticised for it, that if money were unlimited, there would be few problems of air pollution control which could not be solved technically. In this statement can be included the supply of manpower and material resources. We have the technical knowledge to absorb gases, arrest grit, dust and fumes, and prevent smoke formation. The chief reason why we still permit the escape of these pollutants is because economics are an important part of the word 'practicable'. A lot of our problems are check book rather than technical, and attitudes which take little account of the economics of scarce resources, on which there are many claims, can so easily get priorities out of perspective. . . . The concept of best practicable means is ageless and I submit that those who criticise it as being out-of-date because it was conceived many years ago, are really criticising the standards and requirements which have been set under it and the toughness of their implementation by the Inspectorate. Best practicable means . . . can always be modern if it is used properly. I have heard it said by a well-known authority from abroad, who has studied the international environmental control scene very carefully for the last 17 years, that when one applies all the so-called modern concepts of control, attempting to apply scientific principles and ideas on a grand scale, making use of computers, telemetering, air quality criteria, etc., one finally ends up with BPM." (Hill, 1982, p. 93)

Regulatory activities: infractions and prosecution. The Inspectorate has a great deal of discretion in defining the law and punishing infractions. Statistics provided by the Inspectorate on these breaches of the rules are, in most cases, incomplete and it is far from clear under what circumstances inspectors actually report them to government, given their general concern with improving conditions by informal means. There have been only very few, minor cases where the Inspectorate has exercised its power to close down unsatisfactory works by refusing to renew the certificate of registration. The other sanction, prosecution, has also been used only very rarely. In the mid-1960s, the number of prosecutions had begun to increase, but they decreased again in the 1980s. Of the 41 infractions recorded in 1983, 13 involved mineral works and 12 were related to the illegal burning of cable to extract its copper content. Excluding cable burning, only two of the remaining cases led to prosecution. Responsibility for pursuing instances of cable burning was later removed from the Inspectorate and given to the local authorities, with the result that prosecutions dropped substantially. A 1974 Social Audit report suggested that much prosecution involved "stamping on mini-polluters". However, the Royal Commission on Environmental Pollution broadly endorsed the Inspectorate's stance on the use of prosecution in terms of the importance of a cooperative relationship with industry.

"The present system of control has achieved great advances in the reduction of emissions, and we are satisfied that much of this progress may be attributed to the policy of persuasion and co-operation with industry that the Inspectorate have adopted. An aggressive policy of confrontation, involving prosecution for every lapse, would destroy this basis of co-operation; it would harden attitudes and dispose industry to resist the imposition of costly programs for pollution abatement. . . . Industry generally is aware of its responsibilities in pollution control. If a firm has installed control equipment to the satisfaction of the Inspectorate and is striving by all reasonable means to maintain its emissions at an acceptable level, there is little to be gained by prosecution in the event of a pollution incident arising from, say, an unforeseeable breakdown of equipment." (RCEP, 1976, p. 62)

Relationship with the public. A key ingredient of criticism of the Inspectorate has been that it is an inaccessible, secretive, and uncommunicative organisation. Some of this criticism is concerned principally

with the legal structure within which the Inspectorate works, some with the way in which the Inspectorate is organised, and some with the way in which it chooses to operate. Social Audit (see Frankel, 1974) criticises the Inspectorate for failing to give information on emissions or details of situations in which firms have been allowed to operate at below "best practicable means" standards. The RCEP's 5th Report (1976) made a series of recommendations concerning these issues:

"The controlling authorities should be able to release data on emission to the public; when a firm has been notified of a breach of requirements the fact should be made public; registration of works should take the form of the 'issue of consents', with 'conditions defining the BPM for the works' available for consultation by the public." (RCEP, 1976)

The main official response to these criticisms has been to support or at least tolerate the setting up of local liaison committees serving local authorities whenever specific emissions give rise to complaints. In these committees, representatives from the troublesome factory, the local authority, the Inspectorate and, occasionally, the public meet twice yearly for discussions. However, in general, these committees have failed to satisfy the public when it wants useful information on emitters and measures taken by the responsible authorities. Until very recently, only limited progress had been made with public consultation, although one of the Chief Inspectors (in fact, the first to be appointed from outside the ranks of the Inspectorate itself) helped to open up his fiefdom to public scrutiny by resuming the publication of the Annual Reports by the District Inspectors. However, the availability of public information remains on the political agenda, not only with respect to the Inspectorate's attitude, but also the disclosure of information in general (RCEP, 1984; ENDS, No. 135, 1986).

Bearing these features in mind, Knoepfel and Weidner (1982, p. 102) have summarised the character of the IAPI as follows. The uniquely strong position of the IAPI is probably attributable to its long tradition, its high degree of specialisation and internationally recognised expertise, as well as the fact that the Inspectorate has a long history as the main authority in the country for systematic air pollution control. A further factor are the undoubted achievements of clean air policy, which led in the past to positive economic benefits through technological innovation. Close cooperation with industry, based on mutual

trust, as well as the legal assurance arising from an extremely restrictive information and cooperation policy in relation to third parties, provides further support. Public conflicts between regulatees and the Inspectorate are very rare indeed. The inspectors regard themselves as partners of industry, as experts in the technology of pollution abatement. The need for good relationships with polluters is assumed. This clientele relationship, which is a partnership as free from disturbance as possible, in fact replaces legal standardisation over wide areas. This leads to an implementation regime which is free of surprises and oriented towards cooperation and equal treatment on a nationwide basis. The implementation process ensures the high flexibility desired and, at the same time, satisfies the economic need for standardisation among branches of the same industry. Technical standards defining BPM generally proceed from a norm formation process in which the affected firms, their trade association, and the Inspectorate are authoritative participants. Endogenous conflicts are only likely when disagreements break out within the industry. However, in view of the very high homogeneity of the regulatee group, this will presumably occur only rarely. Furthermore, the regionally responsible inspector retains a considerable degree of flexibility, allowing site specific choices. All in all, the IAPI plays a "persuasive" (i.e., providing authoritative guidance to industry) not a "command and control" role.

4.2.2. The Local Authorities

For small-scale, domestic and commercial sources, a very different legislative and implementation approach has developed (Ashby and Anderson, 1979, 1981). As Clarke (n.d., p. 9) has put it:

"... The fundamental problem was the widespread use in British homes of rather primitive heating systems, often open fireplaces for which bituminous coal was an unsuitable fuel. No foreseeable technical improvements would significantly reduce the high rates of emission of a number of pollutants: smoke, sulphur dioxide, dust, and unburnt hydrocarbons. The principal aim of the Clean Air Acts was therefore to convert all premises to more modern systems, generally enclosed stoves burning either smokeless solid fuel, gas or domestic heating oil. All-electric heating was, of course, a further option."

Under the Clean Air Acts, areas can be designated as smokeless zones and a Smoke Control Order may be issued by local government. All premises thus covered would then be required to equip themselves with approved appliances burning approved (smokeless) fuels, complying with British Standard (BS) 3841. Solid fuels such as bituminous coal may be used, however, with appliances capable of smokeless combustion. Significantly, up to 70% of the required conversion costs could be paid by local and central government grants.

The process of conversion progressed at different rates; it was generally slow and laborious. Smoke control still does not cover all of the UK, and even in some urban areas it did not go into effect immediately. Resources were concentrated in "black areas" where the need for pollution abatement was greatest. In general, therefore, smoke control has spread outward from the inner cities to the outer suburbs, with rural areas usually remaining unaffected. Since 1956, the UK has established some 6,000 smoke control areas. By 1981, nearly nine million premises had been converted, and many major cities are now completely covered by Smoke Control Orders (Clarke, n.d., p. 10; DOE, 1986b). During extremely cold weather, however, Smoke Control Orders may be temporarily lifted.

The Smoke Control Order is the principal instrument used to implement the EC directive on air quality standards for SO₂ and smoke. In general, all emissions from domestic premises and non-scheduled types of industry are the responsibility of the Environmental Health Officers within District or Borough Councils, using a variety of different laws, the preventative powers of which, as regards industrial premises, are severely limited. Most of these laws concentrate on emissions arising from combustion processes.

The discretionary powers available to local authorities primarily concern the controls of new furnaces. Local authorities must be informed of any proposal to install a new furnace. New furnaces other than domestic boilers with a given maximum heating capacity, must be capable of being operated continuously without smoke being emitted when burning fuel of the type for which they were designed. The local authorities also have the power to ensure that certain types of new furnaces are fitted with abatement equipment to prevent the emission of grit and dust. They are further empowered to approve the height of

any new chimney constructed for furnaces of the types mentioned above. The DOE may exempt certain classes of furnaces from the need to be fitted with grit and dust emission abatement equipment, and it has done so. Some of those exempted included furnaces in hospitals, buildings owned by the crown, and military establishments, although these are often among the big emitters.

This implementation system is thus highly decentralised; there are no regional control authorities and there are no institutional controls and lines of supervision from the central authority to local authorities. The harshest measure which the central administration has at its disposal is the ability to "call in" an approval process, placing it under its immediate supervision. Standard setting by the local authorities, in the sense of taking ground level concentrations into consideration, occurs frequently, as an immediate reaction to local air quality and power supply situations. It is estimated that about 150,000 industrial works are under control of Environmental Health Officers.

The annual report of the Institution of Environmental Health Officers for 1983/4 reported adverse trends in the quality of the environment for which local authorities have the responsibility. It also mentioned a larger number of contraventions of clean air legislation by industry, industrial contraventions of the dark smoke provisions of the Clean Air Acts 1956 and 1968 having risen from 3,128 in 1982 to 3,662 in 1983/4. A total of 247 breaches of the grit and dust provisions were also recorded. The report states that it is high time that the emission standards recommended a decade ago by the working party on grit and dust were fully implemented. The report also warns that smoke control is losing impetus because of financial problems.

4.2.3. Vehicle Emissions

Responsibilities for vehicles rest with central government, which is empowered to make regulations prescribing the pollutant content of fuel used in motor vehicles. The sulphur content of diesel fuel and the lead content of petrol are now subject to restrictions. Environmental Health Officers are not responsible for enforcing legislation relating to motor vehicle emissions. This rests primarily with the police. Quantitative limits on vehicle emissions were first set in Britain by the Motor

Vehicles (Construction and Use) Regulations 1973; subsequent regulations have been guided by ECE and EC regulations.

The 1985 EC directive on vehicle emissions was considerably weaker than the proposal made by the governments of the Federal Republic of Germany and other countries, because of strong opposition to this proposal from the UK, France, and Italy, opposition which related very much to the economic and commercial implications of this proposal. For the first time ever, a tax incentive was used to support an environmental measure in the 1987 budget when the 5p per gallon excise duty was removed for unleaded petrol to bring its price down to that of the leaded variety. According to government (CEED Bulletin, 1987), there are now plans for further tax measures to improve the environment. As of autumn 1987, of the 20,640 outlets in the United Kingdom, 400 were able to supply lead-free petrol. There is pressure from a number of organisations for more rapid introduction of unleaded petrol outlets (Schwar, 1987).

4.2.4. Recent Developments

4.2.4.1. Overview

During the last decade, several proposals for the reorganisation of the British air pollution control system have been made, but by 1986 only minor changes had taken place, and not all of these were conducive to better pollution control. Government consultations on a review of industrial air pollution control, promised in 1982 in response to the RCEP's 5th Report (published in 1976), were taken up again very belatedly.

A Management Information System for Ministers (MINIS), introduced into the DOE in 1979 to promote the twin goals of "efficiency" and "effective management", revealed in 1983 that the efficiency of environmental policy making had suffered badly in the wake of the manpower reductions made between 1980 and 1983 (ENDS, No. 107, 1983). The Central Directorate on Environmental Pollution, the Air and Noise Division, and the Directorate of Rural Affairs had all, on average, fared twice as badly as the civil service, and the fate of the Directorate of Science and Research Policy had been five times worse. The remaining

civil servants, according to ENDS, were largely preoccupied with routine administration, tasks set by earlier legislation and, increasingly, with reacting to international initiatives rather than evolving Britain's own environmental policies. In 1984, for the first time in five years, virtually all the main environmental protection divisions of the DOE escaped manpower cuts. However, the DOE's scientific strength and its role as a coordinator of environmental policy remain seriously weakened as a result of these earlier decisions (ENDS, No. 115, 1984).

Proposals for a comprehensive reform of the UK's environmental policy (backed by proposals for over 100 specific measures to tighten controls on pollution) have been presented to Ministers by the Central Policy Planning Unit of the DOE. A report by this Unit has argued that government policy should take account not only of the increasing value being placed on environment by the public, but also of the scientific uncertainty surrounding many of today's leading environmental problems. Both, the Unit pointed out, would require a more far-sighted, precautionary approach. Integration of environmental thinking into other policies such as energy, agriculture, and industry was also advocated. Furthermore, the "polluter pays principle" should be extended, albeit at a pace which did not disadvantage British industry in international markets. Subsidies for pollution abatement equipment, according to the report, might be justified in some industries in place of the "implicit subsidies contained in lax emission standards if this would be more cost effective in improving the environment and stimulating the pollution abatement equipment industry" (ENDS, No. 133, 1986, p. 3). With regard to air pollution, the report stated that the British position on acid deposition was becoming increasingly unacceptable. It was also proposed that the government establish a pilot desulphurisation plant on the site of at least one of the UK's fossil fuelled power stations, with a phased programme to extend retrofitting to the others in the future (ENDS, No 133, p. 1986).

In 1986, a new "Central Unit on Environmental Issues" was set up within the DOE as the first fruit of the mentioned review by the DOE's Central Policy Planning Unit. This measure was welcomed by some environmentalists but, according to ENDS (No. 135, 1986), some officials remained privately sceptical about the powers the unit will have

compared to what it would need to ensure that environmental considerations are fully integrated into other departmental policies.

Under growing pressure from European countries receiving Britain's emissions of air pollutants, and the approaching June 1987 elections, the British Cabinet decided, against the advice of the Treasury and the Department of Energy, to introduce new measures to abate SO₂ and NO_x. In December 1986, proposals for a new Clean Air Act were made by the DOE, eleven years after the RCEP had recommended this. Part of the new Clean Air Act called for the setting up of an integrated pollution inspectorate, which the then Secretary of State, Mr. Waldegrave, had initially promised in 1984. Although this restructuring involved considerable conflict with the Health and Safety Executive, it was favoured by the IAPI.

The essence of the new Act was to increase the discretionary powers of the Secretary of State for Environment to define air quality and set emission standards (ENDS, No. 143, 1986), and to grant initial approval of specific industrial processes. Lower authorities would have greater powers with respect to some industrial processes, mirroring the discretionary powers of the IAPI under the BPM principle. Official certificates would replace informal consent and be based upon national guidelines. However, according to ENDS (No. 143, 1986, p. 9), an "all pervasive man-power shortage" will make the implementation of those new regulations impossible for quite some time. Some sceptic observers of British achievements in air pollution control fear that what is likely to happen with the new regulations will be a repeat of the Control of Pollution Act 1972 story. Part II of that Act was on the statute book and in effect in 1972, but was not actually implemented until 1986.

Continental Europe generally greeted the announcement by the British government in September 1986 that it intended to retrofit three 2000-megawatt (MW) power stations with FGD and to equip all newly built power stations with FGD in the future (DOE, News Release, 11 September 1986). In April 1987, it was announced that the CEGB would be fitting low-NO_x burners to 12 of the largest coal-fired power stations over the next 10 years (Power News, Staff Newspaper of the CEGB, April 1987).

4.2.4.2. Developments in Detail

According to information provided by Jim Skea of the University of Sussex (Skea, 1987), recent (and potentially future) developments in British air pollution control may be divided into four categories:

- proposals to alter clean air legislation,
- recent changes in administrative arrangements,
- positive measures to reduce emissions,
- the proposed privatisation of the electricity industry.

Legislative changes. The UK government promised to carry out a comprehensive review of UK clean air legislation in response to the Royal Commission on Environmental Pollution's 5th Report on air pollution. A consultative document ("Green Paper") was published in December 1986, soliciting views from interested parties. Replies were requested by 31 March 1987 and it had been intended to pass a revision to the Clean Air Acts by 30 June 1987, when the EC "framework" directive on emissions from industrial plants (Dir 84/360/EEC) came into force. The revisions did not take place because of the general election in June 1987. However, it is reasonable to suppose that some changes will take place during the 1987/88 parliamentary session. The following are the principal changes proposed (for full details, see Air Pollution Control in Great Britain: Review and Proposals—A Consultation Paper, Department of Environment, Scottish Development Department, Welsh Office, December 1986):

- The principle of "best practicable means" is to be kept.
- The secretary of State of the Environment is to have the power to set emission limits and air quality standards. These powers would be exercised through setting regulations. Air quality standards would have to be taken into account when regulatory authorities define BPM.
- A new prior consent system is to replace registration. Operating a scheduled process without a consent would become an offence. A consent would specify: maximum concentrations or discharge rates of pollutants, the quantity and nature of raw materials or fuels used, the method of use of control equipment, the height and mode of emission discharges, and monitoring requirements. Consents would be available for public inspection. Consents for individual works would be negotiated on the basis of centrally developed "notes on BPM" for

particular classes of works. An appeal against the terms of a consent could be made to the Secretary of State. Interestingly, it would not be an offence to break the terms of a consent once it had been granted. The only basis for prosecution would remain the failure to use BPM.

- There are to be changes in the allocation of processes between the national inspectorates and the local authorities. The processes listed in the EC "framework" industrial plant directive are more numerous than those currently controlled by the national inspectorates in the UK. Therefore, some new processes will be scheduled, but they will remain under the control of local authorities. There will be a two part schedule of processes—part A controlled by the inspectorates and part B controlled by the local authorities. In general, processes will be regulated by the inspectorates only when it is felt that the local authorities do not have the necessary technical expertise.
- Local authorities are to have powers of prior approval and to require BPM. To allow the local authorities to deal with scheduled processes, they will be given powers to specify BPM in agreeing consent conditions with plants covered under part B of the new schedule. The consents, and the results of monitoring carried out under the terms of a consent, would be available for public inspection. This does not mean that they would be published in a journal: they would, for example, have to be looked at in the local town hall.

Changes in administrative arrangements. Administrative arrangements for air pollution control in England and Wales changed from 1 April 1987. The Industrial Air Pollution Inspectorate was absorbed in a new inspectorate, Her Majesty's Inspectorate of Pollution (HMIP), which has, in addition, taken over the functions of the Hazardous Waste Inspectorate, the DOE's water pollution inspection functions, and the Radiochemical Inspectorate. Since HMIP reports to the DOE, the Health and Safety Executive (HSE) has now lost its role in air pollution control. Formally, under the Health and Safety at Work Act 1974, the HSE is still responsible, but the DOE now carries out its functions under an agency agreement. The proposed new legislation (see above) will sort out the present anomalies.

The changes follow from the government's review of air pollution control arrangements promised in 1982 and the Efficiency Scrutiny Report

on the inspectorates which was carried out during 1986. The change implements many of the recommendations made by the Royal Commission on Environmental Pollution in its 5th Report of 1976.

Internally, the new HMIP has an Air, Water and Wastes Division headed by the former Chief Inspector of the IAPI. A recommendation of the Efficiency Scrutiny Report was that some of the IAPI inspectors (up to 25%) should be transferred to other responsibilities within the new HMIP. The government has accepted this recommendation "in principle" (see ENDS, No. 139, 1986 and No 146, 1987; Inspecting Industry: Pollution and Safety, Efficiency Scrutiny Report, 1986; Inspecting Industry: Pollution and Safety--Action Plan, DOE, 1986).

Measures to reduce emissions. In September 1986, the CEGB and the DOE announced plans to fit FGD to three existing 2000 MW coal-fired power stations

"in a phased programme which will extend from 1988 to 1997. Officially it is suggested that the measures announced for existing power plants should secure a 14% reduction in (sulphur dioxide) emissions by 1993, on the basis of 1980 national levels. On the basis of current trends in energy consumption and emissions, this could bring the UK close to, but not necessarily below, the '30% Club' target. . . ." (NSCA, 1986, p. 136)

Subsequently, the CEGB has announced plans for two new 1900 MW coal-fired stations to be completed by 1995, which will both be fitted with FGD. The capital cost of the retrofit programme will be £600 million (DOE, News Release, 11 September 1986 and 19 September 1986; CEGB, Press Information, 11 September 1986). In April 1987, it was announced that the CEGB would be fitting low-NO_x (low nitrogen oxide) burners to 12 of the largest coal-fired stations over the next 10 years. The capital cost will be £170 million. According to a CEGB press release

"The new low-(nitrogen oxide) equipment, which modifies combustion in the boilers, should cut nitrogen oxide emissions from the Board's (CEGB's) 500 and 660-megawatt units by 30 per cent. The new station drop should be 40 per cent. The 10-year programme--which affects 2,000 burners in 44 boilers--will be carried out during routine plant overhauls. The stations affected are: Fiddlers Ferry, West Burton, Kingsnorth, Thorpe Marsh, Eggborough, Ironbridge, Rugeley B, Cottam, Ferrybridge C, Ratcliffe, Didcot and Drax." (Power News, Staff Newspaper of the CEGB, May 1987)

4.3. Financing

There are no comprehensive data sets by either central or local government on air pollution control spending. Financial support by government to industrial plants for reducing emissions seems not to exist--a strong contrast to other EC member countries, especially the FRG (Weidner, 1986). The "polluter pays principle" (PPP) has thus been implemented fairly strictly in the UK. Yet in the 10th Report of the House of Commons Select Committee on the European Communities (Session 1982-3), implementation of the PPP is recommended. This recommendation is based on a somewhat unorthodox, pragmatic interpretation of the PPP as a short-hand phrase for internalising the social costs of manufacturing and industry. The importance and political value of the PPP lie in its use as a means of limiting the exploitation of the environment by polluters. On the basis of this interpretation, the Lords' Committee argued that with regard to subsidies, the UK might adopt a somewhat less rigorous attitude to subsidies. The UK should take advantage of EC guidelines which allow certain forms of aid to be granted for pollution control investments, and full use should also be made of available Community funds for promoting cleaner technologies. The committee also recommended the application of charging systems to those who benefit from free use of the environment. As of October 1987, no such system had been introduced for air pollution control.

Since 1979 when the conservatives took office, some budgets for environmental protection programmes have suffered funding cuts approaching 50%. Cuts have been imposed on air pollution control and radioactive waste management in order to accommodate a £450,000 increase in research on acid rain, which brought the funding level of DOE sponsored acid rain research to about £1,000,000 (ENDS, No. 100, 1983). In a reply to the 4th Report of the House of Commons Environment Committee, the government generally accepted that there is a need for long-term commitment in the area of air pollution research. According to the government, its research and monitoring programmes on air pollution (at a cost of £2.5 million for 1984/85 and £3.5 million for 1985/86) were an indication of its resolve to continue these activities on a long-term basis (DOE, 1984).

Public subsidies (from central and local government) are in fact a cornerstone of smoke control programmes as implemented by the local authorities. Over 9 million premises in over 5,600 control areas are now covered by the Clean Air Act, with over 100 new Smoke Control Orders covering about 200,000 additional premises being approved each year. The introduction of a smoke control area may involve the domestic householder in expenditures for the conversion of domestic units and legislation provides for up to 7/10 of the necessary expenditures being paid by financial grants. This clear breach of the polluter pays principle is surely justified by the success of the clean-up programme which ridded British towns and cities of the smoke that had plagued them for so long; and, it is justified for social reasons: without grant aid, many householders would not have been able to afford the costs of conversion.

4.4. Environmental Reporting and Information Policy

Information on ambient air pollution and total emissions in the UK is fairly well documented by the DOE in its report series Digest of Environmental Protection and Water Statistics and by the Warren Spring Laboratory in several of its reports, as well as in the reports of some of the local authorities and the Greater London Council (abolished in 1985). However, there are some gaps in the monitoring network which result in incomplete information on specific pollutants and concentrations in certain areas (see section 2.2 above). Specific information on emissions, especially those from individual industrial sources and power plants, is almost unavailable. This is due, in part, to a very rigid interpretation of the trade secrets regulations and the IAPI policy to avoid disclosure of specific information on sources under its control.

Several times in the past and again in its 10th Report, the Royal Commission on Environmental Pollution referred to the issue of confidentiality in environmental matters. The Commission expressed the view that only in exceptional cases could otherwise inaccessible trade secrets be inferred from the information that regulatory authorities are entitled to receive by statute. Furthermore, the Commission argued, to deny access to data on the grounds that the public was not competent to make correct use of them was untenable and that half-kept secrets simply served to fuel fear. The RCEP proposed the following general principle:

"There should be a presumption in favour of unrestricted access for the public to information which the pollution control authorities obtain or receive by virtue of their statutory powers, with provision for secrecy only in those circumstances where a genuine case for it can be substantiated." (DOE, 1984)

In response to this view, the DOE published a report by the "Interdepartmental Working Party on Public Access to Information Held by Pollution Control Authorities" entitled Public Access to Environmental Information (Pollution Paper No. 23, 1986). Although the recommendations made with regard to information on air pollution represent some improvement, they fall far short of the proposals made by the RCEP. In general, therefore, the public will continue to face difficulties in obtaining comprehensive information on the emissions of single sources. According to one source, although the DOE Working Party's report did not explicitly

". . . recommend that emission measures and details of enforcement action should be made available to the public(;) spokesmen for both the DOE and the IAPI say that these, too, will be disclosed--albeit in a form yet to be decided. The IAPI according to its Chief Inspector . . . also intends to discuss with industry arrangements to publicise the results of emission monitoring carried out by firms--with the aim being to provide a fuller picture of average emission performance than that available from emission measurements by inspectors. Local authorities are likely to be empowered by forthcoming air pollution legislation to enter details about the exercise of their controls under the Clean Air and Public Health Acts. But the working party has rejected the Royal Commission on Environmental Pollution's recommendation that their barely used discretionary power under the Control of Pollution Act 1974 to disclose information about air pollution should be replaced by a statutory duty." (ENDS, No. 135, 1986, p. 19)

It may be noted that a strong public debate over access to environment related information has been taking place in the UK for some time. The "Campaign for Freedom of Information" for a number of years has attempted to have legislation passed, establishing a statutory right of access to information on environmental pollution hazards. In 1985, a related bill (sponsored by a Conservative MP with the backing of the "Campaign") failed to be passed by Parliament. The bill had three main clauses:

"The first would have given members of the public the right of access to any official document relating to pollution,

noise, radiation, pathogens, or storage of dangerous chemicals as long as the access did not involve specifically exempted information. The second would have required pollution authorities to notify anyone whose health or property was 'seriously at risk'. The third clause said that those who discharge pollutants or store dangerous chemicals should be required to make information on the hazards available to anyone who asks for it. Enforcement would have been by an 'environmental information commissioner', who would have specific statutory powers." (International Environment Reporter, 8-14-85, p. 272)

The principal changes proposed by government in its consultation paper on air pollution control in Great Britain (DOE, Scottish Development Department, Welsh Office, 1986) also include proposals on public access to environmental information. For example, it was proposed that public registers of applications for consent and consents actually granted by the authorities should be established, and that the results of the emission tests should be made available to the public. However, the proposals were more reticent about the disclosure of data on industry's performance and the performance of controlling authorities.

Generally speaking, however, British government's or, more specifically the IAPI's and British industry's strict opposition to public disclosure of pollution related data has noticeably subsided in recent years. The issue of public access to emissions data is now at the top of the political agenda and it is reasonable to expect that some significant improvements will be made in this area.

5. ABATEMENT TECHNOLOGY FOR MAJOR AIR POLLUTANTS

In the 1930s, flue gases from three London power stations (Fulham, Bankside, and Battersea) were scrubbed with flue gas desulphurisation systems. These were eventually closed down because of their high operating costs, damaging effects on the River Thames and the poor dispersion of the wet plume they produced. Today, there is no modern, full-scale commercial FGD plant or denitrification plant (nitrogen oxide emission abatement system) operating in the UK. Although within the framework of the procedure for planning permission the Secretary of State set the requirement that fossil fuelled power plants must leave sufficient space for retrofitting with an FGD system, no retrofit order has been made by the IAPI. This was due to the prevailing opinion within the IAPI that no practicable abatement technology for SO₂ emissions was available other than dilution using high chimneys.

In its 1981 report, the IAPI defended the high chimney policy as effective from a domestic point of view and in line with air pollution policies adopted abroad.

"There is no doubt that in the light of present knowledge, this policy of dispersion has proved adequate to protect the UK environment. It is worth noting that although tall chimneys are often referred to in disparaging terms in international circles as the UK approach to pollution control, in fact every other industrial country has adopted similar policies for power station emissions. It is only more recently that alternative approaches have become available but even these do not dispense with the need for tall chimneys." (Wetstone and Rosencranz, 1983, pp 70-71)

Coal washing has so far been the only technological SO₂ abatement measure widely practiced in Britain. Although used primarily to lower ash content, this technique has nevertheless the indirect effect of lowering sulphur content as well.

As recently as 1982, a study published by the Central Electricity Generating Board, the largest operator of power plants in Britain (in 1984 its power plants accounted for nearly 70% of total SO₂ emissions), stated:

"In this country there are no restrictions on the levels of sulphur dioxide emissions because the CEGB's power stations have chimneys tall enough to ensure that the flue gases are adequately diluted before they reach ground level." (CEGB, 1982, p. 14)

The CEBG maintained this position until mid-1986, arguing that the evidence for harmful effects due to long-range transportation of British emissions remained inconclusive. In September 1986, as mentioned above, the government announced that it would accept recommendations by the CEBG to retrofit three 2,000 MW power stations with FGD and to put FGD on new power plants. The CEBG submitted these recommendations voluntarily; it was not required to do so by the IAPI. The final decision, however, was to be authorised by the government.

In its laboratories, the CEBG has begun experimenting with a high gradient magnetic separation device to test its ability to remove iron pyrites, which account for about half the sulphur content of British coals, from pulverised fuel. The trials are scheduled to be carried out for three years at a cost of £280,000 (ENDS, No. 132, 1986). In 1985, the CEBG launched its first full-scale trial of a nitrogen oxide emission abatement system (ENDS, No. 130, 1985). In April 1985, the CEBG announced plans to install low-NO_x burners at its 12 largest coal-fired stations over a period of 10 years. This was expected to lead to a reduction of NO_x output by 10% of the 1980 levels at a cost of £170 million (CEED Bulletin 12, March/April 1987).

In light of the various available pollution abatement technologies, the CEBG and the government have displayed a clear preference for Pressurised Fluidised Bed Combustion (PFBC). There are many different fluidised bed combustion (FBC) systems, all with the common feature of burning coal in a bed of ash, sand, or limestone kept in a state of turbulent motion by an upward flow of combustion air through the bed. The advantages of FBC include, among other things, a high rate of heat transfer, the ability to burn fuels of widely differing quality, low emissions of nitrogen oxides, and the ability, when limestone is added to the bed, of reducing SO₂ emissions. In May 1984, the government announced that the reduction of SO₂ emissions from coal-fired power plants with PFBC would be investigated under a new £25 million research programme to be funded jointly by the CEBG and the National Coal Board and to be based at an 80 MW (heat) experimental unit. According to a statement by a National Coal Board official, up to 95% of sulphur can be retained through PFBC, and it would enable coal to be burned in an environmentally clean way without the heavy costs associated with FGD (International Environment Reporter, 6-13-84, p. 196).

Nevertheless considerable scepticism persists about the prospects of PFBC because of technological and environmental problems that still need to be solved, for example, a high rate of tube metal wastage, turbine damage caused by hot, particle-laden gases, and waste disposal constraints because of the large amounts of fuel ash produced (a mixture of calcium oxide, hydroxide, and carbonate) (ENDS, No. 117, 1984). One study on the development of PFBC in Britain has come to a pessimistic conclusion about this technology.

"While the National Coal Board argues that the emissions from coal combustion, particularly in the industrial sector, can be controlled by the use of fluidised bed combustion, past experience gives little room for optimism about the speed with which industry will adopt the new technology." (ENDS, Pollution 1990, p. 191)

The only PFBC in the UK today is the experimental unit at Grimethorpe. Table 15 gives an overview of FBC in the United Kingdom (1982).

The market for air pollution abatement technologies in the UK has remained relatively small. A market analysis by Technical Marketing Ltd., The Pollution Control Equipment in the United Kingdom (1980), yielded the following results largely based on estimates. In 1979, the British market for air pollution control products (including monitoring equipment) amounted to only about £35.8 million. For 1983, an increase up to £40.7 million was anticipated. A comprehensive market analysis by Environmental Data Services Ltd (ENDS), Pollution 1990, did not predict a particularly rosy future for the eco-industrial sector in the UK.

"Although the concept of clean technology is, inevitably, being oversold at the moment, it does represent one area in which the various regulatory agencies can adopt a constructive stance—rather than being seen as a dead weight on the economy." (Quoted in Knoepfel and Weidner, 1985, p. 233)

With respect to energy saving or efficient energy systems, the picture in the UK is not very good compared to that in other EC member countries. This point is made in several studies, all of which came to the same conclusion, namely that an energy future based predominantly on improved energy efficiency, energy conservation, and renewable energy would not only be preferable economically to existing policies, but would also lead to a considerable reduction in major air pollutants and to an increase in jobs (Earth Resources Research Ltd., 1982, 1983;

Table 15. Atmospheric fluidised bed boilers operating in the United Kingdom (1982).

Organisation	Location	Description	Thermal Output in MW	Function
National Coal Board (NCB)	Coal Research Establishment (CRE) Cheltenham, Glos.	hot water sectional boiler converted to fluidised bed firing	0-35	test unit to provide design data
NCB/Parkinson Cowan GWB Ltd	Parkinson Cowan GWB factory, Dudley, West Midlands	Vekos Powermaster horizontal shell boiler converted to fluidised bed firing	1- 2	to demonstrate the application of fluidised bed combustion to horizontal shell boilers
NCB	CWS nurseries, Fromington, Marden, Herefordshire	vertical shell hot water boiler	2- 3	demonstration prototype heating glass houses for tomato growing
NCB	Coal Utilisation Research Laboratory, Leatherhead, Surrey	vertical shell boiler	2- 5	test plant
NCB	Antlers Ltd, Bury, Lancashire	vertical shell steam boiler	2- 8	demonstration prototype heating factory
NCB	CRE	Thompson Cochran Multipac horizontal boiler adapted to fluidised bed firing	3	experimental purposes particularly to provide heat transfer data
NCB/Babcock International Ltd	CRE	water tube wall horizontal shell boiler	4- 3	development unit to prove new design
NCB/Vosper Thornycroft Ltd	Edmonton, London	vertical shell boiler	4- 5	district heating operated by Associated Heat Services Ltd
NCB/Vosper Thornycroft Ltd	CRE	horizontal open bottom boiler	6-25	development unit to prove new design
NCB	Rists Ltd, Newcastle-under-Lyme, Staffordshire	locomotive type horizontal boiler	10	provision of steam for space heating and process
Combustion Systems Ltd/Babcock International Ltd	Babcock's factory, Renfrew, Scotland	cross-tube type boiler converted to fluidised combustion	13- 5	to provide operating data
NCB/ME Boilers Ltd	British Steel Corporation's River Don works, Sheffield	high pressure steam coil-type water tube boiler	30	provision of steam for hammers and electricity generation
Energy Equipment Company Ltd	Olney, Buckinghamshire	horizontal shell boiler	1- 5	testing in advance of installation
Energy Equipment Company Ltd	Bournville factory of Cadbury Schweppes, Birmingham	water tube boiler	10	test and demonstration
Stone-Platt Fluid-fire Ltd	Hayward Tyler factory, Keighley, Yorkshire	packaged water tube boiler	3	test and demonstration
Northern Engineering Industries Ltd (NEI)	Derby	horizontal shell boiler	1	works test unit to provide design data
NEI	NEI Thompson Cochran's boiler works, Annan, Scotland	chain-grate horizontal shell boiler converted to fluidised bed firing	5	provision of steam for space heating

Source: National Coal Board, United Kingdom. Quoted in NATO, 1982.

International Institute for Environment and Development, 1982; Gaskell and Pike, 1983).

Many studies have criticised the government for its weak support for energy supply options which offer substantial advantages over existing policies if economics, comfort, fuel efficiency, and long-term environmental benefits are taken into account. Combined heat and power systems (CHP), for example, could be one such alternative to existing energy production. A report from the House of Commons Select Committee on Energy (1983) concluded that official encouragement for CHP/district heating in the UK suffered by comparison to many continental European countries (ENDS, No. 111, 1984).

The principal recommendations for the removal of legal and financial obstacles to investment in CHP schemes, made in a report by the Energy Committee in 1986 (see ENDS, No. 143, 1986), were rejected by government. Government has also pointed out that the grant aid awarded to three consortia to examine the potential for developing CHP/district heating schemes in Leicester, Belfast, and Edinburgh will not be extended to other cities, and that any future investment in CHP must be financed wholly by the private sector (ENDS, No. 146, 1987).

In 1987, the CEEGB concluded that significant development of CHP by the end of the century was not likely and, moreover, that the only significant contributions to energy supply capacity likely to be made would come from wind and tidal power. The CEEGB has recently proposed two strategies for the expansion of energy supply capacity by the year 2000: a nuclear/coal option involving six new 1155 MW pressurised water reactors (PWRs) and four 850 MW coal-fired power stations fitted with FGD; and a coal only strategy requiring nine new power stations (CEGB Information, May 1987). The nuclear/coal option is the strategy preferred by the CEEGB.

In 1983, the all-party Select Committee on Energy concluded that energy policies were encouraging irrationality in energy use, and that the promotion of conservation was sluggish and sporadic (ENDS, No. 97, 1983). The Select Committee also pointed out that the potential of cost-effective energy savings in buildings alone would amount to 30% of energy use at that time. Furthermore, in a 1981 review of the proposed nuclear programme the Select Committee had criticised the Department of Energy for lacking any clear idea of whether investing money in nuclear

power plants would be as cost-effective as spending similar sums on energy conservation. In 1982, the Select Committee concluded that many conservation measures were likely to be much more cost-effective than most energy supply investments. In its 9th Report (Session 1983/4), the Select Committee extensively criticised the government's energy research, development, and demonstration efforts. It found a serious imbalance between government spending on R&D in energy supply and energy conservation, as well as a practice of discriminating against renewable energy sources in favour of nuclear power (ENDS, No. 115, 1984). For the third time since 1980, the House of Commons Select Committee on Energy in 1985 again strongly criticised the serious imbalance in official energy policy (ENDS, No. 130, 1985).

A Review of Energy Policy by the British Institute of Professional Civil Servants (IPCS) published in November 1986 recommended that urgent attention should be given to improving oil conservation measures and finding substitutes for oil as a transport fuel. The report also concluded that current levels of funding for research into renewable energy sources were inadequate in the UK (IPCS, 1986). To sum it up, there is strong and convincing evidence that the British government has in the past not only failed to tackle air pollution from power plants and industrial sources by changing the energy supply system, but that it is also unlikely to change its attitude substantially in the near future, particularly concerning novel, cleaner, lower risk forms of energy production. Even after the nuclear accident in Chernobyl in April 1986, the British government has continued to emphasise an expansion of nuclear power just as it had in the past (see, for example, ENDS, No. 130, 1986).

A report by the International Energy Agency (IEA) severely criticised the scale and direction of the UK's research and development activities on clean coal utilisation technology. The IEA concluded that the British approach to air pollution control has failed to provide the necessary incentives for the development of emission abatement technologies. It suggests that this was partly due to the UK's BPM approach to air pollution control and deficient environmental standards. The IEA recommended, among other things, that reduction in both sulphur and nitrogen oxide emissions should be given greater attention, including retrofit and new technologies. Furthermore, British government funding

of R&D related to technologies for the clean use of coal compares very badly to German, Danish and Swedish programmes (IEA, 1987).

With respect to mobile emission sources, the British government and the automobile manufacturers have successfully opposed the intentions of other EC countries to make the 3-way catalytic converter mandatory for new, medium sized cars. Instead, they have argued for the development of cheaper solutions for cutting down automobile exhaust gases, such as lean-burn engines.

Finally, to summarise British efforts in research, promotion, and development of air pollution abatement technology, it can be stated without exaggeration that the responsible governmental authorities as well as the major industrial emitters have been slow and reluctant to introduce available abatement technology. They stress high cost, the potential for operating problems and negative side-effects (e.g., waste disposal difficulties), as well as the uncertainty of the benefits to be derived from control (Burgess, 1985). Furthermore, the British government and the CEGB, the agency responsible for producing most of Britain's electric power and SO₂ emissions, had by 1986 undertaken only very minor steps towards changing energy policy in a way more beneficial to the environment.

6. COST BENEFIT CONSIDERATIONS OF AIR POLLUTION CONTROL: DIFFERENT VIEWS

The British government's air pollution control policy for major air pollutants reflects a strong emphasis on cost-effectiveness. With respect to a major sulphur dioxide and nitrogen oxides abatement programme for existing and new stationary emission sources as well as the establishment of automobile exhaust standards comparable to those in the US and Japan, the government claims this will result in high costs for the British economy without reasonable benefits for the environment in Britain and other countries.

The UK's attitude and official policy on the issue of acid rain were presented by an official from the DOE (Burgess, 1985) at the 52nd Annual Conference of the National Society for Clean Air at Scarborough, 14-17 October 1985. The following quotation, although lengthy, probably offers a good illustration of official thinking behind the resistance to a fundamental change in air pollution control policy.

". . . What happens to our emissions? Where are they deposited? Here our information relates mainly to (sulphur dioxide) and derives from EMEP. The main conclusion to be drawn from the Programme is that no country stands in isolation. All European countries to greater or lesser extent share each other's emissions. So far as the UK's emissions are concerned slightly more than 30% is deposited in the UK itself, some 40% in the sea and rather less than 30% is deposited in other countries. The 30% of our own emissions which is deposited in the UK represents about 80% of total UK deposition—that is, we receive only 20% from other countries.

"The picture for other European countries is rather different. In general a smaller proportion of their own emissions are deposited in continental European countries than is the case in the UK. So, for example, only 25% of Sweden's emissions appear to be deposited in Sweden and the remainder of their deposition comes in relatively small quantities from several other countries. The UK's contribution is estimated at 6% of Sweden's deposition which is about the same amount as that contributed by Poland and East Germany. But as is the case in a number of countries, the amount of deposition the source of which cannot be decided, exceeds all other amounts. The country which receives the highest proportion of its deposition from the UK is Norway, where UK-source deposition at 10% equals Norway's own contribution. Again, however, a lot of countries contribute to Norway's deposition and no less than 40% of their deposition is unattributable.

"From these figures it can be appreciated that the UK's position does differ to some extent from that of other countries. On the assumption--which not everyone agrees with--that a cut in emissions will result in comparable reduction in deposition, even a large reduction in the UK's total emissions would make very little difference to the deposition burden in other countries. . . .

"The picture for (nitrogen oxides) is probably very similar to that for (sulphur dioxide) except that West Germany is responsible for relatively more of the emissions so that there are likely to be some adjustments as a result of which the UK's exports will be relatively lower than those of (sulphur dioxide). . . .

"The situation on emissions is therefore not as straightforward as it is sometimes represented. On the figures provided by Governments, the UK is indeed the largest emitter of (sulphur dioxide) in western Europe and the second largest in Europe as a whole--although in terms of emissions per capita 9 other European countries are higher. We are not however the largest contributor to other countries' deposition--not only do four of the eastern countries exceed us in this respect but so does West Germany whose emissions contribute half as much again as ours to others' depositions.

"I think this shows that, purely in terms of reducing deposition in other countries, the effectiveness of measures to reduce UK emissions at a greater rate than they are already going down would be questionable. I should stress that I am not commenting on the effectiveness of emission in reducing environmental damage, which is quite another matter. I merely wish to illustrate that the figures do not reveal the UK to be the ogre it is sometimes called. And this is significant when policies are discussed.

"Another aspect of the problem--and this receives surprisingly little attention--is that in reducing emissions other environmental problems might be created. . . .

"Now to costs. Again if we consider controls on sulphur emissions we must first think of FGD. Present estimates suggest that the cost would be some £150m for retrofit of FGD at an existing 2000 MW power station and £1600m for a programme of FGD at 12 stations. These are significant sums, and the cost of reducing (nitrogen oxide) emissions--by use of low (nitrogen oxide) burners--might add a further £250m. But these burners would not meet the (EC) Directive's full requirements. Obviously if controls were retrofitted at fewer stations capital costs would be lower and the effect on electricity prices might be relatively small. But action to meet the EC Directive (on emissions from large plants) might add 5-6% to the UK's total electricity bill. And the sums involved are certainly sufficiently large to be a major consideration in any decision making process on policy.

"There is of course the other side of the coin--the costs to the environment. Here, as is often the case, costs are almost impossible to produce. Various attempts have been made, and I am sure many of you have seen them quoted, but those who have made these attempts have generally acknowledged the inaccuracy of their figures. . . .

"Finally there are the wholly political considerations. It is undeniable that those countries, including the UK, which have not joined the 30% club, are receiving a bad press in those countries which have. And this of course lends a diplomatic dimension to the problem. Within the UK, however, although many people are concerned about acidity, I think it is fair to say that air pollution is of less concern generally than is, for example, preservation of the countryside." (Burgess, 1985)

The above view shows that little can be expected from the British government with regard to abatement of major air pollutants from large emission sources other than those power plants for which retrofitting has been officially announced. Furthermore, the British attitude on air pollution policy expressed here remains the most identical to that revealed in a speech on UK environmental policy made before the German Foreign Policy Society in Hamburg, September 1985, by the Minister for the Environment at the DOE (see Environmental Policy and Law, 15/3/4, 1985, pp 106-115). At the November meeting of the EC Environment Ministers in 1985, another British official stated that the proposal by the EC Commission to cut SO₂, NO_x, and dust emissions from large power plants by up to 60% between 1980 and 1995 would cost the UK some £1.8 billion, which it could not afford.

However, official policy may be becoming less popular in the UK itself, with the government and especially the CEEB more isolated and subject to criticism from within the Conservative Party. A different view on the need for major emission reductions from British sources and their benefits for the UK and other countries is held by most of the environmental pressure groups, a number of independent British research institutions, the Royal Commission for Environmental Protection, the House of Lords Select Committee on the European Communities, the House of Commons Environment Committee and, prior to the 1987 election, by both major opposition parties.

In the House of Commons Environment Committee's Report on Acid Rain (Vol. 1, 1984), the following statements and recommendations were made.

"The Government must, of course, take fully account of these scientific questions in coming to its conclusions. . . . Throughout our Report we have sought to show the extent of evidence in separate areas for the value of reducing emissions. . . . We have taken full into account reservations which have been expressed to us, but we do not feel these outweigh the weight of evidence which we have received. We believe our work demonstrates that sufficient evidence exists to show that the decision to reduce emissions of (sulphur dioxide), (nitrogen oxides), and hydrocarbons should be taken now.

"Our inquiry has left us deeply disturbed over the United Kingdom's current policy position on acid rain. This policy appears to be that the case for controls is 'not proven' and that controls which have been approved are 'not cost-effective'.

"As our inquiry has progressed the stance of the United Kingdom has become increasingly isolated by its refusal to legislate to reduce (sulphur dioxide) and (nitrogen oxide) emissions. . . . (Sulphur dioxide) emissions in the United Kingdom have indeed fallen by 37 per cent since 1970, but the levels of high-stack emissions which affect remote areas have not fallen. In 1970, when the 37 per cent fall began, we were the largest emitter in Western Europe. In 1984, we are still the largest emitter. (Nitrogen oxide) emissions have not fallen. . . .

"Our work, in discussion with independent scientists in this country and abroad, in public and in private, has shown a massive degree of support for controls. Uncertainty over the mechanisms of damage persists, but in all hypotheses the culprits, ultimately, are (sulphur dioxide), (nitrogen oxides) and hydrocarbons. Evidence exists that reduced depositions will alleviate damage. Further evidence proves that a reduction in all emissions will lead to a reduction in depositions.

"Policy-makers have then to evaluate the cost element. This is not just a matter of cost benefit; many environmental benefits are unquantifiable. It is a matter of the cheapest possible methods of control, and whether a given price is reasonable to achieve benefits. Once imposed, control costs will fall as serious research into control methods begins. We firmly believe that the Government's present position pays too little heed to the weight of scientific consensus in Britain and in Europe that (sulphur dioxide), (nitrogen oxides) and hydrocarbons emissions are separately and in conjunction destructive to any natural and build environments. That position is accelerating the destruction of our cathedrals. It is destroying fish life. It is placing many of our most outstandingly beautiful areas at quite unacceptable risk. Controls must be introduced as soon as possible. . . .

"For the United Kingdom, the quickest way to reduce (sulphur dioxide) emissions is by retrofitting power stations: the technology, whilst costly and difficult, is available. We recommend

(a) that the United Kingdom join the 30 per cent club immediately, and that this target be achieved by the CEEB being required to reduce its emissions accordingly;

(b) that in the medium-term as power stations come to be refitted the CEEB should be required to instal (sic) equipment to attain the overall national reduction of 60 per cent in accordance with the EEC draft directive, that is, by the end of 1995. . . .

"Insofar as industry is concerned, we are aware that for some the high costs of meeting control standards may render them uncompetitive, and for others, even if cost is not of major consideration, it would be impractical to install control technology. Accordingly we recommend that

- (1) EC emission controls (sic) levels for (sulphur dioxide) should apply to all new industrial plants;
- (2) For all existing plants the stringent application of 'best practicable means' by the Air Pollution Inspectorate should continue;
- (3) The Government should give assistance to industry to convert existing plants to meet (sulphur dioxide) control standards.

"Turning now to (nitrogen oxides), we recommend, again consistent with 'best practicable means' that all power stations should have low (nitrogen oxide) burners installed during routine shutdowns. With the exception of those industries totally dependent on high combustion temperatures, which we feel should continue to explore other means of reducing their (nitrogen oxide) emissions, we recommend that all industrial users be required to fit low (nitrogen oxide) burners. As before, we recommend that Government assistance to industry to install low (nitrogen oxide) burners in existing plants. We recommend that new motor vehicles be required to have reduced (nitrogen oxide) emissions levels of 40 per cent by 1.1.87, and that the Department of Transport should inquire into the best possible means of reducing emissions from existing motor vehicles. . . .

"We have also emphasised in our Report the need for more research to improve technology to reduce emissions. High levels of reductions can be achieved for (sulphur dioxide). We recommend that the Government encourage the development of research to reduce further the levels of (nitrogen oxide) emissions. In order to assess more accurately the effect of individual pollution sources, we recommend that the Government require the emitters of (sulphur dioxide) and (nitrogen oxide), from plants over 50 MW to monitor their emissions sources.

"A more fundamental strategy is also needed, based upon energy conservation and the more efficient transmission of

energy. Combined heat and power and district heating are crucial components in this. It is essential that energy conservation be encouraged by Government incentives and the Government and the CEBG promote CHP/DH far more positively than either has to date." (House of Commons Environmental Committee, 1985, pp. lxx-lxxiii)

The government's response to the conclusions and recommendations of the House of Commons Environment Committee was cool.

"Consideration of the case for reduction of (sulphur dioxide) emissions has to have regard to the scientific, technological and economic position. . . .

"The arbitrary choice of 1980 as a base year masks the UK's achievements in the previous decade. UK (sulphur dioxide) emissions declined by 23 per cent from the peak year of 1970, when total emissions amounted to 6.09 million tonnes, to 4.7 million tonnes in 1980. In 1983 emissions amounted to 3.72 million tonnes, representing a cumulative reduction of nearly 40 per cent since 1970. This reduction has been due to a number of factors such as fuel substitution, energy conservation and industrial restructuring, which may continue to influence emission patterns over the next 15-20 years. It is reasonable to assume that much of this reduction will not be reversed as a consequence of continued industrial growth. However, the future pattern of industrial structure and energy use is not easy to predict, making it difficult in turn to estimate what further effort and investment might be required in order to be certain of achieving the targets set by the '30 per cent club'.

"The substantial costs of meeting the draft EC Directive have already been mentioned . . . : some £1.5 billion for power stations alone. This represents the costs of installing FGD at some ten major power stations at a capital cost and an annual operating cost of £150m and £35m respectively for each station. This would add some 5 per cent to electricity bills. Joining the 30 per cent club could require relatively little action to abate emissions if the trends in recent years . . . continue. But stronger growth in electricity demand could reverse these trends and could entail the installation of FGD at a number of power stations involving expenditure of several hundred million pounds. Control costs for industrial plants would be even higher in relation to the emissions abated.

"The Committee's recommendation that a 60 per cent reduction in emissions from large plants should be accomplished by 1995 by controls on CEBG power stations alone would be particularly onerous. Even on the assumption that power generation remained at the level of the past few years, achievement of the 60 per cent target would require retrofitting of controls to many more than the 10 major stations mentioned above. These would inevitably include a number of older stations

with a short remaining life and low load factors, substantially increasing the costs of such a programme and extending it well beyond 1995.

"The Government will continue to keep under review projections of likely future emission levels. It also believes that there are good prospects that new and better combustion technologies which will lead to reductions in (sulphur dioxide) emissions will be developed as a consequence of research now in hand or foreseen. In these circumstances the Government does not intend to commit the country to expensive emission controls, especially when there is uncertainty about the environmental benefits to be achieved in this country and in continental Europe. The Government intends to achieve further reductions in national (sulphur dioxide) emissions, aiming at a reduction of 30 per cent from 1980 levels by the end of the 1990s. . . .

". . . Emissions of (nitrogen oxides) are far more difficult to estimate than (sulphur dioxide) emissions, since combustion temperature as well as quantity of fuel influences the level of emissions. Best estimates are that industrial emissions have declined over the past 15 years although not to the same extent as (sulphur dioxide) emissions; this decline has been offset by increased vehicle emissions. Low (nitrogen oxide) burner technology does appear to have potential for reducing emission levels, but is not yet available in a form suitable for most UK power station boilers. . . .

". . . In consequence, it would not be sensible to set a target or timetable for emission reductions from existing plants, or emission limits on new plants. There can also be no question of the Government assisting industry to convert existing plants; this would be contrary to the polluter pays principle which must apply to (nitrogen oxides) as it does to other emissions. However, economically feasible technology to reduce (nitrogen oxide) emissions from vehicles is further advanced. Against this background, the Government intends to achieve further reductions in national nitrogen oxide emissions from motor vehicles, aiming again at a reduction of 30 per cent of the 1980 levels by the end of the 1990s." (DOE, 1984, pp. 23-25)

In June 1986, the Trade Union Congress (TUC) was reported to have asked the government to show "much greater commitment" to acid rain. However, the TUC's plea was not very strong; it called for more research on emission control and insisted that specific measures should be undertaken only when technologies are "reasonably established". Furthermore, the TUC wanted the CEBG and the coal industry to be shielded from the polluter pays principle, recommending FGD and low-NO_x burners for one power station if the government would bear the

costs. The TUC called for new power stations to be equipped with Presurised Fluidised Bed Combustion, but asked for government funding of the PFBC development programme sponsored jointly by the coal and electricity generating industries (ENDS, No. 137, 1986).

Since 1985 the opposition parties (Labour and the Alliance) have published a number of statements on environmental policy (ENDS, No. 128, 1985; ENDS, No. 138, 1986). These policy statements stress the need for the British government to take on a more positive, international role and to put Britain back in the forefront of action to improve the environment. They also call for more intensive promotion of renewable energy, improved energy efficiency, and increased efforts in air pollution abatement and control. Finally, these policy statements recommend Britain's joining the "30% Club".

Jobs and the Environment, an interim report by David Clark (1987), Member of Parliament, Labour Party, purported to show that if the kind of environmental policies already adopted in most progressive Western countries were put into practice in Britain, some 200,000 additional jobs could be created within 2 to 3 years (Clark, in assoc. with MacGarvin, 1987). Reports from other organisations and institutions generally came to similar conclusions, showing that strengthened environmental policy would have a positive impact on employment (see CEED Bulletin, No. 11, 1987). Finally, a report by the Confederation of British Industry entitled Clean Up--It's Good for Business (published in 1986), provides some indication that "industry is becoming more sensitive to international market demands for higher standards of environmental care" (CEED Bulletin, No. 11, 1987, p. 4).

An extensive opinion poll commissioned by the DOE and published in 1987 showed that most citizens want stricter laws and more positive action by government in the field of environmental protection policy (DOE, 1987). The results of this survey, the most detailed poll of public attitudes on environmental issues in the UK to date, were summarised in ENDS as follows.

"One early indication of the rising importance of environmental issues came at the beginning of the survey, when people were asked to say in their own words what are the most important problems facing Britain today. Environmental problems were named by 8%, joint sixth with housing after unemployment (75%), health and social services (22%), law and order (17%),

pensions (15%) and education (14%). No other issue scored over 4%.

"This result contrasts with the findings of 14 attitudinal surveys carried out in the 1970s. In all but two of these surveys only 1-4% of respondents mentioned pollution or environmental matters generally as priorities for government action, while in the remaining two polls the scores were 6% and 7%.

". . . The survey puts a new gloss on the findings of recent polls that people are less worried about their local environment than about issues on a larger scale. Half the sample said that the environmental problems in their locality had grown worse in the past five years, while only 7% had detected an improvement.

"Respondents were asked about their level of concern about 18 specific environmental issues. Clear majorities were 'very worried' about nuclear waste disposal and chemical pollution of waters, while between one-third and one-half were very worried about agrochemicals, wildlife destruction, bathing water quality and acid rain. . . .

". . . Only 29% of respondents thought that legislation had helped to protect the environment, while 53% believed that laws 'have made no difference'.

"Most people nevertheless retained their faith in legislation, with over 80% saying the Government should pass tougher laws. Stricter legislation was particularly favoured to deal with chemical pollution of rivers and seas (85% of respondents), nuclear waste disposal (76%), agrochemicals (73%), and industrial emissions into the atmosphere (71%). . . .

"Attitudes to a few problems were explored in greater depth-- and the conservationist current was particularly visible in people's replies to questions on air pollution in general and acid rain in particular. While 32% were unable to name a single cause of acid rain, and 19% included nuclear power stations among the causes, 85% said that the Government should spend money to prevent damage in other countries caused by the UK's acid emissions.

"Similarly, clear majorities were themselves prepared to pay for air pollution abatement measures. Almost 70% felt it would be a 'good idea' to put 16p on a gallon of petrol, against 25% who felt it to be a 'bad idea'; while 59% agreed would be happy (sic) to see 50p on their weekly electricity bill as against 34% who would be opposed.

". . . A final series of questions explored people's willingness to pay for environmental improvements in general when balanced against other priorities. A total of 42% were prepared to pay more themselves through higher product prices, rates or taxes, while another 36% felt that cuts could be made

in other areas of public spending to pay for enhanced environmental protection. . . .

"The only trade-off in which the environment came out second best was with unemployment. Only 24% felt that priority should be given to protecting the environment if this implied higher unemployment, while 56% of the entire sample, and 70% of the 18-24 year olds, were prepared to see the environment suffer in the cause of reducing unemployment." (ENDS, No. 146, 1987, p. 17)

Table 16 provides an overview on attitudes towards environmental protection in the UK.

The results of the DOE survey on environmental attitudes have been more or less supported by findings of a more recent opinion poll conducted in 1987 by MORI on behalf of Friends of the Earth and the World Wildlife Fund:

". . . 81% of respondents (felt) that Government should give a much higher priority to protecting the environment. However, voting intentions may be less strongly swayed by environmental considerations: only 4% of respondents said that the environmental policies of the parties would be crucial when making up their mind how to vote at the next general election. . . . On paying for measures to protect the environment, the MORI poll asked more specific questions about monetary trade-offs: 41% said they would pay a extra 2p per gallon of petrol to help reduce air pollution and acid rain, 34% said they would pay 1p more in income tax to protect the environment and conserve natural resources and 26% said they would be prepared to support a 5% increase in their food bill if this meant their fruit and vegetables would be free from pesticide residues." (CEED Bulletin, No. 12, 1987, p. 7)

Although, as revealed in the DOE's opinion poll, there is a certain hesitancy on the part of the British to trade-off employment and environment, the overall results of recent polling in conjunction with statements from various environmental organisations, political parties, and expert commissions on air pollution issues reveal that the government's cost-benefit deliberations regarding air pollution control tend to be biased in favour of sheer economic interests. In fact, there appears to be greater scope for manoeuvring and greater public pressure on the government to tighten environmental policy than was the case previously; but it should be borne in mind that air pollution problems have been considerably less politicised in the UK than elsewhere and that the British public in general has a much lower interest in the long-range transport of air pollutants and forest damage than other Europeans,

Table 16. Attitudes towards environmental protection—opinion poll 1986

Environmental Problem	Relative Concern (in Percentages)			
	Very worried	Quite worried	Not Very worried	Not at all worried
Chemicals put into rivers and seas	54	32	8	6
Getting rid of nuclear waste	62	20	9	8
Destruction of wildlife	38	44	12	6
Dirty beaches and bathing waters	37	42	13	8
Insecticides, fertilisers, and chemical sprays	39	35	16	9
Litter and rubbish	30	42	20	8
Decay of inner cities and derelict land	27	42	20	11
Acid rain	35	33	16	16
Losing "green belt" land	26	40	19	14
Oil slicks from ships	27	37	23	12
Fumes and smoke from factories	26	37	22	15
Car exhaust fumes	23	37	26	14
Fouling by dogs	30	29	26	14
Loss of hedgerows	17	36	28	19
Neglect of old buildings and monuments	11	29	34	20
Lack of access to open spaces/countryside	11	29	33	26
Ugly new buildings	13	26	32	28
Traffic, aircraft, lawnmower etc., noise	10	22	37	31

Source: DOE (1986a). Quoted in CEED Bulletin, No. 12, 1987.

particularly the Scandinavians, the Dutch, the Swiss, the Austrians, and West Germans (Watts, 1987; Richardson and Watts, 1985; Kimber and Richardson, 1974).

7. BASIC FEATURES OF AIR POLLUTION CONTROL POLICY

This section provides a brief description of the basic elements of British air pollution control policy for major pollutants, drawing on the information in foregoing sections. (The politics of air pollution control in Britain are described and generalised in Blowers, 1986.) The British air pollution control regime is based on the fundamental principle of BPM which permits a great deal of flexibility and latitude in standard setting and implementation. In the case of smoke (grit and dust as well) emissions, this flexibility was used successfully to reduce emissions at source. In contrast to this approach, as regards SO_2 and NO_x , the practice has been to dilute emissions through regulation of chimney heights in a way so as to render emissions harmless in the immediate vicinity. This practice also contradicts claims that the basic approach to pollution control in Britain is to reduce emissions at the source; the actual policy was until recently to permit almost unlimited emissions of SO_2 and NO_x from stationary sources. The only relevant means of control has been constructing tall chimneys. The decision in 1986/7 to retrofit three power stations with FGD and some others with low- NO_x burners, although not yet implemented, is still the first substantial.

The "high chimney policy" leads, in effect, to a "problem shifting approach" (Weidner, 1986), particularly with respect to long-range transport of major pollutants and the effects of this on other countries. From an international perspective, the British approach can be characterised as "selfish", or the "egocentric" environmental policy approach, because it served only to clean up British towns and countryside at the expense of neighbouring European countries. This approach did not change significantly until recently, although the UK is one of the signatories (1979) of the Convention on Long-Range Transboundary Air Pollution. Furthermore, the EC directive on ambient air quality standards for SO_2 and smoke, which has already gone into effect in the UK, has had only little effect on the traditional British pollution control approach, at least as it is practiced (Knoepfel and Weidner, 1985; for a contrasting opinion, see Haigh, 1984). To be fair, the same charge of "selfishness" or "policy egocentrism" can be levied justifiably against most other EC member countries whose main form of pollution abatement was also the high chimney. The difference, however, between the UK

and other countries lies in its stubborn reluctance to change this policy in the face of new evidence (Wetstone and Rosencranz, 1983; Knoepfel and Weidner, 1985; Weidner, 1986).

Strict reliance by government on cost-effectiveness considerations and scientific certainty as a precondition for pollution abatement measures are two further elements of the British approach to pollution control. Both principles are interpreted in a manner strongly biased in favour of British emitters and British interests in general. The cost-benefit argument was used by British government to avoid the necessity of retrofitting stationary and mobile emission sources with available abatement technologies. Scientific uncertainty about the harmful effects of pollutants on the environment and human health is also used as an argument by the British government as why abatement measures are therefore economically unreasonable as well as unnecessary from an environmental perspective. This attitude does not, however, take into account the recognition shared by many environmental scientists that the complexity of environmental interactions virtually precludes the establishment of a precise dose-effect relationship. Furthermore, although the British government and the big emitters demand from environmentalists and others who insist on the implementation of abatement measures, that the criterion of scientific certainty about the harmfulness of pollutants must be fully satisfied, they themselves are unable to fulfill this rigid requirement. The UK government and emitters cannot prove with certainty that their own activities and policies are not harmful to the environment and human health. Once the burden of proof is placed on government, the weakness of official arguments becomes apparent.

In general, the financial risks of litigation and the rules governing legal costs have inhibited British environmental groups from engaging in the kinds of legal action more prevalent in countries such as the United States. Furthermore,

" . . . in critical areas such as pollution control, the judiciary in this country (the UK) have contributed little to the interpretation and conceptual development of the complex statutory framework of laws that now exist. . . . One example, which still never fails to surprise visiting lawyers from other countries: we have yet to see a decision of the higher courts interpreting the meaning of 'best practicable means' as it appears in the legislations concerning major industrial air emissions and that despite it being the

formula that has formed the heart of such controls for over a hundred years." (CEED Bulletin, No. 10, 1986, p. 20)

In summary, the British arguments in defence of current positions and in spite of recent progress remain biased towards narrow national interests and the polluting industries. The government demands from those who insist on greater efforts that they provide conclusive evidence for their claims. However, the government itself does not adhere to such scientific rigour with respect to its own measures. From a political point of view, therefore, the main objective of most British arguments is to erect barriers against the claims of other countries and increasingly the British public, in order to avoid having to fulfill demands for the adoption of emission abatement technologies that have actually been available for quite some years (in Japan, for instance, FGD and "denox" equipment were installed in the early 1970s) (Weidner, 1985).

Despite growing international and national protest, the British government's policy has nevertheless remained one of problem transfer: the pollutants are merely dispersed through the use of high chimneys. The UK government has not even adopted an effective "react and cure" strategy. Emphasis is placed on repair after environmental damage has occurred. In this respect, an "anticipate and prevent approach"—that is, the implementation of long-term policy which gives due consideration to the whole "ecological context" and is designed to avoid environmental damage (Jänicke, 1985; O'Riordan, 1985; Scimemi, 1987)—is still a long way off. The "wait-and-see" attitude in conjunction with a "case-by-case" approach have made British air pollution control policy for major pollutants not only unacceptable, but also totally unsuitable for tackling existing or future environmental problems resulting from trans-boundary air pollution. To change present policy substantially will be a difficult task, and probably more so in the UK than it has or would be in other European countries, because official government policy to control air pollution has concentrated for so long on manipulating or defending past policy rather than developing new, future-oriented preventative policies.

8. OUTLOOK

Under the Convention on Long-Range Transboundary Air Pollution, which came into force in 1983, the signatories committed themselves to develop, without undue delay, policies and strategies for combatting the emission of major air pollutants, using the best available abatement technology. On the basis of the preceding discussion of British air pollution control policy, this section provides a brief overview of what other Europeans may expect from the UK in terms of implementation of these international objectives in the medium-term future.

Past and present British government policy on the emission of SO₂ and NO_x does not give much ground for optimism. Effective measures which would significantly reduce the total emission load by the mid-1990s are unlikely to be adopted. The British government has promised but did not commit itself to a 30% reduction of its 1980 emission levels by the end of the 1990s. The view that the British government will make only half-hearted attempts to reduce emissions of major air pollutants is lent support by the following facts.

- It has declined to take drastic measures to combat acid rain in spite of recommendations to this effect by the House of Lords Select Committee on the European Communities, the House of Commons Environment Committee, and many British environmental organisations.
- The British government had declined until recently to retrofit existing fossil fuel power plants with flue gas desulphurisation equipment although it is now committed to FGD for new power plants.
- There is currently no legislation (and none planned) to make denitrification equipment mandatory for large boilers. It was announced in 1987 that 12 power stations are to be retrofitted with low-NO_x burners, but this equipment has a much lower cleaning efficiency than, for instance, "denox" facilities which use the selective catalytic reduction method.
- Together with France and Italy, the British government has successfully opposed the implementation within the EC of strict car exhaust limits which would have made mandatory the use of 3-way catalytic converters for medium sized cars.
- The British government still fears that massive reductions in emissions would inhibit economic development and that there is a need for more

research and greater certainty in the scientific data on damage by air pollutants to justify costly abatement measures.

- The British government refuses to join the "30% Club", the members of which have pledged, as soon as possible, but at the latest by 1993, to reduce their total SO₂ emissions by at least 30% of their 1980 levels.
- The British government did not support the international agreement to reduce each ECE member country's NO_x emissions by 30% between 1985 and 1995 as proposed in the September 1987 meeting in Geneva of the working group set up under the ECE Convention on Long-range Transboundary Air Pollution. Austria, the Netherlands, Sweden, Switzerland, and West Germany were the only countries to argue for a reduction target to be included in the NO_x protocol. The UK and some other countries as well were only willing to discuss a freeze on NO_x.
- The British government is--like some other member countries--opposed to the proposed EC directive which originally required member states to reduce SO₂, NO_x, and dust emissions from existing large plants by 60%, 40%, and 40% respectively, and which would also require the imposition of strict emission limits for these pollutants on all new large plants. (This directive was modelled on the West German Großfeuerungsanlagen-Verordnung, the large combustion plants ordinance of 1983.) However, a compromise giving the UK and other EC member states a bonus for their pre-1980 emission reductions is considered acceptable to the British government.
- Finally, there are few positive indications that the British government and the CEGB, the major British power plant operator and also the biggest emitter of SO₂ in Britain intend to steer the present energy supply structure into an environmentally more benign direction.

Finally, two recently published studies are worth noting because they shed even more doubt upon the British government's ability to keep its promise to reduce emissions significantly by the end of the 1990s. A report by the UK-based economic forecasting group, "DRI Europe Ltd" completed in early 1986, gives estimates of likely sales within the EC of emissions controlled petrol-engined and diesel-engined cars and vans. The report concluded inter alia EC member countries such as the UK, France, Belgium, Italy, and Spain, where small cars form the bulk of automobile demand, are likely to avoid stricter car emission standards

(requiring the 3-way catalytic converter), and that unleaded petrol will be available in substantial quantities only in the FRG, the Netherlands, and Denmark, long before it is in the UK and France. As it will take a long time before new, cleaner cars replace those currently on the road, it is estimated that the majority of petrol-engined cars in use will not conform to the new EC standards (which are still relatively weak compared to those already in force in the US and Japan) until 1998 (Europe Environment, No. 252, 1986).

Secondly, there is the study by Jim Skea (1987) for the British Watt Committee Acid Rain Group, which deals with the prospects of UK emissions of acid precursors during the coming decades if now new environmental laws or regulations are passed. It concludes that recent decisions by the British government to retrofit existing coal-fired power stations with a capacity of 6000 MW and all new coal-fired power stations with FGD, and to retrofit 12 power stations with low-NO_x burners should allow the DOE target of a 30% reduction in SO₂ and NO_x emissions by the end of the 1990s to be met. However,

"... the 30% Club target will be attained only under adverse economic circumstances, if a vigorous energy conservation programme is initiated or if a combination of other measures, such as importing low sulphur coal, using more natural gas or building a second Channel electricity link, was undertaken. . . . The emission reductions proposed by the EEC for (sulphur dioxide) and (nitrogen oxides) could not be obtained without active abatement measures under any foreseeable combination of circumstances; in the longer term, beyond the end of the century, there is a clear prospect for significantly reduced levels of all types of emissions." (Skea, 1987, p. 8)

To conclude, positive indicators for mid-term improvements in the air pollution control policy of Europe's major polluter, the United Kingdom, remain sparse. On the one hand, this negative prognosis is due partly to the UK's economic recovery which began in 1987 and is expected to continue; on the other, it is a result of expected delays in the CEEB's investment plans for FGD and British motor manufacturers' reluctance to invest in lean-burn engine development, a technology designed to reduce NO_x emissions from automobile exhaust and increase fuel efficiency. Altogether, these factors do not augur well for significant reductions of SO₂ and NO_x emissions in the near future. In fact, if the UK government does not begin to strengthen its efforts towards reducing the

nation's acid gas emissions soon, it is not very likely that it will meet its target to reduce total sulphur and nitrogen oxide emissions by 30% between 1980 and 1999—a rather modest policy aim compared to those recently adopted by some other European countries.

This implies that other European countries must face up to the unhappy prospect of continuing to receive considerable pollution loads from the UK. Although there is increasing pressure by British environmental organisations and parliamentary organs, foreign governments, international institutions, and European environmental organisations on the British government to improve its air pollution control policy, as well as mounting evidence of domestic damage from air pollutants, it is nevertheless still too early to predict whether the British government will react to this pressure in a more effective way than it has up to now. There is at least some positive indication that Britain's long-standing insensitivity to international pressure has notably decreased. The British approach to tackling air pollutants has undergone substantial changes in recent years. Under this new approach, still in the design stage, more effective pollution control measures giving greater attention to the international environmental context are possible.

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STATISTICAL ANNEX

A Set of Core Information on Air Pollution in the European Community

Sources: EUN/ECE, National Strategies and Policies for Air Pollution Abatement, Geneva 1987; idem, European Forest Damages Intolerably High, Press Release ECE/ENV/9, July 2, 1987; OECD, Environmental Data Compendium 1987, Paris 1987; as well as statistical data collected and computed by the author.

Attention: When interpreting these tables, caution should be exercised because definitions and classifications may vary from country to country.

1

	POPULATION Unit: 1000	AREA 1000 sq.km	POPULATION DENSITY Inhabitants per sq.km	GROSS DOMESTIC PRODUCT IN PURCHASERS' VALUES Billion US \$ 1980	INDEX GDP 1980 = 100		UNEMPLOYMENT RATE, 1984 in %
					1970	1985	
BELGIUM	9 900	31	323	117.80	72.9	103.2	14.4
DENMARK	5 100	43	119	66.32	80.2	111.8	10.0
FRANCE	54 300	544	100	655.37	70.0	105.7	10.2
GERMANY, F.R.	61 400	249	247	813.65	76.6	106.5	8.4
GREECE	9 900	132	75	40.15	63.1	104.8	1.9
IRELAND	3 500	70	50	19.23	64.3	109.3	16.5
ITALY	56 700	301	188	395.52	73.5	104.7	12.9
LUXEMBOURG	400	3	141	4.54	75.8	112.8	1.7
NETHERLANDS	14 300	41	349	169.38	75.1	103.4	14.4
PORTUGAL	10 100	92	110	25.09	62.2	105.1	1983: 8.2
SPAIN	38 400	505	76	212.12	69.4	107.1	20.5
UNITED KINGDOM	56 400	244	231	534.03	82.8	109.7	11.9

	Motor Vehicles in Use Unit: 1000		Change 1970 - 1985 in %		Road Traffic Volumes of all Vehicles in billion veh.-km		Change 1970 - 1985 in %		Total HC/VOC Emission ^{*)} Year 1000 Metric Tonnes		Total CO Emission Year 1000 Metric Tonnes	
	1970	1985	1970	1985	1970	1985	1970	1985	Year	Year	Year	Year
BELGIUM	2 327	3 662	57		33.3	47.3	42				1980	839
DENMARK	1 329	1 767	33		23.0	29.7	29		1980	106 ^x	1980	602 only mobile sources
FRANCE	14 395	24 366	69		208.0	328.0	58		1984	2 000 - 2 300	1980	5 200 ^x excl. ind. processes
GERMANY, F.R.	15 107	27 416	82		234.2	338.9	53		1986	2 400	1986	9 300
GREECE	345	1 885	446		9.2	28.6	211		1978	82 ^x excl. industr. processes	1978	695 excl. ind. processes
IRELAND	446	808	81		10.7	18.8	76		1984	62	1985	456
ITALY	11 134	24 300	118		146.4	257.8	76		1978	496 ^x excl. industr. processes	1978	4 036 excl. ind. processes
LUXEMBOURG	105	165	57		1.5	2.5	67					
NETHERLANDS	2 777	5 200	87		48.3	77.7	61		1981	434	1984	1 112
PORTUGAL	668	2 210	231		9.4	29.1	210		1983	376	1980	533
SPAIN	3 119	10 884	249		34.2	75.1	120		1980	739 ^x	1980	3 780
UNITED KINGDOM	13 571	19 660	45		178.9	277.2	55		1985	2 059	1985	5 394

*) HC/VOC data marked x from OECD, Environmental Data 1987.

PRIMARY ENERGY REQUIREMENTS
BY SOURCE IN MTOE

3

	Solid Fuels		Oil		Gas		Nuclear Power		Hydro-, Geothermal and Solar Energy	
	1973	1985	1973	1985	1973	1985	1973	1985	1973	1985
BELGIUM	11.2	9.9	27.6	17.4	7.3	7.5	0.0	7.7	0.1	0.3
DENMARK	2.2	8.0	17.4	10.9	0.0	0.6	0.0	0.0	0.0	0.0
FRANCE	29.4	25.2	122.6	84.5	13.8	25.1	3.3	50.1	10.8	14.4
GERMANY, F.R.	84.8	82.8	188.2	112.0	26.3	41.5	2.6	28.1	3.5	3.9
GREECE	2.6	6.5	9.4	11.1	0.0	0.1	0.0	0.0	0.5	0.6
IRELAND	1.6	2.6	5.5	4.3	0.0	2.0	0.0	0.0	0.1	0.3
ITALY	10.1	16.5	97.6	81.9	14.5	27.7	0.7	1.6	9.3	10.6
LUXEMBOURG	2.4	1.5	1.7	1.1	0.2	0.3	0.0	0.0	0.2	0.1
NETHERLANDS	3.2	6.7	30.8	21.2	29.0	33.0	0.3	0.9	0.0	0.0
PORTUGAL	1.2	1.6	5.4	8.5	0.0	0.0	0.0	0.0	1.6	2.4
SPAIN	9.0	19.6	37.6	39.0	1.0	2.2	1.5	6.3	6.6	7.4
UNITED KINGDOM	76.6	61.8	111.3	78.3	25.6	47.5	6.3	13.7	1.0	1.6

4

NUCLEAR POWER PLANTS OPERATED

	NUCLEAR POWER PLANTS OPERATED		Percentage of Total Electricity Supply 1986	TOTAL ENERGY REQUIREMENTS in MTOE		
	Number 1985	Gross Capacity in MW 1985		1980	1983	1985
BELGIUM	8	5 700	67.0	45.61	39.75	42.83
DENMARK	—	—	—	19.37	16.59	19.46
FRANCE	43	39 500	69.8	194.20	186.25	197.16
GERMANY, F.R.	19	17 300	29.4	274.53	252.69	268.50
GREECE	—	—	—	16.24	16.81	18.38
IRELAND	—	—	—	8.69	8.66	9.16
ITALY	3	1 300	4.5	142.78	135.50	140.21
LUXEMBOURG	—	—	—	3.71	2.94	3.27
NETHERLANDS	2	540	6.2	65.96	57.80	62.15
PORTUGAL	—	—	—	11.42	12.48	12.76
SPAIN	8	5 800	29.4	71.77	71.93	74.31
UNITED KINGDOM	21	11 900	18.4	201.32	193.02	202.80

TOTAL SO₂ EMISSION
in 1000 Metric Tonnes

	in 1000 Metric Tonnes			Reduction Rate			Reduction Rate from 1980		
	Year	Amount	Year	Amount	from	to	%	to	%
BELGIUM	1970	1 033	1984	467	1970	1984	55	1984	42
DENMARK	1970	523	1985	326	1970	1985	38	1985	26
FRANCE	1971	2 966	1985	1 845	1971	1985	38	1985	48
GERMANY, F.R.	1970	3 600	1985	2 400	1970	1985	33	1985	25
GREECE			1983	720				1983	10
IRELAND	1972	186	1985	138	1972	1985	26	1985	37
ITALY	1972	3 200	1983	3 150	1972	1983	2	1983	17
LUXEMBOURG	1970	35	1985	13	1970	1985	63	1985	44
NETHERLANDS	1970	685	1983	315	1970	1983	54	1983	35
PORTUGAL	1970	116	1983	305	1970	1983	+ 62	1983	+ 13
SPAIN	1975	3 004	1983	3 250	1975	1983	+ 8	1983	0
UNITED KINGDOM	1970	6 120	1985	3 580	1970	1985	42	1985	23

TOTAL NO_x EMISSION
in 1000 Metric Tonnes

	1980			Year	Amount			Change Rate			Change Rate from 1980		
	Year	Amount	1980		Year	Amount	Amount	from	to	%	to	to	%
BELGIUM			442	1984	385						1984	- 13	
DENMARK	1970	192	251	1985	238		1970	1985	+ 19		1985	- 5	
FRANCE	1973	1 699	1 867	1985	1 693		1973	1985	- 0.4		1985	- 9	
GERMANY, F.R.	1970	2 400	3 100	1985	2 900		1970	1985	+ 17		1985	- 7	
GREECE			127	1983	150						1983	+ 15	
IRELAND	1972	55	67	1985	68		1972	1985	+ 19		1985	+ 1.5	
ITALY			1 480 a)	1983	1 462 b)						1983	- 1.2	
LUXEMBOURG			23	1985	22						1985	- 4	
NETHERLANDS	1970	398	535	1983	522		1970	1983	+ 24		1983	- 2.4	
PORTUGAL	1970	72	166	1983	192		1970	1983	+ 63		1983	+ 14	
SPAIN	1975	624	ca. 950	1985	950 c)		1975	1985	+ 34		1985	0	
UNITED KINGDOM	1970	2 033	1 916	1985	1 837		1970	1985	- 10		1985	- 4	

a) Arithmetic mean; basic data: 1 410 - 1 550 000 Metric Tonnes

b) Arithmetic mean; basic data: 1 387 - 1 537 000 Metric Tonnes

c) Arithmetic mean; basic data: 779 - 1 122 000 Metric Tonnes

TOTAL SO₂ EMISSION PER :

7

	Most Recent Year	Area in tonnes/sq.km		Inhabitants in kg/cap.		Unit of Gross Domestic Product in kg/1000 US \$		Unit of Energy Requirements in kg/TOE	
		most rec. year	1980	most recent year	1980	most recent year	1980	most recent year	1980
BELGIUM	1984	15.07	25.77	47.17	80.71	6.78		11.26	17.52
DENMARK	1985	7.58	10.19	63.92	85.88	6.60		16.75	22.61
FRANCE	1985	3.39	6.54	33.98	65.53	5.43		9.36	18.32
GERMANY, F.R.	1985	9.64	12.85	39.09	52.12	3.93		8.94	11.66
GREECE	1983	5.46	6.06	72.73	80.81	19.93		42.83	49.26
IRELAND	1985	1.97	3.13	39.43	62.57	11.39		15.07	25.20
ITALY	1983	10.47	12.63	55.36	67.02	9.61		23.25	26.61
LUXEMBOURG	1985	4.33	7.67	32.50	57.50	5.07		3.98	6.20
NETHERLANDS	1983	7.68	11.88	22.03	34.06	2.88		5.45	7.38
PORTUGAL	1983	3.32	2.89	30.20	26.34	10.60		24.44	23.29
SPAIN	1983	6.44	6.44	84.64	84.64	15.32		45.18	45.28
UNITED KINGDOM	1985	14.67	19.14	63.48	82.80	8.75		17.65	23.20

* TOE from 1985

8

TOTAL NO. x EMISSION PER :

	Most Recent Year	Area in tonnes/sq.km most rec. year 1980	Inhabitants in kg/cap. most recent year 1980	Unit of Gross Domestic Product in kg/1000 US \$ 1980	Unit of Energy Requirements in kg/TOE most recent year 1980
BELGIUM	1984	12.42	38.89	3.75	9.28
DENMARK	1985	5.54	46.67	3.79	12.23
FRANCE	1985	3.11	31.18	2.85	8.59
GERMANY, F. R.	1985	11.65	47.23	3.81	10.80
GREECE	1983	1.14	15.15	3.16	8.92
IRELAND	1985	0.97	19.43	3.48	7.42
ITALY	1983	4.86	23.79	3.74	10.37
LUXEMBOURG	1985	7.33	55.00	5.07	6.73
NETHERLANDS	1983	12.73	36.50	3.16	9.03
PORTUGAL	1983	2.09	19.01	6.62	15.39
SPAIN	1985	1.88	24.74	4.48	12.78
UNITED KINGDOM	1985	7.53	32.57	3.59	9.06

* TOE from 1985

SO₂ EMISSIONS :
BY SOURCE IN 1000 METRIC TONNES AND PERCENTAGE CONTRIBUTION

Year	Stationary Combustion Sources	%	Industrial Non-combustion Sources	%	Non-industrial and domestic sources incl. resid. heating	%	Mobile Sources	%
BELGIUM	300	64	80	17	64	14	23	5
DENMARK	264	81			47	14	15	5
FRANCE	1 288	70	227	12	223	12	107	6
GERMANY, F.R.	1 990	82	110	5	230	9	90	4
GREECE	Power Plants	61	Industry	30	Small Sources	9		
IRELAND	Power Plants	31	Industry, incl. commercial sect.	48	Small Sources	17		
ITALY	Power Plants	52	Industry	30	Small Sources	12		
LUXEMBOURG	6	45	5	37	1.6	12	0.8	6
NETHERLANDS	211	67	56	18	13	4	35	11
PORTUGAL	216	71	77	25			12	4
SPAIN		73		23		4		
UNITED KINGDOM	3 180	90			310	9	50	1

NO_x EMISSIONS :
BY SOURCE IN 1000 METRIC TONNES AND PERCENTAGE CONTRIBUTION

Year	Stationary Combustion Sources	%	Industrial Non-combustion sources	%	Non-industrial and domestic sources incl. resid. heating	%	Mobile Sources	%
BELGIUM	87	23	20	5	26	7	252	65
DENMARK	144	60	1	0.4	8	3.6	85	36
FRANCE *	370	22	53	3	140	8	1 130	67
GERMANY, F.R.	1 090	37	20	1	130	5	1 670	57
GREECE	Power Plants	17	Industry	9	Small Sources	2		72
IRELAND	Power Plants	33	Industry, incl. commercial sect.	7	Small Sources	7		34
ITALY	Power Plants	24	Industry	14	Small Sources	16	ECE-Data for 1983: 51-46%	46
LUXEMBOURG	2.5	11	3.6	17	1.6	7	14	65
NETHERLANDS	138	27	23	4	38	7	323	62
PORTUGAL	44	23	28	15			120	62
SPAIN	350-357 a)	37	110-204 b)	16			339-361 c)	47
UNITED KINGDOM	830	49	100	6			750	45

* not including 700 t from agricultural activities

a) Arithmetic mean: 354

b) Arithmetic mean: 157

c) Arithmetic mean: 450

INDEX : TOTAL SO₂ AND NO_x EMISSIONS IN 1980 PER

11

	AREA in tonnes/sq.km		INHABITANTS in kg/cap.		GROSS DOMESTIC PRODUCT in kg/1000 US \$		ENERGY CONSUMPTION in kg/TOE	
	SO ₂	NO _x	SO ₂	NO _x	SO ₂	NO _x	SO ₂	NO _x
BELGIUM	100	100	94	78	34	57	36	67
DENMARK	40	41	100	86	33	57	46	89
FRANCE	25	24	76	60	27	43	37	66
GERMANY, F.R.	50	87	61	88	20	58	24	78
GREECE	24	7	94	22	100	48	100	54
IRELAND	12	7	73	33	57	53	51	53
ITALY	49	35	78	45	48	57	54	71
LUXEMBOURG	30	54	67	100	25	77	13	43
NETHERLANDS	46	92	40	65	15	48	15	56
PORTUGAL	11	13	31	29	53	100	47	100
SPAIN	25	13	99	43	77	68	92	91
UNITED KINGDOM	74	55	96	59	44	54	47	66
INDEX 100 =	25.77	14.26	85.88	57.50	19.93	6.62	49.26	14.54

	Convention on Long-Range Transboundary Air Pollution (as of 1 July 1987) Date of Ratification:	SO ₂ Protocol "30 - Percent - Club" (as of 1 July 1987)		Promised/Planned SO ₂ Reduction from 1980		EMEP Protocol on Long-Term Financing of the Co-operative Programme for Monitoring and Evaluation ...	
		Signature	Ratification	%	until	Signature	Ratification
BELGIUM	July 1982	July 1985		50	1995	Feb 1985	
DENMARK	June 1982	July 1985	April 1986	50	1995	Sept 1984	April 1986
FRANCE	Approval: Nov 1981	July 1985	Approval: March 1986	50	1990	Feb 1985	
GERMANY, F.R.	July 1982	July 1985	March 1987	60	1993	Feb 1985	Oct 1986
GREECE	Aug 1983						
IRELAND	July 1982					April 1985	June 1987
ITALY	July 1982	July 1985		30	1993	Sept 1984	
LUXEMBOURG	July 1982	July 1985		58	1990	Nov 1984	
NETHERLANDS	July 1982	July 1985	Acceptance: April 1986	50	1995	Sept 1984	Acceptance: Oct 1985
PORTUGAL	Sept 1980						
SPAIN	June 1982						
UNITED KINGDOM	July 1982					Nov 1984	Aug 1985

	DAMAGE TO FORESTS	AMBIENT AIR QUALITY STANDARDS (LONG-TERM AVERAGE)	
		SO ₂	NO ₂
BELGIUM	18 % of total forested area	80/779/EEC = 0.08/0.12 mg/m ³	85/203/EEC (only short-term standard) = 0.20 mg/m ³ 98 perc.
DENMARK	Western peninsula of Jylland	80/779/EEC	85/203/EEC (see Belgium)
FRANCE	38% of coniferous trees 1986 (1 Million hectares surveyed)	80/779/EEC	85/203/EEC (see Belgium)
GERMANY, F.R.	5% of total forested area (1986)	0.14 mg/m ³ and 0.07 in areas with concentr. below 0.05 mg/m ³	0.08 mg/m ³
GREECE	no information	80/779/EEC	85/203/EEC (see Belgium)
IRELAND	no information	80/779/EEC	85/203/EEC (see Belgium)
ITALY	5 % of total forested area (1986)	80/779/EEC	85/203/EEC (see Belgium)
LUXEMBOURG	20 % of coniferous trees (1986)	80/779/EEC	85/203/EEC (see Belgium)
NETHERLANDS	59 % of coniferous trees (1986)	0.075 mg/m ³ 50 perc./24 h 0.250 mg/m ³ 98 perc./24 h	0.135 mg/m ³ limit value 0.080 mg/m ³ guide value
PORTUGAL	no information	0.08 mg/m ³ daily mean 0.25 mg/m ³ 98 perc. all d.m./y.	85/203/EEC (see Belgium)
SPAIN	39 % of coniferous trees 1986 (500 000 hectares surveyed)	80/779/EEC	85/203/EEC (see Belgium)
UNITED KINGDOM	67 % of coniferous trees 1986 (1 461 000 hectares surveyed).	80/779/EEC	85/203/EEC (see Belgium)

	Emission Charge System	Car Exhaust Standards: Support for stricter Standards as in the EEC Directive	Green Parties in National Parliament	Number of petrol stations with unleaded petrol *	
				1986	June 1987
BELGIUM	no		yes	100	69
DENMARK	no	yes	no	900	2 500
FRANCE	Since 1986 very small charge on SO ₂ Emissions	no	no	89	253
GERMANY, F.R.	no	yes	yes	12 500	14 500
GREECE	yes	no	no	40	34
IRELAND	no	no	no	—	7
ITALY	no	no	yes	90	300
LUXEMBOURG	no		yes	24	100
NETHERLANDS	Fuel levy	yes	no	8 000	8 000
PORTUGAL	no		no	—	21
SPAIN	no	no	no	70	42
UNITED KINGDOM	no	no	no	174	300

* Figures for 1986 provided by the European Commission;
Figures for June 1987 provided by Ministry of the Environment, F.R. Germany.

	Abatement Technology in Large Combustion Plants in operation or under construction				Sulphur Content Limit Value for Gasoil in weight-%	General Speed Limit km/h	
	Flue Gas Desulfurization	Flue Gas Denitrification	Fluidized Bed Combustion			Motorways	Trunk Roads
BELGIUM	no	no	no		120	90	
DENMARK	yes	no			100	80	
FRANCE	no	no	yes		130	90	
GERMANY, F.R.	yes	yes	yes	0.3 (0.2 1988)	no	100	
GREECE	no	no	no	0.3	80	80	
IRELAND	no	no	no	0.3-0.5	97	97	
ITALY	yes	no	no	0.3	90/140	80/110	
LUXEMBOURG	no	no	no	0.3-0.5	120	90	
NETHERLANDS	yes	yes	yes	0.3	100	80	
PORTUGAL	no	no	no	0.5	120	90	
SPAIN	no	no	no	0.3-0.5	120	90	
UNITED KINGDOM	planned	no	yes	0.3-0.5	112	97	

RANKING LIST
SO₂ EMISSION (INDEX)
1980

COUNTRY	INDEX
GREECE	80
SPAIN	73
BELGIUM	66
UNITED KINGDOM	65
ITALY	57
DENMARK	55
IRELAND	48
FRANCE	41
F.R. GERMANY	39
PORTUGAL	36
LUXEMBOURG	34
NETHERLANDS	29

Note: Mean values of indices for area, inhabitants, GDP, and energy requirement.
The higher the number, the more unfavourable the emission situation.

RANKING LIST
NO_x EMISSION (INDEX)
1980

COUNTRY	INDEX
F.R. GERMANY	78
BELGIUM	76
LUXEMBOURG	69
DENMARK	68
NETHERLANDS	65
PORTUGAL	61
UNITED KINGDOM	59
SPAIN	54
ITALY	52
FRANCE	48
IRELAND	37
GREECE	33

Note: Mean values of indices for area, inhabitants, GDP, and energy requirement.
The higher the number, the more unfavourable the emission situation.