UK Emissions of Air Pollutants 1970 to 2004

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Executive Summary

1 This is the 18th annual report from the UK National Atmospheric Emissions Inventory (NAEI), and is produced by the National Environmental Technology Centre.

2 **UK air pollutants -** This report presents the latest estimates of emissions to the atmosphere from the UK for the period 1970 to **2004.** 44 pollutant species are included in the 2004 annual inventory including 10 pollutant groups (NMVOC, Particulate Matter, PCDD/F, PAH, PCB, HFC, PFC, SCCP, PCN and PBDE). Size fractionation is available for particulate matter and speciation is available for: 500 NMVOCs, oxidation states of Hg, Ni and Cr, 11 PAHs and 209 PCBs. The pollutants considered in this report are:

Greenhouse Gases

- carbon dioxide, CO_2
- methane, CH_4
- nitrous oxide, N_2O
- hydrofluorocarbons, HFC
- perfluorocarbons, PFC
- sulphur hexafluoride, SF_6

Acidifying Pollutants & Ozone Precursors

- nitrogen oxides, NO_x
- sulphur dioxide, SO_2
- non-methane volatile organic compounds, NMVOC *
- ammonia, NH_3
- hydrogen chloride, HCl
- hydrogen fluoride, HF

Persistent Organic Pollutants

- polycyclic aromatic hydrocarbons, PAH * †
- dioxins and furans, PCDD/F
- polychlorinated biphenyls, PCB *
- pesticides:
  - lindane, hexachlorobenzene, pentachlorophenol
- short-chain chlorinated paraffins, SCCPs
- polychlorinated napthalenes, PCNs
- polybrominated diphenyl ethers, PBDEs

Air Quality Strategy Pollutants

- particulate matter, PM_{10} *
- black smoke
- carbon monoxide, CO
- benzene, C_6H_6
- 1,3-butadiene, C_4H_6
- PAH * †

Base Cations

- calcium, Ca
- magnesium, Mg
- sodium, Na
- potassium, K

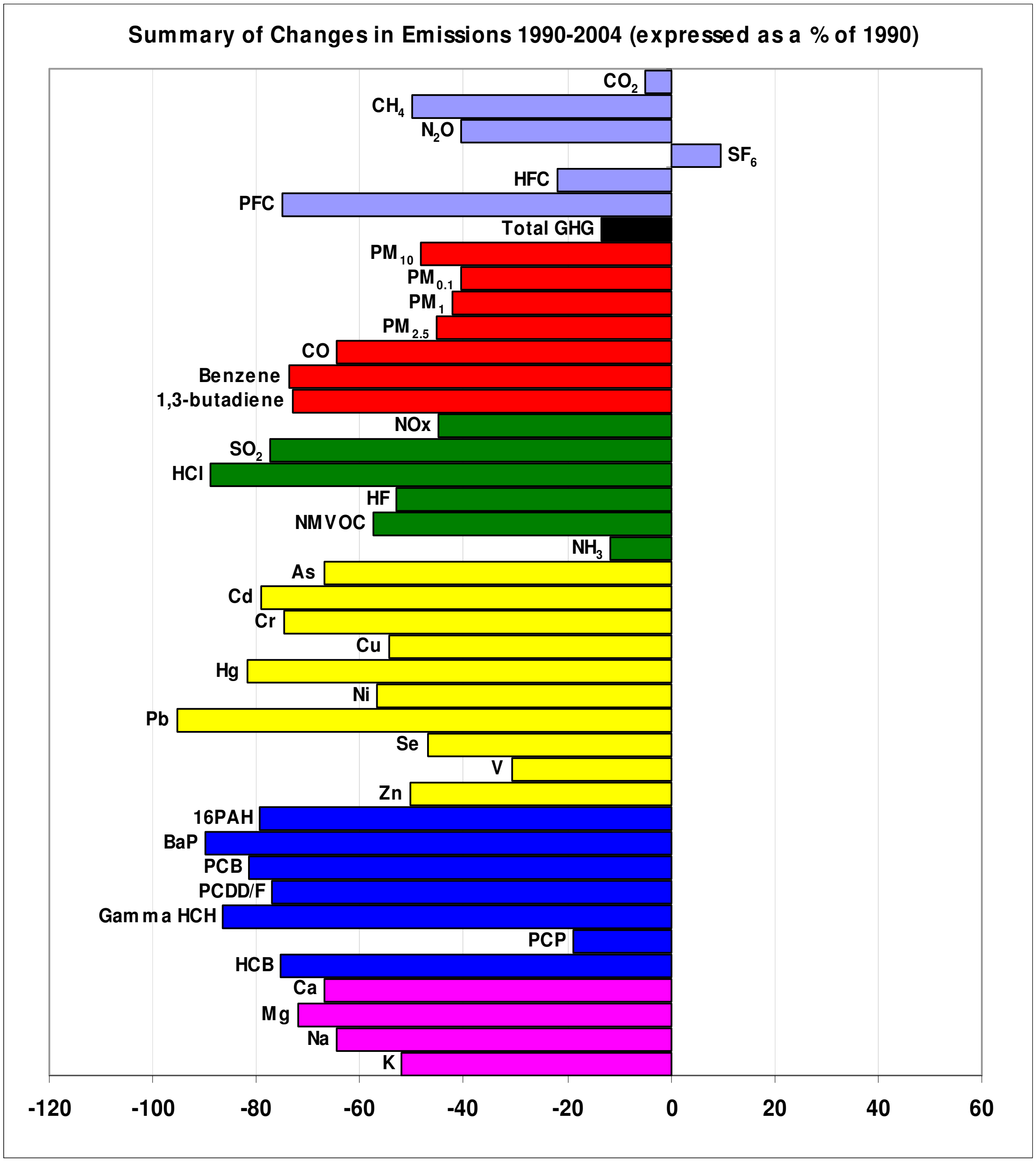
Heavy Metals

- arsenic, As
- beryllium, Be
- cadmium, Cd
- chromium, Cr *
- copper, Cu
- lead, Pb
- manganese, Mn
- mercury, Hg *
- nickel, Ni *
- tin, Sn
- selenium, Se
- vanadium, V
- zinc, Zn

* Pollutant emissions are given as a total emission and speciated emissions. Particulate matter emissions are given as PM_{10} , $PM_{2.5}$, $PM_{1.0}$ and $PM_{0.1}$.

† Benzo[a]pyrene is included in the Air Quality Strategy, but appears in this report in the chapter on Persistent Organic Pollutants, as it is a PAH.

The change in emissions for these pollutants, is summarised in the following plot. The change is given as the difference between the 1990 and 2004 emissions, expressed as a percentage of the 1990 values.



The greenhouse gas SF$_6$ is the only pollutant showing an increase across this period. SF$_6$ emissions arise from a relatively small number of sources (magnesium production, high voltage switchgear, electronics and manufacture of trainers), with most of these giving increased emissions since 1990.

However, these emissions of SF$_6$ should be placed in context by considering the other greenhouse pollutants. Comparison of the 1990 and 2004 emissions of a basket of six greenhouse gases indicates a 14% decrease in the contribution to global warming.

Therefore the impact of the increased SF$_6$ emissions is more than counteracted by the decreased emissions of other greenhouse gases (see Figure 2.1).

3 **CO_2 –** Emission estimates for CO_2 from the UK show a decrease of 5% between 1990 and 2004, giving an emission of 153.6 Mt of carbon in 2004. The most significant reductions arise from the public power and industrial combustion sectors. 2004 road transport emissions account for 21% of the total emission and indicate a reasonably constant absolute emission since 1997.

4 **CH_4 -** Estimates of methane emissions show a decrease of 50% from 1990 to 2004, giving emissions of 2.55 Mt in 2004. The largest sources are landfills, agriculture, natural gas distribution and coal mining. Reduction is largely due to the decline in the coal mining industry and increased levels of methane recovery on landfill sites.

5 **N_2O -** UK emissions of nitrous oxide were 0.132 Mt in 2004, corresponding to a decrease of 40% between 1990 and 2004. Emissions of nitrous oxide are dominated by agricultural emissions and passenger cars. Emission estimates of N_2O are highly uncertain (see Section 2.4).

6 **HFC, PFC and SF_6-** The UK emissions in 2004 were HFCs: 2.4 Mt of carbon equivalent, PFCs: 0.1 Mt of carbon equivalent and sulphur hexafluoride: 0.3 Mt of carbon equivalent. These correspond to reductions of 22% and 76% for HFC and PFC respectively. The increase in SF_6 has been discussed above in point 2 above.

7 **PM –** The UK emissions of PM_{10} declined by 48% between 1990 and 2004, giving an emission of 0.15 Mt in 2004. This reflects a trend away from coal use particularly by domestic users. Coal combustion and road transport together contribute 41% of UK emissions of PM_{10} in 2004. PM_{10} emissions from road transport have shown a steady decline across recent years. Other PM size fractions are also included in this report. $PM_{2.5}$ emissions have also fallen, but by a smaller amount, the largest source sector being road transport, accounting for 30% of the 2004 total emission.

8 **BS -** Black smoke emissions in the UK have significantly declined (by some 84% between 1970 and 2004). Emissions in 2004 were estimated to be 165 kt. These estimates are based on old measurement data and are hence very uncertain. They are included here for completeness only.

9 **CO -** Emissions in 2004 (2.9 Mt) represent a 65% reduction on the emission in 1990. UK emissions of CO are dominated by those from road transport (47% of UK emissions in 2004). The change in emissions between 1990 and 2004 is dominated by the reduction in emissions from the road transport sector, caused by the increased use of catalytic converters in cars.

10 **Benzene** –Benzene emissions have decreased by 74% between 1990 and 2004, giving an emission of 14.5 kt in 2004. Fuel combustion from residential plants is the most significant source of benzene, accounting for some 36% of the 2004 UK emission. The use of benzene in the chemical industry gives rise to stack and fugitive emissions, however these emissions sum to contribute only 3% to the UK total emission.

11 **1,3-Butadiene** – Emissions in 2004 were estimated to be 3.4 kt, representing a decrease of 73% between 1990 and 2004. Emissions of 1,3-butadiene are dominated by fuel combustion in the road transport sector, which account for some 55% of the 2004 UK emission. There have been significant reductions in the emissions from this sector due to the increase in the number of cars equipped with catalytic convertors.

12 **NO_x -** UK emissions of NO_x were 2.9Mt in 1990. Emissions have fallen significantly to 1.6 Mt in 2004, representing a 45% reduction on the 1990 emissions estimate. This is primarily a consequence of: abatement measures in road transport, abatement measures in coal fired power stations and the increased use of other fuels for power generation. Road transport and coal combustion combine to account for 64% (1A1, 1A3b) of UK emissions in 2004.

13 **SO_2 -** UK emissions of sulphur dioxide have fallen from 3.7 Mt in 1990 to 0.8 Mt in 2004, representing a decrease of 77%. This is a result of reduced emissions from the industrial and public power sectors arising from the decreasing use of coal and increasing use of abatement equipment. However, coal combustion still accounts for 72% of the 2004 UK SO_2 emissions.

14 **HCl -** UK emissions of hydrogen chloride have decreased by 89% between 1990 and 2004, giving an emission of 30 kt in 2004. This reduction is largely as a result of declining coal use.

15 **NMVOC -** UK emissions of NMVOC are estimated as 2.4Mt for 1990 and 1.0 Mt for 2004, a decrease of 57%. The observed decrease arises primarily from the road transport and industrial sectors.

16 **NH_3 -** The total UK emission of ammonia for 2004 is estimated at 0.34 Mt, compared to the 1990 estimate of 0.38 Mt, giving a 12% reduction. The agricultural sector dominates the ammonia emissions, and emissions have decreased substantially since 1999. There have been increases in the emissions from the road transport sector (caused by increased use of catalytic convertors), but these have been more than offset by the impact of decreased agricultural livestock numbers.

17 **HF –** The total HF emissions for 2004 are estimated to be 4.7 kt, representing a 53% reduction on the 1990 emission estimates. As with HCl the dominant source is coal combustion for public power contributing 62 % of emissions.

18 **POPs –** The 2004 UK emissions of persistent organic compounds may be summarised as follows: 1723 t **PAH** (USEPA 16), 285 g I-TEQ **PCDD/F** (grammes of "toxic equivalent" of dioxins & furans) and 1.33 t **PCB**. Emissions from all three of these pollutant groups have greatly decreased. Emissions in 2004 equate to decreases of 79%, 77% and 81% on the 1990 emission, for PAHs, PCDD/Fs and PCBs respectively.

19 **Pb -** UK Emissions of lead have declined sharply following reductions in the lead content of leaded petrol, and the increased use of unleaded and lead replacement petrol. Emissions in 2004 are estimated to be 0.13 kt, a decrease of 95% on the 1990 estimates. Road transport now contributes only 1% to UK emissions total in 2004.

20 The 2004 emission inventory indicates that the dominant sources of many of the air pollutants are from road transport and the use of coal (see table below).

Road Transport and Coal Combustion Contribution to Emissions of Selected Pollutants (2004)

Pollutant	**Total Coal Combustion**	**Road Transport**	**Total Contribution**
HCl	90%	0%	**90%**
HF	83%	0%	**83%**
Sn	57%	12%	**69%**
16 PAHs	19%	49%	**68%**
SO_2	61%	0%	**61%**
Be	14%	42%	**56%**
1,3-Butadiene	0%	54%	**54%**
CO	7%	46%	**53%**
Se	31%	20%	**50%**
NO_x	16%	31%	**48%**
Cu	7%	37%	**44%**
Mg	44%	0%	**44%**
PM_{10}	10%	31%	**41%**
Carbon	21%	20%	**40%**
Na	33%	0%	**33%**
Benzo[a]pyrene	28%	4%	**32%**
Mn	23%	6%	**29%**
Benzene	3%	22%	**25%**
K	20%	0%	**20%**
As	10%	0%	**10%**

It is therefore likely that future trends in emissions will be substantially determined by market demand and UK Government/devolved administration policies associated with these areas.

21 A copy of this report may be found at the NAEI web site (http://www.naei.org.uk) along with a facility for local interrogation of the data and links to data on emissions in other countries.

Contents

1 Introduction

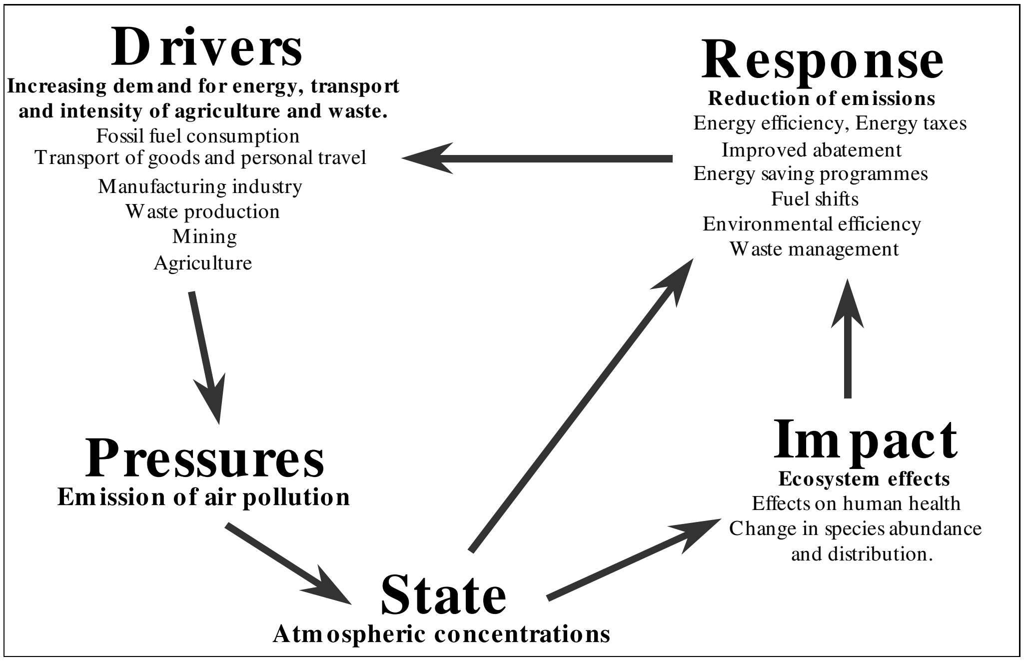
1.1 AN INTRODUCTION TO EMISSION INVENTORIES

Emission inventories play an important role in assessing the effects of anthropogenic (man-made) activity on atmospheric pollution. The principal demands for energy, transportation, materials and food may be regarded as the "***drivers***" for the production of air pollutants. In order for an economy to continue to develop in a sustainable way these sources of pollution must be managed. To do this we must understand the "***impacts***"- i.e. what types of pollution affect which parts of the environment or human health, and to what extent. To decide whether action is necessary we also need to know the "***state***" of the environment- i.e. to evaluate whether the levels in the environment exceed those which will cause environmental harm.

In taking appropriate action we must be able to respond in a focused way to control and reduce pollution while avoiding larger-scale damage to economic development. ***Emission inventories*** provide policy makers and the public with an understanding of the key polluting sources or the "***pressures***", how these sources have developed with economic growth and how they are likely to contribute to pollution in the future. This understanding is essential for a focused "***response"*** to the problems associated with air pollution and to meet the demands of sustainable development.

Figure 1.1 shows how our understanding of the ***pressures*** (through emission inventories) interact with other areas of environmental knowledge such as ***impact*** assessment and monitoring (***state***). Figure 1.1 also clearly shows the relationship between: emission inventories, economic activity and effective environmental policy.

Figure 1.1 "DPSIR" Relational Diagram



1.2 THE UK NATIONAL ATMOSPHERIC EMISSIONS INVENTORY

The UK National Atmospheric Emission Inventory (NAEI) is compiled by the UK Emissions Inventory Team, at the National Environmental Technology Centre (NETCEN). The inventory, and related programme of work is conducted on behalf of the Department for Environment, Food and Rural Affairs (Defra) and the devolved administrations. More specifically, within Defra, work in air quality pollutants is conducted for the Air and Environment Quality (AEQ) Division, and work on greenhouse gases (GHGs) is conducted for the Global Atmosphere Division. The NAEI is a single internally consistent programme, but this notional split into two components (an air quality inventory and a GHG inventory), allows more focussed delivery on the relevant environmental issues and Government commitments.

The NAEI is the standard reference air emissions inventory for the UK and includes emission estimates for a wide range of important pollutants. These include: greenhouse gases, regional pollutants leading to acid deposition and photochemical pollution, persistent organic pollutants and other toxic pollutants such as heavy metals. The full range of pollutants is summarised in Table 1.1 Where possible, estimates are presented for 1970-2004. However, for some pollutants, e.g. ammonia and N_2O, there is insufficient information to produce a 1970-2004 time series and estimates are presented from 1990-2004.

Emission inventories serve several important functions, as explained in Section 1.1. The following highlight several of the more important uses of the UK NAEI:

1. **Provision of Public Information-** The data from the NAEI is made available to the public in various forms (see Section 1.2.3). The aim is to make information available in an easily understandable format, informing the public of emissions in their area as well as making national emissions data available. The NAEI is paid for by tax payers money, through the national and devolved administration Government, and consequently it is important to maintain a high public profile and accessibility to the work. A copy of this report is available on the internet at http://www.naei.org.uk. Further information can be found in Section 1.2.3.

2. **Development of policy-** The data from the NAEI is used to inform development of policies to tackle emissions of air quality pollutants and greenhouse gases.
    - **Identification of Primary Sources-** The NAEI compiles emissions from all possible anthropogenic and natural sources (where information allows). Consequently it is simple to determine which source sectors are the major emitters of individual pollutants.

    - **Temporal and Spatial Trend Assessment-** The NAEI provides information to allow temporal trend analysis as it is compiled annually (from 1970 for most pollutants). This information feeds directly into policy associated with reducing future emissions. UK maps are also generated for several of the pollutants, allowing spatial trends to be assessed.

    - **Inventory Comparisons-** Mapped emission inventories exist for a number of cities across the UK. In some cases the techniques used to compile these emission inventories differ from the NAEI. As a result comparison with the NAEI highlights the potential strengths and weaknesses of the different techniques.

- **National Modelling Studies-** The NAEI is used in a variety of modelling studies investigating spatial and temporal trends in deposition and concentration of pollutants. Furthermore, it is possible to use the NAEI alone to investigate the impact on emissions of particular future policy scenarios.

- **Local Support-** Data from the NAEI is frequently used by Local Authorities to support air quality assessments, and aid the generation of local policy.

3. **National and International Reporting-** The NAEI provides the official air emissions estimates for the UK. National and International reporting requirements are given in more detail in the following Sections.

4. **Progress on Complying with National and International Commitments-** The annual inventory provides an important assessment tool for policy makers. The inventory is used to monitor progress towards emission limits and ceilings at both the national and international level, and is therefore an important tool in assessing the effectiveness of existing policy measures.

5. **Provision of Information to the Private Sector-** Data that goes towards compiling the NAEI emissions inventory is often used by industry. This allows planning emissions reduction by either introduction of abatement equipment, altering processes or improving efficiencies.

1.2.1 International Commitments

The NAEI provides the UK air emission data for submission to United Nations Economic Commission for Europe (UN/ECE) and the United Nations Framework Convention on Climate Change (UNFCCC). Under the UNFCCC, the UK is committed to developing, publishing and regularly updating national emission inventories of greenhouse gases using reporting guidelines from the Intergovernmental Panel on Climate Change (IPCC). The inventories for both direct greenhouse gases (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride) and indirect greenhouse gases (nitrogen oxides, carbon monoxide and non-methane volatile organic compounds) are drawn from the UK NAEI emissions data included in this report. Likewise, NAEI estimates of emissions of nitrogen oxides, carbon monoxide, ammonia, sulphur dioxide, NMVOC, persistent organic pollutants and heavy metals are submitted to UN/ECE under the Convention on Long-Range Transboundary Air Pollution (CLRTAP). As part of the commitments to the CLRTAP, countries are also required to submit emission projections for selected pollutants (under the Gothenburg Protocol). These emission projections are compiled and reported as part of the NAEI programme. NAEI data are also provided to international emission inventory activities such as the EC's CORINAIR and EUROSTAT inventories.

Members of the UK inventory team have a strong international profile, and play an important role in the development of international guidelines by the European Environment Agency and the UN/ECE. The aim of these organisations is to achieve a consistent set of good quality inventories for all European countries, and UK inventory experts contribute to this process in a number of ways. More information may be found at the EMEP and UNFCCC websites at:

http://www.emep.int and http://www.unfccc.de

Not all international reporting of emissions are drawn from the UK NAEI. One exception is the EC's European Pollutant Emissions Register (EPER) which arises from the IPPC Directive. The Environment Agency's Pollution Inventory (PI) provides data for the EPER for England and Wales. Scotland construct their own PI equivalent, and Northern Ireland have an "ISR" Inventory.

1.2.2 National Information

The NAEI is a key database used to provide air emissions data to the public, UK Government, the devolved administrations, Local Authorities and private sector organisations. Many of the specific policy uses have been outlined above, but there are a number of other ways in which the data is used. Several are given below:

- A significant amount of time is spent providing detailed emission estimates, output from scenario analysis and supporting information to Defra and the devolved administrations. This information is required for a wide variety of uses- from long-term policy support to specific short-term issues.

- A great deal of information is made available to other organisations working on Defra projects, projects for the devolved administrations, academia for research projects or organisations involved in international projects and programmes. This ensures a high level of consistency and efficiency in providing UK specific information.

- Mapped emission inventories for the UK are generated on a 1x1km scale. These are frequently used as a starting point for many local emission inventories, and input into Local Authority Review and Assessment process, which assesses current and future air quality.

- Emission estimates for point sources and emissions arising from the surrounding area are used in modelling studies as part of Environmental Impact Assessments by developers and their consultants.

- There is a two way exchange of data with Trade Associations. This ensures that the NAEI and the Trade Associations can arrive at emission estimates that are truly representative.

- Emission factor data is fed into the UK's Emission Factor Database for access by Local Authorities.

Table 1.1 Pollutants Covered by the Inventories

Pollutant		**Range of Estimates**[1]	**Type of Pollutant**[2]
Carbon Dioxide	CO_2	1970-2004	G
Methane	CH_4	1970-2004	G
Nitrous Oxide	N_2O	1990-2004	G
Hydrofluorocarbons	HFC	1990-2004	G
Perfluorocarbons	PFC	1990-2004	G
Sulphur Hexafluoride	SF_6	1990-2004	G
Nitrogen Oxides	NO_x (NO_2 + NO)	1970-2004	NAQS, AC, IG, O
Sulphur Dioxide	SO_2	1970-2004	NAQS, AC, IG
Carbon Monoxide	CO	1970-2004	NAQS, O
Non-Methane Volatile Organic Compounds	NMVOC	1970-2004	NAQS, O, IG
Black Smoke	BS	1970-2004	NAQS
Particulates < 10 µm	PM_{10}	1970-2004	NAQS
Ammonia	NH_3	1990-2004	AC
Hydrogen Chloride	HCl	1970-2004	AC
Hydrogen Fluoride	HF	1970-2004	AC
Lead	Pb	1970-2004	NAQS, TP
Cadmium	Cd	1970-2004	TP
Mercury	Hg	1970-2004	TP
Copper	Cu	1970-2004	TP
Zinc	Zn	1970-2004	TP
Nickel	Ni	1970-2004	TP
Chromium	Cr	1970-2004	TP
Arsenic	As	1970-2004	TP
Selenium	Se	1970-2004	TP
Vanadium	V	1970-2004	TP
Beryllium	Be	2000-2004	TP
Manganese	Mn	2000-2004	TP
Tin	Sn	2000-2004	TP
Polycyclic Aromatic Hydrocarbons	PAH	1990-2004	TP
Dioxins and Furans	PCDD/F	1990-2004	TP
Polychlorinated Biphenyls	PCB	1990-2004	TP
Lindane (gamma-HCH)	HCH	1990-2004	TP
Pentachlorophenol	PCP	1990-2004	TP
Hexachlorobenzene	HCB	1990-2004	TP
Short-chain chlorinated paraffins	SCCP	1990-2004	TP
Polychlorinated Napthalenes	PCN	NE	TP
Polybrominated diphenyl ethers	PBDE	SE	TP
Sodium	Na	1990-2004	BC
Potassium	K	1990-2004	BC
Calcium	Ca	1990-2004	BC
Magnesium	Mg	1990-2004	BC

[1] An explanation of the codes used for time series:

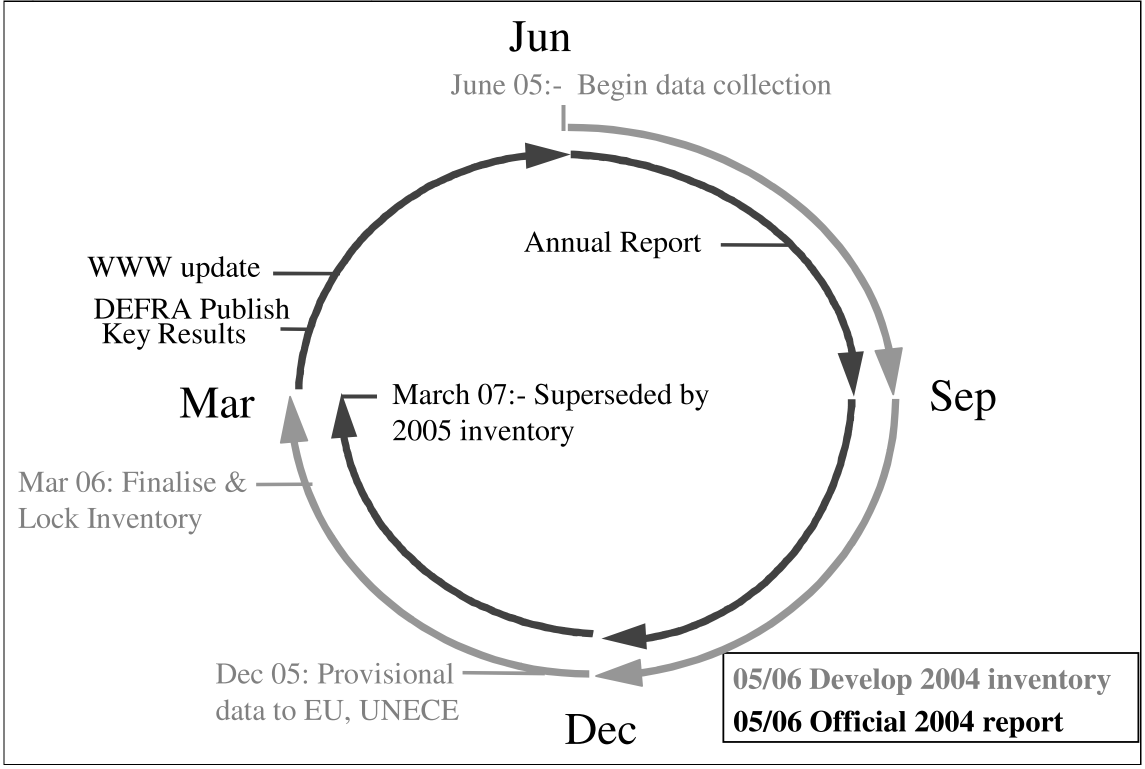
SE	A "Single Emission" estimate not attributed to a specific year
NE	"Not Estimated" due to lack of information currently available

[2] An explanation of the codes used for pollutant types:

G	Greenhouse gas	**IG**	Indirect greenhouse gas
O	Ozone precursor	**AC**	Acid gas
NAQS	National Air Quality Standard/Local Air Quality Management pollutant		
TP	Heavy metals and POPs are generally referred to as "Toxic Pollutants" (although other pollutants also have toxic properties)		
BC	Base cation		

The NAEI is compiled on an annual basis, each year the latest set of data are added to the inventory and the full time series are updated to take account of improved data and any advances in the methodology used to estimate the emissions. Updating the full time series is an important process as it ensures that the entire dataset uses the methodology that is the most current, and hence considered to give the most accurate results and the most accurate indication of temporal trends. The new data are then reported to UN/ECE, UNFCCC and other international fora. This annual cycle of activity is represented schematically in Figure 1.2.

Figure 1.2 The Annual NAEI Cycle



This report presents the definitive 2004 data from the NAEI and is the latest in a series of annual reports published by the NAEI (Eggleston, 1988; Eggleston and Munday, 1989; Munday, 1990; Leech, 1991; Gillham *et al* 1992; Gillham *et al* 1994; Salway *et al* 1996, 1996a, 1997, Salway 2000, Salway *et al* 1999, Goodwin *et al* 2000, Goodwin *et al* 2001, Goodwin *et al* 2002, Dore *et al* 2004, Dore *et al* 2004, Dore *et al* 2005). In addition, the NAEI also produces an annual GHG Report (Baggott *et al* 2006).

This report discusses trends in pollutant emissions, the accuracy of the emission estimates and in many cases the pattern of their spatial disaggregation within the UK. Appendices are now not included with this hard copy of the report, but more detailed information can be accessed from the NAEI webpage (http://www.naei.org.uk).

Chapters 1 to 7 present the NAEI emission estimates for the UK. They have been divided into five groups, reflecting the national and international activity relating to atmospheric pollution, namely GHGs, National Air Quality Strategy pollutants, stratospheric ozone depletors, acidifying gases and tropospheric ozone and other hazardous air pollutants. Each of these chapters include a discussion of the importance of the pollutants concerned, present time series emission data, and discuss the data trends and the accuracy of the emission estimates.

1.2.3 Information Dissemination

Data from the NAEI is made available to national and international bodies in a number of different formats- as explained in Sections 1.2.1 and 1.2.2 An annual report is produced, giving the most recent emissions data and other information such as: temporal trends, new pollutants and methodology changes. The NAEI team also hold seminars with representatives from industry, trade associations, UK Government and the devolved administrations.

In addition there is a continuous drive to make information available and accessible to the public. A large amount of information is made available on the internet. The NAEI web pages may be found at:

http://www.naei.org.uk

These web pages are arranged to allow easy access to the detailed emissions data, but also general overview information for those less well versed in air pollutants and emissions inventories in general. Some things that can b located on the NAEI web pages include:

- **Data Warehouse:-** Emissions data is made available in numerous formats through a queriable database. This allows extraction of overview summary tables, or highly detailed emissions data.

- **Emissions Maps: -** Emissions of pollutants are given in the form of UK maps. These maps give emissions of various pollutants on a 1 x 1 km resolution. The maps are available as images, but in addition the data behind the maps can also be accessed directly from the website.

- **Post Code Search: -** This search facility enables visitors to the site to enter their post code, and obtain emissions data concerning the major sources in the vicinity.

- **Reports: -** The most recent NAEI annual report is made available in electronic format, along with a host of other reports compiled by the inventory team, and reports on related subjects.

- **Methodology: -** An overview of the methods used for the compilation of the NAEI is included on the website.

The web site is constructed so that the air emissions are placed in context. In addition there are numerous links to locations explaining technical terms, pages giving airborne pollutant concentrations and why there is an interest in particular pollutants. In particular there are links to the various Defra pages containing comprehensive measurement data on ambient concentrations of various pollutants. The Defra air quality sites can be found at:

http://www.defra.gov.uk/environment/airquality/index.htm

and

http://www.defra.gov.uk/environment/climatechange/index.htm

1.2.4 Basic Methodology

Throughout the compilation of the inventory, considerable effort has been made to ensure both consistency with other national statistics and that all available data sources are considered. Hence, the data in the inventory need to be drawn from a wide range of sources.
That is:

Emission = Emission Factor × Activity

e.g.

Carbon Emission from coal use in domestic heating (in 2004) = Carbon content of domestic coal (in 2004) × Coal consumption in the domestic sector (in 2004)

Emission factors are generally derived from measurements on a number of sources assumed to be representative of a particular source sector. The resulting emission factor may then be applied to similar sources within the sector. However, some sectors are particularly well characterised and individual point sources within the sector may report a specific emission, which is regarded as being more reliable. This is often the case with sectors incorporating large point sources (an example being the Power Station sector). The inventories presented here are generated using a combination of reported point source emissions, and emissions calculated using emission factors.

One of the most significant source is the provision by the Environment Agency of the emissions data for Part A Processes in the Pollution Inventory. Where specific point source emission data are unavailable, emissions are estimated from other activity data such as fuel consumption, distance travelled, production or some other statistical data that is directly related to the emissions. Emission estimates are calculated by applying an emission factor to an appropriate activity statistic.

For many of the pollutants, the major source of emission is fossil fuel combustion. As a result fuel consumption statistics feature prominently in the calculation of these emission estimates. It is important to consider the difference between consumption and deliveries when making use of fuel statistics. Most readily available statistics refer to deliveries which for many source categories relate closely to actual consumption of fuel. However, where fuel can be stockpiled, deliveries and consumption may differ significantly. This is just one example of having to ensure that the available data is correctly interpreted, and used in the most appropriate way to arrive at representative emission estimates. The NAEI uses the DTI’s annual Digest of UK Energy Statistics (DUKES) as a primary source of fuel use data.

Emissions from sources such as industrial processes, farm animals and motor fuel evaporation require different statistics; in these cases data on process output, population and motor fuel sales are appropriate.

In other cases, where emissions are more complex, further refinements or an alternative methodology is required. The emissions from road vehicles can be considered by way of an example. An obvious activity indicator would be distance travelled, but emissions per unit distance travelled will depend on: vehicle type, vehicle age, engine size, fuel type, average speed and several other parameters. Clearly the methodology rapidly becomes complicated. To accommodate this a separate road transport model is used for calculating the emissions given in the NAEI.

1.2.5 Mapping Emissions

The sources contributing to the UK emissions can be represented as one of three categories: points, lines or areas. Sectors such as power stations, refineries and large industrial plant can be represented by points. Their locations are known and data to estimate emission contributions are available. Major roads and railways are sectors that can be represented by lines if data are available. Other disperse and numerous source sectors such as agriculture, domestic and commercial are represented by areas.

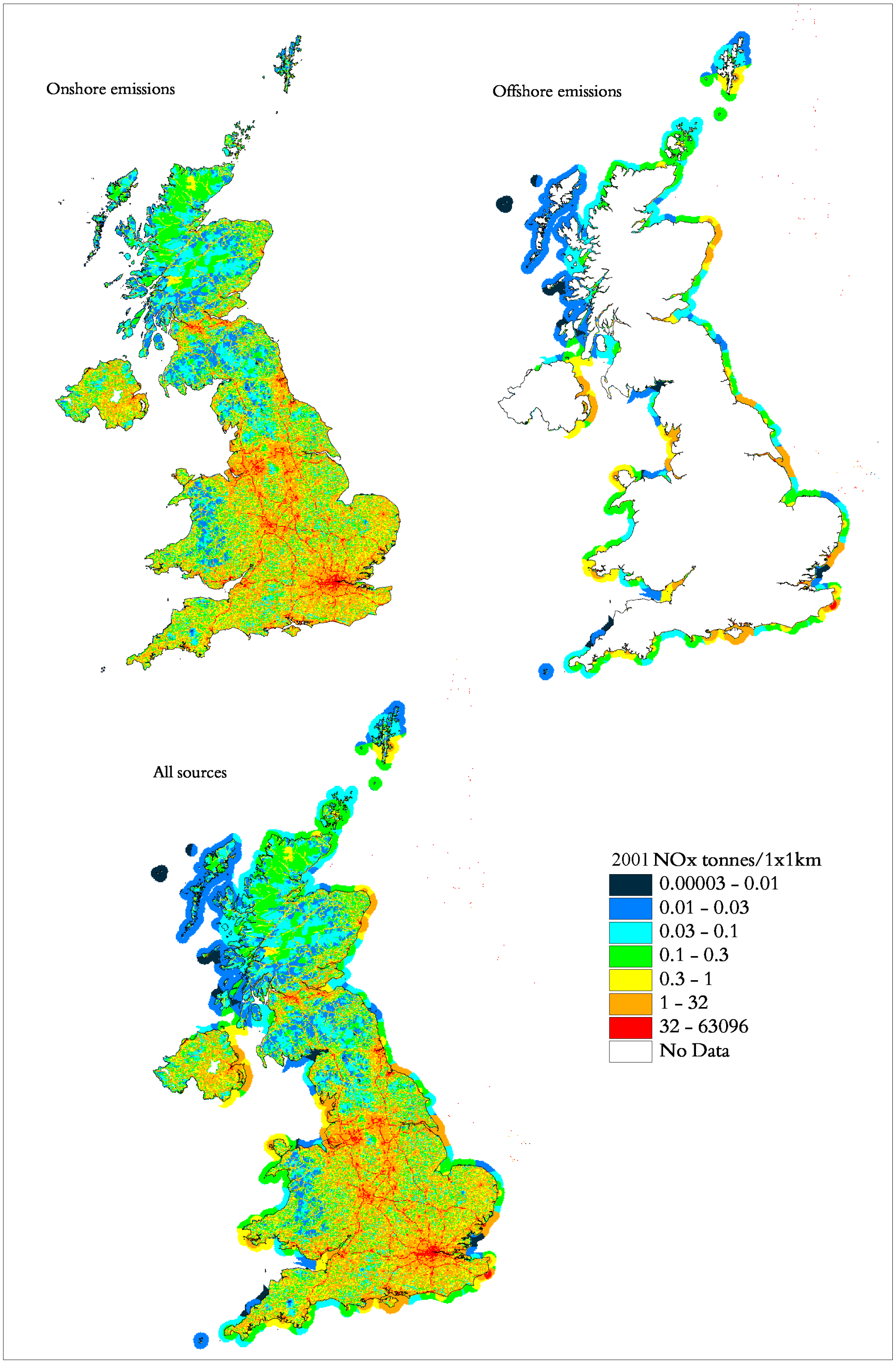
The method used to map emissions in the UK is shaped by the data that are available. The technique employs a combination of reported emissions (for emission sources at regulated sites) and surrogate geographical statistics to distribute emissions from line and area sources.

The emission maps combine the different sources represented by the point, line and area sources. In order to map this combination, the UK is divided into a grid of 1km squares. Emissions are then represented in terms of tonnes per 1km grid square. Maps of emissions for the majority of the pollutants covered under the NAEI have been included in this report. These maps show emissions from all sources including some offshore sources. The offshore component is made up of shipping and fishing related emissions within a 12km coastal zone and also offshore oil and gas extraction further afield. This is to match the sources included in the maps with standard international reporting protocols. The onshore and offshore components of the maps are shown separately for NO_x below in Figure 1.3.

It is difficult to identify an offshore total for many of the pollutants as the emissions occur from a number of different sectors under reporting formats. For example, CH_4 emissions from offshore platforms will arise from a number of activities. Emissions may be included under "Extraction and Distribution of Fossil Fuels", however other emissions may fall within the "Waste Treatment and Disposal" category (e.g. venting of CH_4). Emissions from fuel combustion in shipping fall into the "Other Mobile Sources and Machinery" sector. Annex 1 gives an explanation of the UN/ECE reporting framework and indicates which source category the emissions are reported under.

These maps meet the needs of a wide range of users. For example, they are used to provide input into air quality modelling, which allows Local Authorities to generate action plans as part of their air quality management role. The maps are also used in research projects investigating pollutant transport and atmospheric chemistry, and by the general public who are interested in understanding the air quality climate in their area.

Figure 1.3 NO_x Emissions Maps[1]- Onshore, Offshore and Total Emissions (illustrative purposes)



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1.2.6 Projections

Projections of UK emissions are compiled at a minimum annually following release of a new inventory baseline, but in addition when new energy / road traffic forecasts are generated by DTI / DfT. The projections indicate whether the UK is on track to meet a variety of international commitments. Projections are currently compiled for the years 2005, 2010, 2015 and 2020.

Methodology

The NAEI method for estimating future emissions follows the methodology outlined in the UNECE Task Force on Emission Inventories and projections (TFEIP) Guidebook (3^{rd} Edition, June 2002). In order to establish consistency between historic and projected emissions, emission inventories and emission projections should be based on the same structure. Therefore a similar method to that used to calculate historic emissions has been used to estimate future emissions. Projected energy consumption statistics, forecasts of traffic growth and changes in the agricultural sector are used to create activity 'drivers'. The projections also take into account the introduction of legislation, and assume that measures are introduced when required by legislation and not earlier (and that all operators comply with this legislation).

A set of emission projections for the four National Emission Ceiling Directive (NECD) pollutants (NO_x, SO_2, NMVOC, NH_3) plus PM_{10} were compiled in February 2006 using the 2004 NAEI. This set of emission forecasts was provided for inclusion in the European RAINS (Regional air pollution information and simulation model) model for the 'UK national scenario' in March 2006.

The emission projections are based on DTI's UEP21 energy forecasts and DfT's September 2004, 10 year plan for transport. Regulations that have been taken into account include:

- The large combustion plant Directive (LCPD)
- IPPC Directive
- The Solvent Emissions Directive
- Marpol VI
- Sulphur content of liquid fuels regulations
- European directives on vehicle emissions and fuel quality
- Introduction of sulphur-free fuels (petrol & diesel), under Directive 2003/17/EC.

The latest set of projections using DTI's UEP21 energy forecasts and the 2004 NAEI as the baseline are referred to as UEP21 (2004).

Progress

If required, these can be obtained from AEA Energy and Environment.
These findings will be continually updated when there are revisions to both the inventory base year and expected future trends, for example in energy use.

1.2.7 Continuous Improvement

The NAEI operates a policy of continuous improvement, and reviews methodologies each year. The 2004 version of the NAEI has seen a considerable number of revisions and improvements, summarised in the following sections.

Many of the estimates contained in the inventory are subject to significant levels of uncertainty and there is a general need for improvements to methodologies to be made wherever possible. The list below indicates which improvements have occurred since the 2003 NAEI report was published.

Use of gas oil by off-road vehicles and trains

The methodologies for estimating consumption of gas oil in off-road vehicles and trains have been revised. The new estimates are generally higher than those used previously and, in order to maintain consistency with total UK consumption figures given in DUKES, estimates of gas oil consumed in stationary plant have been reduced. The new figures are considered to be more reliable and are more in line with other data such as off-road vehicle and train population/usage data and data on fuel use in medium and large stationary combustion plant.

Revision of consumption estimates for fuel oil

Estimates of sectoral consumption of fuel oil were previously generated using the so-called black oils data supplied by DTI. These data are now considered to be of poor quality and their use has stopped. Data from DUKES is now used. This has lead to revisions in estimates from many source categories due to the differing way in which the activity data is reported.

Addition of domestic combustion of peat

Peat is used as a domestic fuel, particularly in Northern Ireland and Scotland. Emission estimates have been added for carbon, methane, nitrous oxide, carbon monoxide, oxides of nitrogen, NMVOC and PM_{10}.

Fuel used for cement production

Previous versions of the inventory have relied upon in-house estimates of fuel consumed by the cement industry. These estimates were consistent with DUKES but did not fit with the fuel types actually known to be in use in cement kilns – however, in the absence of alternative data, they had to be used. For this version of the inventory, the British Cement Association (BCA) have provided data on actual/estimated fuel use in UK cement kilns for the years 1990 and 2000-2004, and these data have been used instead. Fuel consumption for other years have been estimated by extrapolation from the BCA data.

Fuel transformation processes at steelworks

Corus UK Ltd have provided advice and data with which to further refine the revised methodology for fuel transformation processes introduced with the 2003 version of the NAEI.

Emissions from combustion sources

A review of emission estimates for CO, NO_X, metals, HCl and black smoke found that emission factors were not included in the NAEI for certain, minor, source-fuel combinations. These gaps in the inventory have been filled by allocating appropriate factors. The impact on overall emissions is, however, relatively trivial.

Review of methane and nitrous oxide factors

Emission factors for minor, combustion-related sources are taken from literature sources such as the EMEP/CORINAIR Emission Inventory Guidebook or the US EPA Compilation of Emission Factors which are subject to periodic review and reissue. In some cases, the factors used in the NAEI/GHGI were those given in superseded versions of these literature sources and these factors have now been updated with factors taken from the current versions of these publications.

Power stations

Emission factors for power stations are based largely on emissions data published in the Environment Agency's Pollution Inventory and similar sources for Scotland and Northern Ireland. This method remains unchanged although the calculations have been reviewed to ensure the most complete set of data are used and that any assumptions are used consistently.

Lime production

An error in the 2003 NAEI which meant that SO_2 emitted due to the use of coal was left out from the inventory, has been corrected.

Waste lubricants

Assumptions made regarding the use of waste lubricants have been reviewed. A number of changes have been made to the inventory as a result. Most significantly, it has been recognised that emissions due to burning of lubricants in engines do not all occur from the road-transport sector and that some of the emissions will occur from other transport sectors and from industry.

Correction of errors in PAH emission factors

A number of errors were found in the emission factors used for PAH species including an error in the factors for combustion of impregnated wood which were therefore too low.

Road Transport

Three main changes have been made to the methodologies and data used for compiling the road transport emission estimates. .

- Combustion of lubricating oil
  - ⇨ This year for the first time has been allocated to the road transport sector. This has affected carbon & SO2 emissions.
- A revision to the vehicle kilometre time series for Northern Ireland.
  - ⇨ This was a re-allocation of the vehicle kilometres between cars and LGVs and an amendment to the vehicle kilometres for HGVs, following a prolonged period of discussions with the DoeNI and DRDNI in 2005.
- Improvements to the estimation of cold start emissions.

Off-road Sources and Rail vehicles

Off-road sources cover emissions from a range of portable or mobile equipment powered by reciprocating diesel or petrol driven engines. They include agricultural equipment such as tractors and combine harvesters; construction equipment such as bulldozers and excavators; domestic lawn mowers; aircraft support equipment; and industrial machines such as portable generators and compressors. In the NAEI they are grouped into four main categories:

- domestic house & garden
- agricultural power units (includes forestry)
- industrial off-road (includes construction and quarrying)
- aircraft support.

Rail emissions relate to diesel powered rail vehicles.
In the 2004 inventory, Netcen's own fuel consumption estimates as opposed to DTI's estimates were used for the first time. This was because it was felt that DTI's estimates were unreliable. Netcen's fuel consumption estimates are based on the population of off-road machinery and hours of use plus other factors. This led to a large increase in fuel consumption and hence carbon emissions being predicted from this sector compared to previous inventories.

Geographical Coverage

Geographical coverage of the UK inventory has been under review. Under selected international protocols, emissions from UK dependent territories (and some other locations) are allotted to the UK. Consequently it has been necessary to estimate the emissions from a number of new geographical locations. Emission estimates have been made for: Gibraltar, Jersey, Guernsey, the Isle of Man and Akrotiri/Dhekhelia (Sovereign Bases on Cyprus), although the pollutant and year coverage is limited in some cases. In addition, the uncertainty for some sectors is known to be higher. Improvements to these emission estimates for overseas locations is on-going.

In addition to the above, the inclusion of other overseas locations is currently being considered. This is because overseas territories can elect to sign up to the Kyoto protocol by coming under the UK's umbrella agreement (i.e. their emissions would be included as part of the UK submission to the UNFCCC). Discussion are underway with Overseas Territories, and the outcome will determine whether they are to be included in next years inventory, covering 1970-2004.

Crown Dependencies and Overseas Territories

The precise geographical definition of the "UK" differs across the international protocols and legislation relating to emissions. For some official reporting, the UK submission is required to include selected UK Overseas Territories (OTs) and Crown Dependencies (CDs). The situation is complex, and the geographical extent of the "UK" can vary from pollutant to pollutant.

In previous years, work has been conducted to make emission estimates of selected air quality pollutants from UK Crown Dependencies (The Bailiwick of Jersey, The Bailiwick of Guernsey and the Isle of Man). This year a full timeseries of GHG emissions were also required for these CDs as well as selected OTs.

An invitation was sent out by the UK Government to all of the UK overseas territories to come under an umbrella agreement with the UK for the ratification of the Kyoto protocol. The invitation was accepted by the following:

• The Bailiwick of Jersey	• The Falkland Islands
• The Bailiwick of Guernsey	• The Cayman Islands
• The Isle of Man	• Bermuda
	• Montserrat
	• Akrotiri and Dhekhelia (Cyprus)[2]
	• Gibraltar[3]

Detailed results and methodologies for all of these emission estimates are reported in Chapter 8.

A decision was made on behalf of the Pitcairn Islands and other smaller territories that they did not wish to be included.

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[2] Akrotir and Dhekhelia are legally classified as "Sovereign Bases".

[3] Classification of Gibraltar is more complex than other OTs because it is a member of the EC. Details are included in Chapter 8.

1.3 UK POLLUTION INVENTORIES

The environmental regulatory authorities in the UK each manage pollution inventories for industrial emissions to air, land and water. Operators of industrial processes that are authorised under IPC (Part A) and PPC (Part A) are required to submit annual estimations of emissions of target substances, and this data is verified by the regulators and then made publicly available.

1.3.1 The Environment Agency of England & Wales - Pollution Inventory

The Environment Agency of England & Wales (EA) compiles a Pollution Inventory (PI) of emissions from around 2,000 major point sources in England and Wales. This requires the extensive compilation of data from a large number of different source sectors. This valuable source of information is incorporated into the NAEI wherever possible, either as emissions data, or surrogate data for particular source sectors. The information held in the PI is also extensively used in the generation of the NAEI maps, as the locations of individual point sources are known. The NAEI and the EA work closely to maximise the exchange of useful information. The PI allows access to air emissions through post code interrogation, and may be found on the Environment Agency website: -

http://www.environment-agency.gov.uk/business/444255/446867/255244/

1.3.2 The Scottish Environmental Protection Agency – EPER Inventory

The Scottish Environmental Protection Agency (SEPA) compiles an emissions inventory for emissions reporting under the Integrated Pollution Prevention and Control (IPPC) Directive and the European Pollutant Emission Register (EPER). The reporting of emissions is required for all activities listed in Annex I of the IPPC Directive, and under EPER requirements, emissions reporting is required for the years 2002, 2004 and 2007. Historically, the Scottish emissions inventory was managed by three regional offices, but in recent years progress has been made to allow a centralised emissions inventory for Scotland to be developed. As with the data from the EA Pollution Inventory, the point source emissions data provided via the SEPA inventory is used within the NAEI in the generation of emission totals, emission factors and mapping data. The SEPA inventory can be found at: -

http://www.sepa.org.uk/data/eper/mainpage.htm

1.3.3 The Northern Ireland Department of Environment – ISR Inventory

The Environment & Heritage Service of the Northern Ireland Department of Environment compiles an inventory of industrial emissions for the purposes of EPER and this point source data, although not as yet available via the web, is readily available to the public via the Department itself. The NAEI utilises this valuable point source emissions data for the development of emissions totals, factors and mapping data. Information can be found at:

http://www.ehsni.gov.uk/environment/industrialPollution/ipc.shtml

2 Greenhouse Gas Emissions

2.1 INTRODUCTION

Increasing atmospheric concentrations of greenhouse gases (GHGs) originating from anthropogenic activities are leading to enhanced warming of the atmosphere and global climate change. The major greenhouse gases are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) all of which have both natural and anthropogenic sources. In contrast, the three industrial gases: hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulphur hexafluoride (SF_6), are potent greenhouse gases but only originate from anthropogenic sources (not natural sources have been verified).

These six greenhouse gases comprise the ‘basket of emissions’ against which reduction targets were agreed at the Third Conference of the Parties of the United Nations Framework Convention on Climate Change (UNFCCC) in Kyoto, Japan in December 1997. The target for the UK is to achieve a reduction of the global warming potential of the six greenhouse gases of 12.5% by 2008-2012 (based on 1990 emissions estimates). Consequently the UK is required to compile annual emission inventories of these greenhouse gases and report the emissions to international bodies, such as the UNFCCC to demonstrate progress against its target under the Kyoto Protocol. The EU is also a signatory to the Protocol, and as a member, the UK has to also submit GHG emissions data to the European Union Monitoring Mechanism (EUMM).

Greenhouse Gas Inventories are submitted to UNFCCC and the EUMM in the Common Reporting Format (CRF). The CRF is a detailed and complex reporting framework, and gives net carbon emissions (that is emissions minus removals). The data in this report is presented here in a UN/ECE reporting format (see Annex 1) and quotes land use change and forestry emissions and removals separately. Consequently emission “totals” will vary between the two reporting formats. More detailed information may be found in the annual report on UK GHG emissions produced by the NAEI (Baggott *et al*, 2006).

The 2004 emissions for each of these six greenhouse gases are summarised in Table 2.1, and their inventories are discussed in the following sections. Inventories for the three indirect greenhouse gases (carbon monoxide, nitrogen oxides and non-methane volatile organic compounds) are included in subsequent chapters (Chapters 4, 5 and 5 respectively).

The total global warming potential of UK greenhouse gas emissions has been calculated using their global warming potentials (GWPs), which measures their effectiveness in global warming relative to CO_2, agreed by IPCC for a 100 year time horizon (IPCC, 1996).

Table 2.1 GWP for UK Emissions of Greenhouse Gases in 2004

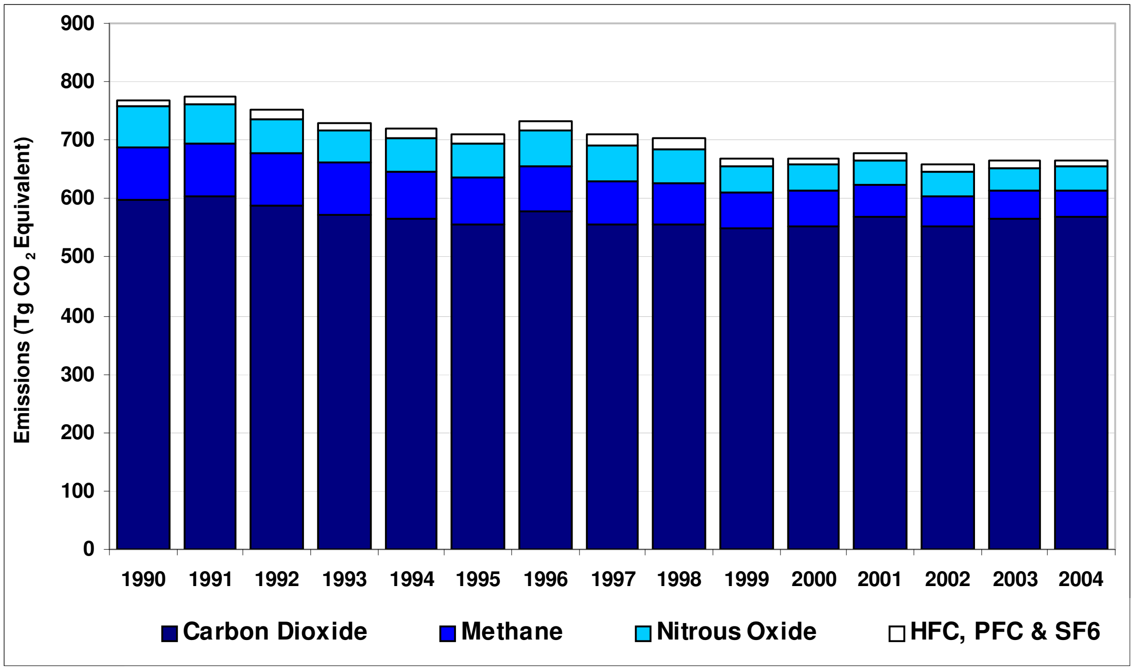
Direct GHG	Emissions (ktonnes) in 2004	GWP (100 years)	Global Warming Equivalence (equivalent kt of CO_2)
CO_2 (as carbon) [1]	153,601	3.7	568,322
CH_4	2469	21	51,857
N_2O	132	310	40,794
HFCs [2]	5.4	140 - 11,700	8,867
PFCs [2]	0.05	6,500 - 9,200	352
SF_6	0.05	23,900	1127

[1] The emissions given here are on a UNECE basis and hence do not include land-use change emissions.

[2] A number of GWPs are used as this refers to a group of compounds.

During the period 1990-2004 there has been a decrease in UK emissions of CO_2, CH_4, N_2O, HFC and PFC but considerable increases in SF_6 emissions. The overall effect has been a decrease in global warming potential from UK emissions. Figure 2.1 shows greenhouse gas emissions (comprising CO_2 , CH_4 , N_2O , HFCs, PFCs and SF_6) as CO_2 equivalent[4] for 1990 to 2004. Reliable emission estimates of HFCs, PFCs, SF_6 and N_2O (from adipic acid production) are not available prior to 1990.

Figure 2.1 Total UK GHG Emissions 1990-2004 (CO_2 equivalent)



CO_2 is the major contributor to greenhouse gas emissions in the UK and arises predominately from the combustion of fossil fuels. Non-fossil fuel sources are more difficult to assess and include the emission and uptake of CO_2 from the global carbon cycle. Following internationally agreed conventions, the NAEI excludes emissions of CO_2 originating from recently photosynthesised carbon as these will be part of the carbon cycle (rather than a "permanent" emission/removal). Hence emissions from biomass combustion, non fossil-fuel derived components of waste incineration, landfill and sewage treatment are not included in the total.

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[4] Different pollutants can be expressed as a carbon equivalent emission by taking their global warming potential relative to CO_2 into account. This then allows comparisons across different pollutant species on a like for like basis.

Emissions of other pollutants from biomass combustion are included in the appropriate inventories. The NAEI also currently excludes CO_2 emissions from the effect of changing land use although these emissions are estimated and included in the UK Greenhouse Gas Inventory (Baggott *et al*, 2006)- see discussion below.

Methane, like carbon dioxide, is naturally occurring and is part of the global carbon cycle. However, the magnitudes of sinks and sources of methane are not well known. Methane in the atmosphere is eventually oxidised to CO_2 and the most recent IPCC estimate of its lifetime in the atmosphere is 12±3 years (IPCC, 1996). Methane has a much greater warming effect on the climate than carbon dioxide (Table 2.1). The major anthropogenic sources of methane are waste disposal, agriculture, coal mining and leakage from the gas distribution system. Due to the nature of these sources the estimation of methane emissions is very uncertain although the methodologies are continuously being improved. Early estimates of methane emissions by sector were based on the findings of the Watt Committee on Energy (Williams, 1994), however many have now been revised to take into account new information and to ensure consistency with the methodologies recommended by the IPCC Revised Guidelines (IPCC, 1997).

The third direct greenhouse gas, nitrous oxide (N_2O), is emitted from natural and anthropogenic sources (agriculture, biomass burning, coal combustion and some industrial processes). As N_2O has a GWP of 310, it is a powerful greenhouse gas. However, emissions from the UK are low, so the overall contribution to global warming is relatively small. A full set of detailed emission factors for man-made sources, e.g. combustion, are not yet available. However, emissions are estimated using the default values given in the guidelines and more detailed data on coal combustion based on UK literature.

The three industrial greenhouse gases included in the ‘basket of emissions’ agreed at Kyoto, namely hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6), have very high GWPs but the quantities emitted to the atmosphere are far smaller than the emissions of CO_2. For example the contribution of these gases to global warming was equivalent to just 2% of the total 2004 GWP weighted GHG emissions. These are gases with particular industrial applications; HFCs and PFCs are substitutes for chlorofluorocarbons (CFC) and hydrochlorofluorocarbons (HCFC) which are being phased out under the Montreal Protocol due to their role in the depletion of ozone in the stratosphere. A more detailed description of the usage, emissions and methodology for calculating emissions of these gases is given by Haydock *et al* (2004).

The following sections present the inventories for each of the six greenhouse gases. To date, most international attention has focused on carbon dioxide and methane. Hence estimates of these pollutants were included in the UK inventory a number of years before the other four pollutants. This is reflected in the longer time series of data available for carbon dioxide and methane. The overall accuracy of the inventories is also discussed. Full details of the methodology used to compile the inventory can be found on the NAEI website (http://www.naei.org.uk)

2.2 CO_2 EMISSION ESTIMATES

2.2.1 Total CO_2 Emissions

Carbon dioxide emissions in 2004 have reduced by 18% since 1970, as shown in Figure 2.2. However, this decline has not been steady, and peaks were observed in 1973 and 1979 which were due to the state of the economy, high oil prices (resulting in the increased use of coal) and severe winters in these years. Emissions fell again during the early eighties reflecting the recession during this period and the coal miners strike of 1984. Since the mid-1980s the emissions profile has been much smoother showing an overall reduction in emissions. There are small increases in several sectors. The elevated emission from the domestic sector in 1996 is considered to be due to the colder than average winter (indicated by lower than average mean air temperatures).

The major emissions of carbon dioxide arise from the combustion of fossil fuels in power generation, and the transport, domestic and industrial sectors (Figure 2.2, Table 2.2). The level of emissions depends on the fuel mix and the fuel consumption data. Details of UK fuel consumption are given annually in the Department of Trade and Industry's Digest of United Kingdom Energy Statistics (DTI, 2005). The fuel consumption data used to calculate the pollutant emission totals in the NAEI are given in Table 2.3; fuels which are used as feedstock are omitted (principally natural gas used for the production of ammonia, methanol and acetic acid and some use of LPG and OPG in petrochemical plants).

Figure 2.3 gives the CO_2 emissions mapped across the UK on a 1km x 1km grid. Fuel combustion sources are clearly dominant and occur in urban centres and across the road network. The mapping concept, and methodology, is outlined in Section 1.2.5.

Table 2.2 UK Emissions of CO_2 as Carbon by UN/ECE[1] Source Category and Fuel (Mtonnes)

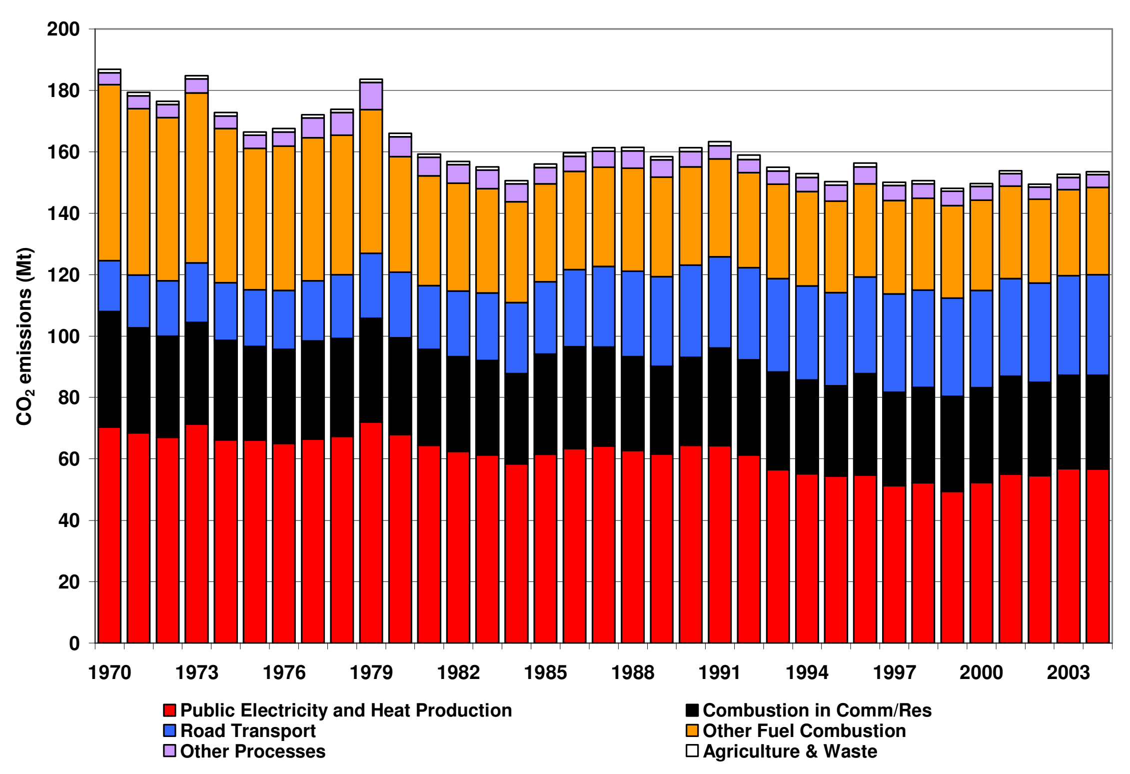
	1970	**1980**	**1990**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2004%**
BY UN/ECE CATEGORY[2]												
Public Power	70	68	64	51	52	49	52	55	55	57	57	37%
Industrial combustion	53	33	27	26	26	26	25	26	23	24	24	16%
Road Transport												
Road Transport/ Passenger Cars	11	15	19	20	20	20	20	20	20	20	20	13%
Road Transport/ Others	5	6	11	12	12	12	12	12	12	13	13	8%
Combustion in Comm/Res	38	32	29	31	31	31	31	32	30	31	31	20%
Processes	4	7	5	5	5	5	5	5	5	5	5	3%
Waste	0	0	0	0	0	0	0	0	0	0	0	0%
Agriculture & Land Use Change	0	0	0	0	0	0	0	0	0	0	0	0%
Off-road Vehicles, Other Machinery[3]	4	4	5	4	4	4	4	4	4	4	4	3%
Emission by fuel												
Solid	94	74	65	39	39	34	35	39	37	39	38	24%
Petroleum	68	56	54	49	48	47	46	48	47	47	48	31%
Gas	21	30	38	57	59	62	63	62	61	62	64	41%
Non-Fuel	3	6	5	5	5	5	4	4	4	4	4	3%
TOTAL	187	166	161	150	151	148	150	154	149	153	154	100%

[1] UK emissions reported in IPCC format (Baggott *et al*, 2006) differ slightly due to the different source categories used.

[2] See Annex 1 for definition of UN/ECE Categories

[3] Including railways, shipping, naval vessels, military aircraft and off-road sources

Figure 2.2 Time Series of CO_2 as Carbon Emissions (Mtonnes)



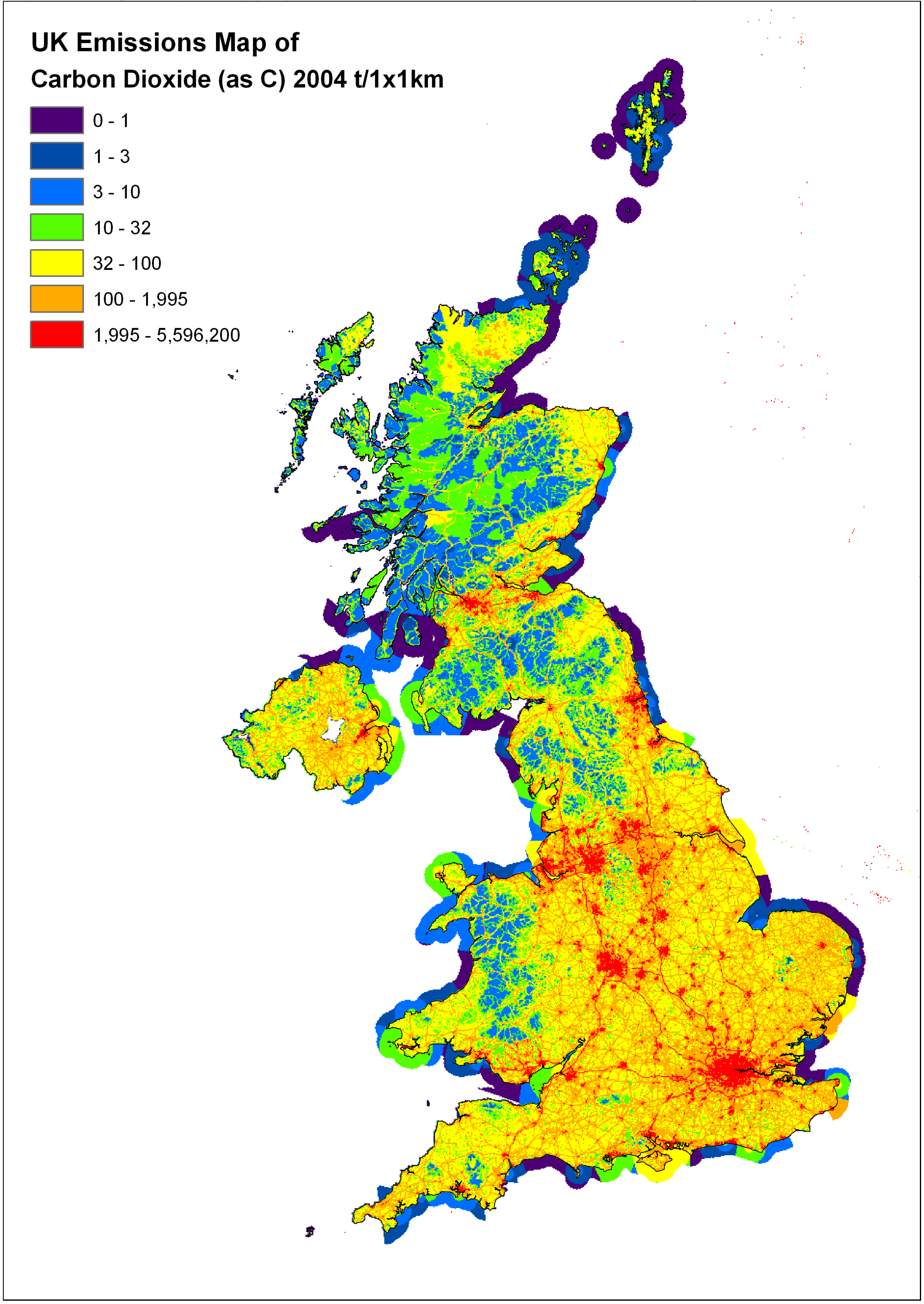


Figure 2.3 Spatially Disaggregated UK Emissions of CO_2 as Carbon Map[5]

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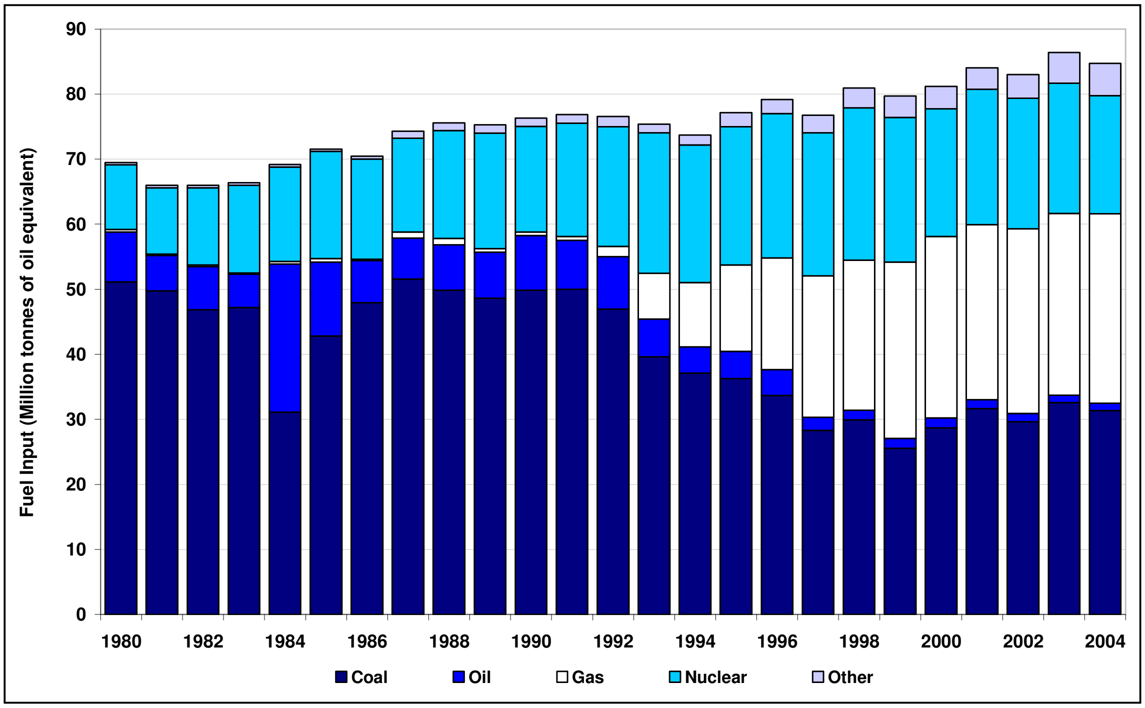
2.2.2 Electricity Supply Industry

The electricity supply industry is the major consumer of fossil fuels, and hence the major source of carbon dioxide emissions in the UK (Table 2.2 and Table 2.3). There have been significant changes in the generating mix between 1980 and 2004, as shown in Figure 2.4. The level of CO_2 emissions is determined by both the fuel mix and the generating technology used. During the 1970s the electricity supply industry was dominated by coal and fuel oil fired thermal power stations, and coal and oil consumption increased to meet the rising demand for electricity. The use of coal for power generation peaked in 1980 at 54.2 Mt of Carbon and has subsequently declined. The fall has not been steady, showing minima in 1982 and 1984 due to recession in the early 1980s and the miners strike of 1984. During the late 1980s and early 1990s, the closure of inefficient plants led to an overall increase in the thermal efficiency of the conventional thermal power plants, and the contribution of nuclear power generation increased with the greater utilisation of existing nuclear plants and the commissioning of Sizewell B in 1995. The use of oil generation peaked in 1972 and apart from increased consumption during the miners strike of 1984 has been in decline ever since. Two oil-fired stations were converted to burn Orimulsion® (an emulsion of bitumen and water) although this practice has been discontinued, largely on environmental grounds. More recently, the privatisation of the power industry has resulted in a move away from coal and oil generation towards combined cycle gas turbines (CCGT). Since 1970 the use of gas in power generation has increased by more than a factor of 100 and further increases may be expected as and when more CCGT stations come on line.

Table 2.3 UK Fuel Consumption, 1970-2004

Fuel	Consumer	Units	1970	1980	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Coal	Major Power	Mt	77	90	83	58	53	45	46	39	44	48	45	50	48
Coal	Industry	Mt	26	12	9	7	6	6	6	6	4	6	5	5	5
Coal	Domestic	Mt	22	7	3	1	1	1	1	2	1	1	1	1	1
Coal	Other	Mt	4	2	1	1	1	1	0	0	0	0	0	0	0
Other Solid Fuels	All consumers	Mt	161	126	113	83	78	70	70	62	64	70	65	69	67
Motor spirit	RT	Mt	19	25	35	35	37	37	37	37	37	37	38	37	38
Gas Oil	Industry	Mt	8	6	4	1	4	4	4	3	3	3	3	3	3
Gas Oil	Other	Mt	6	7	6		6	6	6	6	6	6	5	5	5
Fuel OIl	Major Power Prod	Mt	12	6	6	2	2	1	1	1	1	1	1	1	1
Fuel Oil	Refineries	Mt	4	4	2	2	2	2	2	2	1	2	2	2	2
Fuel Oil	Industry	Mt	22	10	4	3	2	2	2	1	1	2	1	1	1
Fuel Oil	Other	Mt	13	5	4	4	4	4	4	3	2	2	2	2	2
Orimulsion	Major Power Prod	Mt	0	0	0	1	1	0	0	0	0	0	0	0	0
Burning oil	Domestic	Mt	1	1	2	2	3	3	3	2	3	3	3	3	2
Burning oil	Other	Mt	4	0	0	1	1	1	1	1	1	2	1	1	1
Aviation Turb Fuel	Air Transport	Mt	3	5	8	9	9	9	10	11	12	12	12	12	13
Other Pet Products	All consumers	Mt	2	2	1	2	2	2	2	2	2	2	2	2	2
Petroleum Gases	Refineries	Mth	44	8	8	4	5	5	18	18	18	20	5	9	9
Petroleum Gases	Other	Mth	700	625	502	561	630	578	566	545	518	541	515	659	630
Natural gas	Major Power	Mth	60	55	3	3645	5109	6896	7608	9219	9457	9325	9829	9654	10327
Natural gas	Domestic	Mth	627	8420	10250	11124	12824	11790	12144	12218	12622	12947	12843	13188	13526
Natural gas	Industry		2724	5602	5227	5627	6225	6635	6897	7330	7845	7505	7138	7211	6753
Natural gas	Other	Mth	230	3099	4758	6076	6661	6428	6854	7035	7166	7591	7072	7085	7178
Other gas	All Consumers	Mth	7976	2197	2756	3683	3769	3484	3090	2959	2777	2429	2312	2245	2353

Figure 2.4 Generating Mix (1980-2004) Million Tonnes Oil Equivalent (Mtoe).

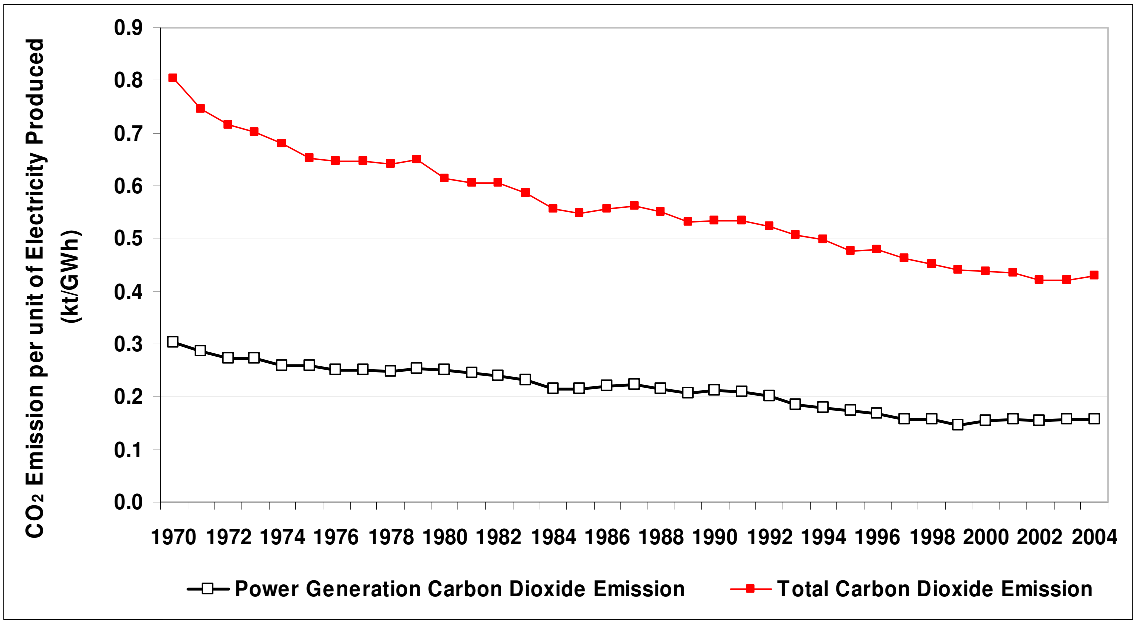


The effect of these changes in the power sector is clearly reflected in the carbon dioxide emissions. Since 1970 electricity generation has substantially increased but emissions have decreased by around 18%. This is due specifically to:

- The greater efficiency of the CCGT stations compared with conventional coal fired stations - around 47% as opposed to 36%.
- The calorific value of natural gas (per unit mass of carbon) being higher than that of coal and oil (the inventory takes account of unrefined gas or sour gas used by some plant).
- and to a lesser extent, the proportion of nuclear generated electricity increasing to 21%.

The overall effect of the fuel and technology changes are also clearly illustrated in Figure 2.5 which shows that the average CO_2 (as Carbon) emission (from power generation) per kWh electricity generated decreases from 303 tonnes/GWh in 1970 to 158 tonnes/GWh in 2004. This trend is likely to continue into the future through the use of more advanced technology and abatement equipment. Also, the extent to which renewable sources and nuclear power is used in the future is expected to have a large impact on air emissions, and the trends illustrated in Figure 2.5.

Figure 2.5 Average Carbon Emission per unit of Electricity Generated (ktonne/GWh)



2.2.3 Domestic

The domestic use of coal (including anthracite) shows an overall decline between 1970 and 2004, falling by 96%. Domestic use of smokeless solid fuels (including coke) has also fallen significantly. This reflects a trend away from solid fuels towards alternatives such as electricity and gas in the domestic sector. Over the same period the domestic use of natural gas has significantly increased.

2.2.4 Industrial

The 2004 industrial emissions show a decrease of 50% since 1970. The peaks in 1973, 1979, and 1988 were due in part to the cold winters in these years but in general the trend of industrial emissions are closely related to economic activity. The reduction in industrial energy consumption since 1970 reflects the decline in a number of energy intensive industries in the UK and improvements in energy efficiency of combustion plants. The shift from coal and oil use to more energy efficient fuels, predominately natural gas, is evident in the industrial sector between 1970-2004.

2.2.5 Transport

Total emissions from the transport sector have steadily increased since 1970. Of these, road transport emissions have risen by 98% and currently account for 94% of the total transport/mobile machinery emissions in 2004. This also equates to 21% of the total UK carbon dioxide emissions. Emissions fell a little during 1974-75 reflecting the increase in motor fuel prices after the oil crisis. The steady increase in fuel use by most forms of transport reflects the increased demand for transport in the UK between 1970 and 2004. The increased use of private motor vehicles has resulted in a 37% increase in the consumption of petrol from 1970 to 2004. However, petrol consumption has declined by 20% since 1990, which is a result of the increase in popularity of diesel cars, and the increased fuel efficiency of petrol driven cars. DERV consumption for use by goods vehicles has increased by approximately 239% since 1970.

2.2.6 Agriculture/Forests/Land Use Change

The effect of changing land-use can result in either net emission or net absorption of CO_2 , particularly on a global scale. For example, forest clearing for agricultural use could be a net source of CO_2. Recently the Intergovernmental Panel on Climate Change agreed new guidelines for preparing national inventories (IPCC, 1997). Land use change and forestry estimates are included in the UK Greenhouse Gas Inventory (Baggott *et al*, 2006) for the years 1990-2004. The estimates are not included under the reporting format for air quality pollutants (the entry under "Agriculture & Land Use Change" in Table 2.2 corresponds to the CO_2 emissions arising from the application of lime to soils). For comparative purposes the carbon emissions and *removals* arising from land use change are summarised in Table 2.4 (Milne, 2004).

Table 2.4 Emissions & Removals of CO_2[1] (as CO_2) from Land Use Change & Forestry(2004)

Sources	**Emissions (ktonnes)**	**Removals (ktonnes)**
A. Changes in Forest and Other Woody Biomass Stocks [1]		16302
B. Forest and Grassland conversion	183	
C. Abandonment of Managed Lands	-	-
D. CO_2 Emissions and Removals from Soil [2]	12654	IE
E. Other [3]	1551	645
Total	**14388**	**16947**

[31] Removals include removals to forest and soil litter, and to forest products.

[2] Emissions include removals to soil due to set aside of arable land

[3] Emissions include emissions from soil due to upland drainage, lowland drainage and peat extraction. Removals are increases in crop biomass.

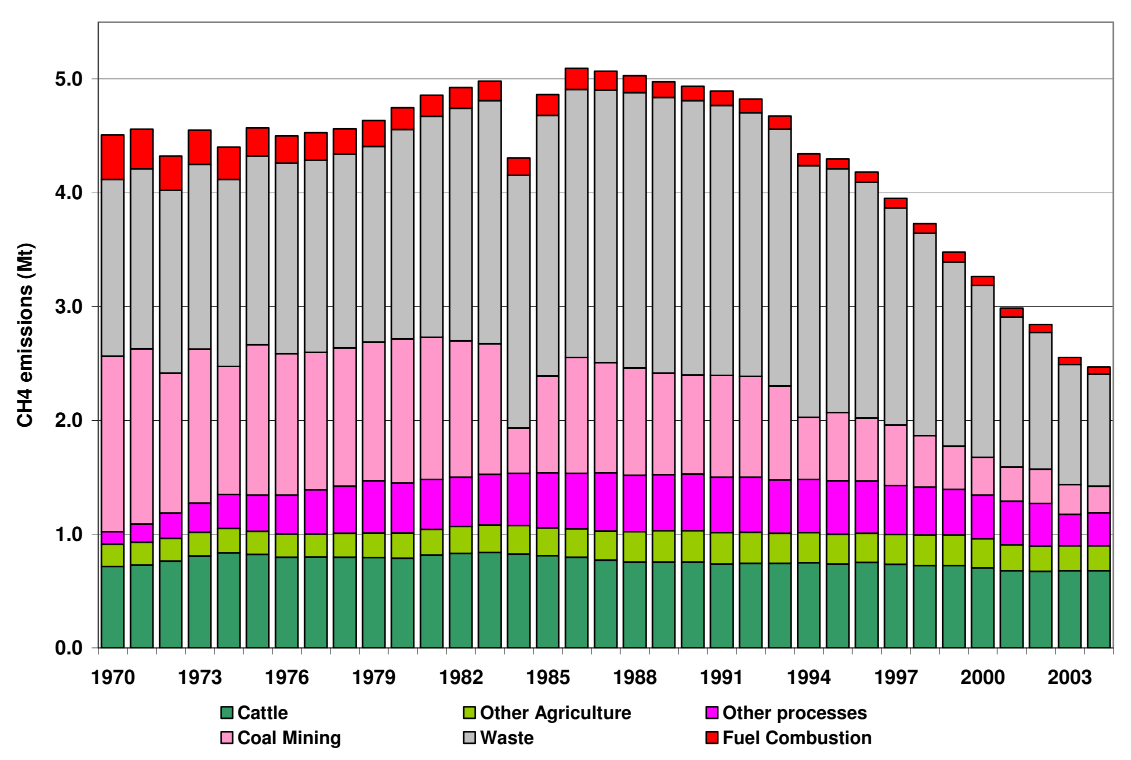
The net emission/removal (i.e. the difference between the emission and removal terms) varies considerably on a year to year basis, and has a significant impact on the net emission of carbon.

2.3 CH_4 EMISSION ESTIMATES

2.3.1 Total CH_4 Emissions

Since 1970, the total methane emission in the UK has declined by 45%, although this has not been a steady decrease with emissions actually increasing throughout the seventies, reaching a peak in 1983 (Figure 2.6). There was a temporary fall in emissions in 1984 as a result of the miners strike reducing emissions from coal mines. There is a wide variety of emissions contributing significant amounts to the methane total. These include landfill sites, livestock in the agricultural sector, leakage during the transmission and distribution of natural gas and coal mines (Table 2.5). The patterns of emissions from each of these sectors are discussed in the following sections.

Figure 2.6 Time Series of CH_4 Emissions (Mtonnes)



2.3.2 Landfill

Landfills are estimated to account for 38% of the UK's methane emissions in 2004. The estimation model is relatively complex as it needs to take account of the wide range of different types of landfill sites in the UK and the variation in methane emissions during the lifetime of a landfill site. Methane emissions are derived from estimates of the amount of putrescible waste disposed of to landfill. Based on a model of the kinetics of anaerobic digestion of waste material, the rate of methane production from landfills is estimated. Corrections are then applied for methane recovery, utilisation, flaring and oxidation by capping soil on different landfill sites.

The trend in methane emissions from landfill shows a gradual increase to a peak in the mid 1980's followed by a decline due to the implementation of methane recovery systems. This trend is likely to continue since all new landfill sites after 1994 must collect and utilise (or flare) the methane emissions. Similarly, since 1994 the combustion of landfill gas has been required at all existing sites in the UK which have significant remaining capacity and where significant gas production is likely. The uncertainties associated with the estimation of methane from landfills are large and it is likely that these estimates will be further refined in the future as more information becomes available.

2.3.3 Agriculture

The largest source of methane emissions in the UK is the agricultural sector where the emissions arise primarily from enteric fermentation in the guts of ruminant animals and from animal wastes. Emissions increased in the early seventies and have declined slowly since 1974. The methane emission is dependent on the numbers and types of farm animals, with dairy cattle being the most significant source. The recent decline results from the reduction in dairy cattle numbers in line with the 1992 Common Agricultural Policy reforms and due to gradual increases in animal productivity. It is anticipated that there will be further reductions in animal numbers leading to a continued reduction in the emission of methane from this sector.

Table 2.5 UK Emissions of Methane by UN/ECE[1] Source Category and Fuel (ktonnes)

	1970	1980	1990	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[2]												
Stationary Fuel Combustion	391	193	125	85	85	86	75	77	69	61	62	3%
Coal Mining	1540	1269	870	532	454	380	333	301	301	259	234	9%
Gas Mains Leakage	88	354	379	331	328	328	315	317	317	223	231	9%
Other Processes	22	83	120	99	91	74	68	67	58	54	58	2%
Agriculture												
Cattle	717	788	755	734	724	724	705	678	674	678	678	27%
Sheep	132	153	212	208	215	216	206	180	176	176	177	7%
Other Livestock	51	49	50	54	56	52	49	46	45	43	44	2%
Other Agriculture	14	21	13	1	1	1	1	1	1	1	1	0%
Landfill	1513	1798	2370	1869	1738	1579	1474	1279	1164	1017	944	38%
Other Waste	41	42	41	37	38	37	38	38	39	39	39	2%
Off-road Vehicles, Other Machinery[3]	1	1	2	2	2	2	2	2	1	1	1	0%
By FUEL TYPE												
Solid	332	141	67	35	36	38	28	32	28	21	23	1%
Petroleum	32	33	35	25	23	21	19	18	16	15	13	1%
Gas	26	18	23	26	25	27	27	26	24	25	25	1%
Non-Fuel	4121	4559	4812	3866	3648	3393	3192	2910	2777	2491	2408	97%
TOTAL	4511	4751	4937	3953	3731	3480	3264	2986	2844	2554	2469	100%

[1] UK emissions reported in IPCC format (Baggott *et al*, 2006) differ slightly due to the different source categories used.
[2] See Annex 1 for definition of UN/ECE Categories
[3] Including railways, shipping, naval vessels, military aircraft and off-road sources

2.3.4 Coal mining

Methane emissions from coal mining have reduced significantly during the past 20 years reflecting the reduction in UK coal production. In 1970 the emission accounted for 33% of total UK emissions but by 2004 this had reduced to just 9%. The strong correlation between coal production and methane emission is clearly illustrated in Figure 2.6 by the large fall in emissions during the 1984 miners strike. The reduction in mining emissions is the most important contributor to the overall fall in methane emissions since 1970.

2.3.5 Leakage from the Gas Distribution System

Methane leakage from the gas distribution system increased substantially between 1970 and 1990 reflecting the growth in gas sales for domestic use, and currently accounts for 9% of UK methane emissions. Emissions are estimated based on the throughput of gas and hence are rather uncertain. However, since 1990, emission estimates are based on a sophisticated gas leakage model from TRANSCO. This model accounts for the fact that old mains are being replaced by modern pipeline, and in recent years emissions have been decreasing significantly.

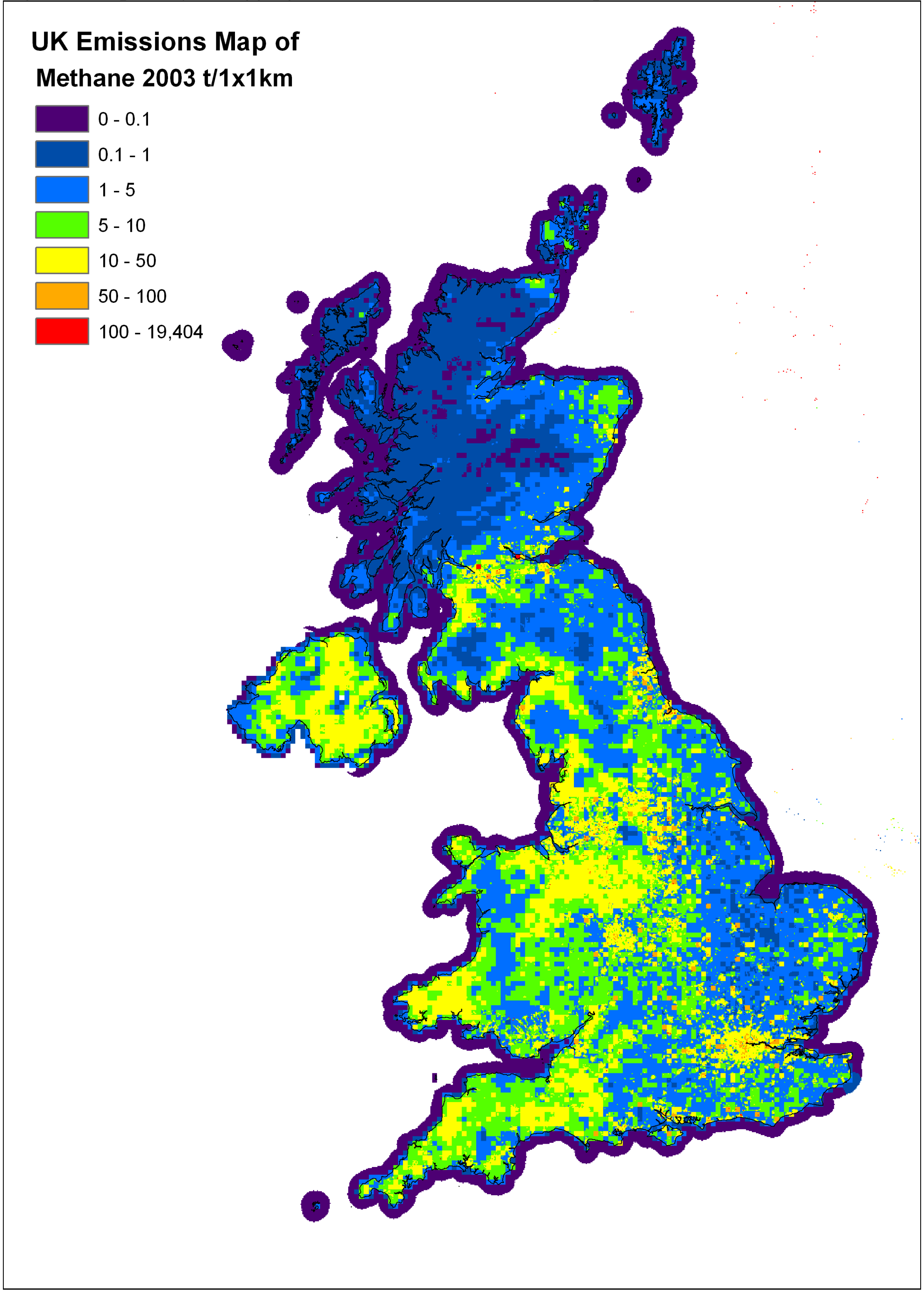
2.3.6 Offshore Oil and Gas

Methane emissions from offshore activities only account for 3% of total UK emissions but have declined in recent years, despite the increase in the number of installations. Emissions are estimated on the basis of data provided by the operating companies to the UK Offshore Operators Association. Methane emissions from cold venting, natural gas use, well testing, fugitive emissions and flaring from offshore platforms are now all estimated separately. Of these, venting is the main source of methane. Other sources are fuel oil and gas combustion and emissions from tanker loading and unloading.

2.3.7 Sewage Disposal

Methane emissions from sewage disposal are fairly uncertain but are currently estimated to be small. The emissions depend on the mode of disposal: sea dumping, land spreading or incineration. There have been substantial changes across the time series as dumping to sea has was banned in 1998, and application to agricultural land has been seen as unattractive. The proportion disposed of in landfills is allocated to the landfill estimate. Emissions are likely to rise as a result of the EC Urban Waste Water Treatment Directive but the rate of increase will depend on the disposal routes adopted.

Figure 2.7 Spatially Disaggregated UK Emissions of CH_4 Map[6]



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2.4 N_2O EMISSION ESTIMATES

The major source of nitrous oxide emissions in the UK are from agricultural activities. Less significant sources include industrial processes, combustion processes in the power generation sector and road transport (Table 2.6 and Figure 2.8).

Table 2.6 UK Emissions of Nitrous Oxide (N_2O) by aggregated UN/ECE[1] Category and Fuel (ktonnes)

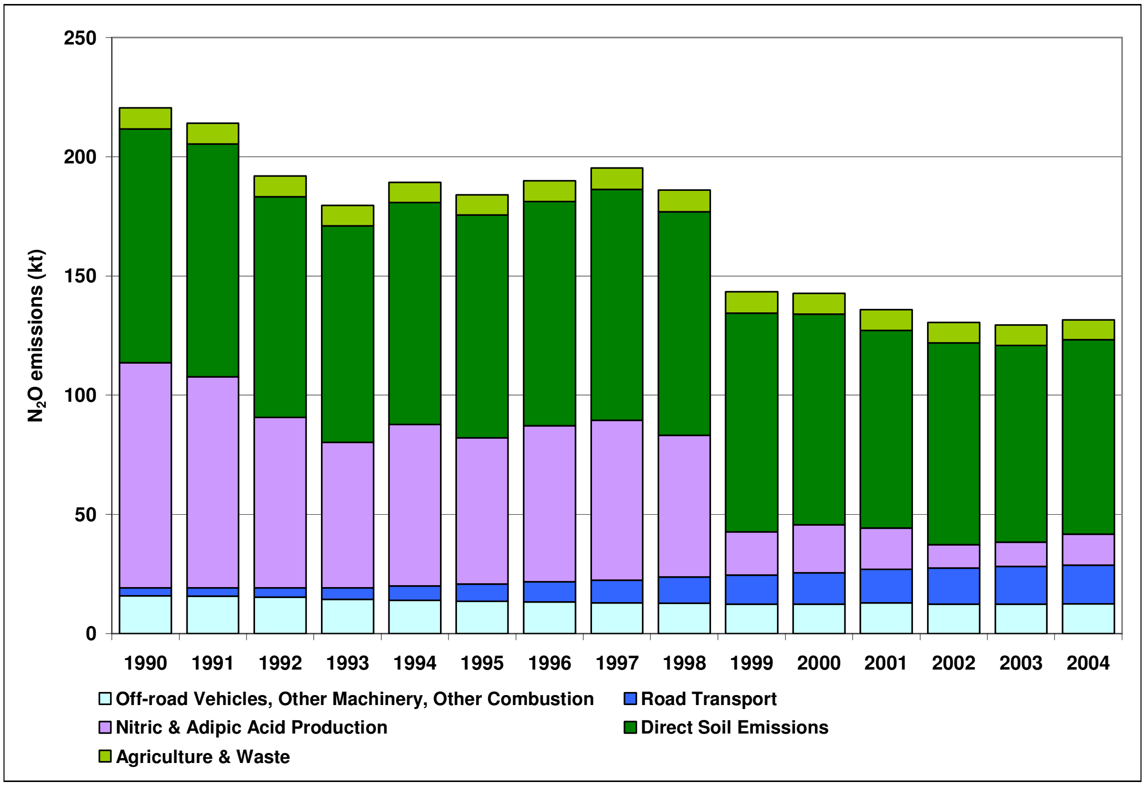
	1990	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[2]											
Industry											
Public Power	6.1	4.4	3.9	4.0	3.5	3.9	4.1	4.0	4.2	4.1	3%
Comm/Residential/Industrial combustion	6.5	5.6	5.5	5.4	5.5	5.1	5.5	5.1	4.9	5.0	4%
Other Processes	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0%
Nitric Acid Production	94.4	65.5	67.0	59.4	18.1	20.2	17.4	9.9	10.3	13.0	10%
Transport											
Road Transport/ Passenger cars	2.0	6.8	7.9	9.1	10.2	11.1	12.0	13.0	13.5	14.0	11%
Road Transport/ Other	1.3	1.6	1.7	1.9	1.9	2.0	2.0	2.1	2.2	2.3	2%
Off-road Vehicles, Other Machinery[3]	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.2	3.2	2%
Agriculture											
Direct Soil Emission	98.1	93.9	96.9	93.8	91.7	88.4	82.8	84.6	82.5	81.6	62%
Other Agriculture	5.4	5.1	5.1	5.1	5.1	4.8	4.6	4.5	4.4	4.2	3%
Waste	3.5	3.6	3.9	4.0	4.0	4.0	4.1	4.1	4.1	4.1	3%
By FUEL TYPE											
Solid	8.7	6.2	5.7	4.9	4.8	4.4	4.4	5.0	4.5	4.6	4%
Petroleum	7.6	11.3	12.6	13.6	14.8	15.7	16.6	17.4	18.3	18.2	14%
Gas	1.4	2.9	3.6	4.3	4.7	5.1	5.5	5.5	5.8	5.6	4%
Non-Fuel	201.4	163.7	168.6	173.4	163.1	119.9	118.2	109.7	103.8	102.0	78%
TOTAL	**220.6**	**189.9**	**195.3**	**186.0**	**143.4**	**142.8**	**135.9**	**130.6**	**129.4**	**131.6**	**100%**

[1] UK emissions reported in IPCC format (Baggott *et al*, 2006) differ slightly due to the different source categories used.

[2] See Annex 1 for definition of UN/ECE Categories

[3] Including railways, shipping, naval vessels, military aircraft and off-road sources

Figure 2.8 Time Series of N_2O Emissions (ktonnes)



2.4.1 Agriculture

The calculation of emissions from agricultural soils and animal wastes have been considerably extended in recent years. In particular, the publication of the Revised IPCC Guidelines (IPCC, 1997) has enabled a greater number of sources to be considered. The emissions from agricultural soils currently account for around 62% of total UK emissions. The most significant sources are fertiliser application and emissions indirectly from leaching.

2.4.2 Production Processes

The production processes sector is comprised of emissions from adipic acid manufacture (a feedstock for nylon) and nitric acid manufacture. This sector accounts for 10% of the total nitrous oxide emissions in 2004. The extent of the emission depends on the production of these acids, hence the time series reflects production levels. However, the UK manufacturer of adipic acid commissioned an abatement unit in 1998 which has significantly reduced the UK total emission.

2.4.3 Power Generation

The contribution from public power generation has been relatively constant between 1990 and 2004 in spite of the trend away from coal towards natural gas combustion.

2.4.4 Road Transport

Emissions from the road transport sector have increased significantly since 1992. This is a direct result of the introduction of three-way catalytic converters which produce significantly more nitrous oxide than cars not equipped with abatement technology. Between 1990 and 2004 the proportion of vehicle kilometres traveled by cars equipped with catalytic converters has increased from <1% to 77% (Figure 2.9) and emissions of N_2O from road transport have increased substantially. The contribution of road transport to the total N_2O emission is small, but is one of the few sources which has been increasing across the time series. More recent catalysts have addressed this problem and give lower N_2O emissions. Emissions of N_2O from the other significant sectors are expected to continue to decrease.

Figure 2.9 The Growth in the Number of Car Kilometres from Cars with Catalytic Converters

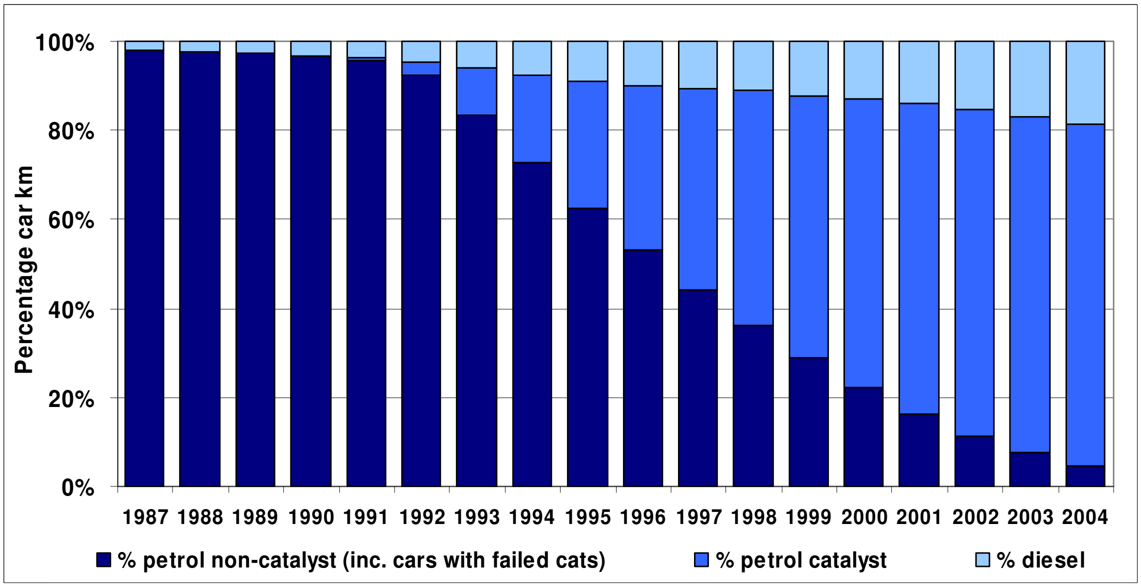
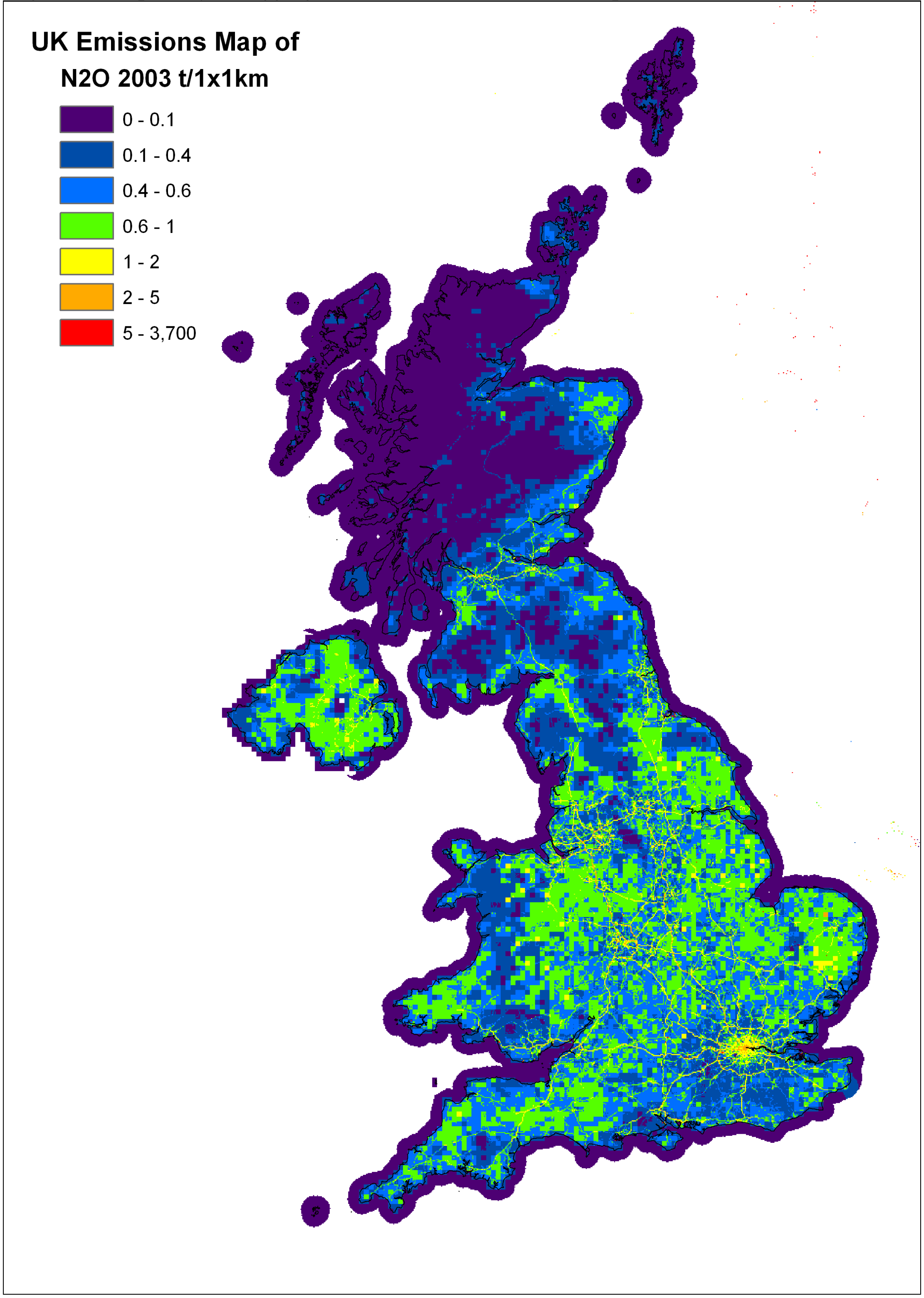


Figure 2.10 Spatially Disaggregated UK Emissions of N_2O Map[7]



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2.5 HFCS, PFCS AND SF_6 EMISSION ESTIMATES

2.5.1 Hydrofluorocarbons

The UK emissions of HFCs are shown in Table 2.7. The emissions are reported in terms of kilotonnes of carbon equivalent to account for their global warming potential (GWP). The HFC emissions comprise many species each with its own GWP, hence it is more helpful to express emissions in terms of GWP as Carbon equivalent. It is not currently possible to give emission estimates for individual HFCs because some of these are considered commercially sensitive data within the industries involved.

HFCs had limited usage primarily as refrigerants blended with CFCs. However, CFCs and HCFCs are being phased out under the Montreal protocol, and hence HFCs are now being used increasingly as:

- Substitutes for CFCs and HCFCs in domestic, commercial and industrial refrigeration and air conditioning
- Substitutes for CFCs in plastic foam blowing
- Substitutes for CFCs for some medical aerosols
- Substitutes for CFCs for industrial and specialist aerosols
- Fire fighting fluids

The NAEI's annual GHG Inventory Report (Baggott *et al,* 2006) reports the emissions, estimation methodology and ongoing improvements in more detail. The UK reports both actual and potential emissions of HFCs, although here only the actual emissions are presented.

Refrigeration is the largest source and contributed 32% of the total HFC emissions in 2004. Emissions arise due to leakage from refrigeration and air conditioning equipment during its life time, from losses during manufacture, and from the recovery of the refrigerants on decommissioning.

There has been a large decrease in emissions from "Halocarbon production" from 1998 to 2004, primarily due to the installation of abatement systems fitted to a plant producing HCFCs.

In the case of closed foams (where the fluid is retained within the foam) there will be some leakage of HFC from the foam during its lifetime and on disposal but with open foams all losses occur during manufacture. Since 1990, the use of HFCs in aerosols has greatly increased, and this source sector now accounts for 29% of the total emission.

The total UK emission of HFC (in C equivalent) has decreased by 22% over 1990-2004 and is characterised by the increasing use of HFCs offset by the large reduction in emissions from halocarbon production between 1998 and 2004.

Table 2.7 UK Emissions of HFCs (ktonnes C equivalent)

	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
METAL PRODUCTION	0	0	0	0	0	0	0	0	0	0	0.3	0%
Halocarbons production (by-product)	3102	3813	3906	4261	3370	1468	730	669	543	505	77	3.2%
Halocarbons use	0	412	655	972	1340	1487	1748	1972	2158	2276	2341	96.8%
Total	**3102**	**4225**	**4561**	**5232**	**4711**	**2955**	**2478**	**2640**	**2701**	**2781**	**2418**	**100%**

[1] Includes metered dose inhalers.

2.5.2 Perfluorocarbons

Table 2.8 shows the UK emissions of PFCs reported as kilotonnes of Carbon equivalent. It is not currently possible to give emission estimates for individual PFCs because some of these are considered commercially sensitive data within the industries involved. PFCs had limited usage prior to the phase out of CFCs in the electronics and electrical industry. PFCs are now used in:

- etching processes in the semiconductor industry
- chemical vapour deposition in the electronics industry
- soldering processes
- leak testing of electrical components
- cooling electrical components, for example in supercomputers and radar systems.

Other uses include
- refrigerant blended with HFC
- fire fighting in specialist applications
- cushioning in the soles of training shoes

Other minor uses of CFCs, which now use PFCs, include cosmetics and tracer gas.

The largest source of PFCs for 2004, representing 43% of the total, is from the aluminium production sector. The emissions are caused by the anode effect which occurs when alumina concentrations become too low in the smelter. This can cause very high electrical current and decomposition of the salt - fluorine bath. The fluorine released reacts with the carbon anode, creating PFC compounds CF_4 and C_2F_6 . Total emissions from aluminium production have declined by89% since 1990, reflecting steps taken by the industry to reduce emissions. PFCs are also produced by the electronics sector, where emissions arise from the manufacture of semiconductors. Emissions from this sector account for 27% of the UK total in 2004.

Table 2.8 UK Emissions of PFCs (ktonnes C equivalent)

	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
METAL PRODUCTION	363	78	77	60	59	52	70	61	43	34	42	43%
Halocarbons production (fugitive)	3	19	21	10	12	5	6	15	16	18	29	30%
Halocarbons use	16	31	37	43	44	51	59	40	29	29	26	27%
Total	**382**	**128**	**135**	**114**	**115**	**109**	**136**	**116**	**88**	**81**	**96**	100%

2.5.3 Sulphur Hexafluoride

SF_6 is used in the following applications:

- insulation medium in high voltage applications such as switchgear and circuit breakers
- cover gas in magnesium foundries to protect the molten magnesium from re-oxidising when it is cast
- degasser in aluminium casting applications, though its use in the UK is rather limited
- insulating gas in double glazing applications, replacing vacuum as an insulation technique
- plasma etching of polysilicon and nitrite surfaces
- atmospheric tracer for scientific studies
- cushioning in soles of training shoes

Table 2.9 shows the UK emissions of SF_6. The largest source is from Electrical insulation, where SF_6 is used for electrical insulation.. Emissions from this sector account for 46% of the UK total in 2004.

The other main sources are from uses as a cover gas from the magnesium sector (34% of UK total) and manufacture of trainers (18% of UK total). The use of SF_6 as a cushioning agent in trainers will be phased out in the near future. Emissions from the electrical insulation arise during the manufacture and filling of electrical switchgear and from leakage and maintenance during the equipment's lifetime. This application has only been in use for the last 20 to 30 years and little of the equipment has been decommissioned. It is expected that users will take great care over future fluid recovery so that emissions will be minimised. SF_6 emissions have increased by 10% since 1990.

Table 2.9 UK Emissions of Sulphur Hexafluoride (ktonnes C equivalent)

	1990	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2004 %**
METAL PRODUCTION	116	116	116	117	129	187	298	206	231	183	106	34%
Halocarbons use	165	222	229	217	216	201	192	182	181	178	202	66%
Total	281	338	345	334	344	389	490	389	412	361	307	100%

2.6 ACCURACY OF EMISSION ESTIMATES OF GREENHOUSE GASES

Quantitative estimates of the uncertainties in the greenhouse gas emissions were calculated using direct simulation, a technique similar to Monte Carlo Simulation. This corresponds to the IPCC Tier 2 approach. This work is described in detail by Eggleston *et al* (1998) though the estimates reported here have been revised to reflect changes in the 2004 Inventory.

Table 2.10 Uncertainty of the Emission Inventories

Pollutant	Estimated Uncertainty %
Carbon Dioxide	+/- 2.1
Methane	+/- 13
Nitrous Oxide	+/- 230
HFCs	+/- 25
PFCs	+/- 19
SF_6	+/- 13

It should be noted that these uncertainties primarily arise from emission factor uncertainties. Activity data is considered to be more reliable and better characterised. As a result it can be assumed that the trends identified from time series plots are considerably more reliable than an absolute emission total.

3 Stratospheric Ozone Depletors

Ozone, ozone depletors and ozone forming compounds (ozone precursors) are all important atmospheric pollutants for differing reasons. Ozone itself is a gas which has an irritant effect on the surface tissues of the body, such as eyes, nose and lungs (as well as damaging crops and buildings). Consequently at tropospheric levels (i.e. near the surface) ozone and ozone precursors are important pollutants. Ozone emissions are not estimated by the NAEI as the direct emissions are not significant compared with photochemical formation of ozone from ozone precursors. Estimating ozone concentrations in the troposphere requires modelling, and the input of information on ozone precursors. Consequently there is a need for emission estimates of ozone precursors, and these are given in this report (for location see Table 3.1 below).

Ozone naturally occurs in the stratosphere (higher layers of the earth's atmosphere) formed by the action of ultraviolet light from the sun on oxygen molecules. At this level, ozone is beneficial to health, filtering out harmful ultraviolet rays that can cause skin cancers. Chemicals which cause stratospheric ozone depletion must therefore be estimated.

Table 3.1 Location of Ozone Depletors and Precursors in this Report

Nitrous Oxide (N_2O)	Ozone Precursor	Chapter 5:Tropospheric Ozone
NMVOCs	Ozone Precursor	Chapter 5:Tropospheric Ozone
HFCs	Stratospheric Ozone Depletor	Chapter 2: Greenhouse Gases
PFCs	Stratospheric Ozone Depletor	Chapter 2: Greenhouse Gases

Evidence suggests that stratospheric ozone depletion is being caused by anthropogenic emissions of chlorine and bromine-containing substances (halocarbons) such as: CFCs, halons, and HCFCs. HCFCs are similar to CFCs but have a lower potential for depleting ozone and in some cases are being used as transitional replacements (for example in refrigeration equipment). Emissions of methyl chloroform, carbon tetrachloride and methyl bromide also contribute to the effect.

International agreement to limit the production and consumption (and hence emission) of ozone depleting substances and phase out use of these substances was reached in 1987 through the Montreal Protocol on Substances that Deplete the Ozone Layer. This has subsequently been strengthened by a number of Amendments. In addition, the EU introduced EC Regulation 3093/94 which in some cases adopted a faster timescale for the reductions. Overall this has led to substantial reductions in the production and consumption of these substances over the last 15 years.

The NAEI does not contain emissions inventories for all of these substances individually, although some of them, such as HCFCs, are included within the emissions for non-methane volatile organic compounds (see Section 4.10 and Appendix 6).

4 Air Quality Pollutants

4.1 INTRODUCTION

The original National Air Quality Strategy (NAQS) published in 1997 (DOE 1997) set out a framework of standards and objectives for the air pollutants of most concern (SO_2, PM_{10}, NO_X, CO, lead, benzene, 1,3-butadiene and tropospheric ozone). The aim of the strategy was to reduce the air pollutant impact on human health by reducing airborne concentrations. Different pollutants have differing timescales associated with human health impacts. Therefore concentrations during episodes (both Winter and Summer) are important for some pollutants, but less so for others.

The NAQS identified air quality standards for 8 priority pollutants based on the recommendations of the Expert Panel on Air Quality Standards (EPAQS) or WHO guidance where no EPAQS recommendation existed. EPAQS was set up by the Secretary of State for the Environment in 1991, and is a panel created to "*advise, as required, on the establishment and application of air quality standards in the UK… taking account of the best available evidence of the effects of air pollution on human health…*". The NAQS has been subject to periodic review, with consultation documents being published in 1998 and 2001 (DETR 1998a, Defra 2001).

The NAQS then evolved into the Air Quality Strategy for England, Scotland, Wales and Northern Ireland (AQS for ESWNI), with the same goals. A second edition of the strategy was published in 2000 (DETR 2000), identifying further revisions and focused on the incorporation of air quality limit values in European Directives, and the impacts of devolution.

In 2002, following consultation, new objectives were announced for particles, benzene, carbon monoxide and polycyclic aromatic hydrocarbons (Defra, 2003). More details can be found at the Defra website (Defra news release 323/02 on www.defra.gov.uk). The situation for Scotland differs slightly - the Air Quality (Scotland) Amendment Regulations came into force on 12 June 2002. More detailed information can be found on the Scottish Executive website (Scottish Executive News Release SEen057/2002 on www.scotland.gov.uk). For Wales, similar information is available from the Welsh assembly web pages (http://www.wales.gov.uk).

In addition to the above, Local Authorities in the UK have a duty, under the 1995 Environment Act: Part IV, to review and assess air quality in their areas. The Air Quality Regulations 2000 define a staged process of review and assessment on the basis of guidance provided by Defra and the Devolved Administrations. The first stage primarily involves the collection of existing data on air quality measurements and emission sources for the 8 pollutants of interest in the AQS for ESWNI. These data are then used to define whether there is likely to be an air quality problem in a specific future year (depending on pollutant). The second and third stages require the use of increasingly sophisticated monitoring and modelling tools to identify hotspots of pollution and to determine whether or not the relevant air quality objectives will be met in each area.

The NAEI is being used as an important source of data for the compilation of appropriate local inventories. Table 4.1 summarises the total 2004 emissions of the 9 priority pollutants covered by the AQS for ESWNI.

Table 4.1 Total UK Emissions of AQS Pollutants

Pollutant	**Total 2004 emission (ktonnes)**
PM_{10}	154
Carbon Monoxide	2930
Benzene	14.5
1,3 Butadiene	3.4
Nitrogen oxides	1621
Sulphur dioxide	833
Tropospheric Ozone	NS[1]
Lead	0.13
PAH[2]	2

[1] No significant ozone emissions from anthropogenic sources

[2] Benzo[a]pyrene is used as an indicator for PAH, but the emission total given here corresponds to the USEPA 16 (see Section 6.2).

The following sections provide a discussion of the UK emissions for particulate matter, carbon monoxide, benzene and 1,3-butadiene whilst a full discussion of the other pollutants is included in other chapters of this report as indicated in Table 4.2.

Table 4.2 Location of Emissions and Discussion of AQS Pollutants

Pollutant	**Location**
PM_{10}	Chapter 4: AQS Pollutants
Carbon Monoxide	Chapter 4: AQS Pollutants
Benzene	Chapter 4: AQS Pollutants
1,3 Butadiene	Chapter 4: AQS Pollutants
Nitrogen oxides	Chapter 5: Acidifying Gases & Ozone Precursors
Sulphur dioxide	Chapter 5: Acidifying Gases & Ozone Precursors
Tropospheric Ozone	Chapter 5: Acidifying Gases & Ozone Precursors
Lead	Section 6.3: Heavy Metals
PAH	Section 6.2: Persistent Organic Pollutants

4.2 PARTICULATE MATTER

4.2.1 Introduction

Historically, interest in particulate matter focused mainly on smoke which can cause health problems especially in combination with other pollutants. The classic example was emissions of smoke and sulphur dioxide leading to the London smogs in the 1950s and early 1960s when several thousand excess deaths were recorded. Smoke emissions have fallen significantly as a result of the Clean Air Act eliminating domestic coal combustion in many urban areas. However, there is increasing interest in the measurement of fine particles, such as those arising from the combustion of diesel fuel in the transport sector, and aerosol concentrations in the atmosphere from other sources which may have harmful effects. Recent epidemiological evidence is linking concentrations of particles in the atmosphere with human health effects. Indeed, current ambient mass concentrations are thought to be sufficient to lead to increased mortality and morbidity (EPAQS, 1995).

Particles can vary widely in size and composition. Particles larger than about 30 µm (a µm is a "micrometre", or one thousandth of a millimetre) fall rapidly under gravity and those larger than about 100 µm fall out of the atmosphere so rapidly they are not usually considered. At the other end of the size scale are particles less than a tenth of a µm which are so small they do not fall under gravity appreciably, but coagulate to form larger particles that are then removed from the atmosphere.

The US PM_{10} standard was a monitoring standard designed to measure the mass of particles less than 10 µm in size (more strictly, particles that pass through a size selective inlet with a 50% efficiency cut-off at 10 µm aerodynamic diameter). This corresponds to the International Standards Organisation thoracic convention for classifying those particles likely to be inhaled into the thoracic region of the respiratory tract. The epidemiological evidence of the effects of particulates shows good correlation in the UK between PM_{10} concentrations and mortality or morbidity (EPAQS 1995, 2001). Therefore PM_{10} has become the generally accepted measure of particulate material in the atmosphere in the UK and in Europe. There is also an increasing interest in the correlation between $PM_{2.5}$ and health indicators, and it may be that $PM_{2.5}$ is used as a primary metric in the future. PM_{10} measurements have been made in the UK for a number of years (see http://www.airquality.co.uk/archive/index.php) and their emissions have been included in the NAEI since 1995.

For many years the monitoring of particulate levels was based on the measurement of "Black Smoke". Levels were estimated using a simple non-gravimetric reflectance method in which air is sampled through a filter and the resulting blackening measured. The method was calibrated for domestic coal smoke. When most of the emissions come from coal combustion the blackening should be approximately proportional to the mass concentrations. In the 50s and 60s, domestic coal combustion was the dominant source of black smoke and hence this method gave an indication of the concentration. The NAEI estimates of black smoke emissions were extended in 1988 to include emissions from all fuel combustion. Prior to 1988 only emissions from coal combustion had been estimated and published in the Digest of Environmental Statistics.

Smoke from different sources has a different blackening effect and so there is no simple relationship between black smoke and the mass of particulate emissions. For example, typically diesel emissions have a blackening effect three times greater, on a mass for mass basis, compared with coal emissions, while petrol emissions are effectively an order of magnitude less. So, black smoke is a poor indicator of the concentrations of particulates in the atmosphere. Furthermore, the measurements used for deriving emission factors of black smoke were conducted several decades ago, and are therefore very dated. Current interest and the AQS is focused on PM_{10} (particulate matter less than 10µm i.e. 10 millionths of a metre) and smaller size fractions (EPAQS, 1995). However, black smoke has been shown to have relationships with health effects and is still used as an indicator.

For completeness the following sections present emission estimates and discussion for PM_{10}, $PM_{2.5}$, $PM_{1.0}$, $PM_{0.1}$. Black Smoke is included in a summarised format.

4.2.2 PM_{10}

4.2.2.1 Sources of emissions

PM_{10} in the atmosphere arises from two sources. The first is the direct emission of particulate matter into the atmosphere from a wide range of sources such as fuel combustion, surface erosion and wind blown dusts and mechanical break-up in, for example, quarrying and construction sites. These are called 'primary' particulates. The second source is the formation of particulate matter in the atmosphere through the reactions of other pollutants such as sulphur dioxide, nitrogen oxides and ammonia to form solid sulphates and nitrates, as well as organic aerosols formed from the oxidation of NMVOCs. These are called 'secondary' particulates. This inventory only considers primary sources. For further information on secondary particulate see the third Quality of Urban Air Review Group report (QUARG, 1996) and the report from the Airborne Particles Expert Group (APEG, 1999) see http://www.airquality.co.uk/archive/index.php and http://www.defra.gov.uk/environment/airquality/airbornepm/index.htm respectively.

There is on-going work sponsored by Defra to measure PM_{10} emissions, and assess the size distribution and chemical composition of the particulate material.

The main sources of primary PM_{10} are briefly described below:

- Road Transport. All road transport emits PM_{10}. However diesel vehicles emit a greater mass of particulate per vehicle kilometre than petrol-engined vehicles. Emissions also arise from brake and tyre wear and from the re-entrainment of dust on the road surface. Emission estimates for the resuspension (or "re-entrainment") of dust have been made. However this emission does not fall within the UN/ECE reporting format and consequently has been included here for information only.

- Stationary Combustion. Domestic coal combustion has traditionally been the major source of particulate emissions in the UK. However, the use of coal for domestic combustion has been restricted in the UK by the Clean Air Acts, and as a result other sources are more important nationally. Domestic coal is still be a significant source in Northern Ireland, some smaller towns and villages, and in areas associated with the coal industry. Other fossil fuels emit PM_{10}, with combustion of wood, gas oil and natural gas all contributing significantly to UK emissions. In general, particles emitted from fuel combustion are of a smaller size than from other sources.

- Industrial Processes. These include the production of metals, cement, lime, coke, and chemicals, bulk handling of dusty materials, construction, mining and quarrying. Emissions from these sources are difficult to quantify due to the contribution of fugitive emissions (i.e. those diffuse emissions which are released directly into the atmosphere from a process rather than being collected in a controlled manner and then vented to atmosphere). Few UK measurements are available for these fugitive releases. Nonetheless, there have been substantial improvements in the estimation of PM_{10} emissions from industrial processes in recent years. Usually a substantial fraction of the particles from these sources is larger than 10 µm but the large quantities emitted ensure that the fraction less than 10 µm is still a substantial source.

4.2.2.2 PM_{10} Emission estimates

Emissions of PM_{10} are shown in Table 4.3 and Figure 4.1. Emissions of PM_{10} from the UK have declined since 1970. This is due mainly to the reduction in coal use. Emissions in the domestic and commercial sector have fallen from 227 ktonnes (46% of the total emission) in 1970 to 26.39 ktonnes (17%) in 2004.

Emission estimates for the resuspension of dust from roads is not included in the standard UN/ECE reporting format (and hence not included in Table 4.3). However for completeness it is given in Table 4.4 below. Estimates for resuspension are based on the deposition of primary particles from all UK sources (including vehicle tailpipes and from brake and tyre wear) that are returned to the air from the turbulence of passing vehicles. As such, resuspension represents a "double count" in the emissions, but is important in reconciling roadside concentration measurements.

Table 4.3 UK Emissions of PM$_{10}$ by aggregated UN/ECE Source Category and Fuel (ktonnes)

	1970	1980	1990	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UNECE CATEGORY[1]													
Stationary Fuel Combustion	347	208	152	99	94	85	78	73	69	57	52	52	34%
Processes	34	32	38	32	31	30	28	26	26	25	26	25	16%
Transport													
Off-road mobile machinery[2]	47	30	28	25	25	25	23	21	22	21	20	21	13%
Road Transport/ Passenger Cars	10	14	18	14	13	12	11	8	8	8	7	7	4%
Road Transport/ Light DUTY vehicles	3	4	7	10	10	10	11	10	11	11	11	11	7%
Road Transport/ Heavy Duty Vehicles	25	27	27	19	16	14	12	11	10	9	8	7	5%
Road Transport/ Other	5	6	8	9	9	9	9	9	9	10	10	10	6%
Agriculture & Waste	20	21	21	20	22	21	21	21	25	21	21	21	14%
By FUEL TYPE													
Solid	315	181	126	69	55	57	53	48	46	36	30	33	21%
Petroleum	86	84	87	79	75	72	68	62	61	58	57	54	35%
Gas	1	2	2	4	13	3	3	3	4	4	4	4	2%
Non-Fuel	87	76	84	76	76	73	69	67	69	63	64	64	42%
TOTAL	**490**	**342**	**299**	**227**	**219**	**205**	**193**	**180**	**180**	**160**	**155**	**154**	**100%**

[1] See Annex 1 for definition of UN/ECE Categories

[2] Including railways, shipping, naval vessels, military aircraft and off-road sources

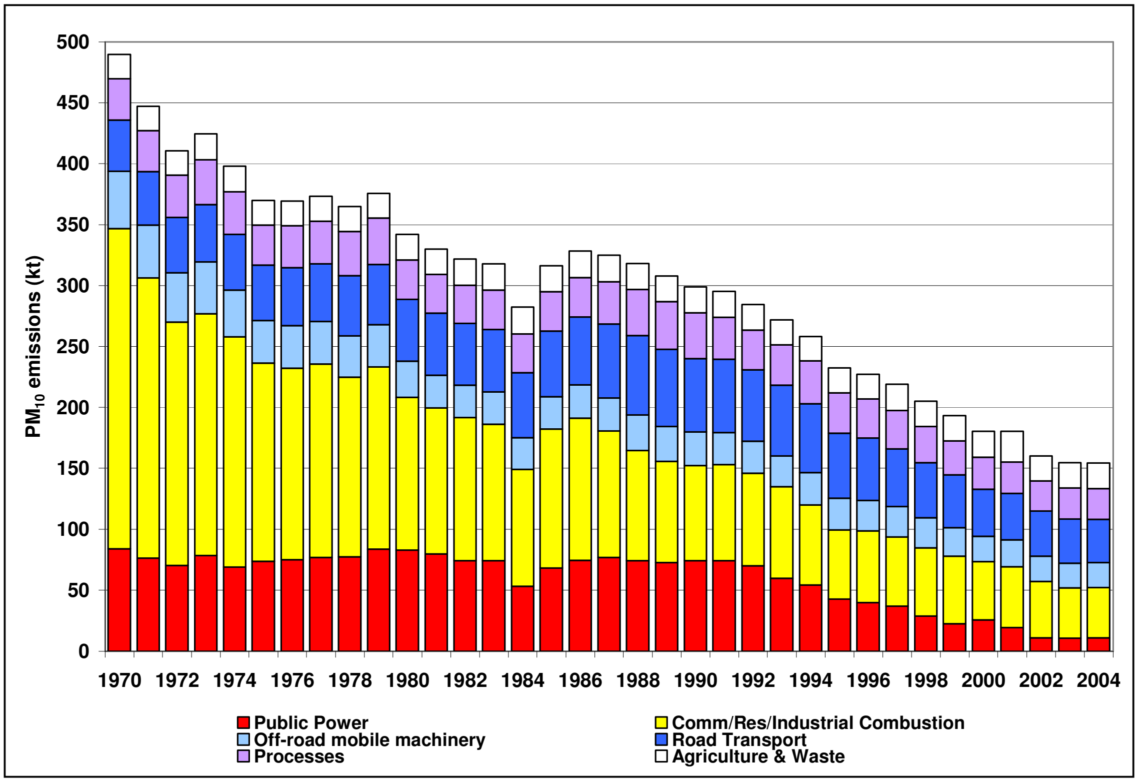
Table 4.4 PM$_{10}$ Emission Estimates from Resuspension (ktonnes)

	1970	1980	1990	1996	1997	1998	1999	2000	2001	2002	2003	2004
Resuspension from Road Transport	8	11	17	18	19	19	19	19	20	20	20	21

The geographical disaggregation of emissions is shown in Figure 4.2. There is a clear distinction between the important sources in rural and urban areas. Indeed, many of the sources do not occur inside towns and cities. While road transport accounts for only 23% of national emissions, it can account for up to 80% of primary emissions in urban areas such as London (Buckingham *et. al.*, 1997).

Emissions from electricity generation have also recently been declining (since 1991) despite a significant growth in the electricity generated between 1970 and 2004. This is due to the move away from coal to natural gas and nuclear power for electricity generation and to improvements in the performance of particulate abatement plant at coal-fired power stations. Also the installation of flue gas desulphurisation at two power stations have reduced particulate emissions further.

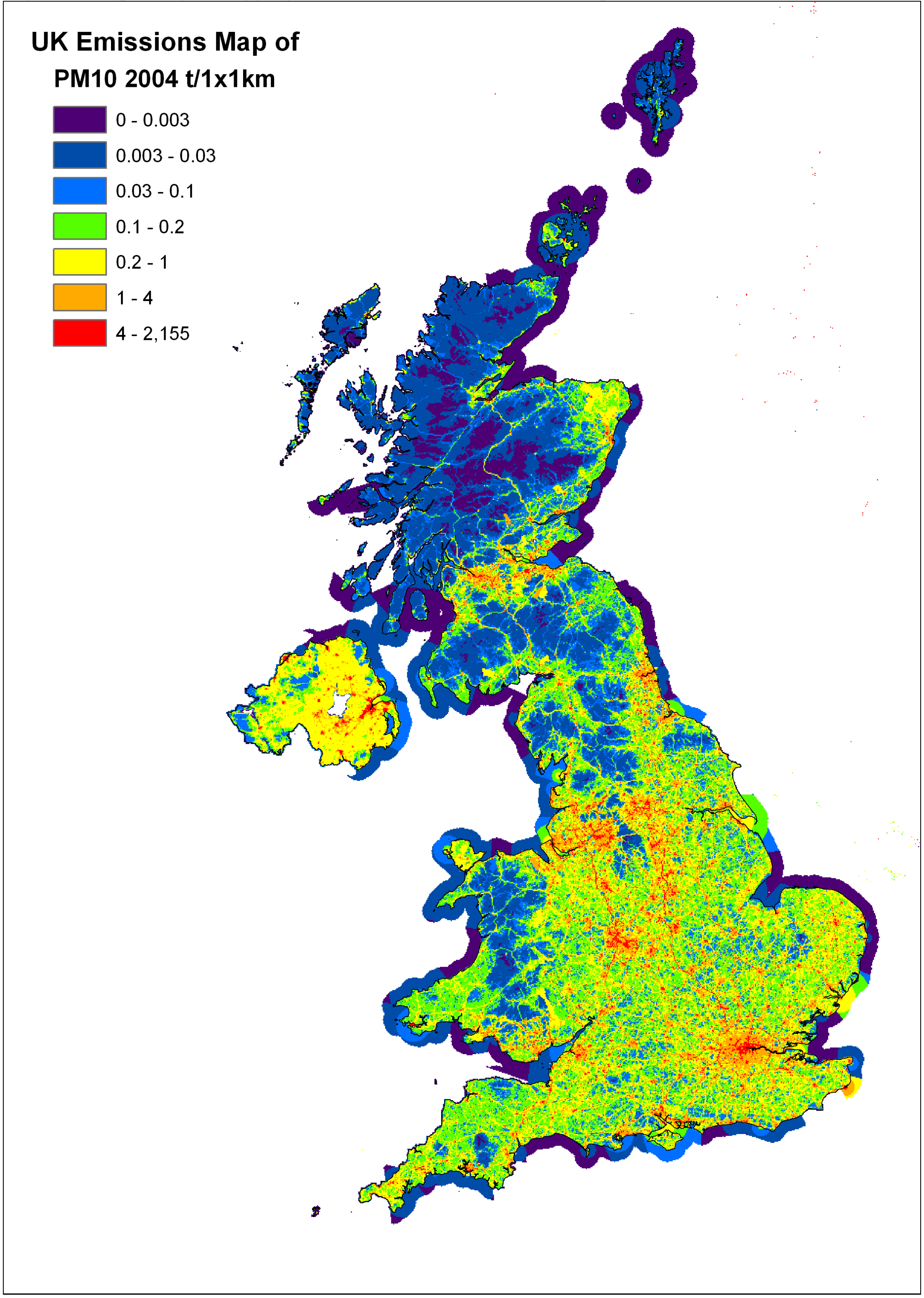
Figure 4.1 Time Series of PM_{10} Emissions (ktonnes)



Emissions from road transport have not increased, but the contribution to the total emission has increased with time due to other sectors decreasing. The contribution to the total UK emission has risen from 9% in 1970 to 23% in 2004. The main source of road transport emissions is exhaust from diesel engine vehicles. Emissions from diesel vehicles have been growing due to the growth in heavy duty vehicle traffic and the move towards more diesel cars. Since around 1992, however, emissions from diesel vehicles have been decreasing due to the penetration of new vehicles meeting tighter PM_{10} emission regulations ("Euro standards" for diesel vehicles were first introduced in 1992).

Among the non-combustion and non-transport sources, the major emissions are from industrial processes, the most important of which is quarrying whose emission rates have remained fairly constant. Other industrial processes, including the manufacture of steel, cement, lime, coke, and primary and secondary non-ferrous metals, are collectively important sources of particulate matter although emissions from individual sectors are relatively insignificant.

Figure 4.2 Spatially Disaggregated UK Emissions of PM_{10} Map[8]



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4.2.3 Finer Particulates: $PM_{2.5}$, $PM_{1.0}$ and $PM_{0.1}$

Inventories for $PM_{2.5}$, $PM_{1.0}$ and $PM_{0.1}$ have been estimated from the PM_{10} inventory and the mass fractions in these size ranges available for different emission sources and fuel types. A total of 33 different size distributions covering $PM_{2.5}$ and $PM_{1.0}$ emissions from different source sectors were taken from the USEPA (1995) as being applicable to sources in the UK. A smaller number of sectors with size fractions in the $PM_{0.1}$ range were available from the study by the TNO Institute of Environmental Sciences in the Netherlands for the Dutch National Institute of Public Health and Environment (RIVM) (TNO, 1997). This study produced a particulate emissions inventory for Europe. In general, combustion processes emit a higher proportion of fine particles (<2.5 µm) than mechanical sources such as quarrying and construction. Gaseous fuels also tend to emit finer particles than petroleum and solid fuels.

Each of the detailed source sectors for which a PM_{10} emission is estimated (a total of 236 individual sectors and sub-sectors) were allocated an appropriate size distribution and used to calculate emission inventories for $PM_{2.5}$, $PM_{1.0}$ and $PM_{0.1}$. The results are shown in Table 4.5-Table 4.7 in the same format as for the PM_{10} inventory.

Figure 4.5-Figure 4.7 show trends in emissions of each particle size by source sector. The results show a comparable decline in emissions of each particle size since 1990, although the $PM_{0.1}$ size fractions indicate a larger decrease. Between 1990 and 2004, UK emissions of PM_{10} fell by 48%, whereas emissions of $PM_{2.5}$ fell by 45%, $PM_{1.0}$ by 42% and $PM_{0.1}$ by 40%. There is a gradual change in the relative source contribution with particle size. This is illustrated in Figure 4.3 to Figure 4.5 which show the contribution of each sector to PM_{10}, $PM_{2.5}$, $PM_{1.0}$ and $PM_{0.1}$ emissions from 1990 to 2004. Road transport becomes an increasingly important sector as the particle size decreases. In 2004, it accounted for 23% of PM_{10} emissions, but 48% of $PM_{0.1}$ emissions.

4.2.3.1 $PM_{2.5}$ Emission estimates

Emissions of $PM_{2.5}$ are shown in Table 4.5. Emissions of $PM_{2.5}$ from the UK have declined since 1990. This is due mainly to the reduction in coal use. Emissions in the domestic, commercial and institutional sector have fallen from 24 ktonnes (15% of the total emission) in 1990 to 15ktonnes (16%) in 2004.

Emissions from electricity generation have also been declining (since 1990) despite a significant growth in the electricity generated between 1990 and 2004. This is due to the move away from coal to natural gas and nuclear power for electricity generation and to improvements in the performance of particulate abatement plant at coal-fired power stations. Also the installation of flue gas desulphurisation at two power stations have reduced particulate emissions further.

Emissions from road transport have not increased, but the contribution to the total emission has increased with time due to other sectors decreasing. The contribution to the total UK emission has risen from 29% in 1990 to 30% in 2004. The main source of road transport emissions is exhaust from diesel engine vehicles. Emissions from diesel vehicles have been growing due to the growth in heavy duty vehicle traffic and the move towards more diesel cars.

Among the non-combustion and non-transport sources, the major emissions are from industrial processes, the most important of which is quarrying whose emission rates have remained fairly constant. Other industrial processes, including the manufacture of steel, cement, lime, coke, and primary and secondary non-ferrous metals, are collectively important sources of particulate matter although emissions from individual sectors are relatively insignificant.

Table 4.5 UK emissions of $PM_{2.5}$ by sector (ktonnes) estimated for the mass fraction of particles below 2.5 μm in each sector in the PM_{10} inventory

$PM_{2.5}$	**1970**	**1980**	**1990**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2004%**
Stationary Fuel Combustion	155	98	77	55	58	48	44	42	40	34	32	32	34%
Processes	15	16	18	16	15	13	13	12	12	11	12	12	12%
Off-road mobile machinery	30	19	19	17	17	17	16	15	16	15	14	15	15%
Road Transport/ Passenger Cars	8	11	14	11	11	10	9	7	7	7	7	6	7%
Road Transport/ Light DUTY vehicles	2	3	6	9	9	9	10	9	10	10	10	10	11%
Road Transport/ Heavy Duty Vehicles	22	25	24	17	14	13	11	10	9	8	7	7	7%
Road Transport/ Other	3	4	5	5	5	5	5	5	5	5	6	6	6%
Agriculture & Waste	10	10	10	9	9	8	9	9	10	8	9	9	9%
TOTAL	**245**	**187**	**173**	**139**	**138**	**124**	**117**	**108**	**108**	**99**	**96**	**95**	**100%**

Table 4.6 UK Emissions of $PM_{1.0}$ by Sector (ktonnes) Estimated for the Mass Fraction of Particles below 1 μm in each Sector in the PM_{10} Inventory

$PM_{1.0}$	**1970**	**1980**	**1990**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2004%**
Stationary Fuel Combustion	112	65	49	37	44	33	31	29	28	25	24	23	32%
Processes	7	10	10	9	9	7	7	6	7	6	7	7	9%
Off-road mobile machinery	18	14	14	13	13	13	12	12	12	12	11	11	16%
Road Transport/ Passenger Cars	6	9	12	10	10	9	8	7	7	6	6	6	8%
Road Transport/ Light DUTY vehicles	2	3	6	8	8	9	9	9	9	9	10	10	13%
Road Transport/ Heavy Duty Vehicles	21	23	23	16	13	12	11	9	8	7	7	6	9%
Road Transport/ Other	1	1	1	1	1	1	1	1	1	1	1	1	2%
Agriculture & Waste	9	9	9	7	7	7	7	7	9	7	7	7	10%
TOTAL	177	134	123	102	105	91	87	80	81	75	72	71	100%

Table 4.7 UK Emissions of $PM_{0.1}$ by Sector (ktonnes) Estimated for the Mass Fraction of Particles below 0.1 μm in each Sector in the PM_{10} Inventory

$PM_{0.1}$	**1970**	**1980**	**1990**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2004%**
Stationary Fuel Combustion	24	16	14	11	14	9	8	8	7	6	6	6	22%
Processes	3	3	3	3	3	2	2	2	2	2	2	2	7%
Off-road mobile machinery	6	4	4	4	4	4	4	4	4	3	3	3	12%
Road Transport/ Passenger Cars	3	4	5	5	5	4	4	4	4	4	4	3	12%
Road Transport/ Light DUTY vehicles	1	1	3	5	5	5	5	5	5	5	6	6	20%
Road Transport/ Heavy Duty Vehicles	12	14	13	10	8	7	6	5	5	4	4	4	13%
Road Transport/ Other	0	1	1	1	1	1	1	1	1	1	1	1	3%
Agriculture & Waste	3	3	3	3	3	3	3	3	3	3	3	3	11%
TOTAL	52	46	47	40	42	35	34	31	31	29	29	28	100%

Figure 4.3 Time Series of PM2.5 Emissions (ktonnes)

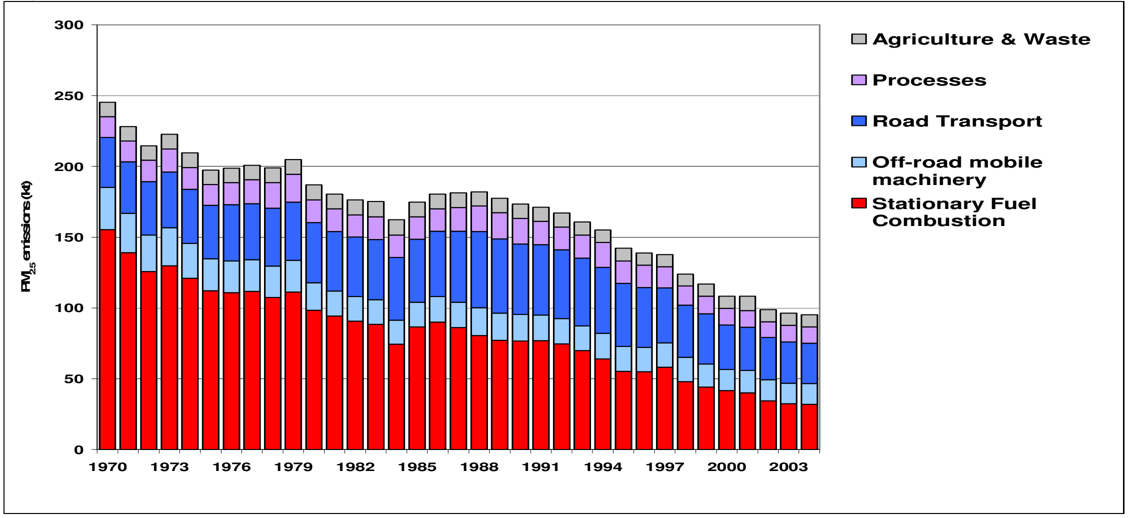


Figure 4.4 Time Series of PM$_{1.0}$ Emissions (ktonnes)

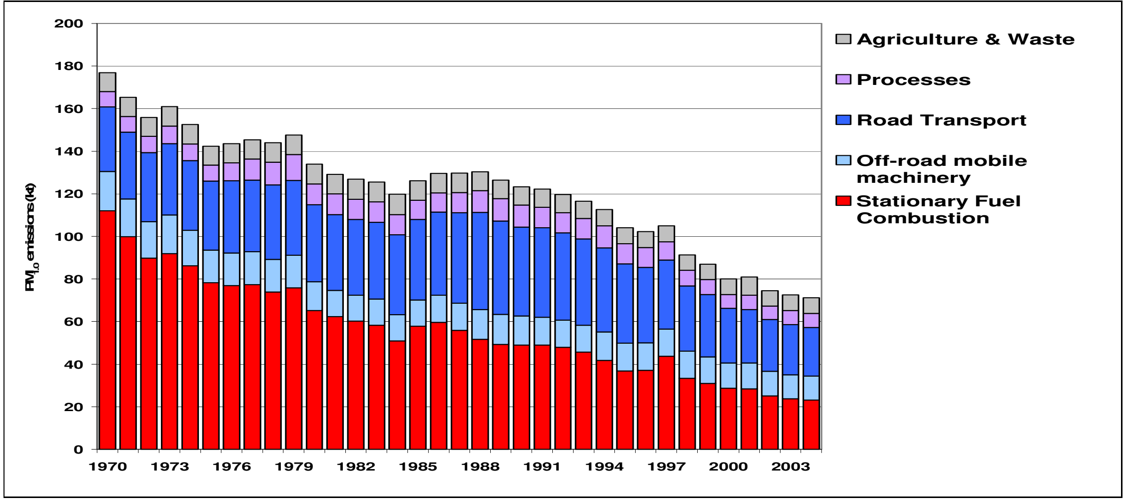
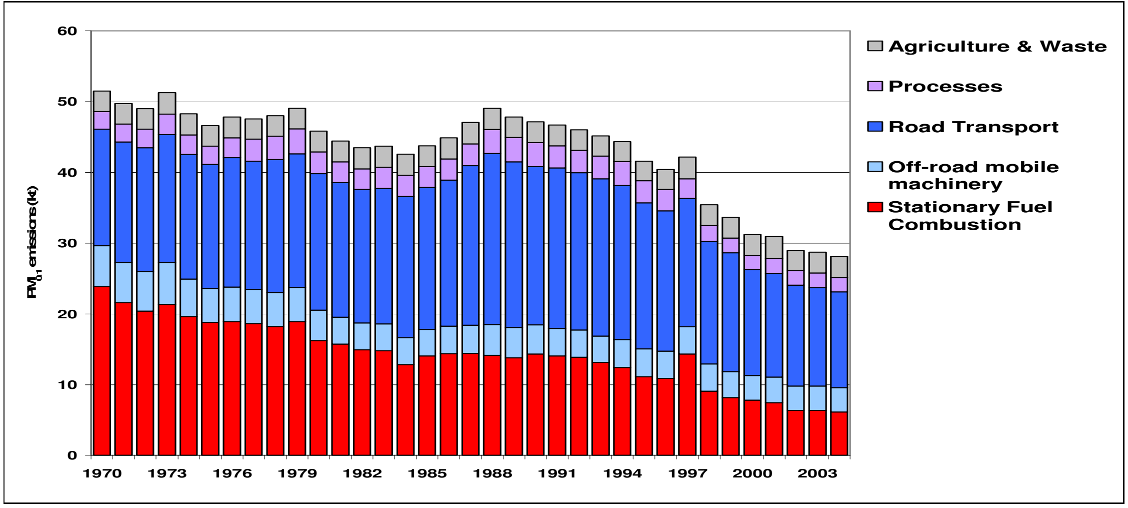


Figure 4.5 Time Series of PM$_{0.1}$ Emissions (ktonnes)



4.2.4 Black Smoke

There has been less interest in the emissions of black smoke in recent years. This is because PM_{10} has superseded black smoke as an indicator of particulate material in the air. In addition, the measurements which are used to derive emission factors for black smoke were conducted several decades ago. It is expected that the blackening effect of some key sources (e.g. road transport) has changed across this time period, and therefore the emission estimates are considered to be very high in uncertainty. The black smoke emission estimates are presented only as a total (Table 4.8), reflecting the associated uncertainties.

Table 4.8 UK Emissions of Black Smoke by UN/ECE Source Category (ktonnes)

	1970	**1980**	**1990**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
TOTAL	1035	566	387	263	223	221	223	185	197	180	160	165

4.3 CARBON MONOXIDE EMISSION ESTIMATES

Carbon monoxide arises from incomplete fuel-combustion and is of concern mainly because of its effect on human health and its role in tropospheric ozone formation. It leads to a decreased uptake of oxygen by the lungs and leads to a range of further symptoms as the concentration increases.

The UK emissions of carbon monoxide are shown in Figure 4.6 and Table 4.9 disaggregated by source and fuel. Over the period 1970-2004 emissions decreased by 76% reflecting significant reduction in emissions from road transport, agricultural field burning and the domestic sector.

Table 4.9 UK Emissions of CO by aggregated UN/ECE[1] Source Category and Fuel (ktonnes)

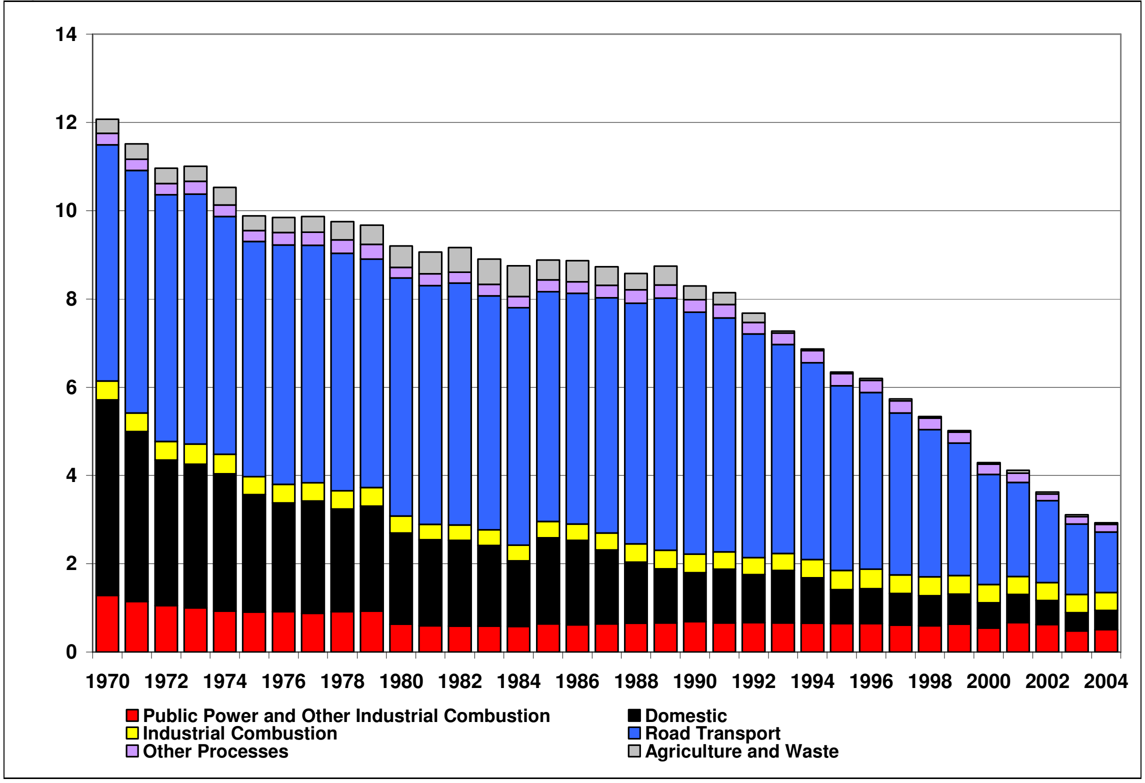
	1970	**1980**	**1990**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2004%**
BY UN/ECE CATEGORY[2]													
Industry													
Public Power	173	140	131	121	70	81	73	83	80	77	84	84	3%
Iron and Steel	780	236	314	288	296	280	290	187	305	274	212	234	8%
Other Industrial Combustion	89	64	68	67	70	68	95	100	105	108	22	22	1%
Residential Combustion	4488	2102	1125	799	732	688	692	581	649	551	424	442	15%
Other Processes	255	245	285	279	279	256	242	222	211	152	164	168	6%
Transport													
Road Transport/ Passenger cars	4759	4624	4534	3353	3065	2785	2526	2108	1802	1587	1363	1171	40%
Road Transport/ Other	593	766	946	646	599	552	478	392	326	269	233	196	7%
Off-road Vehicles, Other Machinery	619	546	587	612	591	594	590	584	582	571	571	577	20%
Agricul. & Land Use Change	288	449	272	6	6	6	7	8	10	8	8	7	0%
Waste	28	28	29	28	27	28	29	28	50	28	29	29	1%
BY FUEL TYPE													
Solid	5464	2458	1543	1154	1054	1011	1008	802	989	858	668	708	24%
Petroleum	5868	5855	5987	4513	4176	3844	3512	3010	2642	2357	2095	1871	64%
Gas	31	63	76	107	104	104	107	104	99	99	106	108	4%
Non-Fuel	708	826	685	426	400	380	393	376	389	312	241	243	8%
TOTAL	12072	9201	8292	6200	5734	5338	5021	4293	4119	3625	3110	2930	100%

[1] UK emissions reported in IPCC format (Baggott *et al*, 2006) differ slightly due to the different source categories used.

[2] See Annex 1 for definition of UN/ECE Categories

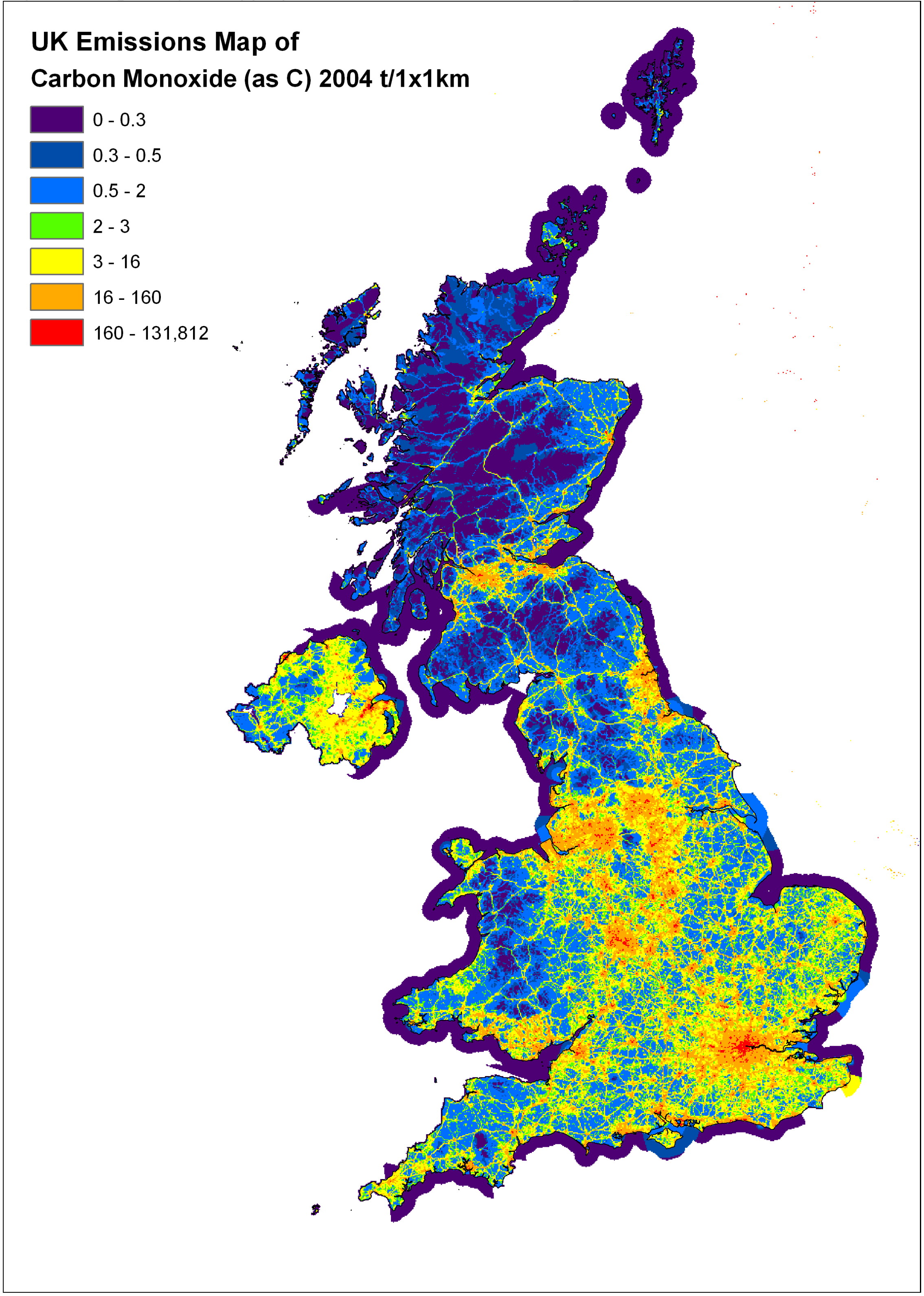
[3] Including railways, shipping, naval vessels, military aircraft and off-road sources

Figure 4.6 Time Series CO Emissions (Mtonnes)



The spatial disaggregation of CO emissions is shown in Figure 4.7. The observed pattern of emissions is clearly dominated by road transport emissions. A large proportion of road transport emissions are from vehicles travelling at slow speeds on urban or minor roads, hence the map shows high emissions in urban conurbations.

Figure 4.7 Spatially Disaggregated UK Emissions of CO Map[9]



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4.3.1 Transport

The most important source of CO is road transport and in particular petrol driven vehicles. Emissions from road transport fell only slightly between 1970 and 1990 but in recent years have declined more significantly. This is due primarily to the increased use of catalytic converters and to a lesser extent to fuel switching from petrol cars to diesel cars. The emissions from off-road sources include portable generators, fork lift trucks, lawnmowers and cement mixers. Recent studies have been aimed at improving these estimates, but estimates of emissions from such machinery is still uncertain since it is based on estimates of equipment population and annual usage time.

4.3.2 Other Sources

Other emission sources of CO are small compared with transport and off-road sources. Combustion-related emissions from the domestic and industrial sectors have decreased by 89% and 51% respectively since 1970 due to the decline in the use of solid fuels in favour of gas and electricity. The sudden decline in emissions from the agricultural sector reflects the banning of stubble burning in 1993 in England and Wales. Currently power generation accounts for only 4% of UK emissions.

4.4 BENZENE

Studies have shown that exposure to benzene gives rise to an increase in the risk of developing leukaemia, and that benzene exerts its effect by damaging the genetic make-up of cells i.e. it is a genotoxic carcinogen. Consequently it is important to understand sources of benzene and their relative strengths, and ensure that emissions do not give rise to unacceptably high concentrations of benzene.

Benzene emissions arise predominately from the evaporation and combustion of petroleum products. Emissions of benzene are dominated by the road transport sector, accounting for 24% of the 2004 emission estimate total. As benzene is a constituent of petrol, emissions arise from both evaporation and combustion of petrol. Benzene emissions for 1990 to 2004 are given in Table 4.10 and Figure 4.8 below.

Benzene emissions also arise as stack emissions and, more importantly, fugitive emissions from its manufacture and use in the chemical industry. Benzene is a major chemical intermediate, being used in the manufacture of many important chemicals including those used for the production of foams, fibres, coatings, detergents, solvents and pesticides.

Benzene emissions have been steadily decreasing since 1990. The most noticeable decrease between 1999 and 2004 arises from the road transport sector. This is because the benzene content of petrol was substantially decreased between 1999 and 2004, resulting in a corresponding decrease in emissions and due to the introduction of cars equipped with catalytic converters since 1991. Emissions from the domestic and industrial sectors are also falling, but the impact is relatively small compared with the changes in the emissions from transport.

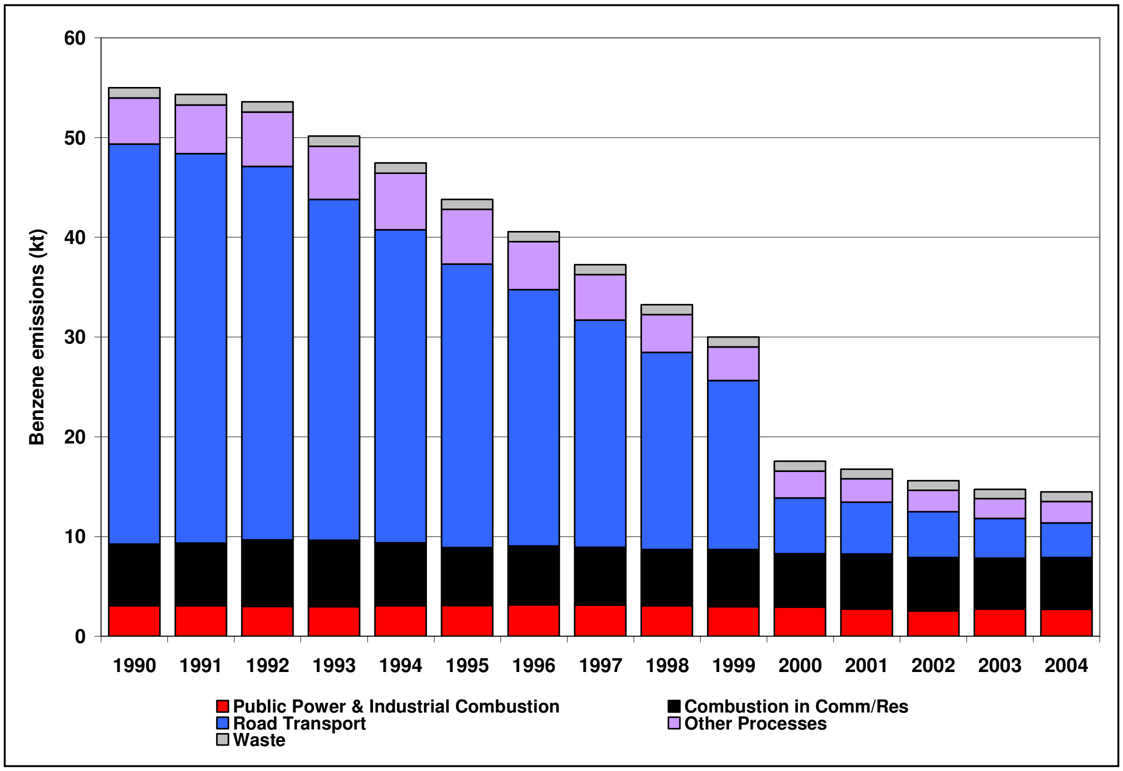
Table 4.10 UK emissions of Benzene by aggregated UN/ECE Source Category and Fuel (ktonnes)

	1990	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[1]											
Industry											
Public Power & Industrial Combustion	1.7	1.8	1.8	1.9	1.8	1.9	1.8	1.7	1.7	1.7	12%
Combustion in Commercial/Residential	6.2	6.0	5.9	5.7	5.9	5.5	5.6	5.4	5.2	5.3	36%
Refining / Storage	2.3	2.1	1.8	1.5	1.2	1.1	0.9	0.8	0.8	1.0	7%
Gas Mains Leakage	0.4	0.4	0.7	0.7	0.7	0.7	0.7	0.7	0.5	0.5	4%
Other Processes	1.9	2.3	2.1	1.6	1.5	1.0	0.8	0.7	0.7	0.7	5%
Road Transport											
Road Transport / Passenger cars	33.4	21.7	19.1	16.5	14.1	4.8	4.4	3.9	3.4	2.9	20%
Road Transport / Others	6.7	3.9	3.6	3.2	2.9	0.8	0.7	0.7	0.6	0.5	4%
Off-road Vehicles, Other Machinery[2]	1.3	1.2	1.2	1.1	1.0	1.0	0.8	0.8	0.9	0.9	6%
Waste	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9	1.0	7%
BY FULE TYPE											
Solid	6	6	6	6	6	5	5	5	5	5	32%
Petroleum	43	28	25	22	20	8	8	7	6	6	38%
Gas	2	2	2	2	2	2	2	1	1	2	10%
Non-Fuel	6	6	6	5	4	4	3	3	3	3	20%
TOTAL	**55**	**41**	**37**	**33**	**30**	**18**	**17**	**16**	**15**	**14**	**100%**

[1] See Annex 1 for definition of UN/ECE Categories

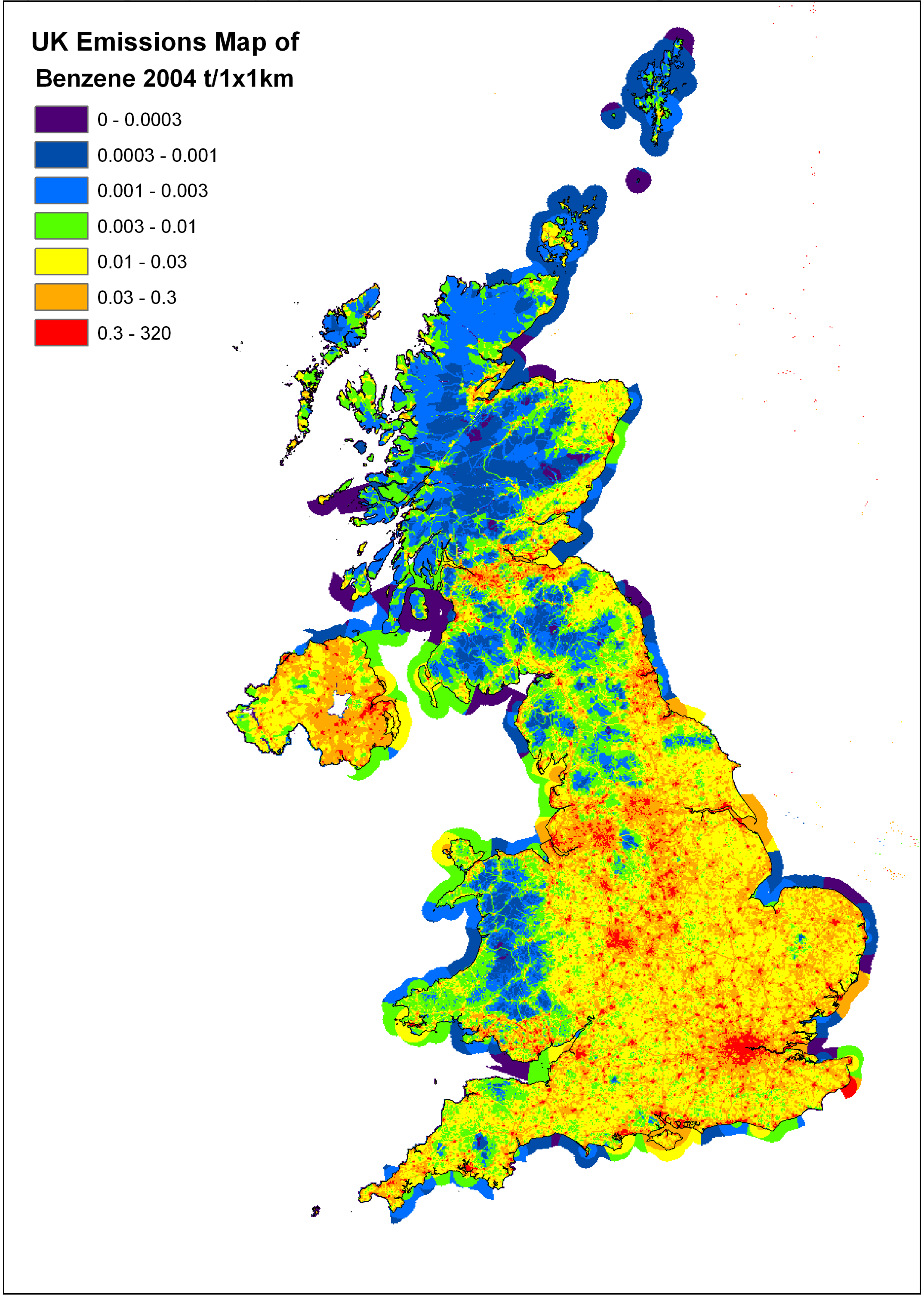
[2] Including railways, shipping, naval vessels, military aircraft and off-road sources

Figure 4.8 Time Series of Benzene Emissions (ktonnes)



Spatially disaggregated emissions of benzene are shown in Figure 4.9 which shows that a high percentage of the total benzene emission arises from the road transport sector. Road transport emissions of benzene are higher at low speeds and decrease as speed increases. However at higher speeds emissions start to rise again. This results in relatively high emissions per km in urban areas. Although evident, motorways and other major roads are not associated with particularly high emissions evident from urban roads.

Figure 4.9 Spatially Disaggregated UK Emissions of Benzene Map[10]



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4.5 1,3-BUTADIENE

Studies have indicated that elevated concentrations of 1,3-butadiene give rise to a variety of cancers, and damages the genetic structures of cells i.e. 1,3-butadiene is a genotoxic carcinogen. Atmospheric concentrations have been determined at which the risk of adverse impacts is considered acceptably small, and it is therefore important to be able to understand the major sources of 1,3-butadiene which contribute to the ambient concentration.

Emissions of 1,3-butadiene arise from the combustion of petroleum products and its manufacture and use in the chemical industry. 1,3-butadiene is not present in petrol but is formed as a by-product of combustion, hence it is not present in road transport evaporative emissions. The road transport sector dominates the UK emissions in 2004, contributing 55% of the total. Emissions of 1,3-butadiene for 1990 to 2004 are given in Table 4.11 and Figure 4.10 below.

As with benzene, the introduction of catalytic converters in 1991 has had a significant impact on the emissions from the road transport sector, causing a reduction in road transport emissions of 82% and a decline in total emissions of 73% from 1990 to 2004. Emissions from other significant combustion sources, such as other transportation and machinery, have not significantly decreased.

1,3-butadiene emissions also arise as stack and, more importantly, fugitive emissions from its manufacture and extensive use in the chemical industry. 1,3-butadiene is used in the production of various forms of synthetic rubber. Reported emission estimates for the chemical industry sectors (Environment Agency, 2004) have been incorporated into the NAEI.

Spatially disaggregated emissions of 1,3-butadiene are shown in Figure 4.11. Emissions of 1,3-butadiene arise predominantly from road transport activities, and an interesting comparison may be drawn with the UK emissions map for benzene (Figure 4.9), where other sources make a significant contribution to the total emissions. As with benzene, emissions of 1,3-butadiene per km from road transport decrease with increasing speed (but then increase at higher speeds). Consequently the emissions density is high in urban areas, and the major roads (such as motorways) are not particularly highlighted.

Benzene and 1,3-butadiene emission maps (Figure 4.9 and Figure 4.11) may be contrasted with mapped NOx emissions Figure 4.13), as the emissions of NO_x at higher speeds are more significant than those for benzene or 1,3-butadiene.

Table 4.11 UK Emissions of 1,3-butadiene by aggregated UN/ECE Category and Fuel (ktonnes)

	1990	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[1]											
Stationary Fuel Combustion	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	1%
Road Transport											
Road Transport / Passenger cars	6.96	4.45	3.89	3.34	2.82	2.30	1.86	1.50	1.16	0.90	27%
Road Transport / Others	0.92	0.55	0.51	0.48	0.44	0.37	0.33	0.29	0.27	0.23	7%
Road Transport / Heavy Duty Vehicle	2.74	1.70	1.53	1.37	1.21	1.09	0.97	0.87	0.79	0.74	22%
Off-road Vehicles and Other Machinery[2]	1.24	1.25	1.26	1.25	1.24	1.23	1.22	1.20	1.18	1.16	34%
Processes	0.64	0.62	0.54	0.47	0.73	0.47	0.38	0.30	0.26	0.32	9%
Waste	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0%
BY FUEL CATEGORY											
Solid	0	0	0	0	0	0	0	0	0	0	0%
Petroleum	11.87	7.95	7.19	6.45	5.73	5.00	4.40	3.87	3.41	3.04	90%
Gas	0	0	0	0	0	0	0	0	0	0	0%
Non-Fuel	0.69	0.66	0.58	0.51	0.76	0.50	0.40	0.33	0.28	0.34	10%
TOTAL	**12.56**	**8.61**	**7.77**	**6.96**	**6.49**	**5.50**	**4.80**	**4.20**	**3.70**	**3.39**	**100%**

[1] See Annex 1 for definition of UN/ECE Categories

[2] Including railways, shipping, naval vessels, military aircraft and off-road sources

Figure 4.10 Time Series of 1,3-butadiene Emissions (ktonnes)

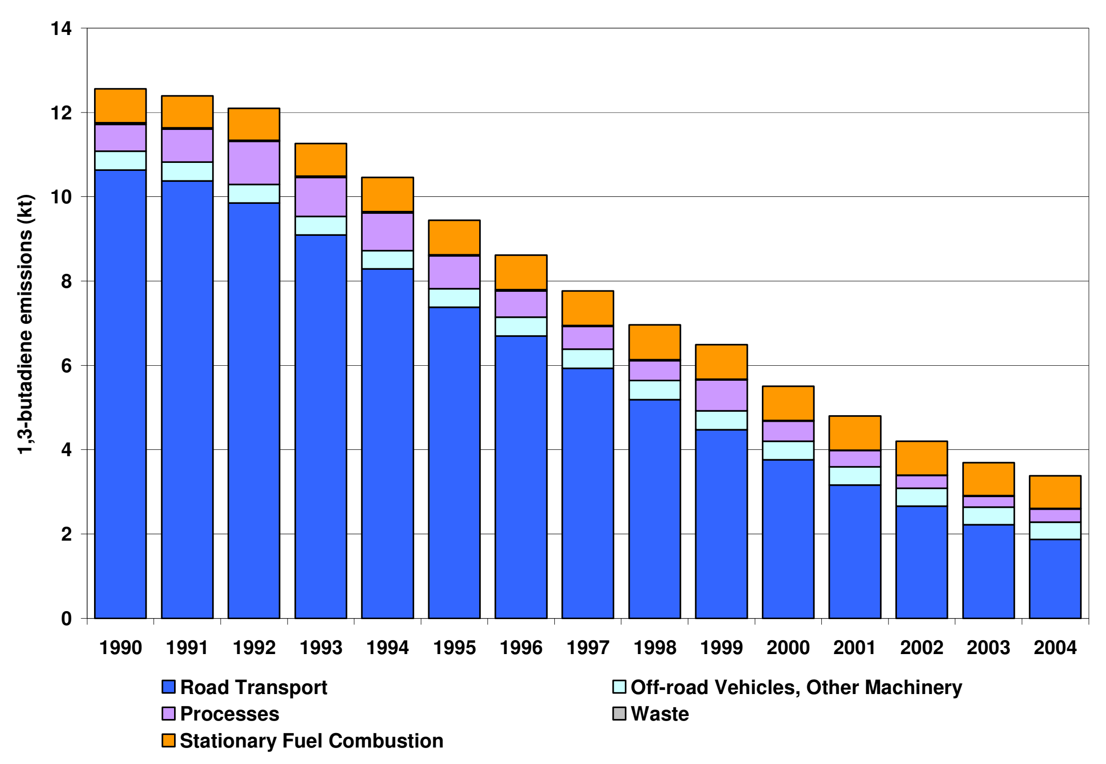
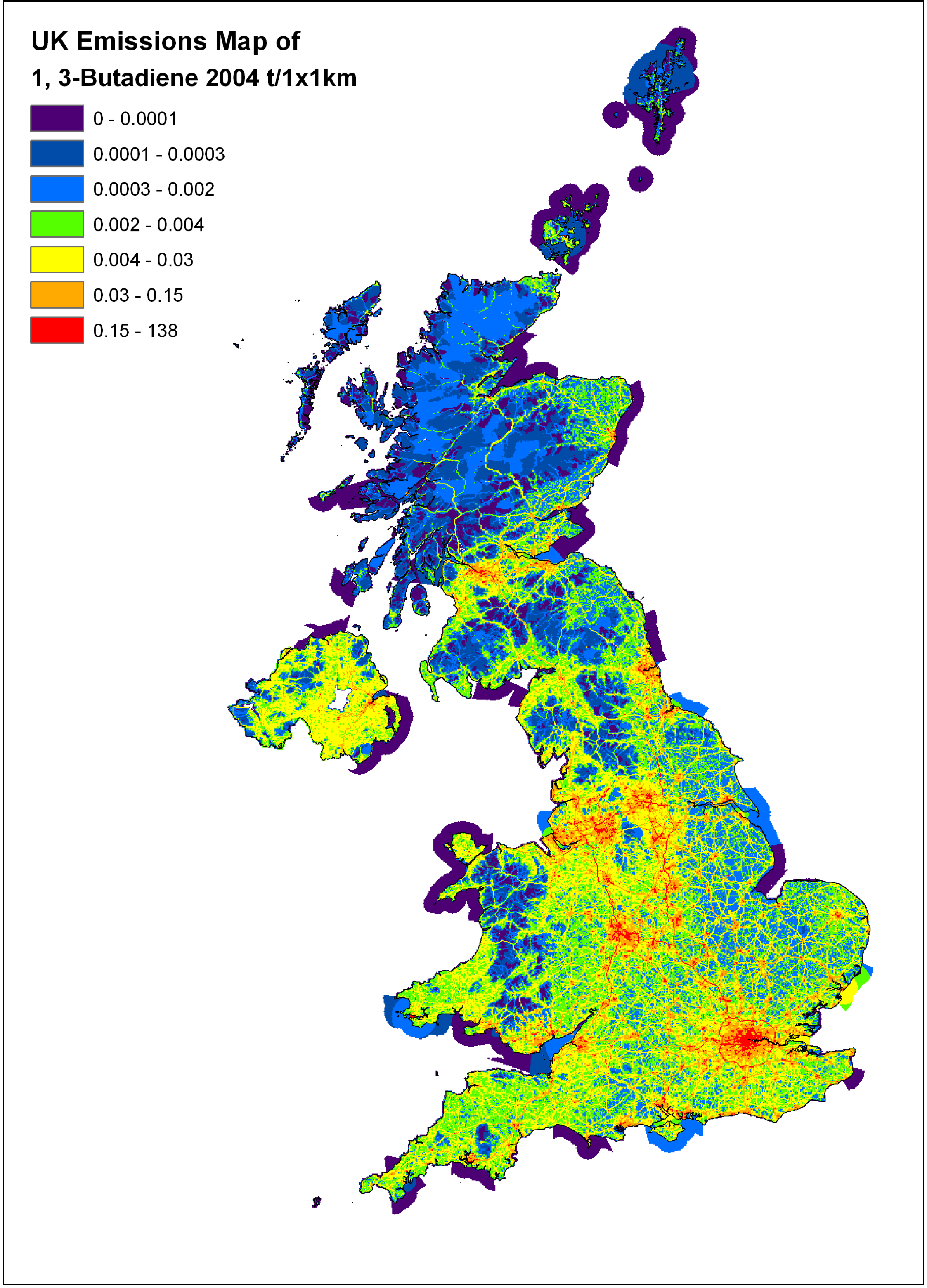


Figure 4.11 Spatially Disaggregated UK Emissions of 1,3-butadiene Map[11]



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4.6 ACCURACY OF EMISSION ESTIMATES OF AIR QUALITY STRATEGY POLLUTANTS

Quantitative estimates of the uncertainties in emission inventories are based on calculations made using a direct simulation technique, which corresponds to the IPCC Tier 2 approach recommended for greenhouse gases and also the methodology proposed in draft guidance produced by the UN/ECE Taskforce on Emission Inventories. This work is described in more detail by Passant (2002b). Uncertainty estimates are shown in Table 4.12.

Table 4.12 Uncertainty of the Emission Inventories for Air Quality Strategy Pollutants

Pollutant	**Estimated Uncertainty %**
Carbon Monoxide	+/- 20
Benzene	-20 to + 30
1,3-butadiene	+/- 20
PM_{10}	-20 to +50
$PM_{2.5}$	-20 to +30
$PM_{1.0}$	-10 to +20
$PM_{0.1}$	+/- 10
Black smoke	-50 to +90

4.5.1 Carbon Monoxide Estimates

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

4.5.2 Benzene and 1,3-butadiene Estimates

There has been much improvement in the benzene and 1,3-butadiene emission estimates in recent years. Information gained in speciating the emissions of NMVOC (see Section 4.10) has helped the generation of more robust emission inventories for both benzene and 1,3-butadiene. However, due in particular to the uncertainty in the levels of both pollutants in NMVOC emissions from road transport and other combustion processes, the uncertainty in these inventories is much higher than the uncertainty in the NMVOC inventory.

4.5.3 Particulate Matter Estimates

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

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

Emission estimates for combustion of fuels are generally considered more reliable than those for industrial processes, quarrying and construction. All parts of the inventory would need to be improved before the overall uncertainty could be reduced to the levels seen in the inventories for CO_2, SO_2, NO_x, or NMVOC.

The approach adopted for estimating emissions of the smaller particle sizes, while it is currently the only one available, includes a number of assumptions and uncertainties. The approach depends on the PM_{10} emission rates estimated for each sector which themselves have great uncertainties. The emission estimates for the smaller particles will be even more uncertain for a given source as there are additional uncertainties in the size fractions and their applicability to individual emission source sectors. The relevance of US and Dutch size fraction data to UK emission sources can also be questioned. Perhaps surprisingly, the inventories for the smaller particles are less uncertain overall than the PM_{10} inventory. This is because the most uncertain PM_{10} emissions are those from industrial processes, quarrying and construction and these sources emit very little of the finer particles, road transport dominating instead.

4.5.4 Black Smoke Estimates

Black smoke emissions are less accurate than those for PM_{10} due to the fact that, since its importance as a policy tool has declined, the black smoke inventory methodology has not been revised for many years and the relevance of the emission factors used in the inventory to current sources such as road transport and industrial technology is in doubt.

4.7 INTRODUCTION TO ACIDIFYING GASES AND TROPOSPHERIC OZONE PRECURSORS

The deposition of acidifying species can have adverse effects on buildings and vegetation, as well as acidifying streams and lakes and damaging the aquatic environment. Sulphur dioxide and nitrogen oxides from fuel combustion are major contributors to acidification (Review Group on Acid Rain-RGAR, 1997). Ammonia (NH_3) plays an important part in the long range transport of the acidifying pollutants by the formation of relatively stable particles of ammonium sulphate and ammonium nitrate. Although ammonia is a basic gas it deposits to soil surfaces and has an indirect effect on acidification. The biological transformation of NH_4^+ to NO_3^- in soils (nitrification) and plant uptake both release acidity into the soil contributing to acidification. NH_3 deposition can also give rise to terrestrial eutrophication- where nutrient enrichment gives rise to changes in ecosystems.

There are no significant ozone emissions from anthropogenic activities. Tropospheric, or ground level, ozone occurs naturally but atmospheric levels can be increased *in-situ* by the photochemical reaction of precursor pollutants such as carbon monoxide, nitrogen oxides and volatile organic compounds. Specific non-methane volatile organic compounds (NMVOC) and groups of compounds play a key role in ozone formation. Ozone episodes in which concentrations rise substantially above background levels occur in summer months when there are long periods of bright sunshine, temperatures above 20^o C and light winds. Ozone can affect human health and can damage plants and crops. The total 2004 UK emissions of acidifying gases and ozone precursors are summarised in Table 4.13.

Table 4.13 Total UK Emissions of Acidifying and Ozone Precursors

Pollutant	**Total 2004 emission (ktonnes)**
Nitrogen oxides (as NO_2)	1621
Sulphur dioxide	833
Hydrogen chloride	30
Non-methane volatile organic compounds (NMVOC)	1024
Ammonia	336
Hydrogen fluoride	4.7

The UK is committed to reducing acidifying gas and ozone precursor emissions and is a party to several protocols under the UN/ECE's Convention on Long-Range Transboundary Air Pollution.

Under the Second Sulphur Protocol, the UK must reduce its total SO_2 emissions by 50% by 2000, 70% by 2005 and 80% by 2010 (all from a 1980 baseline). The UK is well on track to meet these targets, and by the end of 2000 had achieved a 76% reduction from 1980 baseline levels, 26% ahead of the UN/ECE target level for the year 2000.

The NMVOC Protocol requires the UK to achieve a 30% reduction of anthropogenic NMVOC emissions by 1999 from a 1988 baseline. The emission estimates given in the 1999 version of the emissions inventory indicated that this was achieved. Emissions excluding those from forests fell from 2475 ktonnes in 1988 to 1577 ktonnes in 1999 - a reduction of 36%. This reduction was achieved largely as a result of emission controls for road vehicles and industrial processes, introduced by European Directives and the Environmental Protection Act 1990 respectively.

Other factors also had an impact:

- prohibition of the burning of crop residues in England and Wales since 1993, except in limited cases of exemption.
- a decline in the use of coal as a fuel by electricity generators, industry and domestic users in favour of gas;
- a decline in the use of petrol as a fuel for cars in favour of diesel;
- improvements in technology introduced for economic reasons, or in response to health & safety legislation (e.g. the introduction of more efficient dry cleaning machines with lower emission levels);
- measures introduced either voluntarily, or in response to pressure from end-users for improved environmental or health and safety performance (e.g. the formulations of many consumer products have been changed, resulting in lower levels of solvent in those products and therefore lower emissions of NMVOC during their use).

The NO_X Protocol required that the total emissions of NO_X in 1994 should be no higher than they were in 1987; UK emissions were 15% lower in 1994 than in 1987 and have fallen substantially since 1994.

In 1996, the UN/ECE started negotiating a new multi-effect, multi-pollutant protocol on nitrogen oxides and related substances. This was aimed at addressing photochemical pollution, acidification and eutrophication. The Protocol to Abate Acidification, Eutrophication and Ground-level Ozone was adopted in Gothenburg in December 2000, where it was signed by the UK. The multi-pollutant protocol incorporates several measures to facilitate the reduction of emissions:-

- Emission ceilings are specified for sulphur, nitrogen oxides, NH_3 and NMVOCs. These are summarised in the following table.

Table 4.14 Emissions Ceilings for 2010 (ktonnes) in the Gothenburg Protocol

Country	**Sulphur (as SO_2)**	**NO_x (as NO_2)**	**NH_3**	**VOC**
Armenia	73	46	25	81
Austria	39	107	66	159
Belarus	480	255	158	309
Belgium	106	181	74	144
Bulgaria	856	266	108	185
Croatia	70	87	30	90
Czech Rep.	283	286	101	220
Denmark	55	127	69	85
Finland	116	170	31	130
France	400	860	780	1100
Germany	550	1081	550	995
Greece	546	344	73	261
Hungary	550	198	90	137
Ireland	42	65	116	55
Italy	500	1000	419	1159
Latvia	107	84	44	136
Liechtenstein	0.11	0.37	0.15	0.86
Lithuania	145	110	84	92
Luxembourg	4	11	7	9
Netherlands	50	266	128	191
Norway	22	156	23	195
Poland	1397	879	468	800
Portugal	170	260	108	202
Rep. of Moldova	135	90	42	100
Romania	918	437	210	523
Slovakia	110	130	39	140
Slovenia	27	45	20	40
Spain	774	847	353	669
Sweden	67	148	57	241
Switzerland	26	79	63	144
Ukraine	1457	1222	592	797
United Kingdom	**625**	**1181**	**297**	**1200**

- The protocol gives emission limits for sulphur, nitrogen oxides and NMVOCs from stationary sources.
- The protocol indicates limits for CO, hydrocarbons, nitrogen oxides and particulates from new mobile sources
- Environmental specifications for petrol and diesel fuels are given.
- Several measures to reduce NH_3 emissions from the agriculture sector are required.

The Gothenburg protocol forms a part of the Convention on Long-range Transboundary Air Pollution. More detailed information on both of the Gothenburg protocol and the Convention may be found at the UN/ECE web site: http://www.unece.org/env/lrtap/

Within the EU, the National Emission Ceilings Directive was agreed in 2001. It sets emission ceilings to be achieved from 2010 onwards for each Member State for the same 4 pollutants as in the Gothenburg Protocol. A number of Member States reduced their ceilings somewhat below the levels included in the Protocol. The UK reduced its SO_2 ceiling to 585 ktonnes and its NO_x ceiling to 1167 ktonnes. Ceilings for NH_3 and NMVOCs were the same as in the Gothenburg Protocol. The ceilings for the EU 15 are summarised above in Table 4.14 Sulphur dioxide has long been recognised as a pollutant because of its role, along with particulate matter, in forming winter-time smogs. Estimates of sulphur dioxide emissions have been produced since the inception of the NAEI. Fuel combustion accounts for more than 93% of UK SO_2 emissions with the sulphur arising from the fuel itself. The SO_2 emission can be calculated from knowledge of the sulphur content of the fuel and from information on the amount of sulphur retained in the ash.

Published fuel consumption data (DTI, 2004), published sulphur contents of liquid fuels (Watson, 2003) and data from coal producers regarding sulphur contents of coals enable reliable estimates to be produced.

The main sources of NO_x in the UK are also combustion processes. However, the estimation of these emissions is complex since the nitrogen can be derived from either the fuel or atmospheric nitrogen. The emission is dependent on the conditions of combustion, in particular temperature and excess air ratio, which can vary considerably. Thus combustion conditions, load and even state of maintenance are important. The estimation of NO_x emissions is often based on relatively few measurements and, in view of the possible variation in emissions from apparently similar combustion plant, there is greater uncertainty in the estimates than for SO_2.

Within the UK, the implementation of the EC's Large Combustion Plant Directive and other associated policy measures has led to substantial reductions in acidifying pollutants from power plants and industrial sources. Emissions of NO_x from road traffic peaked in 1989 but have since been declining.

The inventories for SO_2, NO_x, HCl, NMVOC, NH_3 and HF are discussed in the following sections. More detailed information on the methodologies used to compile the inventories, and more detailed data are available from the NAEI website (http://www.naei.org.uk).

4.8 $\mathrm{NO_X}$ EMISSION ESTIMATES

Since 1970 there has been a reduction in total $\mathrm{NO_x}$ emissions of 47%, however this decrease in emissions has not been constant (Figure 4.12). Up to 1984 the $\mathrm{NO_x}$ emission profile was relatively flat with small peaks in 1973 and 1979, as seen previously for $\mathrm{CO_2}$, which were due largely to the cold winters in those years. However, from 1984, emissions rose markedly as a result of the growth in road traffic reaching a peak in 1989 (Table 4.15). Since then, total emissions have declined by 45% as a result of a 55% reduction from power stations and 55% decrease from road transport.

The spatially disaggregated UK emission inventory of $\mathrm{NO_x}$ emissions, based on a 1x1 km grid, is shown in Figure 4.13. Data files are also available from the NAEI internet site (http://www.naei.org.uk). A large fraction (the order of 30%) of the total $\mathrm{NO_x}$ emission is concentrated in approximately 50 grid squares, which contain point sources. Road transport is a significant source, with approximately one third of the UK $\mathrm{NO_x}$ emission deriving from major sections of road. Vehicles travelling at high speeds contribute most. As a result the major route-ways (e.g. motorways and primary routes) are clearly defined on the map. Conurbations and city centres show high emissions resulting from large volumes of road transport, residential and commercial combustion. A combination of high national shipping emission and relatively few large ports result in significant localised emissions from shipping in port areas.

Table 4.15 UK Emissions of Nitrogen Oxides (as $\mathrm{NO_2}$) by aggregated UN/ECE[1] Category & Fuel (ktonnes)

	1970	1980	1990	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[2]													
Public Power	1334	937	853	512	432	428	385	413	433	431	457	445	27%
Iron & Steel and Processes	174	102	92	91	82	77	81	63	69	54	57	46	3%
Industrial combustion & Off-road mobile machinery[3]	675	578	545	484	482	475	458	449	429	402	422	418	26%
Road Transport													
Passenger Cars	371	527	799	596	550	502	458	397	347	311	273	245	15%
Heavy Duty Vehicles	358	417	454	401	393	387	374	355	337	318	299	290	18%
Other Road Transport	36	45	71	70	71	70	68	66	65	62	61	60	4%
Residential	120	108	103	118	108	111	110	111	116	113	113	115	7%
Agriculture & Waste	17	23	16	5	2	2	2	2	3	2	2	2	0%
BY FUEL TYPE													
Solid	967	903	803	435	347	337	295	313	352	324	354	329	20%
Petroleum	1462	1512	1785	1478	1402	1332	1254	1160	1080	1001	954	918	57%
Gas	532	196	223	292	303	311	324	324	313	317	324	319	20%
Non-Fuel	125	127	121	72	69	73	64	60	54	51	54	56	3%
TOTAL	3085	2737	2933	2278	2121	2052	1937	1857	1799	1693	1685	1621	100%

[1] UK emissions reported in IPCC format (Baggott *et al*, 2006) differ slightly due to the different source categories used.

[2] See Annex 1 for definition of UN/ECE Categories

[3] Including railways, shipping, naval vessels, military aircraft and off-road sources

Figure 4.12 Time Series of NO_x Emissions (Mtonnes)

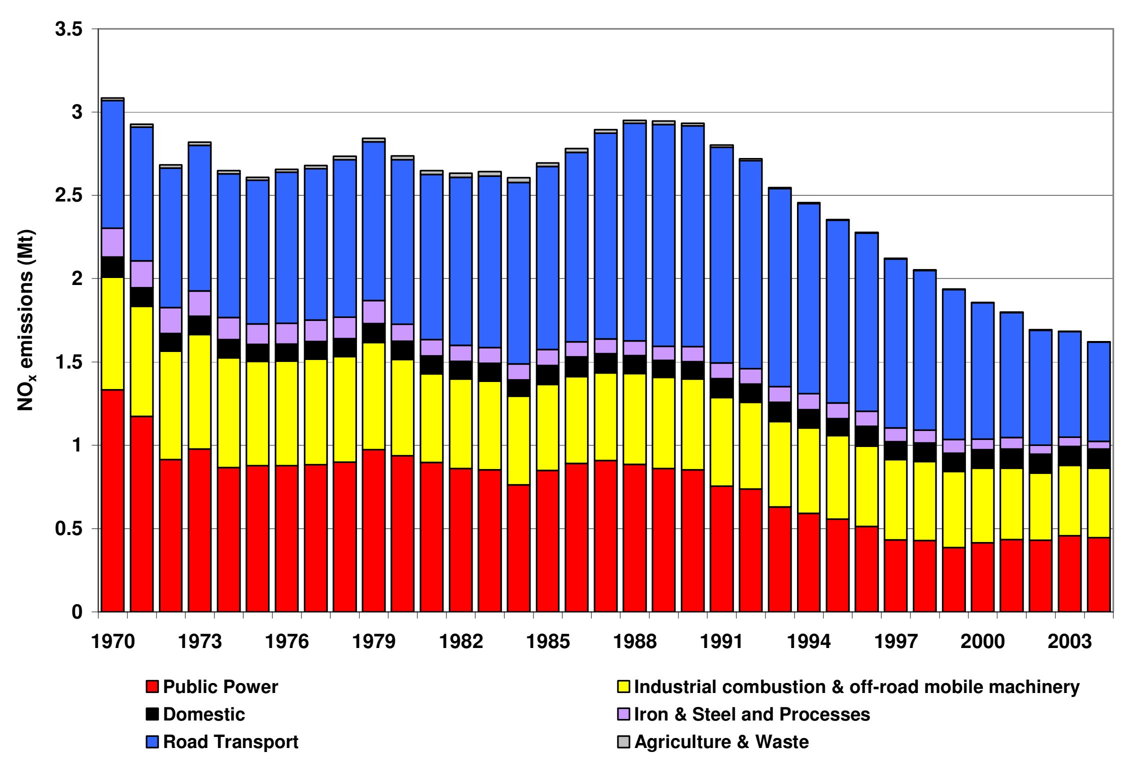
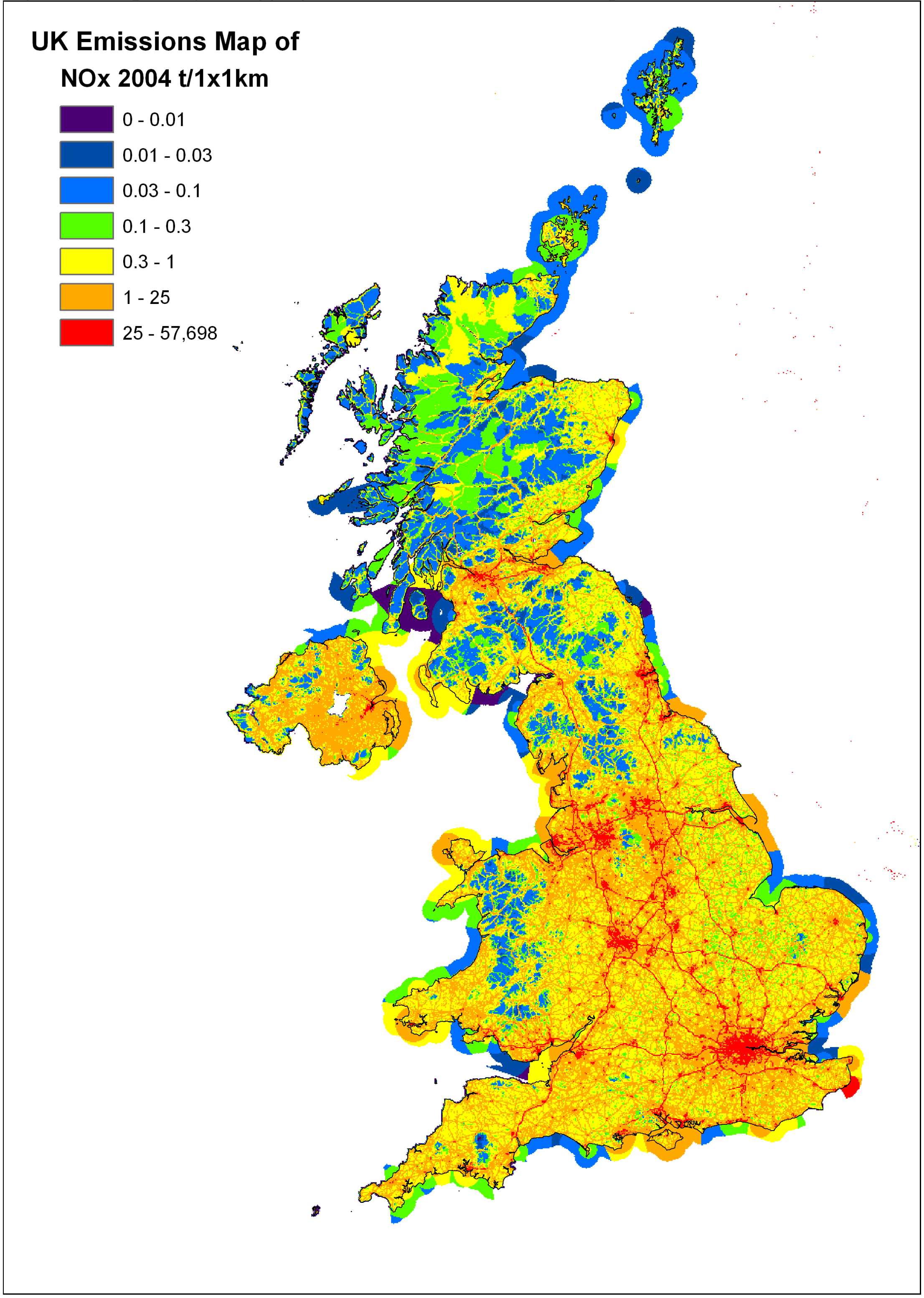


Figure 4.13 Spatially Disaggregated UK Emissions of NO_x Map[12]



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4.7.1 Transport

In 2004 the major source of NO_x emissions in the UK is the transport sector with road vehicles and off-road vehicles contributing 37% and 5%, respectively, to the total emission. Road emissions rose steadily between 1970 and 1989 reflecting the overall growth in road traffic in the UK. During this period emissions from total petrol consumption, predominantly cars, rose by 41% compared to the 1970 level and emissions from diesel consumption rose by 8%. Figure 4.14 clearly shows the growth in the vehicle fleet and vehicle mileage during this period. Since 1989 there has been a steady decline in emissions due to the introduction of catalytic converters on cars and stricter regulations on truck emissions.

Figure 4.14 Emissions of NO_x from Road Transport by Vehicle Type (ktonnes)

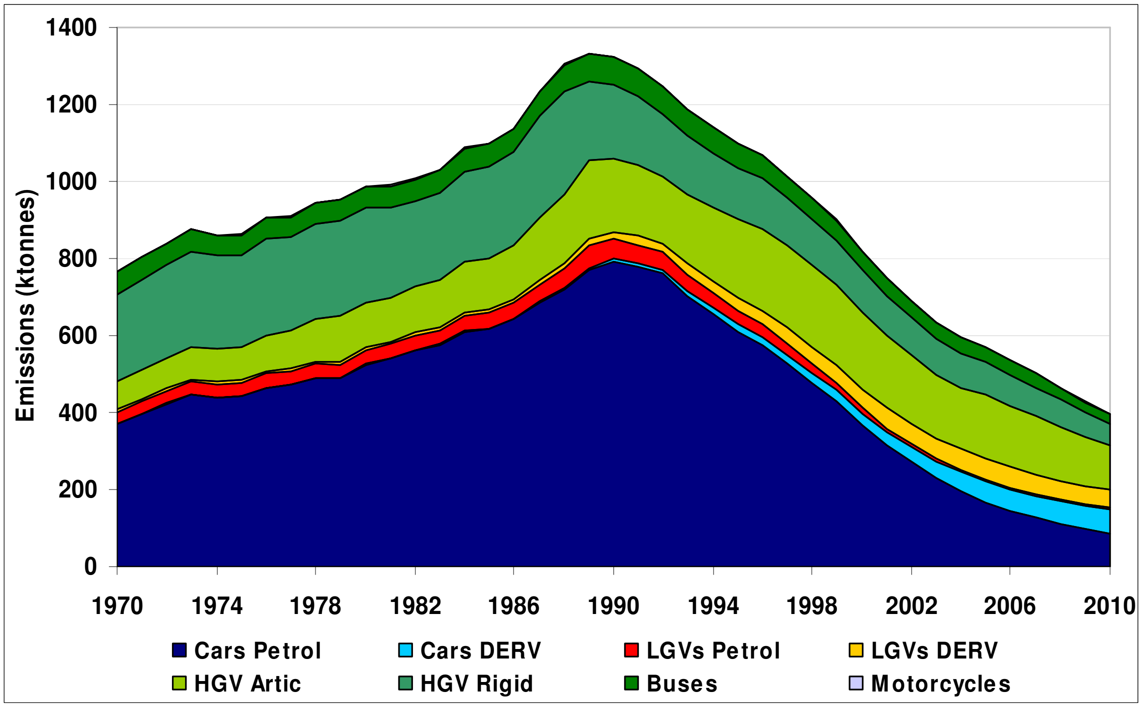


Figure 4.15 shows the average NO_x emissions per vehicle kilometre for different vehicle types. Various emission regulations on new petrol cars which have come into effect in stages since 1976 have led to the gradual reduction in emission rates from petrol cars. The more rapid decline in emissions from 1992 is due to the penetration of cars fitted with three-way catalysts. Limits on emissions from diesel cars and Light Goods Vehicles (LGVs) did not come into effect until 1993/94. Overall emissions per kilometre from Heavy Goods Vehicles (HGVs) showed a small rise from 1970-1987 due to the increasing usage of larger HGVs for freight movement. Limits on emissions from HGVs first came into effect in 1988 leading to a gradual reduction in emission rates as new HGVs penetrated the fleet, accelerated by tighter limits on emissions from new HGVs in 1993/94.

Figure 4.15 NOx Emissions per Vehicle km by Vehicle Type

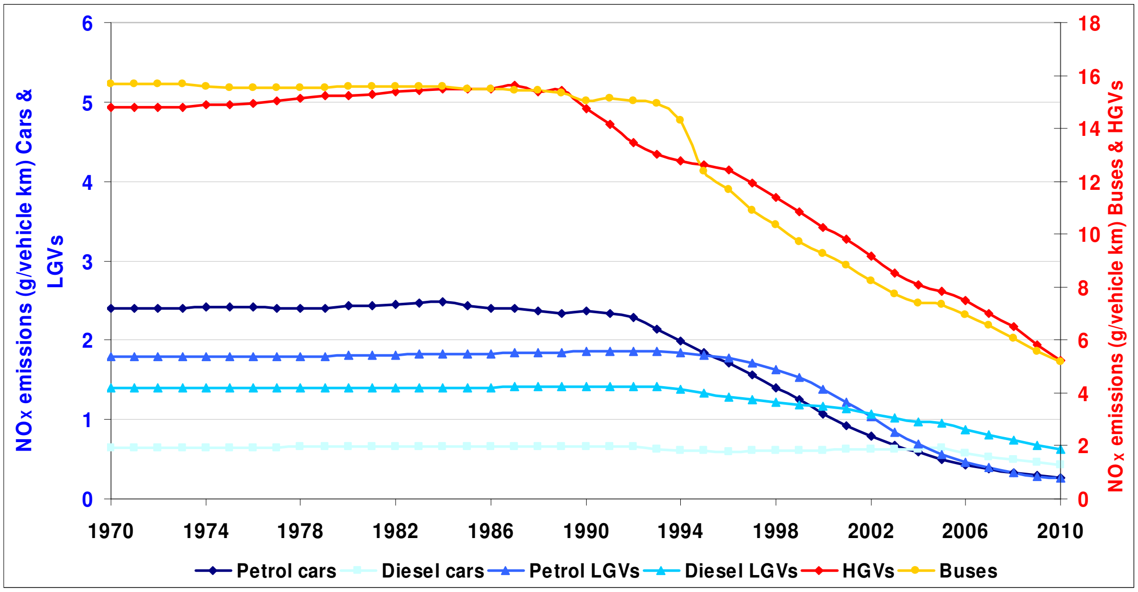
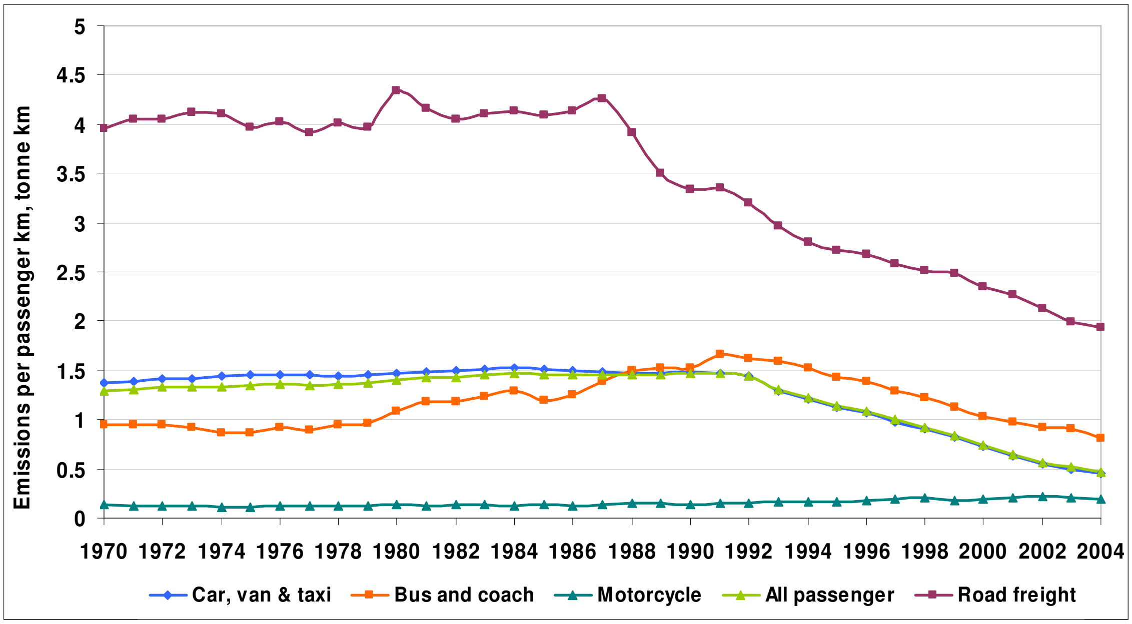


Figure 4.16 shows emissions per passenger km and by tonne km of freight. Technological improvements to HGVs give rise to approximately half the emissions per tonne of freight moved in 2004 compared with 1970. Emissions per passenger km from cars, vans and taxis have significantly decreased since 1970 due mainly to the introduction of catalytic convertors in 1992 now penetrating the car fleet. Per passenger km emissions from buses and coaches have increased from 1970 to 1993. This was due to the gradual decrease in occupancy rate of buses and their under utilisation over this period. Since 1993, this rise in per passenger km emissions has been halted by the penetration of buses meeting tighter emission standards into the fleet.

Figure 4.16 Emissions of NO_x (grammes) by Passenger Kilometre or Freight Tonne Kilometre



In 2004 other transport and machinery contributed a further 11% to total UK NO_x emissions. Of these only those from civil aircraft have grown steadily over the period 1970 to 2004 (take-off and landing cycles up to an altitude of 1000 m only are considered here in accordance with UN/ECE guidelines). However, these emissions contribute only a small percentage of the total emission.

4.7.2 Power Generation

Emissions from power stations have declined over the period 1970-2004 by 55%. Emissions in the seventies were fairly constant from year to year, with peaks in severe winters. Since 1979 emissions have declined with a significant decrease at the time of the miners strike in 1984. Prior to 1989 this decline was due to the increased use of nuclear power and an increase in the average efficiency of the thermal power stations. Since 1988 the electricity generators have adopted a programme of progressively fitting low NO_x burners to their 500 MWe (megawatt electric) or larger coal fired units. More recently the increased use of nuclear generation and the introduction of CCGT (Combined Cycle Gas Turbine) plant burning natural gas (See Section 2.2.2) have further reduced NO_x emissions. The emissions from the low NO_x turbines used are much lower than those of pulverised coal fired plant even when low NO_x burners are fitted. Assuming that these trends continue, power station emissions are expected to fall further.

4.7.3 Industry

The emissions from industrial combustion have declined by 55% since 1970 and they currently contribute 17% to total UK emissions. This is due to the decline in coal use in favour of gas and electricity.

4.8 SO_2 EMISSION ESTIMATES

Since 1970 there has been a substantial overall reduction of more than 87% in SO_2 emissions (Figure 4.17). The emission profile exhibits a steady decline between 1970 and 2004 with the exception of small peaks in 1973 and 1979 corresponding to the harsh winters in those years, and a short period at the end of the 1980s when emissions were relatively constant from year to year. It is also evident that there is little decrease between total SO_2 emissions in 1997 and 1998. This occurs because the large reductions in emissions from the power generation sector are not as substantial between 1997 and 1998. However the downward trend resumes between 1998 and 2004.

Table 4.16 shows emissions broken down by fuel categories. The two main contributors are solid fuel and petroleum products. Emissions from solid fuel use have declined by 84% since 1970 and those from petroleum by 95%. The most important factors associated with the fall in emissions from petroleum use are the decline in fuel oil use and the reduction in the sulphur content of gas oil and DERV (diesel fuel specifically used for road vehicles). The reduction in the sulphur content of gas oil is particularly significant in sectors such as domestic heating, commercial heating and off-road sources where gas oil is used extensively. The sulphur content of DERV has steadily reduced across recent years, giving rise to a significant reduction in SO_2 emissions. SO_2 emissions from DERV in the early 1990's were relatively constant, however between 1994 and 2004 there has been a 96% reduction in emissions.

Figure 4.17 Time Series of SO_2 Emissions (Mtonnes)

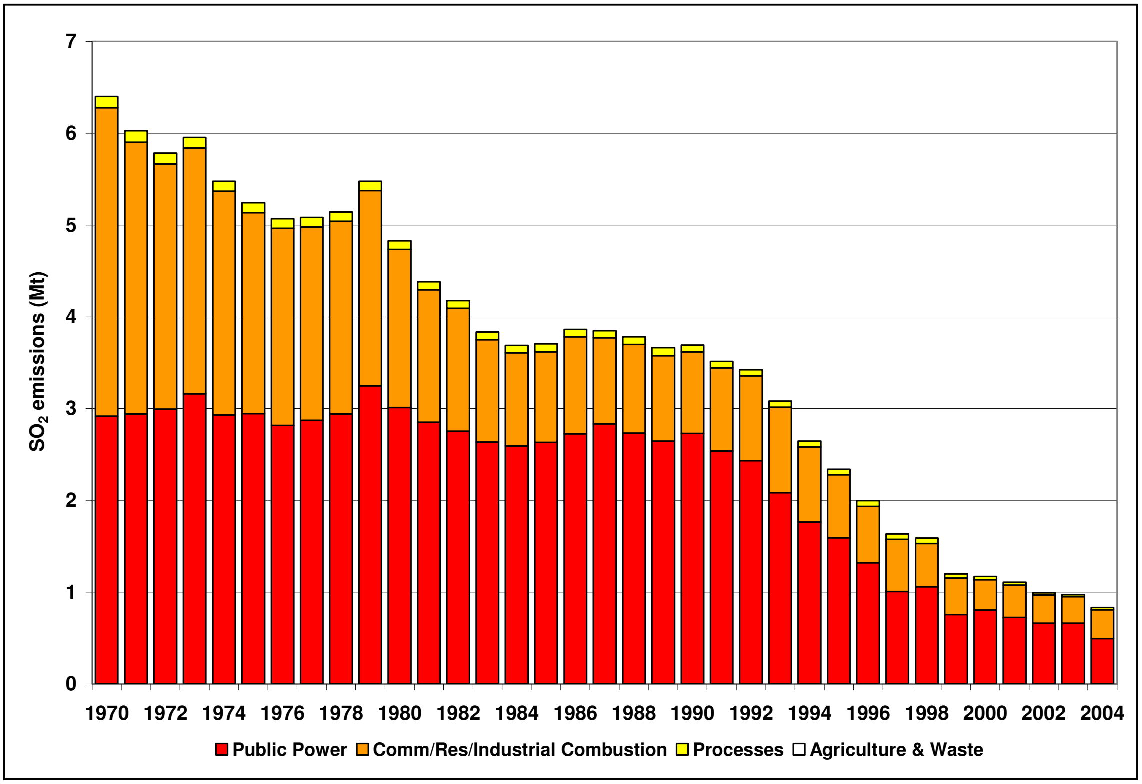


Table 4.16 UK Emissions of SO_2 by aggregated UN/ECE[1] Source Category and Fuel (ktonnes)

	1970	1980	1990	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[2]													
Public Power	3349	3296	2888	1469	1144	1160	849	888	796	733	730	565	68%
Other Stationary Combustion	1286	522	224	151	139	119	106	84	93	70	54	53	6%
Other Industrial combustion	1525	820	395	233	220	191	150	125	156	134	126	142	17%
Gas Mains Leakage	62	39	28	19	19	17	10	9	10	7	9	10	1%
Production Processes	59	59	46	42	41	41	36	26	23	18	16	14	2%
Agriculture & Waste	8	8	7	3	1	1	1	1	2	1	1	1	0%
Off-road Vehicles and Other Machinery[3]	72	53	46	44	43	38	35	33	27	26	35	44	5%
Road Transport	46	43	64	38	28	23	14	7	4	4	4	4	0%
BY FUEL CATEGORY													
Solid	3721	3154	2774	1338	1141	1178	876	897	853	772	748	598	72%
Petroleum	2512	1536	798	541	360	284	224	190	179	147	148	160	19%
Gas	19	10	9	13	20	16	13	12	11	10	9	11	1%
Non-Fuel	154	138	118	107	114	112	89	73	68	65	67	64	8%
TOTAL	6407	4838	3699	1999	1635	1591	1202	1173	1111	994	973	833	100%

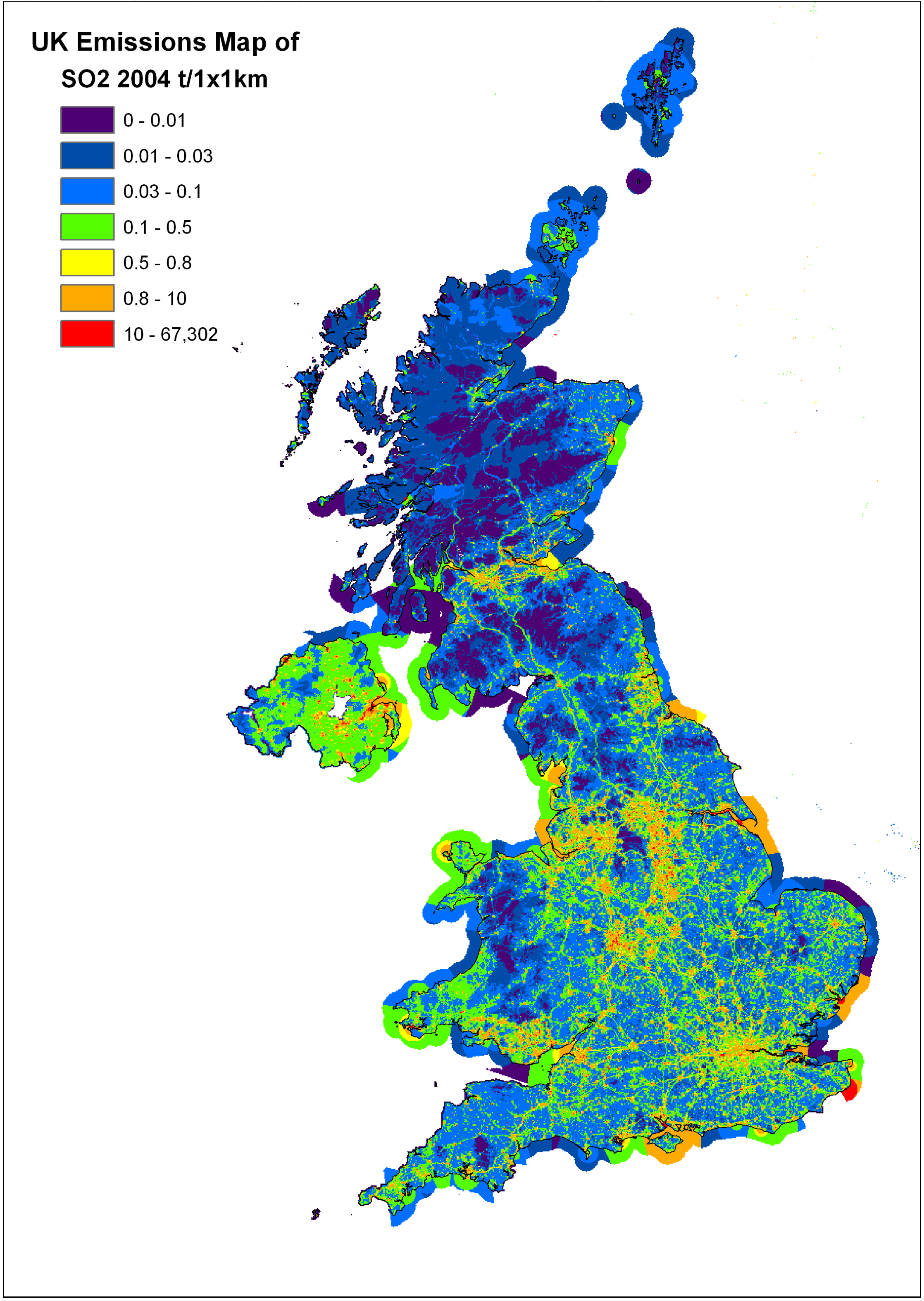
[1] UK emissions reported in IPCC format (Baggott *et al*, 2006) differ slightly due to the different source categories used.

[2] See Annex 1 for definition of UN/ECE Categories

[3] Including railways, shipping, naval vessels, military aircraft and off-road sources

The geographical distribution of SO_2 emissions is shown in Figure 4.18. A large fraction (of the order of 80%) of the SO_2 emissions are concentrated into relatively few 1x1 km grid squares containing the major point sources such as refineries and power stations and large industrial plant. The resulting map highlights the main conurbations. High emissions in Plymouth and Newport result from a combination of shipping and industry. London and Birmingham, which are covered by Smoke Control Areas, show relatively low SO_2 emission levels. High emission densities are noted in Belfast where there is substantial consumption of solid fuels in the domestic sector for heating etc.

Figure 4.18 Spatially Disaggregated UK Emissions of SO_2 Map[13]



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4.8.1 Power Generation

The largest contribution to SO_2 emissions is from power stations which accounts for 60% of the total in 2004. Historically coal combustion has been the most important source- the sulphur content of the coal being directly proportional to the emission estimate. Since 1970 there has been a gradual decline in power station emissions of around 83%. This reflects the changes in fuel mix and in the types of power plant which have taken place during the period. From 1970 to 1990 the reduction was due to a gradual increase in the use of nuclear plant and improvements in efficiency (See Section 2.2.2). Since 1990, this decline has accelerated because of the increase in the proportion of electricity generated in nuclear plant and the use of Combined Cycle Gas Turbine (CCGT) stations and other gas fired plant. CCGTs are more efficient than conventional coal and oil stations and have negligible SO_2 emissions. It is expected that these reductions will continue in the near future as more CCGT stations are built. Most recently the flue gas desulphurisation plants, constructed at Drax and Ratcliffe power stations, have had a significant effect on emissions.

4.8.2 Industry

Emissions of SO_2 from industry result from the combustion of coal and oil, some refinery processes and the production of sulphuric acid and other chemicals. Between 1970 and 2004 emissions from combustion sources have fallen by 90% though most of the fall took place between 1970-1985 reflecting the decline in the energy intensive iron and steel industry and other heavy industries. There has been also been a decline in the use of coal and oil in favour of natural gas.

4.8.3 Transport

Road transport emissions account for less than 1% of the total SO_2 emissions. Between 1970 and the early 1990s, road transport emissions grew with the increase in road vehicles, however more recently emissions have declined with the reduction in the sulphur content of DERV. Similarly the reduction in sulphur content of gas oil is reflected in the emissions from off-road vehicles.

4.8.4 Other

Emissions from the remaining categories are low compared with those discussed above. Emissions from domestic and other commercial/institutional sectors have declined substantially during the period 1970-2004, reflecting the major changes in fuel mix from oil and coal to gas. The decrease in emissions from waste reflects the closure of a number of old incinerators due to the introduction of new emission standards and their replacement with modern equipment.

4.9 HYDROGEN CHLORIDE EMISSION ESTIMATES

HCl is an acidic gas primarily released to air from combustion of fuels which contain trace amounts of chloride. This results in the emissions of HCl being dominated by the combustion of solid fuel.

Table 4.17 and Figure 4.19 and Figure 4.20 summarise the UK emissions of hydrogen chloride. Emissions have fallen by 91% since 1970. The main source of these emissions is coal combustion so the fall is a result of the decline in coal use and also the installation of flue gas desulphurisation at Drax and Ratcliffe since 1993, and the impact of the miners' strike of 1984 is clearly visible. The other significant source of hydrogen chloride is waste incineration. Here the commissioning of new incinerators and the closure or upgrading of old plant has resulted in a large decrease for all years since 1996.

Table 4.17 UK Emissions of HCl by aggregated UN/ECE[1] Source Category and Fuel (ktonnes)

	1970	1980	1990	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[2]													
Public Power	226.9	259.4	239.1	108.6	71.3	102.4	60.2	70.5	57.2	33.6	30.8	19.9	66%
Residential Combustion	56.9	25.2	13.3	8.1	7.6	6.5	6.8	5.2	6.2	4.7	3.2	3.4	11%
Other Industrial Combustion	38.7	12.9	10.9	6.4	6.0	5.7	6.8	4.1	7.0	5.9	4.7	5.8	19%
Iron and Steel	3.0	0.8	0.8	0.8	0.9	0.9	0.8	0.6	0.6	0.6	0.7	0.7	2%
Production processes	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	1%
Road Transport	0.4	0.4	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Off-road Vehicles, Other Machinery[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Waste	6.9	6.9	5.3	3.7	0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.1	0%
BY FUEL TYPE													
Solid	330.2	304.1	267.8	126.3	84.5	114.2	73.3	79.3	70.1	43.8	38.3	28.7	96%
Petroleum	0.7	0.6	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0%
Gas	0	0	0	0	0	0	0	0	0	0	0	0	0%
Non-Fuel	2.0	1.2	1.6	1.6	1.6	1.6	1.5	1.2	1.4	1.2	1.2	1.3	4%
TOTAL	**332.9**	**305.9**	**269.7**	**128.0**	**86.2**	**115.9**	**74.9**	**80.6**	**71.6**	**45.0**	**39.5**	**30.0**	**100%**

[1] UK emissions reported in IPCC format (Baggott *et al*, 2006) differ slightly due to the different source categories used.

[2] See Annex 1 for definition of UN/ECE Categories

[3] Including railways, shipping, naval vessels, military aircraft and off-road sources

Figure 4.19 Time Series of HCl Emissions (ktonnes)

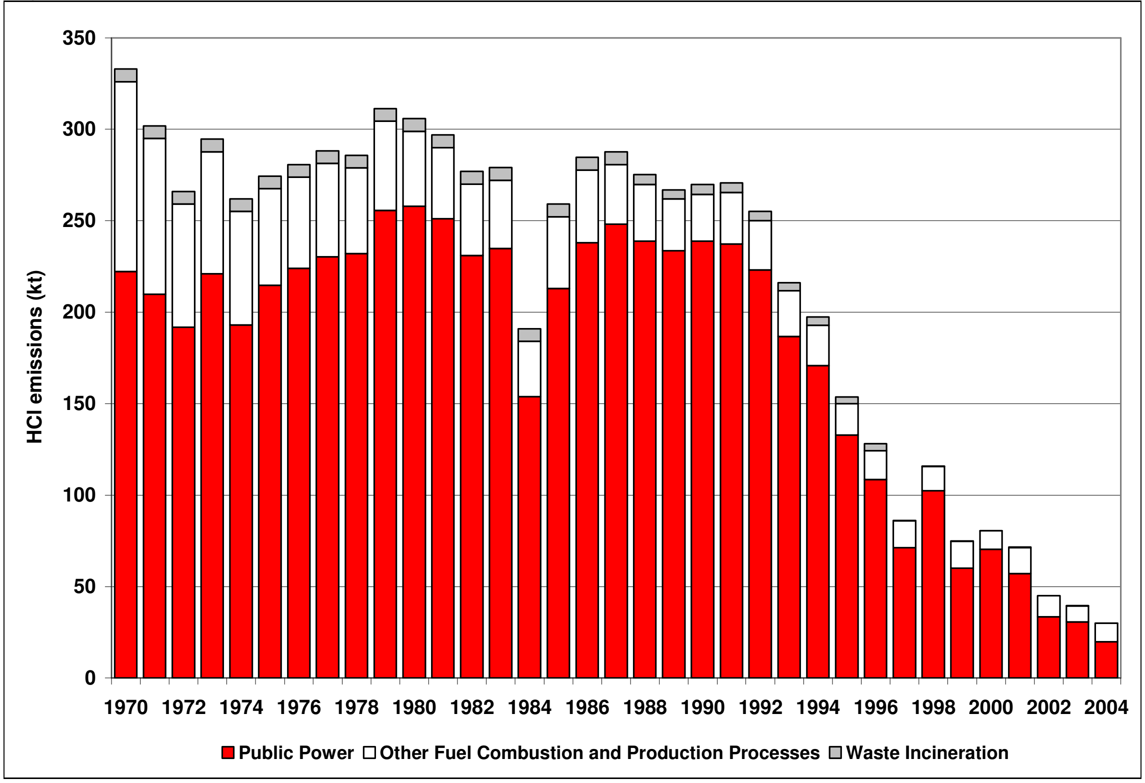
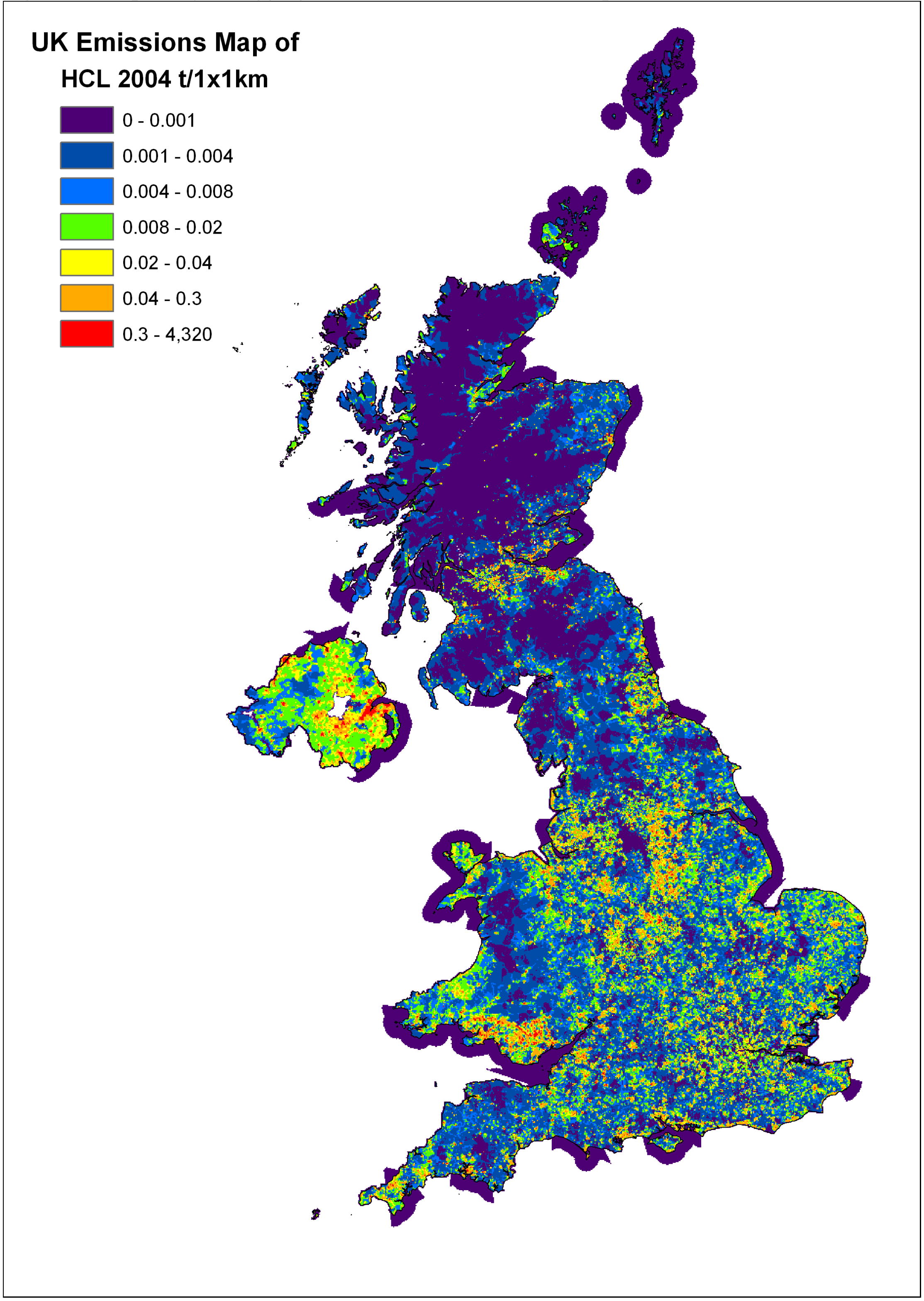


Figure 4.20 Spatially Disaggregated UK Emissions of HCl Map[14]



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4.10 NON-METHANE VOLATILE ORGANIC COMPOUNDS

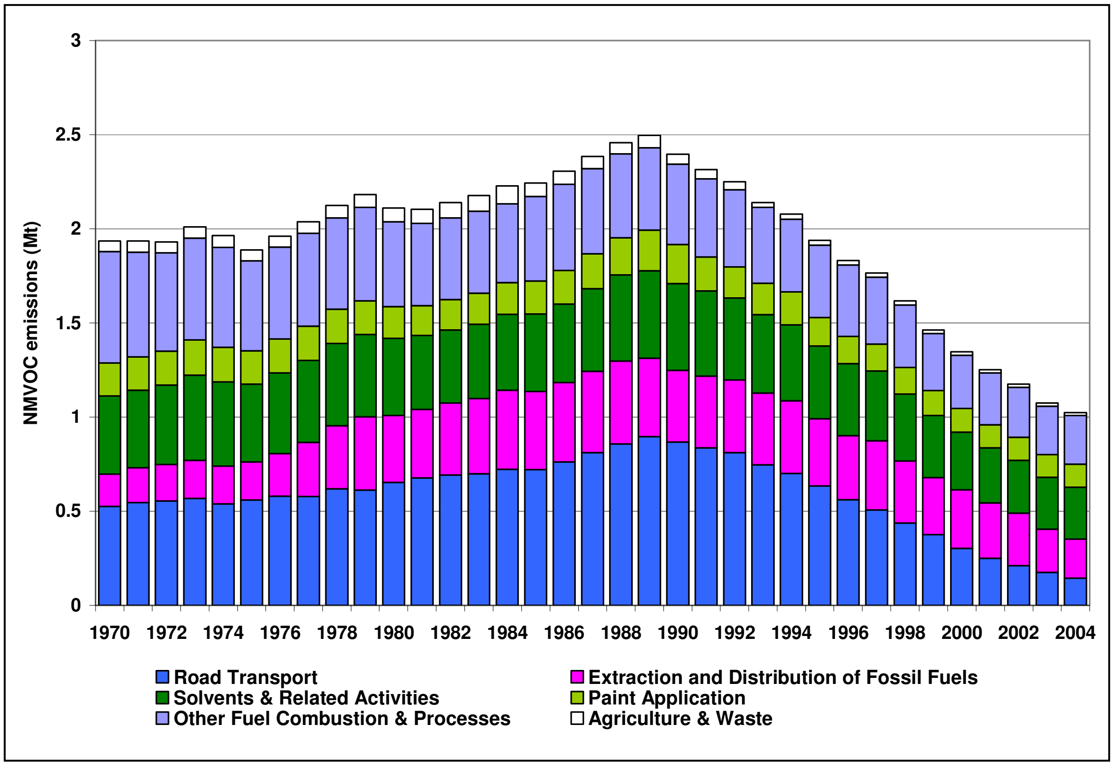
NMVOCs are organic compounds which may differ widely in their chemical composition. These organic compounds are often grouped under the NMVOC label as the majority display similar behaviour in the atmosphere. NMVOCs are emitted to air as combustion products, as vapour arising from handling or use of petroleum distillates, solvents or chemicals, and from numerous other sources.

Interest in NMVOC emissions has grown as their role in the photochemical production of ozone has been appreciated. The diversity of processes which emit NMVOCs is huge, covering not only many branches of industry, but also transport, agriculture and domestic sources.

The NMVOC inventory is summarised in Table 4.18. Only 22% of the NMVOC emissions arise from combustion sources (unlike SO_2 and NO_x where the contribution from combustion sources is much higher). Of these emissions from combustion sources, it is the transport sector which dominates. Other major sources of NMVOC emissions are the use of solvents and industrial processes. Natural emissions of NMVOCs are also reported, but are not included in the UK total (as per UN/ECE guidelines). These natural sources are primarily emissions from forests.

The NMVOC emission profile, presented in Figure 4.21, shows a small overall increase in emissions between 1970 and 1989 with minor peaks in 1973 and 1979, followed by a steady reduction in emissions during the 1990s. The latter is largely a reflection of the increasingly stringent emission limits across a range of sectors.

Figure 4.21 Time Series of NMVOC Emissions (Mtonnes)



VOC emission estimates for organic solvent-borne wood preservatives, industrial adhesives, and car-care aerosols have all been revised downwards. These changes, together with the revisions to estimates from road transport, have led to a decrease in overall NMVOC emission estimates compared with the previous version of the NAEI.

Table 4.18 UK Emissions of NMVOCs by aggregated UN/ECE[1] Source Category and Fuel (ktonnes)

	1970	1980	1990	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[2]													
Domestic	305	139	74	51	49	49	51	42	46	42	36	38	4%
Road Transport	524	652	867	560	506	436	376	303	249	210	175	144	14%
Other Fuel Combustion & Processes[3]	93	92	95	96	93	89	85	85	82	81	78	76	7%
Extraction and Distribution of Fossil Fuels	173	356	381	341	369	330	303	310	295	280	230	208	20%
Production Processes	193	220	256	233	214	195	165	155	148	143	142	145	14%
Paint Application	176	167	209	144	142	141	133	126	123	122	122	122	12%
Solvents & Related Activities	414	410	461	384	370	355	330	306	291	281	275	276	27%
Agriculture & Waste	56	73	53	24	23	22	20	19	17	16	16	15	1%
BY FUEL TYPE													
Solid	315	147	81	56	53	51	52	43	47	43	37	39	4%
Petroleum	593	722	944	638	582	510	448	372	317	275	239	207	20%
Gas	3	5	6	9	9	9	10	12	10	12	10	11	1%
Non-Fuel	1024	1236	1364	1129	1122	1046	953	920	878	844	787	767	75%
TOTAL	**1936**	**2111**	**2396**	**1832**	**1766**	**1617**	**1463**	**1348**	**1252**	**1175**	**1073**	**1024**	**100%**
Natural Emissions[4]	91	91	92	92	92	91	91	92	92	91	93	92	

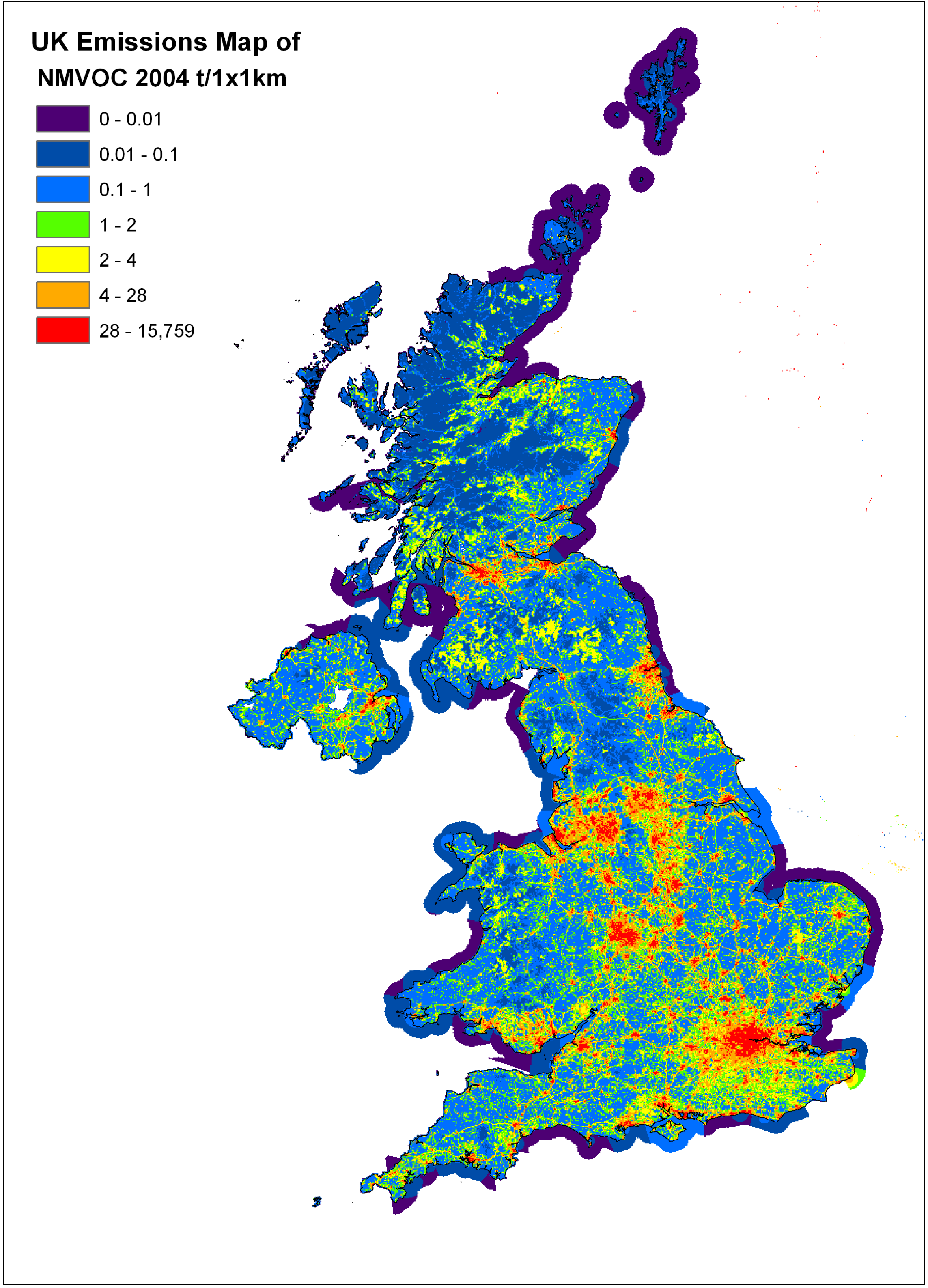
[1] UK emissions reported in IPCC format (Baggott *et al*, 2006) differ slightly due to the different source categories used.
[2] See Annex 1 for definition of UN/ECE Categories
[3] Including railways, shipping, naval vessels, military aircraft, off-road sources and Power Stations
[4] Primarily emissions from forests, but also includes accidental biomass fires

The spatial disaggregation of NMVOC emissions in the UK is shown in Figure 4.22. A large proportion of emissions are caused either as a result of the activities of people in and around their homes (e.g. domestic solvent use or domestic combustion), or by widespread industrial activities such as small-scale industrial coating processes, dry cleaning shops, and small bakeries, which are present in towns and cities throughout the UK. Consequently the resulting emissions map is well correlated with population density.

The NMVOC map includes a large number of point sources, including oil refineries, crude oil terminals, large combustion plant, chemicals manufacture, iron and steel processes, whisky manufacture, large bread bakeries, and industrial solvent using processes. The domestic sources are distributed using population density statistics, and the sources arising from other industrial processes are mapped using information on the size and locations of industrial installations.

Unlike the map presented previously for NO_x, the NMVOC map has little major road definition except where the major roads go through rural areas. This reflects the fact that NMVOC emissions are dependent on vehicle speed and are higher on minor and urban major roads than on the high-speed motorways and major roads.

Figure 4.22 Spatially Disaggregated UK Emissions of NMVOC Map[15]



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4.10.1 Solvent Use and Production Processes

Solvent use and production processes are responsible for 27% and 14%, respectively, of the 2004 emission total. The estimates are derived either based on plant specific data provided by process operators or regulators or by use of appropriate emission factors combined with solvent consumption data or industrial production data. The NMVOC inventory has been subject to a continuous programme of review and improvement over the past decade, and these estimates can be considered reasonably reliable.

The solvent use sector comprises both industrial and domestic applications, both being significant sources. Emissions from industrial solvent use reached their peak in 1973, then dipped to a low in 1982, before increasing again until 1989. Since 1989 emissions have fallen as a result of emission controls, technological changes, and reduced manufacturing output in some sectors. In comparison, domestic solvent emissions showed little temporal variation until the mid 1980s when they increased sharply. Since 1990 however, solvent use emissions have decreased by 56 % due to a trend towards formulating products such as paints and aerosols with lower solvent contents.

The production processes sector includes emissions from the chemical industry, petroleum refining, and food and drink manufacture as well as minor sources such as iron and steel production and road construction. Emissions from the chemical industry grew steadily until 1989, since when tightening emission controls have led to a reduction in emissions. The emissions from the petroleum refining sector show little trend over the period from 1970 until 1994, but since then emission controls and, latterly, refinery closures have led to emissions falling by 6% since 1994.

Emissions from the food and drink industry comprised 8% (81 ktonnes) of the total NMVOC emission in 2004. The largest source is whisky maturation although bread baking, animal feed manufacture, fat and oil processing and barley malting are also important. Emissions from the sector peaked in 1980 before falling again. The trends with time are primarily driven by production in these sectors.

4.10.2 Transport

Total transport emissions are currently responsible for 17% of NMVOC emissions of which 14% are a result of road transport. With increasing car numbers emissions rose from 1970, to a peak of in 1989. Since then emissions have declined by 84% owing to the increased use of catalytic converters and fuel switching from petrol to diesel cars. Emissions from the road transport sector for 2004 has decreased by 73% since 1970.

4.10.3 Other Sectors

Offshore oil and gas emissions have increased substantially since 1970 with the growth of the UK’s offshore activities. The most important sources of NMVOC emissions are tanker loading, flaring and fugitive emissions.

Emissions from gas leakage currently comprise around 4% of the total NMVOC emission. This estimate has been significantly revised upwards in light of new data. The mass of mains gas being released has decreased due to pipe replacement in recent years, and significantly between 2002 and 2004. There is slight countering temporal trend of increasing NMVOC content in mains gas, but the impact of this is small compared to the impact of pipeline replacement.

The evaporative losses from the distribution and marketing of petrol rose between 1970 and the early 1990s reflecting the growth in road transport. Since then emissions have decreased, partly as a result of fuel switching to diesel, and partly as a result of increasing usage of petrol vapour recovery systems to prevent emissions from petrol terminals and service stations. They currently account for 5% of national NMVOC emissions.

The contribution from domestic heating has fallen by 86% between 1970 and 2004 as the use of coal for domestic and commercial heating has declined. It now accounts for just 4% of the UK emission.

NMVOC emissions from waste treatment and disposal contribute 1% to national emissions. Data from the Environment Agency (2004) shows emissions from municipal waste incinerators to be very small.

NMVOCs, in particular isoprene and mono-terpenes, are emitted from several natural and agricultural sources- such as forests. These are included under natural sources and are not included in the UK total. Entries under Agriculture in Table 4.18 represent emissions from agricultural field burning.

4.10.4 Speciation of NMVOCs

As mentioned previously, the term NMVOC covers a wide range of compounds and although a total NMVOC inventory is sufficient for most purposes, in some cases greater detail is required concerning the nature and concentration of individual compounds. For example, when assessing the photochemical production of ozone, individual species have different ozone creation potentials hence information is required on the concentration of individual species (QUARG, 1993). Table 4.19 shows the emissions of the 50 most important NMVOC species disaggregated as far as possible by source. "Unspeciated" emissions are those where no suitable speciation profile is available. In some cases the speciation profile that is available includes groups of compounds (e.g. C6's- representing all hydrocarbons with six carbon atoms). These are reported in the table as "other grouped species".

Table 4.19 The 50 Most Significant NMVOC Species in Terms of Mass Emission (tonnes)

	Stationary combustion									
	Energy production	Commercial/ residential	Industrial	Production processes	Extraction and distribution of fossil fuels	Solvent use	Road transport	Other transport[3]	Waste treatment and disposal	Total
ethanol		3.73	0.18	55.55		42.00			0.44	101.91
butane	0.34	1.82	0.33	4.54	39.06	19.07	9.23	0.48	0.04	74.90
ethane	0.18	4.11	0.13	1.28	34.26	0.00	2.19	0.42	4.82	47.40
propane	0.20	1.81	0.16	2.28	19.29	3.72	0.80	0.25	4.51	33.02
toluene	0.12	1.09	0.09	2.87	0.20	12.24	10.52	2.69	0.25	30.08
methanol				1.88	0.00	27.64			0.11	29.64
ethylene	0.05	4.86	0.22	5.71	0.03		9.50	4.32	1.02	25.71
2-methylbutane	0.11	1.74	0.12	1.01	9.52	0.05	12.13	0.74	0.02	25.46
pentane	0.29	0.87	0.36	1.90	11.75	0.44	5.91	0.29	0.03	21.83
acetone	0.03	0.01	0.03	1.45		18.22	0.67	0.07	0.00	20.47
hexane	0.13	0.14	0.06	4.08	6.69	2.55	5.44	0.20	0.17	19.45
m-xylene	0.45	0.17	0.04	1.08	0.08	12.87	3.14	0.79	0.12	18.73
2-methylpropane	0.02	0.73	0.01	0.23	11.13	0.96	4.08	0.23	0.01	17.40
formaldehyde	3.29	0.76	0.59	0.47	0.13	0.03	4.70	2.85	3.00	15.80
trichloroethene				0.77		13.85			0.09	14.72
benzene	0.09	5.28	0.49	1.59	0.65	0.00	3.44	1.95	0.96	14.46
propylene	0.06	1.36	0.04	6.15	0.02	0.00	4.35	1.45	0.06	13.48
dichloromethane				3.09	0.06	9.67			0.10	12.92
2-butanone				0.06		12.27	0.19	0.02	0.03	12.57
butyl acetate				0.01		11.20			0.03	11.24
decane	0.00	0.03		0.79	0.02	8.21	0.69	0.90		10.65
ethylbenzene	0.13	0.06	0.02	1.29	0.02	4.92	2.77	0.74	0.19	10.15
1,2,4-trimethylbenzene	0.00	0.00		0.26	0.00	5.75	3.23	0.64		9.88
2-propanol		0.01		0.41		8.58			0.03	9.02
heptane	0.02	0.49	0.00	0.08	5.29	1.55	1.14	0.14		8.70
ethyl acetate				1.03		7.27			0.03	8.33
o-xylene	0.10	0.10	0.01	0.50	0.04	3.21	2.93	0.83	0.07	7.78
p-xylene	0.00	0.14	0.02	0.60	0.02	3.46	2.43	0.61	0.09	7.36
octane	0.00	0.05		0.05	4.61	1.31	0.49	0.09		6.60
tetrachloroethene				0.20		5.83			0.19	6.21
4-methyl-2-pentanone				0.03		6.07				6.11
acetylene	0.01	0.01	0.05	0.59	0.01	0.00	3.93	1.48		6.09
nonane	0.00	0.04		0.46	0.06	4.96	0.17	0.16		5.84
2-methylpropene	0.00	0.10	0.00	0.65	0.22		3.17	1.37	0.01	5.52
undecane	0.00	0.00		0.41		4.28		0.28		4.98
methyl acetate				4.85						4.85
1-butanol				0.05		4.78			0.01	4.85
acetaldehyde	0.00	0.00		0.75			2.26	1.41	0.00	4.41
2-methylpentane	0.01	0.01	0.01	0.81	1.90	1.22		0.01	0.08	4.03
2-butoxyethanol						3.98				3.98
1,3,5-trimethylbenzene	0.00	0.00		0.12	0.00	1.95	1.23	0.32		3.63
1-propanol						3.40			0.06	3.46
1,3-butadiene	0.00			0.32	0.01		1.88	1.17	0.01	3.39
dipentene						3.35				3.35
2-butene	0.00	0.41	0.00	0.14	0.69		1.77	0.20	0.03	3.25
1-methoxy-2-propanol						3.16				3.16
1,2,3-trimethylbenzene	0.00	0.00		0.11	0.00	1.96	0.73	0.21		3.01
methylethylbenzene						2.97				2.97
4-methyldecane				0.24		2.49				2.73
2-pentene	0.01	0.25	0.00	0.01	1.22		1.09	0.04	0.00	2.62
Total Top 50	5.64	30.16	2.96	110.77	146.98	281.47	106.18	27.33	16.61	728.10
Other VOC	0.24	1.86	0.11	20.39	3.02	97.60	11.14	5.22	2.41	142.00
Other grouped species	0.00	0.42	0.00	21.84	8.88	7.81	25.82	27.81	1.97	94.55
unspeciated	0.00	10.36	0.63	28.36	3.71	8.90	0.97	1.61	4.56	59.10
Total VOC	5.89	42.81	3.71	181.36	162.60	395.77	144.11	61.97	25.56	1023.76

An entry of "0.00" represents a value of <0.005 ktonnes (i.e.<5 tonnes)

4.10.5 Photochemical Ozone Creation Potential

Table 4.19 (and Appendix 5) is a useful reference for finding the emission of a particular NMVOC compound. However, species specific emissions do not reflect the fact that NMVOC compounds have different efficiencies in generating ozone through photochemical reactions. To resolve this, the concept of a photochemical ozone creation potential (POCP) was created. This POCP identifies, on a relative basis, the ozone creation potential for each NMVOC compound through modelling studies. The creation potentials are then normalised by defining ethene as a creation potential of 1.

It is therefore possible to determine which NMVOCs are the most important for the photochemical formation of ozone in the atmosphere. This is achieved by scaling the emissions of each NMVOC by the corresponding POCP to determine a weighted total (Table 4.20).

Table 4.20 POCP Weighted NMVOC Emissions

	POCP	code	Stationary combustion	Production processes	Extraction and distribution of fossil fuels	Solvent use	Road transport	Other transport[3]	Waste treatment and disposal	Total (Mass Emissions)	Total (POCCP weighted)	Total (POCCP weighted %)
ethanol	39.90	a	3.91	55.55	0.00	42.00	0.00	0.00	0.44	101.91	40.66	8.7%
butane	35.20	a	2.48	4.54	39.06	19.07	9.23	0.48	0.04	74.90	26.37	5.6%
ethane	12.30	a	4.42	1.28	34.26	0.00	2.19	0.42	4.82	47.40	5.83	1.2%
propane	17.60	a	2.17	2.28	19.29	3.72	0.80	0.25	4.51	33.02	5.81	1.2%
toluene	63.70	a	1.31	2.87	0.20	12.24	10.52	2.69	0.25	30.08	19.16	4.1%
methanol	14.00	a	0.00	1.88	0.00	27.64	0.00	0.00	0.11	29.64	4.15	0.9%
ethylene	100.00	a	5.13	5.71	0.03	0.00	9.50	4.32	1.02	25.71	25.71	5.5%
2-methylbutane	40.50	a	1.98	1.01	9.52	0.05	12.13	0.74	0.02	25.46	10.31	2.2%
pentane	39.50	a	1.51	1.90	11.75	0.44	5.91	0.29	0.03	21.83	8.62	1.8%
acetone	9.40	a	0.06	1.45	0.00	18.22	0.67	0.07	0.00	20.47	1.92	0.4%
hexane	48.20	a	0.33	4.08	6.69	2.55	5.44	0.20	0.17	19.45	9.37	2.0%
m-xylene	110.80	a	0.66	1.08	0.08	12.87	3.14	0.79	0.12	18.73	20.76	4.4%
2-methylpropane	30.70	a	0.76	0.23	11.13	0.96	4.08	0.23	0.01	17.40	5.34	1.1%
formaldehyde	51.90	a	4.64	0.47	0.13	0.03	4.70	2.85	3.00	15.80	8.20	1.8%
trichloroethene	32.50	a	0.00	0.77	0.00	13.85	0.00	0.00	0.09	14.72	4.78	1.0%
benzene	21.80	a	5.86	1.59	0.65	0.00	3.44	1.95	0.96	14.46	3.15	0.7%
propylene	112.30	a	1.46	6.15	0.02	0.00	4.35	1.45	0.06	13.48	15.14	3.2%
dichloromethane	6.80	a	0.00	3.09	0.06	9.67	0.00	0.00	0.10	12.92	0.88	0.2%
2-butanone	37.30	a	0.00	0.06	0.00	12.27	0.19	0.02	0.03	12.57	4.69	1.0%
butyl acetate	26.90	a	0.00	0.01	0.00	11.20	0.00	0.00	0.03	11.24	3.02	0.6%
decane	38.40	a	0.03	0.79	0.02	8.21	0.69	0.90	0.00	10.65	4.09	0.9%
ethylbenzene	73.00	a	0.21	1.29	0.02	4.92	2.77	0.74	0.19	10.15	7.41	1.6%
1,2,4-trimethylbenzene	127.80	a	0.00	0.26	0.00	5.75	3.23	0.64	0.00	9.88	12.62	2.7%
2-propanol	18.80	a	0.01	0.41	0.00	8.58	0.00	0.00	0.03	9.02	1.70	0.4%
heptane	49.40	a	0.51	0.08	5.29	1.55	1.14	0.14	0.00	8.70	4.30	0.9%
ethyl acetate	20.90	a	0.00	1.03	0.00	7.27	0.00	0.00	0.03	8.33	1.74	0.4%
o-xylene	105.30	a	0.21	0.50	0.04	3.21	2.93	0.83	0.07	7.78	8.19	1.8%
p-xylene	101.00	a	0.16	0.60	0.02	3.46	2.43	0.61	0.09	7.36	7.44	1.6%
octane	45.30	a	0.05	0.05	4.61	1.31	0.49	0.09	0.00	6.60	2.99	0.6%
tetrachloroethene	2.90	a	0.00	0.20	0.00	5.83	0.00	0.00	0.19	6.21	0.18	0.0%
4-methyl-2-pentanone	49.00	a	0.00	0.03	0.00	6.07	0.00	0.00	0.00	6.11	2.99	0.6%
acetylene	8.50	a	0.07	0.59	0.01	0.00	3.93	1.48	0.00	6.09	0.52	0.1%
nonane	41.40	a	0.04	0.46	0.06	4.96	0.17	0.16	0.00	5.84	2.42	0.5%
2-methylpropene	62.70	a	0.10	0.65	0.22	0.00	3.17	1.37	0.01	5.52	3.46	0.7%
undecane	38.40	a	0.00	0.41	0.00	4.28	0.00	0.28	0.00	4.98	1.91	0.4%
methyl acetate	5.90	a	0.00	4.85	0.00	0.00	0.00	0.00	0.00	4.85	0.29	0.1%
1-butanol	62.00	a	0.00	0.05	0.00	4.78	0.00	0.00	0.01	4.85	3.00	0.6%
acetaldehyde	64.10	a	0.00	0.75	0.00	0.00	2.26	1.41	0.00	4.41	2.83	0.6%
2-methylpentane	42.00	a	0.02	0.81	1.90	1.22	0.00	0.01	0.08	4.03	1.69	0.4%
2-butoxyethanol	48.30	a	0.00	0.00	0.00	3.98	0.00	0.00	0.00	3.98	1.92	0.4%
1,3,5-trimethylbenzene	138.10	a	0.00	0.12	0.00	1.95	1.23	0.32	0.00	3.63	5.01	1.1%
1-propanol	56.10	a	0.00	0.00	0.00	3.40	0.00	0.00	0.06	3.46	1.94	0.4%
1,3-butadiene	85.10	a	0.00	0.32	0.01	0.00	1.88	1.17	0.01	3.39	2.88	0.6%
dipentene	74.54	b	0.00	0.00	0.00	3.35	0.00	0.00	0.00	3.35	2.49	0.5%
2-butene	113.90	a	0.41	0.14	0.69	0.00	1.77	0.20	0.03	3.25	3.70	0.8%
1-methoxy-2-propanol	35.50	a	0.00	0.00	0.00	3.16	0.00	0.00	0.00	3.16	1.12	0.2%
1,2,3-trimethylbenzene	126.70	a	0.00	0.11	0.00	1.96	0.73	0.21	0.00	3.01	3.82	0.8%
methylethylbenzene	94.10	c	0.00	0.00	0.00	2.97	0.00	0.00	0.00	2.97	2.79	0.6%
4-methyldecane	37.67	b	0.00	0.24	0.00	2.49	0.00	0.00	0.00	2.73	1.03	0.2%
2-pentene	111.90	a	0.26	0.01	1.22	0.00	1.09	0.04	0.00	2.62	2.93	0.6%
Total Top 50			38.77	110.77	146.98	281.47	106.18	27.33	16.61	728.10	323.30	69.2%
Other VOC	0.38[a]		2.22	20.39	3.02	97.60	11.14	5.22	2.41	142.00	54.27	11.6%
Other grouped species	0.63[a]		0.43	21.84	8.88	7.81	25.82	27.81	1.97	94.55	59.37	12.7%
unspeciated	51.30	c	10.99	28.36	3.71	8.90	0.97	1.61	4.56	59.10	30.32	6.5%
Total VOC			52.40	181.36	162.60	395.77	144.11	61.97	25.56	1,023.76	467.26	100.0%

An entry of "0.00" represents a value of <0.005 ktonnes (i.e. <5 tonnes)
a: estimates

4.11 AMMONIA EMISSION ESTIMATES

NH_3 emissions play an important role in a number of different environmental issues including acidification, nitrification and eutrophication (see Section 1.1). The atmospheric chemistry of NH_3 and NH_4^+ mean that transport of the pollutants can vary greatly. As a result NH_3 emissions can impact on a highly localised level, as well as contributing to effects from long-range pollutant transport.

Emission estimates for NH_3 are only available from 1990 onwards. This is because earlier data from the most significant industrial sources are not available, or considered reliable enough, to use in emission estates.

Emissions in 2004 represent a decrease of 12% on the 1990 emissions. The primary source of NH_3 emissions in the UK is manure management from livestock, and in particular cattle. The most significant cause of reductions in recent years has been decreasing cattle numbers in the UK.

Table 4.21 gives a sectoral breakdown of the emissions of NH3 in the UK. There are several sources of NH3 which are not included in the official UK NH3 totals. These are included in Table 4.21 as memo items. There is on-going discussion aimed at identifying whether some of these sources should be included in the UK totals or not.

Table 4.21 UK Emissions of NH_3 by aggregated UN/ECE[1] Source Category and Fuel (ktonnes)

	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE												
Stationary Combustion	5.9	4.6	4.6	4.4	4.2	4.7	4.0	4.6	4.2	3.5	3.5	1%
Road Transport	0.9	9.1	11.7	11.9	12.1	12.3	12.5	12.4	12.1	11.4	10.6	3%
Production Processes	8.6	8.7	9.5	7.8	10.2	6.2	5.1	5.2	4.8	4.5	4.6	1%
Off-road Vehicles and Other Machinery	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0%
Cattle	169.2	161.8	163.2	157.2	154.6	154.4	147.4	149.6	153.3	160.0	163.7	49%
Poultry	40.1	35.9	39.6	43.2	39.8	43.6	40.4	41.8	39.0	38.1	38.5	11%
Other Livestock	90.0	87.4	86.9	90.2	91.5	86.5	80.5	72.6	69.9	66.8	66.1	20%
Direct Soil Emissions	53.8	36.7	31.6	34.7	33.7	37.3	33.1	37.7	35.4	29.2	36.0	11%
Waste	13.0	14.7	14.7	14.7	14.3	13.4	13.5	13.4	13.5	13.3	13.2	4%
BY												
Solid	5.4	3.8	3.8	3.6	3.4	3.5	2.9	3.3	2.9	2.2	2.3	1%
Petroleum	1.0	9.2	11.8	12.0	12.3	12.4	12.6	12.5	12.2	11.5	10.7	3%
Gas	0	0	0	0	0	0	0	0	0	0	0	0%
Non-Fuel	382.6	353.2	353.4	355.7	352.2	349.3	327.9	328.3	323.8	320.0	330.2	96%
TOTAL	**381.5**	**358.9**	**361.8**	**364.1**	**360.6**	**358.4**	**336.6**	**337.3**	**332.1**	**326.9**	**336.4**	**100%**
Wild Animals	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	
Humans	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	

[1] See Annex 1 for definition of UN/ECE Categories

There have been a number of significant improvements to the NH_3 inventory across the last several years. In particular efforts have been made to unify estimates being made by different organisations to arrive at a definitive emissions inventory for the UK.

4.11.1 Agricultural Sources

Ammonia emissions in 2004 are dominated by agricultural sources with emissions from livestock and their wastes comprising 79% of the total emission. These emissions derive mainly from the decomposition of urea in animal wastes and uric acid in poultry wastes. Emissions depend on animal species, age, weight, diet, housing systems, waste management and storage techniques.

Hence emissions are affected by a large number of factors which make the interpretation of experimental data difficult and emission estimates uncertain.

Emissions from the agricultural sector are taken directly from the agricultural ammonia (NH_3) inventory compiled for Defra each year by a consortium of organisations. This inventory considers each source in detail, drawing on official livestock datasets and using combinations of emission factors from the literature considered to be the most appropriate available. As part of this work, the agricultural NH_3 emissions inventory is reviewed each year to capture the most up to date livestock numbers, emission factors and views on methodologies (Misselbrook *et al* 2004).

As well as emissions from livestock, the agriculture inventory includes emissions from fertiliser use, crops and decomposition of agricultural vegetation. These estimates are particularly uncertain owing to the complexity of the processes involved, and less data available from the literature.

NH_3 emissions from agricultural livestock are decreasing with time. This is driven by decreasing animal numbers. In addition, there is a decline in fertiliser use, which also gives rise to decreasing emissions.

4.11.2 Other Sources

The non-agricultural sources comprise a number of diverse sources and equal 21% (including 4D1, 4F otherwise 10%) of the total. However, emission estimates for these sources are high in uncertainty due to a lack of data. A combination of estimates are used from the NETCEN emissions inventory team and from CEH Edinburgh (Dragosits and Sutton 2004).

Emissions of NH_3 from road transport although relatively small have been increasing as a result of the increasing number of three way catalysts in the vehicle fleet. However, emissions are projected to fall across the next several years as the second generation of catalysts (which emit less NH_3 than first generation catalysts) penetrate the vehicle fleet.

Figure 4.23 Time Series of NH3 Emissions (ktonnes)

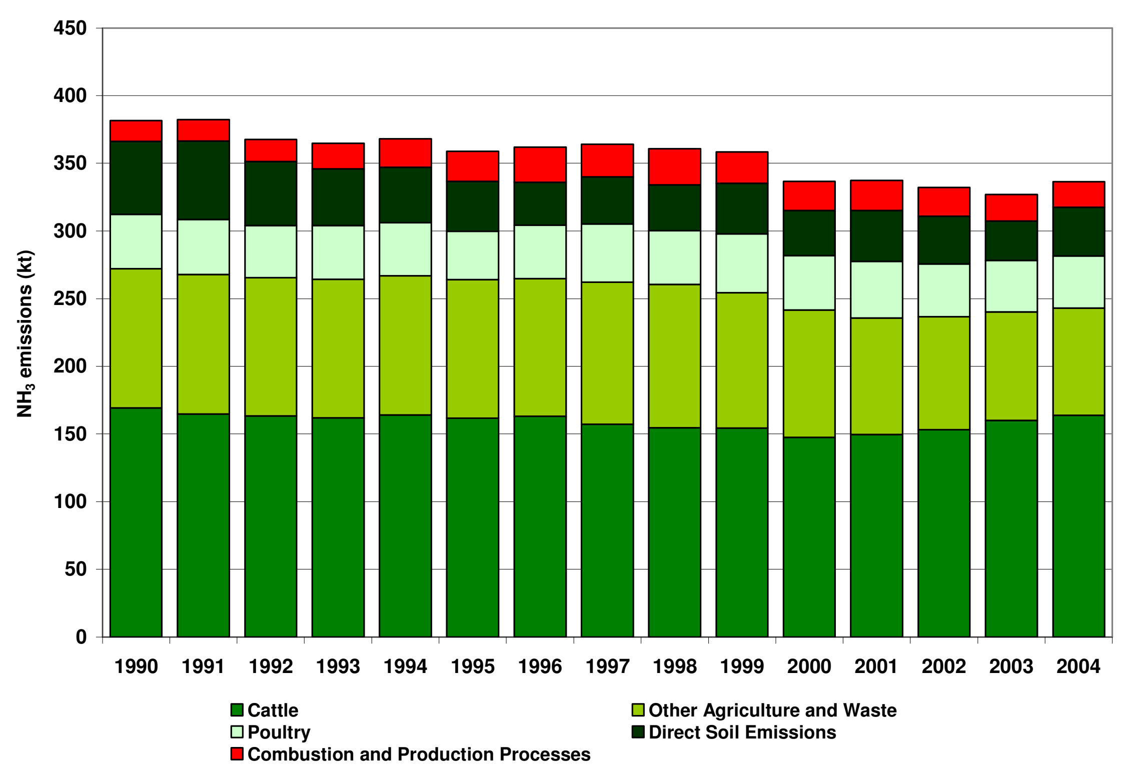
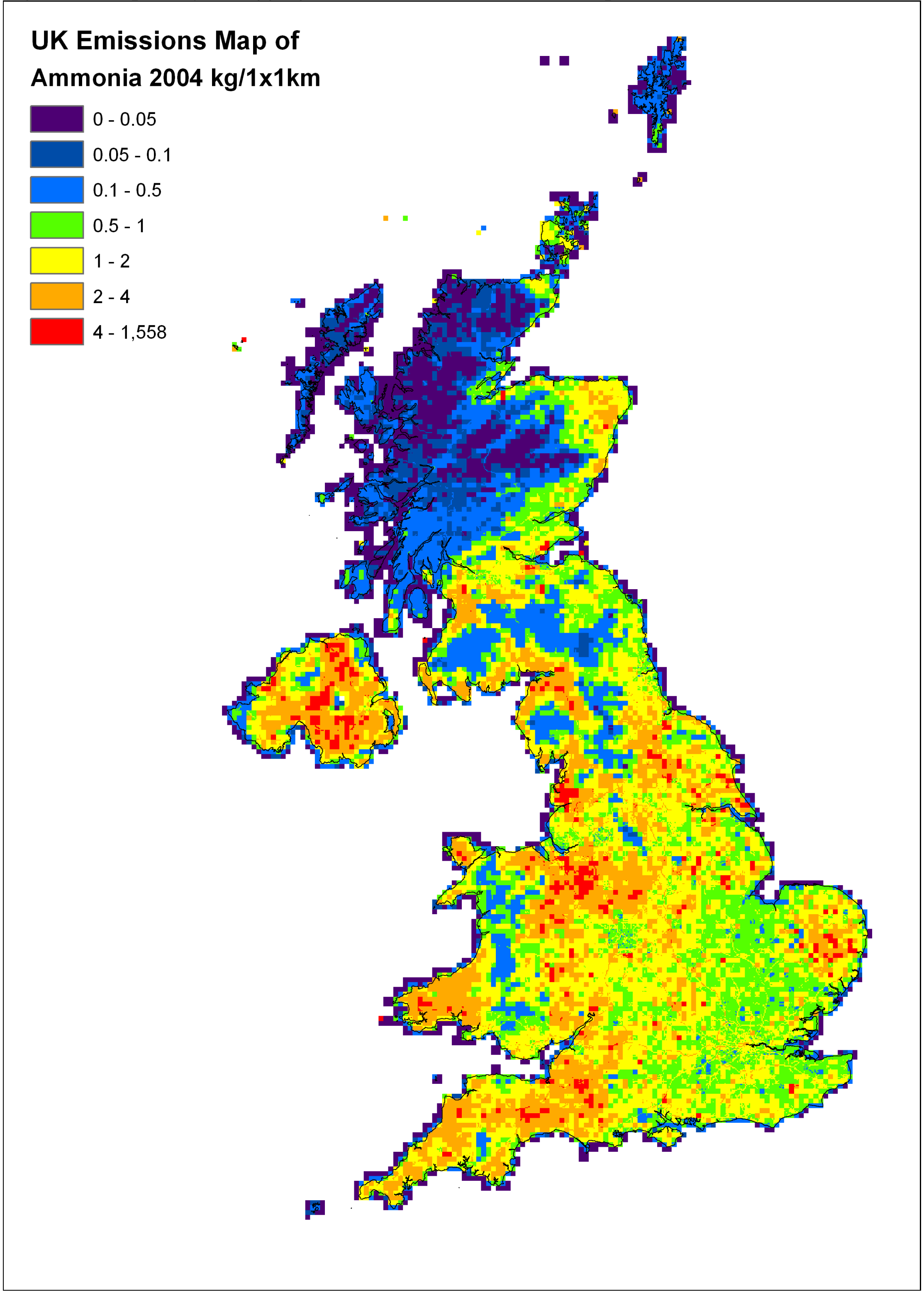


Figure 4.24 shows mapped NH_3 emissions. High emission densities are observed in agricultural areas, for example East Anglia, the South West and the North of England and Northern Ireland. Non-agricultural emissions are also noted to give rise to high emission densities in major urban areas such as London. The NH_3 emissions map is constructed at a lower resolution than other maps due to the associated uncertainties, and the restricted nature of the spatial distributions.

Figure 4.24 Spatially Disaggregated UK Emissions of NH_3 Map[16]



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4.12 HYDROGEN FLUORIDE EMISSION ESTIMATES

Hydrogen fluoride (HF) is an acidic gas released to air from combustion of fuels which contain trace amounts of fluoride. Some industrial processes use HF as an acidic reagent (or produce HF), giving rise to emissions. HF is chemically very similar to HCl.

The emissions of HF display a similar source pattern to HCl (see Section 4.9). However, the emissions of HF from the power generation sector do not account for such a high percentage of the total (see Table 4.22). The reduction of the emissions from this sector with time is an indication of the increased use of emission abatement equipment in power stations. Emissions of HF from the residential sector have also decreased with time. This is due to the decreasing use of coal in domestic heating. These trends with time are highlighted in Figure 4.25, and the impact of the miners strike in 1984 is apparent.

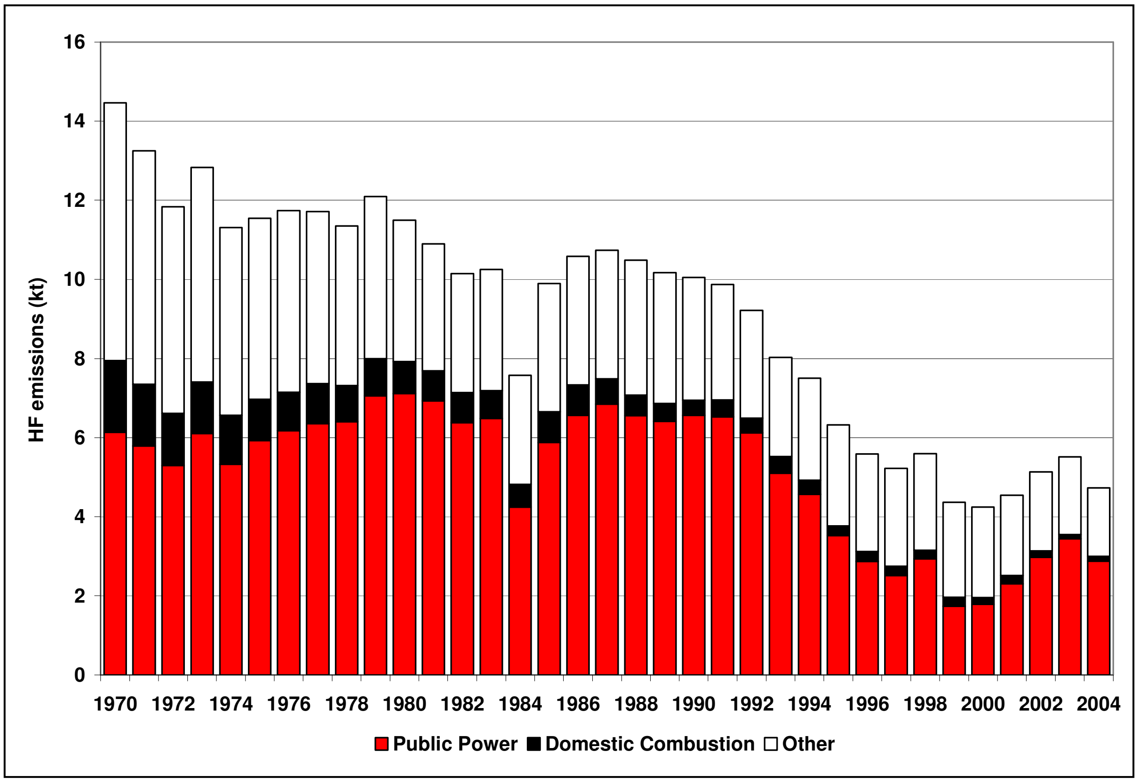
The increase of 84% in HF emission between 1999 and 2004 is caused by the increased coal consumption in electricity generation. Interestingly this trend is not noted for HCl (which exhibits a decrease of 60% from 1999 to 2004). This is because the HCl emission per unit of coal consumed decreased between 1999 and 2004, whereas that for HF remained reasonably constant.

Table 4.22 UK Emissions of HF by aggregated UN/ECE[1] Source Category and Fuel (ktonnes)

	1970	**1980**	**1990**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2004%**
BY UN/ECE CATEGORY													
Public Power	6.7	7.2	6.6	2.9	2.5	2.9	1.7	1.8	2.3	3.0	3.4	2.9	61%
Industrial Fuel Combustion	0.5	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1%
Combustion Residential plants	1.8	0.8	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	3%
Brick manufacture	2.7	1.4	1.4	1.1	1.1	1.1	1.1	1.0	0.9	0.7	0.6	0.7	15%
Solid fuel transformation	2.5	1.3	1.0	0.8	0.8	0.8	0.8	0.8	0.7	0.6	0.6	0.5	11%
Other Processes	0.2	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.6	0.7	0.4	9%
Waste	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
BY FUEL TYPE													
Solid	13.3	10.2	8.9	4.5	4.1	4.4	3.2	3.1	3.7	4.2	4.5	4.0	85%
Petroleum	0	0	0	0	0	0	0	0	0	0	0	0	0%
Gas	0	0	0	0	0	0	0	0	0	0	0	0	0%
Non-Fuel	1.1	1.3	1.2	1.1	1.1	1.2	1.1	1.1	0.8	1.0	1.0	0.7	15%
TOTAL	**14.5**	**11.5**	**10.0**	**5.6**	**5.2**	**5.6**	**4.4**	**4.2**	**4.5**	**5.1**	**5.5**	**4.7**	**100%**

[1] See Annex 1 for definition of UN/ECE Categories

Figure 4.25 Time Series of Hydrogen Fluoride Emissions (ktonnes)



4.13 ACCURACY OF EMISSION ESTIMATES OF ACIDIFYING GASES AND TROPOSPHERIC OZONE PRECURSORS

Quantitative estimates of the uncertainties in emission inventories have been based on calculations made using a direct simulation technique, which corresponds to the IPCC Tier 2 approach recommended for greenhouse gases and also the methodology proposed in draft guidance produced by the UN/ECE Taskforce on Emission Inventories. This work is described in detail by Passant (2002b). Uncertainty estimates are shown in Table 4.23.

Table 4.23 Uncertainty of the Emission Inventories

Pollutant	Estimated Uncertainty %
Sulphur Dioxide	+/- 3
Oxides of Nitrogen	+/- 8
Non-Methane Volatile Organic Compounds	+/- 10
Ammonia	+/- 20
Hydrogen Chloride	+/- 20
Hydrogen Fluoride	+/- 20 [a]

[a] Assumed to be same as for hydrogen chloride (see text below for discussion)

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

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

From the above, one might expect the NO_x inventory to be very uncertain, however the overall uncertainty is in fact lower than any pollutant other than SO_2. This is probably largely as a result of two factors. First, while emission factors are uncertain, activity data used in the NO_x inventory is very much less uncertain. This contrasts with inventories for pollutants such as volatile organic compounds, PM_{10}, metals, and persistent organic pollutants, where some of the activity data are very uncertain. Second, the NO_x inventory is made up of a large number of emission sources with many of similar size and with none dominating (the largest source category contributes just 18% of emissions, and a further 42 sources must be included to cover 90% of the emission). This leads to a large potential for error compensation, where an underestimate in emissions in one sector is very likely to be compensated by an overestimate in emissions in another sector. The other extreme is shown by the inventories for PCP, HCH and HCB (see Section 5.2.3) where one or two sources dominate and the inventories are highly uncertain.

Non-Methane Volatile Organic Compounds
The NMVOC inventory is more uncertain than those for SO_2 and NO_x. This is due in part to the difficulty in obtaining good emission factors or emission estimates for some sectors (e.g. fugitive

sources of NMVOC emissions from industrial processes, and natural sources) and partly due to the absence of good activity data for some sources. As with NO_x, there is a high potential for error compensation, and this is responsible for the relatively low level of uncertainty compared with most other pollutants in the NAEI.

Ammonia

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

Hydrogen Chloride

The hydrogen chloride inventory is equally as uncertain as the ammonia inventory. As with ammonia, a few sources dominate the inventory and the levels of uncertainty in these sources is generally quite high.

Hydrogen Fluoride

Uncertainty analysis has not been performed on the hydrogen fluoride inventory as this is not a core part of the NAEI. However, the sources of hydrogen fluoride are very similar to those for hydrogen chloride and the level of uncertainty in emission factors might also be expected to be similar. As a result it seems reasonable to assume the same level of overall uncertainty as for hydrogen chloride.

5 Persistent organic pollutants

5.1 INTRODUCTION

This section includes pollutants singled out for control under recent international protocols of the UN/ECE under the Convention on Long-range Transboundary Air Pollution- namely Persistent Organic Pollutants (POPs).

5.1.1 UN/ECE POPs Protocol

The Convention on Long-range Transboundary Air Pollution was signed in 1979 and entered into force in 1983. Since its entry into force the Convention has been extended by a number of protocols, including the 1998 Protocol on POPs. This Protocol is given in outline below; more information may be found at the UN/ECE web site, located at:- http://www.unece.org/env/lrtap/. The UK has signed this protocol.

5.1.1.1 Persistent Organic Pollutants (POPs)

The UN/ECE Protocol on Persistent Organic Pollutants focuses on a list of 16 substances (or groups of substances), that have been identified according to certain risk criteria. In brief, these 16 pollutants may be classified in three source sectors as follows:

1. **Pesticides**: aldrin, chlordane, chlordecone, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene (HCB), mirex, toxaphene, hexachlorocyclohexane (HCH, which includes “lindane”);

2. **Industrial Chemicals**: hexabromobiphenyl, polychlorinated biphenyls (PCBs);

3. **By-products or Contaminants**: dioxins, furans, polycyclic aromatic hydrocarbons (PAHs).

The ultimate objective of the protocol is to eliminate any losses, discharges and emissions of POPs to the environment. This is achieved through several different legislative mechanisms. First, the production and use of several compounds is banned (aldrin, chlordane, chlordecone, dieldrin, endrin, hexabromobiphenyl, mirex and toxaphene). Second, several compounds are scheduled for elimination at a later date (DDT, heptachlor, hexachlorobenzene, PCBs). Finally, the protocol severely restricts the use of selected compounds (DDT, HCH- including lindane and PCBs). Limited uses which are thought to be essential and for which there are no adequate substitutes can be exempted. For instance, the use of substances like DDT would be allowed under the protocol for public health emergencies. The protocol includes provisions for dealing with the surplus of products that will be banned.

Under the protocol, countries are also required to reduce their emissions of dioxins, furans, PAHs and HCB below their levels in 1990 (or an alternative year between 1985 and 1995). The protocol requires the best available techniques (BAT) to be applied to cut emissions of these POPs. For the incineration of municipal, hazardous and medical waste, it lays down specific limit values. The protocol allows for the addition of further compounds into control, depending on the development of the scientific basis for such an action.

In 1999, EPAQS (Expert Panel on Air Quality Standards) published a report on PAHs which recommended an Air Quality Standard of 0.25 ng m^{-3} benzo[a]pyrene as an annual average. As a result, further work assessing the concentrations of PAHs in the atmosphere has been commissioned by Defra and the results compared with the spatially disaggregated emissions inventory.

In August 2002, PAHs were added to the list of pollutants covered by the Air Quality Strategy for England, Scotland, Wales and Northern Ireland (see Section 5.2), and an objective was set relating to the PAH concentrations in the air. As a consequence there is a continued drive to decrease PAH emissions from the major sources.

Continued improvements have been made in compiling the 2004 UK emission estimates for POPs. This has been instigated in a response to the increasing interest in hazardous air pollutants and their impact on the environment over the last several years. The level of data available for many of these pollutants is relatively limited and hence several areas of the current emission inventory have been targeted for improvements which will be included in future emission estimates as a part of the NAEI continuous improvement process.

Table 5.1 lists POPs included in the current inventory together with their total UK emissions in 2004. Each of the pollutant classes are considered in more detail in the following sections.

Persistent organic pollutants (POPs) are organic compounds of anthropogenic origin that do not readily break down in the environment. Their long lifetime means that they can be transported over long distances, resulting in widespread distribution across the earth, including remote regions. They accumulate in the food chain, and their toxicity poses a threat to humans and the environment.

Over recent years there has been a growing interest in these pollutants and in particular their potential chronic toxicity and impacts on human health. This is reflected by the recent international agreement to reduce releases of these chemicals under the UN/ECE Persistent Organic Pollutants Protocol (detailed in Section 5.1) and their consideration for air quality standards by the Expert Panel on Air Quality Standards (EPAQS). The detailed methodology for the compilation of these inventories depends on the combination of emission factors gathered from a range of sources and production statistics used elsewhere in the emission inventory or developed for the specific sector concerned.

The UK NAEI does not include emission estimates for a number of POPs that have been banned in the UK for several years. Table 5.2 below indicates the years in which the use of particular POPs were banned or their use severely restricted, and whether the listed POPs are included in the NAEI.

Table 5.1 Total UK Emissions of POPs

Pollutant	**Total 2004 UK emission**	
Persistent organic compounds (POPs)		
• Polycyclic aromatic hydrocarbons (PAHs)	1723	tonnes (USEPA16)[1]
• Dioxins and Furans (PCDD/F)	285	I-TEQ grammes[2]
• Polychlorinated biphenyls (PCBs)	1.33	tonnes
• Pesticides		**tonnes**
- lindane (γ-HCH)	13	
- pentachlorophenol (PCP)	437	
- hexachlorobenzene (HCB)	0.87	
• Short Chain Chlorinated Paraffins (SCCPs)	1.048	tonnes
• Polychlorinated Napthalenes (PCNs)	NE[3]	
• Polybrominated Diphenyl Ethers (PBDEs)	7	

[1] See Table 6.3 for different PAHs included under different groupings.

[2] TEQ- “Toxic Equivalents” is a way of weighting emissions according to their toxicity. See Table 6.4

[3] NE - Not Estimated. It has not been possible to make an emission estimate

Table 5.2 POPs Included/Not Included in the NAEI and Corresponding Year of Ban on Use

Compound or Compound Group	Banned in UK	Included in NAEI
Polycyclic aromatic hydrocarbons (PAHs)	-	**Yes**
Dioxins and Furans (PCDD/Fs)	-	**Yes**
Polychlorinated biphenyls (PCBs)	-	**Yes**
Hexabromobiphenyl	Never Used	No
Pesticides		
γ-Hexachlorocyclohexane	-	**Yes**
Pentachlorophenol[1]	1995[2]	**Yes**
Hexachlorobenzene[1]	1975	**Yes**
Aldrin	1989	No
Chlordane	1992	No
Dichlorodiphenyl-trichloroethane (DDT)	1984	No
Chlordecone	1977	No
Dieldrin	1989	No
Endrin	1984	No
Heptachlor	1981	No
Mirex	Never Used	No
Toxaphene	Never Used	No

[1] Hexachlorobenzene and pentachlorophenol are also emitted from other sources as well as being or having been active ingredients in pesticides.

[2] Use of pentachlorophenol is severely restricted rather than banned absolutely.

5.2 POLYCYCLIC AROMATIC HYDROCARBONS (PAHS)

Polycyclic aromatic hydrocarbons are a large group of chemical compounds with a similar structure comprising two or more joined aromatic carbon rings. Different PAHs vary both in their chemical characteristics and in their environmental sources and they are found in the environment both as gases and associated with particulate material. They may be altered after absorption into the body into substances that are able to damage the genetic material in cells and initiate the development of cancer, although individual PAHs differ in their capacity to damage cells in this way.

The speciated PAH inventory was first compiled for the 1996 emissions inventory (Wenborn *et al*, 1999) and has allowed a more detailed understanding of the PAH emissions in the UK.

There have been several pollutant classifications relating to PAHs. Although there are a vast number of PAHs, the NAEI inventory focuses on sixteen. These 16 PAHs have been designated by the United States Environmental Protection Agency (USEPA) as compounds of interest using a suggested procedure for reporting test measurement results (USEPA, 1988). A subset of this includes six of the PAHs identified by the International Agency for Research on Cancer (IARC) as probable or possible human carcinogens (IARC 1987). In addition, the Borneff 6 PAHs (another subset focussing on the health impacts of the PAHs) have been used in some EC emission inventory compilations. A further subset of PAHs are those to be used as indicators for the purposes of emissions inventories under the UN/ECE's Persistent Organic Pollutants Protocol. These classifications are given in the following table.

Table 5.3 The USEPA 16 PAH Primary Pollutants, and other PAH Subsets.

	Included in the NAEI	**USEPA Priority pollutants (16 PAH)**	**IARC Probable or possible Human carcinogens (6 PAH)**	**Borneff (6 PAH)**	**UN/ECE POPs Protocol Indicators for purpose of emission inventories**
Naphthalene	✓	✓			
Acenapthene	✓	✓			
Acenapthylene	✓	✓			
Fluorene	✓	✓			
Anthracene	✓	✓			
Phenanthrene	✓	✓			
Fluoranthene	✓	✓		✓	
Pyrene	✓	✓			
Benz[a]anthracene	✓	✓	✓		
Chrysene	✓	✓			
Benzo[b]fluoranthene	✓	✓	✓	✓	✓
Benzo[k]fluoranthene	✓	✓	✓	✓	✓
Benzo[a]pyrene	✓	✓	✓	✓	✓
Dibenz[ah]anthracene	✓	✓	✓		
Indeno[1,2,3-cd]pyrene	✓	✓	✓	✓	✓
Benzo[ghi]perylene	✓	✓		✓	

The main environmental impact of PAHs relate to their health effects, focusing on their carcinogenic properties. The most potent carcinogens have been shown to be benzo[a]anthracene, benzo[a]pyrene and dibenz[ah]anthracene (APARG 1996). The semi-volatile property of PAHs makes them highly mobile throughout the environment via deposition and re-volatilisation between air, soil and water bodies. It is possible that a proportion of PAHs released in the UK are deposited in the oceans and/or subject to long-range transport making them a widespread environmental problem.

In 1999 the Expert Panel on Air Quality Standards (EPAQS) published a recommendation for an air quality standard for PAHs. This standard was based on the use of benzo[a]pyrene as an indicator of the overall carcinogenicity of the PAHs present in the atmosphere. In August 2002 PAHs were included in the Air Quality Strategy for England, Scotland, Wales and Northern Ireland (see Section 4.1) through the introduction of an objective relating to concentrations in ambient air.

Emissions of the total amount of the 16 PAHs and benzo[a]pyrene (BaP) are summarised in Tables 5.4a and 5.4b. Whilst BaP emissions are included in the 16 PAHs, it is also considered here individually due to its importance.

Aluminium production and anode baking (carried out for the aluminium industry) was the largest source of PAH emissions in the UK until 1996 (contributing nearly half of the total PAH emission). Emissions since then have declined and in 2004 these sources accounted for only 1% of the total PAH emissions. This is a consequence of the closure of the plant at Kinlochleven and investment in abatement equipment following from the authorisation regime implementing the Environmental Protection Act 1990. One of the anode baking plants has dramatically reduced its emissions and the other is timetabled to follow shortly.

Road transport combustion is currently the largest source of PAH emissions contributing 49% of the emissions in 2004. There have been a number of significant revisions to these emission estimates across the last several years. This is due to the limited availability of data on emission factors- and hence very high uncertainty results. The next largest sources of emissions in 2004 were domestic combustion and other forms of industrial combustion.

Emissions of PAH and BaP from domestic combustion increased between 1997 and 1999 but have since declined. This trend follows the reported consumption of coal in the domestic sector (DTI, 2004).

There are several source sectors relevant to PAHs which have been recently improved. Wood treatment is a source of some of the lighter PAHs such as acenapthene, fluorene and anthracene, and emission estimates from this source have been included. Emissions from bitumen production and use have not been estimated due to a lack of emission data. Bitumen use has also recently been included in the emission estimates. It is a significant source of benzo[a]pyrene and several other PAHs.

The most notable recent changes to the BaP inventory include significantly reduced emissions from some industrial sources and smaller road transport emissions. Further details can be found in Coleman *et al* (2001). Increased measurement of PAHs by both industry and regulators, particularly in the aluminium sector, has allowed improvements in the precision of the emission estimates. The uncertainties associated with the emissions estimates of PAHs are very high, and are considered in Section 5.3.

Table 5.4a UK Emissions of 16 PAHs[1] by aggregated UN/ECE Source Category (tonnes)

	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[2]												
Combustion in Manufacturing Industry	483	349	316	289	279	325	233	341	300	256	304	18%
Residential Combustion	758	465	486	472	479	513	400	445	398	323	357	21%
Road Transport	2327	1870	1738	1590	1441	1313	1189	1080	976	903	848	49%
Gas Mains Leakage	104	84	84	84	83	79	83	74	61	62	58	3%
Metal Production	3492	2308	737	432	122	71	34	38	34	13	12	1%
Paint Application	104	87	83	80	76	73	69	70	71	71	44	3%
Agriculture	933	0	0	0	0	0	0	0	0	0	0	0%
Waste	38	37	36	35	35	35	35	48	35	36	36	2%
Other[3]	111	82	83	84	76	70	66	63	61	64	64	4%
Total	8349	5282	3563	3065	2592	2479	2109	2159	1937	1728	1723	100%

[1] The PAHs selected are listed above in Table 6.3

[2] See Annex 1 for definition of UN/ECE Categories

[3] Including railways, shipping, naval vessels, military aircraft and off-road sources

Emissions of BaP are included in the 16 PAH emissions, but it is an important pollutant, and is therefore also reported in its own right in the following table.

Figure 5.1 Time Series of 16 PAHs Emissions (tonnes)

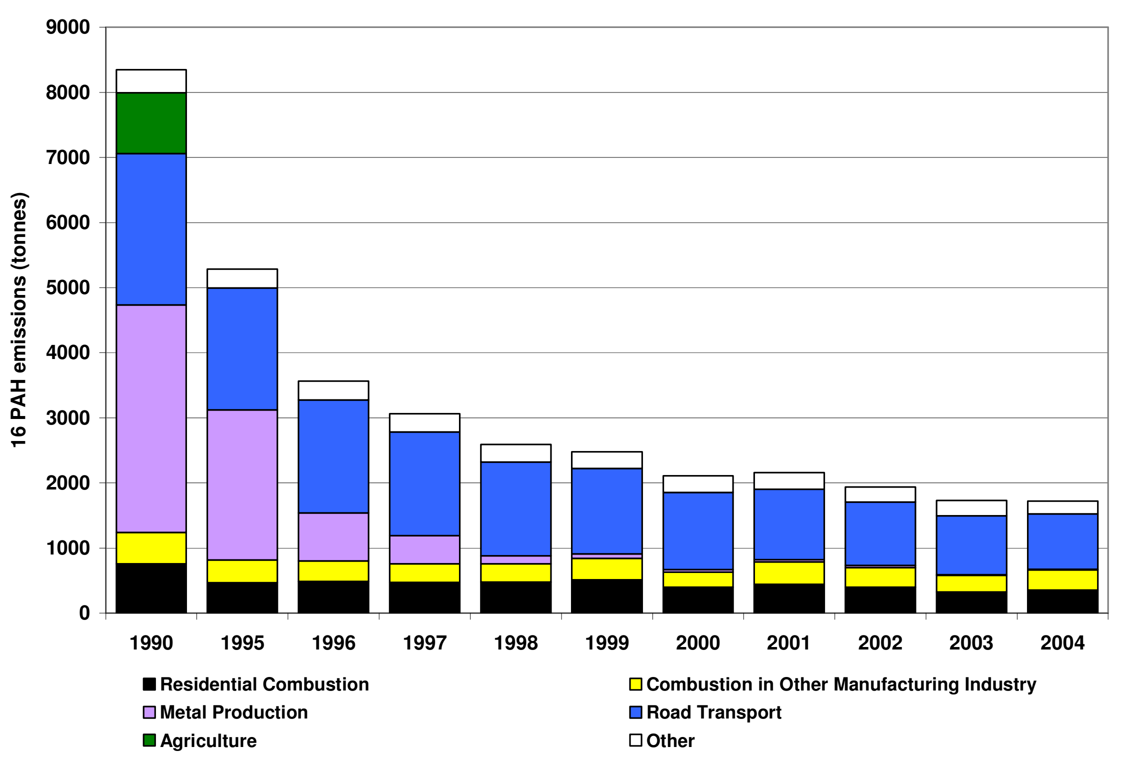


Table 5.4b UK Emissions of BaP[1] by aggregated UN/ECE Source Category (tonnes)

	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[2]												
Combustion in Other Manufacturing Industry	3.9	2.7	2.4	2.1	2.1	2.4	1.6	2.6	2.2	1.8	2.3	31%
Residential Combustion	6.1	3.4	3.6	3.4	3.5	3.8	2.8	3.2	2.8	2.2	2.5	33%
Road Transport	5.4	2.1	1.7	1.4	1.1	0.9	0.7	0.6	0.6	0.5	0.4	6%
Gas Mains Leakage	1.2	1.0	1.0	1.0	1.0	0.9	1.0	0.9	0.7	0.7	0.7	9%
Metal Production	24.7	16.4	5.3	4.0	2.7	1.6	0.8	0.8	0.7	0.3	0.3	4%
Agriculture	28.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Waste	0.9	0.8	0.8	0.8	0.8	0.8	0.8	1.2	0.8	0.8	0.8	11%
Other	1.5	0.8	0.9	0.9	0.7	0.7	0.6	0.6	0.5	0.5	0.4	5%
Total	72.0	27.3	15.6	13.6	11.9	11.2	8.4	9.9	8.4	6.8	7.4	100%

[1] Benzo[a]pyrene

[2] See Annex 1 for definition of UN/ECE Categories

Figure 5.2 Time Series of Benzo[a]Pyrene Emissions (tonnes)

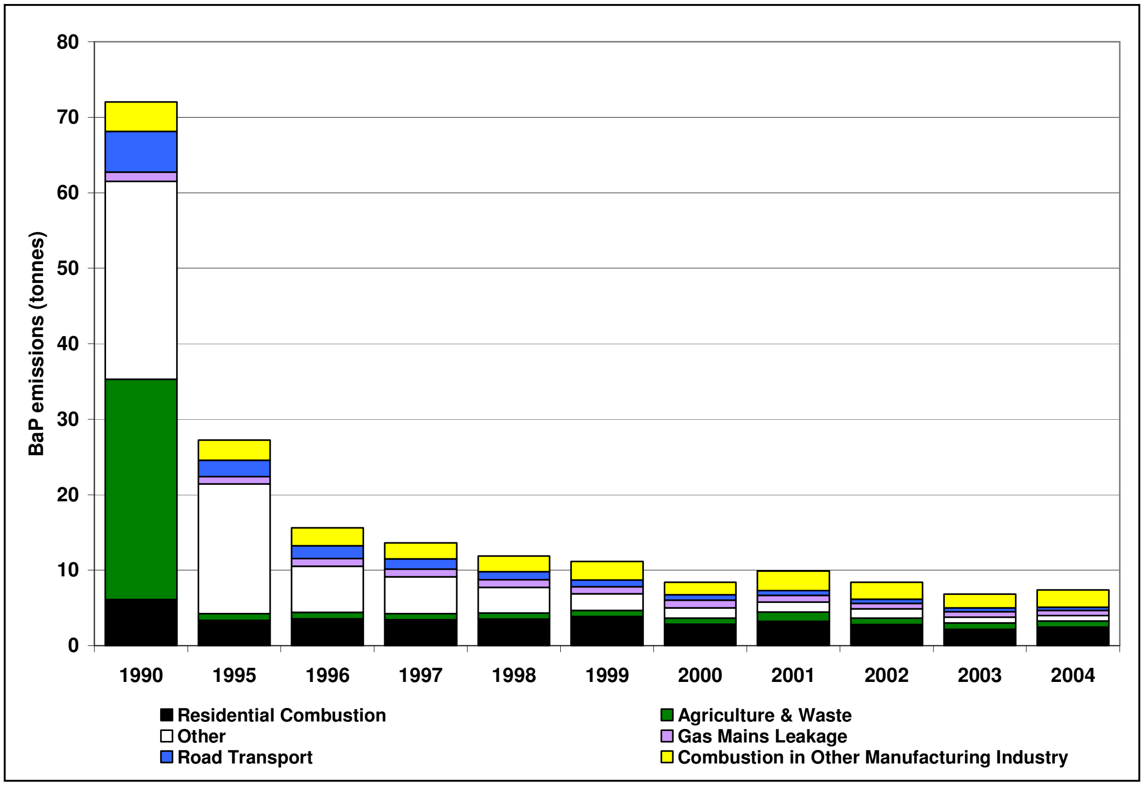
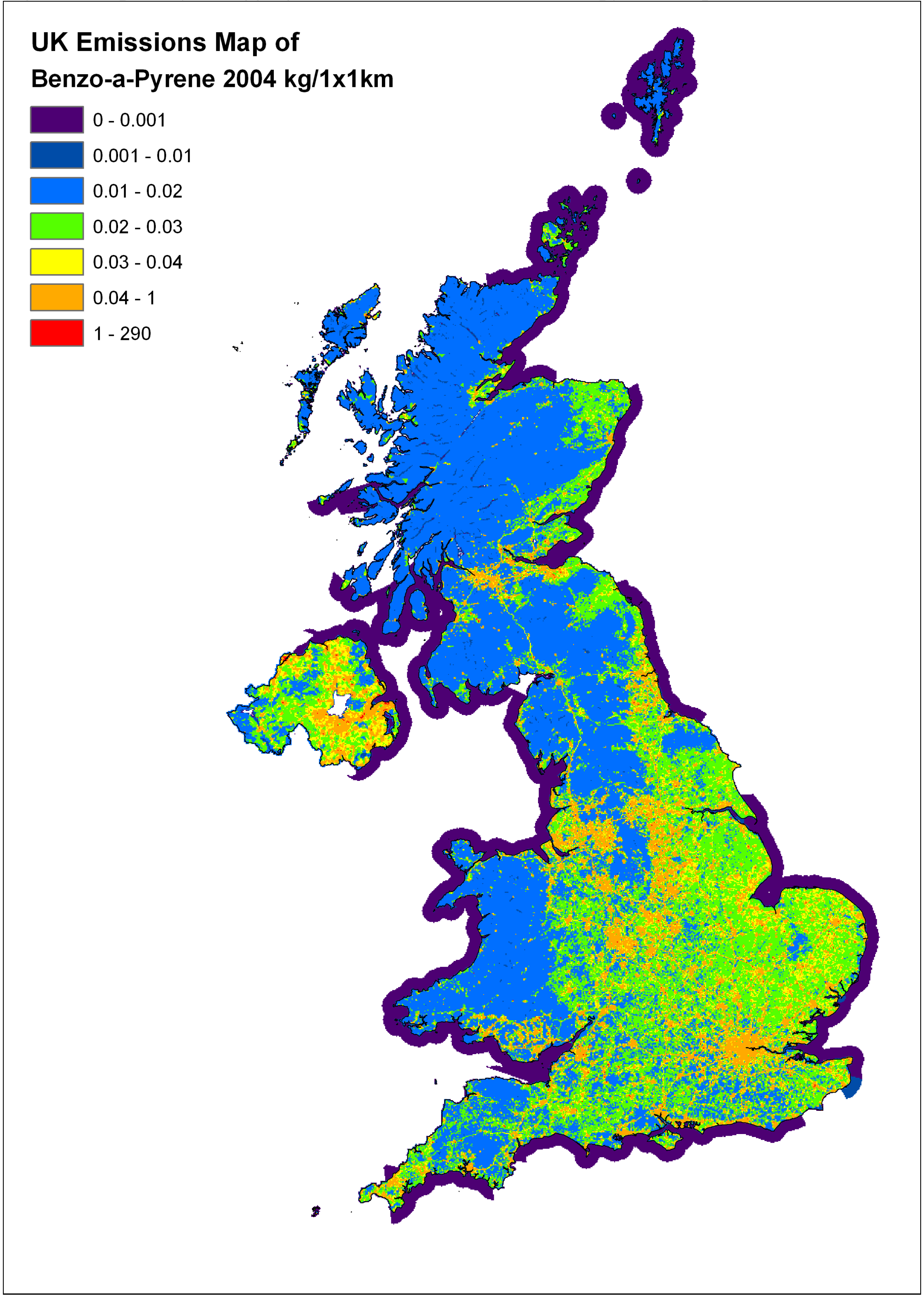


Figure 5.3 Spatially Disaggregated UK Emissions of Benzo[a]pyrene Map[17]



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5.2.1 Dioxins and Furans (PCDD/F)

The term “dioxin” is used to refer to the polychlorinated dibenzo-*p*-dioxins (PCDD) and “furan” is used for polychlorinated dibenzofurans (PCDF). There are 210 PCDD/F compounds in total, which can be described as "congeners"- i.e. different compounds within a family or group having a similar structure. Of these 210 congeners the emissions of importance are those of the 17 PCDD/Fs (7 PCDDs and 10 PCDFs) as defined by the NATO/CCMS (Committee on the Challenges of Modern Society 1988) international toxic equivalent (I-TEQ) scheme. TEQ schemes weight the toxicity of the less toxic congeners as fractions of the toxicity of 2,3,7,8-TCDD, the most toxic congener.

The inventory presented here is in terms of the sum of the weighted emissions expressed as ‘I-TEQs’ which are widely used in UK and European legislation. However, more recently the World Health Organisation (WHO) has suggested a modification to the values used to calculate the toxic equivalents for some of the PCDDs and PCDFs. They have also suggested that there is value in using a similar approach for the PCBs which have dioxin-like toxicity and combining the PCDD/F and PCB TEQs together. The International and the WHO toxic equivalence factors (TEFs) for PCDD/Fs are shown in Table 5.5

Table 5.5 The International and the WHO Toxic Equivalence Factors for PCDD/Fs
(the differences are highlighted)

Dioxins	**International TEFs [1]**	**WHO TEFs [2]**
2,3,7,8 tetraetrachlorodibenzo-p-dioxin	1	1
1,2,3,7,8 pentachlorodibenzo-p-dioxin	**0.5**	**1**
1,2,3,4,7,8 hexachlorodibenzo-p-dioxin	0.1	0.1
1,2,3,6,7,8 hexachlorodibenzo-p-dioxin	0.1	0.1
1,2,3,7,8,9 hexachlorodibenzo-p-dioxin	0.1	0.1
1,2,3,4,6,7,8 heptachlorodibenzo-p-dioxin	0.01	0.01
Octachlorodibenzo-p-dioxin	**0.001**	**0.0001**
Furans		
2,3,7,8 tetra4chlorodibenzofuran	0.1	0.1
1,2,3,7,8 pentachlorodibenzofuran	0.05	0.05
2,3,4,7,8 pentachlorodibenzofuran	0.5	0.5
1,2,3,4,7,8 hexachlorodibenzofuran	0.1	0.1
1,2,3,6,7,8 hexachlorodibenzofuran	0.1	0.1
1,2,3,7,8,9 hexachlorodibenzofuran	0.1	0.1
2,3,4,6,7,8 hexachlorodibenzofuran	0.1	0.1
1,2,3,4,6,7,8 heptachlorodibenzofuran	0.01	0.01
1,2,3,4,7,8,9 heptachlorodibenzofuran	0.01	0.01
Octachlorodibenzofuran	**0.001**	**0.0001**

[1] NATO/CCMS (1988) WHO (1998)

PCDD/Fs have been shown to possess a number of toxicological properties. The major concern is centred on their possible role in immunological and reproductive effects. The main sources of PCDD/Fs are thermal processes, but they can also be released to the environment from some chemical processes.

PCDD/Fs can arise from any thermal process where chlorine is present. For example, coal and other solid fuels contain trace amounts of chlorine compounds which can under certain combustion conditions result in PCDD/F formation. In addition PCDD/Fs can be present in the feedstock material, or chlorinated impurities may be introduced into the feedstock of some thermal processes. The amount of chlorine required for PCDD/F formation may be small and consequently many processes have the potential to emit these pollutants. PCDD/Fs can also be emitted from the chemical production and use of polychlorinated aromatic pesticides and herbicides, many of which are now controlled. However, some chlorinated organic chemicals such as the wood preservative pentachlorophenol are still present in the UK in reservoirs such a treated wood which have the potential on disposal to be sources of PCDD/Fs e.g. from the combustion of the treated wood.

Estimated PCDD/F emissions for 1990-2004 are summarised in Table 5.6 below.

Table 5.6 UK emissions of PCDD/Fs by aggregated UN/ECE Source Category (grams I-TEQ/year)

	1990	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2004%**
BY UN/ECE CATEGORY[1]												
Industry												
Public Power	148.8	195.6	65.0	60.4	35.5	27.0	27.7	29.0	29.1	14.4	12.4	4%
Iron & Steel and Non-Ferrous Metals	84.0	83.9	85.7	86.5	66.1	57.6	41.7	43.6	35.5	37.8	35.8	13%
Other industrial Combustion	89.6	82.3	80.8	78.2	75.5	72.4	65.7	70.9	61.2	61.5	89.0	31%
Solvent and Metals Products	29.0	27.6	26.1	27.1	24.3	21.1	14.2	13.8	15.2	12.9	12.3	4%
Combustion in Comm/Res	106.9	50.6	33.2	33.3	25.0	25.4	21.3	21.7	15.7	11.6	8.0	3%
Transport												
Road Transport	29.7	13.5	11.1	9.1	7.0	5.0	3.2	3.1	3.0	2.8	2.7	1%
Off-road Vehicles and Other Machinery[2]	9.8	10.3	10.3	10.4	10.3	10.2	10.0	10.0	10.0	10.0	10.9	4%
Agriculture	57.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Waste Incineration	687.9	332.9	224.1	147.7	116.0	115.3	115.1	115.6	115.1	115.4	113.5	40%
Total	1243	797	536	453	360	334	299	308	285	266	285	100%

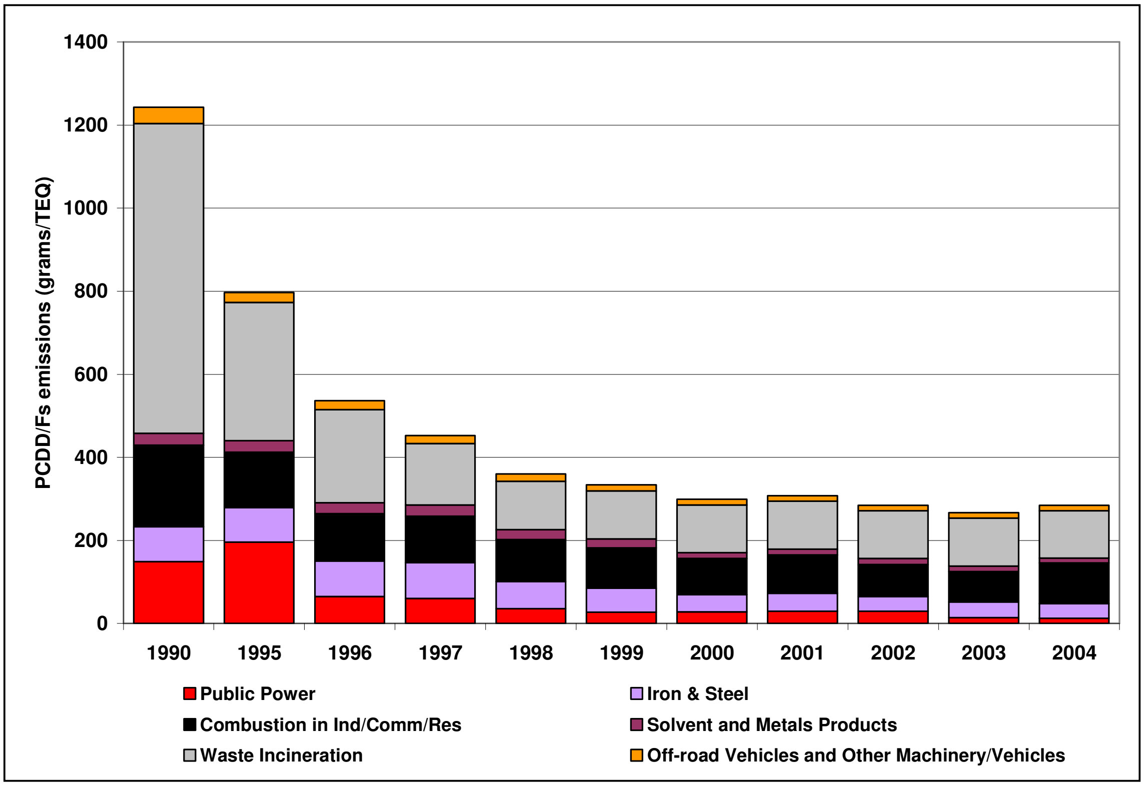
[1] See Annex 1 for definition of UN/ECE Categories

[2] Including railways, shipping, naval vessels, military aircraft and off-road sources

The largest sources of PCDD/F emission has been, and still is, waste incineration. However emissions from waste incineration have fallen by 80% between 1993 and 2004. This significant trend has been driven by the introduction of control measures. Municipal Solid Waste (MSW) incinerators not meeting the new standards closed in the period leading up to December 1996. Improved combustion and flue gas controls, and developments in abatement technology in modern MSW incinerator design, has resulted in significantly lower levels of PCDD/F emissions.

The relatively low emissions from chemical incinerators reflects the use of rotary kilns and the incorporation of a secondary combustion chamber in the process to destroy organic contaminants together with the relatively low waste throughput and advanced pollution abatement equipment. However, clinical waste incineration remains a significant source. This is due to the fact that emissions from clinical waste incinerators (although showing significant reductions) have not been reducing as rapidly as the total PCDD/F total.

Figure 5.4 Time Series of PCDD/Fs Emissions (grams I-TEQ)



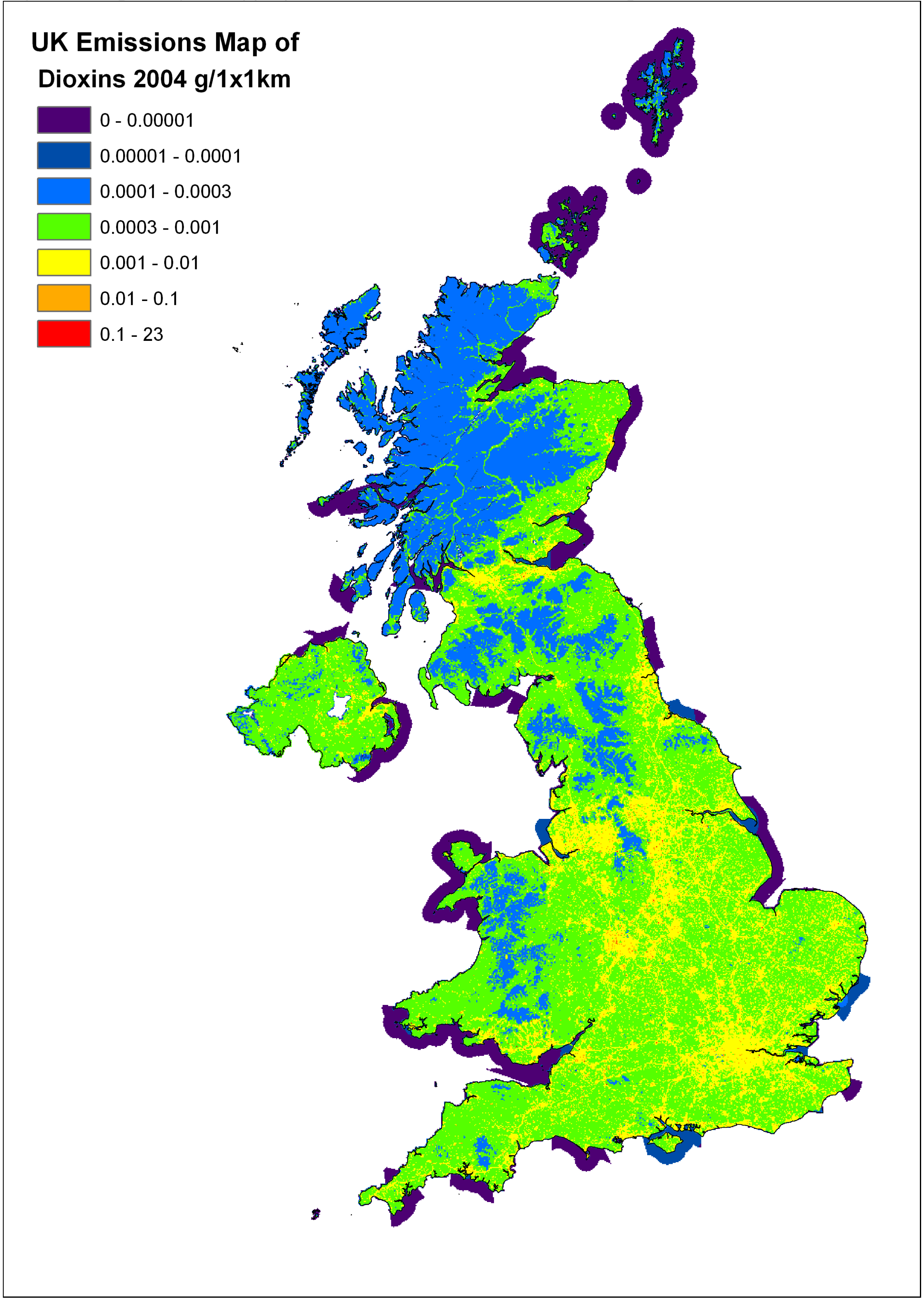
Emissions from power stations are fairly low because the combustion is efficient and the post-combustion fly ash temperatures are rapidly reduced. The emission factors associated with industrial and domestic coal combustion are significantly higher and sum to give a similar contribution, even though the coal consumption is much smaller. However, emissions from all three sectors have decreased with the reduction in the quantity of coal burned.

Emissions from open agricultural burning and accidental fires are included in the agricultural and nature sectors. The former has declined to near zero since the cessation of stubble burning. Accidental fires are currently treated as a source of constant magnitude, and consequently, the percentage contribution from this sector to the total PCDD/F emission has risen as emissions from other significant sectors have decreased.

There are significant emissions from sinter plants owing more to the large gas volumes emitted than to high concentrations. Emissions from iron and steel plants are probably underestimated since only electric arc furnaces are considered. Scrap used in electric arc furnaces and secondary non-ferrous metal production will contain chlorinated impurities such as plastics and cutting oil which contribute to PCDD/F formation.

It is generally accepted that the source of PCDD/F emissions from road transport are the 1,2-dichloroethane scavengers added to leaded petrol. Over recent years both the consumption of leaded petrol, and the lead content of leaded petrol has decreased. Consequently the emissions of PCDD/F from this sector are thought to have decreased. Unleaded petrol and diesel is likely to contain only trace quantities of chlorinated impurities. For 2004, the contribution to the PCDD/F emission total from road transport fuel was 1%.

Figure 5.5 Spatially Disaggregated UK Emissions of PCDD/F Map[18]



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5.2.2 Polychlorinated biphenyls (PCBs)

PCBs are synthetic organic compounds that have mainly been used in electrical equipment as dielectric insulating media.

PCBs have been linked with effects such as reduced male fertility and long-term behavioural and learning impairment. They are classified as probably carcinogenic to humans. Certain PCBs have been assessed as having dioxin-like effects. PCBs are extremely persistent in the environment and possess the ability to concentrate up the food chain. These compounds are highly insoluble in water but accumulate in body fat. Present human exposure is probably dominated by the accumulation through the food chain of the PCBs present in environmental reservoirs such as soils and sediments as a result of previous releases to the environment.

PCBs have not been manufactured and used in the UK for many years, but old equipment containing dielectric fluids (which in turn contain PCBs) still exist. The emissions to air are from equipment still in use leaking, or from destruction of such equipment by using fragmentisers. It is estimated that in 2004, 68% of primary PCB emissions to the atmosphere are associated with such appliances- primarily capacitors and transformers. These emissions primarily arise from in-service appliances; however emissions during disposal are also considered to be significant. Large quantities of PCBs are thought to have been disposed of to landfill in the past, mainly in the form of electrical components or fragmentiser residues, but now such equipment containing PCBs are disposed of by chemical incineration. This process ensures significant reduction in the amount of PCBs being released into the environment. PCBs are also emitted from the soil having previously been deposited there from the air.

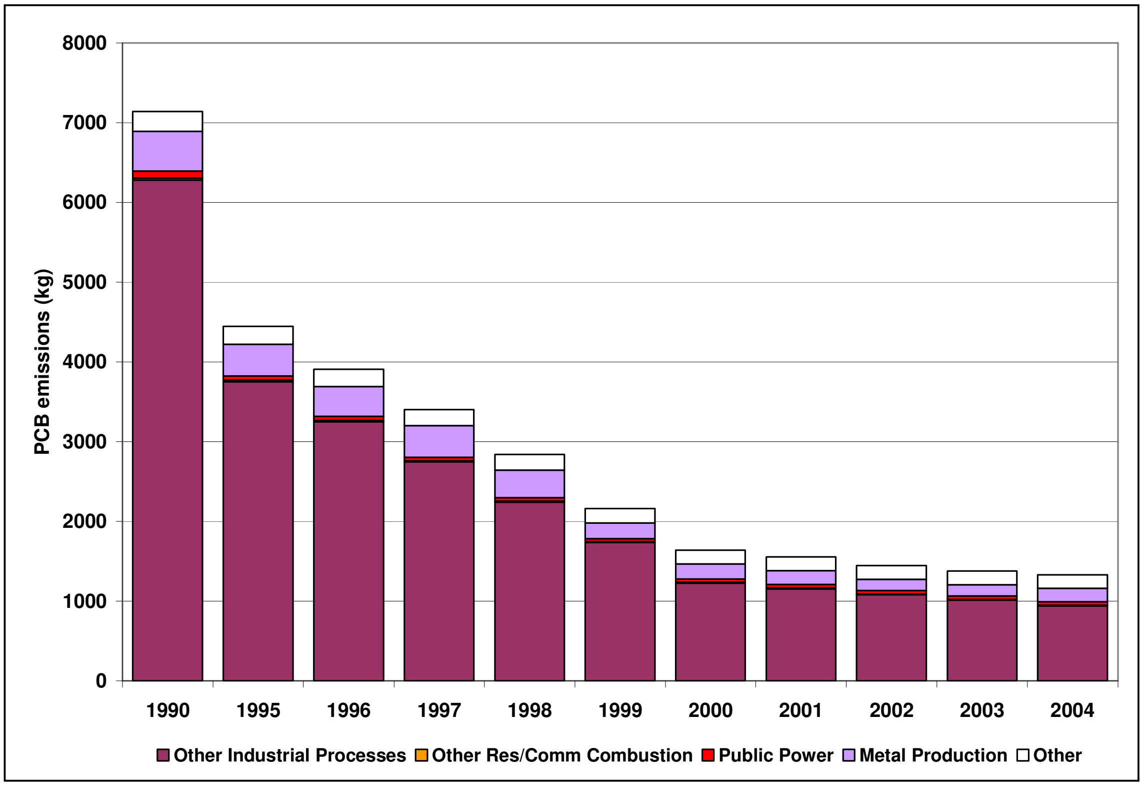
PCB speciation has been incorporated into the emission estimates since the 1998 inventory report. A summary of the total PCB emission estimates for 1990 to 2004 is given below in Table 5.7

Table 5.7 – UK Emissions of PCB Emissions by aggregated UN/ECE Source Category (kg)

	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[1]												
Public Power	91	56	51	43	45	38	42	46	43	47	45	3%
Other Industrial Processes	24	16	16	14	13	14	11	13	11	8	8	71%
Other Res/Comm Combustion	6278	3753	3248	2745	2239	1733	1224	1153	1078	1012	942	1%
Metal Production	496	395	375	398	347	193	188	170	141	141	167	13%
Other	248	227	217	203	193	184	175	173	172	171	169	13%
Total	7138	4447	3908	3403	2837	2161	1640	1554	1444	1378	1331	100%

[1] See Annex 1 for definition of UN/ECE Categories

Figure 5.6 Time Series of PCBs Emissions (kg)



Sales of PCBs in the UK were stopped in 1986. It is thought that they are still manufactured in some countries. The total PCB emission in 1990 was dominated by leaks from capacitors (87% of total emission), and this is the case for 2004.

In 1997 an Action Plan was published by DETR (now Defra) which laid out the commitments made by the UK at the Third International North Sea Conference at the Hague in 1991 in accordance with the requirements of Directive 96/59/EC. These regulations require all PCB holders in the UK to report their stocks to the relevant regulatory bodies. These stocks (except for certain exemptions) were destroyed before the end of December 2000. However, not all electrical equipment containing PCBs is readily identifiable. Emissions from electrical equipment will probably continue, and will only start to fall significantly as the relevant electrical equipment is either destroyed or reaches the end of its working life.

PCBs can be formed in trace amounts from chlorinated precursors in thermal processes such as scrap metal recycling. As a result, there are significant emissions from the iron and steel industrial sector, as with PCDD/Fs.

PCBs occur in sewage sludge due to their persistent nature, and may occur in significant quantities. Not all the PCBs spread on land will volatilise but the potential for emissions to air is greater than that of landfill. The emission estimate comprises only 1% of the total and is highly uncertain. Emissions arise from waste incineration and refuse-derived fuel production resulting from the PCB content of the waste.

5.2.3 Pesticide Emissions

Although there is little available information to enable accurate estimates of pesticide emissions to air, the emission estimates presented here follow from significant improvements to the earlier emission estimates first made in 1996.

Despite these improvements, the confidence in the accuracy of these estimates is low. Relevant data is currently scarce with the majority of emission factors coming from the USA or Europe. The emission factors used here have been derived for a particular method of pesticide application (during specific atmospheric conditions), which may not be representative of the situation in the UK. Until further data become available it is difficult to reduce the uncertainty associated with these estimates. At present no relevant measurement programmes are known of, and therefore the possibility of acquiring additional data is considered to be poor.

Pesticide emissions to the air occur predominately through three pathways: during manufacture, during application and volatilisation after application. Tables 5.8, 56.9 and 5.10 show the estimated emissions of lindane (γ-HCH), pentachlorophenol (PCP) and hexachlorobenzene (HCB) respectively.

5.2.3.1 Lindane (γ-HCH)

Acute (short-term) effects caused by the inhalation of lindane consist of irritation of the nose and throat, as well as effects on the blood. Chronic (long-term) effects through inhalation have been associated with effects on the liver, blood, immune and cardiovascular systems.

Lindane is applied as an insecticide, fungicide and used as a wood preservation treatment. Lindane is used in the agriculture, domestic and veterinary sectors. Until 1990 lindane was also used as a remedial wood treatment i.e. in a curative role rather than a preservative/preventative. However, data on quantities used for a remedial wood treatment prior to 1990 are not available.

HCH exists in several isomers, however as a result of regulation in the UK, γ-HCH accounts for more than 99% of the total HCH use. Consequently only the γ isomer has been considered in any detail here. The emission estimates presented in Table 6.8a were made assuming that emissions arise from: the application of γ-HCH, treated wood and agricultural and domestic use. γ-HCH emissions are dominated by emissions from treated wood, contributing 98% to the 2004 total emission. Emissions from wood preserving have fallen since 1990.

Emissions from agricultural pesticide activities account for around 2% of total 2004 γ-HCH emissions. These emissions are based on statistics on the use of pesticides containing lindane, obtained from the Pesticide Usage Survey Group (MAFF, 1991a,b, c; 1992a,b, c, d). The emission factors used are taken from van der Most *et al* (1989).

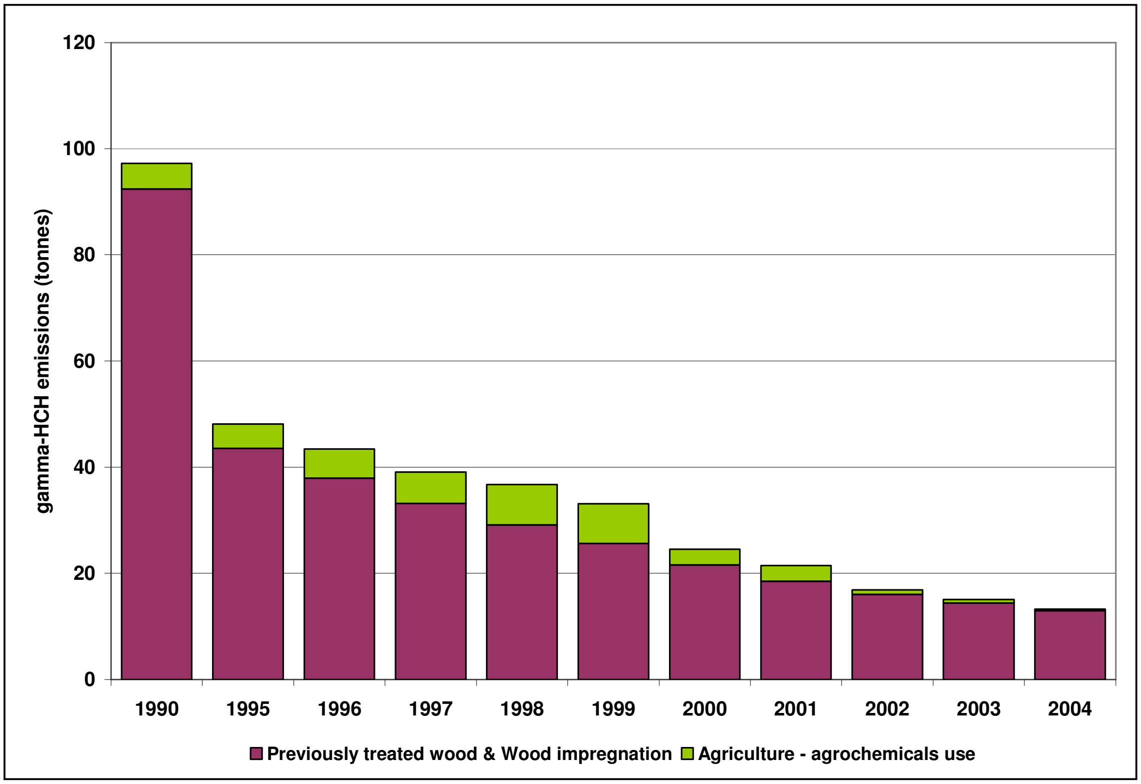
Emissions of γ-HCH arising from domestic applications are thought to be comparatively small. However, usage statistics are scarce and were only available for 1988 (DOE, 1989). Emission factors are taken from van der Most *et al* (1989).

Table 5.8a – UK Emissions of γ-HCH by aggregated UN/ECE Source Category (tonnes).

	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[1]												
Solvent use - treated wood & wood impregnation	92.4	43.5	37.9	33.2	29.1	25.6	21.6	18.5	16.0	14.4	13.0	98%
Agriculture - agrochemicals use	4.8	4.6	5.4	5.9	7.6	7.5	3.0	2.9	0.8	0.6	0.3	2%
Total	97.3	48.1	43.4	39.1	36.8	33.1	24.6	21.4	16.9	15.1	13.2	100%

[1] See Annex 1 for definition of UN/ECE Categories

Figure 5.7 Times Series of γ-HCH Emissions (tonnes)



For completeness, the total emissions of HCH are also included here (see Table 5.8b below), although the differences are obscured due to rounding. These total HCH emissions estimates assume the worst case scenario of 1% contribution from non γ isomers to the HCH total.

Table 5.8b – UK Emissions of Total HCH by aggregated UN/ECE Source Category (tonnes)

	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[1]												
Solvent use - treated wood & wood impregnation	93.3	43.9	38.3	33.5	29.4	25.9	21.8	18.7	16.2	14.5	13.1	98%
Agriculture – agrochem use	4.8	4.6	5.5	6.0	7.7	7.6	3.0	2.9	0.8	0.6	0.3	2%
Total	98.3	48.6	43.8	39.5	37.2	33.4	24.8	21.6	17.1	15.3	13.3	100%

[1] See Annex 1 for definition of UN/ECE Categories

5.2.3.2 Pentachlorophenol (PCP)

Pentachlorophenol is associated with both acute and chronic effects on humans through inhalation. Acute effects can lead to eye irritation as well as liver, blood and neurological effects. Chronic exposure can result in effects on the respiratory tract, immune system, liver, kidneys, blood as well as the eyes and nose.

Pentachlorophenol is used as a biocide, and is effective in destroying insect eggs. It is used in the timber and textile industries. The emission estimates given here also include emissions from the use of sodium pentachlorophenoxide (NaPCP) and pentachlorophenyl laureate (PCPL) as well as PCP since these were also included in the proprietary formulations.

The estimated PCP emissions for 1990 to 2004 are given in Table 5.9. The largest percentage contribution to the total PCP emission arises from wood that has been treated within the last 16 years. This accounts for some 99.9% of the 2004 total PCP emission.

Once again it is very difficult to be certain of these estimates due to the lack of research into emission rates and limited knowledge of quantities used both in the year of the estimate and in previous years. An emission factor of 3% of the wood content per year has been used.

PCP emissions from the textile industry primarily arise from volatilisation during application as a cotton preservative. Emission factors used were based on a study of PCP emissions in the UK (Wild, 1992) reporting that approximately 30% of the applied PCP is lost through volatilisation. Emissions from this sector are comparatively small.

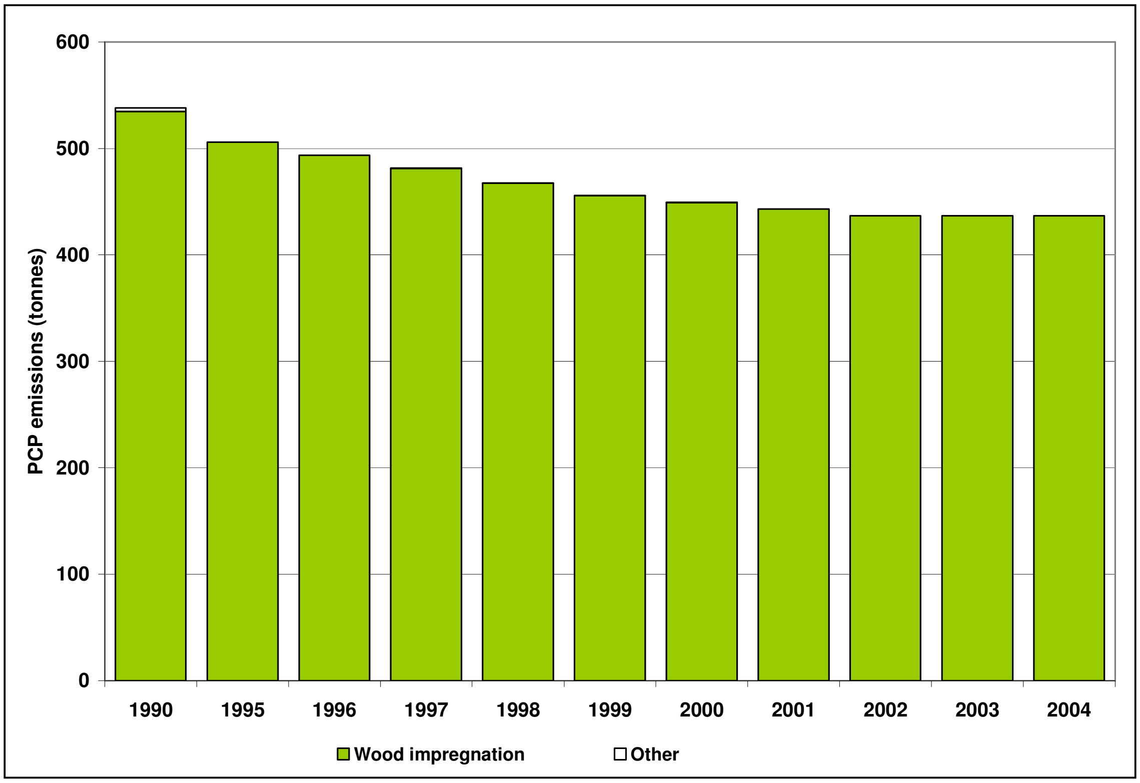
PCP has been used in the agricultural sector as the active ingredient in disinfecting wooden trays used in mushroom farming (classified as solvent use). Usage statistics are reliable coming from the Pesticide Usage Survey Group (MAFF, 1991a,b,c; 1992a,b,c,d). The emission factor assumes 30% loss due to volatilisation (Wild, 1992). Emissions from this sector are comparatively small.

Table 5.9 – UK Emissions of PCP by aggregated UN/ECE[1] Source Category (tonnes)

	1990	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2004%**
Other	3.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0%
Wood impregnation	534.7	505.9	493.4	481.2	467.3	455.6	449.1	442.8	436.7	436.7	436.7	100%
Total	**538.0**	**505.9**	**493.5**	**481.3**	**467.4**	**455.7**	**449.2**	**442.9**	**436.8**	**436.8**	**436.8**	**100%**

[1] See Annex 1 for definition of UN/ECE Categories

Figure 5.8 Times Series of PCP Emissions (tonnes)



The emission inventory for PCP is very uncertain as only limited emission factors are available on the release of PCP during agricultural activities and statistics are not actively collected on the extent of its usage. There is some data on release of PCP from combustion processes, but the available studies are not consistent with each other suggesting that the uncertainty may be considerable. Without new data becoming available, significant improvements are not expected in the near future.

5.2.3.3 Hexachlorobenzene (HCB)

Very little information is available on the health effects of HCB via inhalation. However, the lungs may be affected by repeated or prolonged exposure. It is also considered to be a possible carcinogen if long term exposure occurs.

Studies in the USA have identified two main industrial sources of HCB (Mumma *et al*, 1975) (Jacoff *et al*, 1986). These are the manufacture of chlorinated solvents (e.g. trichloroethylene, tetrachloroethylene and carbon tetrachloride) and the manufacture of specific pesticides where HCB remains as an impurity. HCB emissions may also arise from combustion sources, but other than waste incineration these could not be estimated, although they are believed to be small.

Statistics for chlorinated solvent production in the UK are commercially confidential, hence estimates were made based on UK solvent usage data from the Solvent Industries Association and import and export statistics.

Although there is no UK manufacture of pesticides that results in the production of HCB, pesticides with HCB as an impurity are still imported and used in the UK for agricultural pest control. Statistics for the use of these pesticides is provided by the Pesticide Usage Survey Group (MAFF, 1991a,b, c; 1992a,b, c, d). The use of chlorothalonil increased significantly in 2004 and this is reflected in the emission estimates (see table 5.10).

HCB emissions in secondary aluminium smelting result from the use of hexachloroethane (HCE) tablets as a degassing agent (van der Most *et al*, 1992). Regulations now control the use of HCE and so since 1999, very little secondary aluminium is now melted using HCE. Data on the quantity of degassing agent supplied and the quantity of HCE used per tonne of aluminium melted were obtained from industrial experts and van der Most *et al* (1989).

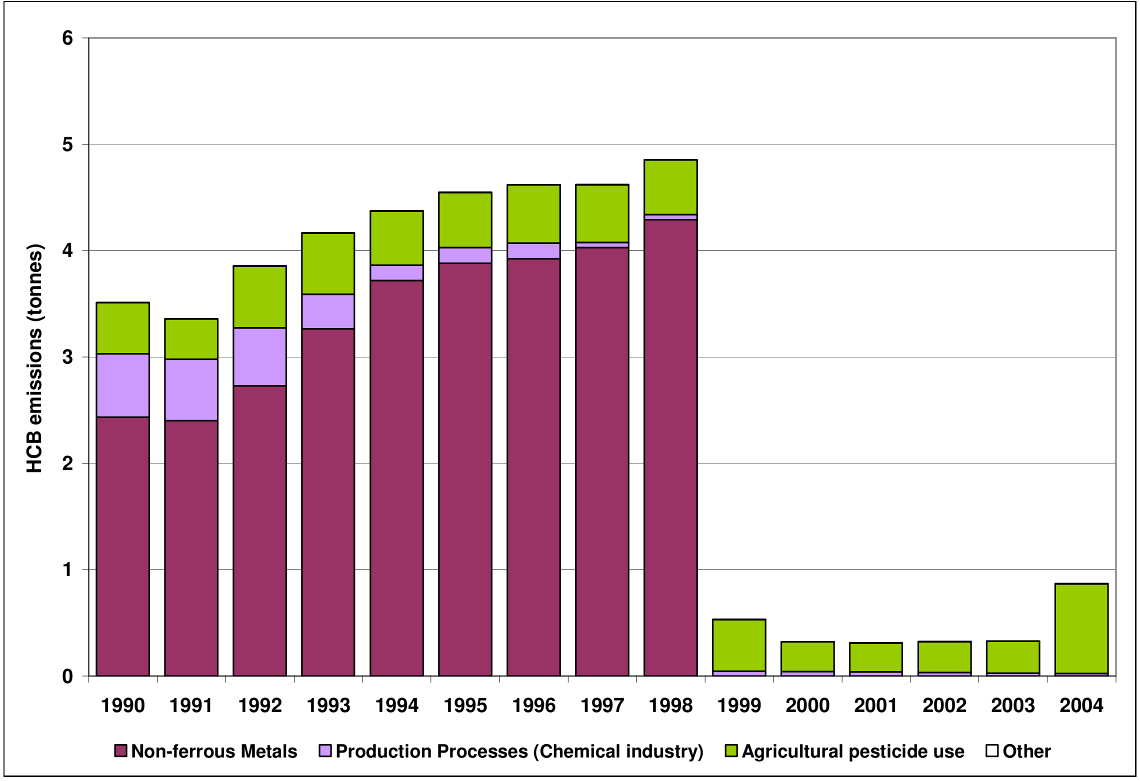
Emissions from pesticide application and chlorinated solvent production now account for virtually all of the UK HCB emissions (Table 5.10). For 2004, these two sources are estimated to account for 97% and 3%, respectively, of the total HCB emissions. This represents a change in the relative contributions to the total for 1990 where the same sectors contributed 14% and 17% respectively. This change is a direct result of the reduced emissions from the production of chlorinated solvents, but only very small changes are noted between more recent years.

Table 5.10 – UK Emissions of HCB by aggregated UN/ECE[1] Source Category (kg)

	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY												
Other	2	2	2	1	2	2	2	2	2	2	2	0%
Non-ferrous Metals	2435	3881	3925	4029	4292	0	0	0	0	0	0	0%
Production Processes (Chemical industry)	596	149	147	50	48	46	43	39	34	28	25	3%
Agricultural pesticide use	481	518	547	542	515	486	280	273	291	299	843	97%
Total	**3514**	**4549**	**4621**	**4622**	**4856**	**534**	**325**	**314**	**327**	**330**	**870**	**100%**

[1] See Annex 1 for definition of UN/ECE Categories

Figure 5.9 Time Series of HCB Emissions (tonnes)



5.2.4 Short Chain Chlorinated Paraffins (SCCP)

5.2.4.1 Introduction

Short chain chlorinated paraffins (SCCPs) are a range of commercially available chlorinated paraffins with 10-13 carbon atoms. The commercial products are usually mixtures of different carbon chain paraffins with a range of different degrees of chlorination. SCCPs are considered persistent organic pollutants- they do not occur naturally and due to their bioaccumulative and toxicological properties they are of concern to the environment.

5.2.4.2 Production and Emissions to Air

SCCPs are currently manufactured in the EU and are marketed under a variety of trade names with an average chlorine content of 40-74%. Current consumption in the UK is estimated to be approximately 1000 tonnes per year.

The main uses of SCCPs are in metal working fluids. It has been reported that there are negligible emissions to air of SCCP from production sources, and releases from the majority of industrial consumption results in emissions primarily to water (with very low emissions to air). Emissions from waste water to the atmosphere are unlikely to be large due to the physical properties of SCCPs.

5.2.4.3 Emission Estimates

Emission estimates have been revised since last years NAEI Report (Goodwin et al, 2003), but this had had little impact on the resulting emission estimates. Current estimates are based on information provided in the European Union Risk Assessment Report (1999) and other data. Emissions of SCCPs have declined considerably since 1990 due to the decrease in consumption caused by a general switch to alternatives.

Table 5.11 UK Emissions of SCCPs (tonnes)

	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
TOTAL	**47**	**24**	**18**	**13**	**8**	**6**	**3**	**0.2**	**1**	**1**	**1**

5.2.5 Polychlorinated Napthalenes (PCN)

5.2.5.1 Introduction

Polychlorinated Napthalenes (PCNs) are a group of 75 theoretically possible chlorinated naphthalenes containing between one and eight chlorine atoms. Their chemical structure is similar to that of PCBs. PCNs are widely considered be associated with cancer and chronic liver disease.

PCNs have been used in a variety of industries. The most important uses are cable insulation, wood preservation, engine oil additives, electroplating masking compounds, feedstock for dye production, dye carriers, capacitors and refractive testing oils.

PCNs have been produced in a number of countries including the UK, USA and France, their synonyms and trade names include Halowax, Nibren waxes, Seekay Waxes, Cerifal Materials and N-Oil. The majority of production generates a standard mixture of the different PCN congeners.

5.2.5.2 Production and Consumption

A number of assumptions give an estimate of the world-wide PCN production as 150,000 tonnes. Similar assumptions can be made to estimate the UK production as 6,650 tonnes.

5.2.5.3 Emission Estimates

There is very little information concerning the production of PCNs for commercial purposes. Commercially produced PCNs are thought to be the most important source of PCNs in the atmosphere with the other source sectors being thermal sources, other industrial processes and contamination in PCB industrially produced mixtures.

PCNs have not been produced in the UK for over 30 years and therefore the major releases that were present during their extensive use have decreased. The potential sources are expected to be dominated by the disposal routes of capacitors and engine oil (this is where the majority of the PCNs produced are thought to have been used). Another potential source of PCNs may be the incineration industry, PCNs have been found in fly ash and flue gas in waste incinerators. Landfills are also expected to be a source of PCN emissions.

PCNs have been found in emissions from incinerators and are thought to be produced from the combustion of PAHs. Therefore PCNs could in theory be produced from other high temperature combustion processes. A full review of emission measurements from such processes would be required prior to ascertaining the scale of the emissions of PCNs from such a potentially large array of sources.

As the information regarding the emission of PCNs in the UK is relatively sparse, it is not currently realistic to quote an emission estimate for PCNs. It is hoped that data will become available to resolve this in the future. However, at this time, no programmes are known of which would provide the data required to help with the generation of PCN emissions.

5.2.6 Polybrominated Diphenyl Ethers (PBDEs)

5.2.6.1 Introduction

There are 209 possible congeners of polybrominated diphenyl ethers (PBDEs). Concern about potential risks to human health and the environment has centred on the potential toxicity, persistence and the tendency for bioaccumulation of some brominated diphenyls.

Since the 1960s, PBDEs have been added as flame-retardants. They are used in a variety of materials (Strandman et al. 2000), including thermoplastics (e.g. high-impact polystyrene) that are used in electrical equipment, computer circuit boards, casings, upholstery, furnishings; interiors in cars, buses, trucks and aeroplanes, rugs, drapery and building materials.

5.2.6.2 Production and Releases to Air

The annual EU production of polybrominated diphenyl ethers has been estimated to be 11,000 tonnes per year. It has been reported (EU 2000) that the UK used up to 2,000 tonnes of polybrominated biphenyl in 1994. Production of the three commercial mixtures (penta-, octa- and deca-dibrominated diphenyl) has virtually ceased in the EU.

The possible routes of release of PBDEs vary from production to the disposal of the materials for which they are used. There is limited information concerning the releases and it is difficult to attempt to estimate an emission inventory without any measurements of releases from sources or potential sources. Attempts have been made to gather UK usage information. However, information is not easily accessible, particularly as PBDEs are a material used in such a wide variety of industries.

5.2.6.3 Emission Estimate

It has not been possible to obtain UK specific emission data for PBDEs, but an estimate of the UK emission of PBDEs has been made using the total EU estimate. This is done by scaling with population. Without further assessment of the potential emissions from materials such as plastic and upholstery during production use and disposal it is not possible to make a more accurate estimate. The resulting UK emission estimate for PBDE's is 7.3 tonnes (Penta-BDE: 2.2t, Octa-BDE: 0.4t, Deca-BDE: 4.7t) per year.

There are a number of improvements that can be made to the UK emission estimate. Resources will be focussed on the following aspects of production and use of secondary products that contain PBDEs.

- Emission from manufacturing sites
- Releases from materials during use
- Release from materials during and following disposal

5.3 ACCURACY OF EMISSION ESTIMATES OF POPS

Quantitative estimates of the uncertainties in emission inventories have been based on calculations made using a direct simulation technique, which corresponds to the IPCC Tier 2 approach recommended for greenhouse gases and also the methodology proposed in draft guidance produced by the UN/ECE Taskforce on Emission Inventories and Projections. This work is described in detail by Passant (2002b). The uncertainty estimates are shown below in Table 5.12.

Table 5.12 Uncertainty of the Emission Inventories for persistent organic pollutants

Pollutant	**Estimated Uncertainty %**
Benzo[a]pyrene	-70 to +200
Dioxins and furans	-50 to +100
Polychlorinated biphenyls	-40 to + 70
Pentachlorophenol	-80 to +200
Hexachlorohexane	-80 to +300
Hexachlorobenzene	-70 to +200
Short-chain chlorinated paraffins	-90 to +1000
Pentabromodiphenyl ether	-90 to +1000
Polychlorinated naphthalenes	not estimated

Inventories for persistent organic pollutants are more uncertain than those for gaseous pollutants, PM_{10}, and metals. This is largely due to the paucity of emission factor measurements on which to base emission estimates, coupled with a lack of good activity data for some important sources. The inventories for polychlorinated biphenyls and short chain chlorinated paraffins are less uncertain than those for other persistent organic pollutants due to the fact that these pollutants are released to air during their use as products and that reasonably robust data are available on the levels of usage. The uncertainty in emission estimates for polychlorinated naphthalenes has not been estimated since no emission estimates are made.

6 Heavy Metal Emission Estimates

6.1 INTRODUCTION

This section includes pollutants singled out for control under recent international protocols of the UN/ECE under the Convention on Long-range Transboundary Air Pollution- Heavy Metals (HMs).

UN/ECE Heavy Metals Protocol

The Convention on Long-range Transboundary Air Pollution was signed in 1979 and entered into force in 1983. Since its entry into force the Convention has been extended by a number of protocols, including the 1998 Protocol on Heavy Metals. This Protocol is given in outline below; more information may be found at the UN/ECE web site, located at:- http://www.unece.org/env/lrtap/. The UK has signed this protocol.

The UN/ECE Protocol on Heavy Metals targets three particularly harmful substances: lead, cadmium and mercury. Countries are obliged to reduce their emissions of these three metals below their levels in 1990 (or an alternative year between 1985 and 1995). The protocol aims to cut emissions from industrial sources (iron and steel industry, non-ferrous metal industry), combustion processes (power generation, road transport) and waste incineration.

The protocol specifies limit values for emissions from stationary sources and requires BAT for obtaining emission reductions from these sources, such as special filters or scrubbers for combustion sources or mercury-free processes. The protocol also requires countries to phase out leaded petrol.

Under the protocol, measures are introduced to lower heavy metal emissions from other products e.g. mercury in batteries, and examples are given of management measures for other mercury-containing products, such as electrical components (thermostats, switches), measuring devices (thermometers, manometers, barometers), fluorescent lamps, dental amalgam, pesticides and paint.

Further metals may be added to the protocol, and further measures may be introduced for lead, cadmium and mercury, depending on the development of the scientific basis for action.

The best known effects of heavy metals are those on humans and animals. Of these, the most important effects are deterioration of the immune system, the metabolic system and the nervous system. They lead to disturbances in behaviour and some heavy metals are suspected to be or have been proven to be carcinogenic.

The impact of heavy metals on the environment due to long-range transport can be summarized as:

1. Impact on aquatic ecosystems. Atmospheric deposition of metals may influence the quality of surface waters and ground water. In addition to the effects on the uses of water (e.g. restricted use of water for human consumption, livestock, recreation etc) accumulation in aquatic organisms may have adverse effects on the food web.

2. Impact on terrestrial systems. Metal uptake by plants is a key route for the entry of metals into the food chain. Contaminants may be toxic to plants and can alter the structure or diversity of a habitat. When plants accumulate metals, these can be ingested by animals creating the potential for toxic effects at higher trophic levels.
3. Mesofauna and macrofauna. The accumulation of cadmium and lead in birds and mammals in remote areas is attributable to long range atmospheric transport.
4. Agricultural products. Airborne heavy metals account for significant fractions of the total heavy metal input to arable soils.

Major environmental problems due to long range transport have been reported, relating to the:

- Accumulation of Pb, Cd and Hg in forest top soils, implying disturbed nutrient recirculation in forest ecosystems and increased stress on tree vitality in central Europe, reinforced by the acidification of soils
- Highly increased content of Hg in fish from lakes, especially in Scandinavia.

Table 6.1 Total UK Emissions of Heavy Metals

Pollutant	**Total 2004 UK emission**
Heavy metals	**tonnes**
• Arsenic	15.6
• Beryllium	9.9
• Cadmium	5.4
• Chromium	40.6
• Copper	66.2
• Lead	134
• Manganese	38.5
• Mercury	6.94
• Nickel	185
• Selenium	47.7
• Tin	6.5
• Vanadium	1344
• Zinc	504

The NAEI currently reports emissions of thirteen metals. These are:

- Arsenic
- Beryllium
- Cadmium
- Chromium
- Copper
- Lead
- Manganese
- Mercury
- Nickel
- Selenium
- Tin
- Vanadium
- Zinc

Emissions inventories for all of the above except beryllium, manganese, selenium, tin, and vanadium were reported by Leech (1993), Gillham *et al* (1994) and Couling *et al* (1994). Emissions of all metals except beryllium, manganese and tin were reported by Salway *et al* (1996, 1996a, 1997) and Goodwin *et al* (1999, 2000, 2001). Emission estimates for beryllium, manganese, and tin were reported for the first time in the 2000 version of the NAEI (Goodwin *et al* 2002).

Heavy metal emissions arise from a number of different sources, but in general fuel combustion and certain industrial processes that produce dust are the main contributors. Metal emissions arise from the trace concentrations in the fuels or in the case of industrial processes, the raw materials. In the case of combustion, metals are emitted either as vapour or particulate matter or both. Volatile metals such as mercury and selenium are mostly emitted as vapour. Metals such as cadmium and lead are emitted as both with some of the vapour condensing onto the ash particles. Other metals such as chromium do not vaporise and may be emitted in the ash particles.

Emission estimates for combustion sources are generally based on emission factors developed from fuel composition data, applied to fuel consumption statistics (DTI, 2004). Emission estimates for industrial processes are generally based on data taken from the Pollution Inventory or based on the use of emission factors and activity data taken from the literature. The methodology for industrial process emissions has recently been reviewed (Passant *et al,* 2002a) and numerous changes have been made. The emissions estimates presented here are based on a recent review of the methodology used for the combustion related sources.

UK data is used for the metal contents of coal and fuel oils where available. Emissions from the combustion of liquid fuels are based on data reported by Wood (1996) and other sources in the literature (Sullivan, 1991; Lloyds 1995). Lead emissions from petrol combustion are based on detailed data on the lead content of petrol published by the Institute of Petroleum (1999). The emissions from coal and oil fired power stations are based on estimates reported in the Pollution Inventory (Environment Agency, 2004) or the operators' annual reports. Emissions from other coal combustion sources follow the PARCOM methodology (van der Most, 1992) but use data based on UK coal (Smith, 1987). Many of the emission factors for industrial processes such as iron & steel, primary lead/zinc manufacture, secondary copper and cement manufacture are based on data given in the Pollution Inventory, although literature-based emission factors are also used (sources include Clayton *et al*, (1991), EMEP/CORINAIR(1996), van der Most (1992), Jockel and Hartje (1991), and Smyllie (1996). Details of the methodology are given in Passant *et al*, (2002a). Emissions from the chloralkali industry are based on manufacturers estimates (Ratcliffe, 1999).

Heavy metal emissions can be reduced using gas cleaning equipment which removes particulates from waste gases. This abatement equipment can be fitted to large coal-fired industrial boilers and power station boilers and also industrial processes which produce large amounts of dust. Hence, when estimating emission factors it is often necessary to assume some efficiency of abatement.

The majority of the emission factors used in generating emission estimates are based on the mass of metal emitted per unit mass of fuel burnt, or mass of metal emitted per unit mass of product for processes. These emission factors are assumed not to vary with time for many of the sources considered. This is assumed as there is usually insufficient information to estimate any temporal variation of the emission factor. However, for sources such as road transport, chlorine production, waste incineration and public power generation, there is sufficient information to allow time dependent emission factors to be estimated.

At the end of 1996 all municipal solid waste and clinical incinerators had to comply with new emission standards (see also Section 5.2.1). As a result, a number of old incinerators have closed, whilst some have been renovated and some new ones opened. Hence there have been significant reductions in emissions from waste incineration. Data is available for most metals for the new plant (Environment Agency, 2004).

In 1984 the miners strike lead to a significant decrease in the use of coal for combustion in electricity generation, industry and the domestic sector. During this period there was an increased use of petroleum products. This fuel switching had a significant impact on the emissions of numerous pollutants, which can be seen in the following time series plots.

6.2 EMISSIONS OF ARSENIC

Acute exposure to high levels of arsenic via the inhalation of dust or fumes leads to gastrointestinal effects such as nausea, diarrhoea and abdominal pain. Chronic inhalation exposure to inorganic arsenic is associated with irritation of the mucous membranes as well as being strongly associated with lung cancer.

Table 6.2 and Figure 6.1 summarise the UK emissions of arsenic. Emissions have declined by 81% since 1970. Historically the largest source of emission was coal combustion with other sources being very small by comparison. Coal use has declined over the period considered, in favour of natural gas use. The emissions from the industrial sector are typically large compared with the emissions from public power generation; this is due to the different levels of abatement efficiency that are assumed. As coal combustion has declined, the use of “CCA” treated wood (the preservative contains Copper, Chromium and Arsenic) as fuel in the industrial sector has become increasingly important- to the extent that it is now the most significant component of Arsenic emissions. The emissions from this source are particularly uncertain because the amount of treated wood used as a fuel source is not well characterised.

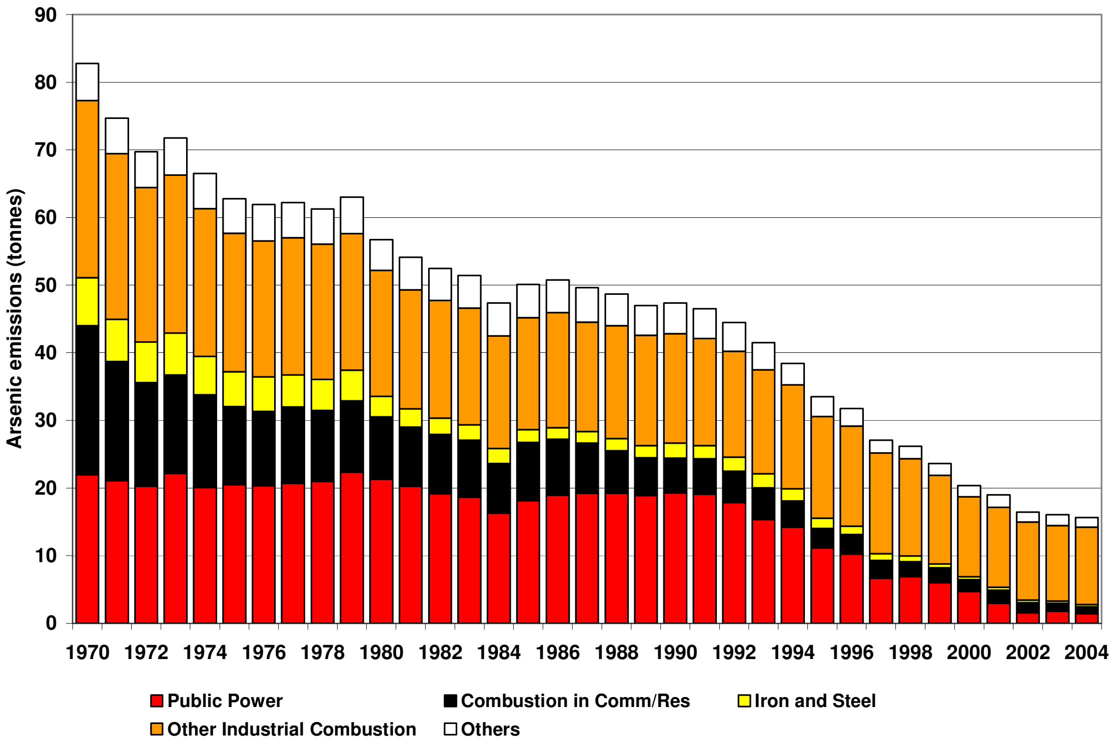
Table 6.2 UK Emissions of Arsenic by aggregated UN/ECE Category and Fuel (tonnes)

	1970	1980	1990	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[1]													
Public Power	22.0	21.3	19.3	10.2	6.6	6.9	6.0	4.7	3.0	1.6	1.8	1.4	9%
Industry													
Iron and Steel	7.1	3.0	2.2	1.2	1.0	0.8	0.6	0.4	0.4	0.4	0.4	0.3	2%
Other Industrial Combustion	26.0	18.5	16.0	14.6	14.7	14.2	12.9	11.7	11.7	11.4	11.0	11.3	72%
Combustion in Comm/Res	22.0	9.2	5.1	2.9	2.7	2.2	2.2	1.7	1.9	1.5	1.1	1.0	7%
Transport													
Road Transport	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Off-road Vehicles and Other Machinery[2]	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.2	0.2	1%
Solvent and other Products	2.1	1.2	1.8	1.8	1.8	1.7	1.7	1.5	1.7	1.4	1.4	1.4	9%
Waste Incineration	3.4	3.4	2.7	0.9	0.1	0.1	0.1	0.1	0.2	0.0	0.2	0.0	0%
Emission by fuel													
Solid	57.1	41.2	34.7	22.4	18.1	18.1	17.3	15.6	14.2	12.2	11.9	11.6	73%
Petroleum	14.3	8.0	5.1	3.8	3.5	3.1	2.6	2.2	2.5	2.3	2.5	2.5	16%
Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Non-Fuel	12.8	8.0	7.9	6.0	6.1	5.5	4.1	2.9	2.6	2.2	2.0	1.8	11%
Total	**82.8**	**56.7**	**47.4**	**31.8**	**27.1**	**26.2**	**23.6**	**20.4**	**19.0**	**16.5**	**16.0**	**15.6**	**100%**

[1] See Annex 1 for definition of UN/ECE Categories

[2] Including railways, shipping, naval vessels, military aircraft and off-road sources

Figure 6.1 Time Series of Arsenic Emission (tonnes)



6.3 EMISSIONS OF CADMIUM

Effects of acute inhalation exposure to cadmium consist mainly of effects on the lung, such as pulmonary irritation. Chronic effects via inhalation can cause a build-up of cadmium in the kidneys that can lead to kidney disease.

Table 6.3 and Figure 6.2 summarise the UK emissions of cadmium. Emissions have declined by 88% since 1970. The main sources are energy production, non-ferrous metal production and iron and steel manufacture (as well as other forms of industrial combustion). The emissions for from energy production include a significant proportion from waste combustion and fuel oil combustion for electricity generation. Emissions from non-ferrous metal activities include a lead-zinc smelting plant and a number of lead battery recycling plants.

The decline in emissions is a result of the general fall in coal combustion and the decline in fuel oil combustion in power generation. The large reduction observed from waste emissions is due to improved controls on Municipal Solid Waste (MSW) incinerators from 1993 onwards and their conversion to power generating plant.

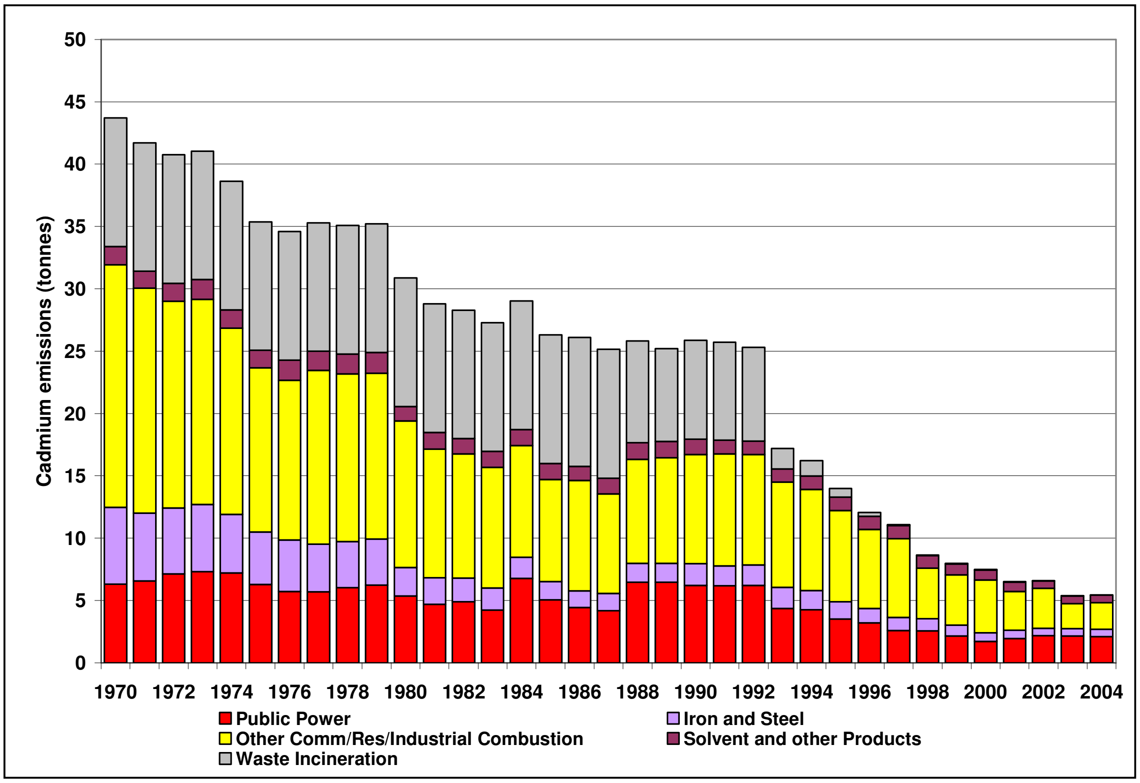
Table 6.3 UK Emissions of Cadmium by aggregated UN/ECE Category and Fuel (tonnes)

	1970	**1980**	**1990**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2004%**
BY UN/ECE CATEGORY[1]													
Public Power	6.32	5.35	6.20	3.20	2.58	2.57	2.16	1.72	1.94	2.19	2.15	2.10	39%
Iron and Steel	6.15	2.30	1.75	1.17	1.06	0.98	0.87	0.70	0.68	0.58	0.60	0.60	11%
Other Ind/Res Combustion	17.59	10.32	7.77	5.39	5.43	3.24	3.24	3.48	2.41	2.51	1.30	1.36	25%
Solvent and other Products	1.45	1.16	1.22	1.06	1.06	1.01	0.86	0.79	0.72	0.60	0.62	0.60	11%
Waste Incineration	10.31	10.31	7.95	0.29	0.06	0.03	0.03	0.06	0.07	0.02	0.02	0.01	0%
Gas Mains Leakage	1.43	1.05	0.51	0.39	0.34	0.29	0.29	0.26	0.23	0.20	0.19	0.15	3%
Off-road Vehicles and Other Machinery/Vehicles[2]	0.46	0.38	0.49	0.55	0.54	0.52	0.51	0.49	0.48	0.49	0.50	0.62	11%
By FUEL TYPE													
Solid	13.1	12.6	12.6	2.2	1.5	1.6	1.3	1.2	1.2	1.2	1.2	1.3	21%
Petroleum	20.6	11.0	6.3	4.8	4.4	4.1	3.3	2.6	3.2	3.0	3.2	3.3	54%
Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Non-Fuel	12.4	8.2	7.8	5.9	6.2	4.0	4.0	4.2	2.7	2.9	1.6	1.5	25%
TOTAL	**43.7**	**30.9**	**25.9**	**12.1**	**11.1**	**8.6**	**8.0**	**7.5**	**6.5**	**6.6**	**5.4**	**5.4**	**100%**

[1] See Annex 1 for definition of UN/ECE Categories

[2] Including railways, shipping, naval vessels, military aircraft and off-road sources

Figure 6.2 Time Series of Cadmium Emissions (tonnes)



6.4 EMISSIONS OF CHROMIUM

Inhaled chromium is a carcinogen, leading to an increased risk of lung cancer. Acute exposure effects can result in shortness of breath, coughing and wheezing, whilst chronic exposure effects lead to perforation and ulceration of the septum, bronchitis, pneumonia, and decreased pulmonary function.

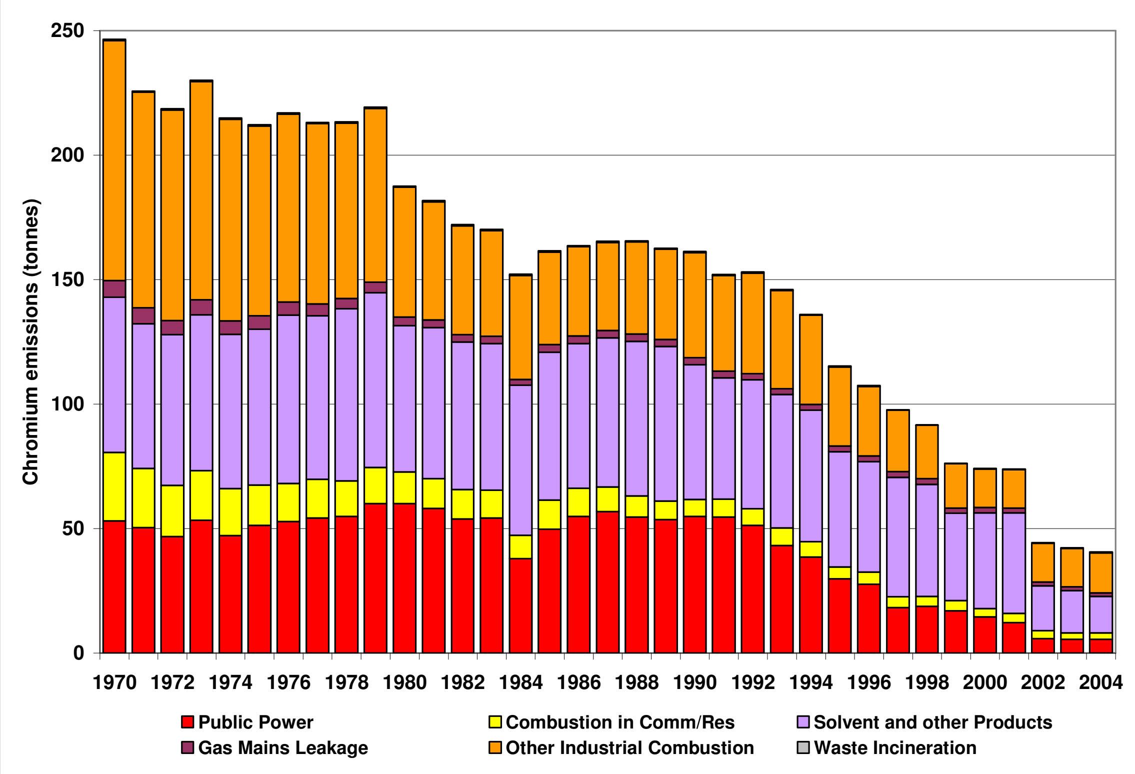
Table 6.4a and Figure 6.3 summarise the UK emissions of chromium. Emissions have fallen by 84% since 1970. The largest sources are various forms of coal combustion, iron and steel production in integrated works and in electric arc furnaces and the production of chromium-based chemicals. More recently as other process emissions have decreased, the emissions from burning “CCA” treated wood in industry as a fuel have become a relatively more important source (see Section 6.4.2).

Table 6.4a UK Emissions of Chromium by aggregated UN/ECE Category and Fuel (tonnes)

	1970	1980	1990	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[1]													
Public Power	53.1	60.0	54.8	27.7	18.3	18.7	16.9	14.5	12.1	5.8	5.5	5.5	14%
Industry													
Iron and Steel	73.8	35.3	28.1	15.0	11.8	8.9	5.8	3.7	3.5	3.2	3.2	2.8	7%
Other Industrial Combustion	22.5	16.9	14.0	13.1	12.8	12.6	12.0	11.7	12.0	12.3	12.2	13.3	33%
Combustion in Comm/Res	27.5	12.7	6.8	4.9	4.3	4.0	4.1	3.4	3.8	3.2	2.6	2.5	6%
Gas Mains Leakage	6.8	3.4	2.8	2.3	2.2	2.2	2.1	2.2	1.9	1.5	1.5	1.4	3%
Solvent and other Products	62.3	58.7	54.2	44.4	48.0	45.1	35.2	38.5	40.4	17.9	16.9	14.7	36%
Waste Incineration	0.5	0.5	0.4	0.3	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.4	1%
By FUEL TYPE													
Solid	85.7	78.5	68.9	39.8	28.2	28.9	27.4	25.2	23.2	16.5	15.6	16.6	40%
Petroleum	21.4	11.4	6.3	5.2	6.8	6.0	5.1	3.7	4.2	3.6	3.8	3.8	9%
Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Non-Fuel	142.0	98.6	87.0	63.3	63.8	57.9	44.5	45.8	47.1	24.8	23.6	20.9	51%
TOTAL	**246.5**	**187.6**	**161.2**	**107.4**	**97.7**	**91.6**	**76.2**	**74.1**	**73.9**	**44.4**	**42.3**	**40.6**	**100%**

[1] See Annex 1 for definition of UN/ECE Categories

Figure 6.3 Time Series of Chromium Emissions (tonnes)



6.4.1 Speciation of Chromium

Chromium may be emitted to air in two oxidised forms - hexavalent (Cr^{6+}) and trivalent (Cr^{3+}). The proportion of each form emitted by each source has been estimated and the overall split between the two forms is shown in Table 6.4b

Table 6.4b Speciated Emissions of Chromium (tonnes)

	Cr^{6+}	Cr^{3+}	Total (2004)
BY aggregated UN/ECE CATEGORY[1]			
Public Power	0.8	4.7	5.5
Other Industrial Combustion	1.8	14.4	16.2
Combustion in Dom/Inst/Com	0.3	2.3	2.5
Production Processes	3.9	10.8	14.7
Road Transport	0.2	0.8	1.0
Off-road Vehicles and Other Machinery	0.0	0.2	0.2
Waste	0.0	0.3	0.4
TOTAL	7.0	33.0	40.0

[1] See Annex 1 for definition of UN/ECE Categories

The profiles used for the speciation are based on the recommendations given in Passant *et al* (2002a). In general, these profiles are subject to great uncertainty and further measurement data are required, particularly for major sources such as coal combustion, glass production, electric arc furnaces and chemical processes (other than chromium chemicals for which good data are available).

6.5 EMISSIONS OF COPPER

Acute effects of copper fumes can lead to irritation of the eyes, nose and throat, resulting in coughing, wheezing and nosebleeds. It may also cause 'metal fume fever', which is a flu-like illness that has symptoms of a metallic taste, fever, chill, aches and chest tightness. Chronic exposure may lead to decreased fertility in both men and women. Severe irritation and ulcers in the nose may also occur.

Table 6.5 and Figure 6.4 summarise the UK emissions of copper. Emissions have declined by 71% since 1970. The main sources are coal combustion, public power generation and road transport. Emissions have declined over the period due to the decline in coal combustion and to a lesser extent the combustion of heavy fuel oil. The large reduction in waste emissions is due to improved controls on MSW waste incinerators from 1997 and their conversion to power generating plant.

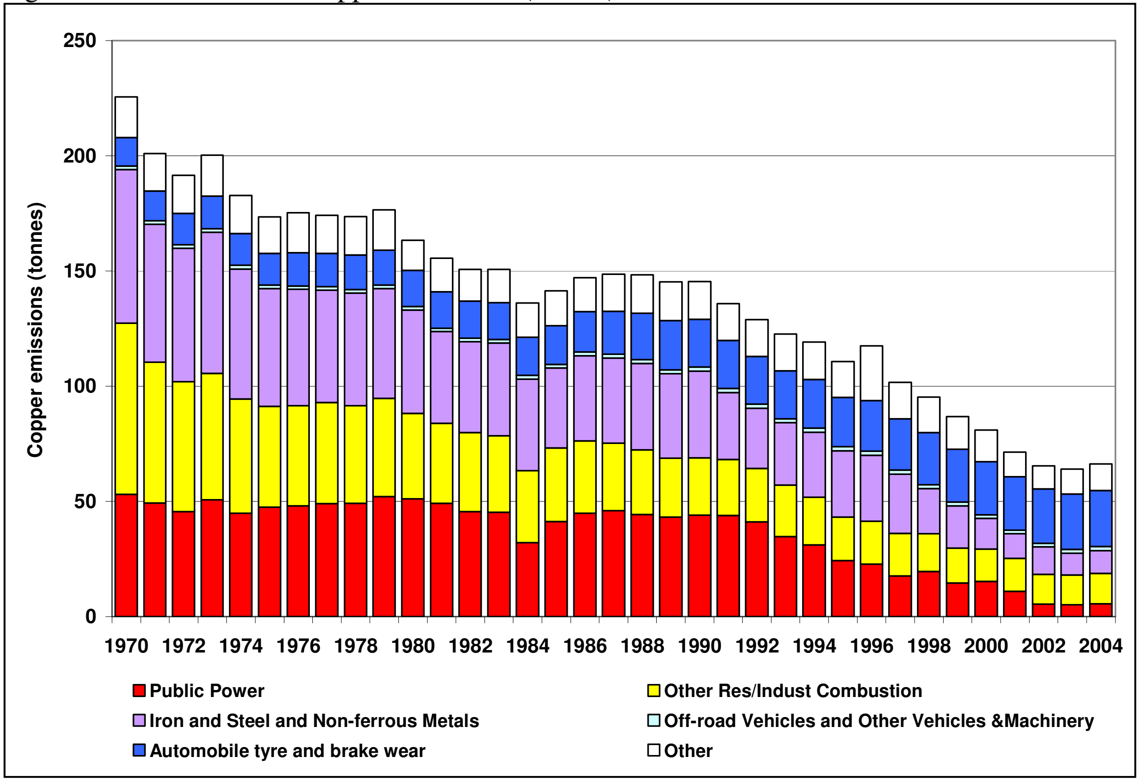
Table 6.5 UK Emissions of Copper by aggregated UN/ECE Category and Fuel (tonnes)

	1970	1980	1990	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[1]													
Public Power	53.0	51.2	44.0	22.7	17.6	19.5	14.6	15.2	11.0	5.5	5.1	5.6	8%
Industry													
Iron and Steel	25.5	12.8	12.1	9.9	9.4	8.4	7.2	6.6	6.4	5.8	5.9	5.4	8%
Non-ferrous Metals	41.1	32.2	25.6	18.7	16.3	11.2	11.1	6.7	4.2	6.1	3.6	4.5	7%
Other Res/Indust Combustion	74.4	37.0	24.9	18.7	18.5	16.5	15.1	14.1	14.3	12.9	12.9	13.1	20%
Transport													
Automobile tyre and brake wear	12.4	15.7	20.6	21.9	22.2	22.6	22.9	23.0	23.2	23.7	24.0	24.3	37%
Off-road Vehicles and Other Vehicles &Machinery[2]	1.5	1.6	1.8	1.8	1.8	1.7	1.7	1.6	1.6	1.5	1.7	1.8	3%
Solvent and other Products	12.4	7.7	11.4	20.1	12.8	12.3	11.1	10.8	7.6	7.0	8.0	8.6	13%
Waste Incineration	5.3	5.3	5.1	3.7	3.0	3.1	3.1	3.1	3.0	2.9	2.9	2.9	4%
By FUEL TYPE													
Solid	100.2	70.0	57.6	31.0	24.7	25.7	20.9	21.4	17.4	11.2	10.4	11.3	17%
Petroleum	30.5	19.5	12.2	11.1	11.7	10.6	9.3	8.5	9.1	8.4	8.8	8.9	15%
Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Non-Fuel	94.7	73.8	75.6	75.4	65.2	59.0	56.6	51.1	44.8	45.8	44.9	46.0	68%
TOTAL	**226**	**163**	**145**	**118**	**102**	**95**	**87**	**81**	**71**	**65**	**64**	**66**	**100%**

[1] See Annex 1 for definition of UN/ECE Categories

[2] Including railways, shipping, naval vessels, military aircraft and off-road sources

Figure 6.4 Time Series of Copper Emissions (tonnes)



6.6 EMISSIONS OF LEAD

Lead is a very toxic element and can cause a variety of symptoms at low dose levels. Lead dust or fumes can irritate the eyes on contact, as well as causing irritation to the nose and throat on inhalation. Acute exposure can lead to loss of appetite, weight loss, stomach upsets, nausea and muscle cramps. High levels of acute exposure may also cause brain and kidney damage. Chronic exposure can lead to effects on the blood, kidneys, central nervous system and vitamin D metabolism.

Table 6.6 and Figure 6.5 summarise the UK emissions of lead. Emissions have declined by 98% since 1970. The largest source was lead from anti-knock lead additives in petrol. The lead content of leaded petrol was reduced from around 0.34 g/l to 0.143 g/l in 1986 and since 1987 sales of unleaded petrol have increased particularly as a result of the increased use of cars fitted with catalytic converters. Leaded petrol was then phased out from general sale at the end of 1999. Consequently a decline in emissions from the road transport sector is seen.

Other major sources are industrial processes and iron and steel combustion. There has been some reduction in emissions from iron and steel production processes due to improved abatement measures. Emissions have also declined as a result of the decreasing use of coal. The large reduction in waste emissions is due to improved controls on MSW incinerators from 1997 onwards.

Table 6.6 UK Emissions of Lead by aggregated UN/ECE Category and Fuel (tonnes)

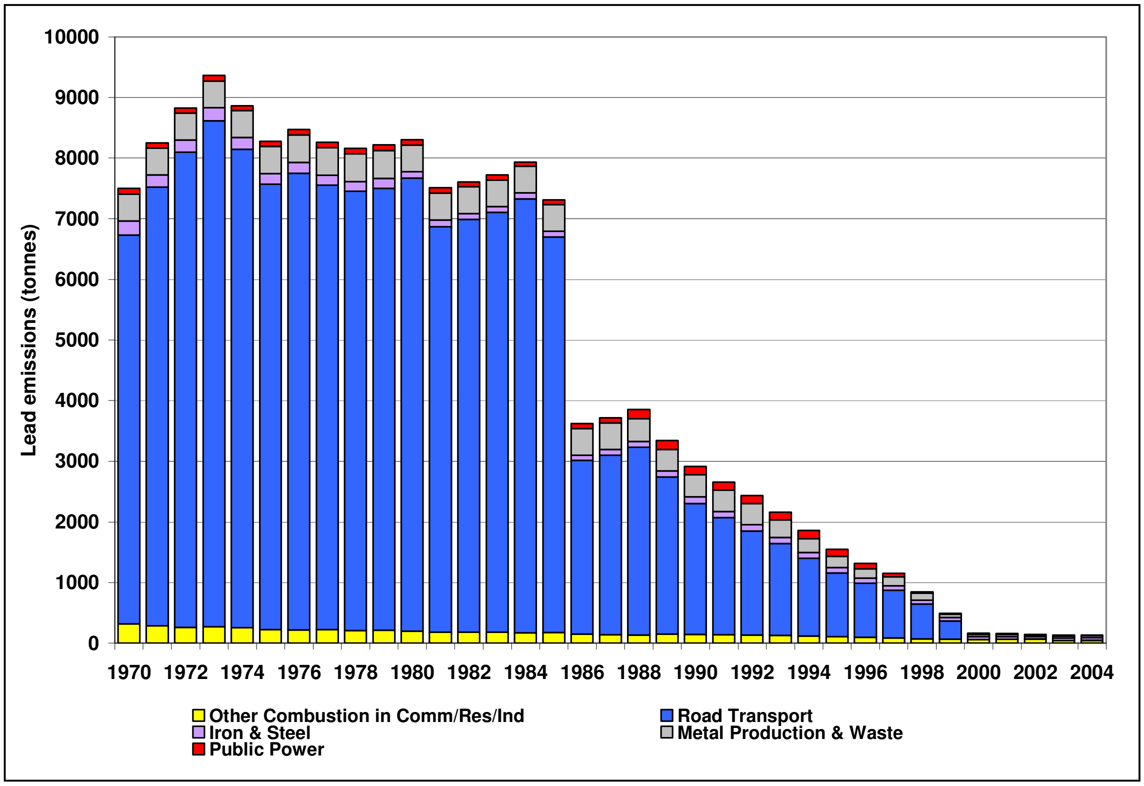
	1970	**1980**	**1990**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2004%**
BY UN/ECE CATEGORY[1]													
Public Power	94	94	135	90	59	23	18	19	16	13	13	14	10%
Iron & Steel	235	105	110	81	75	66	57	48	43	38	44	43	32%
Non-ferrous Metals	67	49	48	37	38	26	25	24	26	30	9	8	6%
Metal Production	36	29	32	29	31	27	23	24	20	14	16	13	10%
Other Combustion in Comm/Res/Ind	224	123	89	53	47	42	39	33	35	36	31	38	28%
Road Transport	6411	7475	2159	895	784	575	302	2	2	2	2	2	1%
Off-road Vehicles and Other Machinery[2]	26	25	7	4	4	3	2	1	1	1	1	1	1%
Solvent and other Products	97	97	96	73	112	87	28	12	14	11	14	15	11%
Waste Incineration	311	311	238	52	2	1	1	1	0	0	0	0	0%
By FUEL TYPE													
Solid[3]	518	443	411	158	75	36	32	30	29	24	21	22	17%
Petroleum	6528	7567	2200	925	813	599	322	19	20	20	21	22	16%
Gas	0	0	0	0	0	0	0	0	0	0	0	0	0%
Non-Fuel	456	297	303	232	264	214	141	114	109	102	89	91	67%
TOTAL	**7502**	**8308**	**2913**	**1315**	**1152**	**850**	**495**	**163**	**158**	**145**	**131**	**134**	**100%**

[1] See Annex 1 for definition of UN/ECE Categories

[2] Including railways, shipping, naval vessels, military aircraft and off-road sources

[3] All emissions from MSW combustion are included under solid fuel.

Figure 6.5 Time Series of Lead Emissions (tonnes)



6.7 EMISSIONS OF MERCURY

Acute exposure to high levels of elemental mercury vapour can lead to irritation of the lungs as well as causing coughing, chest pain and shortness of breath. High levels can also result in central nervous system (CNS) effects such as tremors and mood changes. Chronic exposure also leads to CNS disorders, with effects such as increased excitability, excessive shyness and irritability.

Table 6.7a and Figure 6.6 summarise the UK emissions of mercury. Emissions have declined by 89% since 1970. The main sources are waste incineration, the manufacture of chlorine in mercury cells, coal and other forms of industrial combustion. Emissions have declined as a result of improved controls on mercury cells and their replacement by diaphragm or membrane cells and the decline of coal use. The large reduction in waste emissions is due to improved controls on MSW incinerators from 1997 onwards and their conversion to power generating plant.

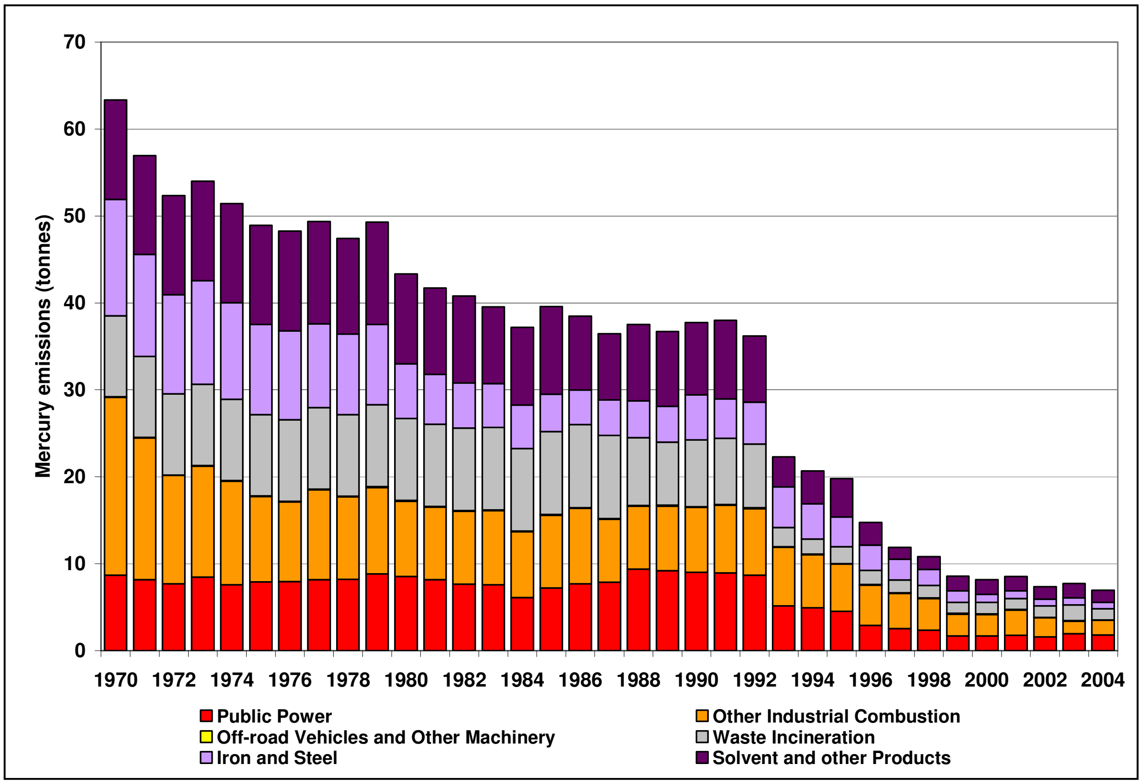
Table 6.7a UK Emissions of Mercury by aggregated UN/ECE Category and Fuel (tonnes)

	1970	1980	1990	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[1]													
Public Power	8.7	8.5	9.0	2.9	2.5	2.3	1.7	1.7	1.8	1.6	1.9	1.8	26%
Iron and Steel	13.4	6.3	5.2	2.9	2.4	1.9	1.3	0.9	0.9	0.8	0.8	0.8	11%
Other Industrial Combustion	20.4	8.7	7.5	4.6	4.1	3.6	2.5	2.5	2.9	2.2	1.4	1.7	24%
Off-road Vehicles and Other Machinery[2]	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1%
Solvent and other Products	11.4	10.3	8.3	2.6	1.4	1.5	1.7	1.7	1.7	1.4	1.6	1.4	20%
Waste Incineration	9.3	9.4	7.7	1.6	1.5	1.4	1.3	1.3	1.3	1.3	1.8	1.3	18%
By FUEL TYPE													
Solid	32.1	21.8	18.9	4.8	4.2	3.8	3.4	3.0	3.5	3.1	2.9	3.0	43%
Petroleum	1.8	1.1	0.8	0.5	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.3	4%
Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Non-Fuel	29.5	20.4	18.0	9.4	7.3	6.6	4.9	4.9	4.7	3.9	4.5	3.7	53%
TOTAL	**63.3**	**43.3**	**37.7**	**14.7**	**11.9**	**10.8**	**8.6**	**8.1**	**8.5**	**7.3**	**7.7**	**6.9**	**100%**

[1] See Annex 1 for definition of UN/ECE Categories

[2] Including railways, shipping, naval vessels, military aircraft and off-road sources

Figure 6.6 Time Series of Mercury Emissions (tonnes)



6.7.1 Speciation of Mercury Emissions

When mercury is emitted to air it occurs in one of several different forms, and the emissions of each of these forms has been estimated individually- the emissions have been "speciated".

Three species of mercury have been considered:

- **Hg^0** unreactive gaseous elemental Hg
- **Hg-p** mercury attached to particulate material
- **RGM** reactive gaseous mercury (includes inorganic and organic forms normally in Hg^{2+} oxidised form)

The methodology for estimating the emissions of each of these three species is similar to that used for speciating the NMVOC emissions. Each source of mercury emission is considered individually. A speciation profile identifying the fractional contribution from each species to the mercury emission from that source is then applied. Summing across the individual sources then allows a total for each of the three species to be evaluated.

Table 6.7b Speciated Emissions of Mercury (tonnes)

	Hg^0	Hg-p	RGM [1]	Total (2004)
BY aggregated UN/ECE CATEGORY[2]				
Public Power	0.85	0.17	0.76	1.78
Other Industrial Combustion	1.39	0.17	0.62	2.18
Combustion in Dom/Inst/Com	0.11	0.05	0.11	0.27
Production Processes	0.99	0.01	0.38	1.38
Road Transport	0.00	0.00	0.00	0.00
Off-road Vehicles and Other Machinery	0.04	0.01	0.03	0.08
Waste	0.41	0.01	0.84	1.26
TOTAL	3.79	0.41	2.74	6.94

[1] in table shown as Hg^{2+}

[2] See Annex 1 for definition of UN/ECE Categories

The profiles used for the speciation are based on the recommendations given in Passant *et al* (2002a). In general, these profiles are subject to great uncertainty and further measurement data are required, particularly for major sources such as coal combustion, crematoria, clinical waste incinerators, sinter plant, chloralkali processes, and primary lead/zinc production.

6.8 EMISSIONS OF NICKEL

Inhalation of nickel can cause irritation to the nose and sinuses and can also lead to the loss of the sense of smell. Long term exposure may lead to asthma or other respiratory diseases. Cancer of the lungs, nose and sinuses as well as the larynx and stomach has been attributed to exposure to nickel.

Table 6.8a and Figure 6.7 summarise the UK emissions of nickel. Emissions have declined by 85% since 1970. Currently the main sources of nickel emissions is the combustion of heavy fuel oil, however in the past coal combustion was a major source. Emissions from both sources have declined in use since 1970 in favour of natural gas and are largely responsible for the reduction in total emissions. Between 1989 and 1997, heavy fuel oil was replaced by Orimulsion (an emulsion of bitumen in water) in some power stations. The nickel content of Orimulsion was higher than that of heavy fuel oil and resulted in higher emissions in spite of the flue gas cleaning equipment required on these power stations. Emissions from refineries are important because of the large amount of refinery fuel oil and residues burnt.

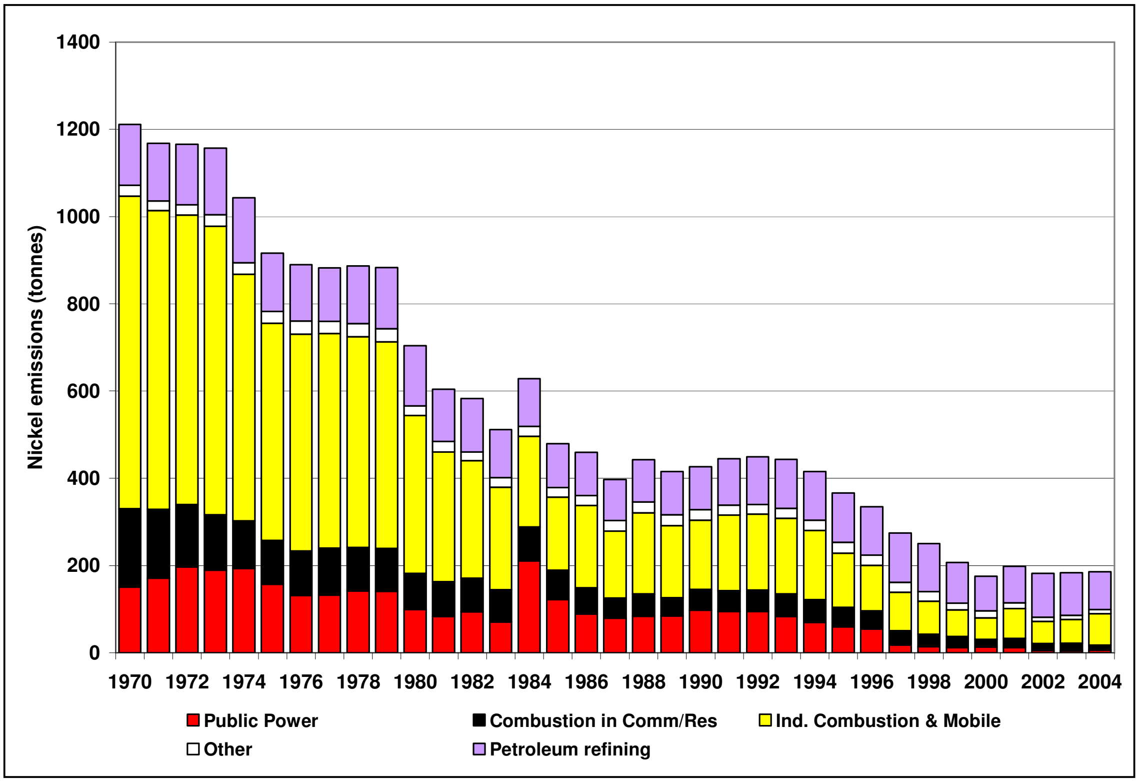
Table 6.8a UK Emissions of Nickel by aggregated UN/ECE Category and Fuel (tonnes)

	1970	1980	1990	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[1]													
Public Power	150	99	97	54	17	14	12	13	12	5	4	5	3%
Petroleum refining	140	138	98	111	113	110	93	79	84	101	98	86	47%
Iron and Steel	172	47	14	8	8	11	13	10	12	9	7	8	4%
Other Industrial Combustion	525	304	132	80	65	52	35	29	46	31	37	47	25%
Combustion in Comm/Res	180	83	48	42	33	29	26	17	21	16	17	12	6%
Off-road Vehicles and Other Machinery[2]	20	12	13	15	14	13	12	11	10	10	11	18	10%
Solvent and other Products	24	21	24	23	23	22	15	16	13	9	9	9	5%
Waste Incineration	0	0	0	0	0	0	0	0	0	0	0	1	1%
By FUEL TYPE													
Solid	61	48	40	21	8	9	7	8	8	5	4	6	3%
Petroleum	1093	617	348	281	235	213	177	147	173	164	167	167	90%
Gas	0	0	0	0	0	0	0	0	0	0	0	0	0%
Non-Fuel	57	39	38	33	31	29	23	20	17	13	12	13	7%
TOTAL	1211	704	427	335	275	250	207	175	198	182	183	185	100%

[1] See Annex 1 for definition of UN/ECE Categories

[2] Including railways, shipping, naval vessels, military aircraft and off-road sources

Figure 6.7 Time Series of Nickel Emissions (tonnes)



6.8.1 Speciation of Nickel Emissions

Nickel is emitted to air in a many different forms, which have been grouped into five 'species' for the NAEI:

- **MN** metallic nickel
- **ON** oxidic nickel compounds such as NiO and Ni_2O_3
- **SolN** soluble nickel salts such as nickel sulphates and nickel chlorides
- **NC** nickel carbonyl, $Ni(CO)_4$
- **SU** sulphidic nickel compounds e.g. nickel sulphide (NiS) & nickel subsulphide (Ni_3S_2)

The proportion of each form emitted by each source has been estimated and the overall split between the two forms is shown in Table 6.8b

Table 6.8b Speciated Emissions of Nickel 2004 (tonnes)

	MN	ON	SolN	NC	SU	Total (2004)
BY aggregated UN/ECE CATEGORY						
Public Power	0.0	35.5	52.3	0.5	2.7	91.0
Other Industrial Combustion	0.6	22.2	30.5	0.3	1.6	55.2
Combustion in Dom/Inst/Com	0.0	4.5	6.7	0.1	0.3	11.6
Production Processes	2.4	5.9	0.2	0.0	0.0	8.5
Road Transport	0.7	0.5	0.8	0.0	0.0	2.0
Off-road Vehicles and Other Machinery	0.0	6.2	9.1	0.1	0.5	15.9
Waste	0.0	0.4	0.6	0.0	0.0	1.0
TOTAL	3.6	75.3	100.3	0.9	5.2	185.3

The profiles used for the speciation are based on the recommendations given in Passant *et al* (2002a). In general, these profiles are subject to great uncertainty and better data are desirable, particularly for major sources such as combustion of coal, fuel oil, anthracite, and petroleum coke, and electric arc furnaces. However current measurement techniques are not able to provide much useful data and so significant improvements are not likely in the short term.

6.9 EMISSIONS OF SELENIUM

Acute exposure to selenium by inhalation results in respiratory effects such as irritation to the mucous membranes, severe bronchitis and bronchial pneumonia.

Table 6.9 and Figure 6.8 summarise the UK emissions of selenium. Emissions have declined by 55% since 1970. The main source of selenium emissions is coal combustion in early years. Only trace amounts are emitted by the combustion of petroleum based fuels. Glass production has previously been considered the dominant source. The estimates for the manufacture of the various types of glass products (flat glass, container glass etc.) are uncertain and there are on-going improvements to the emission estimates. Revised estimates have been made for flat glass and this has significantly reduced the national estimate of selenium emissions.

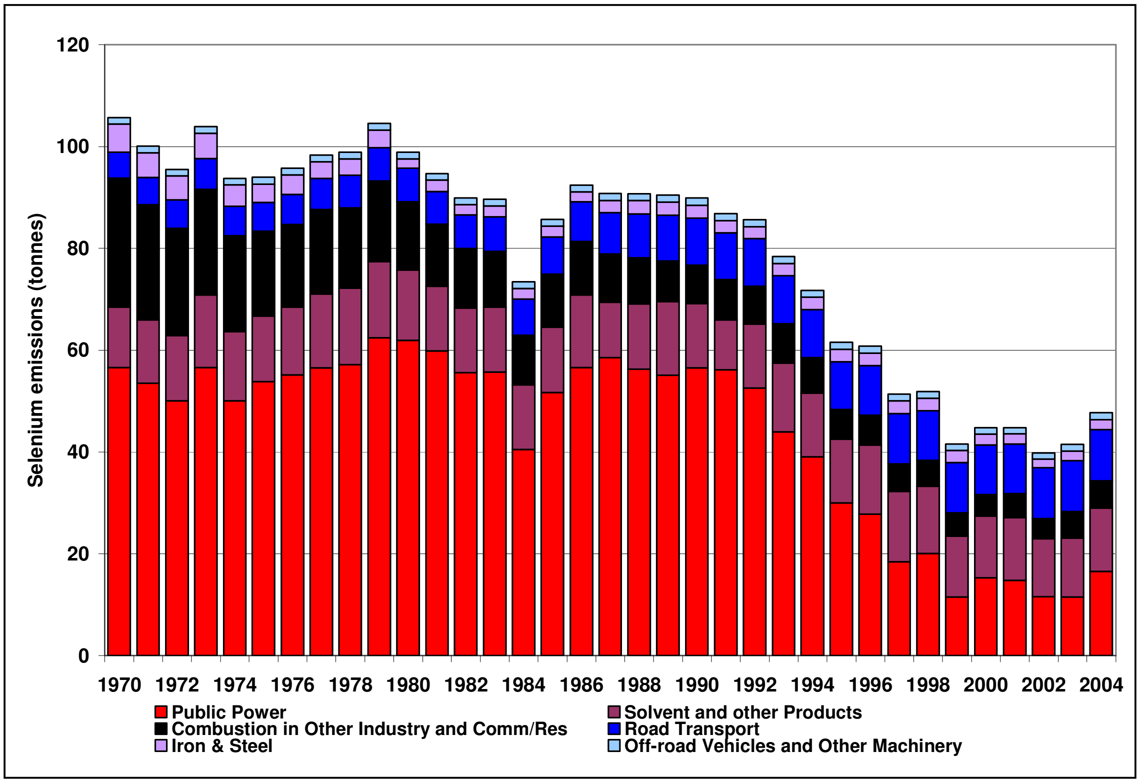
Table 6.9 UK Emissions of Selenium by aggregated UN/ECE Category and Fuel (tonnes)

	1970	1980	1990	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[1]													
Public Power	57	62	57	28	18	20	12	15	15	12	12	17	35%
Industry													
Iron & Steel	6	2	2	2	3	2	2	2	2	2	2	2	4%
Other industrial Combustion	9	5	3	3	2	2	2	2	2	2	3	4	8%
Combustion in Comm/Res	17	8	4	3	3	3	3	2	2	2	2	2	3%
Transport													
Road Transport	5	7	9	10	10	10	10	10	10	10	10	10	21%
Off-road Vehicles and Other Machinery[2]	1	1	1	1	1	1	1	1	1	1	1	1	3%
Solvent and other Products	12	14	13	14	14	13	12	12	12	11	12	12	26%
By FUEL TYPE													
Solid	67	65	58	29	17	19	11	14	14	11	12	17	35%
Petroleum	24	18	17	16	18	18	16	16	16	16	16	17	35%
Gas	0	0	0	0	0	0	0	0	0	0	0	0	0%
Non-Fuel	15	15	15	16	16	16	14	14	14	13	14	15	30%
Total	106	99	90	61	51	52	42	45	45	40	42	48	100%

[1] See Annex 1 for definition of UN/ECE Categories

[2] Including railways, shipping, naval vessels, military aircraft and off-road sources

Figure 6.8 Time Series of Selenium Emissions (tonnes)



6.10 EMISSIONS OF VANADIUM

Acute exposure to vanadium by inhalation can cause irritation to the respiratory tract. Chronic exposure may lead to pneumonia.

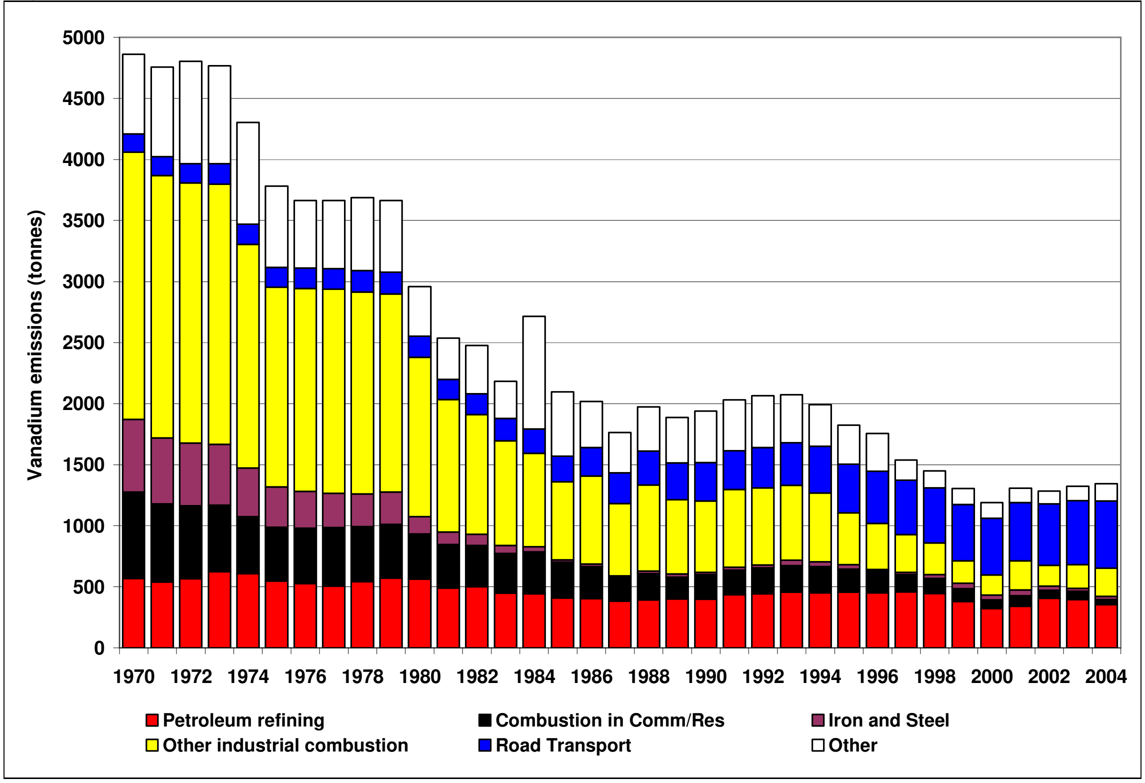
Table 6.10 and Figure 6.9 summarise the UK emissions of vanadium. Emission data are rather scarce so the estimates are very uncertain. Estimates of emissions have declined by 73% since 1970. The major source of emissions are the road transport sector accounting for 41% and the combustion of fuel oils with liquid fuels accounting for some 32% of the estimated emission in 2004. The total contribution from petroleum based fuels is 99% of the total vanadium emission. The reduction in emissions with time reflects the decline in the use of fuel oils by the electricity supply industry, industry in general and the domestic sector. Between 1989 and 1997, heavy fuel oil was partly replaced by Orimulsion (an emulsion of bitumen in water) in some power stations. Emissions from refineries are very important because of the high consumption of heavy fuel oil and residues. The vanadium content of Orimulsion was higher than that of heavy fuel oil and resulted in higher emissions in spite of the flue gas cleaning equipment required on these power stations. Of the other sources, estimates for the iron and steel industry are very uncertain since emissions will depend on the type of steel or alloy produced and its vanadium content. The available emissions data apply only to a generalised steel production process.

Table 6.10 UK Emissions of Vanadium by aggregated UN/ECE Category and Fuel (tonnes)

	1970	1980	1990	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[1]													
Petroleum refining	570	562	398	450	459	446	378	322	339	406	397	352	26%
Iron and Steel	594	143	19	15	19	32	46	38	47	33	23	26	2%
Other industrial combustion	2190	1304	583	376	309	261	183	166	238	172	193	231	17%
Combustion in Comm/Res	706	371	201	179	140	122	107	71	88	65	67	44	3%
Road Transport	149	173	316	426	444	449	460	464	476	502	525	549	41%
Production Processes	9	4	7	7	7	6	6	5	5	4	5	5	0%
Other	644	404	416	304	160	134	127	124	116	102	113	137	10%
By FUEL TYPE													
Solid	92	104	195	194	187	189	171	186	142	164	150	156	12%
Petroleum	4755	2850	1736	1551	1342	1252	1126	997	1161	1114	1169	1183	88%
Gas	0	0	0	0	0	0	0	0	0	0	0	0	0%
Non-Fuel	14	7	10	11	9	9	8	7	7	5	5	5	0%
TOTAL	**4861**	**2961**	**1941**	**1756**	**1539**	**1450**	**1305**	**1190**	**1309**	**1284**	**1324**	**1344**	**100%**

[1] See Annex 1 for definition of UN/ECE Categories

Figure 6.9 Time series of Vanadium Emissions (tonnes)



6.11 EMISSIONS OF ZINC

Although zinc metal poses no documented health risks, if its physical state is altered during use then health risks can be created. Inhalation of metallic oxide fumes can lead to metal fume fever.

Table 6.11 and Figure 6.10 summarise the UK emissions of zinc. Emissions of zinc have declined by 68% since 1970. The main sources are iron and steel production and combustion in industry. The road transport emission is almost entirely due to tyre wear. This arises from the zinc content of the tyre rubber - around 2% ZnO by weight. The reduction in emissions over the period considered is largely due to the decline in coal combustion and improvements in abatement measures in the iron and steel industry. The large reduction in emissions from MSW incinerators is due to improved emission controls applied from 1997 onwards.

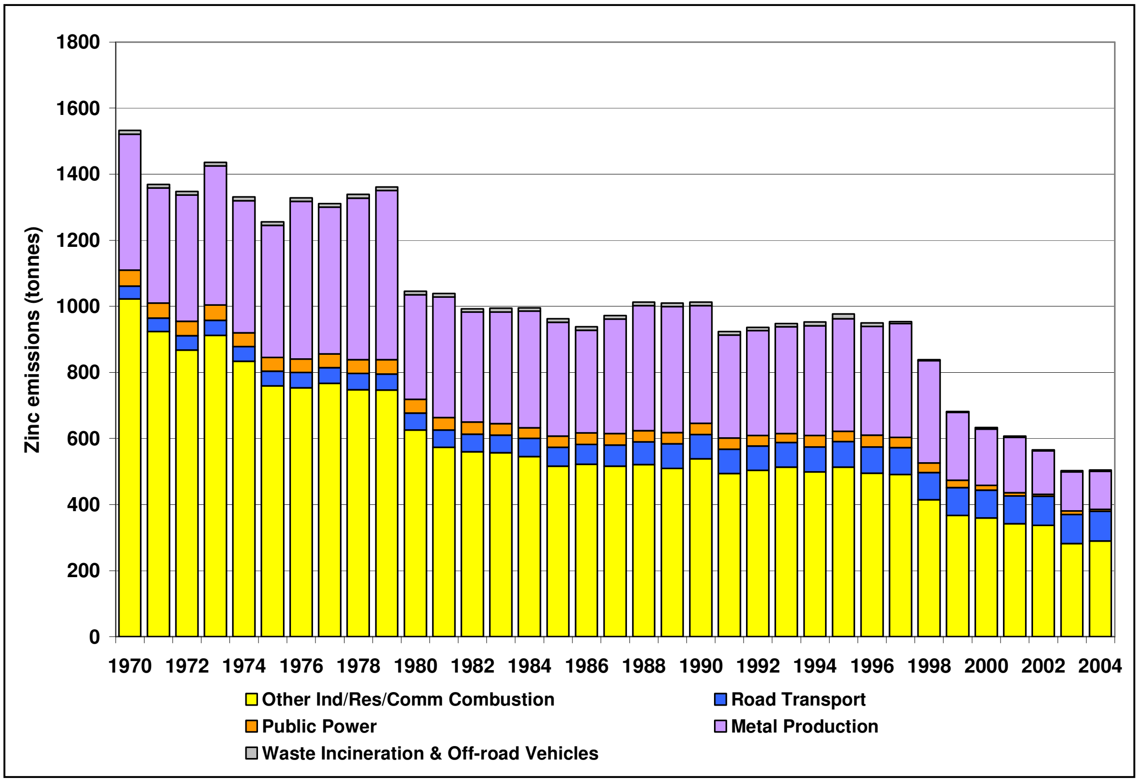
Table 6.11 UK Emissions of Zinc by aggregated UN/ECE Category and Fuel (tonnes)

	1970	1980	1990	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[1]													
Public Power	48	41	34	35	32	29	22	14	9	7	10	6	1%
Industry													
Iron and Steel	312	150	122	66	53	41	27	18	17	16	16	14	3%
Non-ferrous Metals	233	171	158	151	155	125	112	116	84	89	24	21	4%
Other Ind/Res/Comm Combustion	466	299	254	274	279	245	224	221	237	230	240	252	50%
Solvent and other Products	31	34	18	10	8	9	9	11	7	7	3	3	1%
Metal Production	381	283	338	319	336	300	196	160	160	124	116	112	22%
Transport													
Road Transport	39	51	74	79	81	83	84	84	85	87	88	90	18%
Off-road Vehicles and Other Machinery[2]	13	7	6	5	5	5	5	5	4	4	3	4	1%
Waste Incineration	10	10	9	9	5	2	2	4	2	2	2	2	0%
By FUEL TYPE													
Solid	183	92	65	37	31	32	30	25	25	19	16	17	3%
Petroleum	339	251	225	256	261	229	207	209	222	220	231	243	48%
Gas	0	0	0	0	0	0	0	0	0	0	0	0	0%
Non-Fuel	1010	703	723	657	662	577	445	400	359	327	255	244	48%
TOTAL	1532	1046	1013	950	954	838	682	633	607	565	502	504	100%

[1] See Annex 1 for definition of UN/ECE Categories

[2] Including railways, shipping, naval vessels, military aircraft and off-road sources

Figure 6.10 Times Series of Zinc Emissions (tonnes)



6.12 EMISSIONS OF BERYLLIUM

Acute inhalation exposure to high levels of beryllium can lead to inflammation of the lungs. Long-term exposure can cause chronic beryllium disease where non-cancerous lesions form in the lungs. Studies also suggest that inhalation can lead to an increased risk of lung cancer.

Table 6.12 summarises the UK emissions of beryllium. Estimates have only been included since the 2000 NAEI report; therefore the figures are very uncertain. Emission factors have been calculated for the combustion of coal and heavy liquid fuels, but emission factors are not available for industrial processes, with the exception of iron & steel manufacture and a few other processes, where emission estimates have been based on data given in the Pollution Inventory. There is on-going development of the beryllium inventory, and improved data will be included in future versions of the NAEI.

Table 6.12 UK Emissions of Beryllium by aggregated UN/ECE Category and Fuel (tonnes)

	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[1]						
Public Power	1.2	1.2	1.2	1.2	1.1	12%
Iron and Steel	0.1	0.2	0.1	0.1	0.1	1%
Other Industrial Combustion	1.2	1.4	1.1	1.2	1.4	14%
Road Transport	3.7	3.8	4.0	4.2	4.4	45%
Off-road Vehicles & Other Machinery[2]	0.8	0.8	0.7	0.8	0.9	9%
Combustion in Comm/Res	3.0	3.6	2.8	1.9	2.0	20%
Other	0.0	0.0	0.0	0.0	0.0	0%
By FUEL TYPE						
Solid	3.7	4.1	3.2	2.4	2.6	26%
Petroleum	6.3	6.8	6.7	7.0	7.2	73%
Gas	0.0	0.0	0.0	0.0	0.0	0%
Non-Fuel	0.0	0.1	0.0	0.1	0.1	1%
TOTAL	10.0	11.0	10.0	9.5	9.9	100%

[1] See Annex 1 for definition of UN/ECE Categories

[2] Including railways, shipping, naval vessels, military aircraft and off-road sources

6.13 EMISSIONS OF MANGANESE

Long-term exposure to high levels of manganese can result in effects on the central nervous system such as visual reaction time, hand-eye coordination and hand steadiness. Exposure to higher levels over a long period of time can result in a syndrome known as manganism. This leads to feelings of weakness and lethargy, tremors and psychological disturbances.

Table 6.13 summarises the UK emissions of manganese. As estimates have only been included since the 2000 NAEI report the figures remain very uncertain. Emission factors have been calculated for the combustion of coal and heavy liquid fuels, but emission factors are not available for many industrial processes, with the exception of iron & steel manufacture and a few other processes, where emission estimates have been based on data given in the Pollution Inventory. Further development of the manganese inventory will occur in future versions of the NAEI.

Table 6.13 UK Emissions of Manganese by aggregated UN/ECE Category and Fuel (tonnes)

	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[1]						
Public Power	20	16	6	6	6	15%
Other Industrial Combustion	18	16	16	16	16	41%
Combustion in Comm/Res	2	2	2	2	2	6%
Production Processes	3	3	2	2	2	5%
Road Transport	0	0	0	0	0	0%
Off-road Vehicles & Other Machinery[2]	26	19	13	14	13	34%
Other	0	0	0	0	0	1%
By FUEL TYPE						
Solid	35	30	19	18	19	49%
Petroleum	2	2	3	3	3	7%
Gas	0	0	0	0	0	0%
Non-Fuel	31	23	19	19	17	44%
TOTAL	**69**	**56**	**40**	**40**	**38**	**100%**

[1] See Annex 1 for definition of UN/ECE Categories

[2] Including railways, shipping, naval vessels, military aircraft and off-road sources

6.14 EMISSIONS OF TIN

Inhalation of dust and fumes may cause a disease of the lungs called stannosis. Table 6.14 summarises the UK emissions of tin. As estimates have only been included since the 2000 NAEI report the figures remain very uncertain. Emission factors have been calculated for the combustion of coal and heavy liquid fuels, but no data are available for other potential sources such as industrial processes. Further development of the tin inventory has been planned for future versions of the NAEI.

Table 6.14 UK Emissions of Tin by aggregated UN/ECE Category and Fuel (tonnes)

	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[1]						
Public Power	3.3	3.6	3.5	3.8	3.6	56%
Non-ferrous Metals	2.7	2.5	0.1	0.0	0.0	0%
Other Industrial Combustion	1.5	1.6	1.4	1.3	1.4	22%
Combustion in Comm/Res	0.1	0.1	0.1	0.1	0.1	2%
Road Transport	0.7	0.7	0.7	0.8	0.8	12%
Off-road Vehicles & Other Machinery[2]	0.6	0.6	0.5	0.4	0.4	7%
Other	0.1	0.1	0.1	0.1	0.1	1%
By FUEL TYPE						
Solid	4.3	4.6	4.2	4.3	4.3	66%
Petroleum	1.8	2.0	1.9	2.0	2.1	65%
Gas	0.0	0.0	0.0	0.0	0.0	0%
Non-Fuel	2.9	2.7	0.2	0.2	0.1	2%
TOTAL	**8.9**	**9.2**	**6.3**	**6.5**	**6.5**	**100%**

[1] See Annex 1 for definition of UN/ECE Categories

[2] Including railways, shipping, naval vessels, military aircraft and off-road sources

6.15 SPATIAL DISAGGREGATION OF HEAVY METALS

All of the heavy metal emission estimates presented here have been spatially disaggregated with the exception of beryllium, manganese and tin, and UK maps are presented in Figures 6.20 to 6.29. The key features that are evident from the maps are briefly considered here:

Arsenic

Significant emissions arise from coal combustion, and consequently emissions in Northern Ireland are noted to be relatively high. Individual points sources are also evident.

Cadmium

The major source for 2004 arises from Public Power generation, but the emissions from this source are not readily visible in a map, so road transport emissions appear the dominant source.

Chromium and Copper

The dominant sources of chromium are coal combustion, iron and steel production processes, and chromium-based chemicals manufacture. In the case of copper, the main sources are coal combustion, transport (Road Transport and off road machinery) and non-ferrous metals production. From the UK emission maps it can be seen that there are a number of point sources, and elevated emissions in Northern Ireland for both of these pollutants.

Lead

A significant contribution of the lead emissions comes from the non-ferrous metal industry but these point sources are not readily visible on the UK emissions map. Selected motorways are clearly visible from the UK emission map.

Mercury

The major sources of mercury in 2004 were waste incineration, coal combustion and specific industrial activities. As a result the UK emission map highlights a number of point sources. Other emissions are generally located in urban areas.

Nickel

Emissions of nickel are dominated by the combustion of coal and heavy fuel oil. Consequently areas of the country with refinery activities are highlighted. It is also interesting to note that urban areas are not particularly elevated, This is due to the higher use of gas in the domestic sector in areas of higher population density.

Selenium

Emissions of selenium arise from power generation and selected industrial processes as well as road transport. Consequently the UK emissions map displays major point sources, which can be rather difficult to see, as well as highlighting the road network.

Vanadium

Vanadium emissions primarily arise from refineries, road transport and the combustion of heavy fuel oil. As a result a large number of point sources may be identified from the emissions map, and the major road network is highlighted. Areas with low population density and domestic coal use are particularly highlighted as having low emissions.

Zinc

Zinc emissions primarily arise from combustion in the non-ferrous metals sector, iron and steel production processes and road transport (brake and tyre wear). As a result the UK emissions map highlights the road network and a number of point sources. However, the point sources are difficult to see due to the large number of grid cells where emissions are governed by the road transport sector.

Figure 6.11 UK Emissions Map[19] of Arsenic 2004

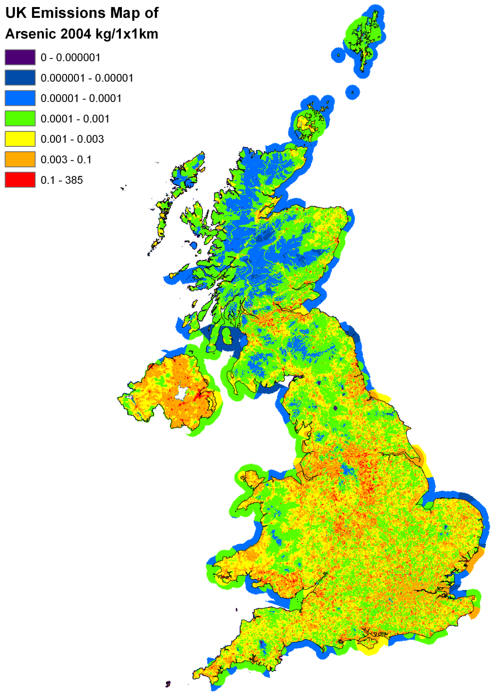


Figure 6.12 UK Emissions Map[20] of Cadmium 2004

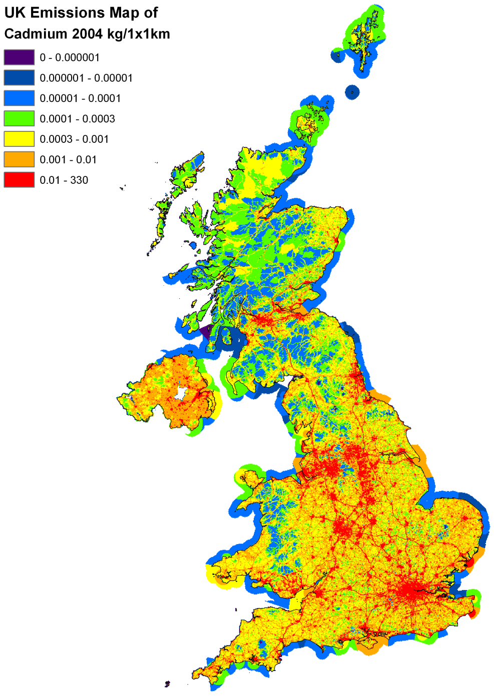


Figure 6.13 UK Emissions Map[21] of Chromium 2004

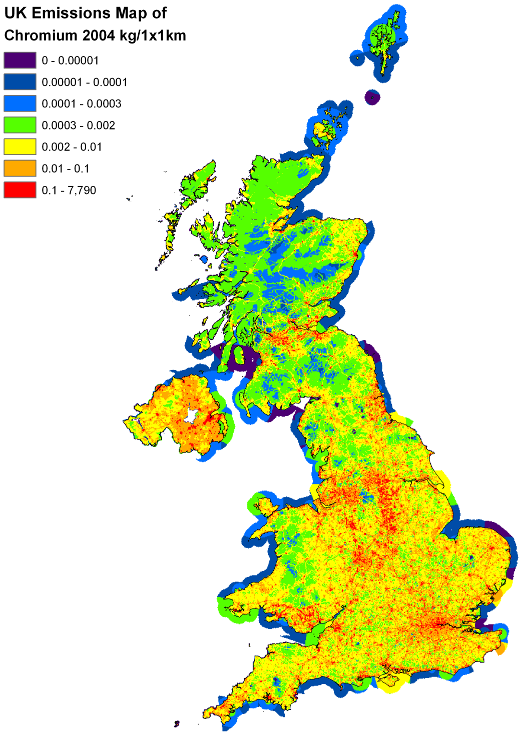


Figure 6.14 UK Emissions Map[22] of Copper 2004

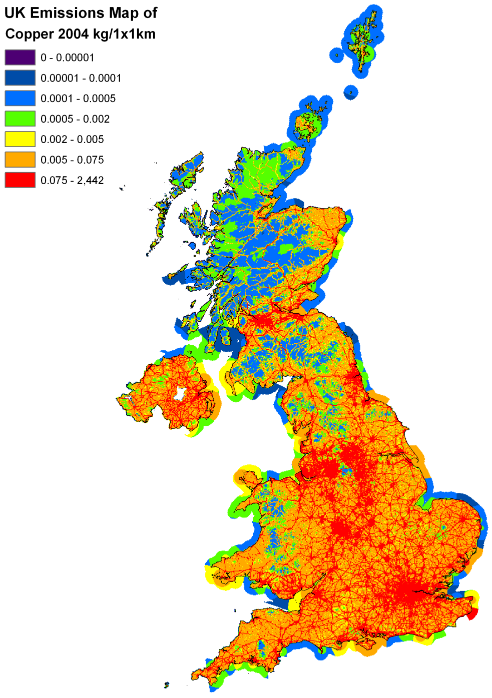


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Figure 6.15 UK Emissions Map[23] of Lead 2004

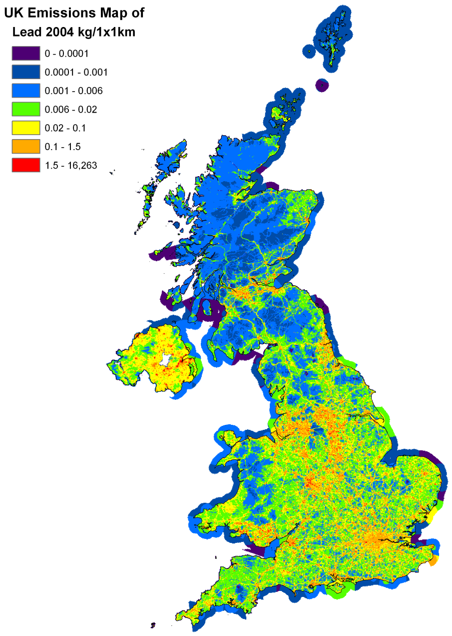

Figure 6.16 UK Emissions Map[24] of Mercury 2004

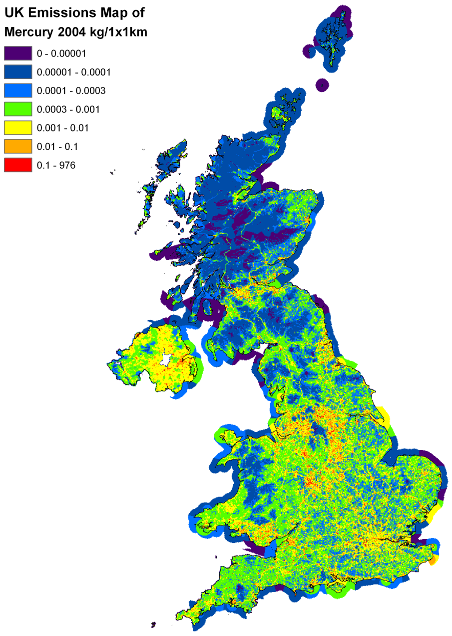

Figure 6.17 UK Emissions Map[25] of Nickel 2004

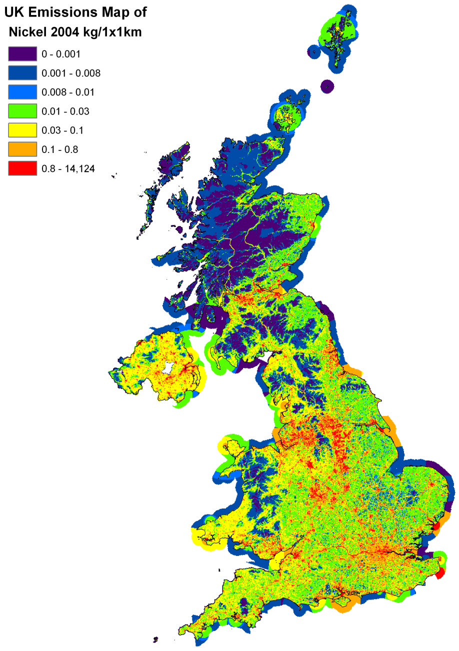

Figure 6.18 UK Emissions Map[26] of Selenium 2004

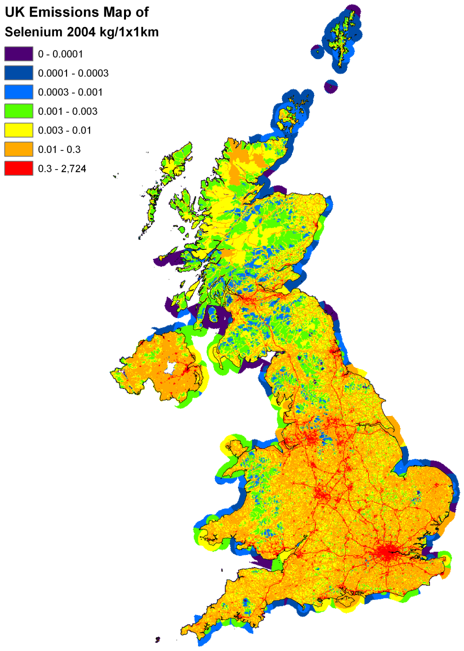

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Figure 6.19 UK Emissions Map[27] of Vanadium 2004

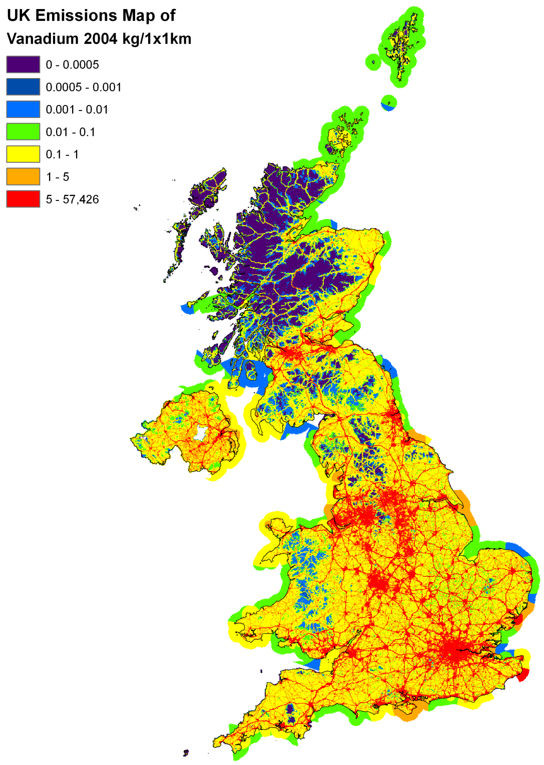
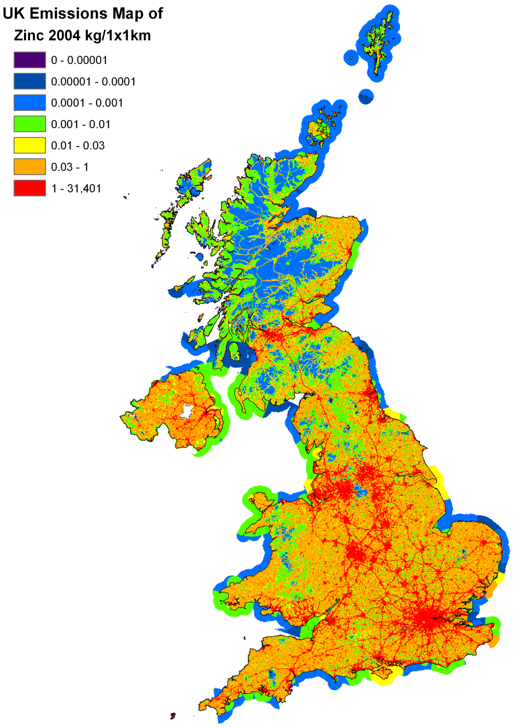


Figure 6.20 UK Emissions Map[28] of Zinc 2004



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6.16 ACCURACY OF EMISSION ESTIMATES OF HEAVY METALS

Quantitative estimates of the uncertainties in emission inventories have been based on calculations made using a direct simulation technique, which corresponds to the IPCC Tier 2 approach recommended for greenhouse gases and also the methodology proposed in draft guidance produced by the UN/ECE Taskforce on Emission Inventories and Projections. This work is described in detail by Passant (2002b). The uncertainty estimates are shown below in Table 6.15.

Table 6.15 Uncertainty of the Emission Inventories for metals

Pollutant	**Estimated Uncertainty %**
Arsenic	-50 to +100
Cadmium	-20 to +30
Chromium	-30 to +60
Copper	-30 to +50
Lead	-20 to +30
Mercury	-30 to +40
Nickel	-40 to +80
Selenium	-20 to +30
Vanadium	-60 to +100
Zinc	-30 to +50
Beryllium	-70 to +200
Manganese	-80 to +300
Tin	-80 to +300

The inventories for beryllium, manganese and tin are still being developed and are currently much more uncertain than those for other metals.

Among the remaining metal inventories, those for lead and chromium are least uncertain, while those for arsenic, selenium, and vanadium are most uncertain. In the case of lead and chromium, these inventories are less uncertain because of the reliability of estimates for major sources such as road transport in the case of lead, and chromium chemicals in the case of chromium. The inventories for arsenic, selenium and vanadium seem to be most uncertain because of the high uncertainty in estimates of emissions for major sources including burning of impregnated wood (arsenic), flat glass production (selenium), and combustion of fuel oil (vanadium).

7 Base Cations

7.1 INTRODUCTION

Base cation emission estimates for the UK are presented in this chapter. The emission estimates cover the period 1990-2004 for Calcium (Ca), Magnesium (Mg), Sodium (Na) and Potassium (K). These estimates are highly uncertain.

A base cation is essentially a positively charged ion from group 1 or 2 of the periodic table (the alkali metals or alkaline earth metals). The most environmentally abundant of these are Na, K, Ca and Mg. Base cations are important in the environment for two reasons.

- First, their deposition has an impact on the surface soil pH. The deposition of base cations increases the alkalinity of the surface; the effect in the environment is to buffer or neutralise the effects of the acidity generated by S and N deposition (which in their mobile anionic form, SO_4^{2-} and NO_3^-, leach Ca and Mg from the soil). Therefore one of the primary uses of these emission estimates is to use them to generate spatially resolved emission maps, which enable deposition maps to be calculated.
- Secondly, their emissions to air have an impact on atmospheric chemistry. It is important to understands the spatial distribution of emissions so that any impact on atmospheric chemistry , and resulting changes to pollutant transport can be accounted for in atmospheric chemistry and transport models.

7.2 BACKGROUND

A “critical load” approach is often taken to predict the maximum levels of acidity or alkalinity that an ecosystem can tolerate. The base cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) are known to be present in ambient air and in precipitation. The deposition of these base cations to ecosystems will offset to some extent the acidification resulting from the deposition of oxides of sulphur, oxides of nitrogen and NH_3.

The Review Group on Acid Rain (1997) reported on the decline in base cation deposition that has been observed in Europe and N America since the early 1970’s and how such a decline may offset some of the benefits of reductions in SO_2 emissions. Interest in the deposition and acid neutralising effects of base cations is mainly confined to Ca, K and Mg. It has long been assumed that the major source of these base cations in air is dust from soil erosion, but patterns of concentrations in air and precipitation also suggest significant emissions from urban and industrial sources. The concentrations of Ca, K and Mg in air and in precipitation measured at three rural sites in the UK declined dramatically between 1970 and 1991 (Lee and Pacyna, 1999). It has been suggested that the decrease in base cation deposition which has been observed is due to the reduction in emissions from urban and industrial sources. Concentrations of Na in air and rain have shown much smaller decreases over this period, consistent with its mainly marine origin as sea-salt.

The NAEI has estimated emissions from the following sources:

- **Stationary combustion of fossil fuels**: mainly in the fly ash from solid fuel combustion
- **Mineral extraction processes**: e.g. limestone quarrying
- **Processes in the mineral products industry**: e.g. cement manufacture and concrete batching
- **Industrial processes using limestone, dolomite and soda lime**:
  - iron and steel manufacture
  - glass manufacture
- **Agricultural use**: e.g. liming of soils and dust due to cultivation.
- **Construction and demolition activities**
- **Mobile sources**: mostly in the form of dust resuspension by traffic and exhaust emissions of potassium from lead replacement petrol (LRP).

There are likely to be base cation emissions from other sources, for example incineration. Currently, these are not included in the estimates as such sources are likely to be much smaller than the sources listed above, and the levels of uncertainty in estimating the above sources do not yet warrant investigation of other sources.

7.3 STATIONARY COMBUSTION OF FOSSIL FUELS

The base cations emitted from stationary combustion arise from the trace concentrations of the cations found in the fuels. The base cations will enter the atmosphere contained in the primary particulate matter (PM), which is emitted from the combustion source. Calcium has been found in large amounts in the fine particle size fraction collected from combustion sources.

The NAEI currently estimates PM_{10} emissions from large combustion plant for power generation using total PM emissions data submitted by the operators to the Environment Agency and the Scottish Environmental Protection Agency. Where reported data are incomplete, PM emission factors for the appropriate fuel are derived and combined with the amount of fuel used by the combustion plant to estimate the total mass of PM emitted.

The mass content of cations in coal has been estimated from the Turner-Fairbank Highway Research Centre (US Transport Department) figures for fly ash from bituminous coal. Data regarding the composition of fuel oil is given in the Marine Exhaust Research Programme.

7.4 MINERAL EXTRACTION PROCESSES

Limestone quarrying is a major source of atmospheric emissions of base cations, principally calcium. Quarrying of dolomite ($CaCO_3$ $MgCO_3$), rock salt (NaCl) and potash (KCl) are the principle sources of magnesium, sodium and potassium respectively.

The NAEI currently estimates PM_{10} emissions from quarrying using USEPA emission factors combined with UK mineral statistics on the production of each type of aggregate. The dust emitted from limestone quarrying will be mainly particles of limestone ($CaCO_3$) itself. These particulates will be mainly in the coarse particle size range (>2.5 µm) and will be deposited close to their source. The quantities of these minerals extracted in the UK are given in the Minerals Yearbook (2003).

7.5 PROCESSES IN THE MINERAL PRODUCTS INDUSTRY

Emissions of calcium from the mineral products industry are estimated from total PM_{10} emissions using emission factors from Lee and Pacyna (1999) or AEAT estimates of PM_{10} composition.

7.6 INDUSTRIAL PROCESSES USING LIMESTONE, DOLOMITE AND SODA ASH

Processes involving limestone, dolomite and soda ash include iron and steel production and glass manufacturing. Emissions of base cations from the iron and steel industry and the glass industry are based on the PM_{10} inventory combined with emission factors for cations taken from Lee and Pacyna (1999) or based on AEAT estimates of PM_{10} composition.

7.7 SOIL LIMING AND CULTIVATION IN AGRICULTURE

The practice of soil liming in agriculture will lead to the emission of Ca when the lime is applied to the ground. Statistics are available on the quantity of limestone used each year for liming (UK Minerals Yearbook 1990-2003) and an emission is estimated using an emission factor for non-metallic particles given by the USEPA. The average quantities of re-suspended dust, as a result of land cultivation, may be estimated from data reported in the MAFF Report CSG 15 (2000). Emissions are estimated from the average chemical abundance of each cation in UK soil (Lindsay, 1979).

7.8 CONSTRUCTION ACTIVITIES

The NAEI currently uses a USEPA emission factor combined with UK construction activity statistics to estimate fugitive emissions of PM_{10} from these processes. A modified PM_{10} emission factor based on the fraction of total aggregate used in construction (UK Minerals Yearbook 1990-2002) that is limestone, dolomite or chalk, is used to estimate the base cation emissions.

7.9 MOBILE SOURCES

Emissions of base cations from mobile sources will mainly arise from the resuspension of road dust by traffic. Recently, Nicholson (2000) has made an estimate of the total PM_{10} emission from UK roads. Using this information with data on the average chemical composition of road dust (Sloss and Smith, 2000) Na, K and Ca emissions have been estimated. There are insignificant quantities of Mg in road dust.

Potassium compounds are the primary additives in Lead Replacement Petrol (LRP). LRP has been available since Autumn 1999 and is the main source of potassium emissions from vehicle exhausts. Emissions have been estimated from UK LRP sales in 1999 (calculated as a fraction of leaded petrol sales) to 2004 given by the Digest of United Kingdom Energy Statistics (DTI, 2004).

7.10 CALCIUM

Combustion in industry and production processes contribute the most emissions of calcium. Within the latter sector quarrying, cement production and lime production are the most significant contributors. However, more recently the introduction of abatement measures have ensured reductions in the emissions.

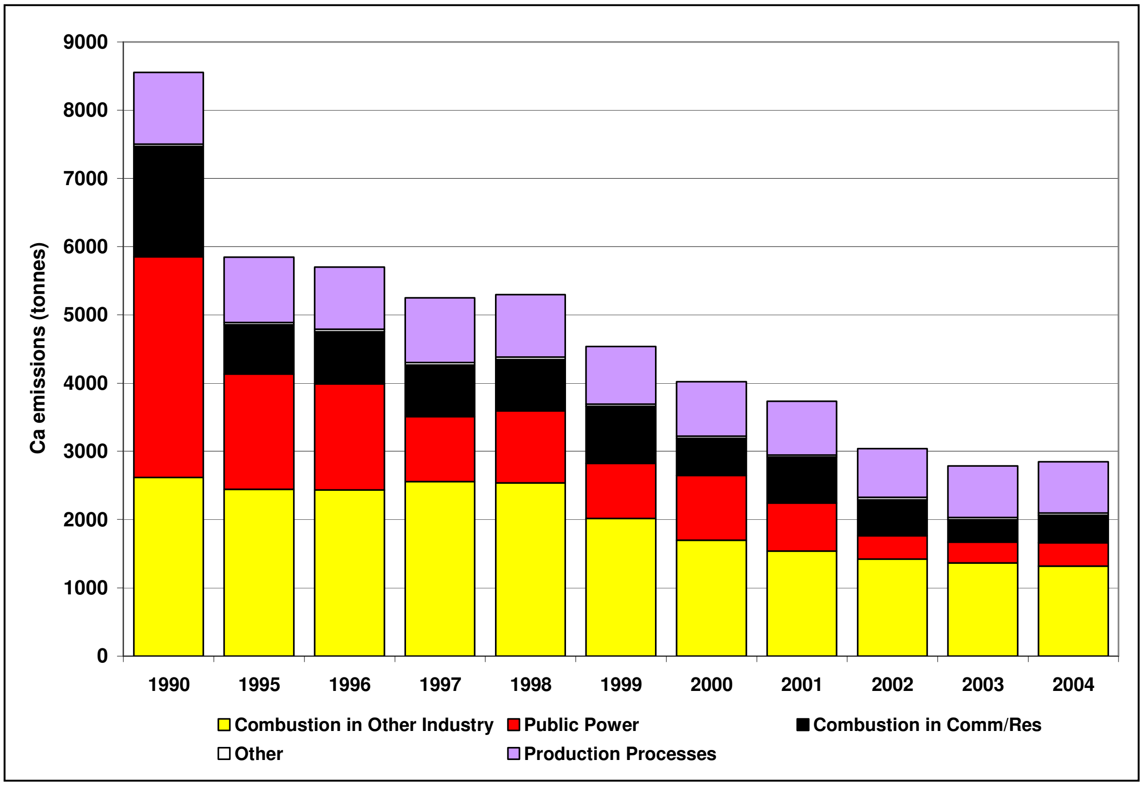
Table 7.1 UK Emissions of Calcium by aggregated UN/ECE Source Category (ktonnes)

	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[1]												
Public Power	3.2	1.7	1.6	0.9	1.1	0.8	0.9	0.7	0.3	0.3	0.3	12%
Iron and Steel	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	2%
Combustion in Other Industry	2.6	2.4	2.4	2.5	2.5	2.0	1.6	1.5	1.4	1.3	1.3	45%
Combustion in Comm/Res	1.6	0.7	0.8	0.8	0.8	0.8	0.5	0.7	0.5	0.3	0.4	14%
Off-road Vehicles and Other Machinery[2]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Production Processes	1.1	1.0	0.9	0.9	0.9	0.8	0.8	0.8	0.7	0.8	0.8	26%
Agriculture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1%
TOTAL	**8.6**	**5.8**	**5.7**	**5.2**	**5.3**	**4.5**	**4.0**	**3.7**	**3.0**	**2.8**	**2.8**	**100%**

[1] See Annex 1 for definition of UN/ECE Categories

[2] Including railways, shipping, naval vessels, military aircraft and off-road sources

Figure 7.1 Time Series of Calcium Emissions (tonnes)



7.11 MAGNESIUM

The largest single source of magnesium emissions is from the quarrying of dolomite, used as an aggregate. This emission falls within the production processes sector. Quarrying in general is a significant source. Domestic coal burning is responsible for 62 tonnes, and coal burning power stations released 107 tonnes.

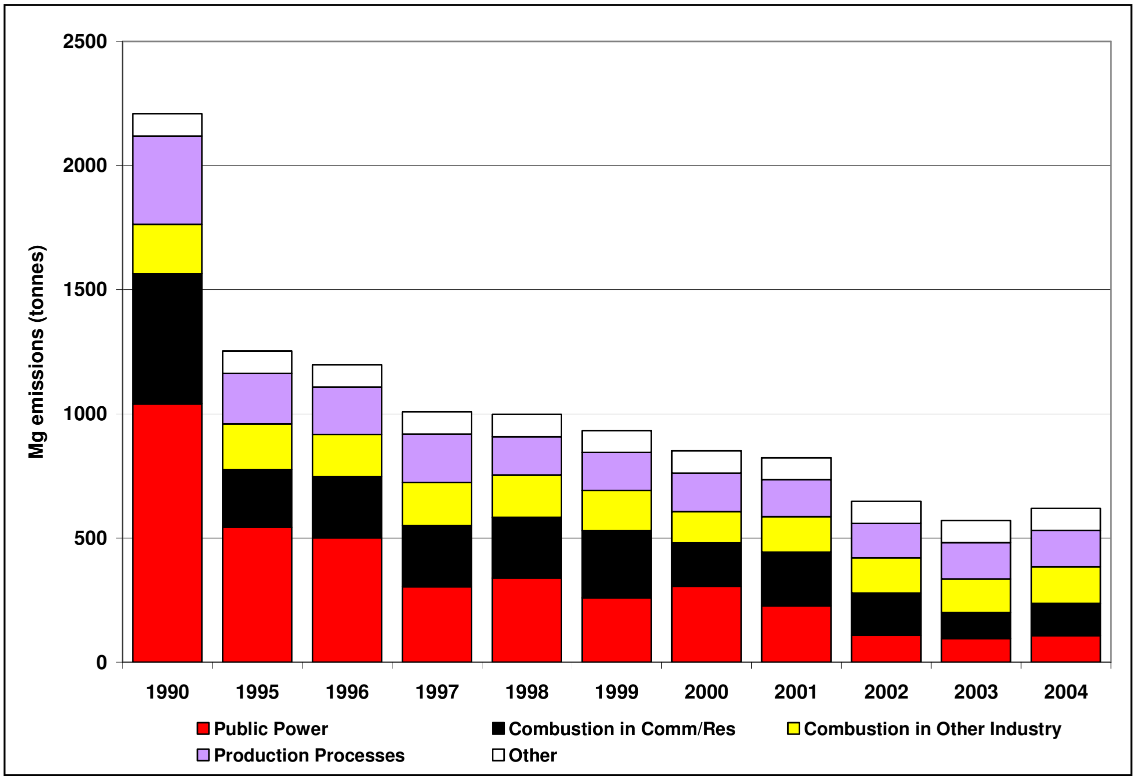
Estimates of emissions of magnesium from coal combustion at Alcan's Ashington power station have been revised downwards. Estimates for slag cement grinding, fireworks and burning of waste lubricants have all been included in the emission estimates.

Table 7.2 UK Emissions of Magnesium by aggregated UN/ECE Source Category (ktonnes)

	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[1]												
Public Power	1.0	0.5	0.5	0.3	0.3	0.3	0.3	0.2	0.1	0.1	0.1	17%
Combustion in Other Industry	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	24%
Combustion in Comm/Res	0.5	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.1	0.1	21%
Production Processes	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	24%
Agriculture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2%
Other	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	12%
TOTAL	**2.2**	**1.3**	**1.2**	**1.0**	**1.0**	**0.9**	**0.9**	**0.8**	**0.6**	**0.6**	**0.6**	**100%**

[1] See Annex 1 for definition of UN/ECE Categories

Figure 7.2 Time Series of Magnesium Emissions (tonnes)



7.12 SODIUM

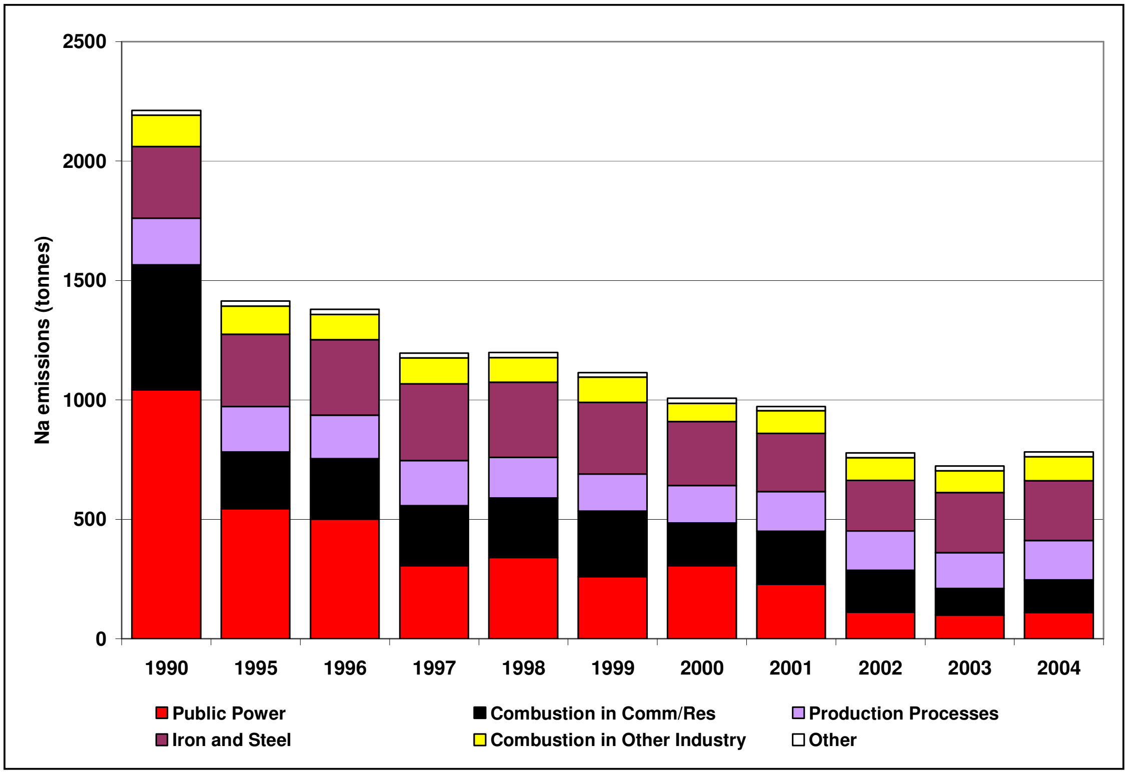
Iron and steel production from sinter plants is responsible for the greatest single emission of sodium with 251 tonnes in 2004. Domestic coal burning emissions contribute 114 tonnes and coal burning power stations 105 tonnes. Other sources include glass manufacture and the food manufacture/preparation sectors.

Table 7.3 UK Emissions of Sodium by aggregated UN/ECE Source Category (ktonnes)

	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[1]												
Public Power	1.04	0.54	0.50	0.31	0.34	0.26	0.31	0.23	0.11	0.10	0.11	14%
Iron and Steel	0.30	0.30	0.32	0.32	0.31	0.30	0.27	0.24	0.21	0.25	0.25	32%
Combustion in Other Industry	0.13	0.12	0.11	0.11	0.10	0.11	0.08	0.09	0.09	0.09	0.10	13%
Combustion in Comm/Res	0.52	0.24	0.25	0.25	0.25	0.27	0.18	0.22	0.18	0.11	0.14	17%
Production Processes	0.20	0.19	0.18	0.19	0.17	0.16	0.16	0.17	0.16	0.15	0.16	21%
Agriculture	0.01	0.01	0.02	0.02	0.02	0.01	0.02	0.01	0.02	0.01	0.01	2%
Other	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	1%
TOTAL	**2.21**	**1.41**	**1.38**	**1.20**	**1.20**	**1.11**	**1.01**	**0.97**	**0.78**	**0.72**	**0.78**	**100%**

[1] See Annex 1 for definition of UN/ECE Categories

Figure 7.3 Time Series of Sodium Emissions (tonnes)



7.13 POTASSIUM

As with sodium, iron and steel productions is responsible for the majority of potassium emissions, 333 tonnes, followed by domestic coal burning with 98 tonnes. Fireworks are the third main contributor, causing the emissions of 332 tonnes of potassium in 2004.

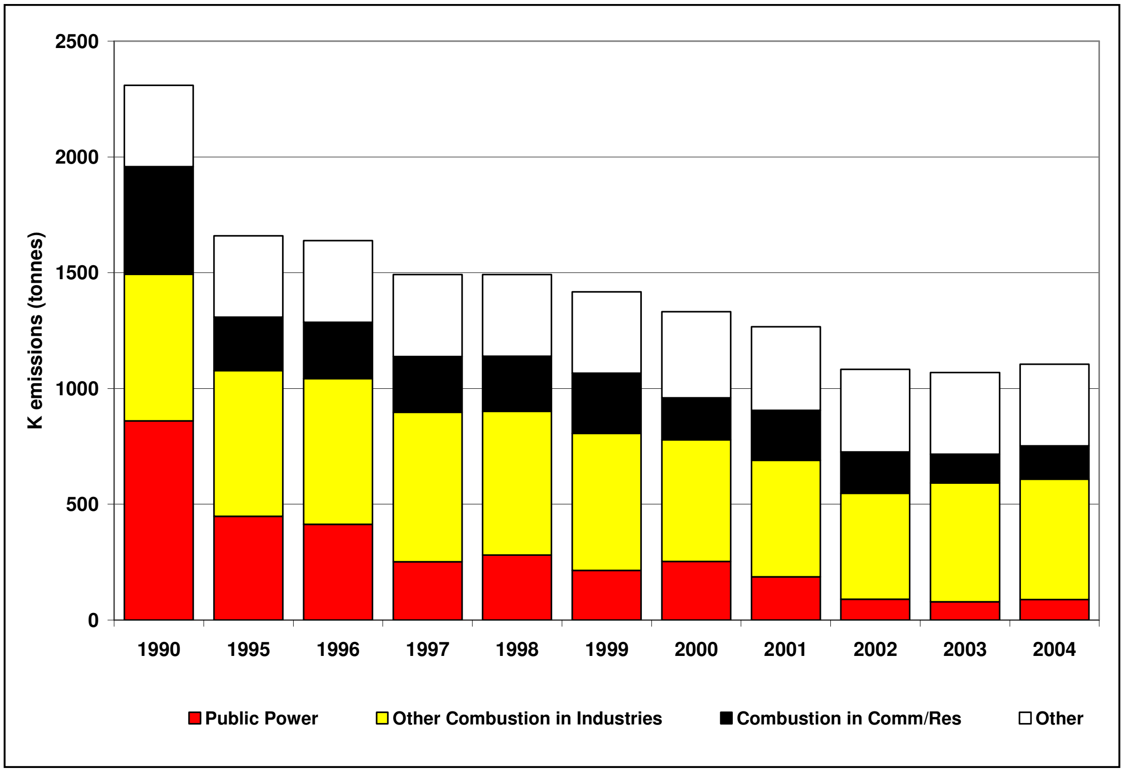
Estimates of emissions of potassium from coal combustion at Alcan's Ashington power station have been revised downwards. Estimates for slag cement grinding, fireworks and burning of waste lubricants have all been added for the first time. The net impact of these changes is that there has been very little change to the total emission quoted in previous versions of the inventory.

Table 7.4 UK Emissions of Potassium by aggregated UN/ECE Source Category (ktonnes)

	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2004%
BY UN/ECE CATEGORY[1]												
Public Power	0.9	0.4	0.4	0.3	0.3	0.2	0.3	0.2	0.1	0.1	0.1	8%
Iron and Steel	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	30%
Combustion in Other Industry	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	11%
Combustion in Comm/Res	0.5	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.1	0.1	13%
Production Processes	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	6%
Agriculture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2%
Other	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.3	30%
TOTAL	2.3	1.7	1.6	1.5	1.5	1.4	1.3	1.3	1.1	1.1	1.1	**100%**

[1] See Annex 1 for definition of UN/ECE Categories

Figure 7.4 Time Series of Potassium Emissions (tonnes)



7.14 ACCURACY OF EMISSION ESTIMATES OF BASE CATIONS

Quantitative estimates of the uncertainties in emission inventories have been based on calculations made using a direct simulation technique, which corresponds to the IPCC Tier 2 approach recommended for greenhouse gases and also the methodology proposed in draft guidance produced by the UN/ECE Taskforce on Emission Inventories and Projections. This work is described in detail by Passant (2002b). The estimates are shown in Table 8.5.

Table 7.5 Uncertainty of the Emission Inventories for Base Cations

Pollutant	**Estimated Uncertainty %**
Calcium	-50% to +200%
Magnesium	-40% to +90%
Sodium	-40% to +100%
Potassium	-60% to +200%

Inventories for base cations continue to undergo improvement and development. However, many of the emission estimates are still subject to significant uncertainty. This is because they are based on emission estimates for PM_{10} (which are themselves highly uncertain), coupled with estimates of the chemical composition of the PM_{10} which add further uncertainty.

8 Crown Dependencies and Overseas Territories

8.1 INTRODUCTION

The following chapter details greenhouse gas emission inventories compiled for UK Crown Dependencies (CDs) and selected UK Overseas Territories (OTs), for the annual periods of 1990 to 2004 inclusive.

The greenhouse gases (GHGs) reported are the basket of six compounds- carbon, methane, nitrous oxide and f-gases (HFCs, PFCs and SF_6). Several air quality pollutants have also been estimated for most of these locations. However, only selected pollutants are reported here for CDs, to reflect those emissions required for international reporting.

Difficulty in obtaining suitable input data has meant that it has not always been possible to apply particularly robust methodologies. The differing economic status and climates of these areas has also had to be taken into account. Methodologies for each location are therefore involved, and are not presented here in detail (but have been reported elsewhere). However tables of emission estimates are presented.

8.2 REPORTING GREENHOUSE GASES

The UK makes two submissions under the UNFCCC. Countries submit greenhouse gas emissions inventories directly, and also EU member states submit data to the EU under the European Union Monitoring Mechanism (EUMM). This is because the EU is itself a signatory to the UNFCCC, and needs to compile it's own EU wide submission for the UNFCCC.

In 2005, an invitation was sent out by the government to all of the UK overseas territories to come under an umbrella agreement with the UK for the ratification of the Kyoto protocol. The invitation was accepted by the following locations:

- The Bailiwick of Jersey
- The Bailiwick of Guernsey29
- The Isle of Man
- The Falkland Islands
- The Cayman Islands
- Bermuda
- Montserrat
- Akrotiri and Dhekhelia30
- Gibraltar

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[29] The Bailiwick of Guernsey includes: Guernsey itself as well as Alderney, Sark and Herm.

[30] These are UK Sovereign Bases (SB) located in Cyprus

A decision was made on behalf of the Pitcairn Islands and other smaller territories that they did not wish to be included. Table 8.1 summarises the current status of the Overseas Territories and Crown Dependencies in the UK GHG inventory.

Table 9.1 Crown Dependencies and Overseas Territories in the UK GHG Inventory

Category	Name	Part of British Isles	Part of the UK	Part of EU	Included in 2004 UK GHG inventory
CD	**The Isle of Man**	✓	✗	✗	✓
	The Bailiwick of Jersey	✓	✗	✗	✓
	The Bailiwick of Guernsey	✓	✗	✗	✓
OT	Anguilla	✗	✗	✗	✗
	British Antarctic Territory	✗	✗	✗	✗
	Bermuda	✗	✗	✗	✓
	British Indian Ocean Territory	✗	✗	✗	✗
	British Virgin Islands	✗	✗	✗	✗
	The Cayman Islands	✗	✗	✗	✓
	The Falkland Islands	✗	✗	✗	✓
	Gibraltar	✗	✗	✓	✓
	Montserrat	✗	✗	✗	✓
	St Helena and Dependencies	✗	✗	✗	✗
	Turk and Caicos Islands	✗	✗	✗	✗
	Pitcairn Island	✗	✗	✗	✗
	South Georgia and South Sandwich Islands	✗	✗	✗	✗
SB	Akrotiri & Dhekhelia	✗	✗	✗	✗

8.3 REPORTING AIR QUALITY POLLUTANTS

The 1979 Geneva Convention on Long-range Transboundary Air Pollution and the 1988 Sofia Protocol (concerning Nitrogen Oxides) define the "UK" as including Bailiwicks of Jersey and Guernsey, the Isle of Man, Gibraltar, and the United Kingdom Sovereign Base Areas of Akrotiri and Dhekhelia on the Island of Cyprus. As a result NO_x and NMVOC emission estimates have been compiled for these locations. For other protocols relating to air quality pollutant emissions, several locations are excluded as the "UK" is defined as including the Bailiwicks of Jersey and Guernsey and the Isle of Man only.

Emission estimates have been compiled in conjunction with the GHG emission estimates indicated in Section 8.2 to ensure consistency, but are not included here as they have been reported elsewhere.

8.4 TABULATED EMISSIONS

8.4.1 THE BAILIWICK OF JERSEY

Table A 1.1 Jersey Carbon emissions (ktonnes)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Energy - power stations & small combustion sources	117	117	146	129	137	140	144	142	158	130	105	95	90	75	81
Energy - road transport	35	35	35	36	37	37	36	37	36	36	35	36	35	35	34
Energy - other mobile sources	121	115	118	124	116	115	114	112	110	113	114	113	111	111	111
Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvent use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Land use change & forestry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A 1.2 Jersey CH4 emissions (ktonnes)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Energy - power stations & small combustion sources	0.10	0.10	0.09	0.09	0.09	0.09	0.10	0.10	0.11	0.11	0.11	0.10	0.10	0.10	0.10
Energy - road transport	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02
Energy - other mobile sources	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvent use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.87	0.85	0.74	0.67	0.67
Land use change & forestry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Waste	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.05

Table A 1.3 Jersey N2O emissions (ktonnes)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Energy - power stations & small combustion sources	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Energy - road transport	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Energy - other mobile sources	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvent use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.016	0.015	0.014	0.012	0.012
Land use change & forestry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Table A1.4 Jersey F-gases (tonnes) (sector 2: Industrial Processes)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
HFC	0.00	0.01	0.02	0.34	1.01	1.91	2.90	3.67	4.73	5.63	6.28	6.84	7.29	7.48	7.52
PFC	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
SF_6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01

8.4.2 THE BAILIWICK OF GUERNSEY

Table A 1.8 Guernsey Carbon emissions (ktonnes)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Energy - power stations & small combustion sources	75	90	77	81	81	85	90	92	91	88	91	43	45	47	28
Energy - road transport	25	25	24	24	24	25	25	27	26	28	28	29	25	25	22
Energy - other mobile sources	42	42	42	42	42	42	45	45	45	45	49	49	49	49	49
Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvent use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Land use change & forestry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A 1.9 Guernsey CH4 emissions (ktonnes)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Energy - power stations & small combustion sources	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
Energy - road transport	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01
Energy - other mobile sources	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02
Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvent use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	0.58	0.58	0.58	0.58	0.58	0.58	0.45	0.45	0.45	0.45	0.45	0.40	0.37	0.37	0.37
Land use change & forestry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Waste	1.89	1.85	1.80	1.74	1.71	1.65	1.59	1.48	1.38	1.15	1.10	0.93	0.86	0.76	0.71

Table A 1.10 Guernsey N2O emissions (ktonnes)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Energy - power stations & small combn sources	0.002	0.003	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.001	0.001	0.001	0.001
Energy - road transport	0.003	0.003	0.003	0.004	0.005	0.007	0.008	0.010	0.011	0.013	0.014	0.016	0.015	0.016	0.015
Energy - other mobile sources	0.026	0.026	0.026	0.026	0.026	0.026	0.027	0.027	0.027	0.027	0.028	0.028	0.028	0.028	0.028
Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvent use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	0.010	0.010	0.010	0.010	0.010	0.010	0.008	0.008	0.008	0.008	0.008	0.007	0.007	0.007	0.007
Land use change & forestry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Waste	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004

Table A1.11 Guernsey F-gases (tonnes) (sector 2: Industrial Processes)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
HFC	0.001	0.010	0.011	0.143	0.458	0.972	1.569	2.082	2.825	3.335	3.821	4.157	4.478	4.662	4.821
PFC	0.003	0.003	0.003	0.003	0.003	0.004	0.005	0.006	0.005	0.006	0.006	0.007	0.000	0.000	0.000
SF_6	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

8.4.3 THE ISLE OF MAN

Table A 1.5 Isle of Man Carbon emissions (ktonnes)

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Energy - power stations & small combustion sources	70	72	72	74	74	81	88	95	101	105	97	66	70	70	87
Energy - road transport	24	24	25	24	24	25	39	36	39	38	30	38	40	43	43
Energy - other mobile sources	36	36	36	36	36	43	43	44	45	45	47	47	48	48	48
Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvent use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Land use change & forestry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A 1.6 Isle of Man CH4 emissions (ktonnes)

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Energy - power stations & small combustion sources	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Energy - road transport	0.04	0.04	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02
Energy - other mobile sources	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvent use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	4.13	4.24	4.34	4.03	4.09	4.16	4.15	4.17	4.46	4.54	4.52	4.36	4.37	2.90	2.83
Land use change & forestry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Waste	2.21	2.19	2.15	2.10	2.07	2.01	1.94	1.80	1.69	1.40	1.35	1.14	1.05	0.94	0.05

Table A 1.7 Isle of Man N2O emissions (ktonnes)

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Energy - power stations & small combustion sources	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Energy - road transport	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.02	0.02	0.03	0.03
Energy - other mobile sources	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvent use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.05	0.05
Land use change & forestry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A1.8 Isle of Man F-gases (tonnes) (sector 2: Industrial Processes)

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
HFC	0.00	0.01	0.01	0.14	0.46	1.00	1.64	2.18	3.02	3.64	4.18	4.59	4.98	5.25	5.50
PFC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00
SF_6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01

8.4.4 BERMUDA

Table A 1.20 Bermuda Carbon emissions (ktonnes)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Energy - power stations & small combustion sources	111	112	113	114	115	116	117	118	119	121	122	123	124	125	126
Energy - road transport	55.2	54.1	53.0	51.9	50.9	49.8	48.8	47.8	46.8	45.8	44.9	43.9	42.9	41.9	40.9
Energy - other mobile sources	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvent use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Land use change & forestry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A 1.21 Bermuda CH4 emissions (ktonnes)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Energy - power stations & small combn sources	0.041	0.037	0.033	0.029	0.025	0.021	0.0202	0.0194	0.0186	0.0178	0.017	0.0162	0.0154	0.0146	0.0138
Energy - road transport	0.02	0.024	0.028	0.032	0.036	0.04	0.040	0.040	0.039	0.039	0.039	0.039	0.039	0.038	0.038
Energy - other mobile sources	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvent use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	0.08	0.082	0.084	0.086	0.088	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Land use change & forestry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Waste	3.26	0.28	0.28	0.28	0.28	0.28	0.282	0.284	0.286	0.288	0.29	0.292	0.294	0.296	0.298

Table A 1.22 Bermuda N2O emissions (ktonnes)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Energy - power stations & small combn sources	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Energy - road transport	0.002	0.002	0.002	0.002	0.002	0.002	0.0018	0.0016	0.0014	0.0012	0.001	0.0008	0.0006	0.0004	0.0002
Energy - other mobile sources	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvent use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Land use change & forestry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Waste	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006

8.4.5 THE CAYMAN Islands

Table A 1.16 Cayman Islands Carbon emissions (ktonnes)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Energy - power stations & small combustion sources	32	34	35	36	37	39	40	41	42	48	52	56	60	62	65
Energy - road transport	6	6	6	7	7	7	7	7	8	8	9	8	5	6	6
Energy - other mobile sources	7	8	8	8	9	9	9	9	8	9	9	9	8	8	9

Table A 1.17 Cayman Islands CH4 emissions (ktonnes)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Energy - power stations & small combn sources	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003
Energy - road transport	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Energy - other mobile sources	0.011	0.012	0.012	0.012	0.011	0.011	0.010	0.009	0.008	0.008	0.007	0.006	0.005	0.005	0.004

Table A 1.18 Cayman Islands N2O emissions (ktonnes)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Energy - power stations & small combustion sources	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002
Energy - road transport	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy - other mobile sources	0.001	0.001	0.001	0.002	0.002	0.003	0.003	0.004	0.004	0.005	0.005	0.005	0.006	0.006	0.006

Table A1.19 Cayman Islands F-gases (tonnes) (sector 2: Industrial Processes)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
HFC	0.000	0.004	0.005	0.143	0.471	0.859	1.317	1.731	2.339	2.965	3.606	4.041	4.506	4.890	5.508
PFC	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.003	0.002	0.003	0.003	0.004	0.000	0.000	0.000
SF_6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.002	0.002	0.002	0.003	0.006

8.4.6 THE FALKLAND ISLANDS

Table A 1.12 Falkland Islands Carbon emissions (ktonnes)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Energy - power stations & small combustion sources	38	40	41	43	45	47	48	50	51	53	54	55	56	57	55
Energy - road transport	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Energy - other mobile sources	10	10	11	11	11	11	11	12	12	11	9	11	11	11	11
Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvent use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Land use change & forestry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Waste	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

Table A 1.13 Falkland Islands CH4 emissions (ktonnes)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Energy - power stations & small combustion sources	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Energy - road transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Energy - other mobile sources	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvent use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	6.16	6.07	5.93	6.00	6.05	5.97	5.70	5.88	5.88	5.89	6.00	5.76	5.54	5.27	5.32
Land use change & forestry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A 1.14 Falkland Islands N2O emissions (ktonnes)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Energy - power stations & small combustion sources	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.000
Energy - road transport	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Energy - other mobile sources	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvent use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	0.124	0.123	0.120	0.121	0.124	0.125	0.122	0.123	0.118	0.118	0.120	0.139	0.136	0.128	0.129
Land use change & forestry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Waste	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table A1.15 Falkland Islands F-gases (tonnes) (sector 2: Industrial Processes)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
HFC	0.000	0.000	0.000	0.008	0.024	0.047	0.074	0.095	0.128	0.150	0.168	0.183	0.199	0.210	0.221
PFC	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SF_6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

8.4.7 GIBRALTAR

Table A 1.23 Gibraltar Carbon emissions (ktonnes)

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Energy - power stations & small combustion sources	34	37	37	32	36	35	33	35	35	37	38	38	38	37	39
Energy - road transport	6	6	6	5	5	5	5	6	6	6	7	8	8	9	10
Energy - other mobile sources	26	28	34	30	29	26	31	33	39	43	44	44	50	55	61
Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvent use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Land use change & forestry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Waste	1	1	1	1	1	1	1	1	2	2	2	0	0	0	0

Table A 1.24 Gibraltar CH4 emissions (ktonnes)

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Energy - power stations & small combustion sources	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002
Energy - road transport	0.008	0.009	0.010	0.007	0.007	0.007	0.007	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Energy - other mobile sources	0.008	0.009	0.011	0.010	0.009	0.008	0.010	0.011	0.013	0.014	0.014	0.014	0.016	0.018	0.020
Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvent use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Land use change & forestry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Waste	0.047	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0	0	0	0

Table A 1.25 Gibraltar N2O emissions (ktonnes)

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Energy - power stations & small combustion sources	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Energy - road transport	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.003	0.003	0.004	0.005	0.005	0.006	0.006
Energy - other mobile sources	0.007	0.008	0.009	0.008	0.008	0.007	0.008	0.009	0.010	0.011	0.011	0.011	0.013	0.014	0.015
Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvent use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Land use change & forestry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Waste	0.001	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0	0	0	0

Table A1.26 Gibraltar F-gases (tonnes) (sector 2: Industrial Processes)

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
HFC	0.001	0.005	0.005	0.138	0.426	0.753	1.115	1.426	1.859	2.241	2.635	3.003	3.295	3.497	3.772
PFC	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.003	0.002	0.002	0.002	0.003	0.000	0.000	0.000
SF_6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.002	0.002	0.004

8.4.8 MONTSERRAT

Table A 1.27 Montserrat Carbon emissions (ktonnes)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Energy - power stations & small combustion sources	5.0	4.9	4.9	4.9	4.8	4.8	3.6	2.8	1.3	1.6	1.8	1.8	2.0	1.8	1.8
Energy - road transport	6.5	6.4	6.3	6.3	6.2	6.2	4.7	3.6	1.6	2.0	2.3	3.3	3.2	3.9	4.3
Energy - other mobile sources	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvent use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Land use change & forestry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Waste	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

Table A 1.28 Montserrat CH4 emissions (ktonnes)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Energy - power stations & small combustion sources	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy - road transport	0.010	0.010	0.010	0.010	0.010	0.010	0.007	0.006	0.003	0.003	0.004	0.004	0.004	0.004	0.004
Energy - other mobile sources	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvent use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Land use change & forestry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Waste	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

Table A 1.29 Montserrat N2O emissions (ktonnes)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Energy - power stations & small combustion sources	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy - road transport	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001	0.001	0.001	0.002
Energy - other mobile sources	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solvent use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Land use change & forestry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Waste	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

Table A1.30 Montserrat F-gases (tonnes) (sector 2: Industrial Processes)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
HFC	0.000	0.002	0.002	0.024	0.077	0.162	0.199	0.202	0.123	0.179	0.230	0.292	0.318	0.327	0.354
PFC	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SF_6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001

9 References

APARG (1996), The Abatement of Toxic Organic Micropollutants (TOMPS) from Stationary Sources. Report to the Air Pollution Abatement Review Group.

APEG (1999), Source Apportionment of Airborne Particulate Matter in the United Kingdom. Report of the Airborne Particles Expert Group. ISBN 0-7058-1771-7.

Baggott SL, Brown L, Milne R, Murrells TP, Passant N, Thistlethwaite G, Watterson JD (2005), UK Greenhouse Gas Inventory, 1990 to 2003. Netcen, AEA Technology, Harwell, Oxfordshire. ISBN 0-9547136-2-1.

Baggott SL, Brown L, Milne R, Murrells TP, Passant N, Thistlethwaite G, Watterson JD, Jackson J (2006), UK Greenhouse Gas Inventory, 1990 to 2004. Netcen, AEA Technology, Harwell, Oxfordshire. ISBN 0-9547136-8-0.

Buckingham, C (1997), Atmospheric Emissions Inventory for Greater Manchester. LRC, London.

Clayton P, Coleman P, Leonard A, Loader A, Marlowe I, Mitchell D, Richardson S, Scott D, (1991), Review of Municipal Solid Waste Incineration in the UK. Warren Spring Laboratory Report LR776(PA).

Coleman P, Bush T, Conolly C, Irons S, Murrells T, Vincent K, Watterson J (2001), Assessment of Benzo[a]pyrene atmospheric concentrations in the UK to support the establishment of a national PAH objective. AEAT/ENV/R/0620 Issue 5.1.1. Netcen, AEA Technology, Harwell, Oxfordshire.

Coleman P, Conolly, C, Dyke, P & Watterson, J (2001), Toxic Organic Micropollutant Moitoring 1999 to 2000, AEA Technology, Report No AEAT/R/ENV/0301 Issue 1

Couling SB, Passant NR, Richardson SR, Marlowe I, Eggleston HS, Salway AG, (1994), UK Emissions to Atmosphere of Heavy Metals covered by the Hague Declaration. AEA/CS/16419044/Z003. Netcen, AEA Technology, Harwell, Oxfordshire.

DETR (1998a), Review of the United Kingdom National Air Quality Strategy - A Consultation Document. 98EP0541/A. The Stationary Office, Norwich.

DETR (2000), The Air Quality Strategy for England, Scotland, Wales and Northern Ireland-Working Together for Clean Air. The Stationary Office, Norwich.

Defra (2001), The Air Quality Strategy for England, Scotland, Wales and Northern Ireland - A Consultation Document on Proposals for Air Quality Objectives for Particles, Benzene, Carbon Monoxide and PAHs. HMSO.

Defra (2003), The Air Quality Strategy for England, Scotland, Wales and Northern Ireland: Addendum. HMSO.

DOE (1989), Sources of HCH discharge to the aquatic environment (Draft).

DOE (1994), Impacts of Nitrogen Deposition on Terrestrial Ecosystems, Report of : The UK Review Group on Impacts of Atmospheric Nitrogen. ISBN 1-870393-22-8.

DOE (1997), The United Kingdom National Air Quality Strategy. CM3587. The Stationary Office, London.

Dore CJ, Goodwin JWL, Watterson JD, Murrells TP, Passant NR, Hobson MM, Haigh KE, Baggott S L, Thistlethwaite G, Pye ST, Coleman PJ, King KR (2003), UK Emissions of Air Pollutants 1970-2001. Netcen, AEA Technology, Harwell, Oxfordshire. Report AEAT/ENV/R/1593. ISBN 1-85580-033-0.

Dore CJ, Watterson JD, Goodwin JWL, Murrells TP, Passant NR, Hobson MM, Baggott S L, Thistlethwaite G, Coleman PJ, King KR, Adams M, Cumine P R (2004), UK Emissions of Air Pollutants 1970-2002. Netcen, AEA Technology, Harwell, Oxfordshire. Report AEAT/ENV/R/1933. ISBN 0954713648.

Dore CJ, Watterson JD, Goodwin JWL, Murrells TP, Passant NR, Hobson MM, Baggott S L, Thistlethwaite G, Coleman PJ, King KR, Adams M, Walker C, Downes MK, Steward RA, Wagner A, Sturman J, Conolly C, Lawrence H, Cumine PR (2004), UK Emissions of Air Pollutants 1970-2002. Netcen, AEA Technology, Harwell, Oxfordshire. Report AEAT/ENV/R/2160. ISBN 0954713672.

Dragosits U and Sutton MA (2003), Update on Ammonia emissions from non-agricultural sources for the NAEI 1970-2002.

DTI (2004), Digest of United Kingdom Energy Statistics 2003. London. The Stationary Office.

Eggleston HS (1988), UK Emissions of Air Pollutants 1970-1986. LR 659 (AP)M. Warren Spring Laboratory, Stevenage.

Eggleston HS, Munday PK (1989), UK Emissions of Air Pollutants 1970-1987. LR733 (AP)M. Warren Spring Laboratory, Stevenage.

Eggleston HS, Charles D, Salway AG, Jones BMR, Milne R (1998), Treatment of Uncertainties for National Estimates of Greenhouse Gas Emissions. AEAT-2688-1.

EMEP/CORINAIR (1996), Atmospheric Emission Inventory Guidebook. ed McInnes G, F.

Environment Agency (2003), Pollution Inventory.

Environment Agency (2003), Agricultural Waste Survey: A study of the management of non-natural agricultural waste on farms.

EPAQS (1995), Expert Panel on Air Quality Standards – Particles. HMSO. London.

EPAQS (2001), Expert Panel on Air Quality Standards - Airborne Particles: What is the Appropriate Measurement on Which to Base a Standard? HMSO. London.

EU (2000), Diphenylether, pentabromo derivative (Pentabromodiphenly ether): Summary of risk assessment report. European Union risk assessment report. ISBN 92-894-6479-5.

Gillham CA, Munday PK, Eggleston HS (1992), UK Emissions of Air Pollutants 1970-1990. LR887 (AP)M. Warren Spring Laboratory, Stevenage.

Gillham CA, Couling S, Leech PK, Eggleston HS, Irwin JG (1994), UK Emission of Air Pollutants, 1970-1991 (Including Methodology Update). LR961 (AP)M. Warren Spring Laboratory, Stevenage.

Goodwin JWL, Salway AG, Murrells TP, Dore C J, Eggleston HS (1999), UK Emissions of Air Pollutants 1970-1997. Netcen, AEA Technology, Harwell, Oxfordshire. Report AEAT-EEQC/0015 Issue 1.

Goodwin JWL, Salway AG, Murrells TP, Dore C J, Passant NR Eggleston HS (2000), UK Emissions of Air Pollutants 1970-1998. Netcen, AEA Technology, Harwell, Oxfordshire. Report AEAT/R/EN/0270. ISBN 0-7058-1794-6.

Goodwin JWL, Salway AG, Murrells TP, Dore C J, Passant NR, King KR, Coleman PJ, Hobson MM, Pye ST, Watterson JD (2001), UK Emissions of Air Pollutants 1970-1999. Netcen, AEA Technology, Harwell, Oxfordshire. Report AEAT/ENV/R/0798. ISBN 1-85580-031-4.

Goodwin JWL, Salway AG, Dore C J, Murrells TP, Passant NR, King KR, Coleman PJ, Hobson MM, Pye ST, Watterson JD, Haigh KE, Conolly CM (2002), UK Emissions of Air Pollutants 1970-2000. Netcen, AEA Technology, Harwell, Oxfordshire. Report AEAT/ENV/R/1283. ISBN 1-85580-031-0.

Haydock H, Adams M, Bates J, Passant N, Pye S, Salway G, Smith A (2004), Emissions and Projections of HFCs, PFCs and SF_6 for the UK and Constituent Countries. Netcen, AEA Technology, Harwell, Oxfordshire. Report AEAT/ED50090/R02.

HMIP (1995), A Review of Dioxin Emissions in the UK, Report No DOE/HMIP/RR/95/004.

IARC (1987)- International Agency for Research on Cancer. Overall Evaluations of Carcinogenicity: An Updating of IARC Monographs Volumes 1 to 42.

IPCC (1996), Climate Change 1995: The Science of Climate Change. Contribution of Working Group 1 to the Second Assessment Report of the Intergovernmental Panel on Climate Change. ed. Houghton JT. Cambridge University Press.

IPCC (1997), Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Vols. 1,2,3. ed. Houghton JT. IPCC WG1 Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK.

Jacoff FS, Scarberry R, Rossa D (1986), Source Assessment of Hexachlorobenzene from the Organic Chemical Manufacturing Industry Proc. Int. Symp. International Agency for research on Cancer, Lyon 24-28 Jun. 1985 . IARC Sci Pub. No. 77 p31.

Jockel W, Hartje J (1991), Datenerhebung uber die Emissionen Umweltgefahrdender Schermetalle, Technischer Uberwachungs-Verein Rheinland e.V, Institut fur Umweltschutz und Energietechnik.

Lee DS and JM Pacyna (1999), An industrial emissions inventory of calcium for Europe. Atmospheric Environment, 33, 1687 – 1697.

Leech PK (1991), UK Emissions of Air Pollutants 1970-1989. LR 826 (AP). Warren Spring Laboratory, Stevenage.

Leech PK (1993), UK Atmospheric Emissions of Metals and Halides 1970-1991. LR 923. Warren Spring Laboratory, Stevenage.

Lindsay WL (1979), Chemical Equilibria in Soils. John Wiley and Sons, p. 7.

Lloyds Register (1995), Marine Exhaust Emissions Research Programme.

MAFF (1991a), Pesticide Usage Survey Report 101: Vegetables for Human Consumption.

MAFF (1991b), Pesticide Usage Survey Report 102: Protected Crops (Edible and Ornamental).

MAFF (1991c), Pesticide Usage Survey Report 103: Mushrooms.

MAFF (1992a), Pesticide Usage Survey Report 107: Aerial Applications, Great Britain.

MAFF (1992b), Pesticide Usage Survey Report 108: Arable Farm Crops in Great Britain.

MAFF (1992c), Pesticide Usage Survey Report 114: Potato Stores in Great Britain.

MAFF (1992d), Pesticide Usage Survey Report 115: Orchards and Fruit Stores in Great Britain.

Milne R (2003), Centre for Ecology and Hydrology, Personal Communication.

Misselbrook TH, Chadwick DR, Chambers BJ, Smith KA, Webb J, Demmers T, Sneath RW (2003), Inventory of Ammonia Emissions from UK Agriculture 2002.

Mumma CE and Lawless EW (1975), Survey of Industrial Processing Data. Task 1. Hexachlorobenzene and Hexachlorobutadiene pollution from Chlorocarbon Processing. USEPA Office of Toxic Substances. EPA 560-3-75-003 (PB-243-641).

Munday PK (1990), UK Emissions of Air Pollutants 1970-1988. LR764 (AP)M. Warren Spring Laboratory, Stevenage.

NATO/CCMS (1988), International Toxicity Equivalent Factor (I-TEF) method of risk assessment for complex mixtures of dioxins and related compounds. Pilot Study on international information exchange on dioxins and related compounds. Report No 176. North Atlantic Treaty Organisation, Committee on Challenges of Modern Society.

Nicholson (2000), Re-suspension from roads: Initial estimate of emission factors. AEAT Internal Report.

Pacyna JM (1999), "Monitoring and modelling of lead, cadmium and mercury transboundary transport in the atmosphere of Europe" in Joint report of EMEP Centres: MSC-E and CCC MSC-E Alexey Ryaboshapko, Ilia Ilyin, Alexey Gusev, Olga Afinogenova Torunn Berg, Anne-Gunn Hjellbrekke Report 3/99.

Passant NR, Peirce M, Rudd HJ, Scott DW, Marlowe IT and Watterson JD (2002a), UK Particulate and Heavy Metal Emissions from Industrial Processes. Netcen, AEA Technology, Harwell, Oxfordshire, Report No AEAT-6270. Issue 2.

Passant NR (2002b), Estimation of Uncertainties in the National Atmospheric Emissions Inventory. AEA Technology. Report No. AEAT/ENV/R/1039 Draft.

Passant, N R (2003/4), Emission factors programme: Task 1 – Summary of simple desk studies, AEA Technology Plc, Report No AEAT/ENV/R/1715/Issue 1.

Passant, N R, Thistlethwaite, G, & Roberts I (2004), NAEI Ad-hoc Emission Factors Project, Task 2.4: Estimation of Particulate Emissions from Quarrying & Construction Processes, AEA Technology Plc, Report No AEAT/ENV/R/1711 Final Draft.

Passant, N R & Woodfield, M J (2004), NAEI Ad-hoc Improvement Programme: PM Emissions from Fires and Natural, Agricultural and Accidental Sources, AEA Technology Plc, Report No AEAT/ENV/R/1809 Issue 1.

Perry, R E (2002), Report on a project to measure emissions and calculate emission factors for a range of pollutants released to air during the combustion of solid fuels on an open fire, CPL Ltd, Report Reference 02/aeat/1.

QUARG (1993), Urban Air Quality in the United Kingdom, First Report of the Quality of Urban Air Review Group. Department of the Environment. ISBN 0-95207-7116.

QUARG (1996), Airborne Particulate Matter in the United Kingdom, Third report of the Quality of Urban Air Review Group. Department of the Environment. ISBN 0-9520771-3-2.

Ratcliffe M (1999), DETR: UK Submission to Oslo and Paris Commissions (OSPARCOM).

RGAR (1997), Acid Deposition in the United Kingdom 1992 to 1994, Fourth Report of the United Kingdom Review Group on Acid Rain. Department of the Environment. Publication Sales, Ruislip.

Salway AG, Goodwin JWL, Eggleston HS (1996), UK Emissions of Air Pollutants 1970-1993. Netcen, AEA Technology, Harwell, Oxfordshire. Report AEA/RAMP/16419127/R/001.

Salway AG, Goodwin JWL, Eggleston HS, Murrells TP (1996a), UK Emissions of Air Pollutants 1970-1994. Netcen, AEA Technology, Harwell, Oxfordshire. Report EA/RAMP/20090001/R/003.

Salway AG, Goodwin JWL, Eggleston HS, Murrells TP (1997), UK Emissions of Air Pollutants 1970-1995. Netcen, AEA Technology, Harwell, Oxfordshire. Report AEAT-1746 Issue 1.

Salway AG, Eggleston HS, Goodwin JWL, Berry JE, Murrells TP (1999), UK Emissions of Air Pollutants 1970-1996. Netcen, AEA Technology, Harwell. Report AEAT-3092 Issue 1.

Salway AG (2000), UK Greenhouse Gas Emission Inventory 1990 to 1998. Netcen, AEA Technology, Harwell. Oxfordshire. ISBN 0-7058-1796-2.

Sloss L and Smith I (2000), Trace Element Emissions. IEA Coal Research – The Clean Coal Centre.

Smith IM (1987), Trace elements from coal combustion: emissions IEA Coal Research. IEACR/01.

Smyllie RJ (1996), Abatement Methods and Costs for Heavy Metal Emissions to Air. Entech Report No 96047.

Stewart, H E , Hewitt, C N , Bunce, R G H , Steingbrecher, R , Smiatek, G & Schoenemeyer, T (2003), A highly spatially and temporally resolved inventory for biogenic isoprene and monoterpene emissions: Model description and application to Great Britain, J. Geophys. Res., 108(D20), 4644, doi:10.1029/2002JD002694.

Strandman T *et al* (2000), Polybrominated diphenly ethers (PBDE's) in placenta and human milk. Organohologen Compounds Vol. 47.

Sullivan (1991), Orimulsion a review. DNV Technica.

Sullivan, R (1992), Orimulsion - A Review, DNV Technica Ltd, Report No DNV-T\I909.

Thistlethwaite, G (2001), Determination of Atmospheric Pollutant Emission Factors at a Small Coal-Fired Heating Boiler, AEA Technology, Report No AEAT/R/ENV/0517.

Thistlethwaite, G (2004), NAEI Ad-hoc Improvement Programme, Task 2.1: Estimation of Emissions from Small Combustion Processes, AEA Technology, Report No AEAT/R/ENV/1713.

TNO (1997), Particulate Matter Emissions (PM_{10}, $PM_{2.5}$, $PM_{<0.1}$) in Europe in 1990 and 1993. TNO Report TNO-MEP-R96/472. Netherlands.

United Kingdom Minerals Yearbook 1990-2001 (2002), British Geological Survey.

USEPA (1995), United States Environmental Protection Agency, Compilation of Air Pollutant Emission Factors. Vol 1, 5th Edition, AP-42, North Carolina.

USEPA (1988), Second Supplement to the Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air. EPA-600/4-89-018. pp TO-13 to TO-97.

US EPA (2004), Compilation of Air Pollutant Emission Factors, AP-42.

van der Most PFJ, Veldt C (1989), TNO 89-036 Emissions into the atmosphere of PAH's, PCB's, Lindane and HCB in Europe.

van der Most PFJ, Veldt C (1992), Emission Factors Manual PARCOM-ATMOS, Emission factors for air pollutants 1992, TNO report ref 92-235. TNO Institute of Environmental and Energy Technology, Apeldoorn, The Netherlands.

Watson M (2003), Personal communications regarding sulphur content of liquid fuels, UKPIA.

Wenborn MJ, Coleman PJ, Passant NR, Lymberidi E, and Weir RA (1999), Speciated PAH Inventory for the UK. Netcen, AEA Technology, Harwell, Oxfordshire. Report AEAT3512/REMC/20459131 Issue1.

WHO (1998), Van den Berg M, Birnbaum L, Bosveld ATC, Brunström B, Cook P, Feeley M, Giesy JP, Hanberg A, Hasegawa R, Kennedy SW, Kubiak T, Larsen JC, van Leeuwen FXR, Liem AKD, Nolt C, Peterson RE, Poellinger L, Safe S, Schrenk D, Tillitt D, Tyskland M, Younes M, Wærn F and Zacharewski T. Toxic Equivalency Factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. Environ Health Perspect, 106: 775-792.

Wild H (1992), Pentachlorophenol in the UK Environment 1: A Budget and Source Inventory (Chemosphere 24 No.7 833-845).

Williams A (1994), Methane Emissions. Watt Committee Report Number 28. The Watt Committee on Energy, London.

Wood P (1996), Heavy Metal Contents of Liquid Fuels. Netcen, AEA Technology, Harwell, Oxfordshire. Report AEA/WMES/20058001/R/001.

Annex 1

Definitions of UN/ECE Source Sectors

CONTENTS

1. UN/ECE Classification of Emission Sources

For this report, the NAEI emission estimates have been reported according to the UNECE/CORINAIR Nomenclature For Reporting (NFR) Categories. These categories replaced the commonly used SNAP categories for official reporting of non-GHGs in 2000. The reason that the reporting structure was changed was to promote harmonisation with the CRF reporting structure used in the official reporting of GHG emissions.

The change from using SNAP codes to NFR codes in this report has only now been made because the SNAP reporting format was considered generally preferable for several reasons. Primarily because the SNAP structure is considered more intuitive, and therefore more user-friendly for those not experienced with emission inventories. In addition, it is a reporting structure which is generally preferred by emission inventory compilers themselves. Table A1 below summarises the NFR reporting structure.

The NFR reporting structure, and the way in which it relates to UK Inventory categories is listed in detail as Table A2 below. In many cases the NAEI categories shown here are aggregates of more detailed emission sectors. The sectors are presented in this way in Table A2 to allow an in depth understanding of the source sector content without presenting an excessive amount of information. In addition, the names of several NAEI categories have been changed to enable a fuller understanding by those not familiar with some of the nomenclature.

There are currently on-going discussions at the international level regarding amendments to the NFR reporting structure, but changes are likely to be small.

The NAEI reports emissions from the combustion of fuels and non-combustion emissions from a range of sectors. The fuels data are taken from the Digest of UK Energy Statistics (DUKES), (DTI, 2004). Hence the fuel definitions and the choice of base sector categories used in the NAEI often reflect those in the DUKES publications. The choice of non-combustion sources generally reflects the availability of data on the emissions from specific activities.

The allocation of a particular source to one of these sectors is well defined and given in more detail in Table A2. The majority of allocations are easy to understand. For example, emissions arising from fuel combustion in the manufacture of glass will come under "1A2 Manufacturing Industries and Construction". Emission arising from the manufacture/handling of the glass material itself and the raw materials will come under " 2A Mineral Products".

Table A1- A Summary of the NFR Reporting Structure

1A	**FUEL COMBUSTION**
1A1a	1 A 1 a Public Electricity and Heat Production
1A1b	1 A 1 b Petroleum refining
1A1c	1 A 1 c Manufacture of Solid Fuels and Other Energy Industries
1A2	1 A 2 Manufacturing Industries and Construction
1A3aii(i)	1 A 3 a ii Civil Aviation (Domestic, LTO)
1A3aii(ii)	1 A 3 a ii Civil Aviation (Domestic, Cruise)
1A3b	1 A 3 b Road Transportation
1A3c	1 A 3 c Railways
1A3dii	1 A 3 d ii National Navigation
1A3e	1 A 3 e Other (Please specify in a covering note)
1A4a	1 A 4 a Commercial / Institutional
1A4b	1 A 4 b Residential
1A4c	1 A 4 c Agriculture / Forestry / Fishing
1A5a	1 A 5 a Other, Stationary (including Military)
1A5b	1 A 5 b Other, Mobile (Including military)
1B	**FUGITIVE EMISSIONS FROM FUELS**
1B1	1B1 Fugitive Emissions from Solid Fuels
1B2	1 B 2 Oil and natural gas
2	**PROCESSES**
2A	2 A MINERAL PRODUCTS (b)
2B	2 B CHEMICAL INDUSTRY
2C	2 C METAL PRODUCTION
2D	2 D OTHER PRODUCTION (b)
2G	2 G OTHER
3	**SOLVENT USE**
3A	3 A PAINT APPLICATION
3B	3 B DEGREASING AND DRY CLEANING
3C	3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING
3D	3 D OTHER including products containing HMs and POPs
4	**AGRICULTURE**
4B	4 B MANURE MANAGEMENT (c)
4C	4 C RICE CULTIVATION
4D1	4 D 1 Direct Soil Emission
4F	4 F FIELD BURNING OF AGRICULTURAL WASTES
4G	4 G OTHER (d)
5B	5 B FOREST AND GRASSLAND CONVERSION
6	**WASTE**
6A	6 A SOLID WASTE DISPOSAL ON LAND
6B	6 B WASTE-WATER HANDLING
6C	6 C WASTE INCINERATION (e)
6D	6 D OTHER WASTE (f)
7	**7 OTHER**
	MEMO ITEMS
1A3ai(i)	International Aviation (LTO)
1A3ai(ii)	International Aviation (Cruise)
1A3di(i)	International maritime Navigation
1A3di(ii)	International inland waterways (Included in NEC totals only)
5E	5 E Other
X	X (11 08 Volcanoes)

Table A2 Mapping of NAEI Base Categories to NFR

NFR Code	NFR Name	Source Name
1A1a	1 A 1 a Public Electricity & Heat Production	Landfill gas combustion
1A1a	1 A 1 a Public Electricity & Heat Production	OvTerr Power Stations (all)- Cayman, Falkland, Montserrat, Bermuda & Gibraltar
1A1a	1 A 1 a Public Electricity & Heat Production	OvTerr Waste incineration (all)- Guernsey, Jersey, IOM
1A1a	1 A 1 a Public Electricity & Heat Production	Power stations
1A1a	1 A 1 a Public Electricity & Heat Production	Sewage gas combustion
1A1b	1 A 1 b Petroleum refining	Refineries - combustion
1A1c	1 A 1 c Manufac. of Solid Fuels & Other Energy Industries	Coke production
1A1c	1 A 1 c Manufac. of Solid Fuels & Other Energy Industries	Collieries - combustion
1A1c	1 A 1 c Manufac. of Solid Fuels & Other Energy Industries	Gas production
1A1c	1 A 1 c Manufac. of Solid Fuels & Other Energy Industries	Gas separation plant - combustion
1A1c	1 A 1 c Manufac. of Solid Fuels & Other Energy Industries	Nuclear fuel production
1A1c	1 A 1 c Manufac. of Solid Fuels & Other Energy Industries	Offshore oil & gas - own gas combustion
1A1c	1 A 1 c Manufac. of Solid Fuels & Other Energy Industries	Solid smokeless fuel production
1A1c	1 A 1 c Manufac. of Solid Fuels & Other Energy Industries	Town gas manufac.
1A2a	1 A 2 a Iron & Steel	Blast furnaces
1A2a	1 A 2 a Iron & Steel	Foundries
1A2a	1 A 2 a Iron & Steel	Iron & steel - combustion plant
1A2a	1 A 2 a Iron & Steel	Sinter production
1A2b	1 A 2 b Non-ferrous Metals	Copper alloy & semis production
1A2b	1 A 2 b Non-ferrous Metals	Lead battery manufac.
1A2b	1 A 2 b Non-ferrous Metals	Primary lead/zinc production
1A2b	1 A 2 b Non-ferrous Metals	Secondary aluminium production
1A2b	1 A 2 b Non-ferrous Metals	Secondary copper production
1A2b	1 A 2 b Non-ferrous Metals	Secondary lead production
1A2b	1 A 2 b Non-ferrous Metals	Zinc alloy & semis production
1A2b	1 A 2 b Non-ferrous Metals	Zinc oxide production
1A2f	1 A 2 f Other	Ammonia production - combustion
1A2f	1 A 2 f Other	Autogenerators
1A2f	1 A 2 f Other	Autogenerators
1A2f	1 A 2 f Other	Brick manufac. - Fletton
1A2f	1 A 2 f Other	Brick manufac. - non Fletton
1A2f	1 A 2 f Other	Cement - non-decarbonising
1A2f	1 A 2 f Other	Cement production - combustion
1A2f	1 A 2 f Other	Glazed ceramics
1A2f	1 A 2 f Other	Industrial engines
1A2f	1 A 2 f Other	Industrial off-road mobile machinery
1A2f	1 A 2 f Other	Lime production - non decarbonising
1A2f	1 A 2 f Other	Other industrial combustion
1A2f	1 A 2 f Other	OvTerr Industrial Combustion (all)- Cayman, Falkland, Montserrat, Bermuda & Gibraltar
1A2f	1 A 2 f Other	Refractories - chromite based
1A2f	1 A 2 f Other	Refractories - non chromite based
1A2f	1 A 2 f Other	Unglazed ceramics
1A3aii(i)	1 A 3 a ii Civil Aviation (Domestic, LTO)	Aircraft - domestic take off & landing
1A3aii(i)	1 A 3 a ii Civil Aviation (Domestic, LTO)	OvTerr Aviation (all)- Cayman, Falkland, Montserrat, Bermuda & Gibraltar
1A3aii(ii)	1 A 3 a ii Civil Aviation (Domestic, Cruise)	Aircraft - domestic cruise
1A3bi	1 A 3 b i R.T., Passenger cars	OvTerr Road Transport (all)- Cayman, Falkland, Montserrat, Bermuda & Gibraltar
1A3bi	1 A 3 b i R.T., Passenger cars	Road transport - all vehicles LPG use
1A3bi	1 A 3 b i R.T., Passenger cars	Road transport - all vehicles LRP use
1A3bi	1 A 3 b i R.T., Passenger cars	Road transport - cars - cold start
1A3bi	1 A 3 b i R.T., Passenger cars	Road transport - cars - motorway driving
1A3bi	1 A 3 b i R.T., Passenger cars	Road transport - cars - rural driving
1A3bi	1 A 3 b i R.T., Passenger cars	Road transport - cars - urban driving

NFR Code	NFR Name	Source Name
1A3bi	1 A 3 b i R.T., Passenger cars	Road Transport - cars Dioxins/PCP
1A3bi	1 A 3 b i R.T., Passenger cars	Road transport - cars non catalyst - cold start
1A3bi	1 A 3 b i R.T., Passenger cars	Road transport - cars non catalyst - motorway driving
1A3bi	1 A 3 b i R.T., Passenger cars	Road transport - cars non catalyst - rural driving
1A3bi	1 A 3 b i R.T., Passenger cars	Road transport - cars non catalyst - urban driving
1A3bi	1 A 3 b i R.T., Passenger cars	Road transport - cars with catalysts - cold start
1A3bi	1 A 3 b i R.T., Passenger cars	Road transport - cars with catalysts - motorway driving
1A3bi	1 A 3 b i R.T., Passenger cars	Road transport - cars with catalysts - rural driving
1A3bi	1 A 3 b i R.T., Passenger cars	Road transport - cars with catalysts - urban driving
1A3bi	1 A 3 b i R.T., Passenger cars	Road vehicle engines
1A3bii	1 A 3 b ii R.T., Light duty vehicles	Road transport - LGVs - cold start
1A3bii	1 A 3 b ii R.T., Light duty vehicles	Road transport - LGVs - motorway driving
1A3bii	1 A 3 b ii R.T., Light duty vehicles	Road transport - LGVs - rural driving
1A3bii	1 A 3 b ii R.T., Light duty vehicles	Road transport - LGVs - urban driving
1A3bii	1 A 3 b ii R.T., Light duty vehicles	Road Transport - LGVs Dioxins
1A3bii	1 A 3 b ii R.T., Light duty vehicles	Road transport - LGVs non catalyst - cold start
1A3bii	1 A 3 b ii R.T., Light duty vehicles	Road transport - LGVs non catalyst - motorway driving
1A3bii	1 A 3 b ii R.T., Light duty vehicles	Road transport - LGVs non catalyst - rural driving
1A3bii	1 A 3 b ii R.T., Light duty vehicles	Road transport - LGVs non catalyst - urban driving
1A3bii	1 A 3 b ii R.T., Light duty vehicles	Road transport - LGVs with catalysts - cold start
1A3bii	1 A 3 b ii R.T., Light duty vehicles	Road transport - LGVs with catalysts - motorway driving
1A3bii	1 A 3 b ii R.T., Light duty vehicles	Road transport - LGVs with catalysts - rural driving
1A3bii	1 A 3 b ii R.T., Light duty vehicles	Road transport - LGVs with catalysts - urban driving
1A3biii	1 A 3 b iii R.T., Heavy duty vehicles	Road transport - buses & coaches - motorway driving
1A3biii	1 A 3 b iii R.T., Heavy duty vehicles	Road transport - buses & coaches - rural driving
1A3biii	1 A 3 b iii R.T., Heavy duty vehicles	Road transport - buses & coaches - urban driving
1A3biii	1 A 3 b iii R.T., Heavy duty vehicles	Road transport - HGV articulated - motorway driving
1A3biii	1 A 3 b iii R.T., Heavy duty vehicles	Road transport - HGV articulated - rural driving
1A3biii	1 A 3 b iii R.T., Heavy duty vehicles	Road transport - HGV articulated - urban driving
1A3biii	1 A 3 b iii R.T., Heavy duty vehicles	Road transport - HGV rigid - motorway driving
1A3biii	1 A 3 b iii R.T., Heavy duty vehicles	Road transport - HGV rigid - rural driving
1A3biii	1 A 3 b iii R.T., Heavy duty vehicles	Road transport - HGV rigid - urban driving
1A3biii	1 A 3 b iii R.T., Heavy duty vehicles	Road Transport - HGVs/buses Dioxins
1A3biv	1 A 3 b iv R.T., Mopeds & Motorcycles	Road Transport - Mopeds & M.cycles Dioxins
1A3biv	1 A 3 b iv R.T., Mopeds & Motorcycles	Road transport - mopeds (<50cc 2st) - urban driving
1A3biv	1 A 3 b iv R.T., Mopeds & Motorcycles	Road transport - m.cycle (>50cc 2st) - rural driving
1A3biv	1 A 3 b iv R.T., Mopeds & Motorcycles	Road transport - m.cycle (>50cc 2st) - urban driving
1A3biv	1 A 3 b iv R.T., Mopeds & Motorcycles	Road transport - m.cycle (>50cc 4st) - motorway driving
1A3biv	1 A 3 b iv R.T., Mopeds & Motorcycles	Road transport - m.cycle (>50cc 4st) - rural driving
1A3biv	1 A 3 b iv R.T., Mopeds & Motorcycles	Road transport - m.cycle (>50cc 4st) - urban driving
1A3bv	1 A 3 b v R.T., Gasoline evaporation	Road transport - cars - evaporative
1A3bv	1 A 3 b v R.T., Gasoline evaporation	Road transport - LGVs - evaporative
1A3bv	1 A 3 b v R.T., Gasoline evaporation	Road transport - mopeds (<50cc 2st) - evaporative
1A3bv	1 A 3 b v R.T., Gasoline evaporation	Road transport - m.cycle (>50cc 2st) - evaporative
1A3bv	1 A 3 b v R.T., Gasoline evaporation	Road transport - m.cycle (>50cc 4st) - evaporative
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - buses & coaches - motorway driving
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - buses & coaches - rural driving
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - buses & coaches - urban driving
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - buses & coaches - urban driving
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - cars - motorway driving
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - cars - rural driving
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - cars - urban driving
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - HGV articulated - motorway driving
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - HGV articulated - rural driving
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - HGV articulated - urban driving
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - HGV rigid - motorway driving
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - HGV rigid - rural driving

NFR Code	NFR Name	Source Name
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - HGV rigid - urban driving
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - LGVs - motorway driving
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - LGVs - rural driving
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - LGVs - urban driving
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - mopeds (<50cc 2st) - motorway driving
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - mopeds (<50cc 2st) - rural driving
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - mopeds (<50cc 2st) - urban driving
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - motorcycle (>50cc 2st) - motorway driving
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - motorcycle (>50cc 2st) - rural driving
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - motorcycle (>50cc 2st) - urban driving
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - motorcycle (>50cc 4st) - motorway driving
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - motorcycle (>50cc 4st) - rural driving
1A3bvi	1 A 3 b vi R.T., Automobile tyre & brake wear	Road transport - motorcycle (>50cc 4st) - urban driving
1A3c	1 A 3 c Railways	Railways - freight
1A3c	1 A 3 c Railways	Railways - intercity
1A3c	1 A 3 c Railways	Railways - regional
1A3dii	1 A 3 d ii National Navigation	Marine engines
1A3dii	1 A 3 d ii National Navigation	Shipping - coastal
1A3eii	1 A 3 e ii Other mobile sources & machinery	Aircraft - support vehicles
1A4a	1 A 4 a Commercial / Institutional	Miscellaneous industrial/commercial combustion
1A4a	1 A 4 a Commercial / Institutional	Public sector combustion
1A4a	1 A 4 a Commercial / Institutional	Railways - stationary combustion
1A4bi	1 A 4 b i Residential plants	Domestic combustion
1A4bi	1 A 4 b i Residential plants	OvTerr Commercial/Residential Combustion (all)- Cayman, Falkland, Montserrat, Bermuda, Gibraltar
1A4bii	1 A 4 b ii Household & gardening (mobile)	House & garden machinery
1A4ci	1 A 4 c i Stationary	Agriculture - stationary combustion
1A4cii	1 A 4 c ii Off-road Vehicles & Other Machinery	Agricultural engines
1A4cii	1 A 4 c ii Off-road Vehicles & Other Machinery	Agriculture - mobile machinery
1A4cii	1 A 4 c ii Off-road Vehicles & Other Machinery	OvTerr Other Mobile (all)- Cayman, Falkland, Montserrat, Bermuda & Gibraltar
1A4ciii	1A 4 c iii National Fishing	Fishing vessels
1A5b	1 A 5 b Other, Mobile (Including military)	Aircraft - military
1A5b	1 A 5 b Other, Mobile (Including military)	Shipping - naval
1B1a	1 B 1 a Coal Mining & Handling	Closed Coal Mines
1B1a	1 B 1 a Coal Mining & Handling	Coal storage & transport
1B1a	1 B 1 a Coal Mining & Handling	Deep-mined coal
1B1a	1 B 1 a Coal Mining & Handling	Open-cast coal
1B1b	1 B 1 b Solid fuel transformation	Coke production
1B1b	1 B 1 b Solid fuel transformation	Iron & steel - flaring
1B1b	1 B 1 b Solid fuel transformation	Solid smokeless fuel production
1B2ai	1 B 2 a i Exploration Production, Transport	Crude oil loading from onshore facilities
1B2ai	1 B 2 a i Exploration Production, Transport	Offshore oil & gas - processes
1B2ai	1 B 2 a i Exploration Production, Transport	Offshore oil & gas - well testing
1B2ai	1 B 2 a i Exploration Production, Transport	Oil terminal storage
1B2ai	1 B 2 a i Exploration Production, Transport	Petroleum processes
1B2aiv	1 B 2 a iv Refining / Storage	Refineries - drainage
1B2aiv	1 B 2 a iv Refining / Storage	Refineries - general
1B2aiv	1 B 2 a iv Refining / Storage	Refineries - process
1B2aiv	1 B 2 a iv Refining / Storage	Refineries - tankage
1B2av	1 B 2 a v Distribution of oil products	OvTerr Extr. Dist Fossil Fuel (all)- Guernsey, Jersey, IOM
1B2av	1 B 2 a v Distribution of oil products	Petrol distribution (Stage 1B & 2)
1B2av	1 B 2 a v Distribution of oil products	Petrol distribution (Stage 1B & 2)
1B2av	1 B 2 a v Distribution of oil products	Petrol stations - spillages
1B2av	1 B 2 a v Distribution of oil products	Petrol stations - vehicle refuelling
1B2av	1 B 2 a v Distribution of oil products	Petrol terminals - tanker loading

NFR Code	NFR Name	Source Name
1B2b	1 B 2 b Natural gas	Gas leakage
1B2b	1 B 2 b Natural gas	OvTerr Extr. Dist Fossil Fuel (all)- Guernsey, Jersey, IOM
1B2c	1 B 2 c Venting & flaring	Offshore oil & gas - venting
2A1	2 A 1 Cement Production	Cement - decarbonising
2A1	2 A 1 Cement Production	Cement & concrete batching
2A1	2 A 1 Cement Production	Slag clement production
2A2	2 A 2 Lime Production	Lime production - decarbonising
2A3	2 A 3 Limestone & Dolomite Use	Basic oxygen furnaces
2A3	2 A 3 Limestone & Dolomite Use	Blast furnaces
2A3	2 A 3 Limestone & Dolomite Use	Construction
2A3	2 A 3 Limestone & Dolomite Use	Glass - general
2A3	2 A 3 Limestone & Dolomite Use	Power stations - FGD
2A3	2 A 3 Limestone & Dolomite Use	Sinter production
2A4	2 A 4 Soda Ash Production & use	Chemical industry - soda ash
2A4	2 A 4 Soda Ash Production & use	Glass - general
2A5	2 A 5 Asphalt Roofing	Bitumen use
2A6	2 A 6 Road Paving with Asphalt	Road dressings
2A7	2 A 7 Other including Non Fuel Mining & Construction	Construction
2A7	2 A 7 Other including Non Fuel Mining & Construction	Dewatering of lead concentrates
2A7	2 A 7 Other including Non Fuel Mining & Construction	Glass - container
2A7	2 A 7 Other including Non Fuel Mining & Construction	Glass - continuous filament glass fibre
2A7	2 A 7 Other including Non Fuel Mining & Construction	Glass - domestic
2A7	2 A 7 Other including Non Fuel Mining & Construction	Glass - flat
2A7	2 A 7 Other including Non Fuel Mining & Construction	Glass - frits
2A7	2 A 7 Other including Non Fuel Mining & Construction	Glass - glass wool
2A7	2 A 7 Other including Non Fuel Mining & Construction	Glass - lead crystal
2A7	2 A 7 Other including Non Fuel Mining & Construction	Glass - special
2A7	2 A 7 Other including Non Fuel Mining & Construction	Other industry - asphalt manufac.
2A7	2 A 7 Other including Non Fuel Mining & Construction	Quarrying
2B1	2 B 1 Ammonia Production	Ammonia production - feedstock use of gas
2B2	2 B 2 Nitric Acid Production	Nitric acid production
2B3	2 B 3 Adipic Acid Production	Adipic acid production
2B5	2 B 5 Other	Chemical industry - alkyl lead
2B5	2 B 5 Other	Chemical industry - ammonia based fertilizer
2B5	2 B 5 Other	Chemical industry - ammonia use
2B5	2 B 5 Other	Chemical industry - cadmium pigments & stabilizers
2B5	2 B 5 Other	Chemical industry - carbon black
2B5	2 B 5 Other	Chemical industry - carbon tetrachloride
2B5	2 B 5 Other	Chemical industry - chloralkali process
2B5	2 B 5 Other	Chemical industry - chromium chemicals
2B5	2 B 5 Other	Chemical industry - ethylene
2B5	2 B 5 Other	Chemical industry - general
2B5	2 B 5 Other	Chemical industry - halogenated chemicals
2B5	2 B 5 Other	Chemical industry - hydrochloric acid use
2B5	2 B 5 Other	Chemical industry - magnesia
2B5	2 B 5 Other	Chemical industry - methanol
2B5	2 B 5 Other	Chemical industry - nitric acid use
2B5	2 B 5 Other	Chemical industry - pesticide production
2B5	2 B 5 Other	Chemical industry - phosphate based fertilizers
2B5	2 B 5 Other	Chemical industry - picloram production
2B5	2 B 5 Other	Chemical industry - pigment manufac.
2B5	2 B 5 Other	Chemical industry - reforming
2B5	2 B 5 Other	Chemical industry - sodium pentachlorophenoxide
2B5	2 B 5 Other	Chemical industry - sulphuric acid use
2B5	2 B 5 Other	Chemical industry - tetrachloroethylene
2B5	2 B 5 Other	Chemical industry - titanium dioxide
2B5	2 B 5 Other	Chemical industry - trichloroethylene
2B5	2 B 5 Other	Coal tar & bitumen processes
2B5	2 B 5 Other	Coal tar distillation

NFR Code	NFR Name	Source Name
2B5	2 B 5 Other	PDBE use
2B5	2 B 5 Other	SCCP use
2B5	2 B 5 Other	Ship purging
2B5	2 B 5 Other	Solvent & oil recovery
2B5	2 B 5 Other	Sulphuric acid production
2C	2 C METAL PRODUCTION	Alumina production
2C	2 C METAL PRODUCTION	Basic oxygen furnaces
2C	2 C METAL PRODUCTION	Blast furnaces
2C	2 C METAL PRODUCTION	Cold rolling of steel
2C	2 C METAL PRODUCTION	Electric arc furnaces
2C	2 C METAL PRODUCTION	Hot rolling of steel
2C	2 C METAL PRODUCTION	Integrated steelworks - stockpiles
2C	2 C METAL PRODUCTION	Iron & steel - flaring
2C	2 C METAL PRODUCTION	Iron & steel - steel pickling
2C	2 C METAL PRODUCTION	Ladle arc furnaces
2C	2 C METAL PRODUCTION	Magnesium alloying
2C	2 C METAL PRODUCTION	Magnesium cover gas
2C	2 C METAL PRODUCTION	Nickel production
2C	2 C METAL PRODUCTION	Other industry - part B processes
2C	2 C METAL PRODUCTION	Other non-ferrous metal processes
2C	2 C METAL PRODUCTION	Primary Alumin. production - anode baking
2C	2 C METAL PRODUCTION	Primary Alumin. production - general
2C	2 C METAL PRODUCTION	Primary Alumin. production - PFC emissions
2C	2 C METAL PRODUCTION	Primary Alumin. production - pre-baked anode process
2C	2 C METAL PRODUCTION	Primary Alumin. production - vertical stud Soderberg process
2C	2 C METAL PRODUCTION	Tin production
2D1	2 D 1 Pulp & Paper	Paper production
2D1	2 D 1 Pulp & Paper	Wood products manufac.
2D2	2 D 2 Food & Drink	Bread baking
2D2	2 D 2 Food & Drink	Brewing - fermentation
2D2	2 D 2 Food & Drink	Brewing - wort boiling
2D2	2 D 2 Food & Drink	Cider manufac.
2D2	2 D 2 Food & Drink	Malting - brewers' malts
2D2	2 D 2 Food & Drink	Malting - distillers' malts
2D2	2 D 2 Food & Drink	Malting - exported malt
2D2	2 D 2 Food & Drink	Other food - animal feed manufac.
2D2	2 D 2 Food & Drink	Other food - cakes biscuits & cereals
2D2	2 D 2 Food & Drink	Other food - coffee roasting
2D2	2 D 2 Food & Drink	Other food - margarine & other solid fats
2D2	2 D 2 Food & Drink	Other food - meat fish & poultry
2D2	2 D 2 Food & Drink	Other food - sugar production
2D2	2 D 2 Food & Drink	Spirit manufac. - casking
2D2	2 D 2 Food & Drink	Spirit manufac. - distillation
2D2	2 D 2 Food & Drink	Spirit manufac. - fermentation
2D2	2 D 2 Food & Drink	Spirit manufac. - other maturation
2D2	2 D 2 Food & Drink	Spirit manufac. - Scotch whisky maturation
2D2	2 D 2 Food & Drink	Spirit manufac. - spent grain drying
2D2	2 D 2 Food & Drink	Sugar beet processing
2D2	2 D 2 Food & Drink	Wine manufac.
2E1	2 E 1 Halocarbons production (by-product)	Halocarbons production - by-product
2E2	2 E 2 Halocarbons production (fugitive)	Halocarbons production - fugitive
2F	2 F Halocarbons use	Aerosols - halocarbons
2F	2 F Halocarbons use	Electrical insulation
2F	2 F Halocarbons use	Electronics - PFC
2F	2 F Halocarbons use	Electronics - SF6
2F	2 F Halocarbons use	Firefighting
2F	2 F Halocarbons use	Foams
2F	2 F Halocarbons use	Metered dose inhalers
2F	2 F Halocarbons use	Mobile air conditioning

NFR Code	NFR Name	Source Name
2F	2 F Halocarbons use	One Component Foams
2F	2 F Halocarbons use	Other PFC use
2F	2 F Halocarbons use	OvTerr F-gas emissions (all)- Cayman, Falkland, Montserrat, Bermuda & Gibraltar
2F	2 F Halocarbons use	OvTerr F-gas emissions (all)- Guernsey, Jersey, IOM
2F	2 F Halocarbons use	Precision cleaning - HFC
2F	2 F Halocarbons use	Refrigeration
2F	2 F Halocarbons use	Sporting goods
2F	2 F Halocarbons use	Supermarket refrigeration
2G	2 G OTHER	Capacitors
2G	2 G OTHER	Fragmentisers
2G	2 G OTHER	Transformers
3A	3 A PAINT APPLICATION	Creosote use
3A	3 A PAINT APPLICATION	Decorative paint - retail decorative
3A	3 A PAINT APPLICATION	Decorative paint - trade decorative
3A	3 A PAINT APPLICATION	Industrial coatings - agricultural & construction
3A	3 A PAINT APPLICATION	Industrial coatings - aircraft
3A	3 A PAINT APPLICATION	Industrial coatings - automotive
3A	3 A PAINT APPLICATION	Industrial coatings - coil coating
3A	3 A PAINT APPLICATION	Industrial coatings - commercial vehicles
3A	3 A PAINT APPLICATION	Industrial coatings - drum
3A	3 A PAINT APPLICATION	Industrial coatings - high performance
3A	3 A PAINT APPLICATION	Industrial coatings - marine
3A	3 A PAINT APPLICATION	Industrial coatings - metal & plastic
3A	3 A PAINT APPLICATION	Industrial coatings - metal packaging
3A	3 A PAINT APPLICATION	Industrial coatings - vehicle refinishing
3A	3 A PAINT APPLICATION	Industrial coatings - wood
3B	3 B DEGREASINGsss & DRY CLEANING	Dry cleaning
3B	3 B DEGREASINGsss & DRY CLEANING	Surface cleaning - 111-trichloroethane
3B	3 B DEGREASINGsss & DRY CLEANING	Surface cleaning - dichloromethane
3B	3 B DEGREASINGsss & DRY CLEANING	Surface cleaning - hydrocarbons
3B	3 B DEGREASINGsss & DRY CLEANING	Surface cleaning - oxygenated solvents
3B	3 B DEGREASINGsss & DRY CLEANING	Surface cleaning - tetrachloroethylene
3B	3 B DEGREASINGsss & DRY CLEANING	Surface cleaning - trichloroethylene
3C	3C CHEMICAL PRODUCTS, MANUFAC. & PROC.	Coating manufac. - adhesives
3C	3C CHEMICAL PRODUCTS, MANUFAC. & PROC.	Coating manufac. - inks
3C	3C CHEMICAL PRODUCTS, MANUFAC. & PROC.	Coating manufac. - inks
3C	3C CHEMICAL PRODUCTS, MANUFAC. & PROC.	Coating manufac. - other coatings
3C	3C CHEMICAL PRODUCTS, MANUFAC. & PROC.	Coating manufac. - other coatings
3C	3C CHEMICAL PRODUCTS, MANUFAC. & PROC.	Film coating
3C	3C CHEMICAL PRODUCTS, MANUFAC. & PROC.	Leather coating
3C	3C CHEMICAL PRODUCTS, MANUFAC. & PROC.	Leather degreasing
3C	3C CHEMICAL PRODUCTS, MANUFAC. & PROC.	Other rubber products
3C	3C CHEMICAL PRODUCTS, MANUFAC. & PROC.	Textile coating
3C	3C CHEMICAL PRODUCTS, MANUFAC. & PROC.	Tyre manufac.
3D	3 D OTHER including products containing HMs & POPs	Aerosols - carcare products
3D	3 D OTHER including products containing HMs & POPs	Aerosols - cosmetics & toiletries
3D	3 D OTHER including products containing HMs & POPs	Aerosols - household products
3D	3 D OTHER including products containing HMs & POPs	Agriculture - agrochemicals use
3D	3 D OTHER including products containing HMs & POPs	Industrial adhesives - other
3D	3 D OTHER including products containing HMs & POPs	Industrial adhesives - pressure sensitive tapes
3D	3 D OTHER including products containing HMs & POPs	Non-aerosol products - automotive products
3D	3 D OTHER including products containing HMs & POPs	Non-aerosol products - cosmetics & toiletries
3D	3 D OTHER including products containing HMs & POPs	Non-aerosol products - domestic adhesives
3D	3 D OTHER including products containing HMs & POPs	Non-aerosol products - household products
3D	3 D OTHER including products containing HMs & POPs	Non-aerosol products - household products
3D	3 D OTHER including products containing HMs & POPs	Non-aerosol products - paint thinner
3D	3 D OTHER including products containing HMs & POPs	Other solvent use
3D	3 D OTHER including products containing HMs & POPs	OvTerr Solvent Use (all)- Guernsey, Jersey, IOM
3D	3 D OTHER including products containing HMs & POPs	Paper coating

NFR Code	NFR Name	Source Name
3D	3 D OTHER including products containing HMs & POPs	Previously treated wood
3D	3 D OTHER including products containing HMs & POPs	Previously treated wood
3D	3 D OTHER including products containing HMs & POPs	Printing - flexible packaging
3D	3 D OTHER including products containing HMs & POPs	Printing - heatset web offset
3D	3 D OTHER including products containing HMs & POPs	Printing - metal decorating
3D	3 D OTHER including products containing HMs & POPs	Printing - newspapers
3D	3 D OTHER including products containing HMs & POPs	Printing - other flexography
3D	3 D OTHER including products containing HMs & POPs	Printing - other inks
3D	3 D OTHER including products containing HMs & POPs	Printing - other offset
3D	3 D OTHER including products containing HMs & POPs	Printing - overprint varnishes
3D	3 D OTHER including products containing HMs & POPs	Printing - print chemicals
3D	3 D OTHER including products containing HMs & POPs	Printing - publication gravure
3D	3 D OTHER including products containing HMs & POPs	Printing - screen printing
3D	3 D OTHER including products containing HMs & POPs	Seed oil extraction
3D	3 D OTHER including products containing HMs & POPs	Wood impregnation - creosote
3D	3 D OTHER including products containing HMs & POPs	Wood impregnation - general
3D	3 D OTHER including products containing HMs & POPs	Wood impregnation - general
3D	3 D OTHER including products containing HMs & POPs	Wood impregnation - general
3D	3 D OTHER including products containing HMs & POPs	Wood impregnation - general
3D	3 D OTHER including products containing HMs & POPs	Wood impregnation - general
3D	3 D OTHER including products containing HMs & POPs	Wood impregnation - LOSP
4A1	4 A 1 Enteric_Fermentation_Cows	Agriculture livestock - other cattle enteric
4A1	4 A 1 Enteric_Fermentation_Cows	OvTerr Agriculture CH4 (all)- Cayman, Falkland, Montserrat, Bermuda & Gibraltar
4A1	4 A 1 Enteric_Fermentation_Cows	OvTerr Agriculture CH4 (all)- Guernsey, Jersey, IOM
4A10	4 A 10 Enteric_Fermentation_Deer	Agriculture livestock - deer enteric
4A3	4 A 3 Enteric_Fermentation_Sheep	Agriculture livestock - sheep enteric
4A4	4 A 4 Enteric_Fermentation_Goats	Agriculture livestock - goats enteric
4A6	4 A 6 Enteric_Fermentation_Horses	Agriculture livestock - horses enteric
4A8	4 A 8 Enteric_Fermentation_Swine	Agriculture livestock - pigs enteric
4B1	4 B 1 Cattle	Agriculture livestock - dairy cattle
4B1	4 B 1 Cattle	Agriculture livestock - dairy cattle wastes
4B1	4 B 1 Cattle	Agriculture livestock - other cattle
4B1	4 B 1 Cattle	Agriculture livestock - other cattle wastes
4B1	4 B 1 Cattle	OvTerr Agriculture NH3 (all)- Guernsey, Jersey, IOM
4B11	4 B 11 Liquid_Systems	Agriculture livestock - manure liquid systems
4B12	4 B 12 Solid_Storage_and_Drylot	Agriculture livestock - manure solid storage & dry lot
4B12	4 B 12 Solid_Storage_and_Drylot	OvTerr Agriculture N2O (all)- Cayman, Falkland, Montserrat, Bermuda & Gibraltar
4B12	4 B 12 Solid_Storage_and_Drylot	OvTerr Agriculture N2O (all)- Guernsey, Jersey, IOM
4B13	4 B 13 Other	Agriculture livestock - deer wastes
4B13	4 B 13 Other	Agriculture livestock - deer wastes
4B13	4 B 13 Other	Agriculture livestock - manure other
4B13	4 B 13 Other	Domestic pets
4B13	4 B 13 Other	Non-agriculture livestock - horses wastes
4B3	4 B 3 Sheep	Agriculture livestock - sheep goats & deer wastes
4B4	4 B 4 Goats	Agriculture livestock - goats wastes
4B6	4 B 6 Horses	Agriculture livestock - horses wastes
4B6	4 B 6 Horses	Agriculture livestock - horses wastes
4B8	4 B 8 Swine	Agriculture livestock - pigs
4B8	4 B 8 Swine	Agriculture livestock - pigs wastes
4B9	4 B 9 Poultry	Agriculture livestock - broilers
4B9	4 B 9 Poultry	Agriculture livestock - broilers wastes
4B9	4 B 9 Poultry	Agriculture livestock - laying hens
4B9	4 B 9 Poultry	Agriculture livestock - laying hens wastes
4B9	4 B 9 Poultry	Agriculture livestock - other poultry
4B9	4 B 9 Poultry	Agriculture livestock - other poultry wastes
4B9	4 B 9 Poultry	Pheasants
4D1	4 D 1 Direct Soil Emission	Agricultural soils
4D1	4 D 1 Direct Soil Emission	Agriculture - stationary combustion

NFR Code	NFR Name	Source Name
4D1	4 D 1 Direct Soil Emission	Composting - NH3
4D1	4 D 1 Direct Soil Emission	House & garden machinery
4F	4 F FIELD BURNING OF AGRICULTURAL WASTES	Field burning
4G	4 G OTHER (d)	Agricultural pesticide use - chlorothalonil use
4G	4 G OTHER (d)	Agricultural pesticide use - chlorthal-dimethyl use
4G	4 G OTHER (d)	Agricultural pesticide use - quintozine
4G	4 G OTHER (d)	Agriculture - agrochemicals use
5B	5 B FOREST & GRASSLAND CONVERSION	5B2 Deforestation
6A	6 A SOLID WASTE DISPOSAL ON LAND	Application to land
6A	6 A SOLID WASTE DISPOSAL ON LAND	Landfill
6A	6 A SOLID WASTE DISPOSAL ON LAND	OvTerr Landfill (all)- Cayman, Falkland, Montserrat, Bermuda & Gibraltar
6A	6 A SOLID WASTE DISPOSAL ON LAND	OvTerr Landfill (all)- Guernsey, Jersey, IOM
6A	6 A SOLID WASTE DISPOSAL ON LAND	Waste disposal - batteries
6A	6 A SOLID WASTE DISPOSAL ON LAND	Waste disposal - electrical equipment
6A	6 A SOLID WASTE DISPOSAL ON LAND	Waste disposal - lighting fluorescent tubes
6A	6 A SOLID WASTE DISPOSAL ON LAND	Waste disposal - measurement & control equipment
6B	6 B WASTE-WATER HANDLING	OvTerr Sewage Treatment (all)- Cayman, Falkland, Montserrat, Bermuda & Gibraltar
6B	6 B WASTE-WATER HANDLING	OvTerr Sewage Treatment (all)- Guernsey, Jersey, IOM
6B	6 B WASTE-WATER HANDLING	OvTerr Sewage Treatment (all)- Guernsey, Jersey, IOM
6B	6 B WASTE-WATER HANDLING	Sewage sludge decomposition
6C	6 C WASTE INCINERATION (e)	Agricultural waste burning
6C	6 C WASTE INCINERATION (e)	Crematoria
6C	6 C WASTE INCINERATION (e)	Foot & mouth pyres
6C	6 C WASTE INCINERATION (e)	Incineration
6C	6 C WASTE INCINERATION (e)	Incineration - animal carcases
6C	6 C WASTE INCINERATION (e)	Incineration - chemical waste
6C	6 C WASTE INCINERATION (e)	Incineration - clinical waste
6C	6 C WASTE INCINERATION (e)	Incineration - MSW
6C	6 C WASTE INCINERATION (e)	Incineration - sewage sludge
6C	6 C WASTE INCINERATION (e)	OvTerr Waste incineration (all)- Cayman, Falkland, Montserrat, Bermuda & Gibraltar
6C	6 C WASTE INCINERATION (e)	Regeneration of activated carbon
6C	6 C WASTE INCINERATION (e)	Small-scale waste burning
6D	6 D OTHER WASTE (f)	Accidental fires - dwellings
6D	6 D OTHER WASTE (f)	Accidental fires - other buildings
6D	6 D OTHER WASTE (f)	Accidental fires - vehicles
6D	6 D OTHER WASTE (f)	Infant emissions from nappies
6D	6 D OTHER WASTE (f)	Other industrial combustion
6D	6 D OTHER WASTE (f)	RDF manufac.
7	7 OTHER	Agriculture - agrochemicals use
7	7 OTHER	Bonfire night
7	7 OTHER	Cigarette smoking
7	7 OTHER	Fireworks
7	7 OTHER	Non-aerosol products - household products
7	7 OTHER	Non-aerosol products - household products
7	7 OTHER	Other industrial combustion
z_1A3ai(i)	International Aviation- LTO (Memo)	Aircraft - international take off & landing
z_1A3ai(i)	International Aviation- LTO (Memo)	Aircraft engines
z_1A3ai(ii)	International Aviation- Cruise (Memo)	Aircraft - international cruise
z_1A3di(i)	International Navigation (Memo)	Shipping - international IPCC definition
z_1A3di(i)	International Navigation (Memo)	Shipping - international IPCC definition
z_5E	Other (Memo)	Accidental fires
z_5E	Other (Memo)	Accidental fires - forests
z_5E	Other (Memo)	Accidental fires - straw
z_5E	Other (Memo)	Accidental fires - vegetation
z_5E	Other (Memo)	Adult breath & sweat
z_5E	Other (Memo)	Natural fires
z_5E	Other (Memo)	Natural sources

NFR Code	NFR Name	Source Name
z_5E	Other (Memo)	Road transport - resuspension
z_5E	Other (Memo)	Wild birds wastes
z_5E	Other (Memo)	Wild other animal wastes