UK Emissions of Air Pollutants 1970 to 2005

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Executive Summary

1 This is the annual report of the National Atmospheric Emission Inventory (NAEI), which forms part of the UK emissions inventory programme funded by Defra and the Devolved Administrations. This report is produced by AEA Technology Energy and Environment, who have been compiling the UK emissions inventory since 1972 (although under different company names through the years).

2 **UK air pollutants -** This report presents the latest estimates of emissions to the atmosphere from the UK for the period 1970 to **2005.** 44 pollutant species are included in the 2005 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. The pollutants considered in this report are:

Air Quality Pollutants

- particulate matter, PM_{10} *
- black smoke
- carbon monoxide, CO
- benzene, C_6H_6
- 1,3-butadiene, C_4H_6
- PAH * †
- nitrogen oxides, NO_x
- sulphur dioxide, SO_2
- non-methane volatile organic compounds, NMVOC *
- ammonia, NH_3
- hydrogen chloride, HCl
- hydrogen fluoride, HF

Base Cations

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

Greenhouse Gases

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

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

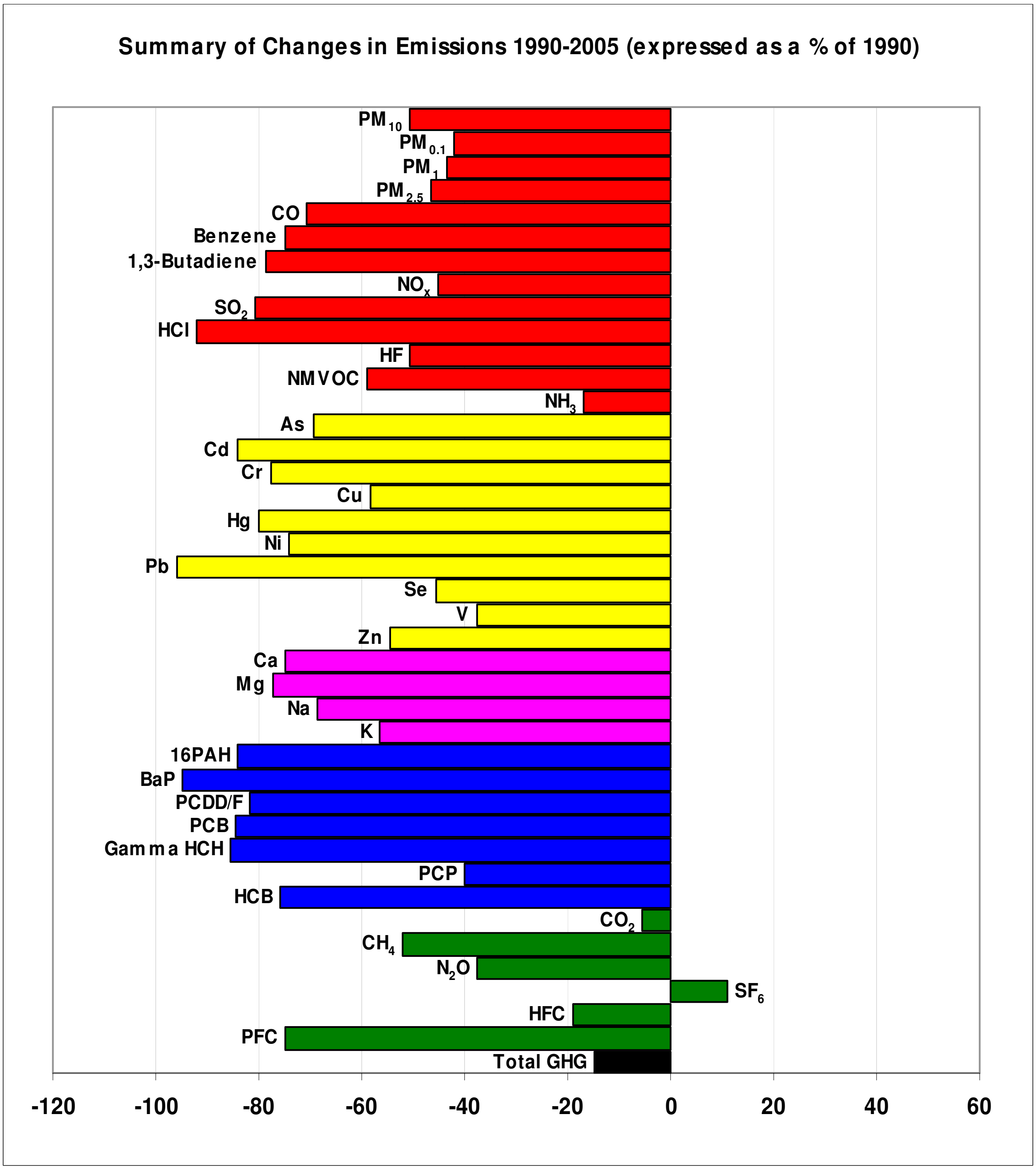
Heavy Metals

- 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 2005 emissions, expressed as a percentage of the 1990 values.



Summary of Changes in Emissions 1990-2005 (expressed as a % of 1990)

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 2005 emissions of a basket of six greenhouse gases indicates a 15% 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 7.1).

3 **CO_2 –** Emission estimates for CO_2 from the UK show a decrease of 6% between 1990 and 2005, giving an emission of 152 Mt of carbon in 2005. The most significant reductions arise from the public power and industrial combustion sectors. 2005 road transport emissions account for 21.5% of the total emission and indicate a reasonably constant absolute emission since 1997.

4 **CH_4 -** Estimates of methane emissions show a decrease of 52% from 1990 to 2005, giving emissions of 2.36 Mt in 2005. 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 0.128 Mt in 2005, corresponding to a decrease of 38% between 1990 and 2005. Emissions of nitrous oxide are dominated by agricultural emissions and passenger cars. Emission estimates of N_2O are highly uncertain (see Section 7.4).

6 **HFC, PFC and SF_6-** The UK emissions in 2005 were HFCs: 2.5 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 19% and 75% since 1990 for HFC and PFC respectively. The increase in SF_6 has been discussed above in point 2.

7 **PM –** The UK emissions of PM_{10} declined by 51% between 1990 and 2005, giving an emission of 0.15 Mt in 2005. This reflects a trend away from coal use particularly by domestic users. Coal combustion and road transport together contributed 31% of UK emissions of PM_{10} in 2005. 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 25% of the 2005 total emission.

8 **BS -** Black smoke emissions in the UK have significantly declined (by some 86% between 1970 and 2005). Emissions in 2005 were estimated to be 150 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 2005 (2.4 Mt) represent a 71% reduction on the emissions in 1990. UK emissions of CO are dominated by those from road transport (47% of UK emissions in 2005). The change in emissions between 1990 and 2005 is dominated by the reduction in emissions from the road transport sector, caused by the increased use of catalytic converters in cars.

10 **Benzene** –Emissions have decreased by 75% between 1990 and 2005, giving an emission of 14.0 kt in 2005. Fuel combustion in the residential sector is the most significant source of benzene, accounting for some 35% of UK emissions in 2005. The next most significant source is emissions from petrol fuelled passenger cars (17%). The decline in emissions over time is primarily due to a marked reduction in benzene emissions from road transport as a result of tighter European vehicle emission standards and fuel quality Directives being introduced.

11 **1,3-Butadiene** – Emissions in 2005 were estimated to be 2.6 kt, representing a decrease of 78% between 1990 and 2005. Emissions of 1,3-butadiene are dominated by fuel combustion in the road transport sector, which account for some 61% of the 2005 UK emissions. There have been significant reductions in the emissions from this sector due to the increase in the number of cars equipped with catalytic converters.

12 **NO_x -** UK emissions of NO_x were approximately 3.0 Mt in 1990. Emissions have fallen significantly to around 1.6 Mt in 2005, 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. Together road transport and power stations contribute 57% of UK emissions in 2005.

13 **SO_2 -** UK emissions of sulphur dioxide have fallen from 3.7 Mt in 1990 to 0.7 Mt in 2005, representing a decrease of 81%. This is a result of reduced emissions from the industrial and public power sectors arising from the decreasing use of high sulphur coal and increasing use of abatement equipment. Combustion of fuels in the power station, refining and manufacture of solid fuels sectors accounted for 65% of the 2005 UK SO_2 emissions.

14 **HCl -** UK emissions of hydrogen chloride have decreased by 92% between 1990 and 2005, giving an emission of 21 kt in 2005. 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 0.98 Mt for 2005, thereby showing a decrease of 59%. The observed decrease arises primarily from tighter European vehicle emission standards and fuel quality directives being introduced and the impact of the Solvent emissions Directive.

16 **NH_3 -** The total UK emission of ammonia was estimated to be 0.32 Mt, compared to the 1990 estimate of 0.38 Mt, giving a 17% reduction. The agricultural sector dominates ammonia emissions, and emissions have decreased substantially since 1999. There were increases in emissions from the road transport sector between 1990 and 2000 caused by the increased use of catalytic convertors. Improvements in these mean that emissions from the road transport sector are now declining. There have also been decreases in the agricultural sector due to decreased agricultural livestock numbers.

17 **HF –** The total hydrogen fluoride emissions for 2005 are estimated to be 4.9 kt, representing a 51% reduction on the 1990 emission estimates. As with hydrogen chloride the dominant source is coal combustion for public power contributing 62 % of emissions in 2005.

18 **POPs –** The 2005 UK emissions of persistent organic compounds may be summarised as follows: 1,248 t **PAH** (USEPA 16), 205 g I-TEQ **PCDD/F** (grammes of "toxic equivalent" of dioxins & furans) and 1.03 t **PCB**. Emissions from all three of these pollutant groups have greatly decreased. Emissions in 2005 equate to decreases of 84%, 82% and 84% on the 1990 emissions, for PAHs, PCDD/Fs and PCBs respectively.

19 **Pb -** UK emissions of lead have declined sharply following the switch from leaded to unleaded and lead replacement petrol. Emissions in 2005 are estimated to be 0.12 kt, a decrease of 96% on the 1990 estimates. Road transport contributed only 2% of total UK emissions in 2005.

20 The 2005 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 (2005)

Pollutant	Total Coal Combustion	Road Transport	Total Contribution
HCl	93%	0%	**93%**
HF	83%	0%	**83%**
Sn	62%	13%	**75%**
16 PAHs	7%	64%	**72%**
SO_2	65%	0%	**65%**
1,3-Butadiene	0%	61%	**61%**
Se	34%	21%	**55%**
NO_x	21%	34%	**55%**
CO	7%	47%	**54%**
Cu	7%	41%	**49%**
Mg	44%	0%	**44%**
Carbon	23%	22%	**44%**
Mn	29%	7%	**37%**
Be	14%	21%	**34%**
Na	33%	0%	**33%**
Benzo[a]pyrene	28%	4%	**32%**
PM_{10}	9%	22%	**31%**
Benzene	2%	21%	**22%**
K	20%	0%	**20%**
As	12%	0%	**12%**

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

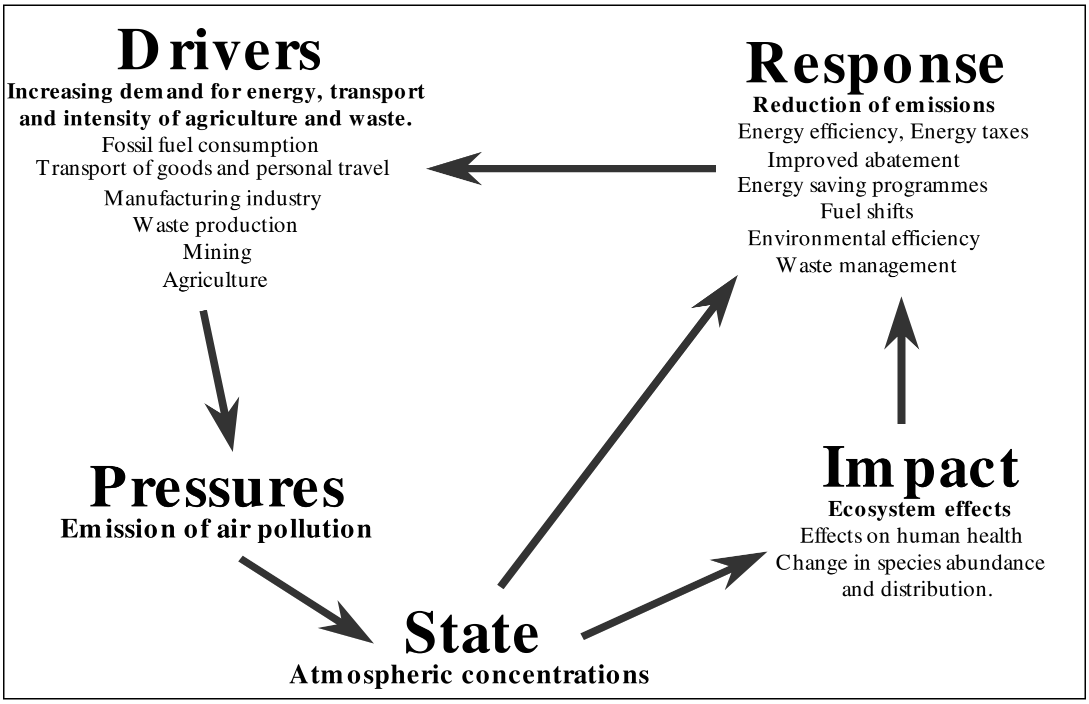
1.1 AN INTRODUCTION/BACKGROUND TO EMISSION INVENTORIES

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) interacts 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



1.1.1 Nomenclature of the inventory

The UK National Atmospheric Emission Inventory is presented in the nomenclature for reporting (NFR) format (2002 Guidelines). The exception to this is the mapping emissions which are presented by SNAP code (1997 Guidelines). Selected Nomenclature for Air Pollution codes were originally developed by the European Topic Centre (ETC) at the European Environment Agency (EEA) for reporting under the National Emissions Ceilings Directive. The use of SNAP codes are however now declining as Member States move towards using the Long-Range Transboundary Air Pollution (LRTAP) convention templates for NECD reporting which use NFR codes[1].

1.2 THE UK NATIONAL ATMOSPHERIC EMISSIONS INVENTORY

The UK emissions inventory is compiled by the UK Emissions Inventory Team, at AEA Energy & Environment. 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 on air quality pollutants is conducted for the Air and Environment Quality (AEQ) Division under the heading of the National Atmospheric Emissions Inventory (NAEI). Work on greenhouse gases (GHGs) is conducted for the Climate, Energy, Ozone, Science and Analysis (CEOSA) Division and is delivered as the Greenhouse Gas Emissions Inventory (GHGI). However, the UK programme is a single internally consistent programme. The 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 and GHGI are the standard reference air emissions inventories for the UK and include 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 1.2 Where possible, estimates are presented for 1970-2005. However, for some pollutants, for example ammonia (NH_3) and nitrous oxide (N_2O), there is insufficient information to produce a 1970-2005 time series and estimates are presented from 1990-2005.

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

1. **Provision of Public Information-** The data from the NAEI and GHGI 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/GHGI is paid for by tax payers money, through the national and devolved administration Governments, 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/GHGI is used to inform development of policies to tackle emissions of air quality pollutants and greenhouse gases.
    - **Identification of Primary Sources-** The NAEI/GHGI compiles emissions from all possible anthropogenic and natural sources (where information

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[1] For details regarding the NECD and LRTAP Convention, please see Annex 1.

allows). Consequently it is simple to determine which source sectors are the major emitters of individual pollutants.

- **Temporal and Spatial Trend Assessment-** The NAEI/GHGI 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 more than 20 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/GHGI. As a result comparison with the NAEI/GHGI highlights the potential strengths and weaknesses of the different techniques.

- **National Modelling Studies-** The NAEI/GHGI 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/GHGI alone to investigate the impact on emissions of particular future policy scenarios.

- **Local Support-** Data from the NAEI/GHGI 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/GHGI 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 ceilings and reductions at both the national and international level. It 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/GHGI emissions inventory is often used by industry. This allows emission reductions to be planned by either introducing 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). The GHGI provides data for submission to the United Nations Framework Convention on Climate Change (UNFCCC) (Table 1.1). 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/GHGI 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). Member States are also required to submit emissions data for four pollutants under the National Emissions Ceilings Directive (NECD). 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.

Table 1.1 Reporting requirements for the 2005 inventory

Legal Obligation	**Reporting requirement**		**2005 reporting deadline**
	Pollutants	**Time period**	
LRTAP Convention (1979 Convention on long range transboundary air pollution)	Emissions of SO_2, NO_x, NH_3, NMVOCs, CO, Heavy Metals, Persistent Organic pollutants (POPs), particulate matter (PM)	1980-2005	15 February 2007
EU NECD (Directive 2001/81/EC)	Emissions of SO_2, NO_x, NMVOCs, NH_3	2004-2005, 2010	31 December 2006
UNFCCC EU Monitoring Mechanism (Council Decision 280/2004/EC)	Emissions of CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, NO_x, CO, NMVOC, SO_2	GHG 2005 , Air Quality Pollutants 2004-2005	15 January 2007 to European Commission 15 April 2007 to UNFCCC

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/GHGI. 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 inventory of sources and releases (ISR). In 2007 E-PRTR (European Pollutant Release and Transfer register) will succeed EPER. E-PRTR extends the scope of EPER to include emissions of more pollutants from more facilities as well as diffuse sources and requires annual instead of triennial reporting. The emissions inventory team are working with DEFRA to achieve these aims.

1.2.1.1 International Review

The Task Force on Emission Inventories and Projections (TFEIP) includes an expert panel on emissions inventory review, which has been developing a plan for introducing the review of data submitted under the LRTAP. The plan is to draw on the UNFCCC systems which are already in place for reviewing greenhouse gas emission inventories, and applying this to air quality pollutants. The UNFCCC process includes a range of different types of review (at different detail levels). Whilst it is possible to use many of these already established processes there are some complications. For example it is possible to combine greenhouse gas pollutants to give a single overall "equivalent" emission, but this is not possible with air quality pollutants.

In 2005 the TFEIP, in conjunction with the EEA, conducted a voluntary "centralised" review. This involved a range of internationally recognised experts being assigned to specific emission sectors, and reviewing the emission inventories of approximately 8 countries. A limited number of pollutant emissions were included for practical reasons. A number of the UK emissions inventory team were involved in the review process, both as experts and as national representatives.

The outcome of this trial review was valuable in both identifying improvements that participating countries could implement, and in identifying the levels of resources needed for an on-going review programme. Since the review there has been discussion on arranging a second voluntary review, but of a more manageable scale. It is anticipated that a review programme will be established in the future for the air quality pollutants, but funding and the additional effort needed by countries to participate remains a barrier.

1.2.2 National Information

The NAEI/GHGI 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. For example the emissions data underpinned air quality modelling carried out as an integral part of the development of the 2007 Air Quality Strategy (see http://www.defra.gov.uk/environment/airquality/strategy/index.htm, http://www.airquality.co.uk/archive/reports/reports.php?action=category&section_id=1, http://www.airquality.co.uk/archive/reports/reports.php?action=category&section_id=16, for details of the modelling carried out and the resulting policies developed)

- 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. The

UK Pollution Climate Mapping model (PCM) (see Kent et al (2006)[2] for the most recent modelling method and results) and the Ozone Source Receptor model (OSRM) (Hayman et al, 2005)[3] use the NAEI 1x1km mapped emissions data to calculate spatially disaggregated maps of ambient concentrations of air quality pollutants. These models are used both in reporting air quality exceedences to the European Commission under the European Daughter Directives on air quality and extensively for scenario modelling to inform policy developments by defra.

- 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/GHGI 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.

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[2] Kent, AJ, Grice, SE, Stedman, JR, Bush, AJ, Vincent, KJ, Abbott, J, Derwent, R, Hobson, M (2006). UK air quality modelling for annual reporting 2005 on ambient air quality assessment under Council Directives 96/62/EC, 1999/30/EC and 2000/69/EC.
http://www.airquality.co.uk/archive/reports/cat09/0709241126_dd12005mapsrep_v2.pdf

3 Hayman, G, Abbott, J, Thompson, C, Bush, T, Kent, AJ, Derwent, R, Jenkin, M, Pilling, M, Rickard, A, Whitehead, L (2005) Modelling of Tropospheric Ozone.
http://www.airquality.co.uk/archive/reports/cat05/0612011037-420_ED47154_Final_Report_Issue1.pdf

Table 1.2 Pollutants Covered by the Inventories

Pollutant		**Range of Estimates**[1]	**Type of Pollutant**[2]
Carbon Dioxide	CO_2	1970-2005	G
Methane	CH_4	1970-2005	G
Nitrous Oxide	N_2O	1990-2005	G
Hydrofluorocarbons	HFC	1990-2005	G
Perfluorocarbons	PFC	1990-2005	G
Sulphur Hexafluoride	SF_6	1990-2005	G
Nitrogen Oxides	NO_x (NO_2 + NO)	1970-2005	NAQS, AC, IG, O
Sulphur Dioxide	SO_2	1970-2005	NAQS, AC, IG
Carbon Monoxide	CO	1970-2005	NAQS, O
Non-Methane Volatile Organic Compounds	NMVOC	1970-2005	NAQS, O, IG
Black Smoke	BS	1970-2005	NAQS
Particulates < 10 µm	PM_{10}	1970-2005	NAQS
Ammonia	NH_3	1990-2005	AC
Hydrogen Chloride	HCl	1970-2005	AC
Hydrogen Fluoride	HF	1970-2005	AC
Lead	Pb	1970-2005	NAQS, TP
Cadmium	Cd	1970-2005	TP
Mercury	Hg	1970-2005	TP
Copper	Cu	1970-2005	TP
Zinc	Zn	1970-2005	TP
Nickel	Ni	1970-2005	TP
Chromium	Cr	1970-2005	TP
Arsenic	As	1970-2005	TP
Selenium	Se	1970-2005	TP
Vanadium	V	1970-2005	TP
Beryllium	Be	2000-2005	TP
Manganese	Mn	2000-2005	TP
Tin	Sn	2000-2005	TP
Polycyclic Aromatic Hydrocarbons	PAH	1990-2005	TP
Dioxins and Furans	PCDD/F	1990-2005	TP
Polychlorinated Biphenyls	PCB	1990-2005	TP
Lindane (gamma-HCH)	HCH	1990-2005	TP
Pentachlorophenol	PCP	1990-2005	TP
Hexachlorobenzene	HCB	1990-2005	TP
Short-chain chlorinated paraffins	SCCP	1990-2005	TP
Polychlorinated Napthalenes	PCN	NE	TP
Polybrominated diphenyl ethers	PBDE	SE	TP
Sodium	Na	1990-2005	BC
Potassium	K	1990-2005	BC
Calcium	Ca	1990-2005	BC
Magnesium	Mg	1990-2005	BC

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

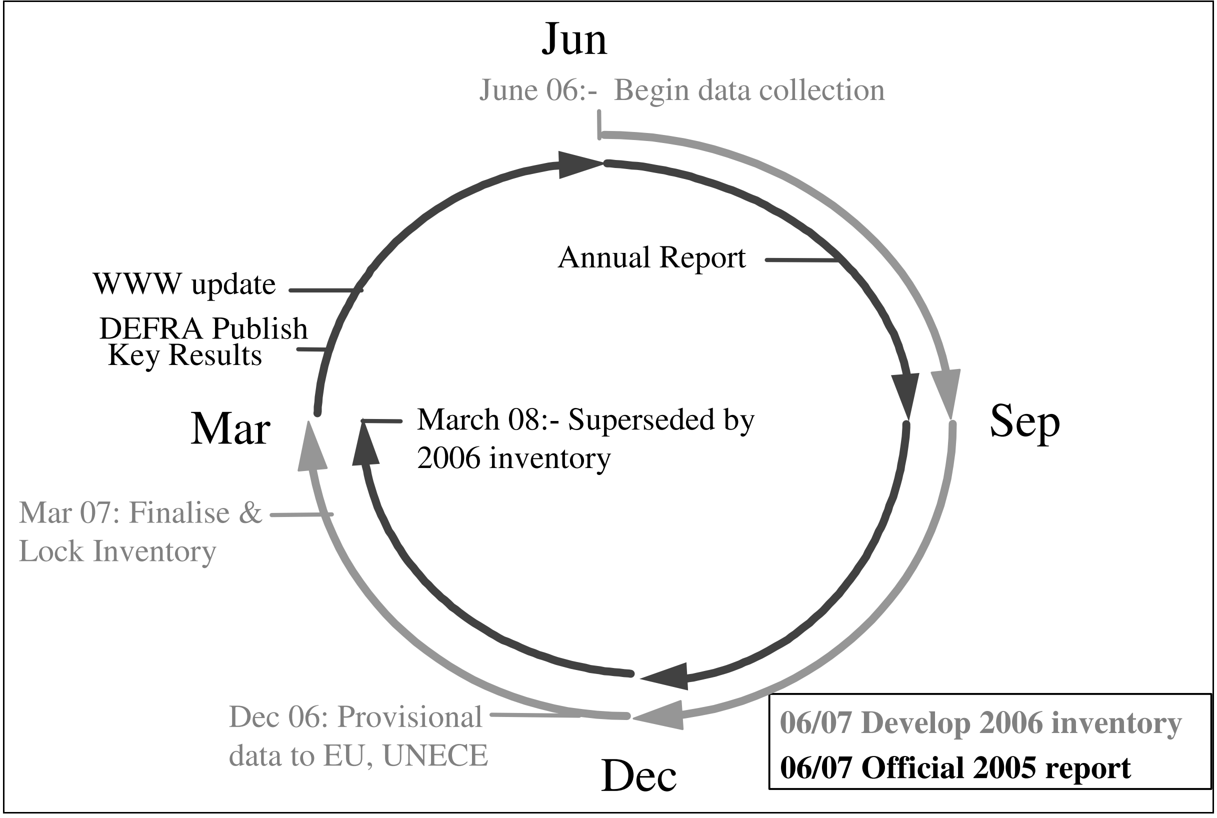
SE	A "Single Emission" estimate not attributed to a specific year
NE	"Not Estimated" due to lack of information currently available

[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/GHGI is compiled on an annual basis; each year the latest set of data are added to the inventory and the full time series is 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 is consistent and 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 and national organisations. This annual cycle of activity is represented schematically in Figure 1.2.

Figure 1.2 The Annual NAEI Cycle



This report presents the definitive 2005 data from the NAEI and is the latest in a series of annual reports published by the UK emissions inventory team (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* 2003, Dore *et al* 2004, Dore *et al* 2005, Dore *et al* 2006). In addition, the NAEI also produces an annual GHG Report (Baggott *et al* 2006).

Methodology appendices are now not included with this hard copy of the report, but more detailed information on the methodology can be accessed from the NAEI webpage (http://www.naei.org.uk).

Chapters 2 to 7 present the NAEI/GHGI emission estimates for the UK. They have been divided into five groups, reflecting the national and international activity relating to atmospheric pollution, namely air quality pollutants, heavy metals, base cations, persistent organic pollutants (POPs), stratospheric ozone depletors and GHGs. 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 spatial disaggregation within the UK as well as the accuracy of the emission estimates.

1.2.3 Information Dissemination

Data from the NAEI/GHGI 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. This annual report is also produced, outlining recent emissions data and other information such as: temporal trends, new pollutants and methodology changes. The NAEI/GHGI 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 be found 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.

- **Reports: -** The most recent NAEI/GHGI 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/GHGI 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 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 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 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.
In summary the emissions are estimated by combining an activity statistic with an emission factor:

$$\text{Emission} = \text{Emission Factor} \times \text{Activity}$$

e.g.

Carbon Emission from coal use in domestic heating (in 2005)	=	Carbon content of domestic coal (in 2005)	×	Coal consumption in the domestic sector (in 2005)

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 sources 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 emissions 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/GHGI uses the Department for Business, Enterprise and Regulatory Reform’s (formerly known as DTI) 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/GHGI.

A detailed description of methodologies can be found in the UK Greenhouse Gas Inventory, 1990 to 2005 (Baggott et al, 2007).

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 dependent upon the data that are available. The technique employs a combination of reported emissions (for emission sources at regulated facilities) and surrogate geographical statistics to distribute emissions from line and area sources. A detailed description of the emission mapping methodology can be found in the reports section of the NAEI website:

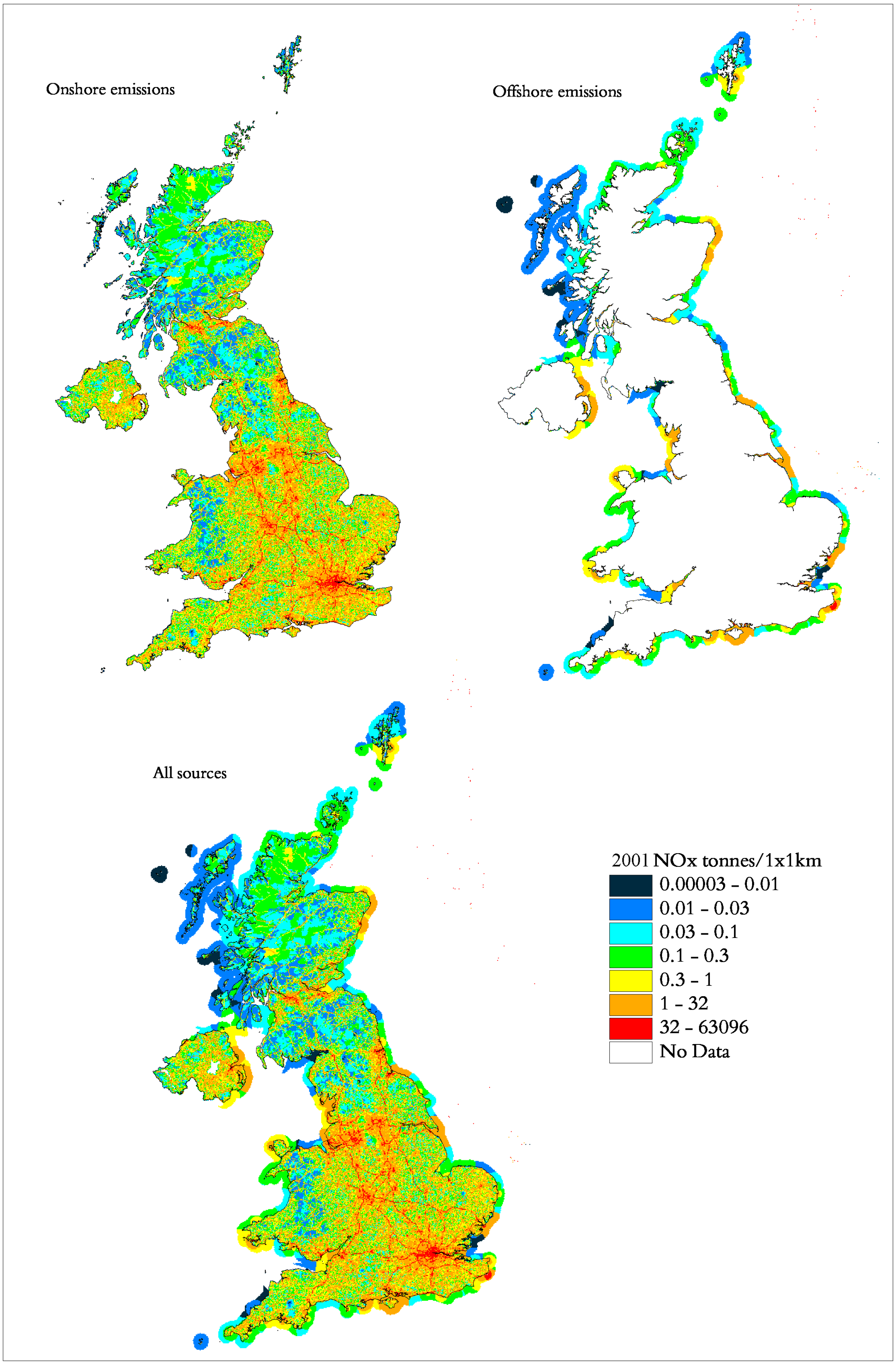
http://www.naei.org.uk/reports.php

The emission maps combine the information from 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/GHGI 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. 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. 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[4]- Onshore, Offshore and Total Emissions (illustrative purposes)



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[4] This map is reproduced from Ordnance Survey material with the permission of Ordnance Survey on behalf of the Controller of Her Majesty's Stationery Office © Crown copyright. Unauthorized reproduction infringes Crown copyright and may lead to prosecution or civil proceedings. Defra, License number 100018880, 2006

1.2.6 Projections

As part of the NAEI programme projections of UK emissions are compiled to enable comparisons with international commitments to be assessed. In addition, projected emissions are used by dispersion modellers to assess the UK's progress in meeting the air quality strategy objectives as well as having many other uses.

The UK has made commitments under the Gothenburg Protocol and the more stringent National Emissions Ceiling's Directive (NECD) to reduce emissions of NOx, SO_2, NMVOCs and NH_3 by 2010. The target emissions are provided in Table 1.3 below together with the UK's actual emissions in 2005 (the latest year available). These targets are to be achieved in 2010 and subsequent years. The data shows that the NMVOC ceiling has already been met and that only a further small NH_3 reduction is required. Larger declines are however needed between 2005 and 2010 for NOx and SO_2 if the UK is to meet its emission ceiling for these pollutants.

Table 1.3: The UK's emissions in 2005 (as reported to the NECD[5]) and the targets in 2010 that the UK is committed to.

Pollutant	Emissions in 2005 (ktonnes)	Gothenburg Protocol target in 2010 (ktonnes)	Emissions ceiling target in 2010 (ktonnes)	Reduction required between 2005 and 2010
NOx	1,629	1,181	1,167	28%
SO_2	706	625	585	17%
NMVOCs	977	1,200	1,200	N/A
NH_3	317	297	297	6%

Projections of UK emissions are compiled when new energy forecasts, road traffic projections and / or a new version of the inventory becomes available.

Methodology

The NAEI method for estimating future emissions follows the methodology outlined in the EMEP / CORINAIR Guidebook. 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. Activity in the base year is scaled using "drivers" such as energy forecasts to indicate future trends. For road transport, a detailed emission forecasting approach is used, adopting the latest traffic forecasts reflecting current Government policies on transport, fleet turnover and the penetration of vehicles meeting the tougher European vehicle emission Directives.

Forecasts also take into account the introduction of policies and measures that have been implemented into UK law. The projections do not include the impact of additional policies and measures that are currently subject to review and have not yet been implemented into UK law. The policies currently included are:

- The large combustion plant Directive (LCPD)
- Integrated Pollution Prevention and Control Directive
- The Solvent Emissions Directive
- Marpol VI agreement requiring marine fuel oil to have a sulphur content less than 1.5%.

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[5] Different conventions require different sectors to be reported.

- Sulphur content of liquid fuels regulations
- European directives on vehicle emissions and fuel quality (currently legislation up to and including Euro 5 & 6 for light duty vehicles is now included. Euro standards for heavy-duty vehicles beyond Euro V have not been included as these standards are still at the proposal stage and no limit values have yet been agreed).
- European Directives on non-road mobile machinery emissions.
- Introduction of sulphur-free fuels (petrol & diesel), under Directive 2003/17/EC.

Two sets of emission projections for the four National Emission Ceiling Directive (NECD) pollutants (NOx, SO_2, NMVOC, NH_3) plus PM_{10} have been compiled using the 2005 NAEI. The first dataset was based on the Department of Business Enterprise and Regulatory Reform's (BERR) updated energy paper (UEP) 26 and the second dataset was based on BERR's UEP30 energy forecasts. The latter forecasts are consistent with those published in the Government's Energy White Paper published in May 2007. The energy projections are based on an analysis of historical trends in energy use and its relationship to such factors as economic growth and fuel prices. They also take into account the impact of existing government policies on energy and the environment. Assumptions about fossil fuel prices, economic growth and other relevant factors are used in the model to investigate possible scenarios for UK energy demand and supply. Various energy demand scenarios are examined in UEP30. The NAEI projections are based on the UEP30 central fossil fuel prices – central white paper policy forecasts. The forecasts take into account agreed climate change measures and carbon pricing (for the power station sector only). Projections are provided for the years 2010, 2015 and 2020. Therefore emission projections have also been produced for these years.

The main changes from the previous energy forecasts, known as UEP26 are that fossil fuel price assumptions have been revised. An increase is now expected in future fuel prices, which is consistent with other major energy projections produced by the IEA. This reflects market tightness and higher costs of production. In addition, the economic growth assumptions have been updated and Budget 2007 implications have been incorporated.

International models

There are various international energy and emission models that have been developed which provide energy and emission forecasts for the UK. These include:

- The PRIMES energy model developed by the National Technical University of Athens;
- The GAINS (the Greenhouse gas and Air Pollution, Interactions and Synergies) model developed by the International Institute for Applied Systems Analysis (IIASA) in Austria. The model provides a consistent framework for the analysis of reduction strategies for air pollutants across Europe and beyond.
- TREMOVE, a policy assessment model designed to study the effects of different transport and environmental policies on emissions from the transport sector. It has been developed by Transport & Mobility Leuven on behalf of DG Environment at the European Commission.
- The CAPRI (Common Agricultural Policy Regional Impact Analysis) model is an agricultural sector model covering the EU27 and Norway at regional level and global agricultural markets. The model has been developed to analyse the impact of different elements of the Common Agricultural Policy, of environmental or trade policies on the EU's agriculture and the environment.

In many cases, data used to generate the UK emission projections and the resulting emissions have been provided to the above model developers to enable them to create as accurate as possible emission estimates for the UK. These models are then used in European policy formation.

Consistency with greenhouse gas emission projections
The UK emissions inventory team also compiles projections of non-CO_2 greenhouse gas emissions. Carbon dioxide forecasts are produced by BERR. The UK is required to submit greenhouse gas emission projections to the EU Monitoring Mechanism bi-annually.

1.2.7 Continuous Improvement

The NAEI/GHGI operates a policy of continuous improvement, and reviews methodologies each year. The 2005 version of the NAEI/GHGI 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 and 2004 NAEI reports have been published.

Review of the treatment of renewable fuels in the inventory.
The use of renewable energy sources has much increased in recent years and a review of the inventory was carried out to ensure that the use of biofuels was adequately dealt with. The review found that previous versions of the inventory did not include all of the renewable fuels given in BERR energy statistics, although this did not necessarily mean that emissions were underestimated. Some revisions were made to the power stations sector estimates as a result of the review and further improvements are likely in future years as the quantity of data available increases.

Revision of methodology for refinery emissions
The methodology for emissions from combustion sources at crude oil refineries has been updated and improved. Emission estimates for CO, NO_X, SO_2, and PM_{10} were previously based on emissions data provided by the process operators. This is still the case, but the apportioning of those emissions to the different fuels burnt at refineries has been improved. For metal emissions, the inventory previously relied upon literature-based emission factors, but the new methodology makes use of emissions reported by process operators in the Pollution Inventory instead.

Revision of methodology estimating emissions of dioxins
There have been a significant number of revisions to the methodology for estimating emissions of dioxins, following a short internal review of the NAEI methodology for persistent organic pollutants (POPs). Most of the revisions have made a small impact relative to UK emissions as a whole, although some are more significant.

The emission factor used for combustion of fuel oil, gas oil and other petroleum-based fuels has been revised downwards and this has led to a decrease in estimated emissions for 2004 of 39 g I-TEQ. The emission factor for coal-fired power stations has also been revised, with a factor given in Environment Agency's Guidance for Combustion Activities on Pollution Inventory Reporting (Environment Agency, 2006) being used instead. This revision has had little impact on the national emission estimate. Revisions to factors for coal burnt by the public sector and domestic wood burning have also had a minor impact.

Pollution Inventory data has been used as the basis of emission factors for the secondary lead industry whereas, previously, a literature factor was used. This change has reduced estimated emissions during 2004 by 3 g I-TEQ.

The changes made to the approach for burning of treated wood have been described above, but these changes also impact upon emission estimates for dioxins, reducing the figure by 4 g I-TEQ for 2004.

Finally, the approach for estimating emissions from accidental vehicle fires has been updated. Previously, the emission factor took account of measurements of fires in vehicles of varying ages, but the approach now adopted is to only use data for more appropriate, newer, vehicles. The 2004 emission estimate reduces by about 6 g I-TEQ as a result.

Emission estimates for polychlorinated bipenyls (PCBs) from capacitors, transformers and fragmentisers have been reduced to reflect expected reductions in air emissions due to the requirements of the Disposal of Polychlorinated Biphenyls and other Dangerous Substances Regulations that came into force in 2000. The regulations require the disposal of PCB containing equipment or decontamination of equipment contaminated with PCBs to acceptable levels. The change in method leads to a reduction in estimated emissions of 242 kg.

Road Transport

Minor changes have been made to the methodologies and data used for compiling the 2005 inventory for the road transport sector. A change in the petrol fuel consumption factors used for certain types of off-road machinery has led to a very small re-allocation of overall petrol consumption from road transport to the off-road machinery sector. This has a very small effect on estimates of CO_2 emissions from the road transport sector in all years, reducing the estimates by around 60Gg in all years from 1990 (0.2%) compared with last year's inventory estimates. Very small changes in emission estimates for other pollutants compared with last year's inventory estimates are due to minor changes in the vehicle kilometre data for traffic in Northern Ireland for the years 2002-2004.

Off-road Sources and rail vehicles

Some changes have been made to the emission factors used for certain types of off-road machinery in the 2005 inventory. These have been made mainly for older types of petrol-engined machinery in order to get a more realistic and consistent carbon balance between their fuel consumption rates and carbon emissions in the form of CO, CH_4 and NMVOCs. Fuel consumption rates for some machinery types were increased so, as a result, estimates of the amount of petrol consumed by off-road machinery in 2004 have been increased by 37% compared with last year's estimates. Relatively small amounts of petrol are consumed by off-road machinery (the majority use diesel or gas oil as a fuel), so this large increase in estimated petrol consumption only increases total carbon emissions from the whole of the off-road machinery sector by 1.7% compared with last year's estimate for the sector in 2004. The overall fuel balance for petrol consumption has been maintained by reducing the estimates of the amount of petrol consumed by road transport, but this re-allocation leads to only a 0.4% (70 ktonnes) reduction in petrol consumption by road transport compared with last year's estimate because this sector is by far the largest consumer of petrol fuel. The changes in fuel consumption rates for certain petrol machinery were accompanied by a reduction in CO, CH_4 and NMVOC emission factors. Consequently, overall emission estimates for these pollutants for off-road machinery in 2004 decreased by 30%, 19% and 18%, respectively, compared with last year's estimates. Inventory estimates for other pollutants are unchanged.

The population and usage surveys and assessments were only able to provide estimates on activity of off-road machinery for years up to 2004. These are one-off studies requiring intensive resources and are not updated on an annual basis. There are no reliable national statistics on population and usage of off-road machinery nor figures from BERR on how these fuels, once they are delivered to fuel distribution centres around the country, are ultimately used. Therefore, other new activity drivers were used to estimate activity rates for the four main off-road categories in 2005. For industrial machinery, manufacturing output statistics were used to scale 2005 activity rates relative to 2004; for domestic house and garden machinery, trends in number of households were used; for airport machinery, statistics on number of take-off and landings at UK airports were used.

Fuel consumption by the railway sector was revised downwards slightly in the 2005 inventory as a result of more reliable data coming available from the Association of Train Operating Companies (ATOC). This lead to a reduction in emission estimates of all pollutants apart from for NOx. This was as a result of improved, but higher NOx emission factors being incorporated into the inventory.

Shipping
Emissions from navigation have been revised in this year's inventory following a review and update of emission factors for different types of shipping and a more detailed examination of their activities in UK waters. In particular, more detailed information on shipping emission factors have been used from the study done by Entec UK Ltd for the European Commissions (Entec, 2002) and from the more recent EMEP/CORINAIR Handbook (CORINAIR, 2002).

1.2.8 Outlook

A number of activities outside the core compilation work are planned for the 2006 inventory cycle. These are:

Biofuels
Two reports on biofuels are planned. A scoping Study will be undertaken which will explain the current availability of biofuel consumption data and emission factors that would be required to calculate emissions from the road transport sector covering vehicles running on different types of biofuels.

A further report on road transport biofuels is planned for the autumn of 2007. This will include a further emission factor literature review and will provide UK NOx and PM_{10} emissions arising from various uptake rates of biofuels.

Primary NO_2 / HONO
Emission inventories are able to report fairly accurate estimates of NO_x emissions, but have paid little attention to the speciation of NO_x into its components nitric oxide (NO) and nitrogen dioxide (NO_2), while air quality models have generally assumed the vast majority of emissions are in the form of NO. However, there is increasing evidence of direct emissions of primary NO_2 and a related species, nitrous acid (HONO) in significant quantities from some sources, especially diesel vehicles. Furthermore, an increased proportion of NO_x is emitted as NO_2 from diesel vehicles fitted with certain exhaust after-treatment devices such as oxidation catalysts and types of particulate filters. This has significant implications to local NO_2 air quality in urban areas.

This report will review emission factors for primary NO_2 and HONO and develop NO_2/NO_x and $HONO/NO_x$ ratios for a number of different sources. By applying these ratios to the current NAEI estimates for NO_x emissions, a UK inventory of primary NO_2 and HONO will be developed over a 1990-2005 time series.

Organic nitrogen

Currently organic nitrogen species are not included in the NAEI. As a result, the summation of N species emissions does not give a full N budget. Consequently there is a need to investigate the possibility of determining the emissions of organic nitrogen species. This report will draw on the available literature and make recommendations as to what approach should be taken.

Mapping improvements

A number of improvements will be made to the 2006 NAEI emission maps. The work will focus on improving the way emissions from landfills, minor roads, airports, petrol stations and the industrial and commercial sectors are mapped.

Dibenzo(a,l,)pyrene

Further information on Poly Aromatic Hydrocarbons (PAHs), in particular dibenzo(a,l)pyrene is required. A scoping study of dibenzo(a,l)pyrene emissions will be conducted outlining the results, recommendations for improvement and general conclusions.

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.

These pollution inventories are, in part, compiled for reporting under the European Pollutant Emission Register (EPER). For emissions in 2007 E-PRTR (European Pollutant Release and Transfer register) will succeed EPER. EPER applies to certain emissions from facilities in a range of industrial activities. E-PRTR will extend the scope of EPER to include emissions of more pollutants from more activities as well as emissions from diffuse sources and requires annual instead of triennial reporting.

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/GHGI 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/GHGI maps, as the locations of individual point sources are known. The UK emissions inventory team 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 EPER/E-PRTR. The reporting of emissions is required for all activities listed in Annex I of the IPPC Directive, and under EPER/E-PRTR requirements, emissions reporting is required for the years 2002, 2004 and 2007 onwards. Historically, the Scottish emissions inventory was managed by three regional offices, but in recent years a centralised emissions inventory for Scotland has been 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/GHGI 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/E-PRTR 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/GHGI 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 Air Quality Pollutants

2.1 INTRODUCTION

This section provides a discussion of the UK emissions affecting local and transboundary air pollution, which are targeted by both international and national policies. Table 2.1 summarises these policies and the pollutants covered.

Table 2.1 Pollutants covered by international and legislative directives

Directive	**Pollutant Covered**
Air Quality Strategy	PM – PM_{10}, $PM_{2.5}$, NO_x, O_3, SO_2, PAH's, Benzene, 1,3-butadiene, CO, Pb
NECD (National Emissions Ceilings Directive)	SO_2, NH_3, NO_x, NMVOC
CLRTAP (Convention on Long Range Transboundary Air Pollutants)	SO_2, NH_3, NO_x, NMVOC, Heavy Metals, POP's
E-PRTR / EPER	91 compounds, including: CH_4, CO, CO_2, HFC's, N_2O, SF_6, NH_3, NMVOC, NO_x, PFCs, SO_x, CFCs, As, Cd, Cr, Cu, Hg, Ni, Pb, Zn, PFC, PM_{10}, Benzene, HCl, HF, PAHs, PCB, PCDD, PCDF, Gamma HCH, PCP, HCB
IPPC (Integrated Pollution Prevention Control)	SO_2, NO_x, CO, VOC, metals, dust, asbestos, chorine and its compounds
LCPD (Large Compustion Plants Directive)	SO_x, NO_x, PM
WID (Waste Incineration Directive)	Dust (PM), HCl, HF, SO_2, NO_x, Heavy metals, dioxins and furans, CO
Solvent Emissions Directive	VOC
Paints Directive	VOC
The Sulphur Content of Liquid Fuels Directive	SO_2
Petrol vapour recovery	VOC
EU Air Quality Directives	SO_2, NO_x, PM, lead, benzene, CO, ozone, PAH, Cadmium, Arsenic, Nickel, Mercury

More detailed information on the methodologies used to compile the following inventories, and more detailed data are available from the NAEI website (http://www.naei.org.uk).

2.1.1 Transboundary air pollution

A number of international policies are currently in place to target transboundary air pollution. A specific target of these policies is acidifying pollutants and tropospheric ozone precursors, of which the total 2005 UK estimated emissions are summarised in Table 2.2.

Table 2.2 Estimated total UK Emissions of Acidifying and Ozone Precursors in 2005

Pollutant	**Total 2005 emission (ktonnes)**
Nitrogen oxides (as NO_2)	1,627
Sulphur dioxide	706
Hydrogen chloride	21
Non-methane volatile organic compounds (NMVOC)	977
Ammonia	318
Hydrogen fluoride	4.9

Concerns about acidifying pollutants arise as 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 NH_3 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.

Tropospheric ozone precursors include pollutants such as carbon monoxide, nitrogen oxides and volatile organic compounds. Tropospheric or ground level ozone occurs naturally, however atmospheric levels can be increased *in-situ* by the photochemical reaction of these ozone precursors. 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°C and light winds. Ozone can affect human health and can damage plants and crops. There are no significant ozone emissions directly from anthropogenic activities.

UN/ECE's Convention on Long-Range Transboundary Air Pollution

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

The NMVOC Protocol required 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 2,475 ktonnes in 1988 to 1,577 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 table 2.3.
- 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/

Table 2.3 Emissions Ceilings for 2010 (ktonnes) in the Gothenburg Protocol

Country	Sulphur (as SO_2)	NO_x (as NO_2)	NH_3	NMVOC
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**

National Emissions Ceilings Directive

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 1,167 ktonnes. Ceilings for NH_3 and NMVOCs were the same as in the Gothenburg Protocol.

Large Combustion Plants Directive

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, specifically NO_x, SO_2 and dust, from power plants and industrial sources.

2.1.2 Local Air Quality

Overall air quality is currently estimated to be better then at any time since the industrial revolution. However air pollution is still estimated to reduce the life expectancy of every person in the UK by an average of 7-8 months (AQS, 2007). A number of policies are currently in place in an attempt to improve air quality, including the air quality strategy for England, Scotland, Wales and Northern Ireland and the air quality framework directive.

Air Quality Framework Directive

The air quality framework directive (AQFD) is an EU directive that provides a framework for setting limit values, assessing concentrations and managing air quality to avoid exceeding the limits for air pollutants known to be harmful to human health and the environment via a series of daughter directives (DD).

Currently limit values are set for twelve pollutants under the AQFD. These include NO_x, SO_2, Pb, PM (first DD), benzene, CO (second DD) and ozone (third DD). The first of these daughter directives requires that member states report annually to the European Commission on whether limits have been achieved.

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

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 was 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 (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 for review and assessments. Table 2.4 summarises the total 2005 emissions of the 9 priority pollutants covered by the AQS for ESWNI.

Table 2.4 Total UK Emissions of AQS Pollutants

Pollutant	**Total 2005 emission (ktonnes)**
PM_{10}	150
Carbon Monoxide	2417
Benzene	14
1,3 Butadiene	2.62
Nitrogen oxides	1627
Sulphur dioxide	706
Tropospheric Ozone	NS[1]
Lead	0.12
PAH[2]	1.2

[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 3.2).

Lead and PAH emissions can be found in section 3.6 and 5.2 respectively.

2.2 AMMONIA

2.2.1 Key Source Description

Ammonia (NH_3) emissions play an important role in a number of different environmental issues including acidification; nitrification and eutrophication (see Section 2.1.1). The atmospheric chemistry of NH_3 means 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. NH_3 emissions are dominated by agricultural sources.

2.2.2 Total NH_3 Emissions

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 2005 represent a decrease of 17% 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 2.5 gives a sectoral breakdown of the emissions of NH_3 in the UK. There are several sources of NH_3 that are not included in the official UN/ECE NH_3 totals. These are included in Table 2.5 as memo items. There is on-going discussion aimed at identifying whether some of these sources should be included in the UN/ECE reporting structure or not.

Table 2.5 UK Emissions of NH_3 by aggregated UN/ECE[1] Source Category and Fuel (ktonnes)

	NFR Codes	1990	1995	2000	2001	2002	2003	2004	2005	2010[2]	2005%
BY UN/ECE											
Stationary Combustion	1A1, 1A2	5.7	4.4	3.8	3.9	3.5	3.2	2.9	2.6		1%
Passenger cars	1A3bi	0.7	8.8	12.1	12.0	11.7	11.0	10.2	9.2		3%
Other Transport	1A3bii-iv, A3aii(i)-1A3aii(ii), 1A3c-1A3eii, 1A4bii, 1A4cii, 1A5b	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.4		0%
Production Processes	1B, 2, 3	8.8	8.8	5.2	5.3	4.9	4.6	4.8	6.8		2%
Cattle	4B1	169.6	168.3	158.0	152.8	150.1	149.7	149.4	148.1		47%
Poultry	4B9	41.3	39.1	39.4	40.9	37.4	36.8	36.1	34.2		11%
Direct Soil Emissions	4D1	50.8	33.9	30.5	35.2	33.8	27.2	34.2	37.5		12%
Other Livestock	4B2-4B8, 4B13	89.0	89.9	78.0	71.4	68.6	65.3	65.2	63.8		20%
Waste\Other	6, 7, 4F	16.8	16.4	15.2	15.1	15.1	15.0	14.9	15.0		5%
BY FUEL											
Solid		5.5	4.1	3.6	3.7	3.2	2.9	2.6	2.3		1%
Petroleum		1.0	9.2	12.6	12.5	12.2	11.5	10.7	9.6		3%
Gas		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0%
Non-Fuel		376.4	356.6	326.4	320.9	310.2	298.9	304.7	305.7		96%
Total		**382.9**	**367.0**	**342.6**	**337.1**	**325.6**	**313.3**	**318.1**	**317.6**	**297**	**100%**
MEMO Items											
Wild Animals		7.0	7	7	7	7	7	7	7		
Humans		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

[2] Total emissions shown for 2010 relate to the target set under the NECD

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.

2.2.3 Agricultural Sources

Ammonia emissions in 2005 are dominated by agricultural sources with emissions from livestock and their wastes comprising 77% 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* 2006).

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 being 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.

2.2.4 Other Sources

The non-agricultural sources comprise a number of diverse sources and equal 23% (including direct soil, waste and road transport emissions) of the total. However, emission estimates for these sources are high in uncertainty due to a lack of data. Estimates are derived from a number of sources including the AEA Energy & Environment 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 2.1 Time Series of NH3 Emissions (ktonnes)

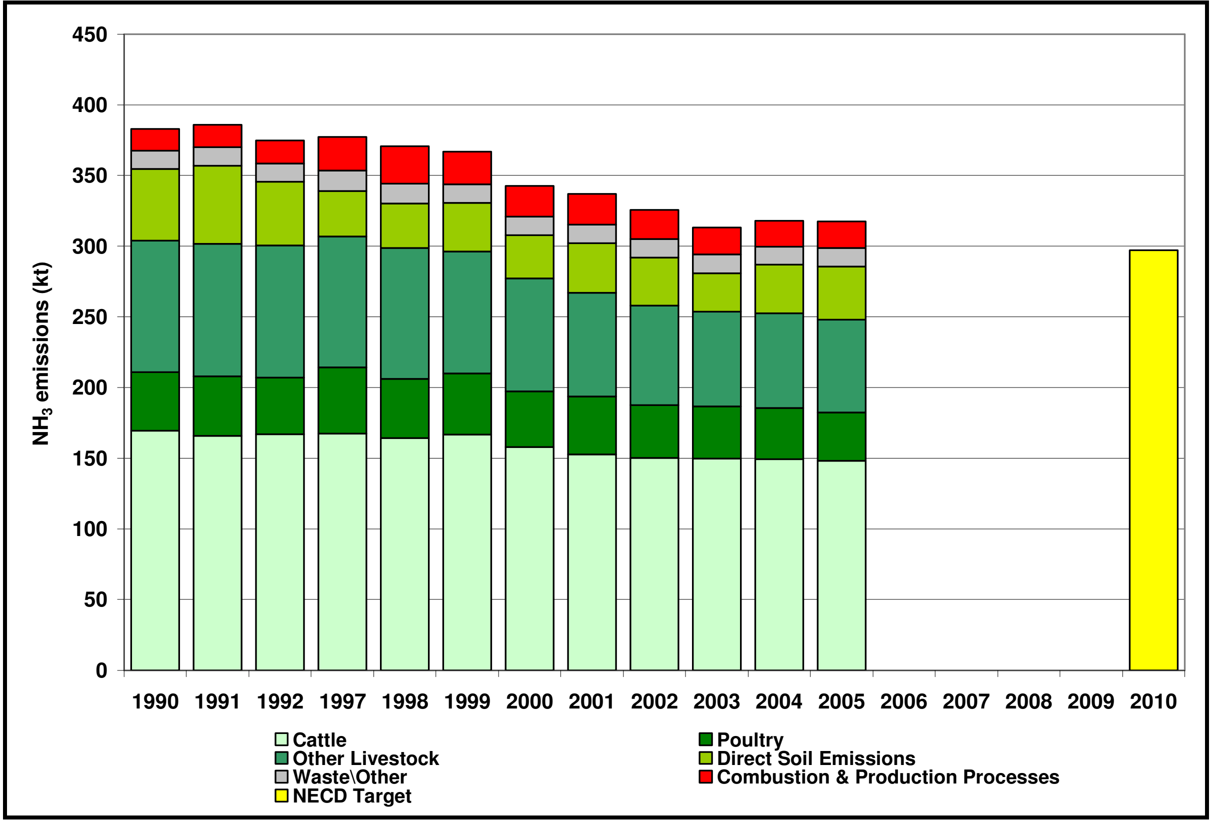
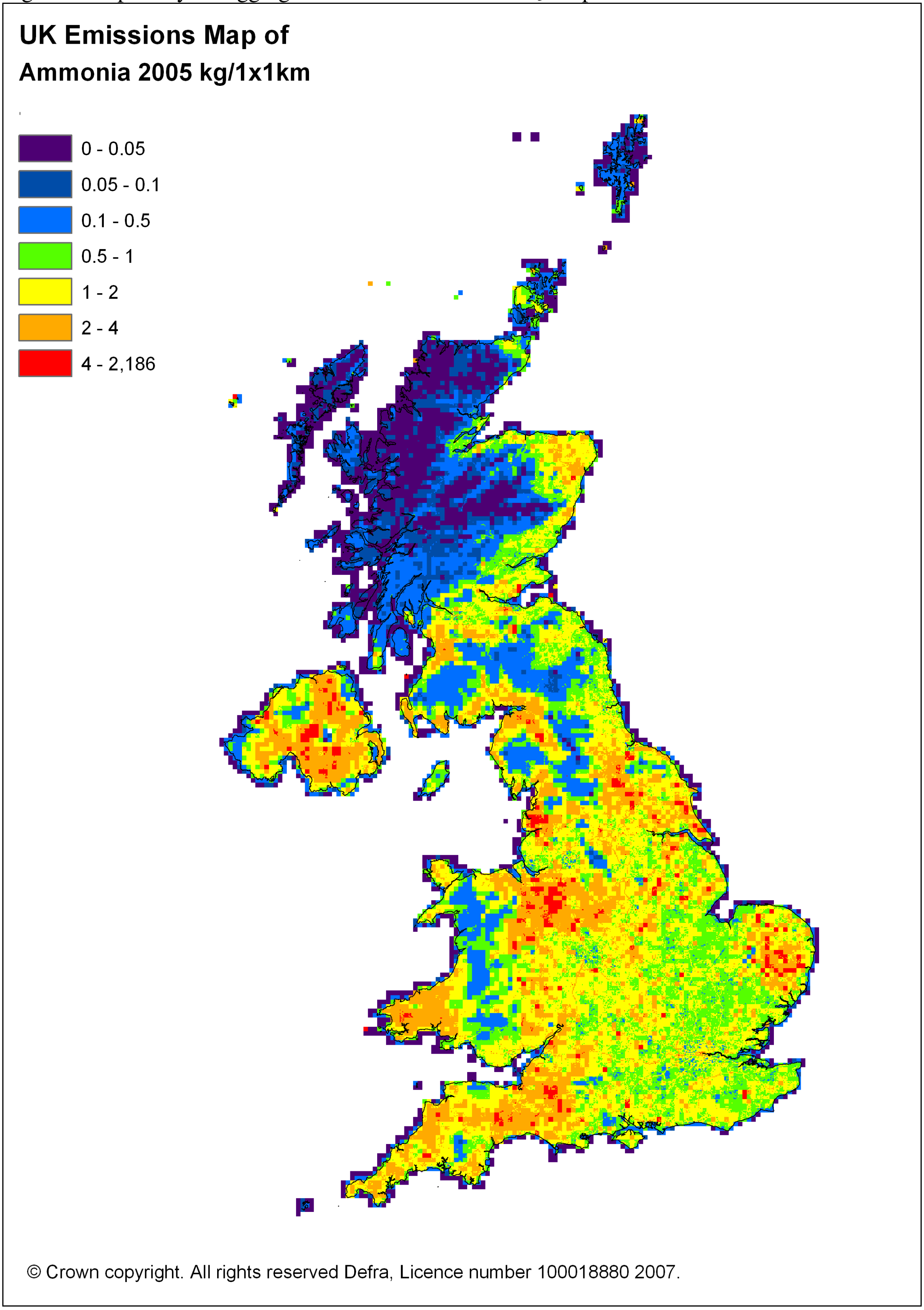


Figure 2.2 shows mapped NH_3 emissions. High emission densities are observed in agricultural areas, for example East Anglia, the South West and the North of England and Northern Ireland. Non-agricultural emissions are also noted to give rise to high emission densities in major urban areas such as London. 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 2.2 Spatially Disaggregated UK Emissions of NH_3 Map



2.3 BENZENE

2.3.1 Key Source Description

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. Fuel combustion in the residential sector is the most significant source of benzene, accounting for 35% of UK emissions in 2005. 21% of the 2005 emission estimate total was from the road transport sector. As benzene is a constituent of petrol, emissions arise from both evaporation and combustion of petrol. Benzene emissions for 1990 to 2005 are given in Table 2.6 and Figure 2.3 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.

2.3.2 Total Benzene Emissions

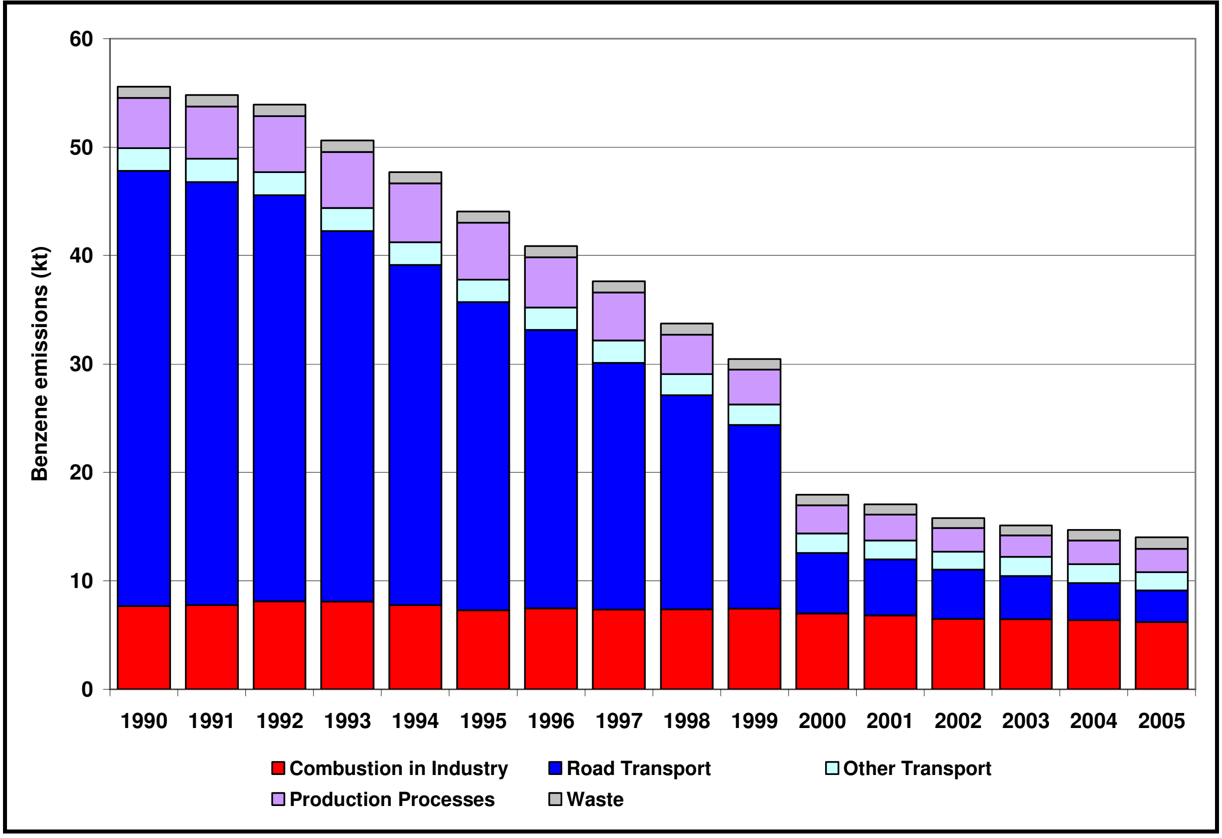
Benzene emissions have been steadily decreasing since 1990. The most noticeable decrease between 1999 and 2005 arises from the road transport sector. This is because the benzene content of petrol was substantially decreased between 1999 and 2005, resulting in a corresponding decrease in emissions and 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 2.6 UK emissions of Benzene by aggregated UN/ECE Source Category and Fuel (ktonnes)

	NFR Codes	**1970**	**1980**	**1990**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2005 %**
BY UN/ECE CATEGORY[1]											
Combustion in Industry + Domestic	1A1, 1A2a, 1A4	16.8	9.3	6.5	5.8	5.6	5.4	5.3	5.3	5.2	37%
Other Industrial Combustion	1A2f	1.0	1.0	1.1	1.2	1.2	1.1	1.1	1.1	1.0	7%
Road Transport: Passenger cars	1A3bi	23.9	27.0	33.4	4.8	4.4	3.9	3.4	2.9	2.4	17%
other Road Transport	1A3bii-v	3.8	5.9	6.7	0.8	0.7	0.7	0.6	0.5	0.5	3%
Waste	6	0.9	0.9	1.1	1.0	0.9	0.9	0.9	1.0	1.0	7%
Production Processes	1B1, 1B2, 2	0.7	0.5	4.6	2.6	2.4	2.2	2.0	2.2	2.2	16%
Other off Road Transport (Rail, Aviation, Navigation)	1A3aii(i)-1A3aii(ii), 1A3c-1A3e, 1A4ci, 1A5b	1.2	1.3	2.1	1.8	1.7	1.6	1.8	1.7	1.7	12%
BY FUEL TYPE											
Solid				6.2	5.3	5.1	4.9	4.9	4.8	4.7	33%
Petroleum				43.0	8.2	7.7	7.0	6.5	5.9	5.4	38%
Gas				0.7	0.8	0.8	0.7	0.8	0.8	0.7	5%
Non-Fuel				5.7	3.7	3.5	3.2	3.0	3.2	3.2	23%
Total		**48.1**	**45.8**	**55.6**	**18.0**	**17.0**	**15.8**	**15.1**	**14.7**	**14.0**	100%

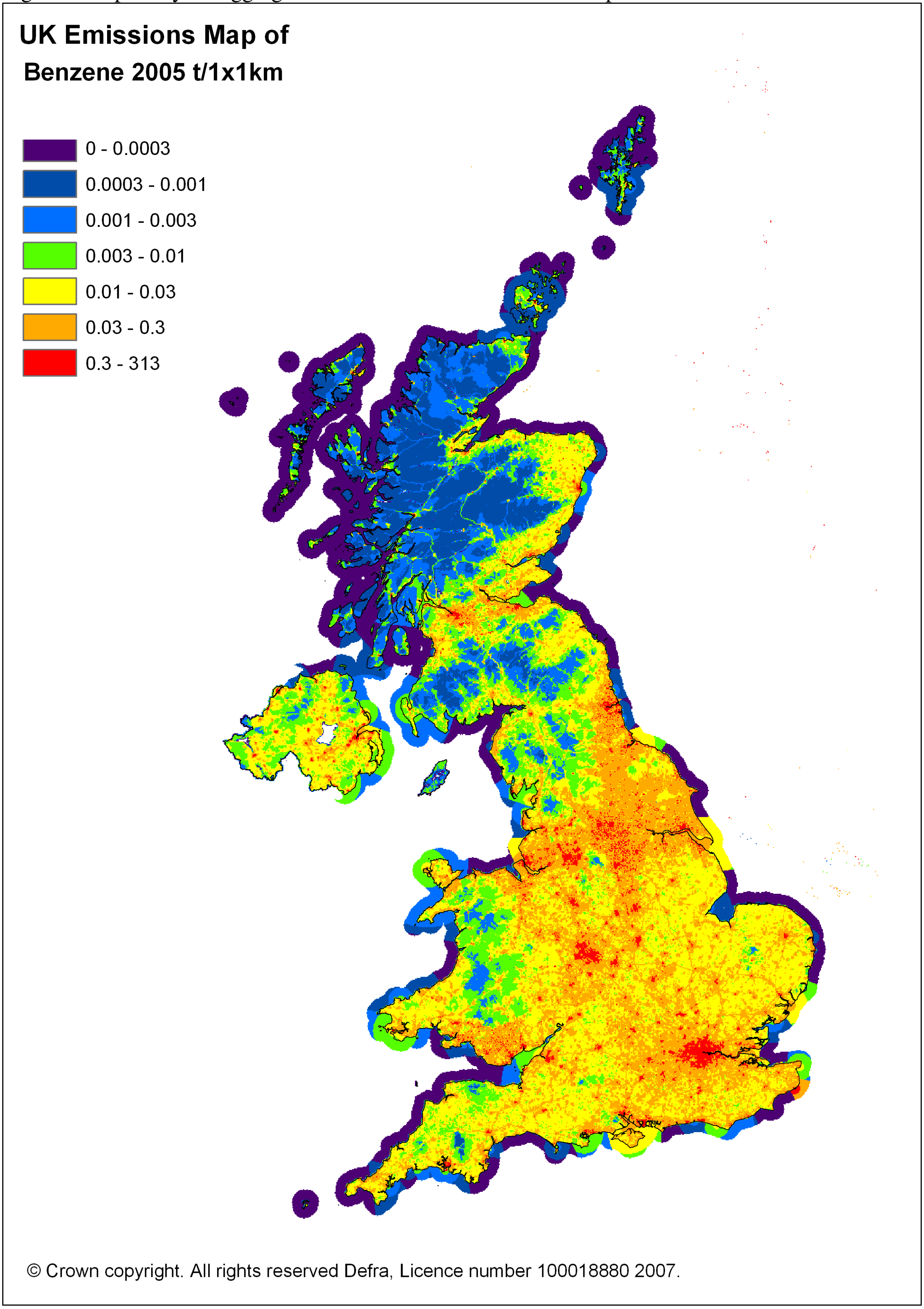
[1] See Annex 1 for definition of UN/ECE Categories

Figure 2.3 Time Series of Benzene Emissions (ktonnes)



Spatially disaggregated emissions of benzene are shown in Figure 2.4. It is not easy to identify the point sources contributing to the UK map. Of the area sources, road transport dominates and it is this source sector which is apparent. 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 kilometre in urban areas.

Figure 2.4 Spatially Disaggregated UK Emissions of Benzene Map



2.4 1,3-BUTADIENE

2.4.1 Key Source Description

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.

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, 2006) have been incorporated into the NAEI.

2.4.2 Total 1,3-Butadiene Emissions

The road transport sector dominates the UK emissions in 2005, contributing 61% of the total. Emissions of 1,3-butadiene for 1990 to 2005 are given in Table 2.7 and Figure 2.5 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 an 85% reduction in road transport emissions and a decline in total emissions of 71% between 1990 to 2005. Emissions from other significant combustion sources, such as other transportation and machinery, have not significantly decreased.

Spatially disaggregated emissions of 1,3-butadiene are shown in Figure 2.6. As discussed above, 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 2.4), where other sources make a significant contribution to the total emissions. As with benzene, emissions of 1,3-butadiene per kilometre from road transport decrease with increasing speed (but then increase at higher speeds). Consequently the emissions density is high in urban areas, and less so on the major roads (such as motorways).

Benzene and 1,3-butadiene emission maps (Figure 2.4 and Figure 2.6) may be contrasted with mapped NOx emissions Figure 2.13, as the emissions of NO_x at higher speeds are more significant than those for benzene or 1,3-butadiene.

Table 2.7 UK Emissions of 1,3-butadiene by aggregated UN/ECE Category and Fuel (ktonnes)

	NFR Codes	1970	1980	1990	2000	2001	2002	2003	2004	2005	2005 %
BY UN/ECE CATEGORY[1]											
Combustion in Industry	1A1a&c	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0%
Road Transport / Passenger cars	1A3bi	4.96	5.61	6.96	2.30	1.86	1.50	1.16	0.90	0.69	26%
Road Transport / Others	1A3bii&iv	0.68	1.00	0.92	0.37	0.33	0.29	0.27	0.23	0.22	8%
Road Transport / Heavy Duty Vehicle	1A3biii	2.59	2.84	2.74	1.09	0.97	0.87	0.80	0.75	0.69	26%
Industrial off-road mobile machinery	1A2f	0.22	0.21	0.25	0.25	0.25	0.25	0.25	0.25	0.24	9%
Other Transport	1A3aii(i) - 1A3aii(ii), 1A3c-1A5b	0.40	0.42	0.45	0.43	0.43	0.42	0.41	0.40	0.38	14%
Production Processes	1B2aiv, 1B2av	0.16	0.20	0.79	0.52	0.46	0.41	0.39	0.39	0.39	15%
Waste Treatment and Disposal	6A	0.00	0.00	0.03	0.02	0.01	0.01	0.01	0.02	0.01	1%
BY FUEL CATEGORY											
Solid				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0%
Petroleum				11.32	4.44	3.83	3.32	2.88	2.51	2.21	84%
Gas				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0%
Non-Fuel				0.84	0.54	0.49	0.44	0.41	0.42	0.41	16%
Total		**9.01**	**10.30**	**12.16**	**4.98**	**4.32**	**3.76**	**3.29**	**2.94**	**2.62**	100%

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

Figure 2.5 Time Series of 1,3-butadiene Emissions (ktonnes)

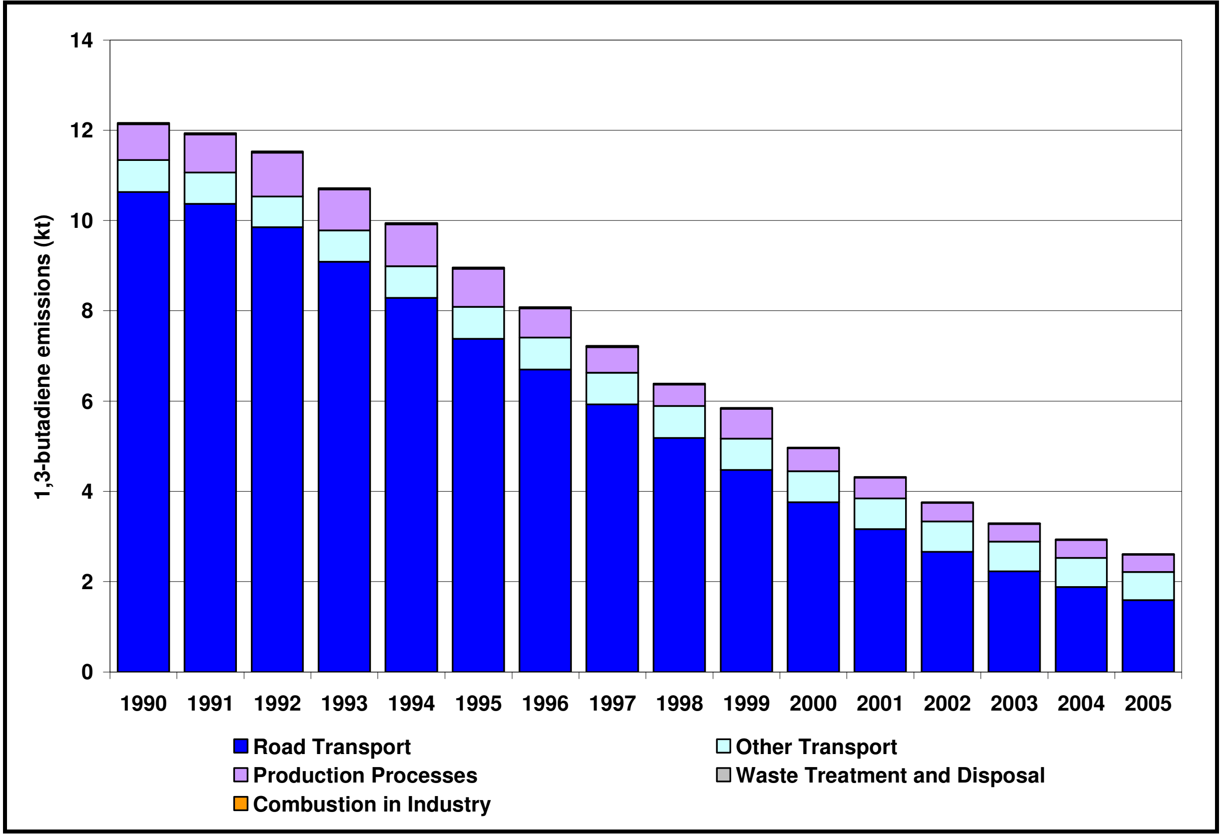
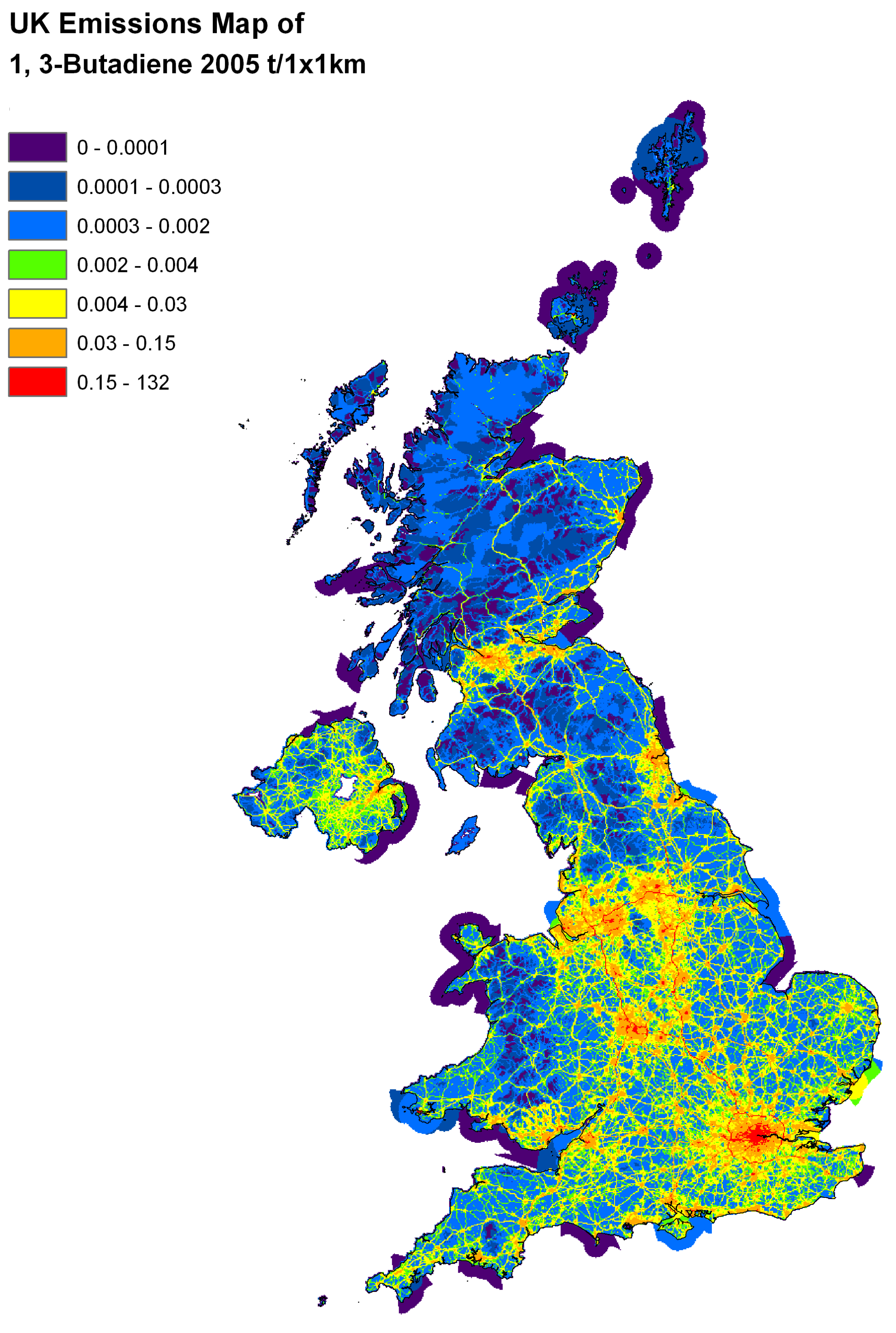


Figure 2.6 Spatially Disaggregated UK Emissions of 1,3-butadiene Map



2.5 CARBON MONOXIDE

2.5.1 Key Source Description

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.

2.5.2 Total Carbon Monoxide Emissions

The UK emissions of carbon monoxide are shown in Figure 2.7 and Table 2.8 disaggregated by source and fuel. Over the period 1970-2005 emissions decreased by 71% reflecting significant reductions in emissions from road transport, agricultural field burning and the domestic sector.

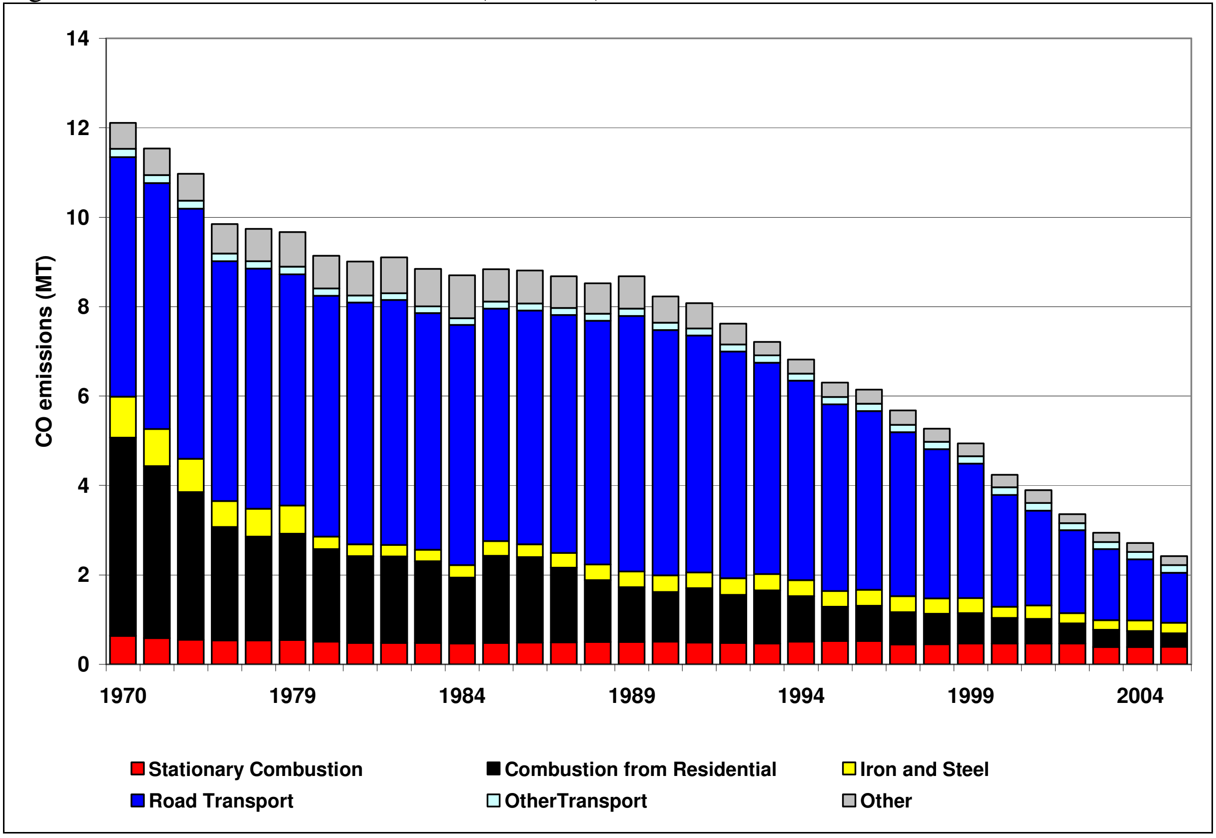
Table 2.8 UK Emissions of CO by aggregated UN/ECE[1] Source Category and Fuel (ktonnes)

	NFR Codes	**1970**	**1980**	**1990**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2005%**
BY UN/ECE CATEGORY[2]											
Public Electricity and Heat Production	1A1a	141	121	113	65	65	62	69	68	70	3%
Combustion in Industry	1A1b&c, 1A2b, 1A4ci	169	104	96	118	122	124	39	40	51	2%
Iron and Steel	1A2a	922	274	378	253	294	233	212	233	240	10%
Other industrial combustion	1A2f	326	282	297	283	276	275	276	276	276	11%
Passenger cars	1A3bi	4759	4624	4534	2108	1802	1584	1360	1169	951	39%
Other Road Transport	1A3bii-iv	593	766	946	392	326	270	234	197	173	7%
Other Transport	1A3aii(i) - 1A3aii(ii), 1A3c-1A3eii, 1A4bii, 1A4cii, 1A5b	190	165	164	171	174	163	161	166	171	7%
Combustion from Residential plants	1A4bi	4431	2072	1110	571	554	450	387	361	292	12%
Production Processes	1B1, 1B2, 2A&B	154	154	148	126	115	65	67	54	47	2%
Metal Production	2C	101	91	137	111	97	87	99	105	104	4%
Other	4, 5, 6, 7	321	483	307	42	66	43	43	42	42	2%
BY FUEL TYPE											
Solid		5606	2497	1606	862	889	720	635	628	560	23%
Petroleum		5763	5752	5865	2887	2516	2229	1967	1746	1521	63%
Gas		30	60	73	99	95	94	100	102	104	4%
Non-Fuel		709	827	684	392	391	313	244	235	231	10%
Total		**12108**	**9137**	**8229**	**4239**	**3891**	**3356**	**2947**	**2711**	**2417**	**100%**

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

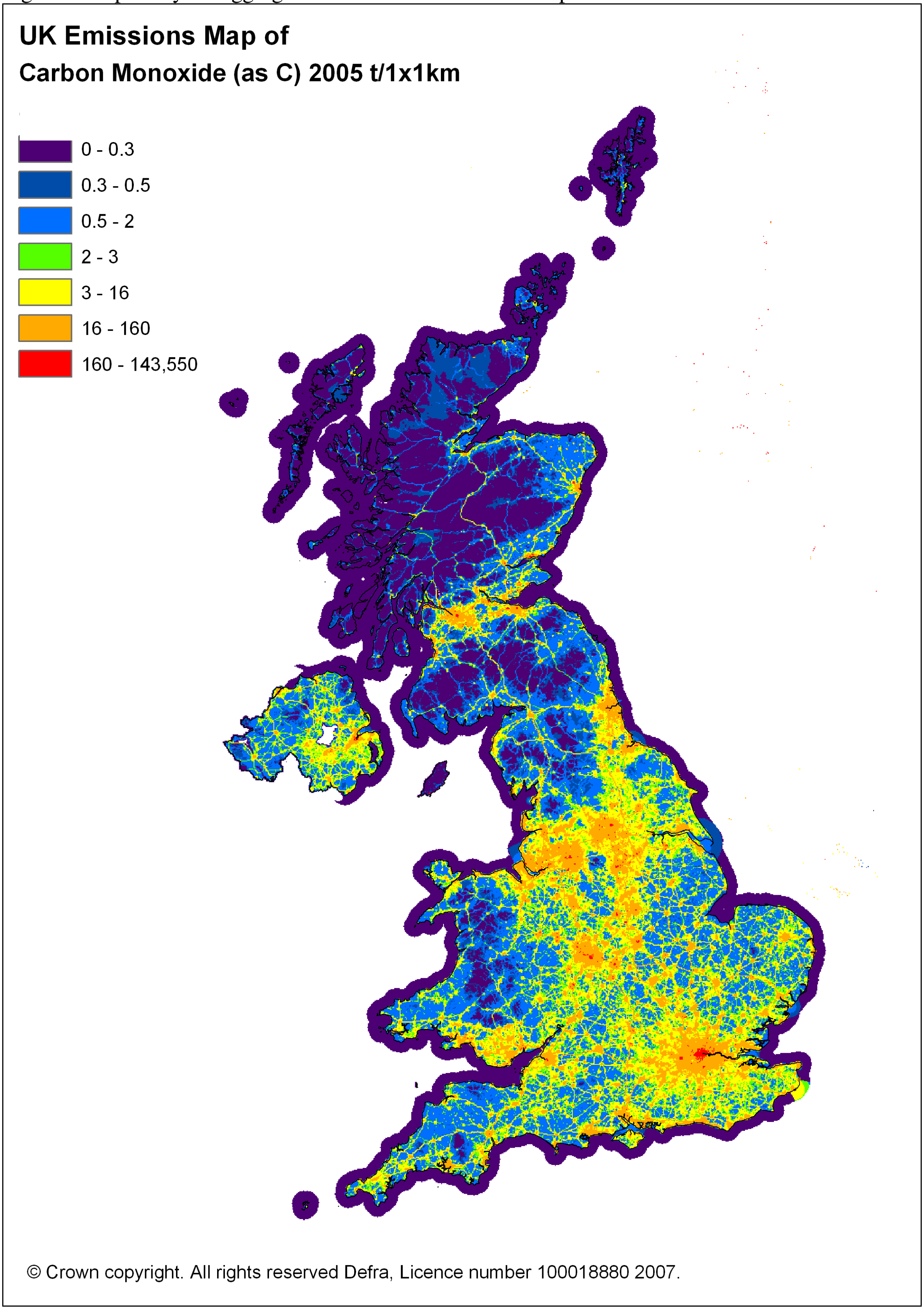
[2] See Annex 1 for definition of UN/ECE Categories

Figure 2.7 Time Series CO Emissions (Mtonnes)



The spatial disaggregation of CO emissions is shown in Figure 2.8. 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 2.8 Spatially Disaggregated UK Emissions of CO Map



2.5.3 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 has 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.

2.5.4 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 93% and 60% 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 3 % of UK emissions.

2.6 HYDROGEN CHLORIDE

2.6.1 Key Source Description

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.

2.6.2 Total Hydrogen Chloride Emissions

Table 2.9 and Figure 2.9 summarises the UK emissions of hydrogen chloride. Emissions have fallen by 94% 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 with tighter emission controls and the closure or upgrading of old plant has resulted in a large decrease for all years since 1996.

Table 2.9 UK Emissions of HCl by aggregated UN/ECE[1] Source Category and Fuel (ktonnes)

	NFR Codes	1970	1980	1990	2000	2001	2002	2003	2004	2005	2005%
BY UN/ECE CATEGORY[2]											
Public Electricity and Heat Production	1A1a	222.28	257.84	238.77	72.47	58.72	34.44	31.46	20.35	12.31	59%
Stationary Combustion	1A1b-c, 1A2b, 1A4ci	4.98	1.72	0.40	0.17	0.19	0.15	0.15	0.15	0.13	1%
Iron and Steel	1A2a	56.94	25.22	13.28	5.12	5.09	3.46	2.84	2.57	1.82	9%
Other Industrial Combustion	1A2f	2.99	0.78	0.83	0.72	0.64	0.55	0.66	0.67	0.44	2%
Production Processes	2	0.19	0.21	0.26	0.18	0.19	0.19	0.18	0.18	0.18	1%
Commercial / Institutional	1A4a	38.28	12.77	10.75	6.57	6.69	6.72	6.59	6.11	5.89	28%
Road & Other Transport	1A3b, 1A3dii, 1A4bii	0.37	0.43	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0%
Waste	6	6.90	6.90	5.28	0.09	0.32	0.10	0.10	0.10	0.16	1%
BY FUEL TYPE											
Petroleum		0.73	0.64	0.24	0.07	0.08	0.08	0.08	0.08	0.07	0%
Solid		330.22	304.05	267.83	83.92	70.27	44.36	40.68	28.73	19.75	94%
Gas		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0%
Non-Fuel		1.98	1.19	1.63	1.33	1.49	1.19	1.22	1.32	1.11	5%
Total		**332.92**	**305.88**	**269.70**	**85.32**	**71.83**	**45.62**	**41.97**	**30.13**	**20.94**	**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

Figure 2.9 Time Series of HCl Emissions (ktonnes)

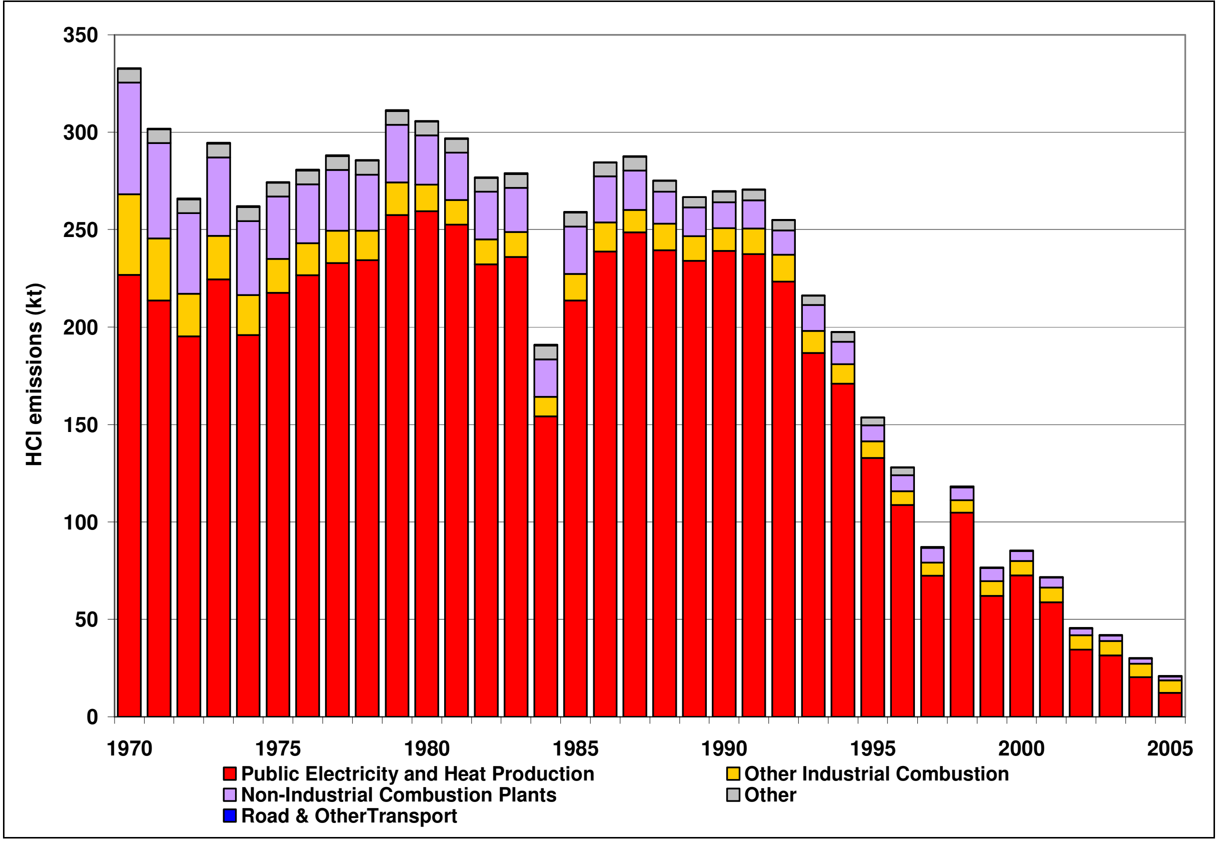
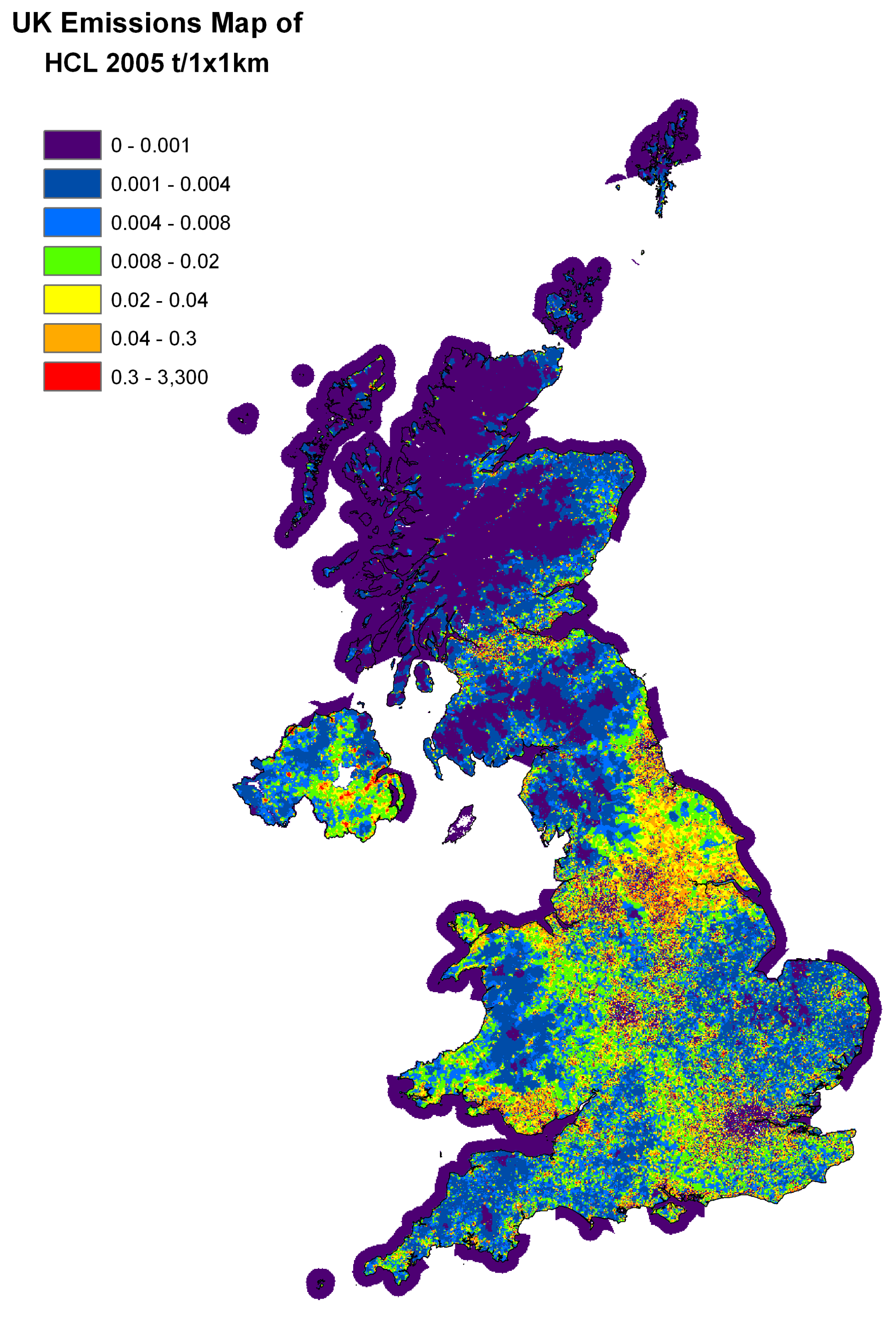


Figure 2.10 Spatially Disaggregated UK Emissions of HCl Map



2.7 HYDROGEN FLUORIDE

2.7.1 Key Source Description

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.

2.7.2 Total HF Emissions

The emissions of HF display a similar source pattern to HCl (see Section 2.6). However, the emissions of HF from the power generation sector do not account for such a high percentage of the total (see Table 2.10). 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 2.11, and the impact of the miners strike in 1984 is apparent.

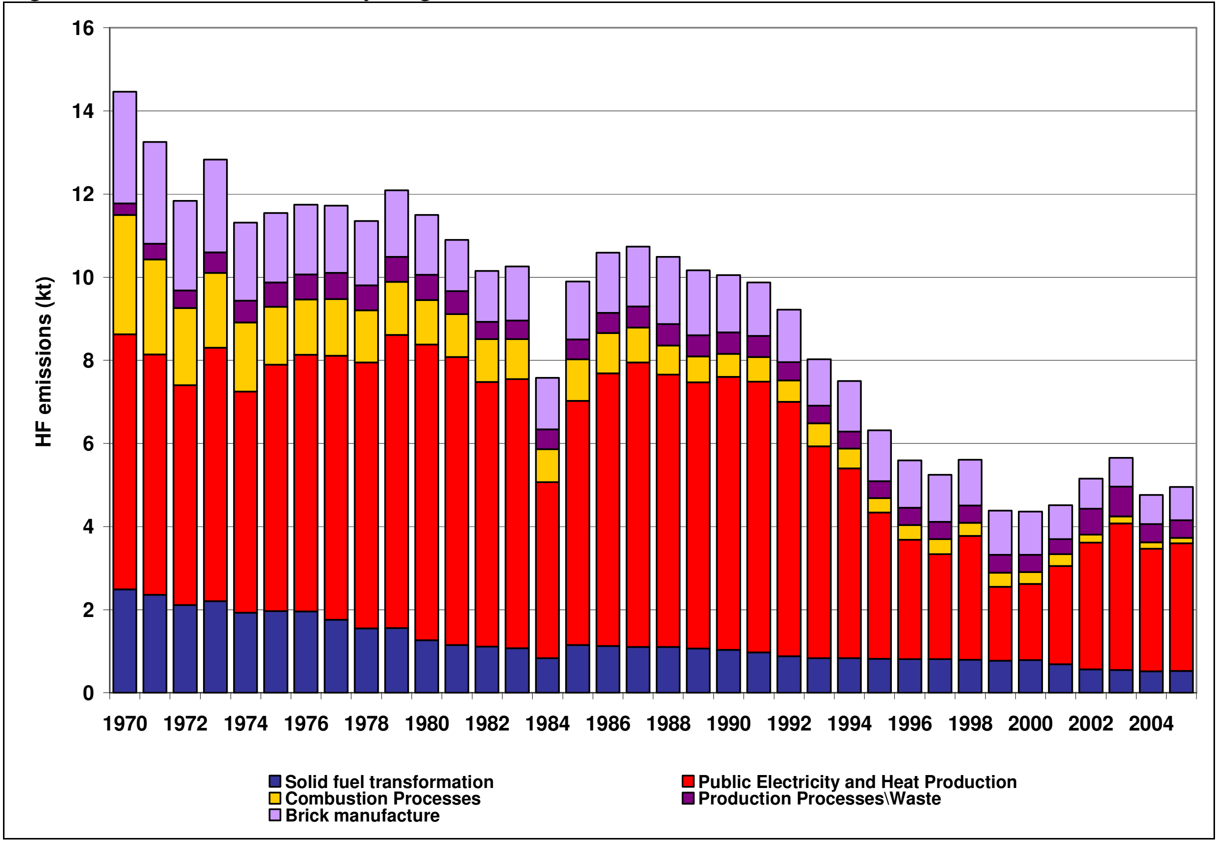
The increase of 13% in HF emission between 1999 and 2005 is caused by the increased coal consumption in electricity generation. Interestingly this trend is not noted for HCl (which exhibits a decrease of 73% from 1999 to 2005). This is because the HCl emission per unit of coal consumed decreased between 1999 and 2005, whereas that for HF remained reasonably constant.

Table 2.10 UK Emissions of HF by aggregated UN/ECE[1] Source Category and Fuel (ktonnes)

	NFR Codes	1970	1980	1990	2000	2001	2002	2003	2004	2005	2005 %
BY UN/ECE CATEGORY											
Public Electricity and Heat Production	1A1a	6.1	7.1	6.6	1.8	2.4	3.1	3.5	2.9	3.1	62%
Combustion Processes	1A1c-1A2b, 1A4	2.9	1.1	0.6	0.3	0.3	0.2	0.2	0.2	0.1	3%
Brick manufacture	1A2f	2.7	1.4	1.4	1.0	0.8	0.7	0.7	0.7	0.8	16%
Solid fuel transformation	1B1b	2.5	1.3	1.0	0.8	0.7	0.6	0.6	0.5	0.5	11%
Production Processes	2	0.2	0.6	0.5	0.4	0.4	0.6	0.7	0.4	0.4	9%
Waste	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
BY FUEL TYPE											
Petroleum		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Solid		13.3	10.2	8.9	3.3	3.8	4.2	4.7	4.0	4.1	84%
Gas		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Non-Fuel		1.14	1.31	1.19	1.09	0.77	0.92	0.97	0.73	0.82	16%
TOTAL		**14.5**	**11.5**	**10.0**	**4.4**	**4.5**	**5.2**	**5.6**	**4.8**	**4.9**	**100%**

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

Figure 2.11 Time Series of Hydrogen Fluoride Emissions (ktonnes)



2.8 NITROGEN OXIDES

2.8.1 Key Source Description

Studies have shown that NO_x can cause lung irritation as well as lowering people's resistance to pneumonia and bronchitis and other respiratory infections. People already suffering lung problems, such as asthma, as well as young children and those that work outside are particularly vulnerable. In the presence of sunlight NO_x can react to help produce a photochemical smog. If hydrocarbons are also present ozone can be produced which has a similar health effect to NO_x. Although higher concentrations of NO_x are found in city areas, resulting ozone concentrations tend to be higher in rural areas, where crop yields can be reduced as a result.

Stationary combustion is the largest source of NO_x in the UK with road transport also forming a significant source. Approximately one third of the UK NO_x emissions arising from major sections of road with vehicles travelling at high speeds contributing most. 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.

2.8.2 Total NO_x Emissions

Since 1970 there has been a reduction in total NO_x emissions of 48%, however this decrease in emissions has not been constant (Figure 2.12). Up to 1984 the NO_x emission profile was relatively flat with small peaks in 1973 and 1979, also seen for 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 (Figure 2.12). Since then, total emissions have declined by 45% as a result of a 52% reduction from power stations and 59% decrease from road transport.
The spatially disaggregated UK emission inventory of NO_x emissions, based on a 1x1 km grid, is shown in Figure 2.13. 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 NO_x emission is concentrated in approximately 50 grid squares, which contain point sources. Conurbations and city centres show high emissions resulting from large volumes of road transport, residential and commercial combustion. Major route-ways (e.g. motorways and primary routes) are also clearly defined on the map. A combination of high national shipping emissions and relatively few large ports results in significant localised emissions from shipping in port areas.

Table 2.11 UK Emissions of Nitrogen Oxides (as NO_2) by aggregated UN/ECE[1] Category & Fuel (ktonnes)

	NFR Codes	1970	1980	1990	2000	2001	2002	2003	2004	2005	2010[3]	2005%
BY UN/ECE CATEGORY[2]												
Public Electricity and Heat Production	1A1a	813	861	776	340	365	345	378	358	373		23%
Stationary Combustion	1A1b-c, 1A2a	687	159	147	140	137	142	141	138	131		8%
Other industrial combustion	1A2f	510	395	342	276	267	248	252	246	248		15%
Passenger cars	1A3bi	371	527	799	397	347	310	273	245	215		13%
Heavy duty vehicles	1A3biii	358	417	454	355	337	320	303	292	275		17%
Other Road Transport	1A3bii, iv	36	45	71	66	65	62	61	60	60		4%
Other Transport	1A3aii(i)-1A3aii(ii), 1A3c-1A3eii, 1A4bii, 1A4cii, 1A5b	203	216	234	201	186	176	202	202	210		13%
Residential plants	1A4bi	120	108	103	111	114	110	111	114	109		7%
Other	1B-6	32	45	41	10	10	9	8	8	8		0%
BY FUEL TYPE												
Solid		981	907	808	334	362	334	370	342	356		22%
Petroleum		1509	1562	1838	1198	1115	1034	995	960	920		57%
Gas		515	176	200	306	297	301	309	305	297		18%
Non-Fuel		126	127	121	60	54	51	54	56	53		3%
Total		**3130**	**2772**	**2966**	**1897**	**1828**	**1721**	**1728**	**1664**	**1627**	**1167**	**100%**

[1] UK emissions reported in IPCC format (Baggott *et al*, 2007) differ slightly due to the different source categories used.

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

[3]Total emissions shown for 2010 relate to the target set under the NECD

Figure 2.12 Time Series of NO_x Emissions (Mtonnes)

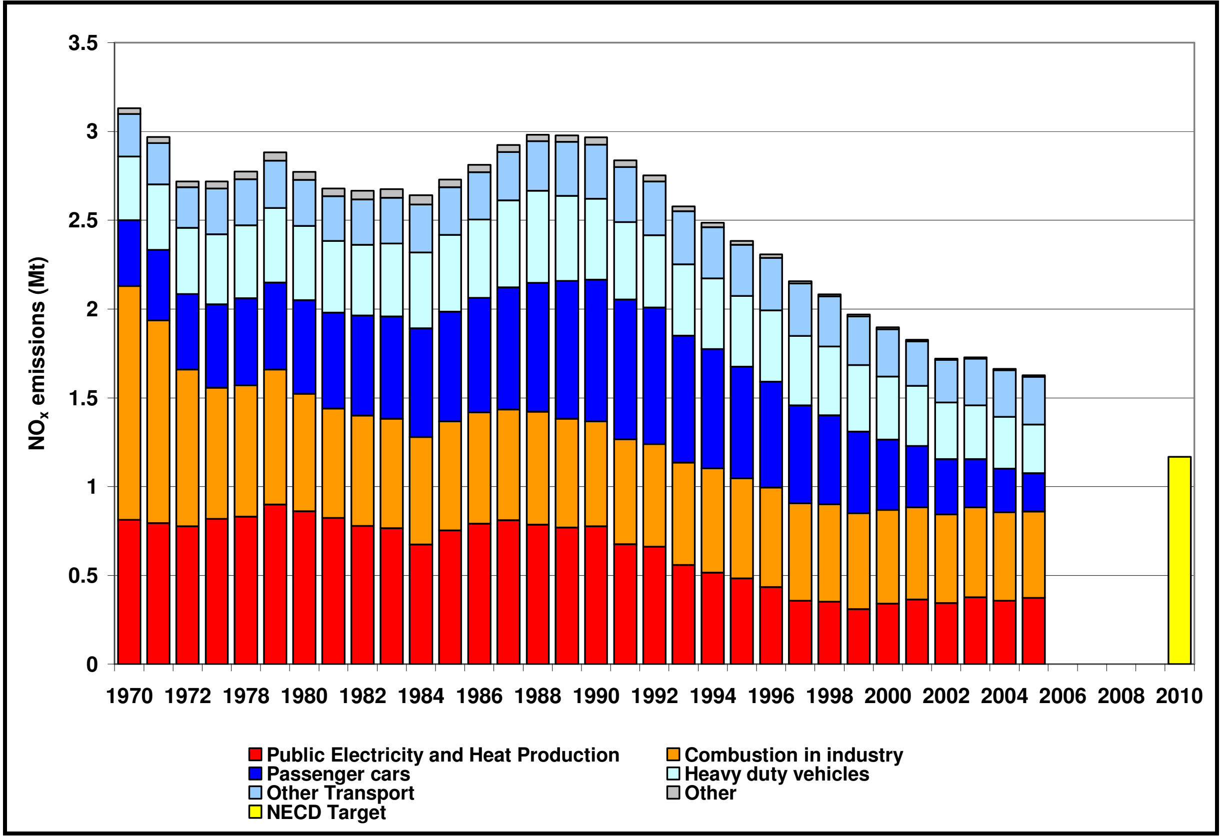
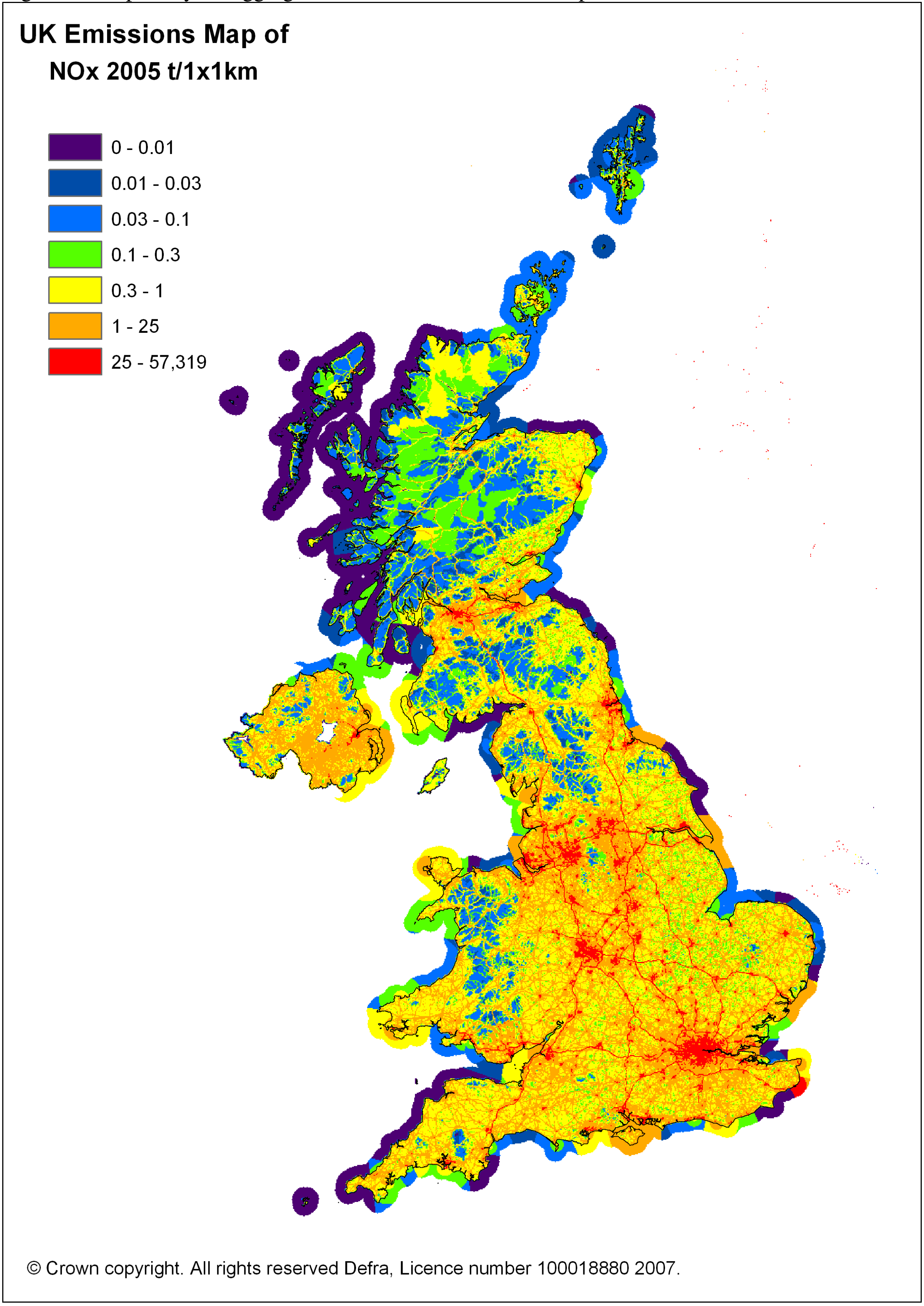


Figure 2.13 Spatially Disaggregated UK Emissions of NO_x Map



2.8.3 Transport

In 2005 a major source of NO_x emissions in the UK is the transport sector with road vehicles and off-road vehicles contributing 34% and 5%, respectively, to the total emission. Road vehicle 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 by cars, rose by 58% compared to the 1970 level and emissions from diesel consumption rose by 5%. Figure 2.14 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 2.14 Emissions of NO_x from Road Transport by Vehicle Type (ktonnes)

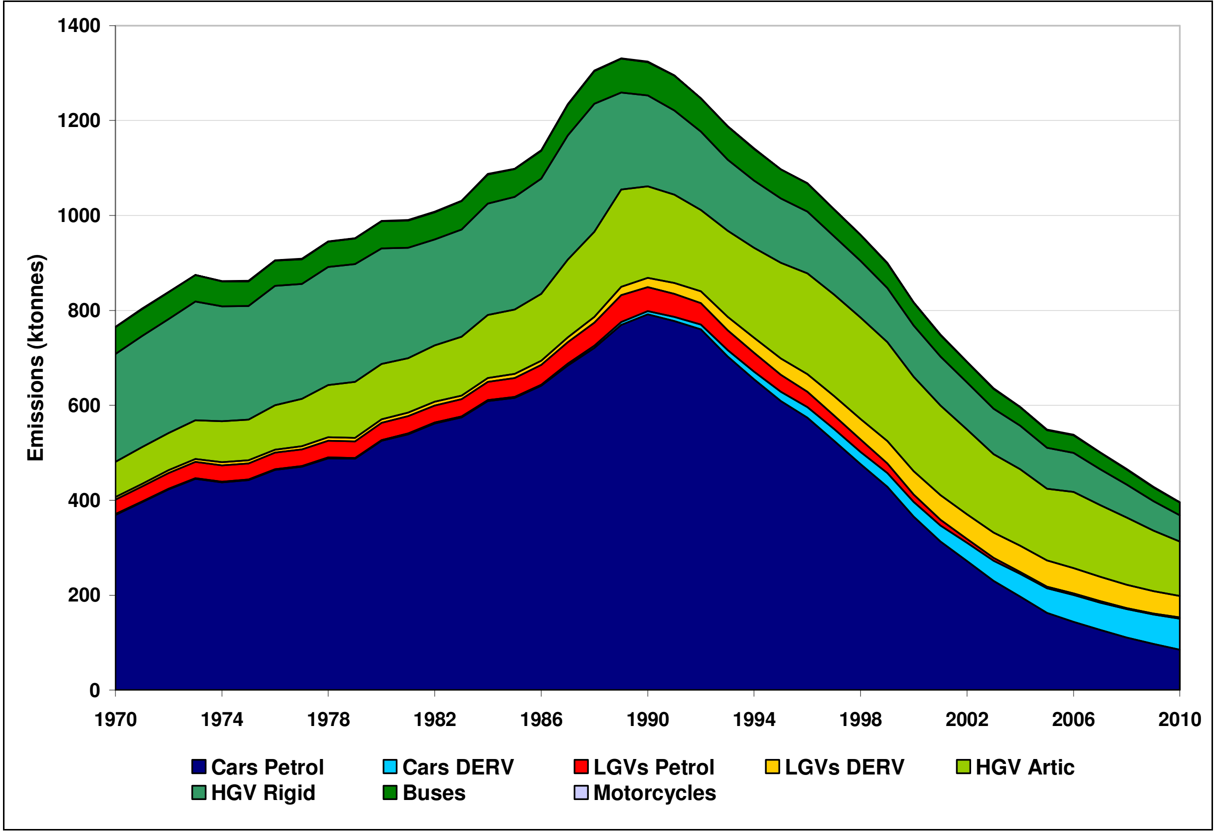


Figure 2.15 shows the average NO_x emissions per vehicle kilometre for different vehicle types between 1970 and 2010. Various emission regulations on new petrol cars which have come into effect in stages since 1976 have led to the gradual reduction in emission rates from petrol cars. The more rapid decline 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. Emissions on a per vehicle kilometre basis are expected to continue to decline until and beyond 2010.

Figure 2.15 NOx Emissions per Vehicle km by Vehicle Type

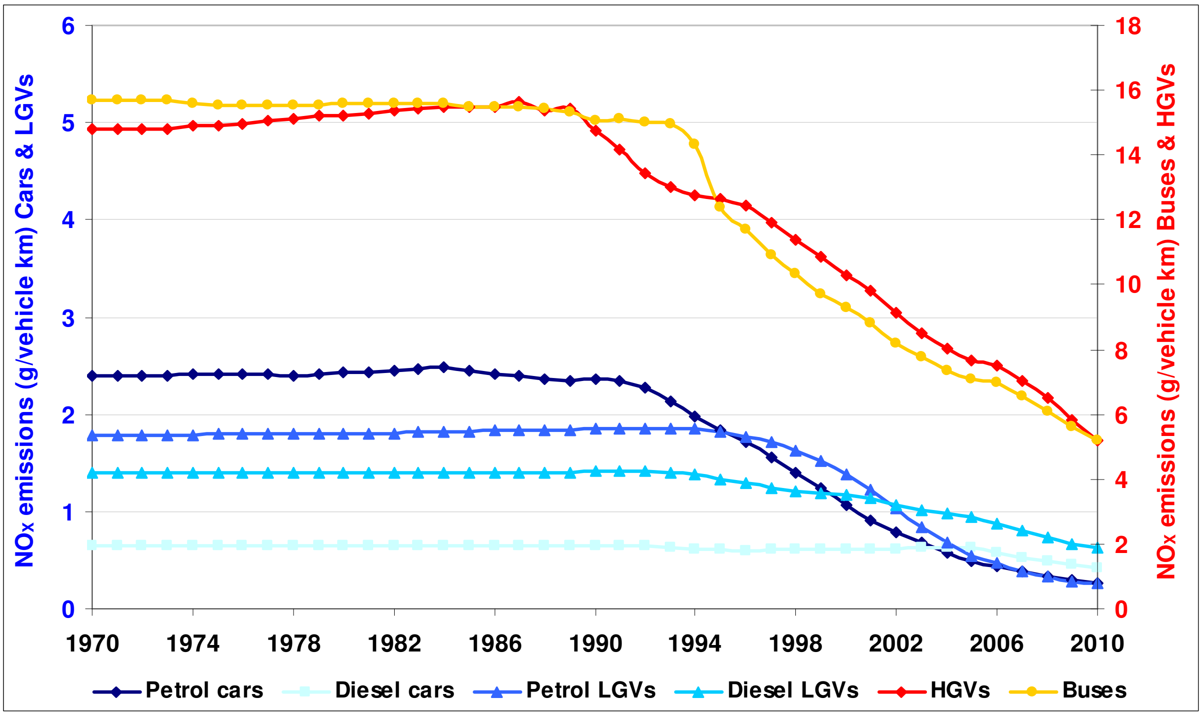
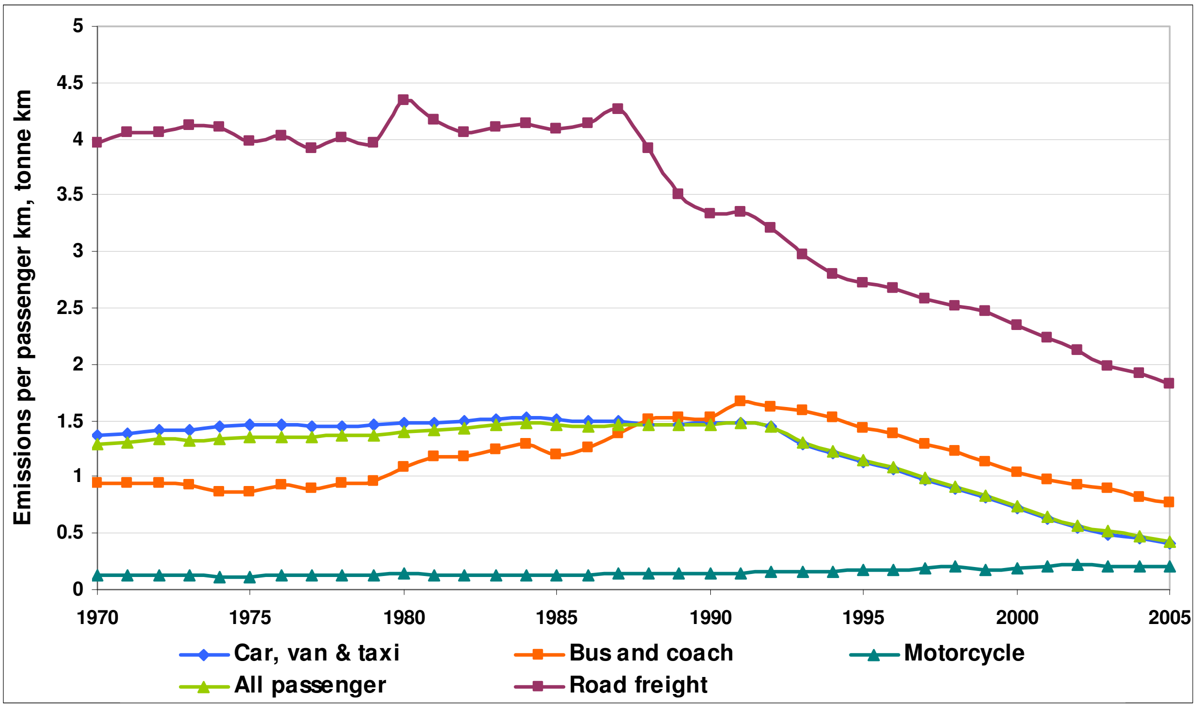


Figure 2.16 shows emissions per passenger km and by tonne km of freight. Technological improvements to HGVs give rise to approximately half the emissions per tonne of freight moved in 2005 compared with 1970. Emissions per passenger km from cars, vans and taxis have significantly decreased since 1970 due mainly to the introduction of catalytic converters in 1992 now penetrating the car fleet. Per passenger km emissions from buses and coaches increased between 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 2.16 Emissions of NO_x (grammes) by Passenger Kilometre or Freight Tonne Kilometre



In 2005 other transport and machinery contributed a further 13% to total UK NO_x emissions. Of these only those from civil aircraft have grown steadily over the period 1970 to 2005 (take-off and landing cycles up to an altitude of 1,000 m only are considered here in accordance with UN/ECE guidelines).

2.8.4 Power Generation

Emissions from power stations have declined over the period 1970-2005 by 54%. 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 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 7.2.3) 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. Power station emissions are expected to fall further primarily as a result of fuel switching and the Large Combustion Plant Directive.

2.8.5 Industry

The emissions from industrial combustion have declined by 56% since 1970 and they currently contribute 17% of the total UK emissions. This is due to the decline in coal use in favour of gas and electricity.

2.9 NON-METHANE VOLATILE ORGANIC COMPOUNDS

2.9.1 Key Source Description

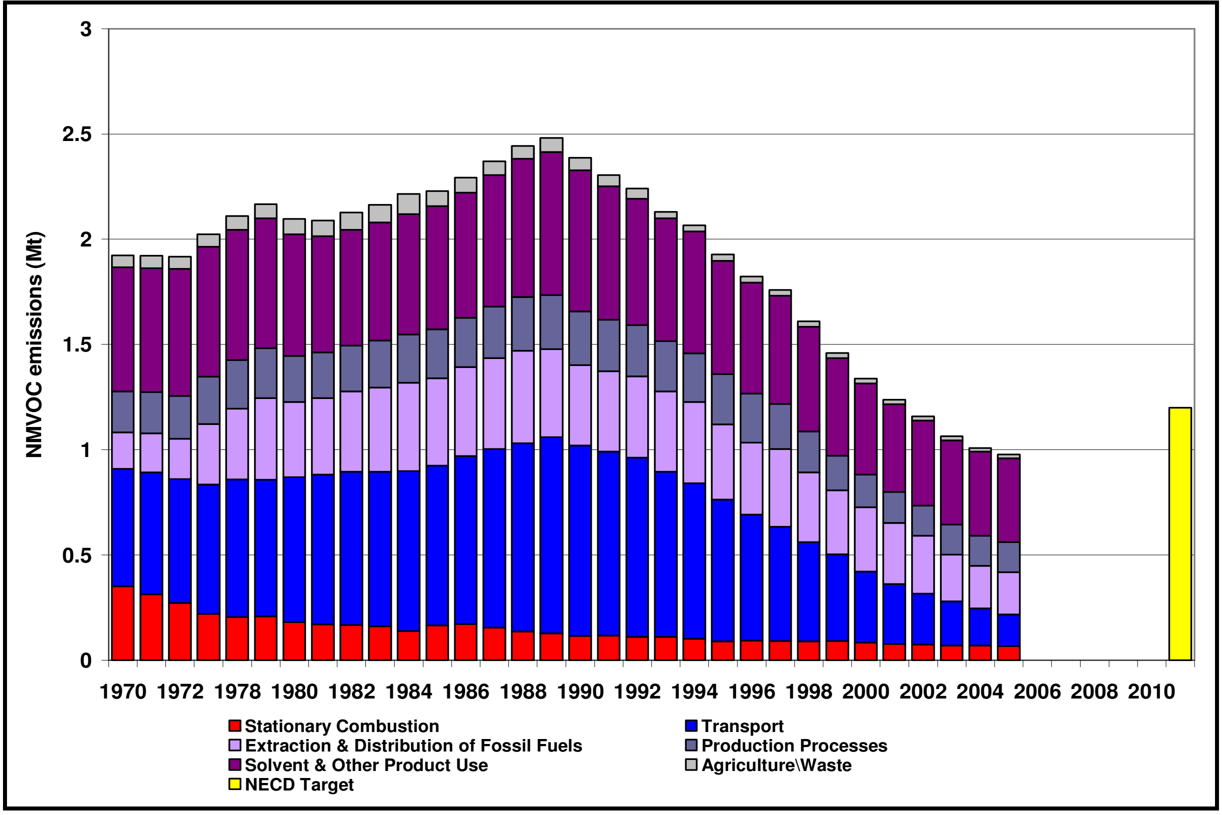
NMVOCs are organic compounds, which may differ widely in their chemical composition. These organic compounds are often grouped under the NMVOC label as the majority display similar behaviour in the atmosphere. NMVOCs are emitted to air as combustion products, as vapour arising from handling or use of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

2.9.2 Total NMVOC Emissions

The NMVOC inventory is summarised in Table 2.12. 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 that 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 (in accordance with UN/ECE guidelines). These natural sources are primarily emissions from forests. The NMVOC emission profile, presented in Figure 2.17, shows a 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 2.17 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 2.12 UK Emissions of NMVOCs by aggregated UN/ECE[1] Source Category and Fuel (ktonnes)

	NFR Codes	1970	1980	1990	2000	2001	2002	2003	2004	2005	2010[3]	2005%
BY UN/ECE CATEGORY[2]												
Stationary Combustion	1A1, 1A2, 1A4a, 1A4bi, 1A4ci	352	182	116	84	79	74	71	69	67		7%
Road Transport	1A3b	524	652	867	303	249	210	175	144	119		12%
Transport	1A3aii(i), 1A3aii(ii), 1A3c, 1A3eii, 1A4bii, 1A4cii, 1A5b	34	36	38	35	34	33	33	33	31		3%
Extraction & Distribution of Fossil Fuels	1B	173	356	381	306	291	275	223	202	201		21%
Production Processes	2A-2C	116	135	178	76	67	63	62	64	65		7%
Processes in wood, paper pulp, food, drink industries	2D	78	86	78	79	81	80	81	80	79		8%
Solvent & Other Product Use	3	590	577	670	433	416	404	400	399	398		41%
Agriculture\Waste	4, 6	56	73	59	23	21	20	19	18	18		2%
BY FUEL TYPE												
Non-Fuel		1025	1237	1370	920	878	845	787	765	762		78%
Solid		315	146	81	43	40	36	34	33	31		3%
Petroleum		580	709	929	362	307	266	231	200	174		18%
Gas		3	5	6	13	12	12	11	11	10		1%
Total		**1923**	**2097**	**2386**	**1338**	**1237**	**1159**	**1064**	**1009**	**977**	**1200**	**100%**
Natural Emissions[4]		91	91	92	92	92	91	93	92	92		0.3%

[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] Total emissions shown for 2010 relate to the target set under the NECD

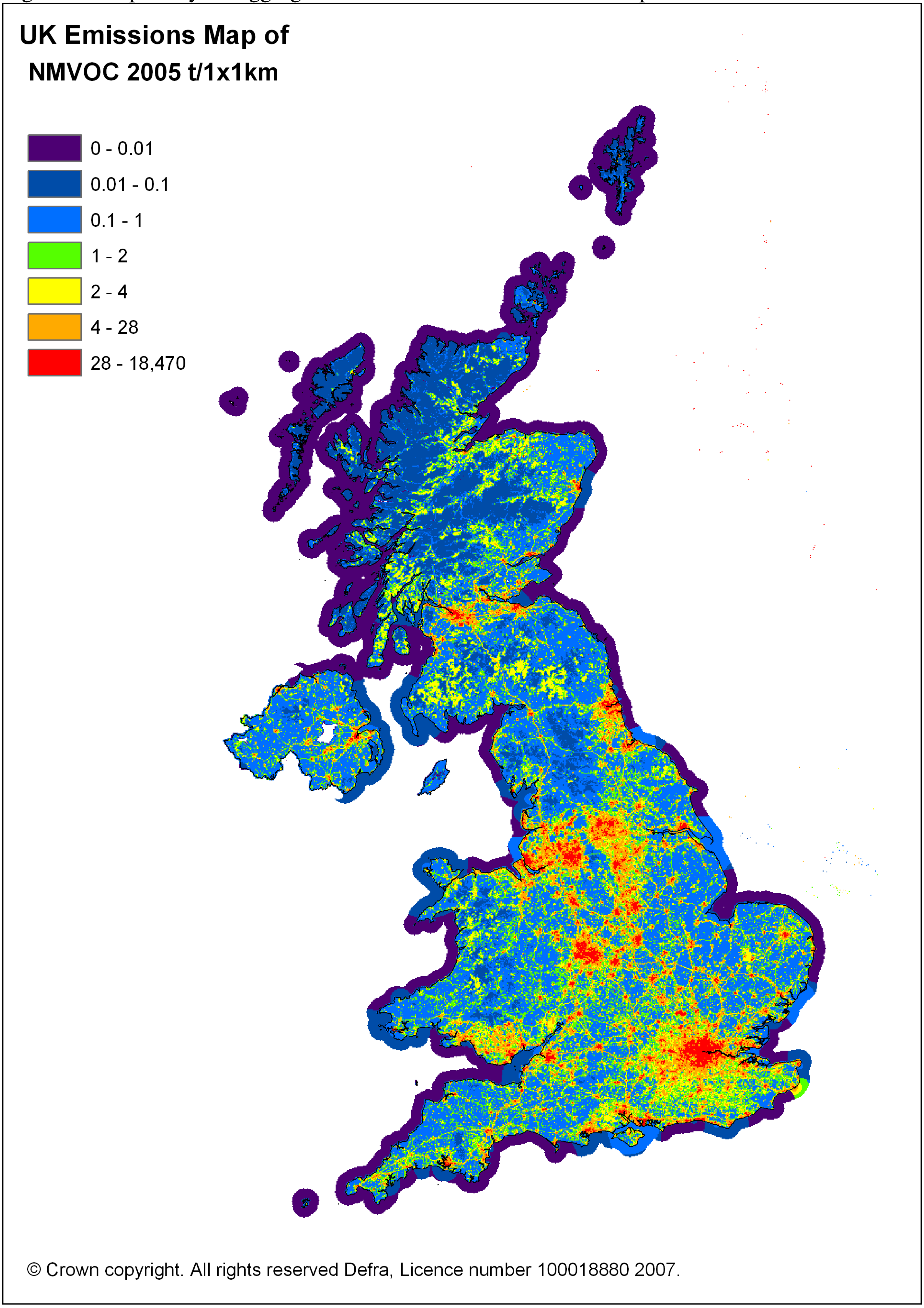
[4] Primarily emissions from forests, but also includes accidental biomass fires

The spatial disaggregation of NMVOC emissions in the UK is shown in Figure 2.18. 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 2.18 Spatially Disaggregated UK Emissions of NMVOC Map



2.9.3 Solvent Use and Production Processes

Solvent & other product use and production processes are responsible for 41% and 7%, respectively, of the 2005 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, and 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 41 % 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 1% since 1994.

Emissions from the food and drink industry comprised 8% (79 ktonnes) of the total NMVOC emission in 2005. 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.

2.9.4 Transport

Total transport emissions are currently responsible for 15% of NMVOC emissions of which 12% are a result of road transport. With increasing car numbers, emissions rose from 1970, to a peak in 1989. Since then emissions have declined by 87% owing to the increased use of catalytic converters and fuel switching from petrol to diesel cars. Emissions from the road transport sector alone have decreased by 77% between 1970 and 2005.

2.9.5 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 2% of the total NMVOC emission. This estimate has been significantly revised upwards in light of new data. The mass of mains gas being released accidentally has decreased due to pipe replacement in recent years. There is a 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. This source currently accounts for 3% of national NMVOC emissions.

The contribution from domestic heating has fallen by 90% between 1970 and 2005 as the use of coal for domestic and commercial heating has declined. It now accounts for just 3% of the UK emissions.

NMVOC emissions from waste treatment and disposal contribute 2% 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 2.12 represent emissions from agricultural field burning.

2.9.6 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 2.13 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 2.13 The 50 Most Significant NMVOC Species in Terms of Mass Emission (tonnes)

	Stationary combustion			Production Processes	Extraction and distribution of fossil fuels	Solvent Use	Road transport	Other transport[3]	Waste treatment and disposal	**Total (Tonnes)**
	Energy production	Commercial/ residential	Industrial							
ethanol		3,734	54	55,084		41,138			605	**100,616**
butane	267	1,182	348	4,617	37,728	19,306	7,288	235	51	**71,023**
ethane	191	2,379	187	1,434	32,237	0	1,800	258	6,028	**44,514**
propane	169	1,118	175	2,311	18,847	3,770	641	186	5,697	**32,913**
toluene	117	732	136	3,930	170	11,264	8,199	1,822	350	**26,719**
methanol				2,078	0	27,874			157	**30,109**
ethylene	47	4,207	104	5,826	27		7,880	3,897	1,068	**23,055**
2-methylbutane	87	1,094	128	1,000	7,754	49	9,538	326	33	**20,008**
pentane	209	771	350	1,909	13,076	436	4,604	139	44	**21,538**
acetone	23	8	20	1,953		17,936	608	56	3	**20,606**
hexane	140	99	95	4,336	6,696	2,461	4,235	87	231	**18,381**
m-xylene	500	70	75	2,107	61	11,861	2,463	536	161	**17,834**
2-methylpropane	17	294	28	223	9,441	945	3,187	125	16	**14,277**
formaldehyde	3,079	738	597	483	153	24	4,218	2,695	3,798	**15,782**
trichloroethene				908		13,034			127	**14,070**
benzene	93	4,924	368	1,640	601	0	2,907	2,438	1,031	**14,002**
propylene	60	798	34	6,289	14	0	3,497	1,132	61	**11,886**
dichloromethane				3,414		9,845			142	**13,401**
2-butanone				669		11,947	171	8	29	**12,823**
butyl acetate				199		10,762			45	**11,005**
decane	0	10		814	22	8,107	629	1,261		**10,843**
ethylbenzene	147	23	54	1,659	18	4,549	2,056	353	259	**9,117**
1,2,4-trimethylbenzene	0	0		520	4	5,295	2,651	462		**8,933**
2-propanol		3		741		8,168			34	**8,945**
heptane	19	337	1	300	6,529	1,481	916	107		**9,690**
ethyl acetate				1,330		7,199			48	**8,578**
o-xylene	111	40	26	724	29	2,983	2,225	473	91	**6,702**
p-xylene	4	54	44	885	13	3,205	1,904	414	125	**6,649**
octane	0	18		185	5,718	1,276	392	38		**7,626**
tetrachloroethene				206		5,805			262	**6,272**
4-methyl-2-pentanone				657		5,733				**6,390**
acetylene	16	7	136	596	12	0	3,054	977		**4,799**
nonane	0	15		499	58	4,893	150	295		**5,911**
2-methylpropene	0	61	0	633	183		2,484	1,295	10	**4,666**
undecane	0	0		424		4,224		557		**5,205**
methyl acetate				4,942						**4,942**
1-butanol				238		4,351			14	**4,603**
acetaldehyde	0	0		733			2,076	1,369		**4,178**
2-methylpentane	5	5	8	916	1,311	1,176		7	109	**3,537**
2-butoxyethanol				101		3,642				**3,743**
1,3,5-trimethylbenzene	0	0		189		1,831	1,006	255		**3,281**
1-propanol				63		3,475			82	**3,620**
1,3-butadiene	1			381	5		1,591	623	15	**2,615**
dipentene				13		3,304				**3,317**
2-butene	1	242	0	138	576		1,405	94	40	**2,497**
1-methoxy-2-propanol				96		3,020				**3,116**
1,2,3-trimethylbenzene	0	0		176		1,844	600	208		**2,829**
methylethylbenzene				230		2,585				**2,814**
4-methyldecane				246		2,460				**2,706**
2-pentene	13	110	0	11	1,015		847	21	0	**2,018**
Total Top 50	**5,316**	**23,074**	**2,968**	**119,054**	**142,297**	**273,257**	**85,223**	**22,750**	**20,766**	**694,705**
Other VOCs	256	1,301	157	23,859	2,191	94,137	9,571	5,034	3,359	**139,865**
Other grouped species	1	266	3	21,453	4,432	7,646	22,924	25,187	2,743	**84,655**
unspeciated	6	8,561	697	31,584	1,010	7,654	896	1,680	4,368	**56,456**
Total VOC	**5,579**	**33,201**	**3,826**	**195,950**	**149,930**	**382,694**	**118,614**	**54,650**	**31,237**	**975,682**

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

2.9.7 Photochemical Ozone Creation Potential

Table 2.13 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 2.14).

Table 2.14 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	3,789	55,084		41,138			605	100,616	40,146	9.2%
butane	35.20	a	1,797	4,617	37,728	19,306	7,288	235	51	71,023	25,000	5.7%
ethane	12.30	a	2,757	1,434	32,237	0	1,800	258	6,028	44,514	5,475	1.2%
propane	17.60	a	1,462	2,311	18,847	3,770	641	186	5,697	32,913	5,793	1.3%
toluene	63.70	a	985	3,930	170	11,264	8,199	1,822	350	26,719	17,020	3.9%
methanol	14.00	a	0	2,078	0	27,874			157	30,109	4,215	1.0%
ethylene	100.00	a	4,358	5,826	27		7,880	3,897	1,068	23,055	23,055	5.3%
2-methylbutane	40.50	a	1,308	1,000	7,754	49	9,538	326	33	20,008	8,103	1.8%
pentane	39.50	a	1,329	1,909	13,076	436	4,604	139	44	21,538	8,508	1.9%
acetone	9.40	a	51	1,953		17,936	608	56	3	20,606	1,937	0.4%
hexane	48.20	a	335	4,336	6,696	2,461	4,235	87	231	18,381	8,860	2.0%
m-xylene	110.80	a	645	2,107	61	11,861	2,463	536	161	17,834	19,760	4.5%
2-methylpropane	30.70	a	339	223	9,441	945	3,187	125	16	14,277	4,383	1.0%
formaldehyde	51.90	a	4,413	483	153	24	4,218	2,695	3,798	15,782	8,191	1.9%
trichloroethene	32.50	a	0	908		13,034			127	14,070	4,573	1.0%
benzene	21.80	a	5,385	1,640	601	0	2,907	2,438	1,031	14,002	3,052	0.7%
propylene	112.30	a	892	6,289	14	0	3,497	1,132	61	11,886	13,348	3.0%
dichloromethane	6.80	a	0	3,414		9,845			142	13,401	911	0.2%
2-butanone	37.30	a	0	669		11,947	171	8	29	12,823	4,783	1.1%
butyl acetate	26.90	a	0	199		10,762			45	11,005	2,960	0.7%
decane	38.40	a	10	814	22	8,107	629	1,261		10,843	4,164	0.9%
ethylbenzene	73.00	a	224	1,659	18	4,549	2,056	353	259	9,117	6,656	1.5%
1,2,4-trimethylbenzene	127.80	a	0	520	4	5,295	2,651	462		8,933	11,416	2.6%
2-propanol	18.80	a	3	741		8,168			34	8,945	1,682	0.4%
heptane	49.40	a	357	300	6,529	1,481	916	107		9,690	4,787	1.1%
ethyl acetate	20.90	a	0	1,330		7,199			48	8,578	1,793	0.4%
o-xylene	105.30	a	178	724	29	2,983	2,225	473	91	6,702	7,058	1.6%
p-xylene	101.00	a	103	885	13	3,205	1,904	414	125	6,649	6,716	1.5%
octane	45.30	a	18	185	5,718	1,276	392	38		7,626	3,455	0.8%
tetrachloroethene	2.90	a	0	206		5,805			262	6,272	182	0.0%
4-methyl-2-pentanone	49.00	a	0	657		5,733				6,390	3,131	0.7%
acetylene	8.50	a	160	596	12	0	3,054	977		4,799	408	0.1%
nonane	41.40	a	15	499	58	4,893	150	295		5,911	2,447	0.6%
2-methylpropene	62.70	a	61	633	183		2,484	1,295	10	4,666	2,926	0.7%
undecane	38.40	a	0	424		4,224		557		5,205	1,999	0.5%
methyl acetate	5.90	a	0	4,942						4,942	292	0.1%
1-butanol	62.00	a	0	238		4,351			14	4,603	2,854	0.7%
acetaldehyde	64.10	a	0	733			2,076	1,369		4,178	2,678	0.6%
2-methylpentane	42.00	a	18	916	1,311	1,176		7	109	3,537	1,486	0.3%
2-butoxyethanol	48.30	a	0	101		3,642				3,743	1,808	0.4%
1,3,5-trimethylbenzene	138.10	a	0	189		1,831	1,006	255		3,281	4,531	1.0%
1-propanol	56.10	a	0	63		3,475			82	3,620	2,031	0.5%
1,3-butadiene	85.10	a	1	381	5		1,591	623	15	2,615	2,226	0.5%
dipentene	74.54	b	0	13		3,304				3,317	2,472	0.6%
2-butene	113.90	a	243	138	576		1,405	94	40	2,497	2,844	0.6%
1-methoxy-2-propanol	35.50	a	0	96		3,020				3,116	1,106	0.3%
1,2,3-trimethylbenzene	126.70	a	0	176		1,844	600	208		2,829	3,584	0.8%
methylethylbenzene	94.10	c	0	230		2,585				2,814	2,648	0.6%
4-methyldecane	37.67	b	0	246		2,460				2,706	1,019	0.2%
2-pentene	111.90	a	124	11	1,015		847	21	0	2,018	2,258	0.5%
Total Top 50			31,358	119,054	142,297	273,257	85,223	22,750	20,766	694,705	302,727	69%
Other VOC	0.38[a]		1,714	23,859	2,191	94,137	9,571	5,034	3,359	139,865	53,451	12%
Other grouped species	0.63[a]		270	21,453	4,432	7,646	22,924	25,187	2,743	84,655	53,156	12%
unspeciated	51.30	c	9,264	31,584	1,010	7,654	896	1,680	4,368	56,456	28,962	7%
Total VOC			42,606	195,950	149,930	382,694	118,614	54,650	31,237	975,682	438,297	100%

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

2.10 PARTICULATE MATTER

2.10.1 Key Source Description

Historically, interest in particulate matter focused mainly on smoke, which can cause health problems especially in combination with other pollutants. A notable 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, particles less than a tenth of a µm 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.

2.10.2 PM_{10}

2.10.2.1 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, 2005) see http://www.airquality.co.uk/archive/index.php and http://www.defra.gov.uk/environment/airquality/publications/particulate-matter/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 now more important nationally. Domestic coal is still 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.

2.10.2.2 PM_{10} Emission estimates

Emissions of PM_{10} are shown in Table 2.15 and Figure 2.19. 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 230 ktonnes (48% of the total emission) in 1970 to 24 ktonnes (19%) in 2005.

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 2.15). However for completeness it is given in Table 2.16 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, and therefore input into modelling studies.

Table 2.15 UK Emissions of PM_{10} by aggregated UN/ECE Source Category and Fuel (ktonnes)

	NFR Codes	1970	1980	1990	2000	2001	2002	2003	2004	2005	2005%
BY UNECE CATEGORY[1]											
Combustion in Energy and Transformation Industry	1A1	83	83	74	25	20	11	11	11	12	8%
Combustion in Manufacturing Industry	1A2	44	20	17	8	8	7	7	7	7	5%
Industrial off-road mobile machinery	1A2f	49	31	28	21	21	20	19	19	18	12%
Residential plants	1A4bi	209	94	50	29	27	24	22	22	21	14%
Passenger cars	1A3bi	10	14	18	8	8	8	7	7	6	4%
Light duty vehicles	1A3bii	3	4	7	10	11	11	11	11	11	7%
Heavy duty vehicles	1A3biii	25	27	27	11	10	9	8	7	7	4%
Other Transport	1A3biv&vi, 1A3aii(i)-1A3aii(ii), 1A3c-1A3eii, 1A4bii, 1A4cii, 1A5b	20	21	24	23	22	22	23	23	23	16%
Production Processes	1B1-3	36	33	39	27	26	25	26	26	26	17%
Agriculture	4	11	12	13	14	14	14	14	14	13	9%
Waste/Other	6, 7	9	9	9	7	11	7	7	7	7	5%
By FUEL TYPE											
Solid		312	180	125	49	41	30	28	28	27	18%
Petroleum		98	92	94	66	64	60	59	58	56	37%
Gas		1	1	2	3	3	3	4	3	4	3%
Non-Fuel		87	76	85	66	69	63	64	64	63	42%
TOTAL		**499**	**349**	**305**	**184**	**178**	**155**	**155**	**154**	**150**	**100%**

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

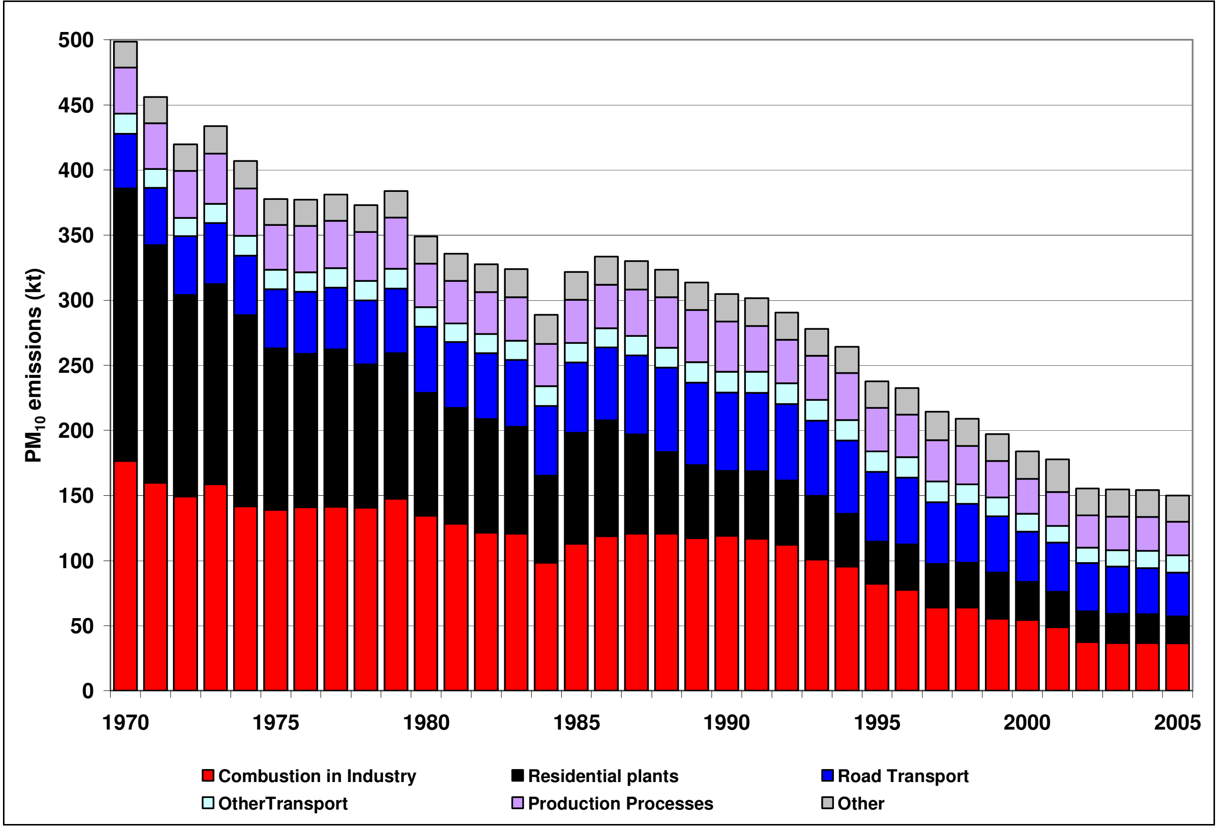
Table 2.16 PM_{10} Emission Estimates from Resuspension (ktonnes)

	1970	1980	1990	2000	2001	2002	2003	2004	2005
Resuspension from Road Transport	8	11	17	19	20	20	20	21	21

The geographical disaggregation of emissions is shown in Figure 2.20. 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 22% 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 2005. 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 has reduced particulate emissions further.

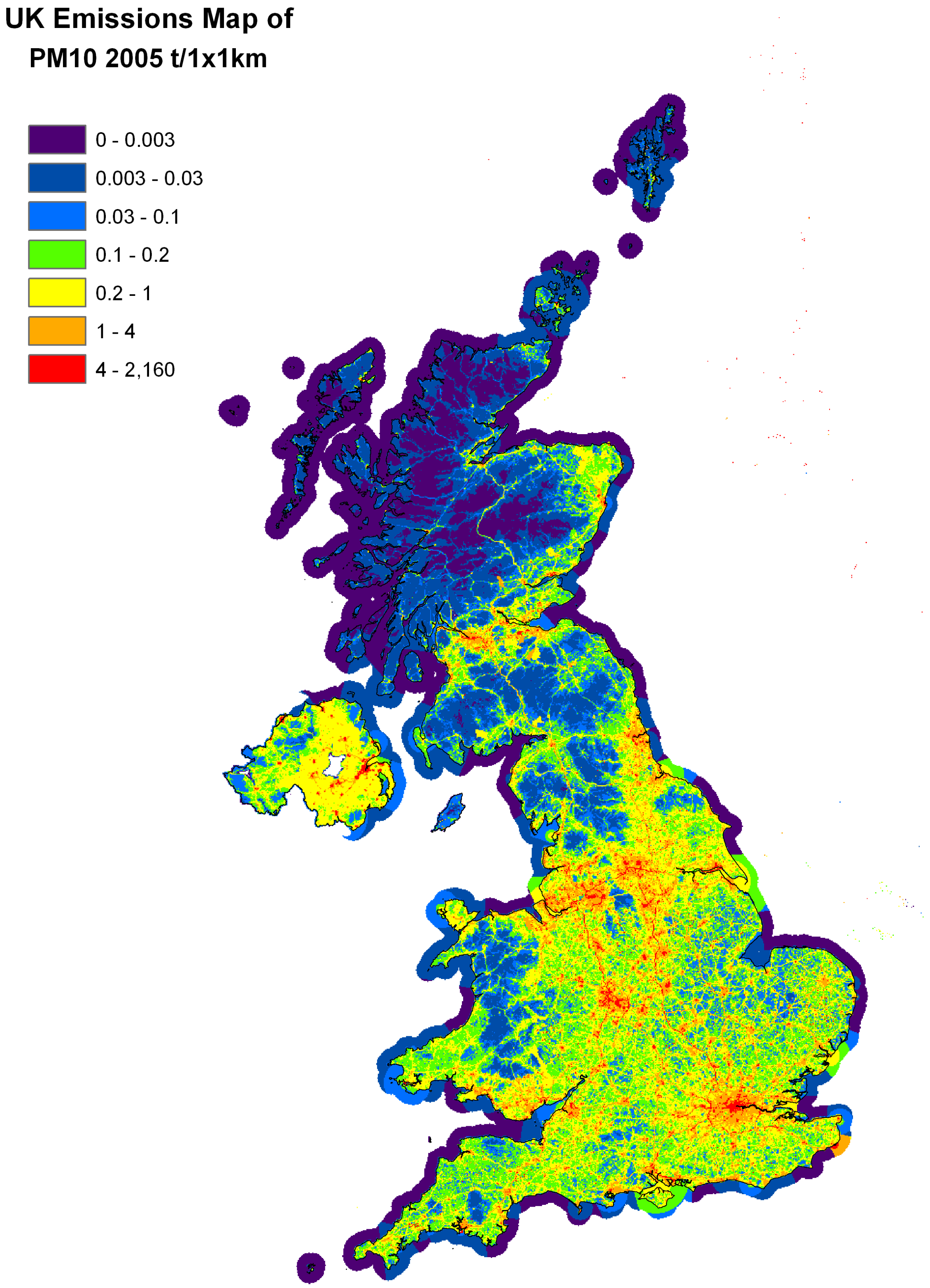
Figure 2.19 Time Series of PM_{10} Emissions (ktonnes)



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 8% in 1970 to 22% in 2005. 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 on a per vehicle kilometre travelled basis 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 2.20 Spatially Disaggregated UK Emissions of PM_{10} Map



2.10.3 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 2.17, Table 2.18 and Table 2.19 in the same format as for the PM_{10} inventory. Figure 2.21 – Figure 2.23 show trends in emissions of each particle size by source sector. The results show a comparable decline in emissions of each particle size. Between 1990 and 2005, UK emissions of PM_{10} fell by 51%, whereas emissions of $PM_{2.5}$ fell by 47%, $PM_{1.0}$ by 44% and $PM_{0.1}$ by 42%. There is a gradual change in the relative source contribution with particle size. Road transport becomes an increasingly important sector as the particle size decreases. In 2005, it accounted for 22% of PM_{10} emissions, but 46% of $PM_{0.1}$ emissions.

2.10.3.1 $PM_{2.5}$ Emission estimates

Emissions of $PM_{2.5}$ are shown in Table 2.17. 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 32 ktonnes in 1990 to 19 ktonnes in 2005. However, these sources contribution to total UK emissions has increased over this time period from 18% to 20%.

In general the $PM_{2.5}$ emission profile follows the PM_{10} trends and the reductions in PM_{10} emissions have also caused reductions in $PM_{2.5}$

Table 2.17 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

$PM_{2.5}$	**NFR Codes**	**1970**	**1980**	**1990**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2005 %**
Combustion in Energy and Transformation Industry	1A1	38	38	34	12	10	6	6	6	6	7%
Combustion in Manufacturing Industry	1A2	29	14	12	6	5	5	5	5	5	5%
Industrial off-road mobile machinery	1A2f	31	21	19	15	15	14	14	14	13	14%
Residential plants	1A4bi	81	39	22	16	15	14	13	13	13	13%
Passenger cars	1A3bi	8	11	14	7	7	7	7	6	6	6%
Light duty vehicles	1A3bii	2	3	6	9	10	10	10	10	10	10%
Heavy duty vehicles	1A3biii	22	25	24	10	9	8	7	7	6	6%
Other Transport	1A3biv & vi, 1A3aii(i) - 1A3aii(ii), 1A3c- 1A3eii, 1A4bii, 1A4cii, 1A5b	16	16	18	17	16	15	16	17	17	18%
Production Processes	1B1-3	15	17	18	12	12	11	12	12	12	12%
Agriculture	4	2	3	2	2	2	2	2	2	2	2%
Waste/Other	6, 7	8	8	8	6	8	6	6	6	6	6%
Total		**252**	**192**	**178**	**112**	**109**	**98**	**98**	**97**	**95**	**100%**

Table 2.18 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

$PM_{1.0}$	**NFR Codes**	**1970**	**1980**	**1990**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2005 %**
Combustion in Energy and Transformation Industry	1A1	19	18	15	6	5	3	3	3	4	5%
Combustion in Manufacturing Industry	1A2	22	11	9	4	4	3	3	3	3	5%
Industrial off-road mobile machinery	1A2f	20	14	14	12	12	11	11	11	11	15%
Residential plants	1A4bi	63	29	16	11	11	9	9	9	9	12%
Passenger cars	1A3bi	6	9	12	7	7	6	6	6	5	7%
Light duty vehicles	1A3bii	2	3	6	9	9	9	10	10	9	13%
Heavy duty vehicles	1A3biii	21	23	23	9	8	7	7	6	6	8%
Other Transport	1A3biv & vi, 1A3aii(i) - 1A3aii(ii), 1A3c- 1A3eii, 1A4bii, 1A4cii, 1A5b	12	12	13	12	11	10	11	12	12	16%
Production Processes	1B1-3	7	10	10	7	7	6	7	7	7	9%
Agriculture	4	2	3	2	2	2	2	2	2	2	3%
Waste/Other	6, 7	7	7	6	5	6	5	5	5	5	7%
Total		**183**	**139**	**128**	**83**	**82**	**74**	**74**	**74**	**72**	**100%**

Table 2.19 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

$PM_{0.1}$	**NFR Codes**	**1970**	**1980**	**1990**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2005 %**
Combustion in Energy and Transformation Industry	1A1	7	7	6	2	2	1	2	1	2	6%
Combustion in Manufacturing Industry	1A2, 1A4bi	15	8	6	4	4	3	3	3	3	11%
Industrial off-road mobile machinery	1A2f	6	5	4	4	3	3	3	3	3	12%
Passenger cars	1A3bi	3	4	5	4	4	4	3	3	3	11%
Light duty vehicles	1A3bii	1	1	3	5	5	5	6	6	5	20%
Heavy duty vehicles	1A3biii	12	14	13	5	5	4	4	4	3	12%
Other Transport	1A3biv & vi, 1A3aii(i) - 1A3aii(ii), 1A3c-1A3eii, 1A4bii, 1A4cii, 1A5b	3	3	3	3	3	3	3	3	3	10%
Production Processes	1B1-3	3	3	3	2	2	2	2	2	2	7%
Agriculture	4	2	2	2	2	2	2	2	2	2	7%
Waste/Other	6, 7	1	1	1	1	1	1	1	1	1	3%
Total		**53**	**47**	**48**	**32**	**31**	**29**	**29**	**29**	**28**	**100%**

Figure 2.21 Time Series of PM2.5 Emissions (ktonnes)

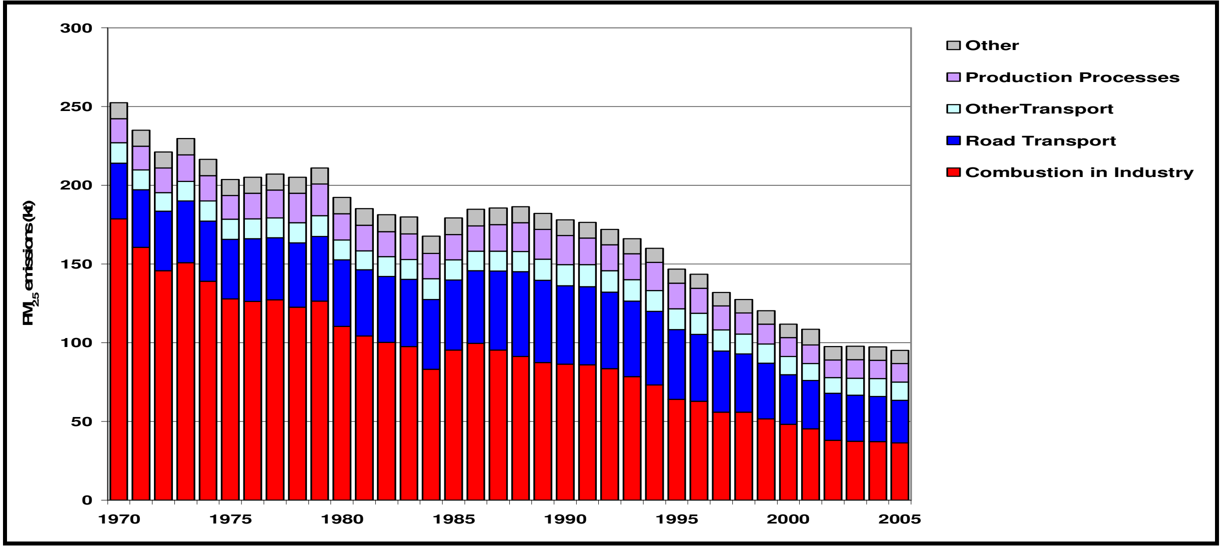


Figure 2.22 Time Series of $PM_{1.0}$ Emissions (ktonnes)

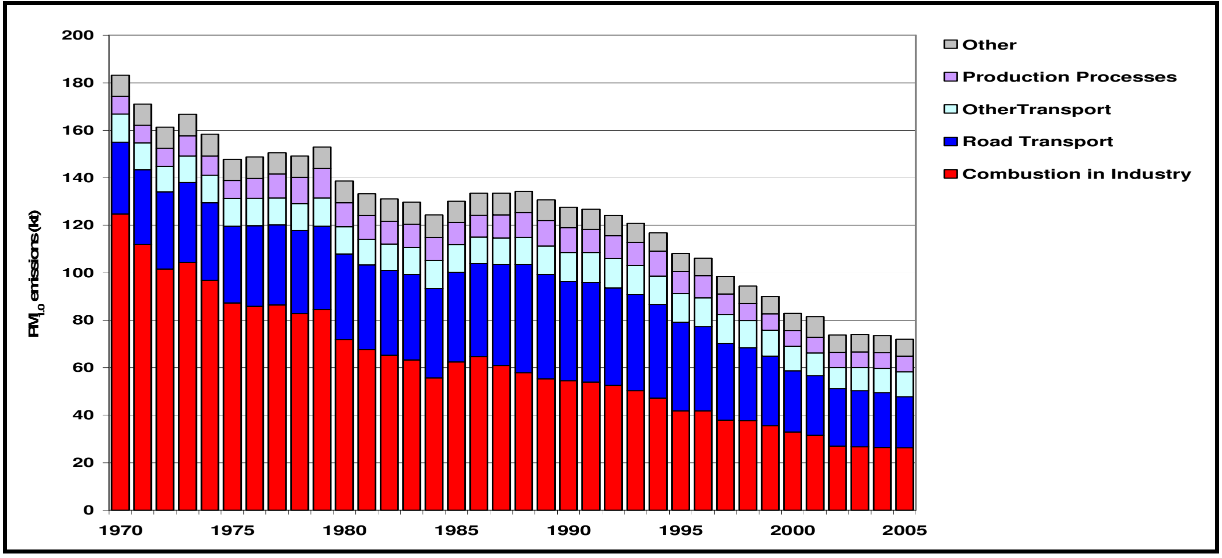
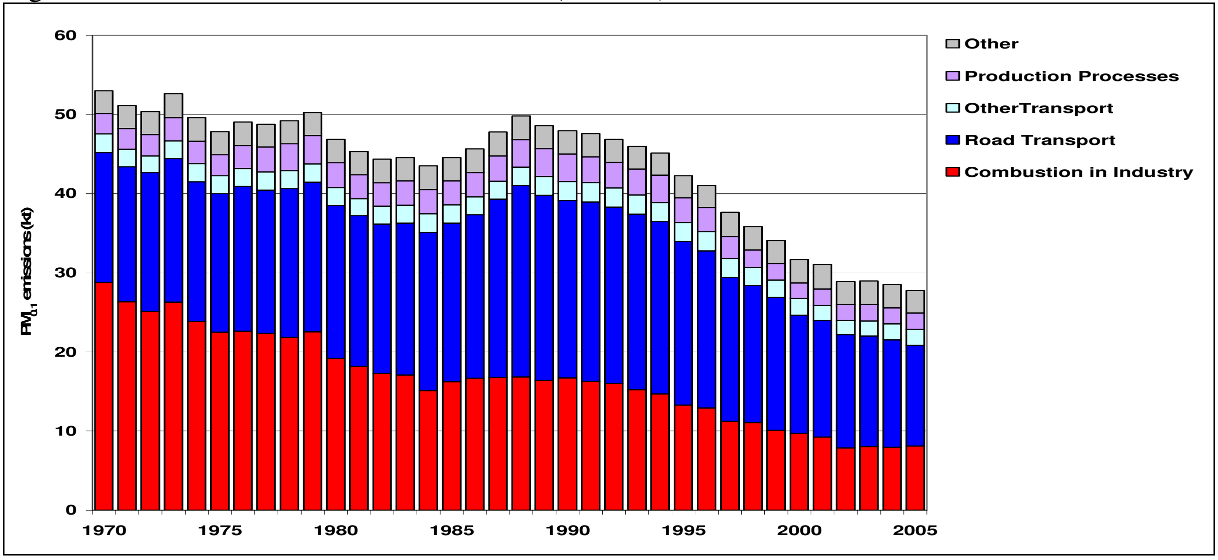


Figure 2.23 Time Series of $PM_{0.1}$ Emissions (ktonnes)



2.10.4 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 2.20), reflecting the associated uncertainties.

Table 2.20 UK Emissions of Black Smoke by UN/ECE Source Category (ktonnes)

	1970	1980	1990	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
TOTAL	1039	570	393	271	231	230	232	195	187	169	163	158	150

2.11 SULPHUR DIOXIDE

2.11.1 Key Source Description

Sulphur dioxide (SO_2) has long been recognised as a pollutant because of its role, along with particulate matter, in forming winter-time smogs. Studies indicate that SO_2 causes nerve stimulation in the lining of the nose and throat. This can cause irritation, coughing and a feeling of chest tightness which may cause the airways to narrow. People suffering from asthma are considered to be particular sensitive to SO_2 concentrations.

Fuel combustion accounted for more then 97% of UK SO_2 emissions in 2005 with the two main sources being the combustion of solid fuel and petroleum products. SO_2 emissions 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, 2006), published sulphur contents of liquid fuels (Watson, 2003) and data from coal producers regarding sulphur contents of coals enable reliable estimates to be produced.

2.11.2 Total SO_2 Emissions

Since 1970 there has been a substantial overall reduction of more than 89% in SO_2 emissions (Figure 2.24). The emission profile exhibits a steady decline between 1970 and 2005 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 2005.

Table 2.21 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 87% since 1970 and those from petroleum by 94%. 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 2005 there has been a 97% reduction in emissions.

Figure 2.24 Time Series of SO_2 Emissions (Mtonnes)

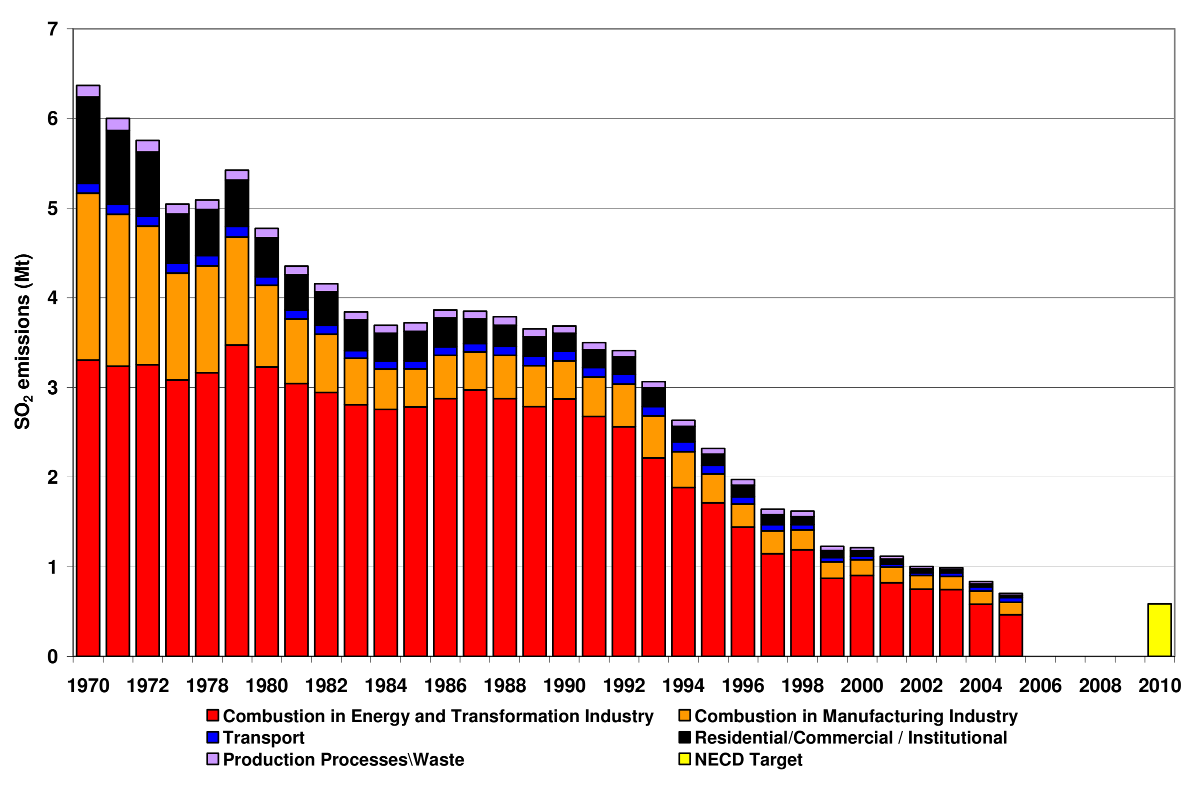


Table 2.21 UK Emissions of SO_2 by aggregated UN/ECE[1] Source Category and Fuel (ktonnes)

	NFR Codes	1970	1980	1990	2000	2001	2002	2003	2004	2005	2010[3]	2005%
BY UN/ECE CATEGORY[2]												
Public Electricity and Heat Production	1A1a	2919	3011	2729	826	746	681	678	509	385		55%
Petroleum refining	1A1b	199	197	138	73	72	66	63	70	73		10%
Stationary Combustion	1A1c, 1A2a, 1A2b, 1A4a, 1A4ci	960	320	121	45	47	31	24	26	25		3%
Other industrial combustion (Autogenerators, Brick Manufacture)	1A2f	1527	821	396	149	147	135	132	131	127		18%
Transport	1A3aii(i), 1A3aii(ii), 1A3b, 1A3c, 1A3eii, 1A4bii, 1A4cii, 1A5b	80	69	82	19	15	15	14	16	15		2%
National Navigation	1A3dii	34	26	28	20	17	14	24	31	37		5%
Residential plants	1A4bi	521	226	113	47	41	33	29	27	21		3%
Production Processes\Waste	1B1, 2, 6	130	106	82	36	35	27	25	26	24		3%
BY FUEL CATEGORY												
Solid		3728	3156	2776	945	861	786	776	608	477		67%
Petroleum		2470	1473	785	185	178	140	137	153	159		23%
Gas		17	9	8	12	13	10	10	9	8		1%
Non-Fuel		155	138	118	73	68	66	68	65	62		9%
Total		**6370**	**4775**	**3687**	**1215**	**1119**	**1002**	**991**	**836**	**706**	**585**	**100%**

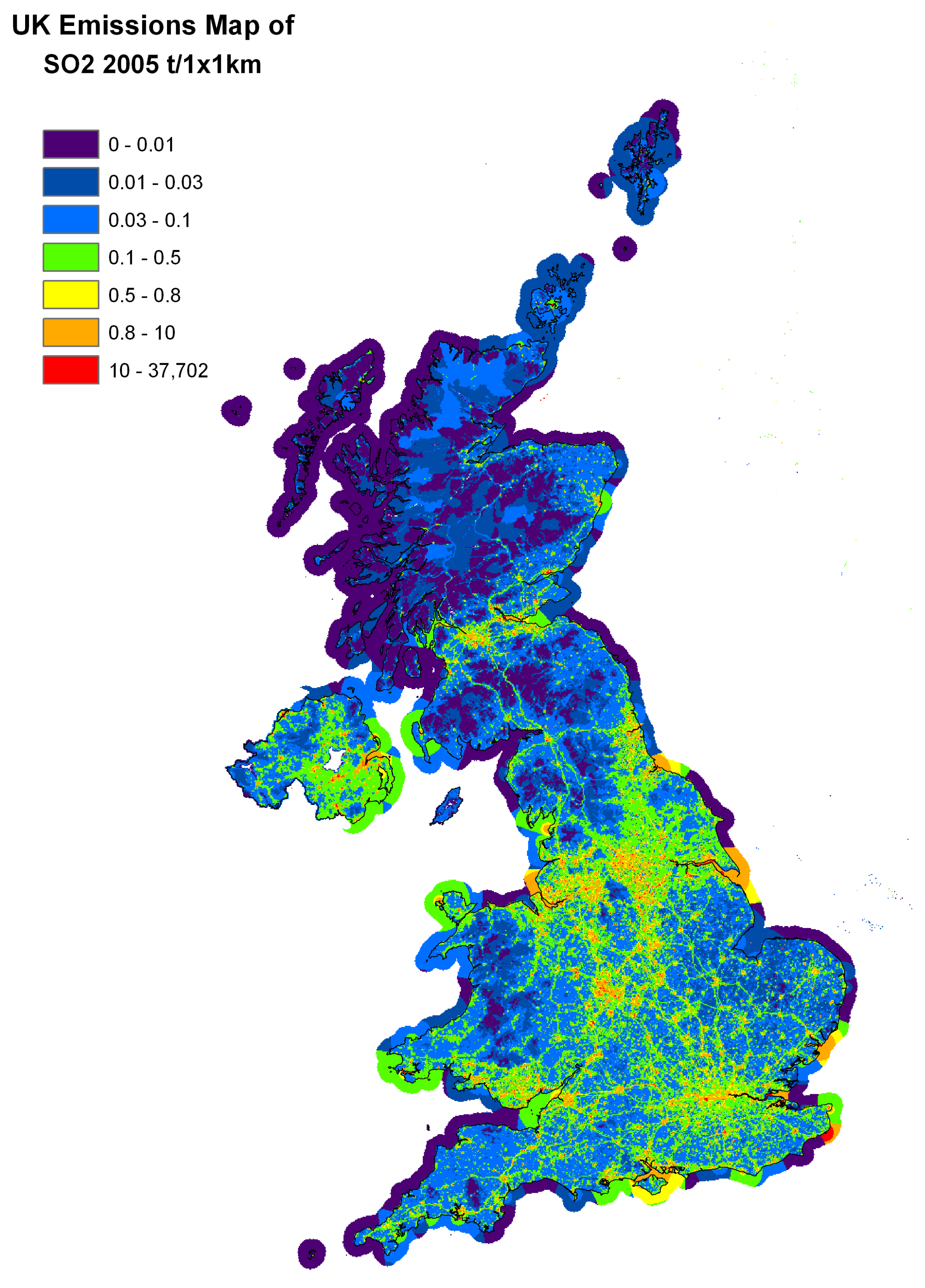
[1] UK emissions reported in IPCC format (Baggott *et al*, 2006) differ slightly due to the different source categories used.

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

[3] Total emissions shown for 2010 relate to the target set under the NECD

The geographical distribution of SO_2 emissions is shown in Figure 2.25. 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. These are difficult to see and therefore 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.

Figure 2.25 Spatially Disaggregated UK Emissions of SO_2 Map



2.11.3 Power Generation

The largest contribution to SO_2 emissions is from power stations, which accounts for 55% of the total in 2005. 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 87%. 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 7.2.3). 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.

2.11.4 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 2005 emissions from combustion sources have fallen by 92% 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.

2.11.5 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.

2.11.6 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 1970-2005, 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.

2.12 ACCURACY OF EMISSION ESTIMATES OF AIR QUALITY 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 2.22.

Table 2.22 Uncertainty of the Emission Inventories for Air Quality 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
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)

2.12.1 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.

2.12.2 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 2.9) 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.

2.12.3 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 emission measurements made and the highly variable results. 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.

2.12.4 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.

2.12.5 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.

2.12.6 Nitrogen Oxides

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 23% 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.

2.12.7 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.

2.12.8 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.

2.12.9 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.

2.12.10 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.

3 Heavy Metal Emission Estimates

3.1 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).

3.1.1 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 can 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.

The NAEI reports emissions of thirteen metals. The estimated emissions of these in 2005 are shown in Table 3.1 below.

Table 3.1 Total UK Emissions of Heavy Metals in 2005

Pollutant (Heavy metals)	**Total 2005 UK emission (tonnes)**
• Arsenic	14
• Beryllium	9
• Cadmium	4
• Chromium	36
• Copper	60
• Lead	118
• Manganese	31
• Mercury	8
• Nickel	87
• Selenium	49
• Tin	6
• Vanadium	975
• Zinc	461

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). This data has been reported by the NAEI in 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. The 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, 2006). 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 was reviewed in 2002 (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, 2006) 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).

A measurement programme to review the metal content of fuels is currently planned. This will to improve the certainty of many of the emission estimates. This has been driven by recent modelling studies which suggest that the emission inventories across Europe are underestimating emissions. Studies are also planned on improving the assessment of resuspension of metals.

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, 2006).

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.

3.2 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.

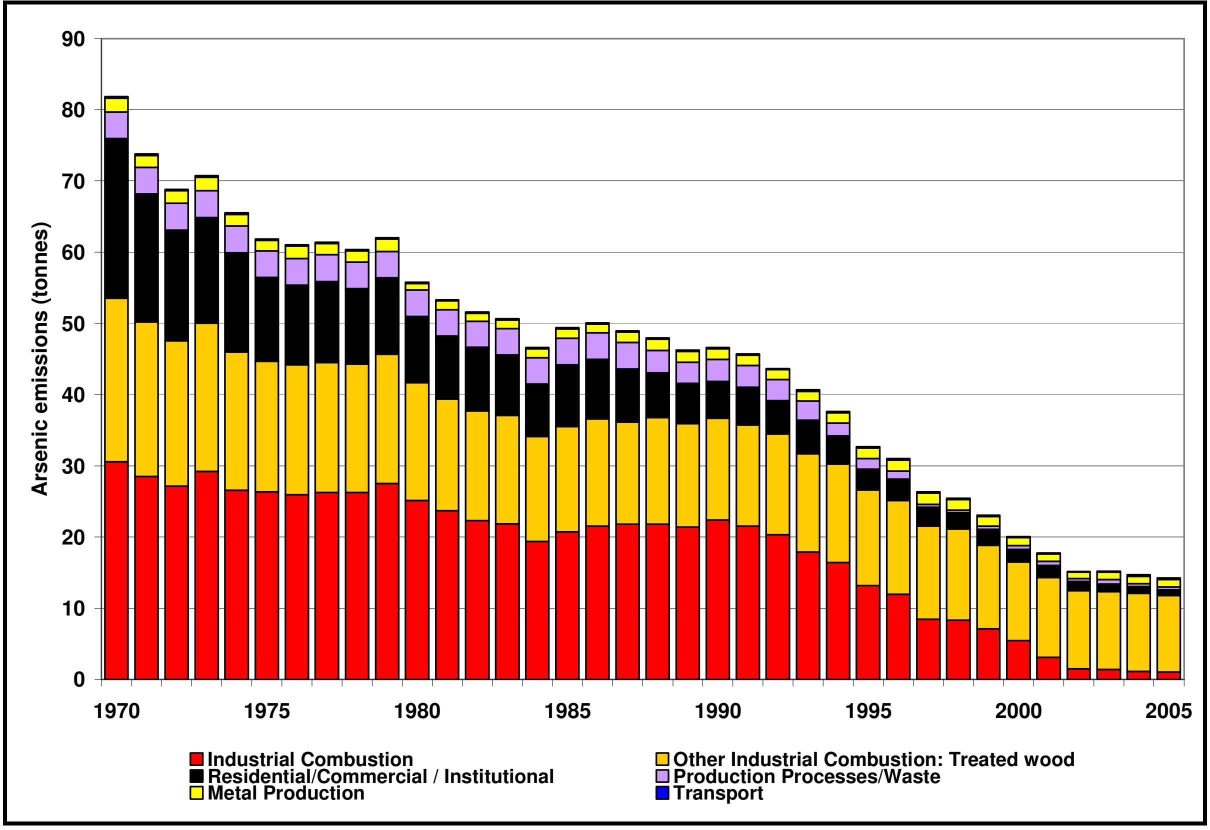
Table 3.2 and Figure 3.1 summarise the UK emissions of arsenic. Emissions have declined by 83% since 1970. Historically the largest source of emission was coal combustion with other sources being very small by comparison. Coal use has declined over the period considered, in favour of natural gas use. 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 3.2 UK Emissions of Arsenic by aggregated UN/ECE Category and Fuel (tonnes)

	NFR Codes	**1970**	**1980**	**1990**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2005%**
BY UN/ECE CATEGORY[1]											
Public Electricity and Heat Production	1A1a	18.2	19.2	18.2	4.1	2.3	0.6	0.9	0.6	0.6	4%
Other Stationary Industrial Combustion	1A1b-c, 1A2b	5.3	3.0	1.9	1.0	0.5	0.5	0.2	0.2	0.2	1%
Iron and Steel	1A2a	7.1	3.0	2.2	0.4	0.4	0.4	0.3	0.3	0.3	2%
Other Industrial Combustion: Treated wood	1A2f	23.0	16.5	14.3	11.0	11.2	11.0	11.0	11.0	10.8	75%
Transport	1A3aii(i)-1A3aii(ii), 1A3b, 1A3c-1A5b	0.6	0.3	0.2	0.2	0.1	0.1	0.2	0.2	0.2	2%
Residential/Commercial / Institutional	1A4	22.0	9.2	5.1	1.7	1.7	1.3	1.1	0.9	0.8	5%
Production Processes/Waste	1B1-2B, 6	3.7	3.7	3.1	0.5	0.6	0.4	0.6	0.4	0.4	3%
Metal Production	2C	1.9	0.9	1.5	1.1	1.0	0.9	1.0	1.1	1.0	7%
BY FUEL											
Solid		57.1	41.1	34.5	15.6	13.7	11.7	11.8	11.3	11.0	77%
Gas		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Petroleum		12.1	6.7	4.2	1.6	1.8	1.5	1.5	1.6	1.5	11%
Non-Fuel		12.6	8.0	7.9	2.8	2.3	2.0	2.0	1.8	1.8	12%
Total		**81.9**	**55.8**	**46.6**	**20.1**	**17.8**	**15.2**	**15.2**	**14.7**	**14.3**	**100%**

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

Figure 3.1 Time Series of Arsenic Emission (tonnes)



3.3 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 3.3 and Figure 3.2 summarise the UK emissions of cadmium. Emissions have declined by 91% 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 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.

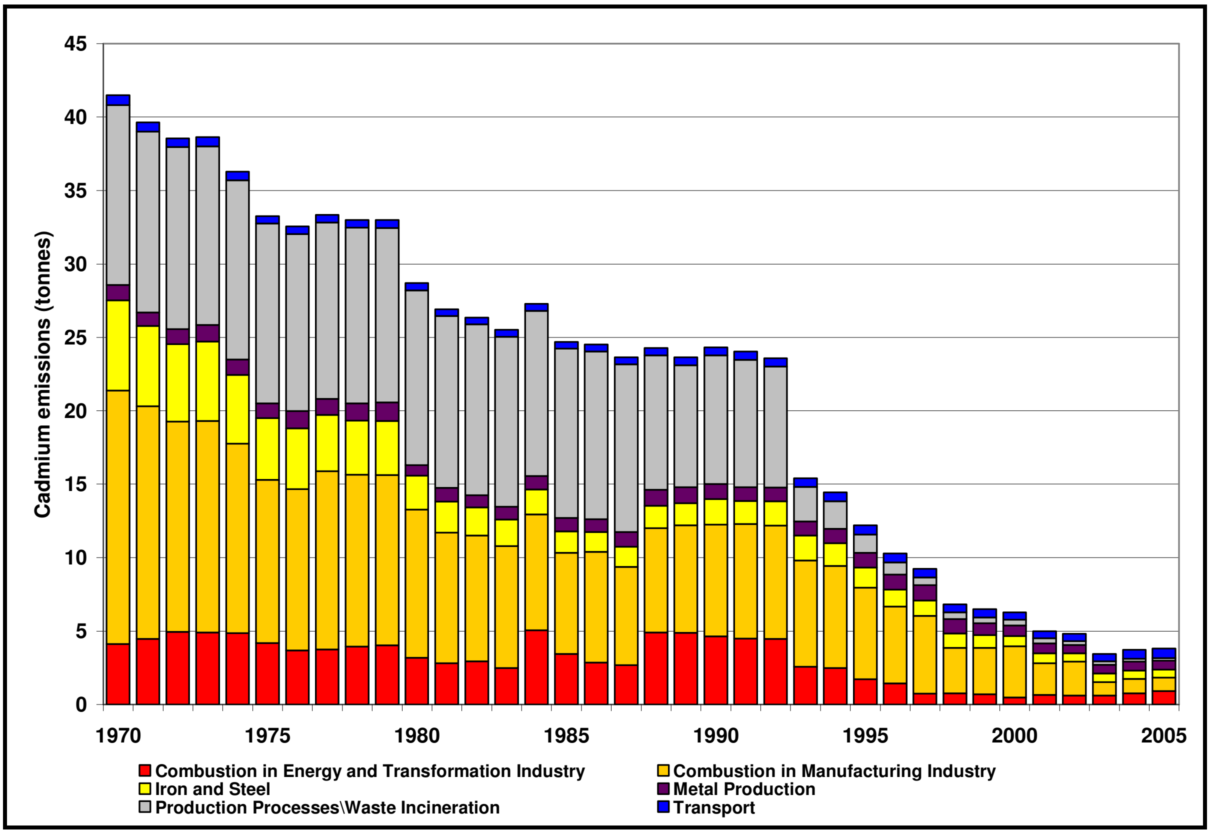
The decline in emissions is a result of the general fall in coal combustion and the decline in fuel oil combustion in power generation. The large reduction observed from waste emissions is due to improved controls on Municipal Solid Waste (MSW) incinerators from 1993 onwards and their conversion to power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

Table 3.3 UK Emissions of Cadmium by aggregated UN/ECE Category and Fuel (tonnes)

	NFR Codes	1970	1980	1990	2000	2001	2002	2003	2004	2005	2005 %
BY UN/ECE CATEGORY[1]											
Public Electricity and Heat Production	1A1a	4.0	3.1	4.6	0.5	0.6	0.6	0.6	0.7	0.9	23%
Other Stationary Combustion	1A1b-c, 1A2b, 1A4a, 1A4bi, 1A4ci	8.7	5.2	5.3	2.9	1.5	1.8	0.5	0.5	0.4	11%
Iron and Steel	1A2a	6.1	2.3	1.7	0.7	0.7	0.6	0.6	0.6	0.5	14%
Other industrial combustion	1A2f	8.9	5.1	2.3	0.6	0.7	0.5	0.4	0.5	0.5	14%
Road Transport	1A3b	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	11%
Other Transport	1A3aii(i), 1A3aii(ii), 1A3c, 1A3dii, 1A3eii, 1A4bii, 1A4cii, 1A5b	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.3	7%
Production Processes\Waste	1B1b, 2A7, 2B5, 6	12.3	11.9	8.8	0.4	0.3	0.3	0.2	0.2	0.2	5%
Metal Production	2C	1.0	0.7	1.0	0.7	0.7	0.6	0.6	0.6	0.6	16%
By FUEL TYPE											
Solid		13.1	12.4	12.1	0.7	0.7	0.7	0.7	0.8	0.9	24%
Petroleum		16.1	8.2	4.4	1.4	1.7	1.3	1.2	1.4	1.4	38%
Gas		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Non-Fuel		12.3	8.1	7.7	4.2	2.6	2.8	1.6	1.5	1.5	38%
Total		**41.5**	**28.7**	**24.3**	**6.3**	**5.0**	**4.8**	**3.4**	**3.7**	**3.8**	**100%**

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

Figure 3.2 Time Series of Cadmium Emissions (tonnes)



3.4 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.

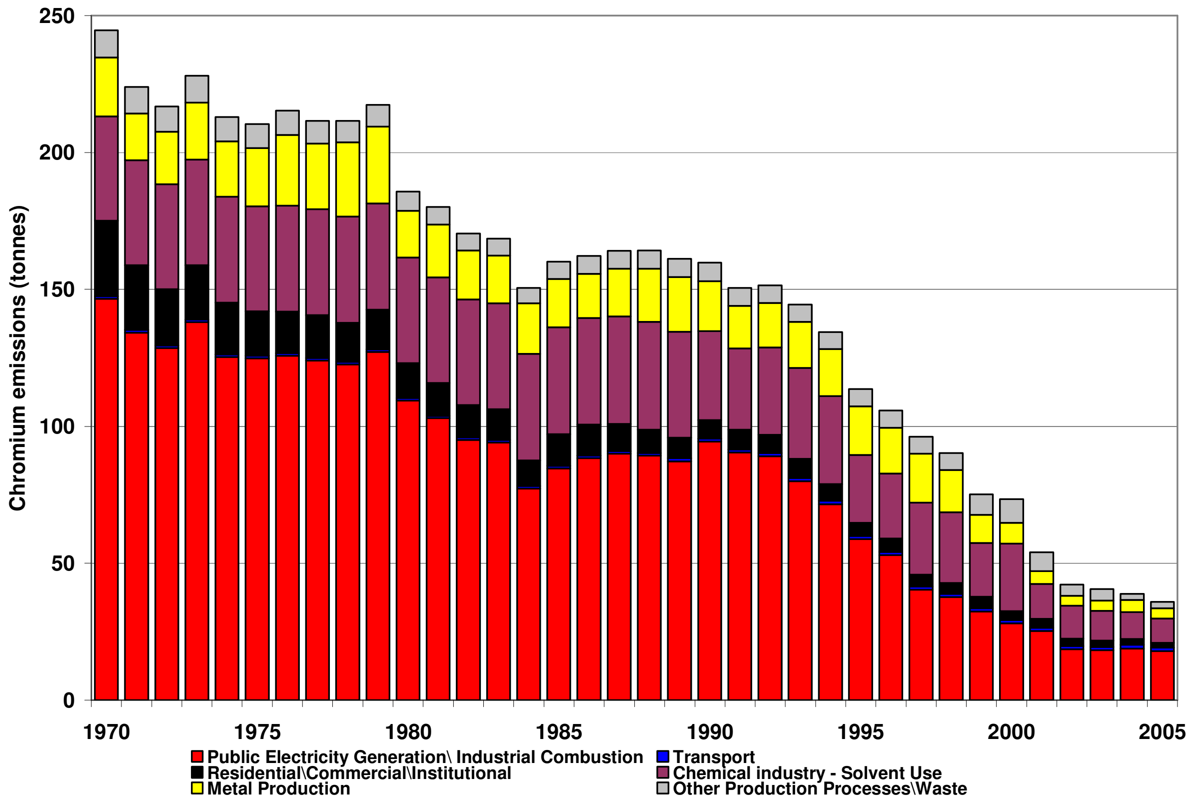
Table **3.4**a and Figure 3.3 summarise the UK emissions of chromium. Emissions have fallen by 85% since 1970. The largest sources are various forms of coal combustion, iron and steel production in integrated works and in electric arc furnaces and the production of chromium-based chemicals. More recently 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.

Table 3.4a UK Emissions of Chromium by aggregated UN/ECE Category and Fuel (tonnes)

	NFR Codes	1970	1980	1990	2000	2001	2002	2003	2004	2005	2005%
BY UN/ECE CATEGORY[1]											
Public Electricity and Heat Production	1A1a	50.5	57.6	53.2	13.7	11.1	4.9	4.3	4.3	4.6	13%
Industrial Combustion	1A1b-c	0.9	0.7	0.3	0.2	0.2	0.2	0.4	0.5	0.2	1%
Iron and Steel	1A2a	73.8	35.3	28.1	3.7	3.5	3.2	3.2	2.9	2.8	8%
Other Industrial Combustion: Treated wood	1A2f	21.3	15.9	12.8	10.5	10.5	10.2	10.3	11.3	10.2	28%
Transport	1A3b, 1A3aii(i), 1A3aii(ii), 1A3c, 1A3dii, 1A3eii, 1A4bii, 1A4cii, 1A5b	1.0	0.9	1.1	1.1	1.1	1.1	1.1	1.3	1.3	4%
Residential\Commercial / Institutional	1A4a-bi	27.4	12.7	6.8	3.4	3.3	2.7	2.4	2.2	1.8	5%
Gas Mains Leakage	2B5	9.9	7.0	6.8	8.6	7.0	4.1	4.2	2.3	2.3	6%
Metal Production	2C	38.2	38.6	32.4	24.6	12.7	12.0	10.9	9.9	8.8	25%
Other Production Processes\Waste	1B1b, 2A7	21.4	17.1	18.3	7.7	4.6	3.6	3.8	4.3	3.7	10%
By FUEL TYPE											
Solid		91.5	81.0	70.8	26.9	24.2	17.0	16.4	17.0	16.3	45%
Petroleum		17.3	9.1	4.8	2.9	2.9	2.1	2.2	2.3	2.1	6%
Gas		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Non-Fuel		135.8	95.6	84.2	43.6	27.0	23.2	22.0	19.5	17.5	49%
Total		**244.6**	**185.7**	**159.8**	**73.4**	**54.1**	**42.2**	**40.6**	**38.8**	**35.9**	**100%**

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

Figure 3.3 Time Series of Chromium Emissions (tonnes)



3.4.1 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 3.4bTable **3.4**Table **3.4**b Speciated Emissions of Chromium (tonnes)

	Cr^{6+}	Cr^{3+}	**Total (2005)**
BY aggregated UN/ECE CATEGORY[1]			
Combustion in Energy and Transformation Industry	0.6	4.1	4.7
Combustion in Manufacturing Industry	1.6	11.5	13.1
Combustion in Dom/Inst/Com	0.2	1.6	1.8
Production Processes	3.5	11.0	14.5
Road Transport	0.2	0.8	1.0
Off-road Vehicles and Other Machinery	0.1	0.2	0.3
Waste Incineration	0.0	0.3	0.3
TOTAL	**6.2**	**29.7**	**35.9**

[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).

3.5 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.

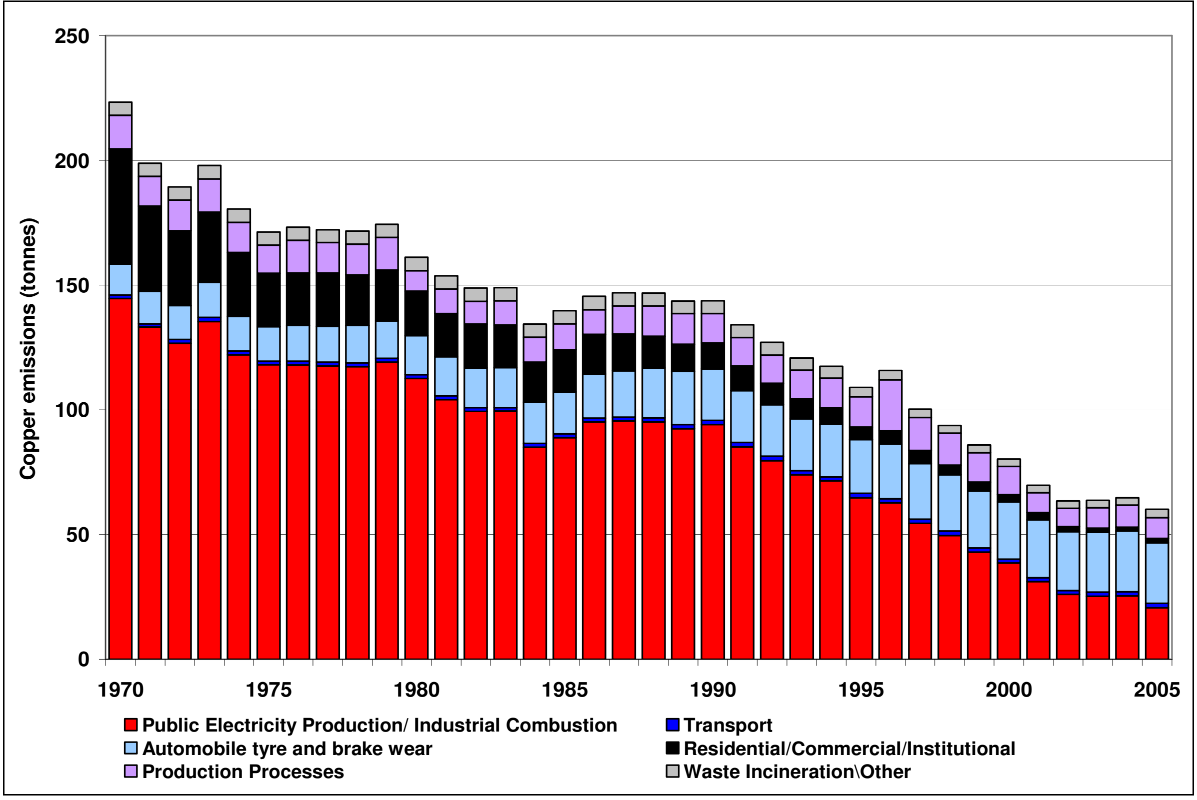
Table 3.5 and Figure 3.4 summarise the UK emissions of copper. Emissions have declined by 73% since 1970. The main sources are coal combustion, public power generation and road transport. Emissions have declined over the period due to the decline in coal combustion and to a lesser extent the combustion 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 3.5 UK Emissions of Copper by aggregated UN/ECE Category and Fuel (tonnes)

	NFR Codes	1970	1980	1990	2000	2001	2002	2003	2004	2005	2005%
BY UN/ECE CATEGORY[1]											
Public Electricity and Heat Production	1A1a	39.3	44.5	41.2	13.7	9.3	3.3	3.0	3.7	3.3	6%
Industrial Combustion	1A1b-c, 1A2b	52.6	36.6	26.7	7.2	4.7	6.8	6.0	5.3	2.7	5%
Iron and Steel	1A2a	25.5	12.8	12.1	6.6	6.4	5.6	5.7	5.2	4.7	8%
Other industrial combustion: Lubricants	1A2f	27.2	18.6	14.1	11.1	10.8	10.2	10.5	11.0	9.9	16%
Transport	1A3b, 1A3aii(i), 1A3aii(ii), 1A3c, 1A3dii, 1A3eii, 1A4bii, 1A4cii, 1A5b	1.5	1.5	1.8	1.6	1.5	1.5	1.6	1.7	1.8	3%
Automobile tyre and brake wear	1A3bvi	58.6	33.5	31.0	25.9	26.1	25.7	25.7	26.0	26.0	43%
Other Production Processes	1B1b, 2A7	3.2	3.1	4.0	5.0	2.7	2.6	2.6	3.3	3.0	5%
Metal Production	2C	10.3	5.2	7.8	6.2	5.3	4.7	5.6	5.5	5.4	9%
Waste Incineration\Other	6, 7	5.3	5.3	5.1	3.1	3.0	2.9	2.9	2.9	3.2	5%
By FUEL TYPE											
Non-Fuel		93.9	73.3	75.2	50.9	44.5	45.4	44.5	45.7	42.6	71%
Petroleum		28.6	17.7	11.2	8.0	8.2	7.4	9.1	7.9	7.4	12%
Solid		101.0	70.1	57.3	21.3	17.1	10.6	10.1	11.1	10.1	17%
Gas		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Total		**223.4**	**161.2**	**143.7**	**80.3**	**69.8**	**63.4**	**63.7**	**64.7**	**60.0**	**100%**

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

Figure 3.4 Time Series of Copper Emissions (tonnes)



3.6 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 3.6 and Figure 3.5 summarises the UK emissions of lead from 1970 to 2005. 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.

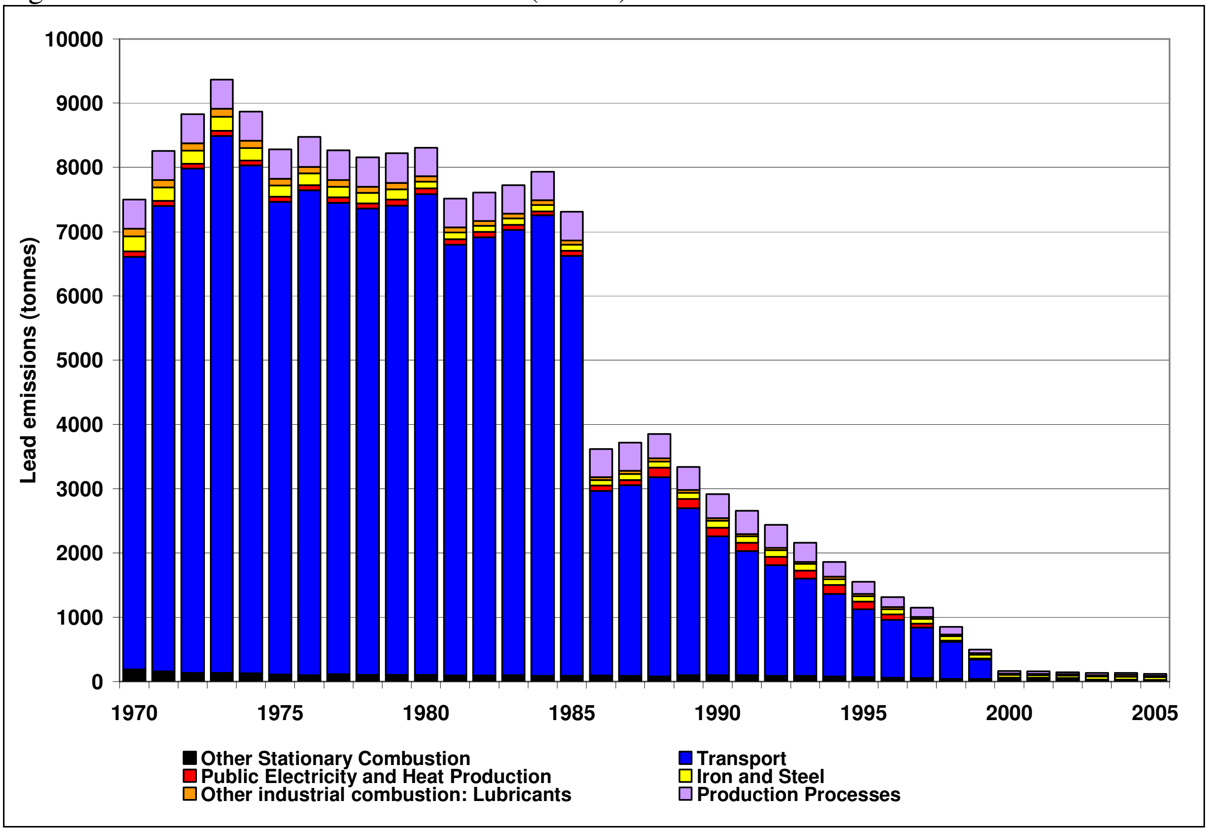
Table 3.6 UK Emissions of Lead by aggregated UN/ECE Category and Fuel (tonnes)

	NFR Codes	1970	1980	1990	2000	2001	2002	2003	2004	2005	2005%
BY UN/ECE CATEGORY[1]											
Public Electricity and Heat Production	1A1a	82	89	133	18	15	12	12	13	10	8%
Other Combustion in Industry	1A1b-c	78	53	49	25	27	30	10	9	6	5%
Iron and Steel	1A2a	235	105	110	48	43	38	44	43	43	37%
Other industrial combustion: Lubricants	1A2f	120	84	40	21	21	24	23	28	20	17%
Residential /Commercial / Institutional	1A4a, 1A4bi, 1A4ci	109	47	48	10	10	8	6	6	5	4%
Transport	1A3b, 1A3aii(i), 1A3aii(ii), 1A3c, 1A3eii, 1A4bii, 1A4cii, 1A5b	6421	7486	2163	3	3	3	3	3	3	3%
Other Production Processes	1B1b, 2A7	327	321	245	7	5	4	4	4	4	3%
Chemical industry	2B5	92	93	93	11	13	10	13	14	14	12%
Metal Production	2C	36	29	32	24	20	14	16	15	14	12%
By FUEL TYPE											
Solid[2]		528	448	415	34	30	25	23	24	19	16%
Petroleum		6527	7566	2199	20	20	19	20	21	19	16%
Gas		0	0	0	0	0	0	0	0	0	0%
Non-Fuel		446	292	298	111	106	99	87	89	79	68%
TOTAL		**7501**	**8306**	**2912**	**165**	**156**	**143**	**130**	**134**	**118**	**100%**

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

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

Figure 3.5 Time Series of Lead Emissions (tonnes)



3.7 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.

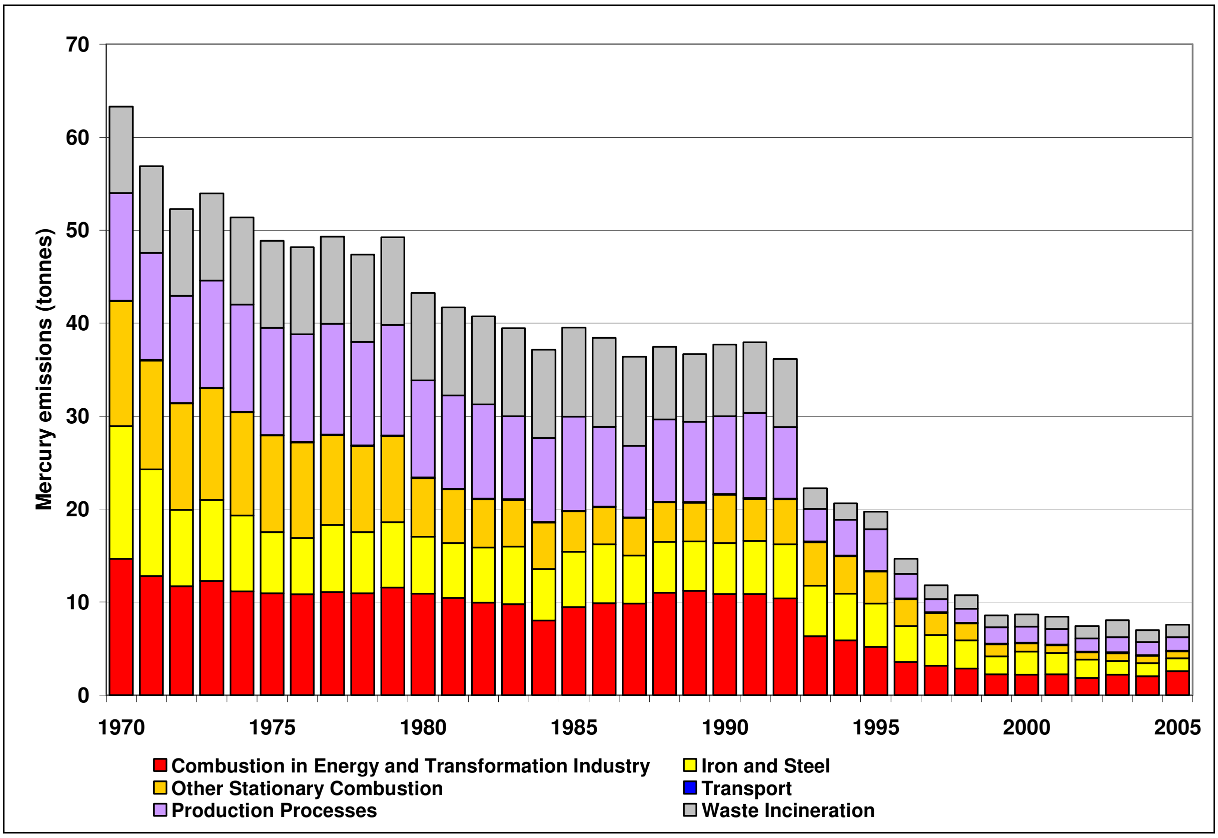
Table 3.7a and Figure 3.6 summarises the UK emissions of mercury. Emissions have declined by 88% since 1970. The main sources are waste incineration, the manufacture of chlorine in mercury cells, coal and other forms of industrial combustion. Emissions have declined as a result of improved controls on 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 3.7a UK Emissions of Mercury by aggregated UN/ECE Category and Fuel (tonnes)

	NFR Codes	1970	1980	1990	2000	2001	2002	2003	2004	2005	2005%
BY UN/ECE CATEGORY[1]											
Public Electricity and Heat Production	1A1a	7.7	8.1	8.9	1.7	1.7	1.5	1.9	1.8	2.3	31%
Stationary Combustion	1A1b-c, 1A2b, 1A4a, 1A4bi, 1A4ci	11.0	5.3	4.9	1.2	1.2	0.6	0.3	0.3	0.3	4%
Iron and Steel	1A2a	13.7	6.5	5.5	1.2	1.1	1.0	1.2	1.0	1.0	13%
Other Industrial Combustion	1A2f	10.3	3.6	2.6	1.7	1.6	1.7	1.5	1.4	1.3	18%
Transport	1A3b, 1A3aii(i), 1A3aii(ii), 1A3c, 1A3dii, 1A3eii, 1A4bii, 1A4cii, 1A5b	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1%
Other Production Processes	1B, 2A	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1%
Chemical industry	2B5	11.1	10.1	8.0	1.4	1.4	1.2	1.2	1.2	1.1	15%
Solid Waste Disposal on Land	6A	0.6	0.6	0.6	0.4	0.4	0.4	0.4	0.4	0.4	5%
Waste Incineration	6B	8.7	8.8	7.1	0.9	0.9	0.9	1.4	0.9	1.0	13%
By FUEL TYPE											
Solid		32.2	21.8	18.9	3.5	3.5	3.2	3.3	3.1	3.5	46%
Petroleum		1.7	1.0	0.8	0.3	0.2	0.2	0.2	0.2	0.4	5%
Gas		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Non-Fuel		29.4	20.4	18.0	4.9	4.7	3.9	4.5	3.7	3.7	49%
Total		**63.3**	**43.3**	**37.7**	**8.7**	**8.4**	**7.4**	**8.1**	**7.0**	**7.6**	**100%**

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

Figure 3.6 Time Series of Mercury Emissions (tonnes)



3.7.1 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.

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 3.7b Speciated Emissions of Mercury (tonnes)

	NFR Codes	Hg^0	Hg-p	RGM [1]	Total (2005)
BY aggregated UN/ECE CATEGORY[2]					
Combustion in Energy and Transformation Industry	1A1	1.1	0.2	1.0	2.4
Combustion in Manufacturing Industry	1A2, 1A4ci	1.4	0.2	0.6	2.1
Combustion in Dom/Inst/Com	1A4a, 1A4bi	0.1	0.0	0.1	0.2
Production Processes	1B1b, 2	1.0	0.0	0.4	1.4
Road Transport	1A3b	0.0	0.0	0.0	0.0
Off-road Vehicles and Other Machinery	1A3aii(i)-1A3aii(ii), 1A3c-1A3eii, 1A4bii, 1A4cii, 1A5b	0.0	0.0	0.0	0.1
Waste Incineration	6	0.4	0.0	0.9	1.3
TOTAL		**4.0**	**0.5**	**3.1**	**7.6**

[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.

3.8 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.

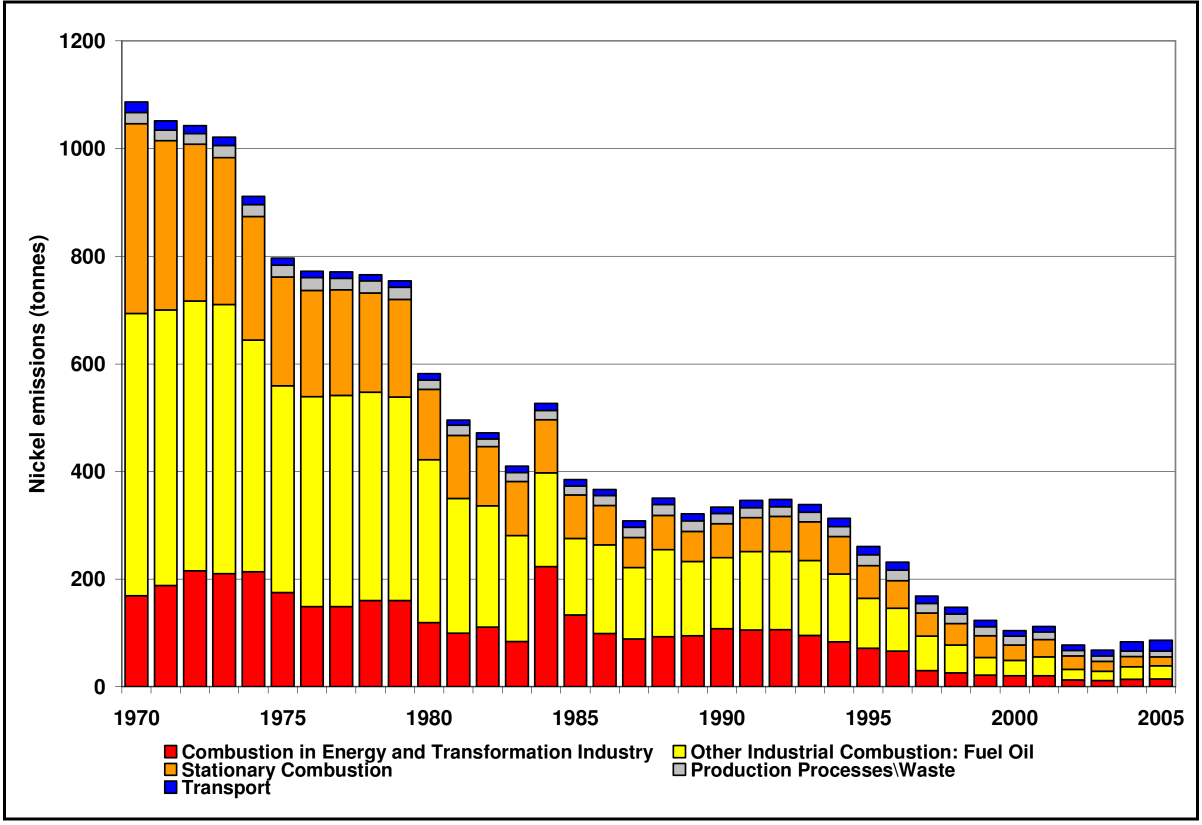
Table 3.8a and Figure 3.7 summarise the UK emissions of nickel. Emissions have declined by 92% since 1970. Currently the main sources of nickel emissions is the combustion of heavy fuel oil, however in the past coal combustion was a major source. Emissions from both sources have declined in use since 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 3.8a UK Emissions of Nickel by aggregated UN/ECE Category and Fuel (tonnes)

	NFR Codes	1970	1980	1990	2000	2001	2002	2003	2004	2005	2005%
BY UN/ECE CATEGORY[1]											
Public Electricity and Heat Production	1A1a	144	96	96	12	11	4	4	5	5	6%
Petroleum refining	1A1b	23	22	12	8	10	8	8	10	9	11%
Other Stationary Combustion	1A1c, 1A2b	3	2	1	0	0	0	0	0	0	0%
Iron and Steel	1A2a	172	47	14	10	11	9	5	6	4	5%
Other Industrial Combustion: Fuel Oil	1A2f	524	303	132	29	35	20	17	23	24	28%
Transport	1A3b, 1A3aii(i), 1A3aii(ii), 1A3c, 1A3eii, 1A4bii, 1A4cii, 1A5b	2	2	3	3	3	4	4	4	4	4%
National Navigation	1A3dii	17	9	9	7	6	6	7	14	17	19%
Residential /Commercial / Institutional	1A4a, 1A4bi, 1A4ci	180	83	48	17	20	15	13	12	13	15%
Production Processes\Waste	1B1b, 2, 6	21	17	19	17	14	10	10	10	10	12%
By FUEL TYPE											
Solid		64	49	50	15	13	10	9	12	12	14%
Petroleum		977	501	254	70	83	55	47	60	63	73%
Gas		0	0	0	0	0	0	0	0	0	0%
Non-Fuel		46	31	30	18	16	12	12	12	12	14%
TOTAL		**1087**	**581**	**334**	**104**	**112**	**77**	**68**	**84**	**87**	**100%**

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

Figure 3.7 Time Series of Nickel Emissions (tonnes)



3.8.1 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 3.8b

Table 3.8b Speciated Emissions of Nickel 2005 (tonnes)

	NFR Code	MN	ON	SolN	NC	SU	Total (2005)
BY aggregated UN/ECE CATEGORY							
Combustion in Energy and Transformation Industry	1A1	0.0	5.6	8.3	0.1	0.4	14.4
Combustion in Manufacturing Industry	1A2, 1A4ci	0.6	11.5	15.8	0.1	0.8	28.8
Combustion in Dom/Inst/Com	1A4a, 1A4bi	0.0	4.9	7.2	0.1	0.4	12.5
Production Processes	1B1b, 2	2.6	6.5	0.2	0.0	0.0	9.3
Road Transport	1A3b	0.7	0.5	0.8	0.0	0.0	2.0
Off-road Vehicles and Other Machinery	1A3aii(i)-1A3aii(ii), 1A3c-1A3eii, 1A4bii, 1A4cii, 1A5b	0.0	7.2	10.6	0.1	0.6	18.4
Waste Incineration	6	0.0	0.4	0.7	0.0	0.0	1.1
TOTAL		**3.8**	**36.6**	**43.5**	**0.4**	**2.3**	**86.6**

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.

3.9 SELENIUM

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

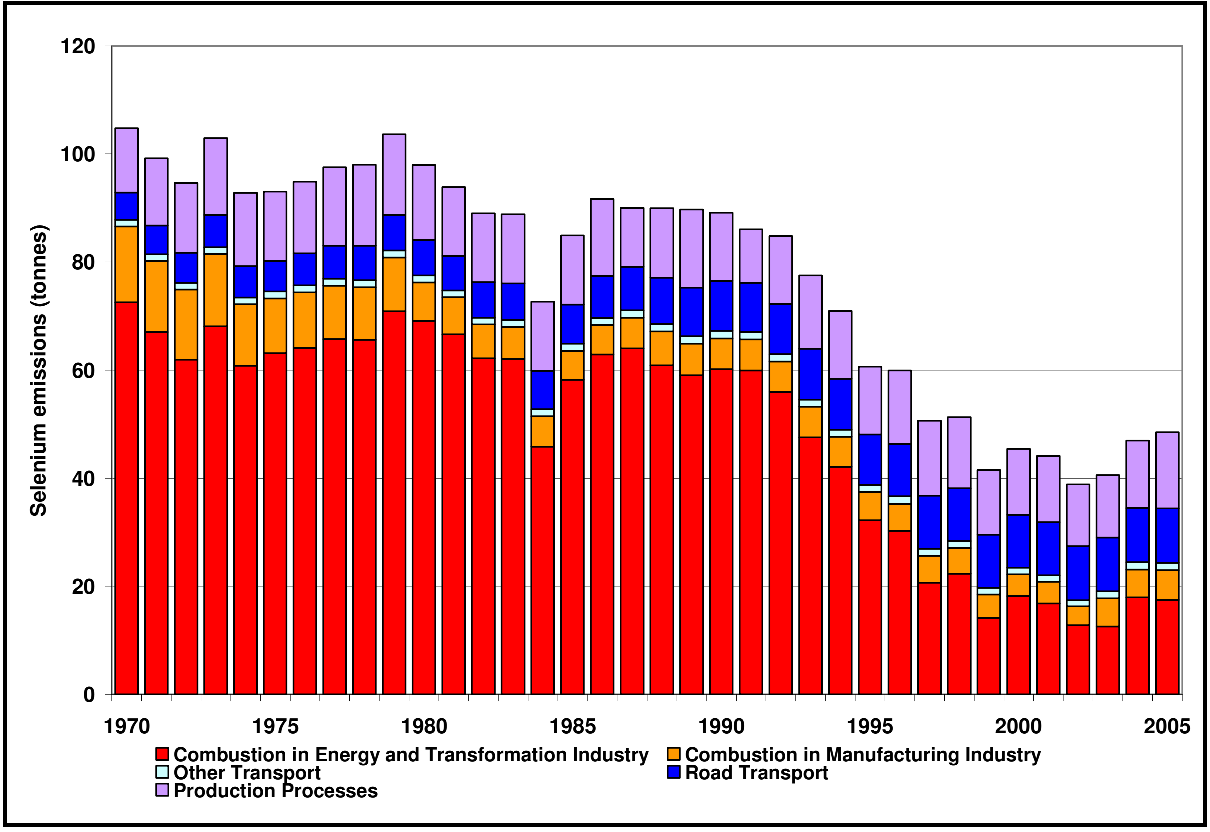
Table 3.9 and Figure 3.8 summarise the UK emissions of selenium. Emissions have declined by 54% since 1970. The main source of selenium emissions in earlier years was coal combustion. Only trace amounts are emitted by the combustion of petroleum based fuels. Glass production has previously been considered 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 3.9 UK Emissions of Selenium by aggregated UN/ECE Category and Fuel (tonnes)

	NFR Codes	1970	1980	1990	2000	2001	2002	2003	2004	2005	2005%
BY UN/ECE CATEGORY[1]											
Public Electricity and Heat Production	1A1a	53.0	59.9	55.3	15.6	14.2	10.8	10.8	16.1	15.8	33%
Other Stationary Combustion	1A1b-c\1A4a\1A2b-f\1A4a-bi\1A4ci	28.0	14.5	8.0	4.5	4.8	3.8	5.1	5.1	5.2	11%
Iron and Steel	1A2a	5.5	1.8	2.5	2.1	1.9	1.7	1.9	1.9	1.9	4%
Passenger cars	1A3bi	3.4	4.6	6.0	6.1	6.1	6.2	6.0	6.0	5.9	12%
Heavy duty vehicles	1A3bii	1.2	1.4	2.2	2.5	2.5	2.5	2.6	2.6	2.7	6%
Other Transport	1A3bii&iv\1A3aii(i)\1A3aii(ii)\1A3c-eii\1A4bii\1A4cii\1A5b	1.7	1.9	2.5	2.4	2.4	2.4	2.6	2.7	2.8	6%
Production of Glass	2A7	11.6	13.7	12.4	11.9	12.0	11.2	11.3	12.2	13.8	29%
Other Production Processes	1A5b\2B5\2C	0.3	0.1	0.2	0.3	0.3	0.3	0.3	0.2	0.3	1%
By FUEL TYPE											
Solid		66.4	65.3	57.8	14.1	13.8	10.5	11.7	16.4	16.7	34%
Petroleum		22.4	17.1	16.0	17.0	16.1	15.1	15.3	16.1	15.6	32%
Gas		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Non-Fuel		16.0	15.5	15.3	14.3	14.3	13.2	13.6	14.5	16.2	33%
Total		**104.8**	**98.0**	**89.1**	**45.4**	**44.1**	**38.8**	**40.6**	**47.0**	**48.5**	**100%**

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

Figure 3.8 Time Series of Selenium Emissions (tonnes)



3.10 VANADIUM

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

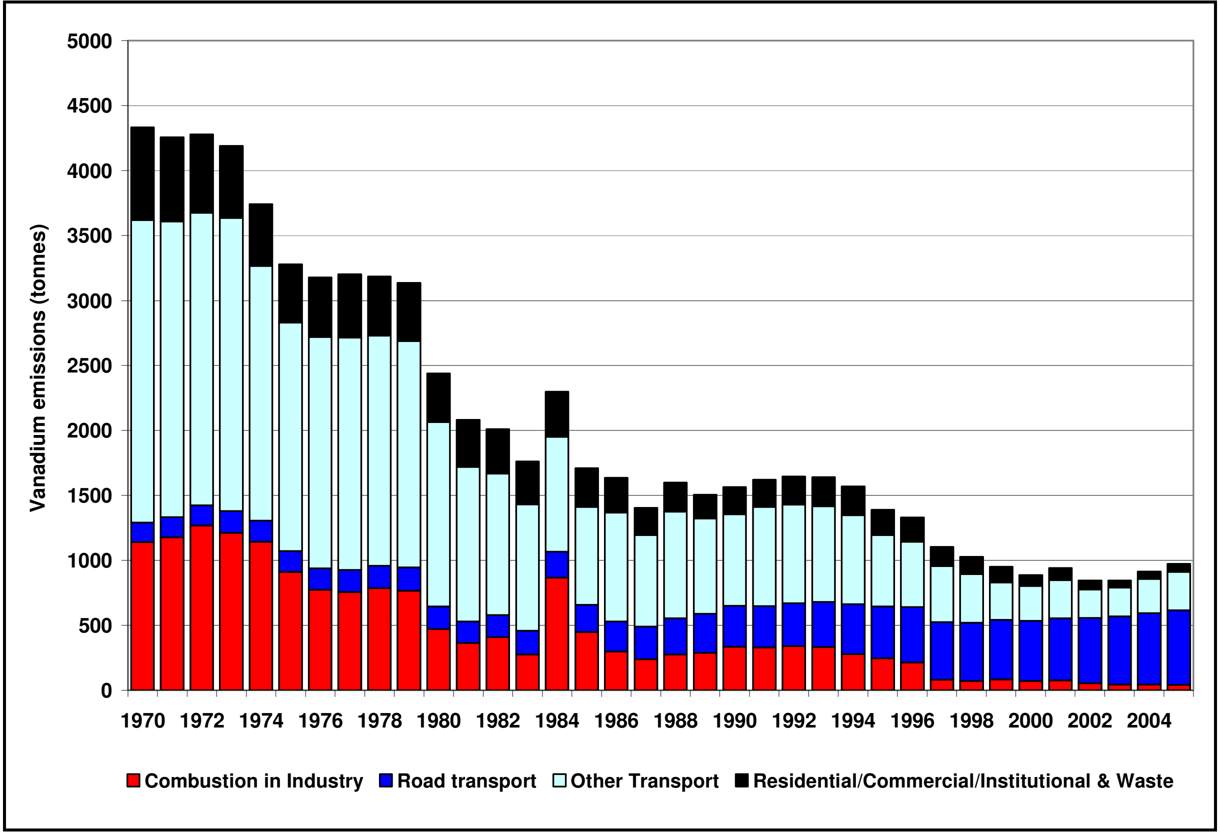
Table 3.10 and Figure 3.9 summarise the UK emissions of vanadium. Emission data are rather scarce so the estimates are very uncertain. Estimates of emissions have declined by 78% since 1970. The major source of emissions are the road transport sector accounting for 59% and the combustion of fuel oils with liquid fuels accounting for some 20% of the estimated emission in 2005. The total contribution from petroleum based fuels is 97% 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 (1A1). 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 3.10 UK Emissions of Vanadium by aggregated UN/ECE Category and Fuel (tonnes)

	NFR Codes	**1970**	**1980**	**1990**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2005 %**
BY UN/ECE CATEGORY[1]											
Combustion in Industry	1A1, 1A2a-b	1141	472	335	72	77	54	44	45	41	4%
Industrial off-road mobile machinery	1A2f	2194	1308	588	166	199	130	116	135	155	16%
Passenger cars	1A3bi	4	6	20	87	91	101	109	120	130	13%
Light duty vehicles	1A3bii	9	13	46	102	110	117	127	134	145	15%
Heavy duty vehicles	1A3biii	136	154	250	275	275	284	290	295	302	31%
Other Transport	1A3c-eii, 1A4bii, 1A4cii, 1A5b	136	111	117	101	95	91	104	127	140	14%
Residential/Commercial/Institutional	1A4a, bii, ci	706	371	202	77	89	65	52	53	59	6%
Production processes	2	9	4	7	5	5	4	5	5	5	0%
By FUEL TYPE											
Solid		50	44	70	28	22	23	20	26	29	3%
Petroleum		4272	2388	1485	851	913	818	821	883	941	97%
Gas		0	0	0	0	0	0	0	0	0	0%
Non-Fuel		12	7	9	7	6	5	5	5	5	0%
TOTAL		**4335**	**2439**	**1565**	**885**	**941**	**846**	**846**	**914**	**975**	**100%**

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

Figure 3.9 Time series of Vanadium Emissions (tonnes)



3.11 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 3.11 and Figure 3.10 summarise the UK emissions of zinc. Emissions of zinc have declined by 70% 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.

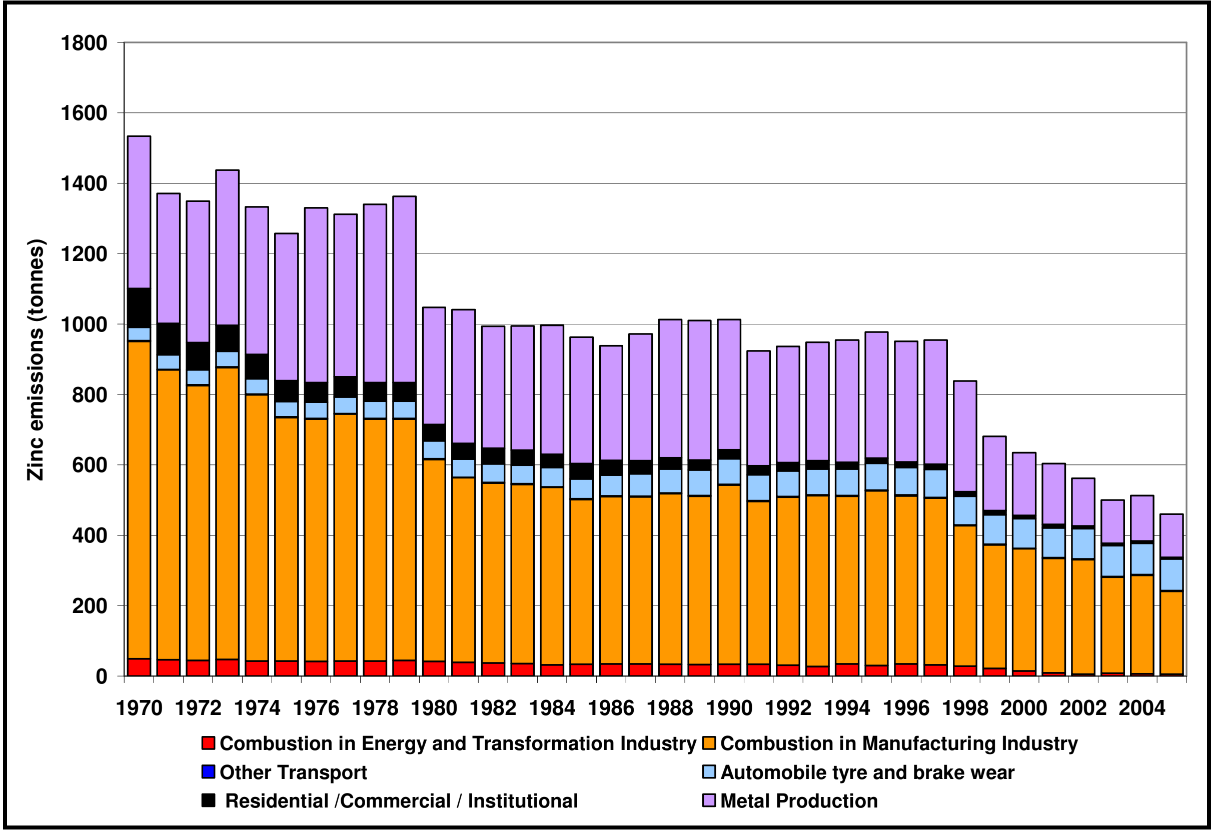
Table 3.11 UK Emissions of Zinc by aggregated UN/ECE Category and Fuel (tonnes)

	NFR Codes	1970	1980	1990	2000	2001	2002	2003	2004	2005	2005%
BY UN/ECE CATEGORY[1]											
Combustion in Energy and Transformation Industry	1A1	49	42	34	15	9	5	9	7	6	1%
Combustion in Manufacturing Industry	1A2	902	573	509	347	326	326	273	280	235	51%
Residential /Commercial / Institutional	1A4a, 1A4bi, 1A4ci	110	47	25	10	10	7	6	6	5	1%
Other Transport	1A3aii(i), 1A3aii(ii), 1A3c-eii, 1A4bii, 1A4cii, 1A5b	1	1	1	1	1	1	1	1	1	0%
Road Transport	1A3bi-iv	0	1	1	1	1	1	1	1	1	0%
Automobile tyre and brake wear	1A3bvi	39	51	73	84	85	87	88	89	89	19%
Metal Production	2C	381	283	338	160	161	124	116	122	114	25%
Other Production Processes	1B1-2B5, 6	52	50	32	18	12	11	8	8	9	2%
By FUEL TYPE											
Solid		194	97	68	31	25	18	21	17	15	3%
Petroleum		341	252	226	210	223	220	230	244	201	44%
Gas		0	0	0	0	0	0	0	0	0	0%
Non-Fuel		1000	698	719	393	356	325	249	252	245	53%
TOTAL		**1534**	**1047**	**1013**	**635**	**604**	**562**	**501**	**513**	**461**	**100%**

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

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

Figure 3.10 Times Series of Zinc Emissions (tonnes)



3.12 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 3.12 summarises the UK emissions of beryllium. Estimates have only been included since the 2000 NAEI report; as a result of the figures being 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 3.12 UK Emissions of Beryllium by aggregated UN/ECE Category and Fuel (tonnes)

	NFR Codes	2000	2001	2002	2003	2004	2005	2005%
BY UN/ECE CATEGORY[1]								
Combustion in Energy and Transformation Industry	1A1	1.2	1.2	1.3	1.2	1.1	1.2	13%
Combustion in Manufacturing Industry	1A2	1.1	1.2	1.0	0.9	1.0	1.0	11%
Passenger cars	1A3bi	0.7	0.7	0.8	0.9	1.0	1.0	11%
Light duty vehicles	1A3bii	0.8	0.9	0.9	1.0	1.1	1.2	13%
Heavy duty vehicles	1A3biii	2.2	2.2	2.3	2.3	2.4	2.4	27%
Other Transport	1A3c-eii, 1A4bii, 1A4cii, 1A5b	0.8	0.7	0.7	0.8	0.8	0.9	10%
Residential/Commercial/Institutional	1A4a, bii, ci	3.0	3.0	2.1	1.7	1.6	1.2	13%
Production Processes\Waste	1B1b, 2, 6	0.2	0.2	0.2	0.2	0.2	0.2	2%
By FUEL TYPE								
Solid		3.7	3.5	2.6	2.2	2.1	1.8	19%
Petroleum		6.3	6.7	6.6	6.7	6.9	7.2	80%
Gas		0.0	0.0	0.0	0.0	0.0	0.0	0%
Non-Fuel		0.0	0.1	0.0	0.1	0.1	0.1	1%
TOTAL		**10**	**10.2**	**9.2**	**9.0**	**9.1**	**9.1**	**100%**

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

3.13 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 3.13 summarises the UK emissions of manganese. Estimates have only been included since the 2000 NAEI report as 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 3.13 UK Emissions of Manganese by aggregated UN/ECE Category and Fuel (tonnes)

	NFR Codes	2000	2001	2002	2003	2004	2005	2005%
BY UN/ECE CATEGORY[1]								
Public Electricity and Heat Production	1A1a	20.7	16.0	5.6	5.4	5.6	5.7	18%
Industrial combustion: Wood	1A2f	9.4	8.3	8.2	8.4	8.4	4.2	14%
Other Combustion	1A1b, c-1A2a, b	4.0	3.7	4.5	4.1	3.5	2.9	9%
Road Transport	1A3b	1.8	1.9	2.0	2.1	2.2	2.3	7%
Residential/Commercial/Institutional	1A4a, bii, ci	2.6	2.8	2.1	1.8	1.7	1.3	4%
Metal Production	2C	25.7	18.7	13.3	13.9	13.4	12.3	40%
Solid fuel transformation	1B1b	3.1	2.7	2.2	2.1	2.0	2.0	7%
Other	1A4bii, 6C	0.2	0.2	0.2	0.2	0.2	0.2	1%
By FUEL TYPE								
Solid		33.9	28.2	16.7	16.4	16.5	12.3	40%
Petroleum		2.8	2.9	2.9	2.9	3.1	3.1	10%
Gas		0.0	0.0	0.0	0.0	0.0	0.0	0%
Non-Fuel		30.9	23.0	18.5	18.7	17.5	15.6	50%
TOTAL		**67.6**	**54.2**	**38.1**	**38.0**	**37.0**	**30.9**	**100%**

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

3.14 TIN

Inhalation of dust and fumes may cause a disease of the lungs called stannosis. Table 3.14 summarises the UK emissions of tin. Estimates have only been included since the 2000 NAEI report and 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 3.14 UK Emissions of Tin by aggregated UN/ECE Category and Fuel (tonnes)

	NFR Codes	2000	2001	2002	2003	2004	2005	2005%
BY UN/ECE CATEGORY[1]								
Public Electricity and Heat Production	1A1a	2.9	3.2	3.0	3.3	3.2	3.3	52%
Other Combustion	1A1b, c-1A2a, b	1.7	1.6	0.7	0.6	0.5	0.5	8%
Industrial Combustion: Lubricants	1A2f	0.8	0.9	0.8	0.8	0.8	0.7	12%
Road Transport	1A3b	0.7	0.7	0.7	0.8	0.8	0.8	13%
Other Transport	1A3c-eii, 1A4bii, 1A4cii, 1A5b	0.1	0.1	0.1	0.1	0.2	0.2	3%
Residential/Commercial/Institutional	1A4a, bii, ci	1.1	1.0	0.8	0.7	0.7	0.7	11%
Other	2C, 6C	0.1	0.1	0.1	0.1	0.1	0.1	1%
By FUEL TYPE								
Solid		4.3	4.5	4.1	4.4	4.2	4.2	67%
Petroleum		1.8	1.9	1.8	1.9	1.9	1.9	30%
Gas		0.0	0.0	0.0	0.0	0.0	0.0	0%
Non-Fuel		1.3	1.3	0.2	0.2	0.1	0.1	2%
TOTAL		**7.4**	**7.7**	**6.2**	**6.4**	**6.3**	**6.3**	**100%**

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

3.15 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 3.20 to 3.29. 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 point sources are also evident.

Cadmium

The major source in 2005 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 2005 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 3.11 UK Emissions Map of Arsenic 2005

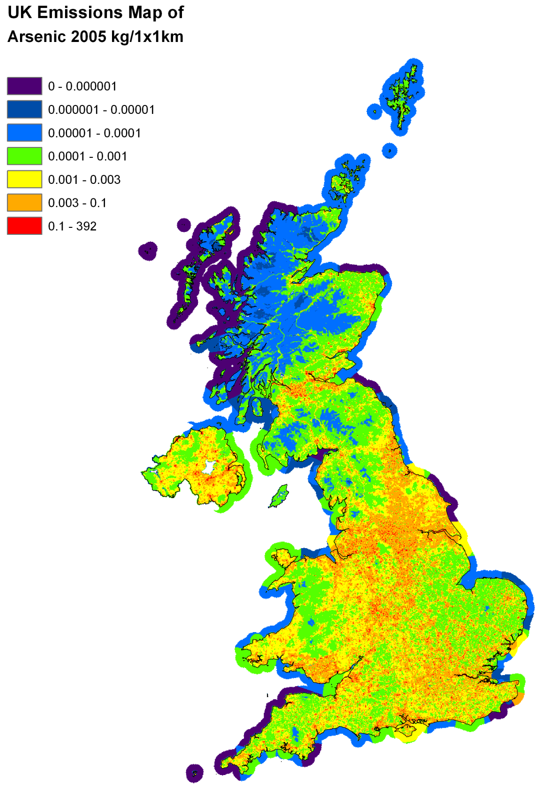


Figure 3.12 UK Emissions Map of Cadmium 2005

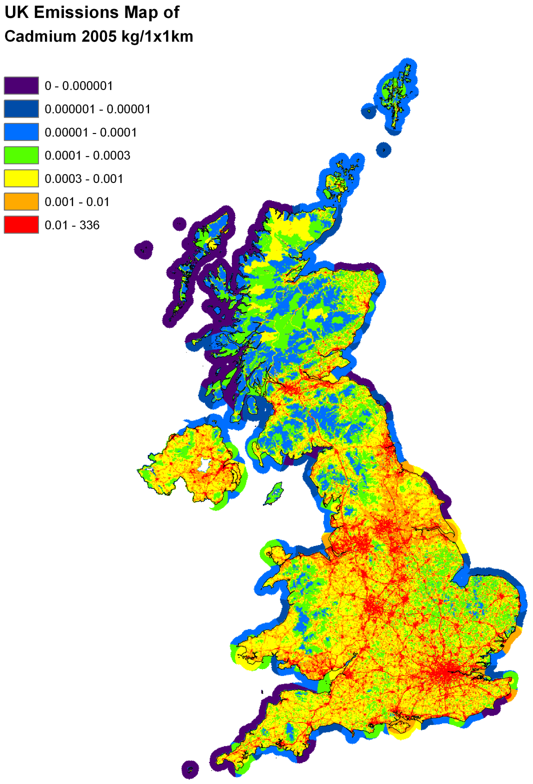


Figure 3.13 UK Emissions Map of Chromium 2005

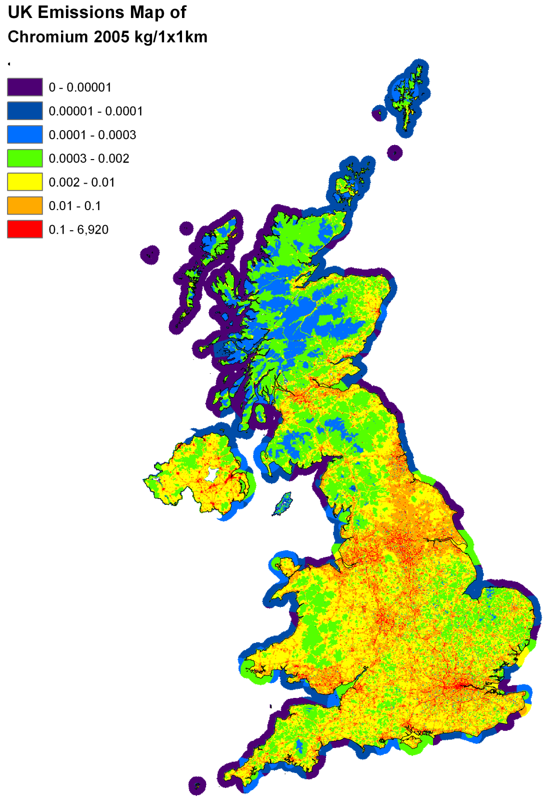


Figure 3.14 UK Emissions Map of Copper 2005

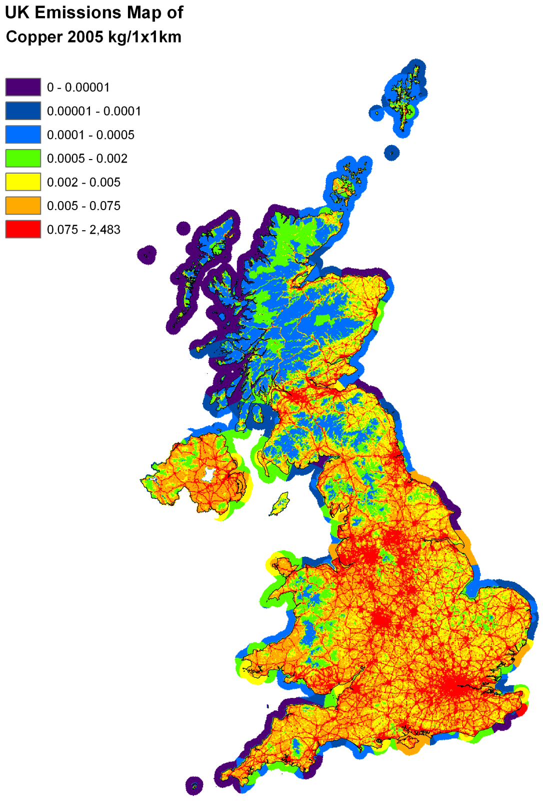


Figure 3.15 UK Emissions Map of Lead 2005

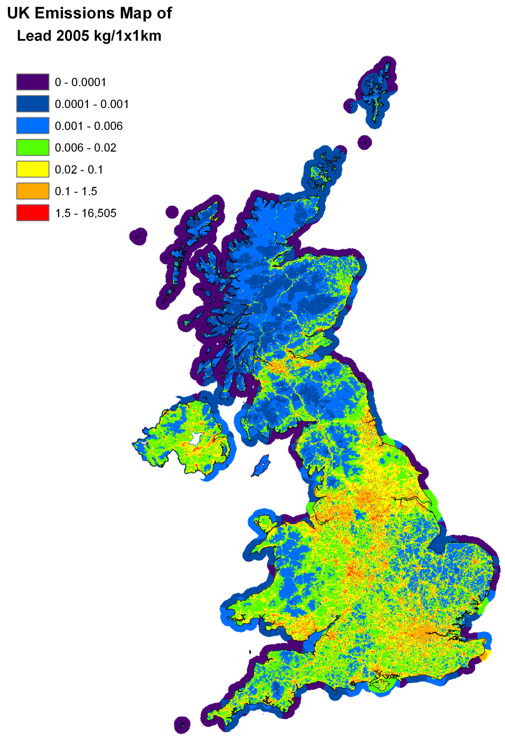


Figure 3.16 UK Emissions Map of Mercury 2005

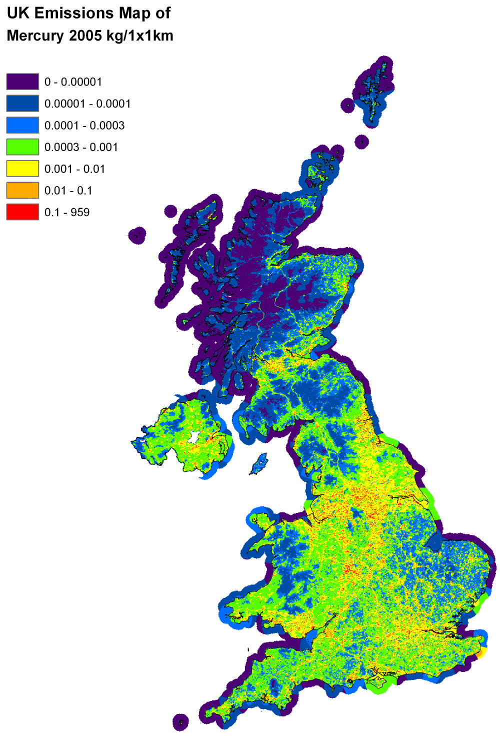


Figure 3.17 UK Emissions Map of Nickel 2005

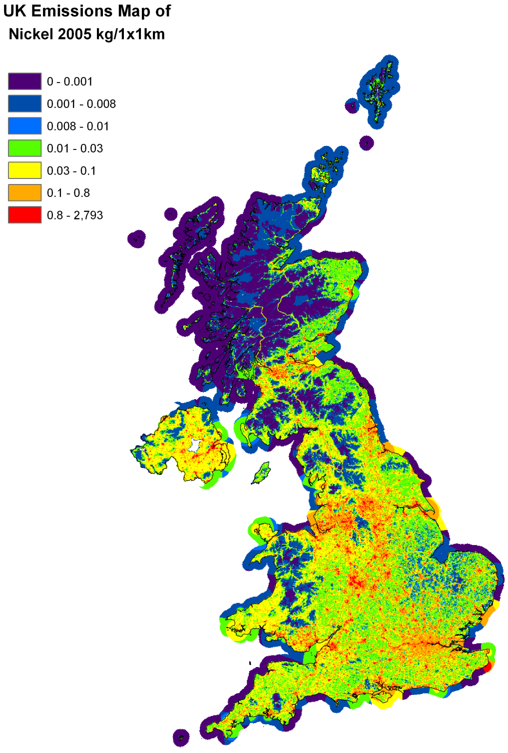


Figure 3.18 UK Emissions Map of Selenium 2005

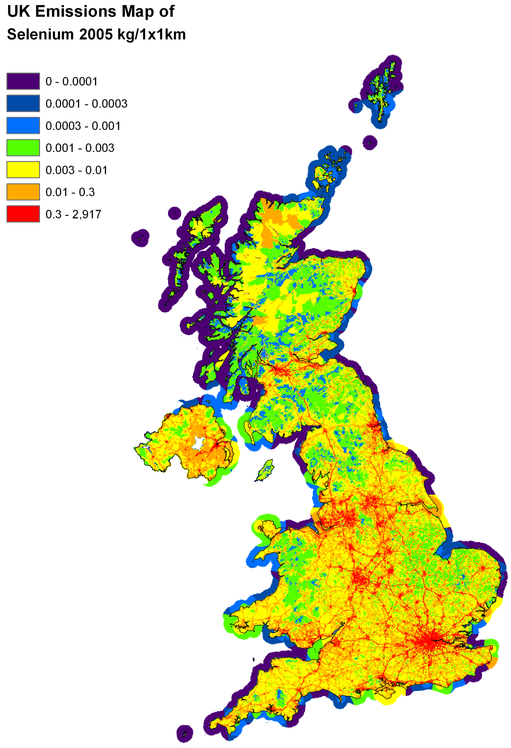


Figure 3.19 UK Emissions Map of Vanadium 2005

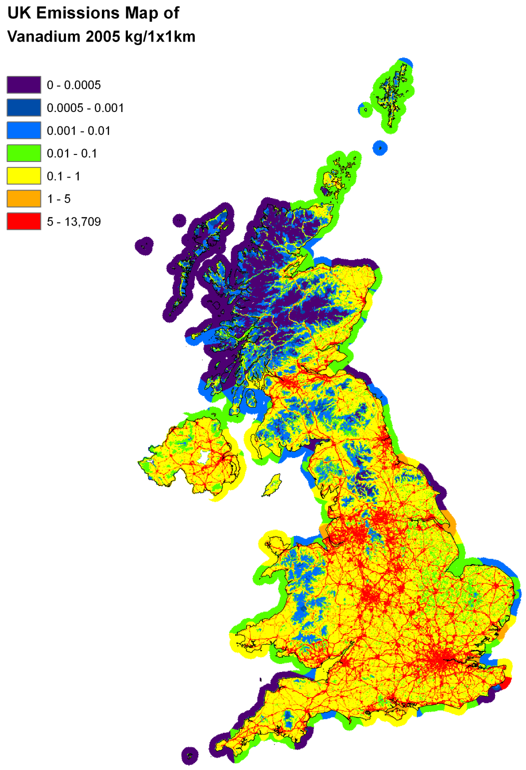
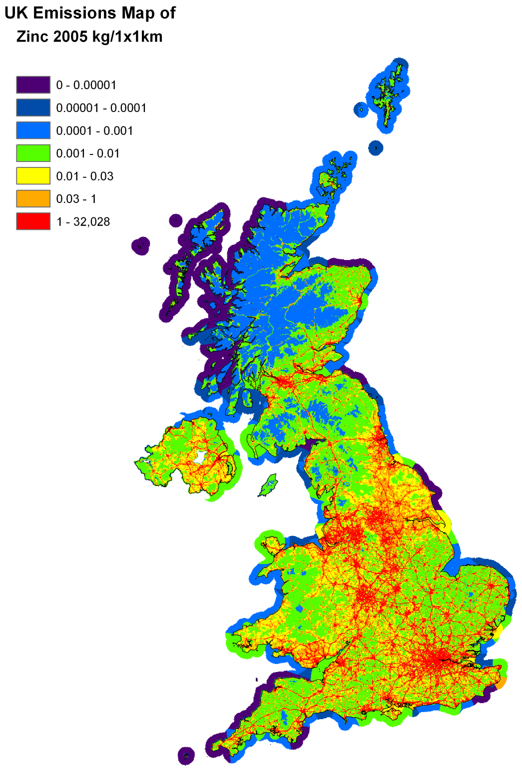


Figure 3.20 UK Emissions Map of Zinc 2005



3.16 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 3.15.

Table 3.15 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 more 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. The inventories for arsenic, selenium and vanadium seem to be more 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).

4 Base Cations

4.1 INTRODUCTION

Base cation emission estimates for the UK are presented in this chapter. The emission estimates cover the period 1990-2005 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 understand 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.

4.2 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.

4.3 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) using figures for fly ash from bituminous coal. Data regarding the composition of fuel oil is given in the Marine Exhaust Research Programme.

4.4 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 (2006).

4.5 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 AEA estimates of PM_{10} composition.

4.6 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 AEA estimates of PM_{10} composition.

4.7 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 1990-2006) 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).

4.8 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 1990-2006) that is limestone, dolomite or chalk, is used to estimate the base cation emissions.

4.9 MOBILE SOURCES

Emissions of base cations from mobile sources will mainly arise from the resuspension of road dust by traffic. Nicholson (2000) 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 2005 given by the Digest of United Kingdom Energy Statistics (DTI, 2004).

4.10 CALCIUM

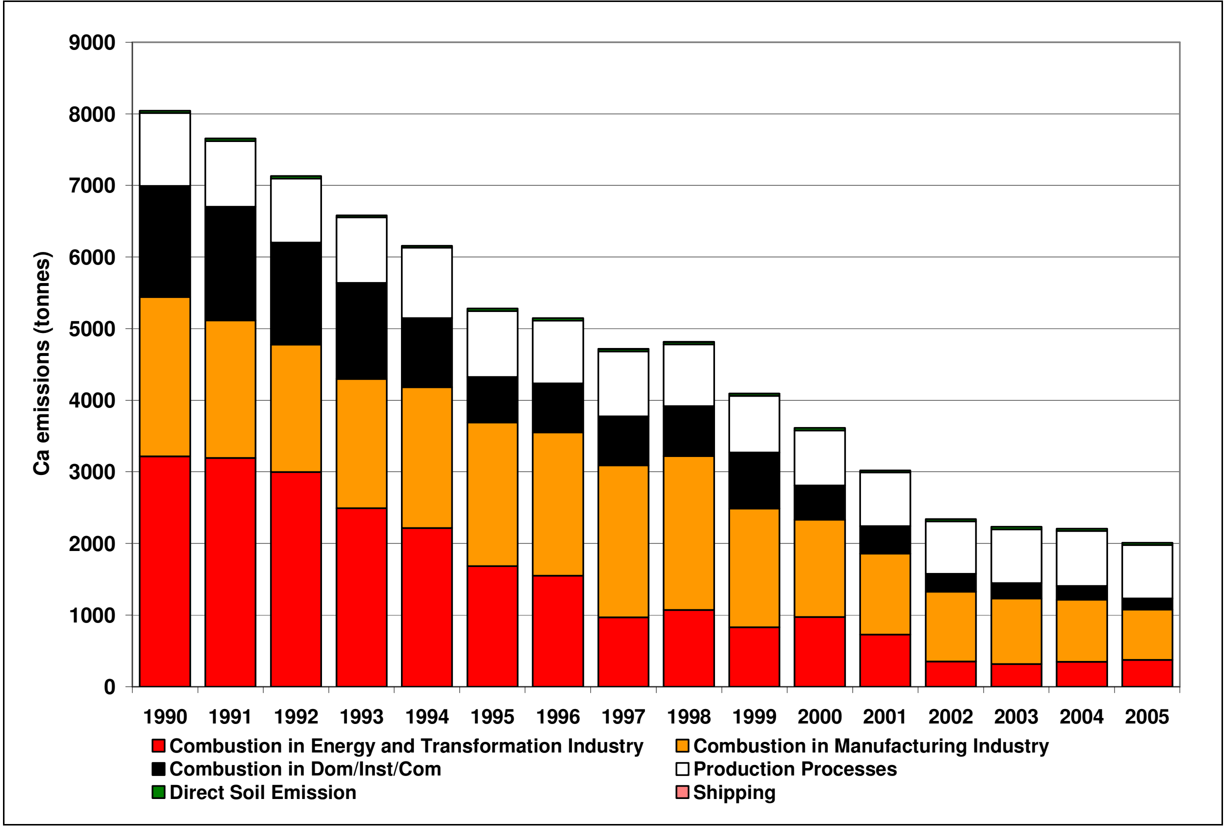
Combustion in industry and production processes contribute the most emissions of calcium. Within the latter sector quarrying, cement production and lime production are the most significant contributors. However, more recently the introduction of abatement measures has ensured reductions in the emissions.

Table 4.1 UK Emissions of Calcium by aggregated UN/ECE Source Category (ktonnes)

	NFR Codes	1990	2000	2001	2002	2003	2004	2005	2005%
BY UN/ECE CATEGORY[1]									
Combustion in Energy and Transformation Industry	1A1	3.2	1.0	0.7	0.4	0.3	0.3	0.4	19%
Combustion in Manufacturing Industry	1A2	2.2	1.4	1.1	1.0	0.9	0.9	0.7	35%
Shipping	1A3dii	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Combustion in Dom/Inst/Com	1A4	1.5	0.5	0.4	0.2	0.2	0.2	0.2	8%
Other Production Industry	2A1, 2C	0.3	0.3	0.2	0.2	0.2	0.2	0.2	11%
Glass Production	2A7	0.7	0.5	0.5	0.5	0.5	0.6	0.5	26%
Direct Soil Emission	4D1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2%
TOTAL		**8.0**	**3.6**	**3.0**	**2.3**	**2.2**	**2.2**	**2.0**	100%

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

Figure 4.1 Time Series of Calcium Emissions (tonnes)



4.11 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 is also a significant source. Domestic coal burning was responsible for 44 tonnes, and coal burning power stations released 119 tonnes in 2005.

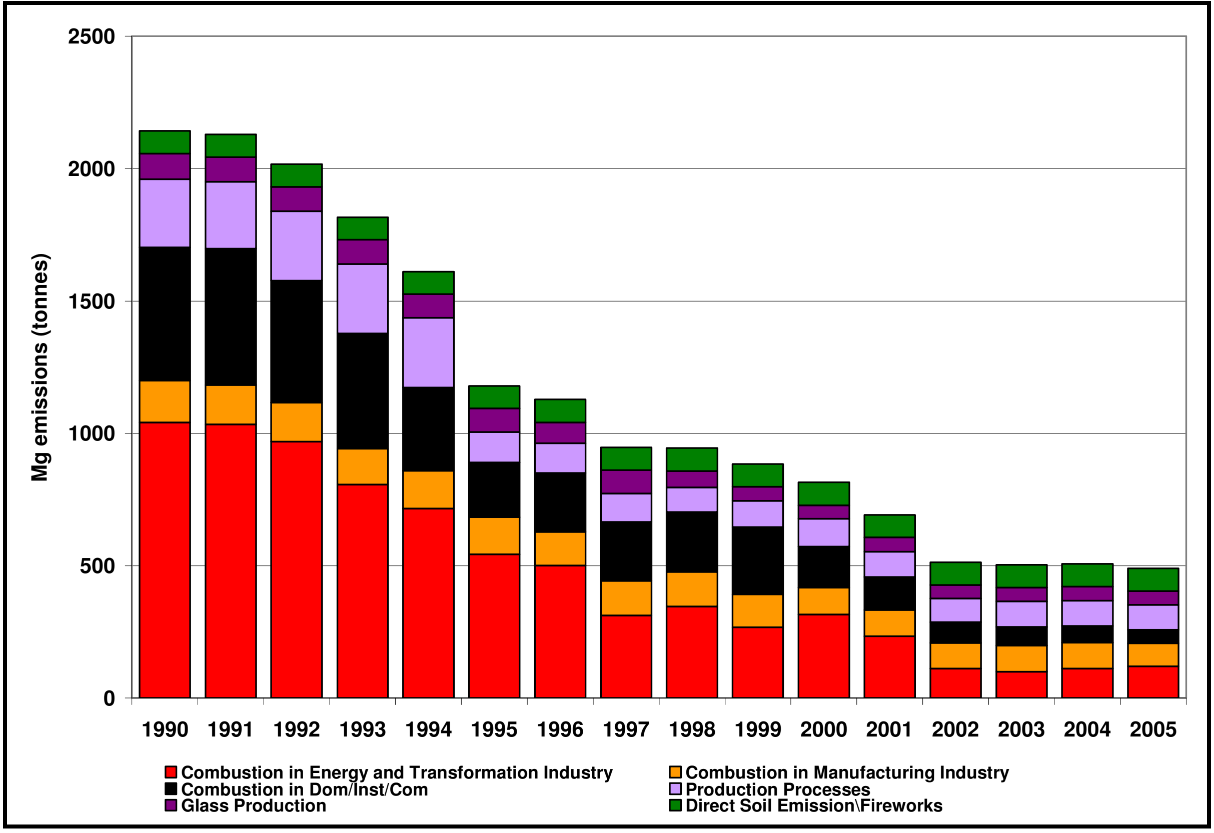
Estimates of emissions of magnesium from coal combustion at Alcan's Ashington power station have been revised downwards in the 2005 inventory. Estimates for slag cement grinding, fireworks and burning of waste lubricants have all been included in the emission estimates.

Table 4.2 UK Emissions of Magnesium by aggregated UN/ECE Source Category (ktonnes)

	NFR Codes	1990	2000	2001	2002	2003	2004	2005	2005%
BY UN/ECE CATEGORY[1]									
Combustion in Energy and Transformation Industry	1A1	1.0	0.3	0.2	0.1	0.1	0.1	0.1	24%
Combustion in Manufacturing Industry	1A2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	18%
Combustion in Dom/Inst/Com	1A4	0.5	0.2	0.1	0.1	0.1	0.1	0.1	10%
Production Processes	2A1, 2C	0.3	0.1	0.1	0.1	0.1	0.1	0.1	19%
Glass Production	2A7	0.1	0.1	0.1	0.1	0.1	0.1	0.1	11%
Direct Soil Emission	4D1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2%
Fireworks	7	0.1	0.1	0.1	0.1	0.1	0.1	0.1	15%
TOTAL		**2.1**	**0.8**	**0.7**	**0.5**	**0.5**	**0.5**	**0.5**	**100%**

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

Figure 4.2 Time Series of Magnesium Emissions (tonnes)



4.12 SODIUM

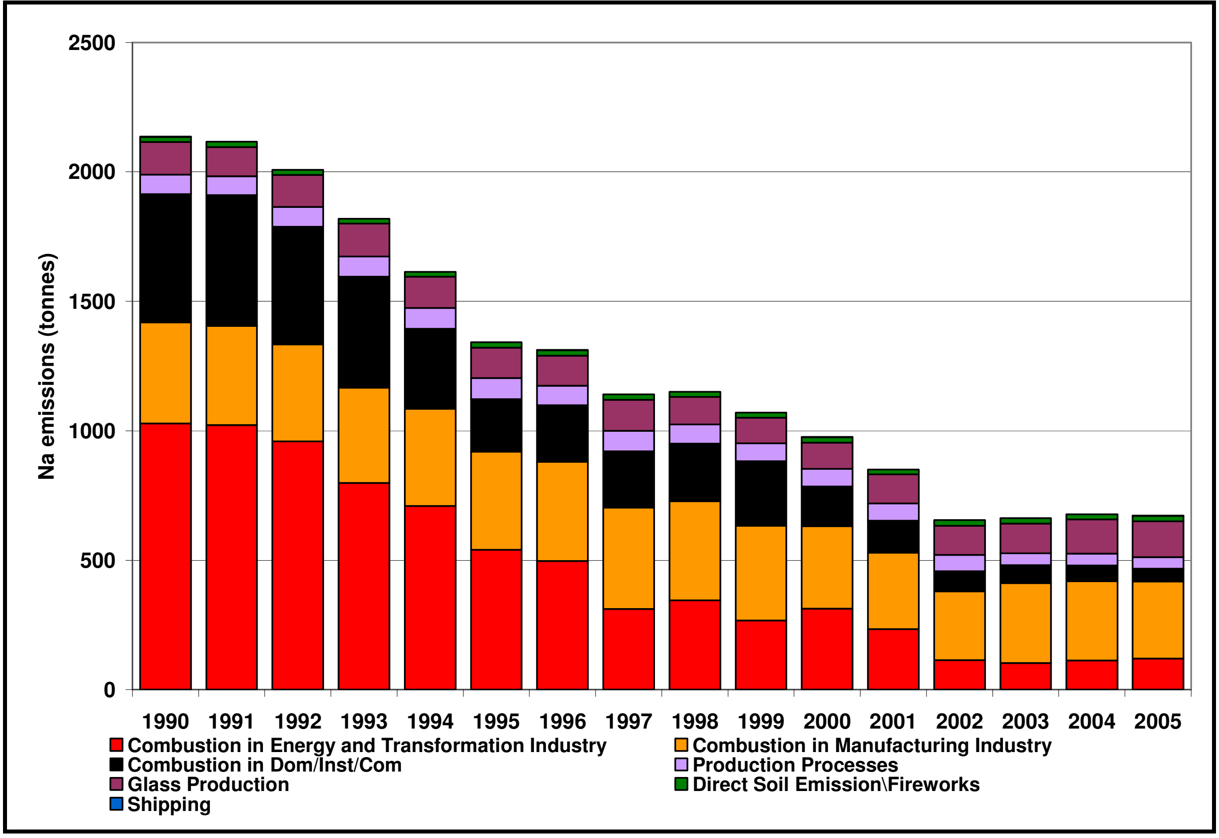
Iron and steel production from sinter plants is responsible for the greatest single emission of sodium with 250 tonnes emitted in 2005. Domestic coal burning emissions contributed 43 tonnes and coal burning power stations 117 tonnes. Other sources include glass manufacture and the food manufacture/preparation sectors.

Table 4.3 UK Emissions of Sodium by aggregated UN/ECE Source Category (ktonnes)

	NFR Codes	1990	2000	2001	2002	2003	2004	2005	2005 %
BY UN/ECE CATEGORY[1]									
Combustion in Energy and Transformation Industry	1A1	1.02	0.31	0.23	0.11	0.1	0.11	0.12	18%
Combustion in Manufacturing Industry	1A2	0.39	0.32	0.3	0.26	0.31	0.31	0.3	44%
Shipping	1A3dii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0%
Combustion in Dom/Inst/Com	1A4	0.49	0.15	0.12	0.08	0.07	0.06	0.05	8%
Production Processes	2A1, 2B5, 2C	0.08	0.07	0.07	0.06	0.05	0.04	0.04	7%
Glass Production	2A7	0.13	0.1	0.11	0.11	0.11	0.13	0.14	21%
Direct Soil Emission\Fireworks	4D1, 7	0.02	0.02	0.02	0.02	0.02	0.02	0.02	3%
TOTAL		**2.14**	**0.98**	**0.85**	**0.65**	**0.66**	**0.68**	**0.67**	**100%**

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

Figure 4.3 Time Series of Sodium Emissions (tonnes)



4.13 POTASSIUM

As with sodium, iron and steel productions is responsible for the majority of potassium emissions. This accounted for 334 tonnes in 2005, followed by Fireworks with of 332 tonnes.
Domestic coal burning is the third main contributor, causing the emissions of 98 tonnes of potassium in 2005.

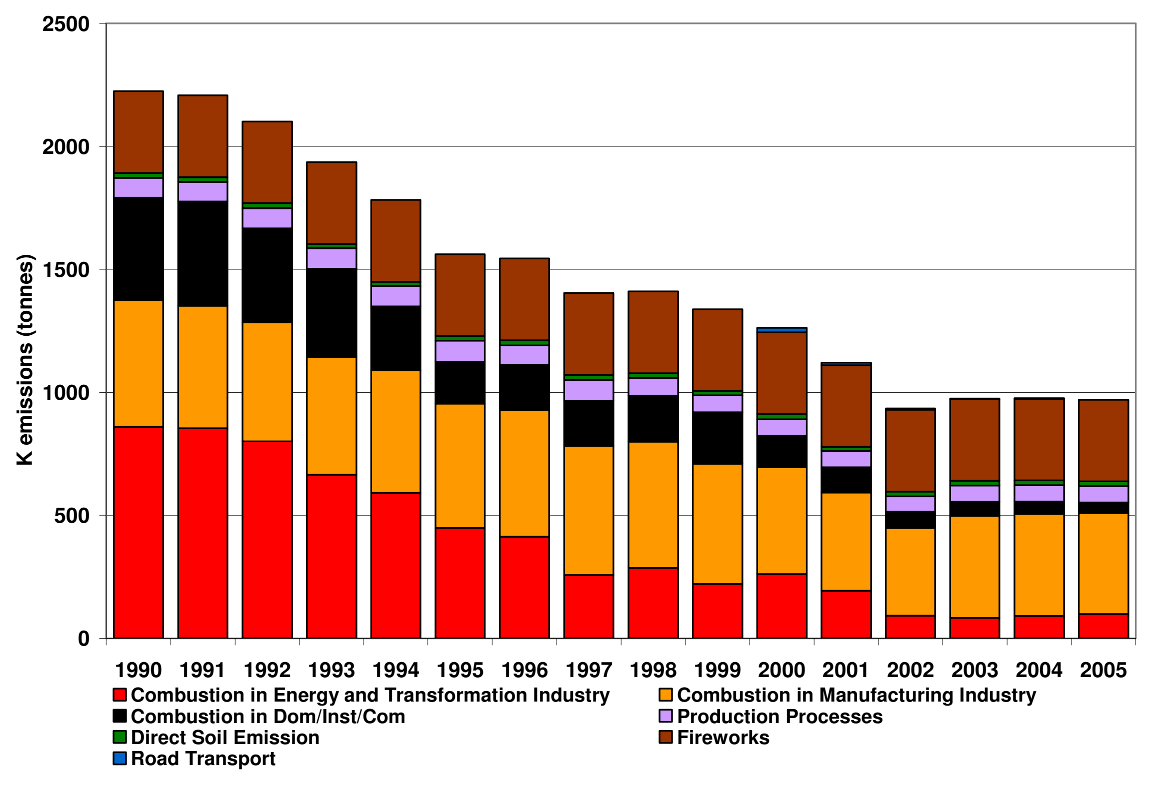
Estimates of emissions of potassium from coal combustion at Alcan's Ashington power station have been revised downwards in the 2005 inventory. Estimates for slag cement grinding, fireworks and burning of waste lubricants have all been added for the first time. The net impact of these changes is that there has been very little change to the total emission quoted in previous versions of the inventory.

Table 4.4 UK Emissions of Potassium by aggregated UN/ECE Source Category (ktonnes)

	NFR Codes	1990	2000	2001	2002	2003	2004	2005	2005%
BY UN/ECE CATEGORY[1]									
Combustion in Energy and Transformation Industry	1A1	0.9	0.3	0.2	0.1	0.1	0.1	0.1	10%
Combustion in Manufacturing Industry	1A2	0.5	0.4	0.4	0.4	0.4	0.4	0.4	42%
Road Transport	1A3bi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Combustion in Dom/Inst/Com	1A4	0.4	0.1	0.1	0.1	0.1	0.1	0	4%
Production Processes	2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	7%
Direct Soil Emission	4D1	0	0	0	0	0	0	0	2%
Fireworks	7	0.3	0.3	0.3	0.3	0.3	0.3	0.3	34%
TOTAL		**2.2**	**1.3**	**1.1**	**0.9**	**1.0**	**1.0**	**1.0**	**100%**

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

Figure 4.4 Time Series of Potassium Emissions (tonnes)



4.14 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 4.5.

Table 4.5 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.

5 Persistent Organic Pollutants

5.1 INTRODUCTION

This section includes pollutants controlled under international protocols on Persistent Organic Pollutants (POPs) of the UN/ECE under the Convention on Long-Range Transboundary Air Pollution.

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, which itself entered into force in 2003 is given in outline below; more information may be found at the UN/ECE web site, located at: www.unece.org/env/lrtap/. The UK ratified this protocol in 2005.

5.1.1.1 Persistent Organic Pollutants (POPs)

The UN/ECE Protocol on Persistent Organic Pollutants aims to control human and environmental exposure to substances that are persistent, bioaccumulative and harmful. It currently addresses 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 2.1.2), and an objective was set relating to attaining an annual average air concentration of 0.25 ng m^{-3} benzo[a]pyrene by 2010. This national objective was reiterated in the 2007 revision of the Air Quality Strategy. The fourth Air Quality Daughter Directive (2004/107/EC) sets a target value for benzo[*a*]pyrene concentrations to be achieved by 2012 of 1 ng/m^3. As a consequence there is a continued drive to decrease PAH emissions from the major sources.

Continued improvements have been made in compiling the 2005 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 2005. 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 5.1.1) 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 2005 UK emission
Persistent organic compounds (POPs)	
• Polycyclic aromatic hydrocarbons (PAHs)	1248 tonnes (USEPA16)[1]
• Dioxins and Furans (PCDD/F)	205 grammes I-TEQ [2]
• Polychlorinated biphenyls (PCBs)	1.03 tonnes
• Pesticides	
- lindane (γ-HCH)	14 tonnes
- pentachlorophenol (PCP)	451 tonnes
- hexachlorobenzene (HCB)	0.85 tonnes
• Short Chain Chlorinated Paraffins (SCCPs)	0.105 kg
• Polychlorinated Napthalenes (PCNs)	NE[3]
• Polybrominated Diphenyl Ethers (PBDEs)	7 tonnes

[1] See Table 3.3 for different PAHs included under different groupings.
[2] TEQ- "Toxic Equivalents" is a way of weighting emissions according to their toxicity. See Table 3.4
[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 (Lindane)	-	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 widely 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)**	**UNECE 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.

Emissions of the total amount of the 16 PAHs and benzo[a]pyrene (BaP) are summarised in Table 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 2005 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.

Road transport combustion is currently the largest source of PAH emissions contributing 64% of the emissions in 2005. 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 2005 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 UNECE Source Category (tonnes)

	NFR Codes	**1990**	**1995**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2005%**
BY UN/ECE CATEGORY[2]										
Public Electricity and Heat Production	1A1a	68	45	34	37	35	38	37	38	3%
Other Industrial Combustion	1A1b-c, 1A2	27	27	23	21	21	21	21	20	2%
Passenger cars	1A3bi	138	125	133	131	132	131	133	134	11%
Light duty vehicles	1A3bii	298	446	416	409	384	371	360	347	28%
Heavy duty vehicles - buses and coaches	1A3biii	1885	1295	634	535	458	398	351	313	25%
Other Transport	1A3biv, 1A3c-1A4cii	9	8	9	9	9	10	9	10	1%
Residential/Commercial / Institutional	1A4a, 1A4bi, 1A4ci	760	455	397	360	308	295	284	268	21%
Other	1B1, 2, 3, 4, 6	4611	2473	178	195	181	161	130	119	10%
Total		**7795**	**4874**	**1823**	**1697**	**1527**	**1425**	**1325**	**1248**	**100%**

[1] The PAHs selected are listed above in Table 3.3

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

Figure 5.1 Time Series of 16 PAHs Emissions (tonnes)

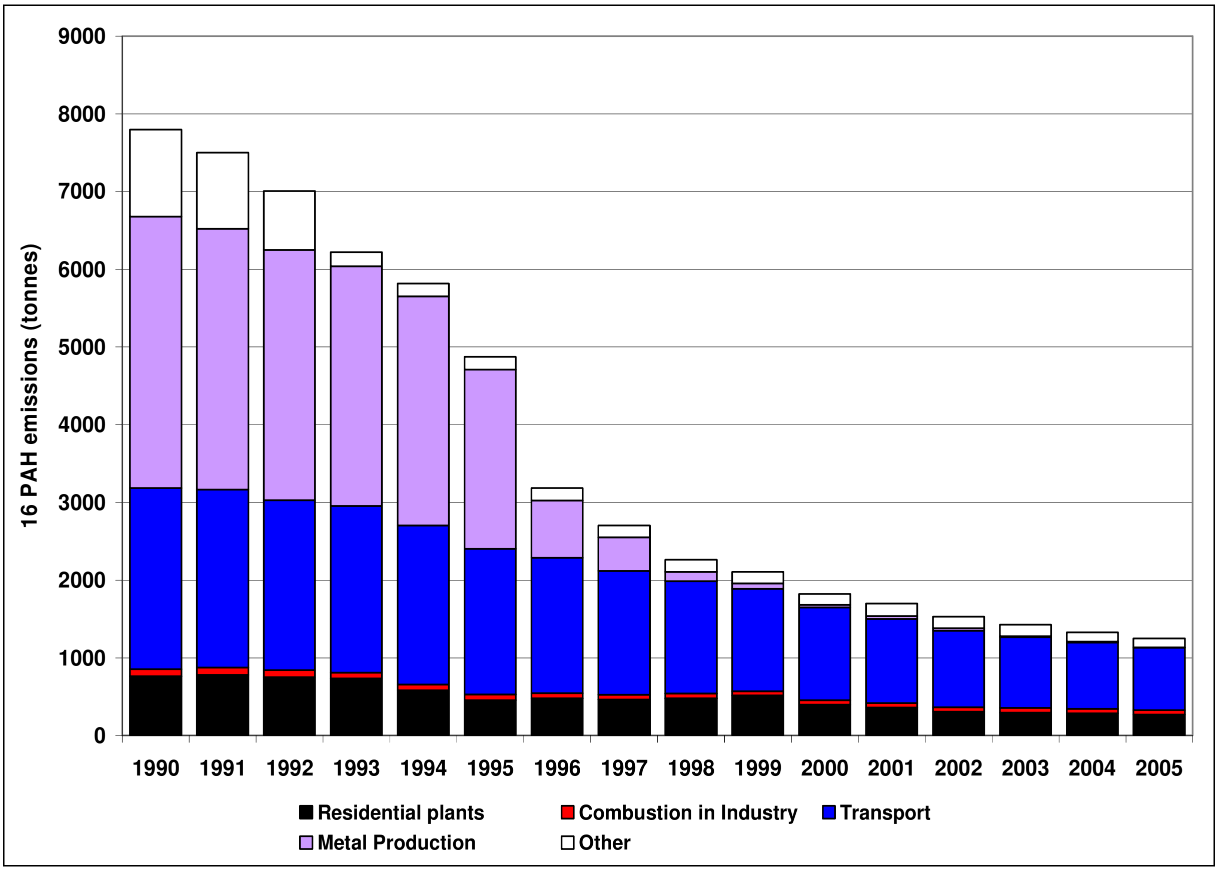


Table 5.4b UK Emissions of BaP[1] by aggregated UNECE Source Category (Kg)

	NFR Codes	1990	1995	2000	2001	2002	2003	2004	2005	2005%
BY UN/ECE CATEGORY[2]										
Combustion in Industry	1A1, 1A2	381	325	225	260	382	242	206	186	5%
Passenger cars	1A3bi	4681	1578	381	304	251	205	174	153	4%
Light&Heavy Duty Vehicles	1A3bii, iii	659	519	304	270	238	216	198	183	5%
Other Transport	1A3biv, 1A3c-1A4cii	140	99	89	91	94	104	98	103	3%
Residential/Commercial / Institutional	1A4a, 1A4bi, 1A4ci	6115	3325	2809	2484	2025	1912	1818	1676	48%
Production Processes	1B1b-3A	24985	16595	966	971	899	474	441	260	7%
Waste Incineration	6C	663	663	662	1044	662	662	662	662	19%
Other	4, 6D, 7	28657	335	296	306	309	324	290	290	8%
Total		**66280**	**23437**	**5732**	**5732**	**4860**	**4139**	**3886**	**3511**	**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)

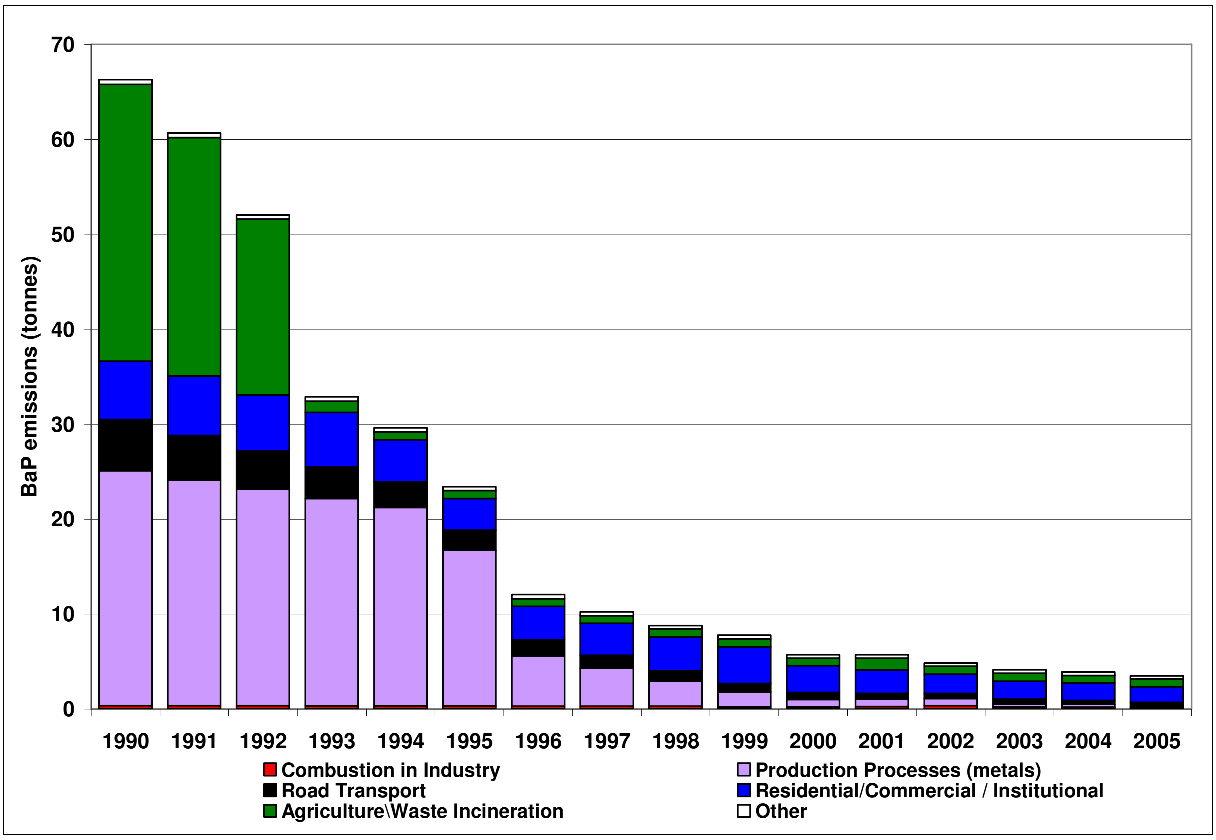
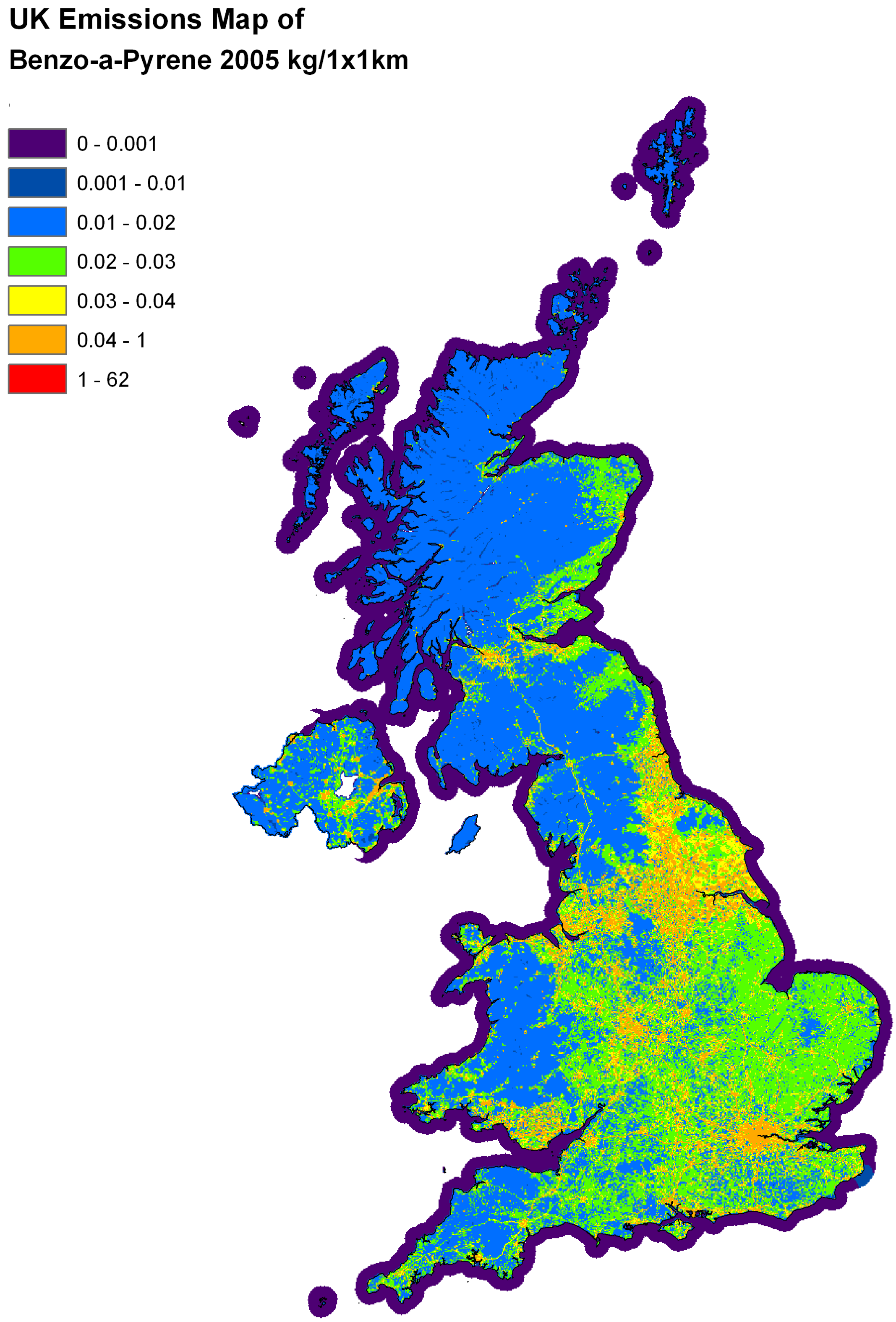


Figure 5.3 Spatially Disaggregated UK Emissions of Benzo[a]pyrene Map



5.2.1 Dioxins and Furans (PCDD/F)

5.2.1.1 Introduction

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, the World Health Organisation (WHO) published a modification to the values used to calculate the toxic equivalents for some of the PCDDs and PCDFs in 1997 which was revised using updated information in 2006. 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 two sets of 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 1997 TEFs** [2]	**WHO 2006 TEFs** [2]
2,3,7,8 tetrachlorodibenzo-*p*-dioxin	1	1	1
1,2,3,7,8 pentachlorodibenzo-*p*-dioxin	**0.5**	**1**	**1**
1,2,3,4,7,8 hexachlorodibenzo-*p*-dioxin	0.1	0.1	0.1
1,2,3,6,7,8 hexachlorodibenzo-*p*-dioxin	0.1	0.1	0.1
1,2,3,7,8,9 hexachlorodibenzo-*p*-dioxin	0.1	0.1	0.1
1,2,3,4,6,7,8 heptachlorodibenzo-*p*-dioxin	0.01	0.01	0.01
Octachlorodibenzo-p-dioxin	**0.001**	**0.0001**	**0.0003**
Furans			
2,3,7,8 tetrachlorodibenzofuran	0.1	0.1	0.1
1,2,3,7,8 pentachlorodibenzofuran	0.05	0.05	**0.03**
2,3,4,7,8 pentachlorodibenzofuran	0.5	0.5	**0.3**
1,2,3,4,7,8 hexachlorodibenzofuran	0.1	0.1	0.1
1,2,3,6,7,8 hexachlorodibenzofuran	0.1	0.1	0.1
1,2,3,7,8,9 hexachlorodibenzofuran	0.1	0.1	0.1
2,3,4,6,7,8 hexachlorodibenzofuran	0.1	0.1	0.1
1,2,3,4,6,7,8 heptachlorodibenzofuran	0.01	0.01	0.01
1,2,3,4,7,8,9 heptachlorodibenzofuran	0.01	0.01	0.01
Octachlorodibenzofuran	**0.001**	**0.0001**	**0.0003**

[1] NATO/CCMS (1988)
[2] WHO (1998)
[3] WHO (2006)

PCDD/Fs have been shown to possess a number of toxicological properties. The major concern is centred on their possible role in immunological developmental and reproductive effects.

5.2.1.2 Production and Emissions to Air

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.

5.2.1.3 Emission Estimates

Estimated PCDD/F emissions for 1990-2005 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)

	NFR Codes	1990	1995	2000	2001	2002	2003	2004	2005	2005%
BY UN/ECE CATEGORY[1]										
Combustion in Industry	1A1, 1A2b	145.3	203.3	16.5	13.5	12.3	9.8	9.1	11.4	6%
Iron and Steel	1A2a	43.2	41.5	35.1	30.0	24.1	28.1	29.3	31.1	15%
Other industrial combustion: Wood&Coal	1A2f	41.9	49.2	29.1	28.7	24.3	23.6	46.0	17.6	9%
Transport	1A3b, 1A3c-1A4cii	32.2	16.5	5.5	5.4	5.3	5.2	6.0	6.3	3%
Residential/Commercial / Institutional	1A4a, 1A4bi, 1A4ci	73.0	42.4	16.4	15.8	14.3	13.3	13.0	12.3	6%
Production Processes	1B1b, 2A&B&D	5.4	3.4	1.9	1.9	1.6	1.8	1.5	1.7	1%
Metal Production	2C	27.3	25.8	13.2	12.7	10.0	9.1	15.8	14.2	7%
Agriculture\Other	4, 7	63.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	3%
Waste Incineration& Other Waste	6	679.6	324.0	104.6	104.6	104.1	104.6	102.2	103.1	50%
Total		**1111.9**	**712.9**	**229.1**	**219.4**	**202.8**	**202.2**	**229.6**	**204.5**	**100%**

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

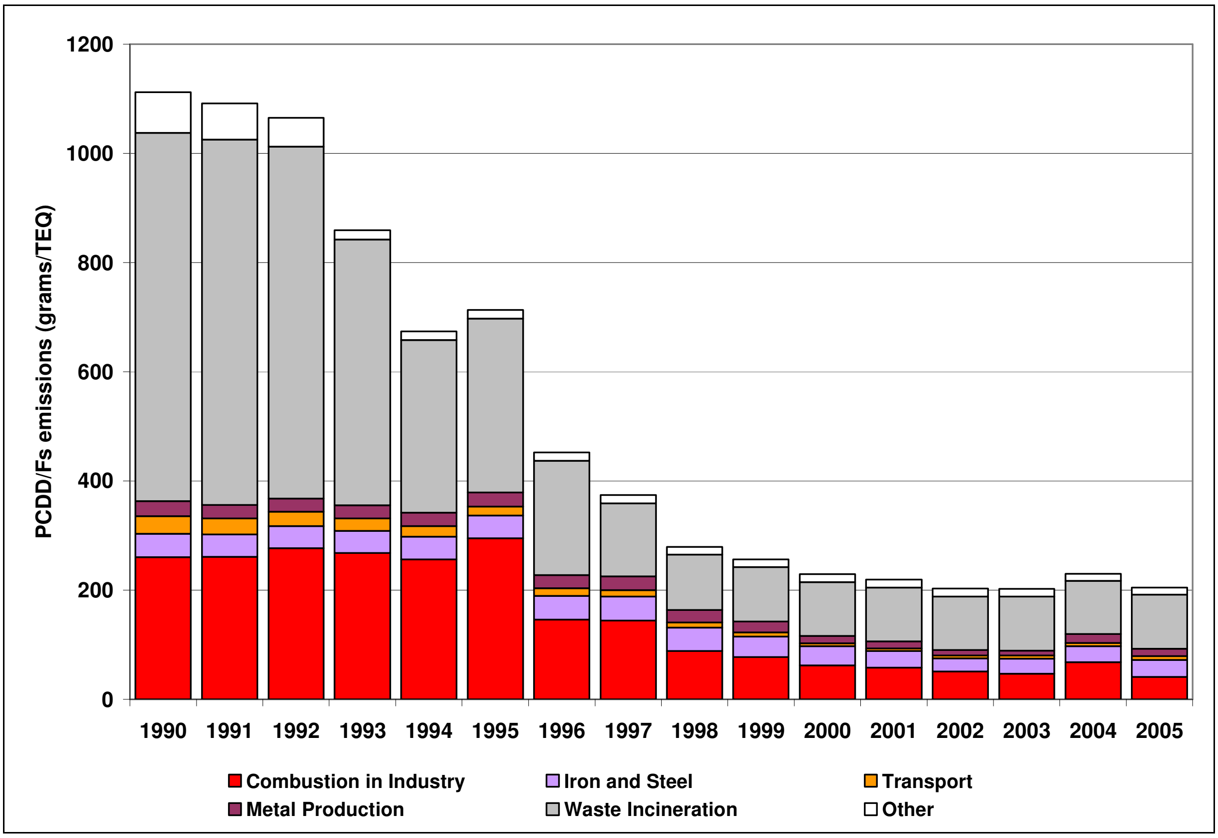
[2] Including railways, shipping, naval vessels, military aircraft and off-road sources

The largest sources of PCDD/F emission is thought to be the burning of waste materials in sources other than well controlled modern waste incinerators. However emissions from waste incineration have fallen by 80% between 1993 and 2005. 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 5.3 Time Series of PCDD/Fs Emissions (grams I-TEQ)



Emissions from power stations are low because the combustion is efficient and the post-combustion fly ash temperatures are rapidly reduced to increase energy efficiency. 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.

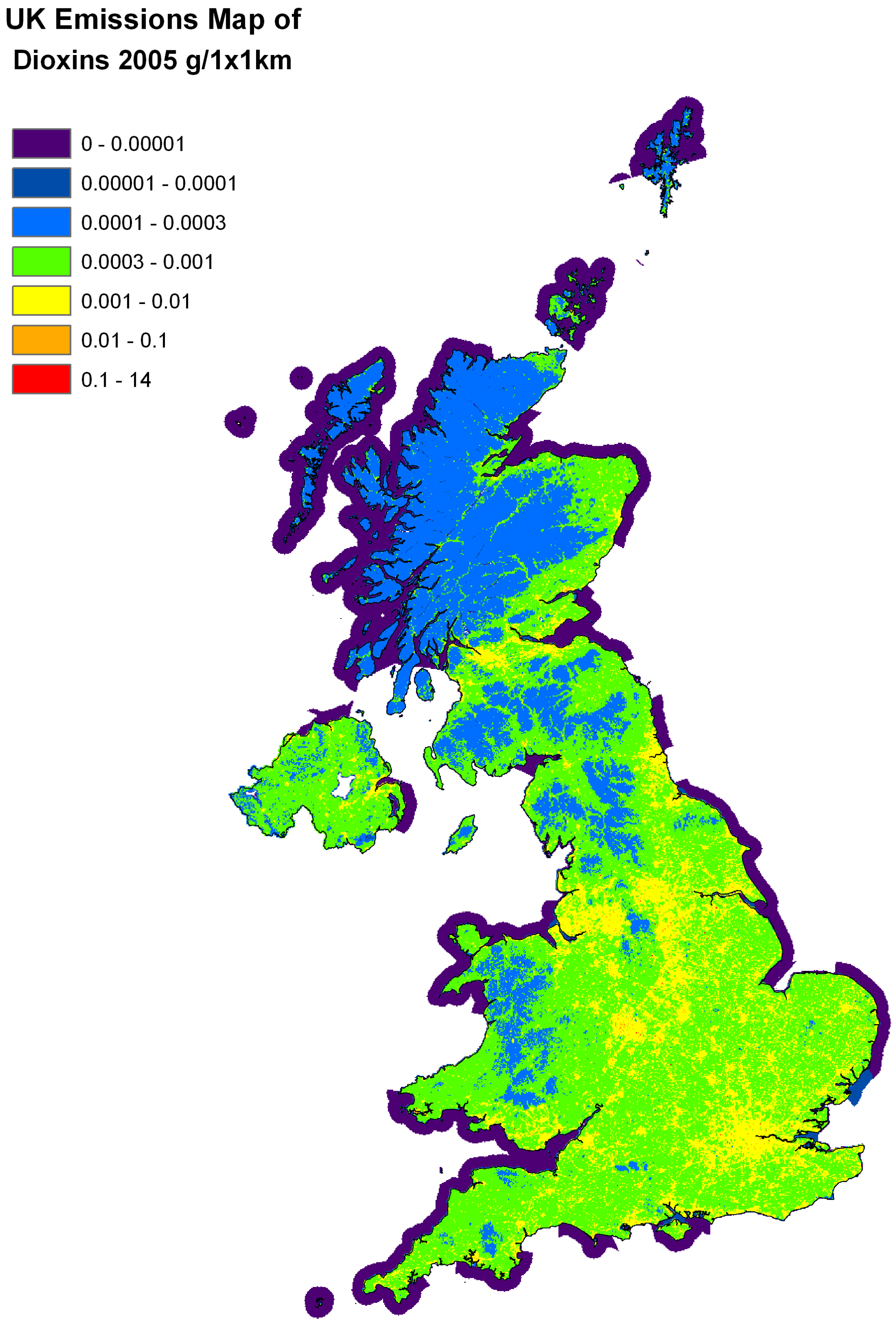
Emissions from open agricultural burning and accidental fires are included in the agricultural and nature sectors. The former has declined to near zero since the cessation of stubble burning. Accidental fires, in the absence of better information, are currently treated as a source of constant magnitude, 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 major source of PCDD/F emissions from road transport are the 1,2-dichloroethane scavengers previously added to leaded petrol. 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 2005, the contribution to the PCDD/F emission total from road transport fuel was 1%.

Figure 5.4 Spatially Disaggregated UK Emissions of PCDD/F Map



5.2.2 Polychlorinated biphenyls (PCBs)

5.2.2.1 Introduction

PCBs are synthetic organic compounds that have had a wide range of uses as a result of their stability. Most recently they 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.

5.2.2.2 Production and Emissions to Air

The sale of products containing PCBs has not been legal since 1986 and so they 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 2005, 61% 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.

5.2.2.3 Emission Estimates

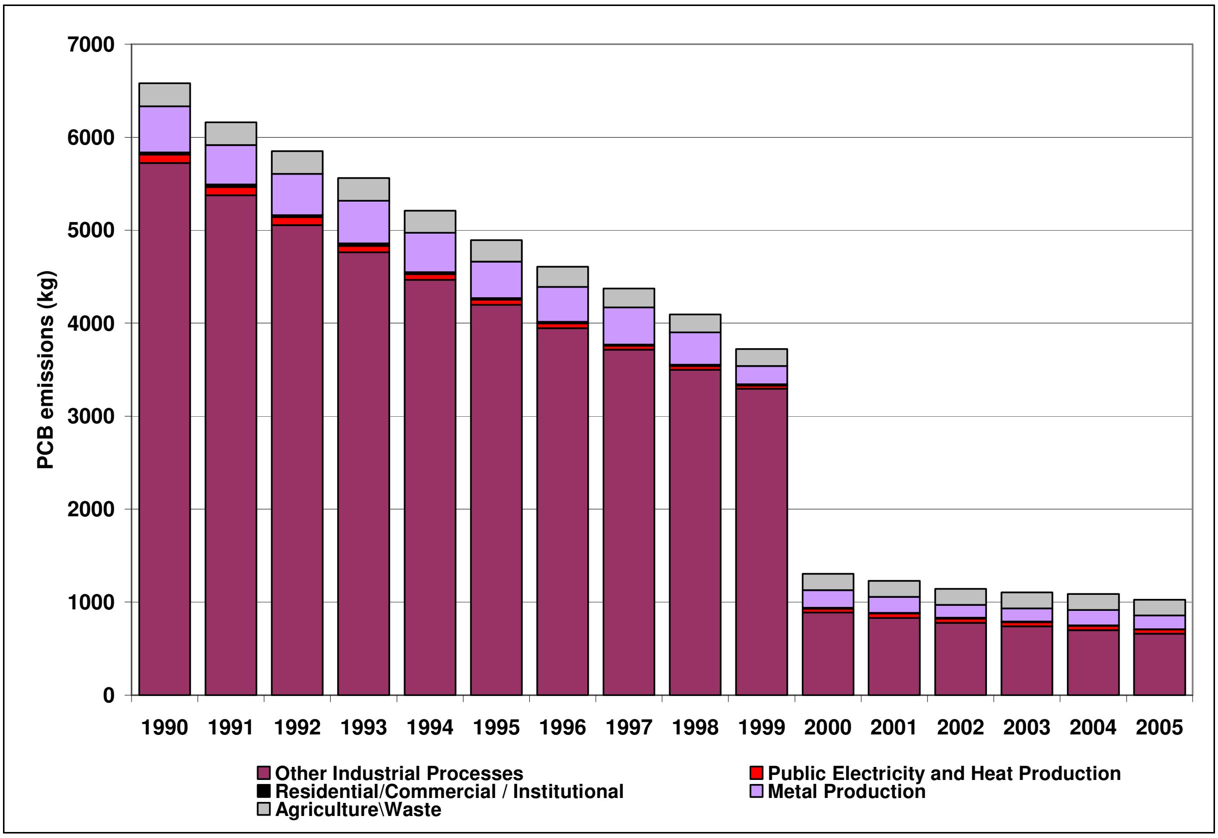
PCB speciation has been incorporated into the emission estimates since the 1998 inventory report. A summary of the total PCB emission estimates for 1990 to 2005 is given below in Table 5.7

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

	NFR Codes	1990	1995	2000	2001	2002	2003	2004	2005	2005 %
BY UN/ECE CATEGORY[1]										
Public Electricity and Heat Production	1A1a	91	56	42	46	43	47	45	46	4%
Residential/Commercial / Institutional	1A4a, 1A4bi, 1A4ci	24	16	11	11	9	7	7	5	1%
Metal Production	2C	496	395	188	170	141	141	167	147	14%
Agriculture\Waste	4, 6	249	228	175	174	173	171	170	169	16%
Other	1A1b-c, 1A2, 1A4ci, 1B1b, 2G	5720	4196	888	831	780	740	699	662	64%
Total		**6580**	**4891**	**1304**	**1231**	**1145**	**1106**	**1087**	**1028**	**100%**

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

Figure 5.5 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 (61% of total emission), and this is the case for 2005.

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 fall as the relevant electrical equipment reaches the end of its working life and is destroyed.

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

5.2.3.1 Introduction

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.

5.2.3.2 Production and Emissions to Air

Pesticide emissions to the air occur predominately through three pathways: during manufacture, during application and volatilisation after application.
Table 5.8, Table 5.9 and Table 5.10 show the estimated emissions of lindane (γ-HCH), pentachlorophenol (PCP) and hexachlorobenzene (HCB) respectively.

5.2.3.3 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 has been used 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. Approvals for the use of lindane containing pesticides in the UK have now been withdrawn and use has not been allowed since 2002.

Hexachlorocyclohexane (HCH) exists in several isomers, however as a result of regulation in 1981 use of products containing less than 99% γ-HCH has not been allowed. 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 99.9% to the 2005 total emission. Emissions from wood preserving have fallen since 1990.

Emissions from agricultural pesticide activities account for around 0.1% of total 2005 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).

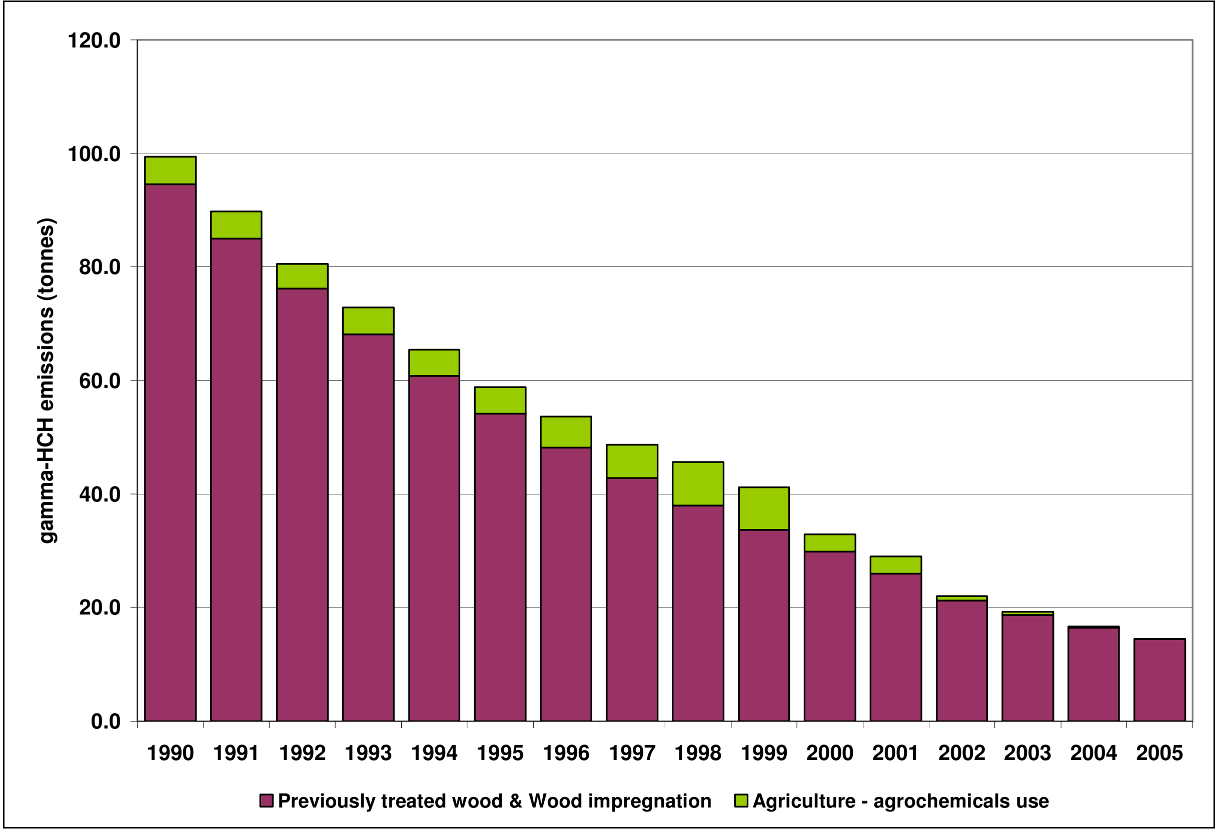
Emissions of γ-HCH arising from domestic applications are thought to be comparatively small. However, usage statistics are scarce and were only available for 1988 (DOE, 1989). Emission factors are taken from van der Most *et al* (1989).

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

		1990	1995	2000	2001	2002	2003	2004	2005	2005%
BY UN/ECE CATEGORY[1]										
Solvent use - treated wood & wood impregnation	3D	94.5	54.2	29.8	25.9	21.2	18.7	16.4	14.5	99.9%
Agriculture - agrochemicals use	4G	4.9	4.6	3.1	3.0	0.8	0.6	0.3	0.0	0.1%
Total		**99.4**	**58.8**	**32.9**	**29.0**	**22.0**	**19.3**	**16.7**	**14.5**	**100%**

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

Figure 5.6 Times Series of γ-HCH Emissions (tonnes)



For completeness, the total emissions of HCH are also included here (see Table 5.8 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	2005	2005%
BY UN/ECE CATEGORY[1]													
Solvent use - treated wood & wood impregnation	95.5	54.7	48.7	43.2	38.4	34.0	30.1	26.2	21.4	18.9	16.6	14.6	100%
Agriculture – agrochem use	4.9	4.7	5.5	5.9	7.7	7.6	3.1	3.1	0.8	0.6	0.3	0.0	0%
Total	**100.4**	**59.4**	**54.2**	**49.2**	**46.1**	**41.6**	**33.2**	**29.3**	**22.3**	**19.5**	**16.9**	**14.6**	**100%**

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

5.2.3.4 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 2005 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 99.99% of the 2005 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.

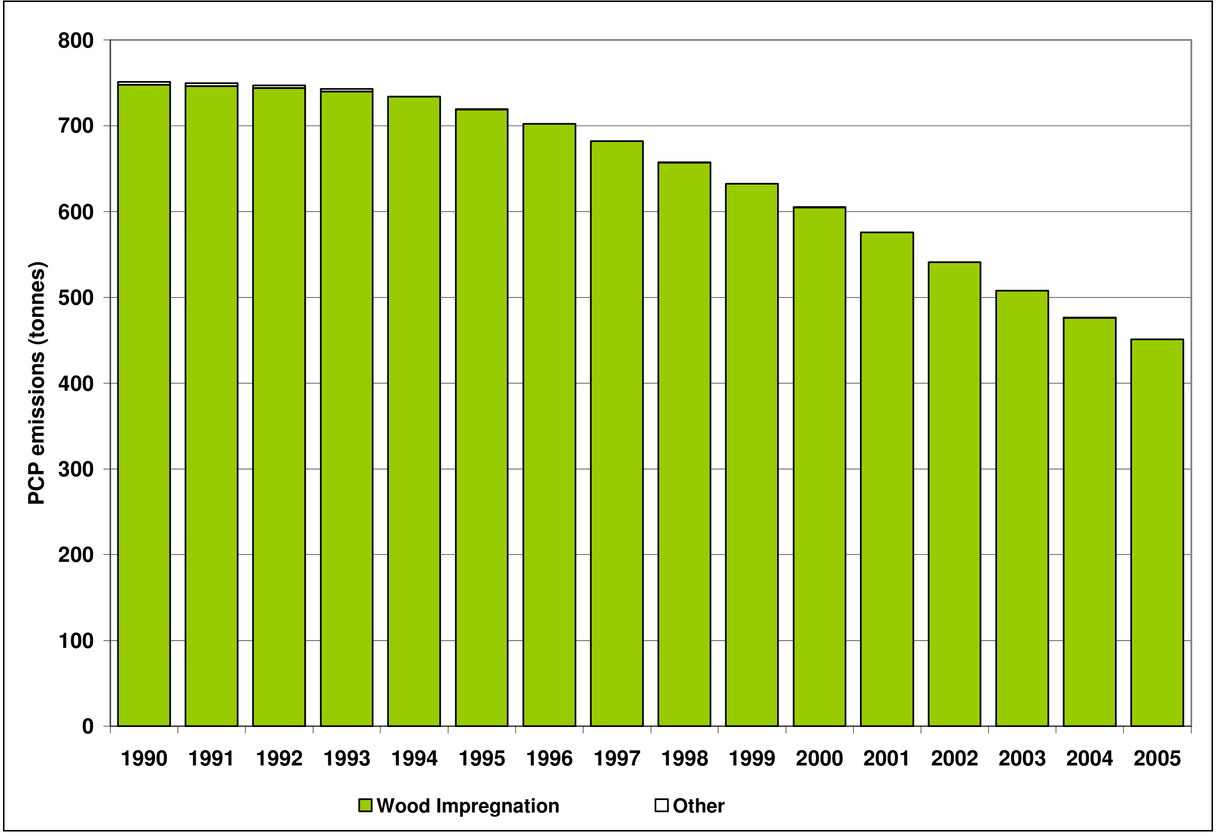
PCP has been used in the agricultural sector as the active ingredient in disinfecting wooden trays used in mushroom farming (classified as solvent use). Usage statistics are reliable coming from the Pesticide Usage Survey Group (MAFF, 1991a,b,c; 1992a,b,c,d). The emission factor assumes 30% loss due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

	NFR Codes	**1990**	**1995**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2005%**
Wood Impregnation	3D	748	719	605	576	541	508	476	451	100%
Other	1A, 2, 3C, 6	3.23	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0%
Total		**751**	**719**	**605**	**576**	**541**	**508**	**476**	**451**	**100%**

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

Figure 5.7 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.

5.2.3.5 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.

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 remained high in 2005. 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).

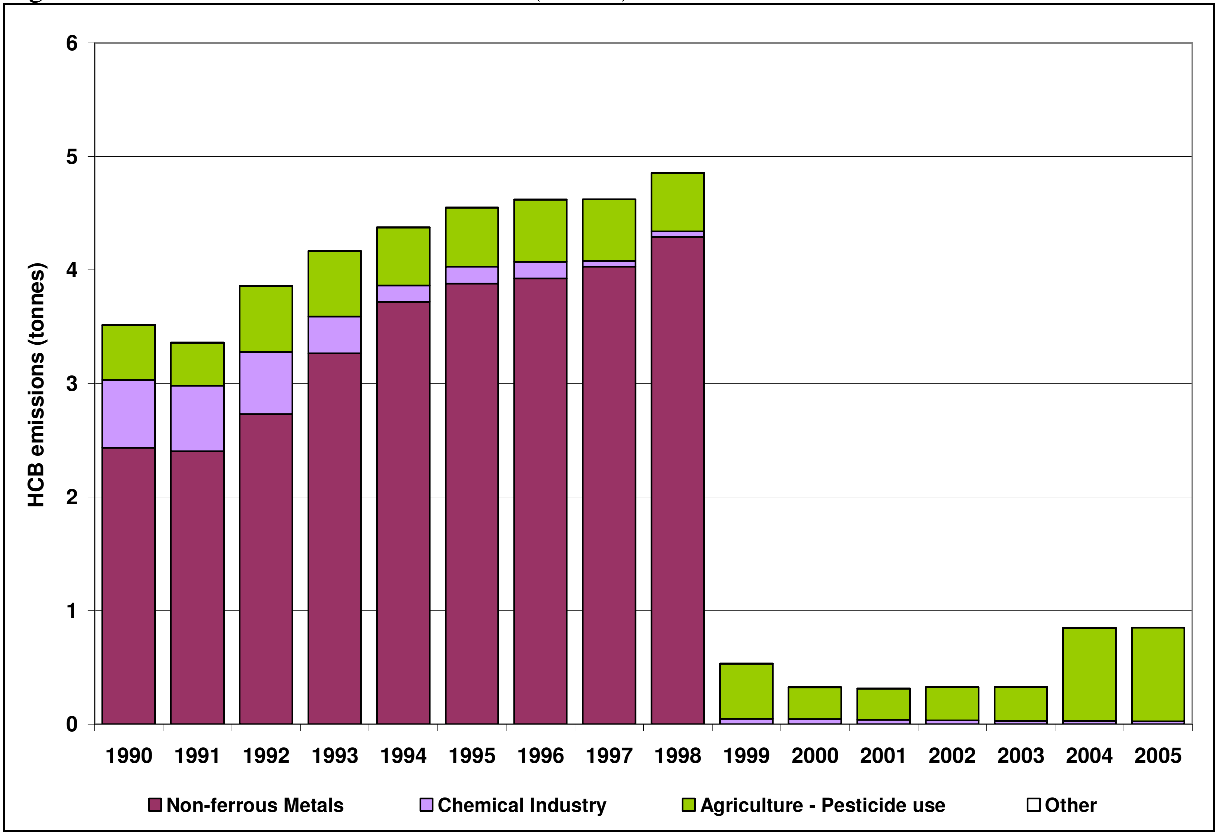
Emissions from pesticide application and chlorinated solvent production now account for virtually all of the UK HCB emissions (Table 5.10). For 2005, these two sources are estimated to account for 97% and 3%, respectively, of the total HCB emissions. This represents a change in the relative contributions 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)

	NFR Codes	**1990**	**1995**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2005%**
BY UN/ECE CATEGORY										
Non-ferrous Metals	1A2b	2435.0	3881.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Chemical Industry	2B5	596.2	148.9	43.5	38.5	33.6	28.5	25.8	24.7	3%
Agriculture - Pesticide use	4G	482.2	517.5	279.9	273.1	291.3	298.4	821.8	824.6	97%
Other	1A1a, 1A4a, 6c	2.0	2.0	1.9	2.0	2.1	2.2	2.1	2.1	0%
Total		**3515.4**	**4549.4**	**325.2**	**313.6**	**327.0**	**329.1**	**849.6**	**851.4**	**100%**

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

Figure 5.8 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 to be persistent organic pollutants. Due to their stability potential to bioaccumulate and toxicological properties they are of concern to the environment and human health.

5.2.4.2 Production and Emissions to Air

SCCPs were manufactured in the EU and 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 10 tonnes per year.

The main use of SCCPs used to be in metal working fluids however these are no longer sold. The remaining market is thought to be as a flame retardant in certain rubbers and textiles. 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 as a result of the physical properties of SCCPs.

5.2.4.3 Emission Estimates

Emission estimates have been revised since last years NAEI Report (Dore et al, 2004), 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	2000	2001	2002	2003	2004	2005
TOTAL	47	24	3	0.199	1	1	0.0001	0.0001

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.

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 their potential toxicity, persistence and the tendency for bioaccumulation.

Since the 1960s, PBDEs have been added to foams and plastics as flame-retardants. They are sold as mixtures containing a certain typical level of bromination; hence pentabromo, octabromo and decabromo diphenyl ethers. They have been 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. However this is thought to have declined rapidly over the last decade. 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 6.6 tonnes (Penta-BDE: 1.5t, Octa-BDE: 0.3t, Deca-BDE: 4.8t) 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 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 6.1 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 6.1 Location of Ozone Depletors and Precursors in this Report

Nitrous Oxide (N_2O)	Ozone Precursor	Section 7.4: Nitrous Oxide
NMVOCs	Ozone Precursor	Section 2.9 : non-methane volatile organic compounds
NOx	Ozone Precursor	Section 2.8: NO_x emissions
HFCs	Stratospheric Ozone Depletor	Section 7.5.1 : Hydrofluorocarbons
PFCs	Stratospheric Ozone Depletor	Section 7.5.2 : Perfluorocarbons

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 2.9).

7 Greenhouse Gas Emissions

7.1 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*, 2007).

The 2005 emissions for each of these six greenhouse gases are summarised in Table 7.1 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 chapter 2.

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).

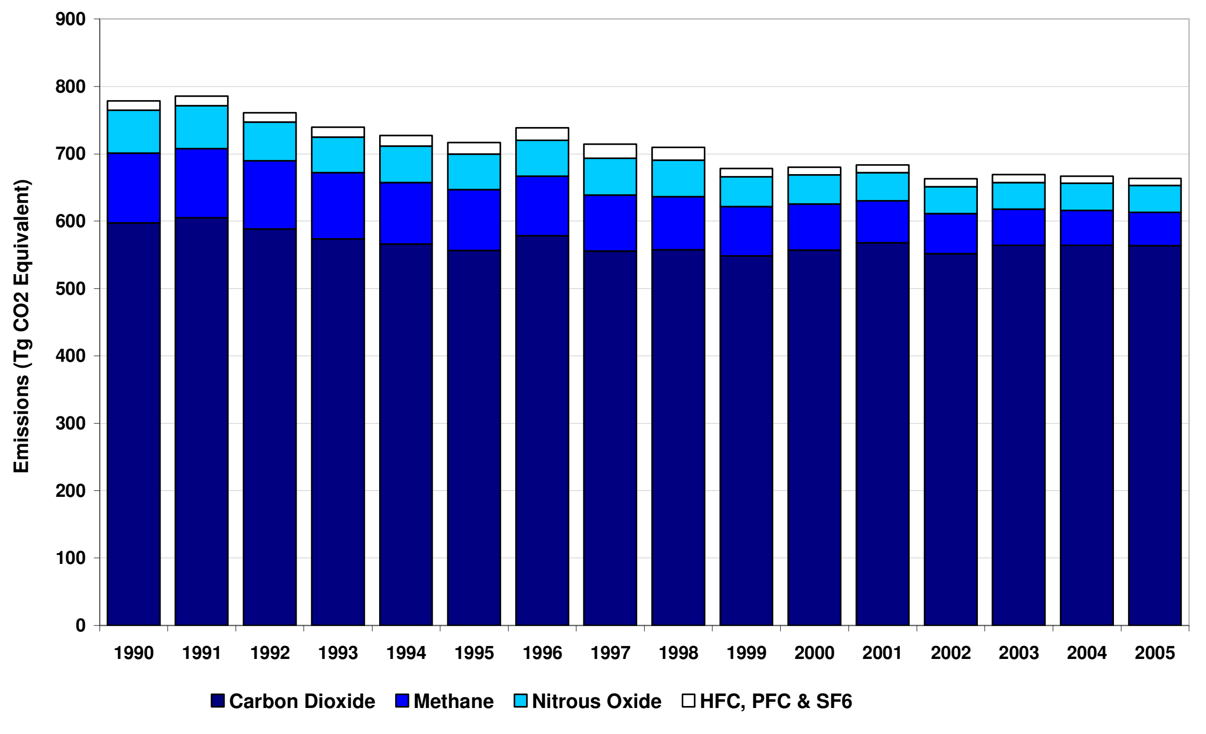
Table 7.1 GWP for UK Emissions of Greenhouse Gases in 2005

Direct GHG	Emissions (ktonnes) in 2005	GWP (100 years)	Global Warming Equivalence (equivalent kt of CO_2)
CO_2 (as carbon) [1]	152,383	3.7	563,816
CH_4	2,358	21	49,525
N_2O	128	310	39,645
HFCs [2]	5.7	140 - 11,700	9,221
PFCs [2]	0.05	6,500 - 9,200	351
SF_6	0.05	23,900	1,143

[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 1990-2005 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 7.1 shows greenhouse gas emissions (comprising CO_2 , CH_4 , N_2O , HFCs, PFCs and SF_6) as CO_2 equivalent[6] for 1990 to 2005. Reliable emission estimates of HFCs, PFCs, SF_6 and N_2O (from adipic acid production) are not available prior to 1990.

Figure 7.1 Total UK GHG Emissions 1990-2005 (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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[6] 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 7.1). 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 2005 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)

7.2 CARBON DIOXIDE

7.2.1 Key Source Description

The major emissions of carbon dioxide arise from the combustion of fossil fuels in power generation, and the transport, domestic and industrial sectors (Figure 7.2, Table 7.2). The level of emissions depends on the fuel mix and the fuel consumption data. Details of UK fuel consumption are given annually in BERR's (formerly known as the Department of Trade and Industry) Digest of United Kingdom Energy Statistics (DTI, 2006). The fuel consumption data used to calculate the pollutant emission totals in the NAEI are given in Table 7.3; 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).

7.2.2 Total CO_2 Emissions

Carbon dioxide emissions in 2005 have reduced by 18% since 1970, as shown in Figure 7.2. 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 however. 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).

Figure 7.3 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 7.2 UK Emissions of CO_2 as Carbon by UN/ECE[1] Source Category and Fuel (Mtonnes)

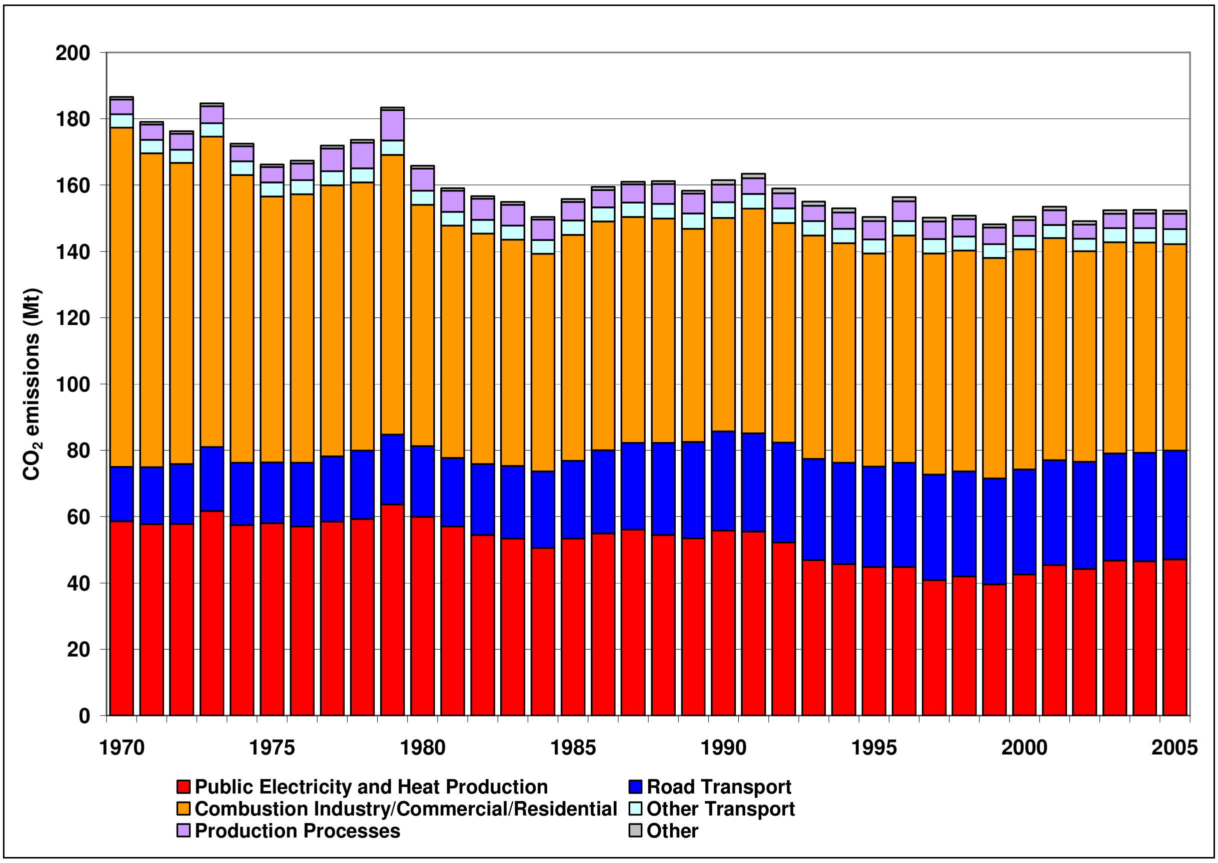
	NFR Codes	**1970**	**1980**	**1990**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2005%**
BY UN/ECE CATEGORY[2]											
Public Electricity and Heat Production	1A1a	58.6	60.0	55.8	42.6	45.4	44.2	46.7	46.6	47.2	31%
Combustion in Industry	1A1b&c, 1A2a, 1A4	64.1	44.8	43.8	46.1	46.4	44.4	44.9	45.4	43.9	29%
Other Industrial Combustion	1A2f	38.2	27.9	20.6	20.3	20.6	19.0	18.9	18.1	18.4	12%
Road Transport:											
Passenger cars	1A3bi	11.0	14.8	19.4	19.9	19.7	20.0	19.6	19.6	19.3	13%
Other Road Transport	1A3bii-iv	5.4	6.5	10.6	11.8	12.0	12.3	12.7	13.0	13.5	9%
Other Transport	1A3aii(i)-1A3aii(ii), 1A3c-1A3eii, 1A4bii, 1A4cii, 1A5b	4.1	4.3	4.7	4.1	3.9	3.9	4.2	4.3	4.4	3%
Production Processes	1B1, 1B2, 2	4.4	6.7	5.3	4.8	4.4	4.2	4.4	4.5	4.6	3%
Agriculture\Other Sources & Sinks	4\5	0.0	0.0	0.5	0.3	0.3	0.3	0.4	0.4	0.3	0%
Waste & Others	6\7	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0%
Emission by fuel											
Solid		92.8	72.4	62.7	33.6	36.8	34.4	36.7	35.1	35.8	23%
Petroleum		69.9	57.6	56.8	50.0	50.6	49.9	49.7	50.5	51.3	34%
Gas		19.2	28.6	36.0	60.9	60.3	59.2	60.2	61.1	59.4	39%
Non-Fuel		4.8	7.2	6.1	5.9	5.7	5.7	5.8	5.8	5.9	4%
Total		186.6	165.8	161.5	150.5	153.5	149.1	152.4	152.5	152.4	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 7.2 Time Series of CO_2 as Carbon Emissions (Mtonnes)



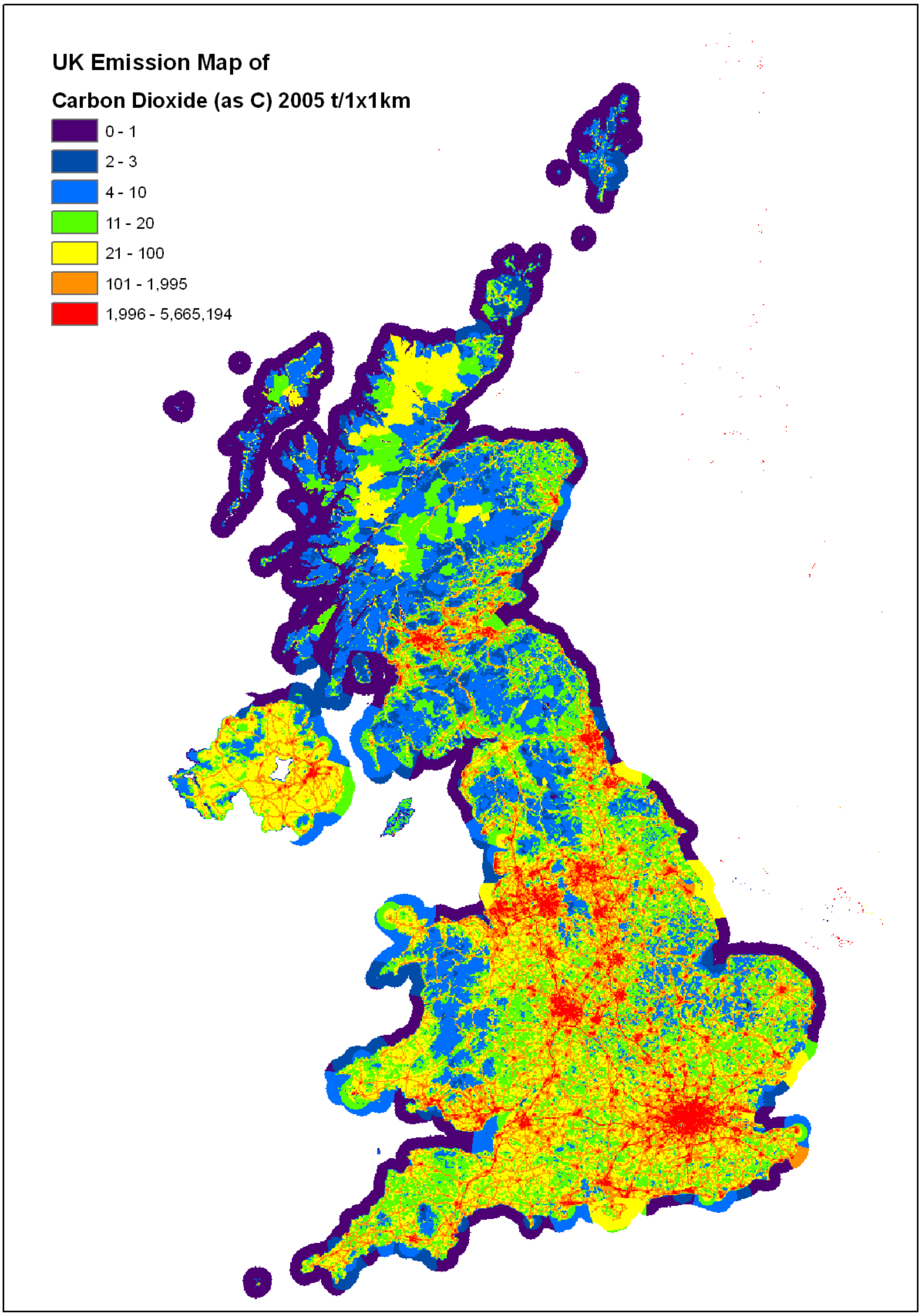


Figure 7.3 Spatially Disaggregated UK Emissions of CO_2 as Carbon Map

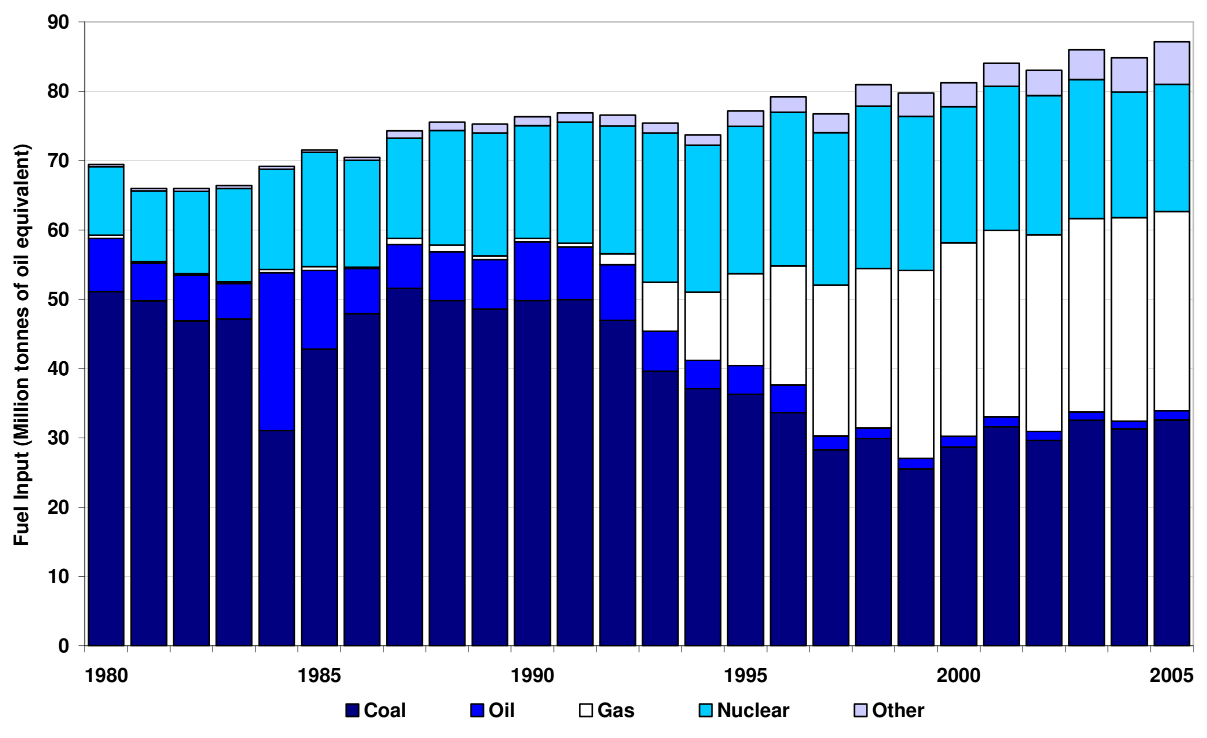
7.2.3 Electricity Supply Industry

The electricity supply industry is the major consumer of fossil fuels, and hence the major source of carbon dioxide emissions in the UK (Table 7.2 and Table 7.3). There have been significant changes in the generating mix between 1980 and 2005, as shown in Figure 7.4. 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 a 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 7.3 UK Fuel Consumption, 1970-2005

Fuel	Consumer	Units	1970	1980	1990	2000	2001	2002	2003	2004	2005
Coal	Major Power	Mt	77	90	83	44	48	45	50	48	50
Coal	Industry	Mt	22	9	8	5	5	5	5	5	5
Coal	Domestic	Mt	20	9	4	2	2	1	1	1	1
Coal	Other	Mt	13	5	3	1	1	1	1	0	0
Other Solid Fuels	All consumers	Mt	17	6	5	3	3	3	3	3	3
Motor spirit	RT	Mt	14	19	25	22	22	22	21	20	20
Gas Oil	RT	Mt	5	6	11	16	16	17	18	19	19
Gas Oil	Industry	Mt	6	5	4	4	4	4	4	4	4
Gas Oil	Other		7	7	8	7	7	6	7	7	7
Fuel Oil	Major Power Prod	Mt	12	6	6	1	1	1	1	1	1
Fuel Oil	Refineries	Mt	4	4	2	1	2	2	2	2	2
Fuel Oil	Industry	Mt	20	10	4	1	1	1	0	1	1
Fuel Oil	Other	Mt	5	2	1	0	0	0	0	0	0
Orimulsion	Major Power Prod	Mt	0	0	0	0	0	0	0	0	0
Burning oil	Domestic	Mt	1	1	2	2	3	2	2	2	2
Burning oil	Other	Mt	4	0	0	1	2	1	1	2	2
Aviation Turb Fuel	Air Transport	Mt	1	1	1	1	1	1	1	1	1
Other Pet Products	All consumers	Mt	1	1	1	2	1	1	1	1	2
Petroleum Gases	Refineries	Mth	1,011	987	1,303	1,308	1,189	1,251	1,137	1,264	1,305
Petroleum Gases	Other	Mth	700	717	679	698	759	671	815	787	782
Natural gas	Major Power	Mth	60	55	3	9,683	9,444	9,938	9,713	10,390	10,088
Natural gas	Domestic	Mth	748	6646	7062	10756	10762	10393	10295	9847	9636
Natural gas	Industry		627	8420	10250	12622	12947	12843	13188	13526	13030
Natural gas	Other	Mth	2206	2188	3019	4645	4757	4209	4402	4433	4265
Other gas	All Consumers	Mth	7009	1126	1284	1082	923	802	902	867	899

Figure 7.4 Generating Mix (1980-2005) Million Tonnes Oil Equivalent (Mtoe).

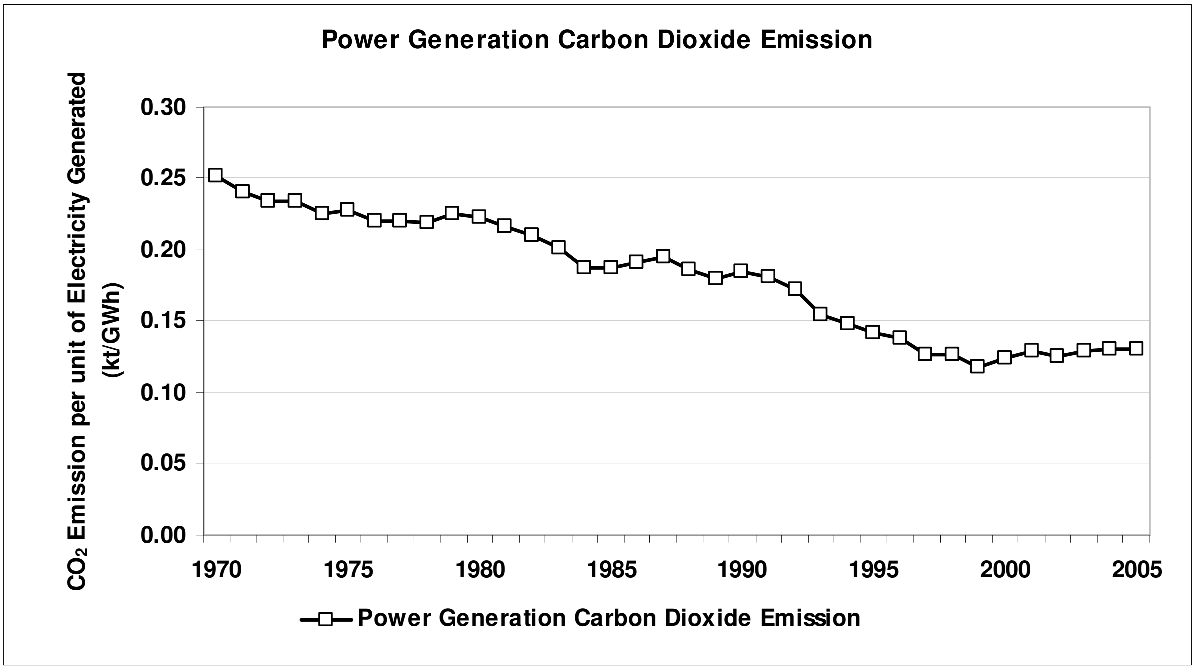


The effect of these changes in the power sector is clearly reflected in the carbon dioxide emissions. Since 1970 electricity generation has substantially increased but emissions have decreased by around 19%. This is due specifically to:

- 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 28%.

The overall effect of the fuel and technology changes are also clearly illustrated in Figure 7.5 which shows that the average CO_2 (as Carbon) emission (from power generation) per kWh electricity generated decreases from 252 tonnes/GWh in 1970 to 130 tonnes/GWh in 2005. 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 6.5.

Figure 7.5 Average Carbon Emission per unit of Electricity Generated (ktonne/GWh)



7.2.4 Domestic

The domestic use of coal (including anthracite) shows an overall decline between 1970 and 2005, falling by 97%. 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.

7.2.5 Industrial

The 2005 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 trends 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 and 2005.

7.2.6 Transport

Total emissions from the transport sector have steadily increased since 1970. Of these, road transport emissions have risen by approximately 100% and currently account for 88% of the total transport/mobile machinery emissions in 2005. This also equates to 22% 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 2005. The increased use of private motor vehicles has resulted in a 2% increase in the consumption of petrol from 1970 to 2005. However, petrol consumption has declined by 23% since 1990, which is a result of the increase in popularity of diesel cars, and the increased fuel efficiency of petrol driven cars. Diesel consumption for use by goods vehicles has increased by approximately 286% since 1970.

7.2.7 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. The Intergovernmental Panel on Climate Change have agreed guidelines for preparing national inventories (IPCC, 1997). Land use change and forestry estimates are included in the UK Greenhouse Gas Inventory (Baggott *et al*, 2007) for the years 1990-2005. The estimates are not included under the reporting format for air quality pollutants (the entry under "Agriculture & Land Use Change" in Table 7.2 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 7.4 (Milne, 2004).

Table 7.4 Emissions & Removals of CO_2[1] (as CO_2) from Land Use Change & Forestry(2005)

Sources	**Net CO_2 emissions /removals (ktonnes)**[1,2]
A. Forest Land	-15738
B. Cropland	15258
C. Grassland	-7934
D. Wetlands	IE, NE, NO
E. Other [3]	6358
Total	**-2056**

[1] According to the Revised 1996 IPCC Guidelines, for the purposes of reporting, the signs for removals are always negative (-) and for emissions positive (+). Net changes in carbon stocks are converted to CO2 by multiplying C by 44/12 and by changing the sign for net CO2 removals to be negative (-) and for net CO2 emissions to be positive (+).

[2] CO2 emissions from liming and biomass burning are included in this column.

[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.

7.3 METHANE

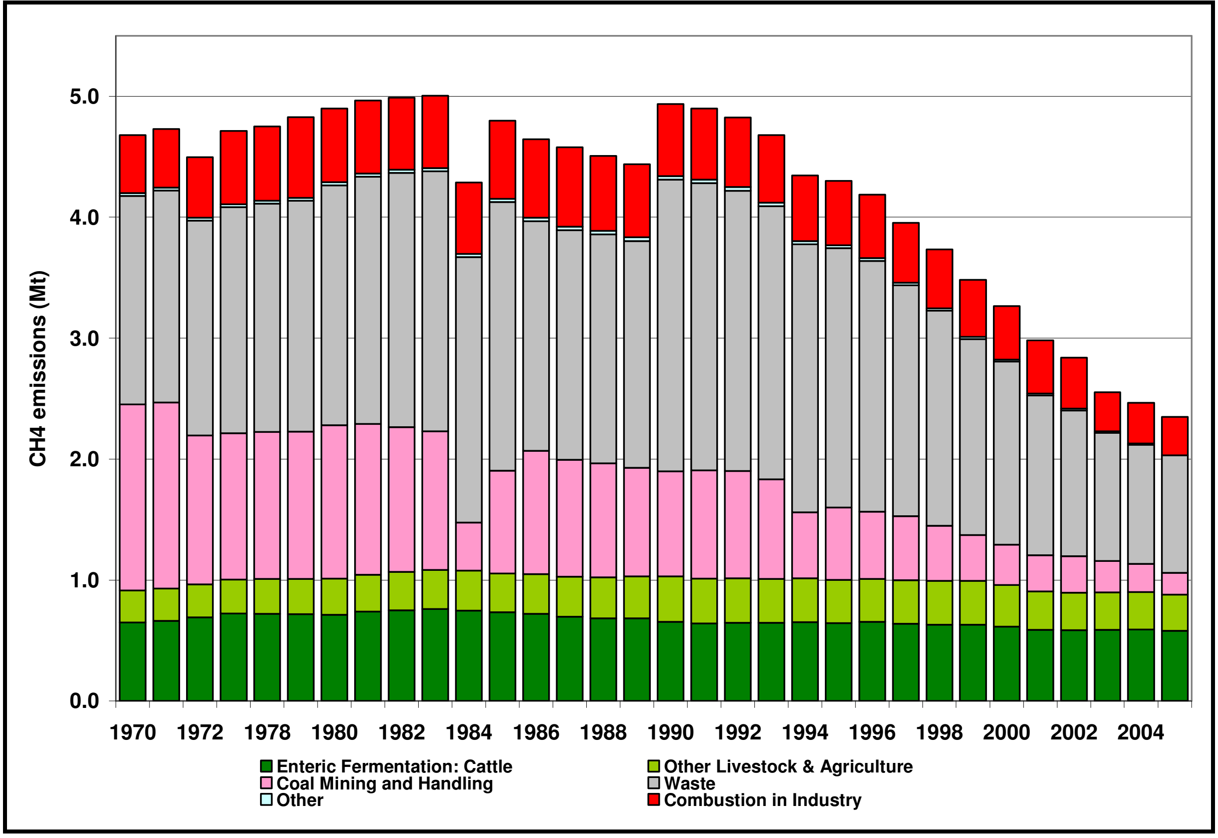
7.3.1 Key Source Description

The largest source of methane (CH_4) 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 from landfills accounts for the second largest source.

7.3.2 Total CH_4 Emissions

Since 1970, the total methane emission in the UK has declined by 50%, although this has not been a steady decrease with emissions actually increasing throughout the seventies, reaching a peak in 1983 (Figure 7.6). 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 7.5). The patterns of emissions from each of these sectors are discussed in the following sections.

Figure 7.6 Time Series of CH_4 Emissions (Mtonnes)



7.3.3 Landfill

Landfills are estimated to account for 39% of the UK's methane emissions in 2005. 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.

7.3.4 Agriculture

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

	NFR Codes	1970	1980	1990	2000	2001	2002	2003	2004	2005	2005%
BY UN/ECE CATEGORY[2]											
Combustion in Industry	1A1, 1A2	370	168	96	60	56	48	48	46	48	2.0%
Road Transport	1A3b	22	25	29	15	13	12	10	9	8	0.3%
Other Transport (Rail, Aviation, Navigation)	1A3aii(i)-1A3aii(ii), 1A3c-1A3eii, 1A4bii, 1A4cii, 1A5b	1	1	1	1	1	1	1	1	1	0.0%
Coal Mining and Handling	1B1a	1540	1269	870	333	301	301	259	234	181	7.7%
Production Processes	1B1ab-2C	22	88	120	68	68	58	54	58	47	2.0%
Natural gas	1B2b	88	354	379	315	317	317	223	231	224	9.5%
Enteric Fermentation: Cattle	4A1	648	712	654	613	588	584	589	589	580	24.6%
Enteric Fermentation: Sheep	4A10	128	150	207	201	176	172	172	173	165	7.0%
Other Livestock & Agriculture	4A3-9, 4B	137	149	168	146	141	139	138	138	134	5.7%
Waste	6	1723	1984	2411	1515	1321	1205	1059	986	970	41.1%
By FUEL TYPE											
Solid		332	141	67	28	24	20	18	16	14	0.6%
Petroleum		32	33	36	20	18	16	15	14	13	0.6%
Gas		26	18	23	27	26	23	25	25	29	1.2%
Non-Fuel		4289	4708	4811	3192	2913	2779	2497	2411	2302	97.6%
TOTAL		**4679**	**4900**	**4937**	**3266**	**2981**	**2838**	**2554**	**2465**	**2358**	**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

7.3.5 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 2005 this had reduced to just 8%. The strong correlation between coal production and methane emission is clearly illustrated in Figure 7.6 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.

7.3.6 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.

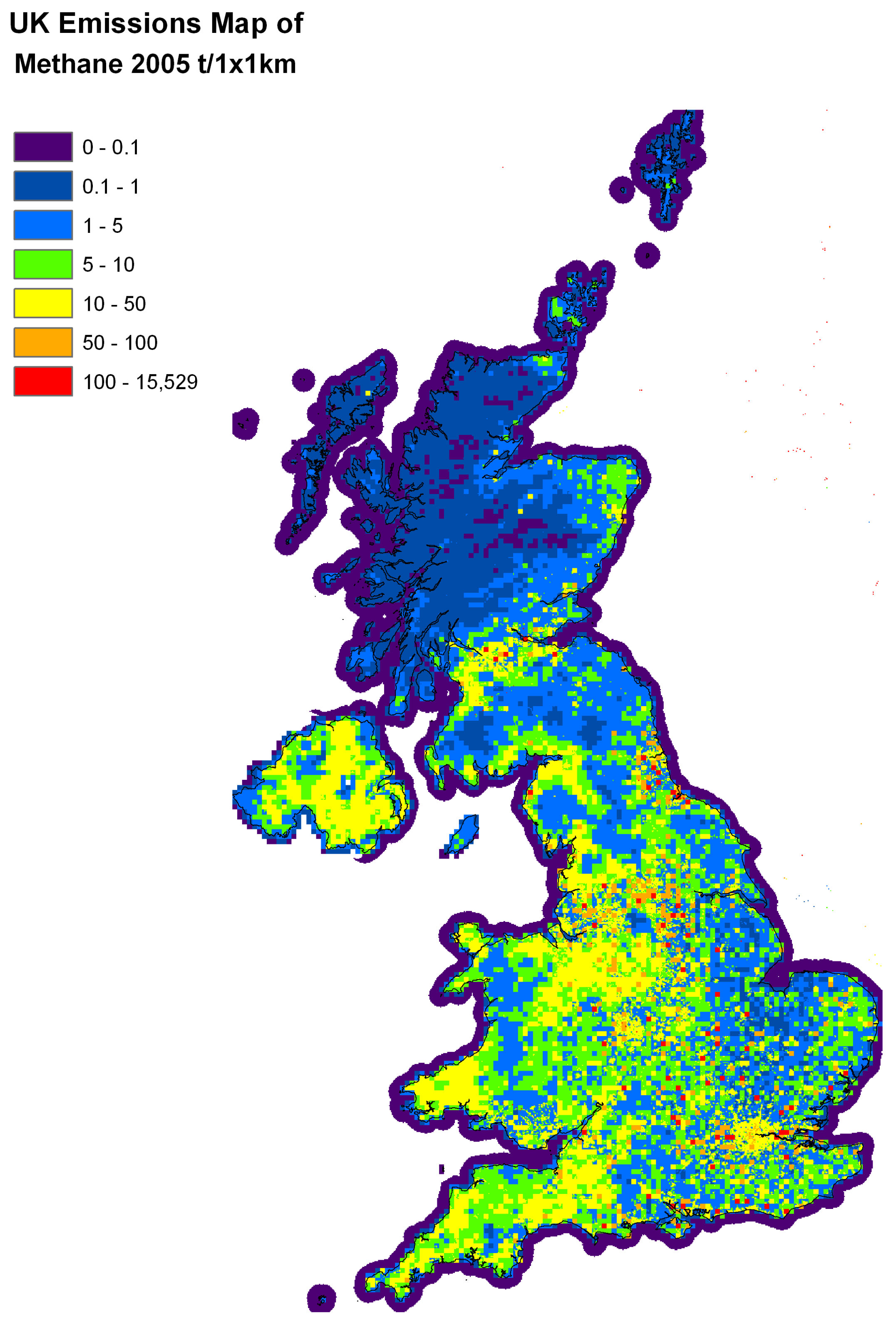
7.3.7 Offshore Oil and Gas

Methane emissions from offshore activities only account for 2% 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.

7.3.8 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 7.7 Spatially Disaggregated UK Emissions of CH_4 Map



7.4 NITROUS OXIDE

7.4.1 Key Source Description

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 7.6 and Figure 7.8).

7.4.2 Total N_2O Emissions

Table 7.6 UK Emissions of Nitrous Oxide (N_2O) by aggregated UN/ECE[1] Category and Fuel (ktonnes)

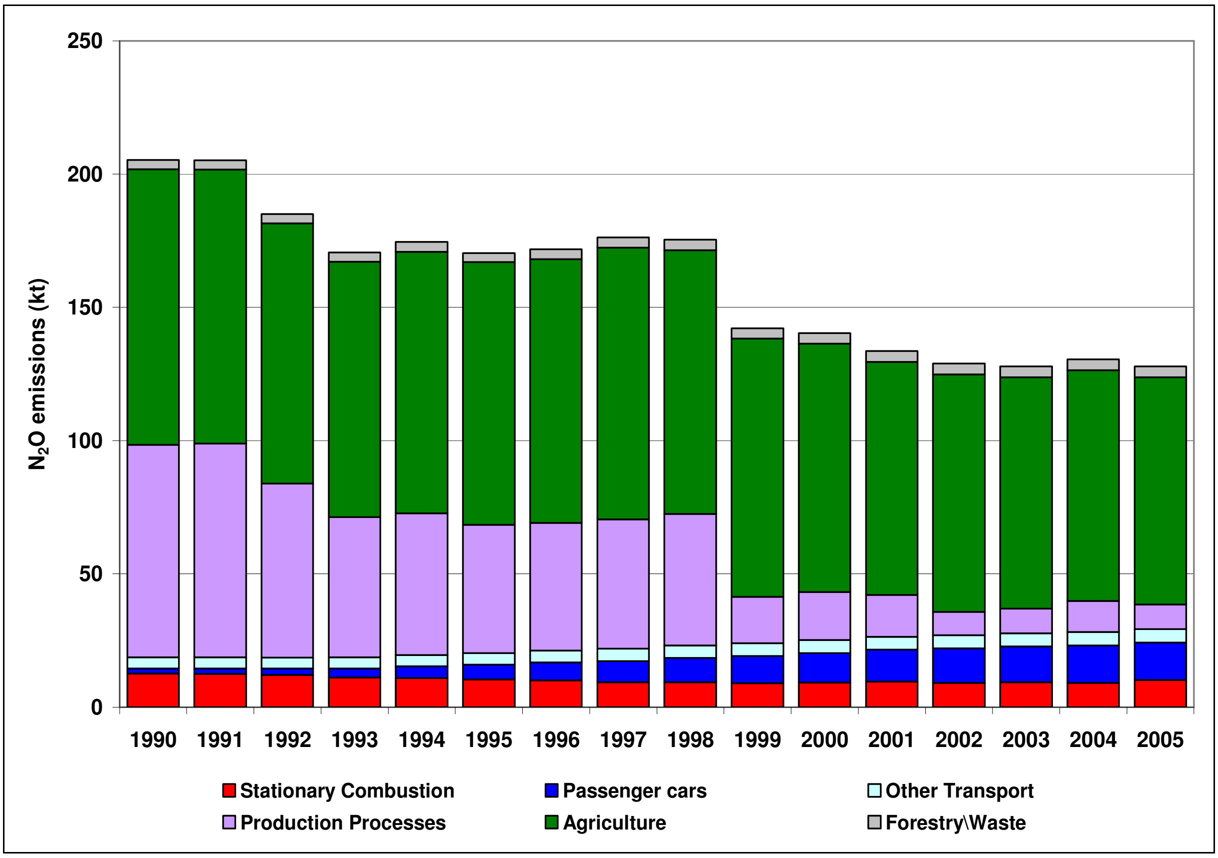
	NFR Codes	1970	1980	1990	2000	2001	2002	2003	2004	2005	2005%
BY UN/ECE CATEGORY[2]											
Public Electricity and Heat Production	1A1a	5.2	5.8	5.4	3.0	3.3	3.1	3.4	3.3	3.4	3%
Stationary Combustion	1A1b-c, 1A2a	6.3	3.2	2.4	2.0	1.9	1.8	1.7	1.7	2.5	2%
Industrial off-road mobile machinery	1A2f	8.2	4.8	4.8	4.2	4.3	4.2	4.2	4.1	4.2	3%
Passenger cars	1A3bi	0.8	1.2	2.0	11.1	12.0	12.9	13.4	14.0	14.1	11%
Road Transport	1A3b	0.9	1.0	1.3	2.0	2.0	2.1	2.2	2.3	2.3	2%
Other Transport	1A3aii(i)- 1A3aii(ii), 1A3c- 1A3eii, 1A4bii, 1A4cii 1A5b	2.6	2.7	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2%
Production Processes	1B, 2	14.3	16.1	79.7	18.1	15.7	8.8	9.2	11.7	9.2	7%
Direct Soil Emission	4D1	61.2	91.9	98.1	88.4	82.8	84.6	82.5	82.1	81.0	63%
Other Agriculture	4B, 4F	5.4	5.9	5.4	4.8	4.6	4.5	4.4	4.4	4.3	3%
Forestry\Waste	5, 6	3.9	3.9	3.5	4.0	4.1	4.1	4.1	4.1	4.1	3%
By Fuel Type											
Solid				7.9	4.2	4.5	4.2	4.4	4.2	4.2	3%
Petroleum				10.0	19.7	20.7	21.6	22.2	22.8	23.2	18%
Gas				0.7	1.0	1.0	1.0	1.0	1.0	1.7	1%
Non-Fuel				186.6	115.4	107.4	102.2	100.4	102.5	98.8	77%
TOTAL		**108.8**	**136.5**	**205.3**	**140.3**	**133.6**	**128.9**	**127.9**	**130.4**	**127.9**	**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 7.8 Time Series of N_2O Emissions (ktonnes)



7.4.3 Agriculture

The calculation of emissions from agricultural soils and animal wastes has 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 63% of total UK emissions. The most significant sources are fertiliser application and emissions indirectly from leaching.

7.4.4 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 2% of the total nitrous oxide emissions in 2005. 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.

7.4.5 Power Generation

The contribution from public power generation has been relatively constant between 1990 and 2005 in spite of the trend away from coal towards natural gas combustion.

7.4.6 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 2005 the proportion of vehicle kilometres travelled by cars equipped with catalytic converters has increased from <1% to 77% (Figure 7.9) 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 that 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 7.9 The Growth in the Number of Car Kilometres from Cars with Catalytic Converters

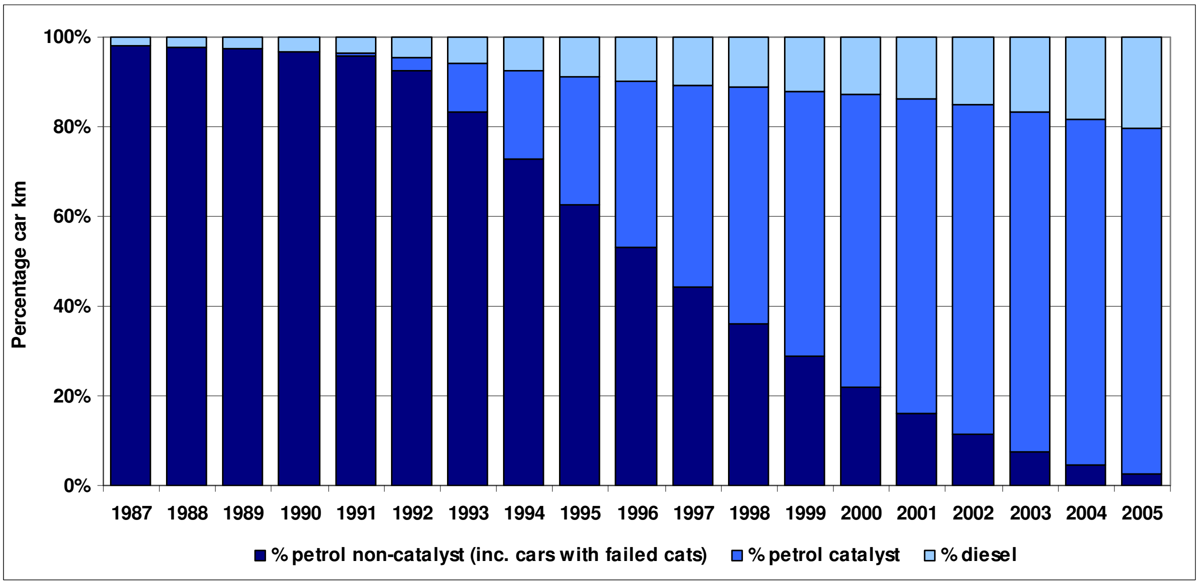
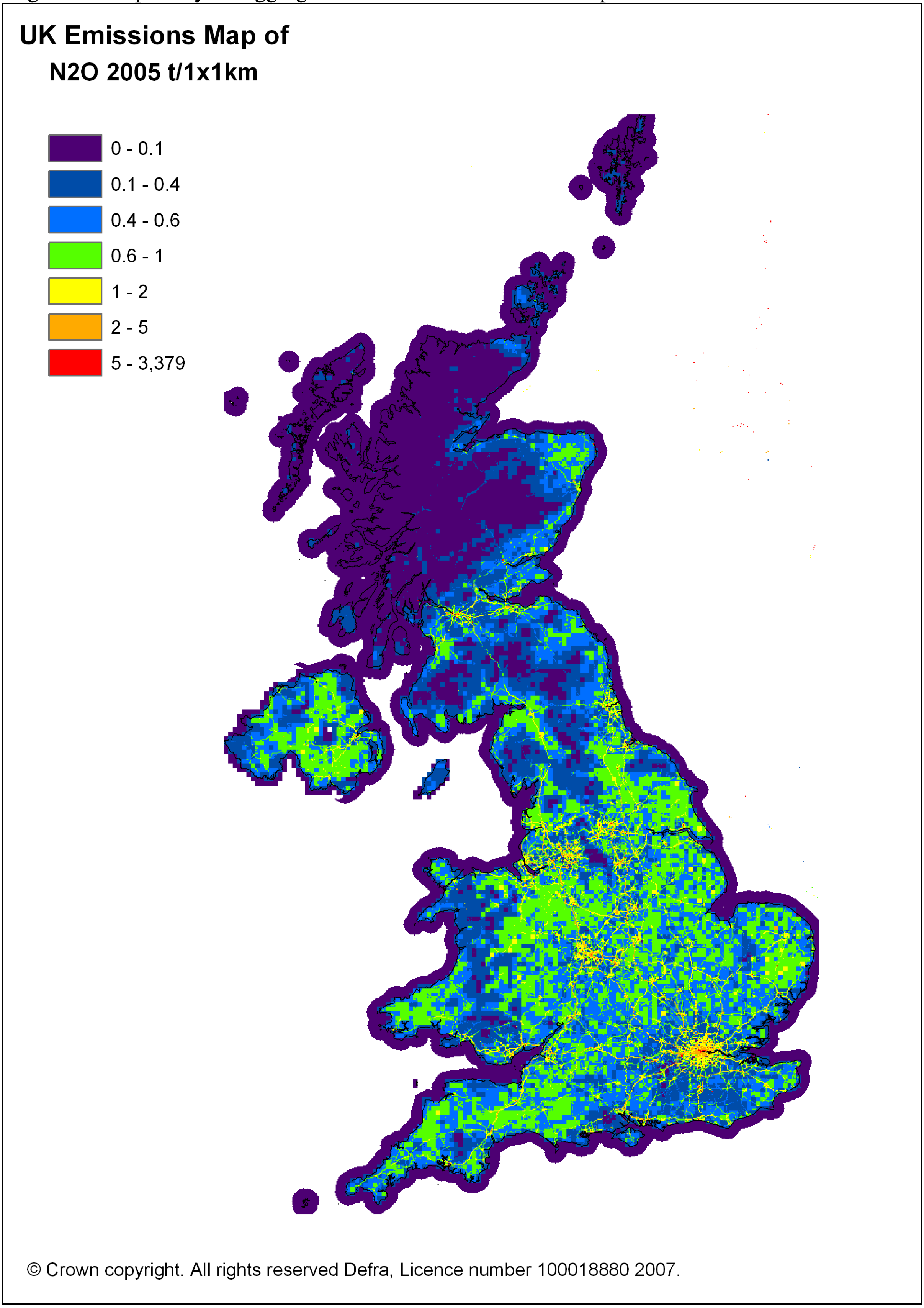


Figure 7.10 Spatially Disaggregated UK Emissions of N_2O Map



7.5 HFCS, PFCS AND SF_6

7.5.1 Hydrofluorocarbons

The UK emissions of HFCs are shown in Table 7.7. 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,* 2007) 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 2005. 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 2005, 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 19% over 1990-2005 and is characterised by the increasing use of HFCs offset by the large reduction in emissions from halocarbon production between 1998 and 2005.

Table 7.7 UK Emissions of HFCs (ktonnes C equivalent)

	NFR Codes	1990	2000	2001	2002	2003	2004	2005	2005%
METAL PRODUCTION	2C	0.0	0.0	0.0	0.0	0.0	0.3	0.5	0%
Halocarbons production (by-product)	2E1	3102	730	669	543	505	77	93	4%
Halocarbons use	2F	0	1757	1981	2170	2292	2363	2421	96%
Total		3102	2487	2649	2712	2797	2440	2515	100%

[1] Includes metered dose inhalers.

7.5.2 Perfluorocarbons

Table 7.8 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 2005, representing 44% 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 by 88% 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 25% of the UK total in 2005.

Table 7.8 UK Emissions of PFCs (ktonnes C equivalent)

	NFR Codes	1990	2000	2001	2002	2003	2004	2005	2005%
METAL PRODUCTION	2C	363	70	61	43	34	42	42	44%
Halocarbons production (by-product)	2E2	3	6	15	16	15	25	30	31%
Halocarbons use	2F	16	59	40	29	29	26	23	25%
Total		382	136	116	88	78	92	96	100%

7.5.3 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 7.9 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 2005.

The other main sources are from uses as a cover gas from the magnesium sector 25% of UK total) and manufacture of trainers (28% 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 11% since 1990.

Table 7.9 UK Emissions of Sulphur Hexafluoride (ktonnes C equivalent)

	NFR Codes	**1990**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2005 %**
METAL PRODUCTION	2C	116	298	206	231	183	106	78	25%
Halocarbons use	2F	165	192	182	181	178	202	233	75%
Total		281	490	389	412	361	308	312	100%

7.6 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 2005 Inventory.

Table 7.10 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.

8 Crown Dependencies and Overseas Territories

8.1 INTRODUCTION

The following chapter details greenhouse gas inventories compiled for UK Crown Dependencies (CDs) and greenhouse gas and air quality inventories for selected UK Overseas Territories (OTs), for the annual periods of 1990 to 2005 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 Guernsey[7]
- The Isle of Man
- The Falkland Islands
- The Cayman Islands
- Bermuda
- Montserrat
- Akrotiri and Dhekhelia[8]
- Gibraltar

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

[8] 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 8.1 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 2005 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, CO, SO_2 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.

GHG emission estimates have been compiled for the Overseas Territories and the Crown Dependencies but are not included here as they have been reported in the 'UK Greenhouse Gas Inventory, 1990 to 2005'[9].

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[9] http://www.naei.co.uk/reports.php

8.4 TABULATED EMISSIONS

8.4.1 THE BAILIWICK OF JERSEY

Table A 1.1 Jersey NO_x emissions (ktonnes)

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1	Energy - Power stations and small combustion sources	0.78	0.78	1.06	0.91	0.97	1.00	1.00	0.89	0.99	0.89	0.64	0.57	0.52	0.40	0.45	0.45
	Energy - road transport	1.03	1.01	0.99	0.95	0.91	0.84	0.75	0.71	0.64	0.57	0.50	0.46	0.41	0.35	0.25	0.25
	Energy - other mobile sources	7.05	6.80	6.95	7.35	6.83	6.76	6.73	6.59	6.46	6.62	6.71	6.65	6.58	6.58	6.58	6.58
2	Industrial processes																
3	Solvent use																
4	Agriculture																
5	Land use change and forestry																
6	Waste																
	TOTAL	**8.85**	**8.59**	**9.00**	**9.21**	**8.71**	**8.60**	**8.48**	**8.18**	**8.09**	**8.08**	**7.86**	**7.68**	**7.51**	**7.34**	**7.28**	**7.28**

Table A 1.2 Jersey CO emissions (ktonnes)

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1	Energy - Power stations and small combustion sources	1.28	1.28	1.33	1.31	1.31	1.32	1.31	1.29	1.30	1.30	1.26	1.24	1.24	1.22	1.23	1.23
	Energy - road transport	6.32	6.06	5.66	5.16	4.67	4.67	4.21	3.74	3.16	2.85	2.30	1.96	1.63	1.38	1.09	1.09
	Energy - other mobile sources	1.77	1.70	1.74	1.79	1.71	1.69	1.68	1.67	1.65	1.68	1.69	1.66	1.63	1.63	1.63	1.63
2	Industrial processes																
3	Solvent use																
4	Agriculture																
5	Land use change and forestry																
6	Waste																
	TOTAL	**9.36**	**9.04**	**8.73**	**8.26**	**7.69**	**7.67**	**7.21**	**6.70**	**6.12**	**5.83**	**5.25**	**4.87**	**4.50**	**4.23**	**3.95**	**3.95**

Table A 1.3 Jersey SO_2 emissions (ktonnes)

		1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
1	Energy - Power stations and small combustion sources	1.90	1.90	2.75	2.32	2.45	2.53	2.48	2.02	2.26	2.13	1.33	1.10	0.97	0.59	0.73	0.73
	Energy - road transport	0.05	0.05	0.05	0.04	0.05	0.04	0.03	0.03	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00
	Energy - other mobile sources	15.57	15.35	15.48	15.88	15.37	15.32	15.28	15.14	15.02	15.17	15.26	15.21	15.16	15.16	15.16	15.16
2	Industrial processes																
3	Solvent use																
4	Agriculture																
5	Land use change and forestry																
6	Waste																
	TOTAL	**17.52**	**17.30**	**18.28**	**18.24**	**17.88**	**17.89**	**17.80**	**17.19**	**17.29**	**17.32**	**16.60**	**16.31**	**16.13**	**15.75**	**15.89**	**15.89**

Table A 1.4 Jersey NMVOC emissions (ktonnes)

		1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
1	Energy - Power stations and small combustion sources	0.09	0.09	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.09	0.09
	Energy - road transport	0.89	0.88	0.85	0.79	0.74	0.67	0.59	0.53	0.44	0.39	0.31	0.26	0.22	0.18	0.13	0.13
	Energy - other mobile sources	0.59	0.58	0.59	0.60	0.58	0.58	0.57	0.57	0.56	0.57	0.56	0.56	0.57	0.55	0.55	0.55
	Energy - fugitive emissions from fuels	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.08
2	Industrial processes																
3	Solvent use	1.12	1.03	0.94	0.84	0.79	0.73	0.70	0.66	0.61	0.59	0.58	0.57	0.55	0.53	0.50	0.50
4	Agriculture																
5	Land use change and forestry																
6	Waste																
	TOTAL	**2.79**	**2.67**	**2.54**	**2.41**	**2.28**	**2.14**	**2.04**	**1.92**	**1.80**	**1.73**	**1.63**	**1.56**	**1.50**	**1.43**	**1.35**	**1.35**

8.4.2 THE BAILIWICK OF GUERNSEY

Table A 2.1 Guernsey NO_x emissions (ktonnes)

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1	Energy - Power stations and small combustion sources	0.48	0.57	0.49	0.51	0.51	0.53	0.56	0.57	0.58	0.57	0.57	0.20	0.20	0.22	0.15	0.15
	Energy - road transport	0.85	0.83	0.79	0.76	0.71	0.69	0.65	0.66	0.57	0.57	0.53	0.50	0.39	0.35	0.26	0.26
	Energy - other mobile sources	2.16	2.16	2.16	2.16	2.16	2.16	2.33	2.32	2.35	2.32	2.57	2.57	2.61	2.61	2.61	2.61
2	Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Solvent use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Agriculture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Land use change and forestry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	**3.49**	**3.57**	**3.44**	**3.44**	**3.39**	**3.39**	**3.53**	**3.55**	**3.50**	**3.47**	**3.66**	**3.27**	**3.20**	**3.18**	**3.01**	**3.01**

Table A 2.2 Guernsey CO emissions (ktonnes)

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1	Energy - Power stations and small combustion sources	0.11	0.13	0.11	0.12	0.12	0.12	0.13	0.13	0.13	0.13	0.13	0.06	0.06	0.06	0.04	0.04
	Energy - road transport	3.85	3.53	3.19	2.88	2.68	2.68	2.41	2.38	1.98	1.91	1.61	1.45	1.08	0.94	0.68	0.68
	Energy - other mobile sources	0.60	0.60	0.60	0.60	0.60	0.60	0.62	0.62	0.62	0.62	0.65	0.65	0.65	0.65	0.65	0.65
2	Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Solvent use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Agriculture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Land use change and forestry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	**4.55**	**4.26**	**3.90**	**3.60**	**3.40**	**3.40**	**3.16**	**3.14**	**2.73**	**2.66**	**2.40**	**2.16**	**1.79**	**1.65**	**1.37**	**1.37**

Table A 2.3 Guernsey SO_2 emissions (ktonnes)

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1	Energy - Power stations and small combustion sources	1.27	1.52	1.30	1.36	1.37	1.42	1.48	1.49	1.54	1.56	1.48	0.42	0.39	0.44	0.34	0.34
	Energy - road transport	0.05	0.05	0.04	0.04	0.04	0.04	0.03	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00
	Energy - other mobile sources	3.82	3.82	3.82	3.82	3.82	3.82	3.98	3.98	4.00	3.98	4.23	4.22	4.27	4.26	4.26	4.26
2	Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Solvent use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Agriculture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Land use change and forestry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	**5.13**	**5.38**	**5.16**	**5.22**	**5.23**	**5.28**	**5.48**	**5.49**	**5.56**	**5.55**	**5.72**	**4.65**	**4.66**	**4.71**	**4.60**	**4.60**

Table A 2.4 Guernsey NMVOC emissions (ktonnes)

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1	Energy - Power stations and 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	0.00
	Energy - road transport	0.63	0.59	0.55	0.49	0.45	0.41	0.37	0.36	0.30	0.28	0.24	0.21	0.15	0.13	0.09	0.09
	Energy - other mobile sources	4.09	4.09	4.09	4.09	4.09	4.09	4.33	4.32	4.48	4.32	4.41	4.40	4.66	4.65	4.63	4.63
	Energy - fugitive emissions from fuels	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05
2	Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Solvent use	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
4	Agriculture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Land use change and forestry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Waste	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	TOTAL	**5.27**	**5.23**	**5.18**	**5.13**	**5.08**	**5.04**	**5.25**	**5.22**	**5.32**	**5.15**	**5.19**	**5.15**	**5.35**	**5.31**	**5.24**	**5.24**

8.4.3 THE ISLE OF MAN

Table A 3.1 The Isle of Man NO_x emissions (ktonnes)

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1	Energy - Power stations and small combustion sources	0.51	0.53	0.53	0.55	0.55	0.59	0.62	0.66	0.70	0.74	0.63	0.33	0.31	0.31	0.53	0.53
	Energy - road transport	0.75	0.74	0.73	0.68	0.62	0.60	0.91	0.80	0.80	0.72	0.59	0.65	0.66	0.67	0.60	0.60
	Energy - other mobile sources	1.89	1.91	1.89	1.88	1.88	2.40	2.40	2.50	2.54	2.53	2.63	2.63	2.62	2.62	2.62	2.62
2	Industrial processes																
3	Solvent use																
4	Agriculture																
5	Land use change and forestry																
6	Waste																
	TOTAL	**3.15**	**3.18**	**3.16**	**3.11**	**3.05**	**3.59**	**3.93**	**3.96**	**4.04**	**3.99**	**3.85**	**3.61**	**3.59**	**3.60**	**3.75**	**3.75**

Table A 3.2 The Isle of Man CO emissions (ktonnes)

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1	Energy - Power stations and small combustion sources	0.11	0.11	0.11	0.12	0.12	0.13	0.13	0.14	0.15	0.16	0.14	0.09	0.09	0.09	0.15	0.15
	Energy - road transport	4.01	3.91	3.46	3.01	2.74	2.74	3.85	3.02	2.76	2.37	1.38	1.61	1.46	1.33	1.12	1.12
	Energy - other mobile sources	0.62	0.62	0.62	0.62	0.62	0.66	0.66	0.67	0.68	0.68	0.73	0.73	0.74	0.74	0.74	0.74
2	Industrial processes																
3	Solvent use																
4	Agriculture																
5	Land use change and forestry																
6	Waste																
	TOTAL	**4.74**	**4.64**	**4.19**	**3.74**	**3.47**	**3.53**	**4.64**	**3.84**	**3.60**	**3.21**	**2.26**	**2.44**	**2.29**	**2.15**	**2.01**	**2.01**

Table A 3.3 The Isle of Man SO_2 emissions (ktonnes)

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1	Energy - Power stations and small combustion sources	1.46	1.51	1.51	1.56	1.57	1.65	1.71	1.81	1.90	1.99	1.59	0.62	0.46	0.46	0.92	0.92
	Energy - road transport	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.00
	Energy - other mobile sources	4.90	4.92	4.90	4.89	4.89	5.41	5.41	5.51	5.56	5.55	5.62	5.62	5.61	5.61	5.61	5.61
2	Industrial processes																
3	Solvent use																
4	Agriculture																
5	Land use change and forestry																
6	Waste																
	TOTAL	**6.40**	**6.47**	**6.46**	**6.48**	**6.50**	**7.10**	**7.17**	**7.36**	**7.49**	**7.56**	**7.22**	**6.25**	**6.08**	**6.08**	**6.53**	**6.53**

Table A 3.4 The Isle of Man NMVOC emissions (ktonnes)

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1	Energy - Power stations and 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	0.01	0.01
	Energy - road transport	0.58	0.57	0.56	0.49	0.43	0.40	0.56	0.45	0.41	0.35	0.22	0.24	0.22	0.20	0.16	0.16
	Energy - other mobile sources	0.19	0.21	0.22	0.21	0.20	0.23	0.25	0.24	0.24	0.26	0.25	0.25	0.24	0.24	0.24	0.24
	Energy - fugitive emissions from fuels	0.59	0.60	0.57	0.55	0.54	0.84	0.72	0.74	0.72	0.47	0.66	0.66	0.66	0.66	0.66	0.66
2	Industrial processes																
3	Solvent use	0.57	0.55	0.52	0.49	0.47	0.44	0.43	0.41	0.40	0.40	0.40	0.39	0.38	0.37	0.36	0.36
4	Agriculture																
5	Land use change and forestry																
6	Waste	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00
	TOTAL	**1.95**	**1.96**	**1.89**	**1.77**	**1.66**	**1.93**	**1.98**	**1.86**	**1.79**	**1.49**	**1.53**	**1.56**	**1.51**	**1.48**	**1.43**	**1.43**

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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. One of these is that 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, 2006). 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