UK Emissions of Air Pollutants 1970 to 2007

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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 the Department for Environment Food and Rural Affairs (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 2007. Details are provided of the economic sectors that contribute to the emissions, the time trend in emission and the factors that have affected the trend and the spatial distribution of the emissions. 44 pollutant species are included in the 2007 annual inventory including 10 groups of related pollutant compounds which include non-methane volatile organic compounds (NMVOCs), hydrofluorocarbons (HFC) perfluorocarbons (PFC) and a number of groups of persistent organic pollutants. Size fractionation is available for particulate matter, speciation is available for 500 NMVOCs and the oxidation states of Hg, Ni and Cr are given. 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)
- Polycyclic aromatic hydrocarbons, (PAHs) * †
- 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, (PAHs) * †
- dioxins and furans, (PCDDs/Fs)
- polychlorinated biphenyls, (PCBs)
- pesticides:
  - lindane, hexachlorobenzene (HCB), pentachlorophenol (PCP)
- short-chain chlorinated paraffins, (SCCPs)
- polychlorinated napthalenes, (PCNs)
- polybrominated diphenyl ethers, (PBDEs)

Heavy Metals

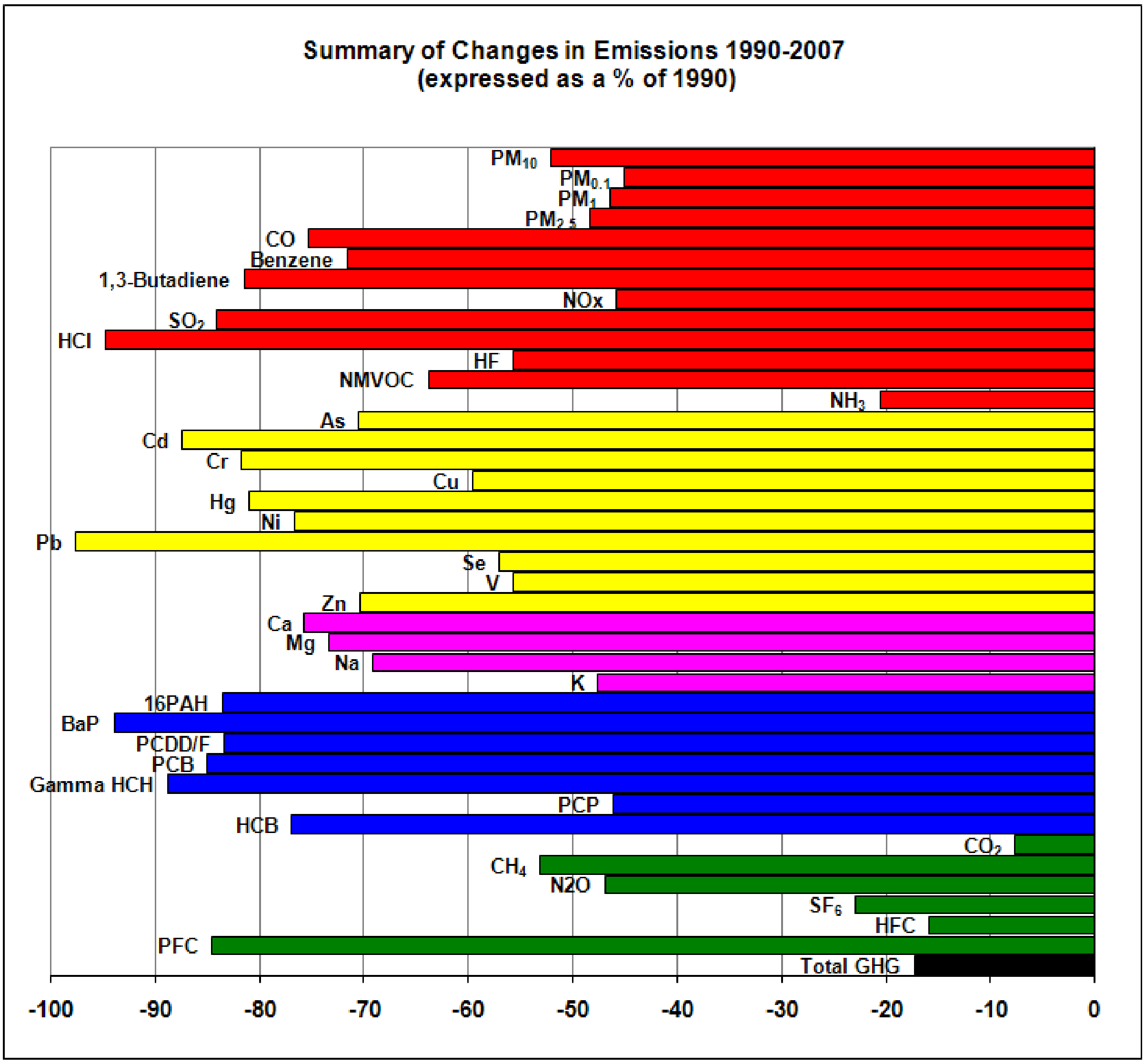
- arsenic, (As)
- beryllium, (Be)
- cadmium, (Cd)
- chromium, (Cr) *
- copper, (Cu)
- lead, (Pb)
- manganese, (Mn)
- mercury, (Hg) *
- nickel, (Ni) *
- tin, (Sn)
- selenium, (Se)
- vanadium, (V)
- zinc, (Zn)

*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.

In the 2007 inventory, there is considerable interest in the four pollutants covered under the National Emissions Ceilings Directive (NECD), as we approach the 2010 target year. The UK has met these targets for volatile organic compounds and ammonia, very little reduction is required for sulphur dioxide, whilst a considerable reduction is required for NO_x. This is considered further in Section 1.2.6 on projections.

The change in emissions for these pollutants between the 1990 and is summarised in the following plot expressed as a percentage change from the 1990 values. Emissions of all pollutants have decreased during this period.



3 **Particulate Matter (PM) –** The UK emissions of PM_{10} declined by 52% between 1990 and 2007, giving an emission of 0.14 Mt in 2007. This reflects a trend away from coal use particularly by domestic users. Coal combustion in residential plants and road transport together contributed 22% of UK emissions of PM_{10} in 2007. 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 slightly smaller amount, the largest source sector being road transport, accounting for 23% of the 2007 total emission.

4 **Black Smoke -** Black smoke emissions in the UK have declined significantly (by some 84% between 1970 and 2007). Emissions in 2007 were estimated to be 180 kt. These estimates are based on old measurement data and are hence very uncertain. The largest

5 source sector of black smoke is road transport.

6 **Carbon Monoxide (CO) -** Emissions in 2007 (2.1 Mt) represent a 75% reduction on the emissions in 1990. UK emissions of CO are dominated by those from road transport (37% of UK emissions in 2007). The change in emissions between 1990 and 2007 is dominated by the reduction in emissions from the road transport sector, caused by the increased use of three-way catalytic converters in cars.

7 **Benzene** –Emissions have decreased by 72% between 1990 and 2007, giving an emission of 16.8 kt in 2007. Fuel combustion in the residential sector is the most significant source of benzene, accounting for some 48% of UK emissions in 2007. The next most significant source is emissions from petrol fuelled passenger cars (10%). 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 European Directives on fuel quality being introduced.

8 **1,3-Butadiene** – Emissions in 2007 were estimated to be 2.4 kt, representing a decrease of 81% between 1990 and 2007. Emissions of 1,3-butadiene are dominated by fuel combustion in the road transport sector, which account for some 53% of the 2007 UK emissions. There have been significant reductions in the emissions from this sector due to the increase in the number of cars equipped with three-way catalytic converters.

9 **Nitrogen Oxides (NO_x) -** UK emissions of NO_x were approximately 2.7 Mt in 1990. Emissions have fallen significantly to around 1.5 Mt in 2007, representing a 46% reduction on the 1990 emissions estimate. This is primarily a consequence of: abatement measures in road transport and coal fired power stations and the increased use of gas for power generation. Together road transport and power stations contribute 54% of UK emissions in 2007.

10 **Sulphur Dioxide (SO_2) -** UK emissions of sulphur dioxide have fallen from 3.7 Mt in 1990 to 0.6 Mt in 2007, representing a decrease of 84%. 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 63% of the 2007 UK SO_2 emissions.

11 **Hydrogen Chloride (HCl) -** UK emissions of hydrogen chloride have decreased by 95% between 1990 and 2007, giving an emission of 14 kt in 2007. This reduction is largely as a result of declining coal use.

12 **Hydrogen Fluoride –** The total hydrogen fluoride emissions for 2007 are estimated to be 4.4 kt, representing a 56% reduction on the 1990 emission estimates. As with hydrogen chloride, the dominant source is coal combustion for public power contributing 62 % of emissions in 2007.

13 **Non-methane volatile organic compounds (NMVOC) -** UK emissions of NMVOC are estimated as 2.6Mt for 1990 and 0.94 Mt for 2007, thereby showing a decrease of 64%. Major sources of NMVOC emissions are the use of solvents and industrial processes. The observed decrease arises primarily from the impact of the Solvent emissions Directive and tighter European vehicle emission standards and fuel quality directives being introduced.

14 **Ammonia (NH_3) -** Total UK emissions of ammonia were estimated to be 0.29 Mt in 2007, compared to the 1990 estimate of 0.36 Mt, giving a 21% reduction. The agricultural sector accounted for 91% of ammonia emissions in 2007. There were increases in emissions from the road transport sector between 1990 and 2000, caused by the increased use of three-way catalytic converters. Improvements in these mean that emissions from the road

transport sector are now declining. There have been decreases in the agricultural sector between 1990 and 2007 due to decreased agricultural livestock numbers.

15 **Lead (Pb) -** UK emissions of lead have declined sharply following the switch from leaded to unleaded and lead replacement petrol. Emissions in 2007 are estimated to be 70 t, a decrease of 98% on the 1990 estimates. Road transport contributed only 2% of total UK emissions in 2007, compared to 74% in 1990.

16 **Persistent Organic Pollutants –** The 2007 UK emissions of persistent organic compounds may be summarised as follows: 1,280 t **PAH** (USEPA 16), 190g I-TEQ **PCDD/F** (grams of International "toxic equivalent[1]" of dioxins & furans) and 0.98 t **PCB**. Emissions from all three of these pollutant groups have greatly decreased. Emissions in 2007 equate to decreases of 84%, 83% and 85% on the 1990 emissions, for PAHs, PCDD/Fs and PCBs respectively.

17 **Carbon Dioxide (CO_2) –** Emission estimates for CO_2 from the UK show a decrease of 8% between 1990 and 2007, giving an emission of 149 Mt of carbon in 2007. The most significant reductions arise from the public power and industrial combustion sectors. 2007 road transport emissions accounted for 22.2% of the total emissions.

18 **Methane (CH_4) -** Estimates of methane emissions show a decrease of 53% from 1990 to 2007, giving emissions of 2.33 Mt (expressed as Mt of CH_4) in 2007. The largest sources are landfills, agriculture, natural gas distribution and coal mining. The reduction in emissions is largely due to the decline in the coal mining industry and increased levels of methane recovery on landfill sites.

19 **Nitrous Oxide (N_2O) -** UK emissions of nitrous oxide were 0.11 Mt (expressed as Mt of N_2O) in 2007, corresponding to a decrease of 47% between 1990 and 2007. Emissions of nitrous oxide are dominated by those arising from the direct soil emission and production processes. Emission estimates of N_2O are highly uncertain (see Section 7.4).

20 **HFC, PFC and SF_6-** The UK emissions in 2007 were HFCs: 2.6 Mt of carbon equivalent, PFCs: 0.1 Mt of carbon equivalent[2] and sulphur hexafluoride: 0.2 Mt of carbon equivalent. These correspond to reductions of 16%, 84% and 23% since 1990 for HFC, PFC and SF_6 respectively.

21 The 2007 emission inventory indicates that the dominant source of many air pollutants if fossil fuel combustion in road transport and the use of coal for power and heating (see table below).

[1] Toxic equivalents are used for PCDD/F to provide an estimate of the toxicity of the mixture of the 209 PCDD/Fs emitted from sources in terms of a mass of the most toxic PCDD/F

[2] A carbon equivalent is the mass of the fluorocarbon released expressed in terms of an equivalent amount of carbon in carbon dioxide.

Road Transport and Coal Combustion Contribution to Emissions of Total UK Atmospheric Emissions of Selected Pollutants (2007)

Pollutant	Total Coal Combustion (% share of UK total)	Road Transport	Total Contribution
Hydrogen Chloride	92%	0%	92%
Hydrogen Fluoride	85%	0%	85%
Tin	13%	22%	35%
16 Polycyclic Aromatic Hydrocarbons	9%	0%	9%
Sulphur Dioxide	72%	0%	73%
Beryllium	22%	52%	74%
1,3-Butadiene	0%	53%	53%
Carbon Monoxide	18%	37%	56%
Selenium	26%	0%	26%
Nitrogen Oxides	22%	30%	52%
Copper	5%	0%	5%
Magnesium	34%	0%	34%
PM_{10}	10%	18%	28%
Carbon	25%	22%	47%
Sodium	31%	0%	31%
Benzo[a]pyrene	18%	0%	18%
Manganese	27%	3%	29%
Benzene	2%	13%	15%
Potassium	13%	0%	13%
Arsenic	12%	0%	12%

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

GLOSSARY

Emission Units

Pollutant emissions are presented using a number of different mass and / or toxicity units, according to convenience, with specific reporting protocols including:

- NO_x emissions are quoted in terms of NO_x as NO_2
- SO_x emissions are quoted in terms of SO_x as SO_2
- Dioxins and Furans are quoted in terms of mass, but accounting for toxicity. This is the I-TEQ and is explained further in the relevant section.
- Pollutant emissions are quoted as mass of the full pollutant unless otherwise stated, e.g. ammonia emissions are the mass of ammonia emitted and not the mass of the nitrogen content of the NH_3.

Acronyms and Definitions

ABI	Annual Business Inquiry
ACTRAFFF	actual rail traffic database
AQD	Air Quality Directive
AQS	Air Quality Strategy
AS	Aviation Spirit
ATF	Aviation Turbine Fuel
ATM	Air Traffic Movement
ATOC	Association of Train Operating Companies
AUP	Auxiliary Power Unit
BAU	Business as usual
BCA	British Cement Association
BCF	British Coatings Federation
BERR	Department for Business, Enterprise & Regulatory Reform
BGS	British Geological Survey
BMW	Biodegradable Municipal Waste
CAA	Civil Aviation Authority
CCA	Climate Change Agreement
CCGT	Combined Cycle Gas Turbine
CD	Crown Dependency
CEH	Centre for Ecology and Hydrology
CHP	Combined heat and power
DA	Devolved Administrations
DECC	Department of Energy & Climate Change
Defra	Department for Environment, Food and Rural Affairs
DfT	Department for Transport
DERV	Diesel Fuel
DoENI	Department of Environment Northern Ireland
DRDNI	Department for Regional Development Northern Ireland
DPF	Diesel Particulate Filters
DUKES	Digest of UK Energy Statistics
EMEP	European Monitoring and Evaluation Program
EE	Energy Efficiency
EEMS	Environmental Emissions Monitoring System
EPR	Environmental Permitting Regulations
EU ETS	European Union Emissions Trading Scheme
ESWNI	England, Scotland, Wales, Northern Ireland
FGD	Flue gas desulphurisation
GDP	Gross Domestic Product
GCV	Gross Calorific Value
GHG	Greenhouse gases
GHGI	Greenhouse gas inventory
GCA	Gross Value Added
GWh	Giga Watt Hour (unit of energy)

GWP	Global Warming Potential
HGV	Heavy Goods Vehicle
HM	Heavy Metals
ICAO	International Civil Aviation Organisation
IEF	Implied Emission Factor
IPC	Industrial Pollution Control
IPPC	Integrated Pollution Prevention and Control
ISR	Inventory of Statutory Releases (DoENI)
ISSB	Iron and Steel Statistics Bureau
KtC	Kilo tonne of Carbon
KtC-e	Kilo tonne of Carbon-equivalent (taking account of GWP)
LAEI	London Atmospheric Emissions Inventory
LA-IPPC	Local Authority Integrated Pollution Prevention and Control
LGV	Larger Goods Vehicles
LPG	Liquefied petroleum gas
LRTAP	Convention on Long-Range Transboundary Air Pollution
LTO	Landing & Take Off
MPP	Major Power Producers (i.e. most power station operators)
MSW	Municipal Solid Waste
NFR	Nomenclature for Reporting
NAEI	National Atmospheric Emissions Inventory
NEC	National Emission Ceilings Directive
NMVOC	Non-Methane Volatile Organic Compounds
OCGT	Open Cycle Gas Turbine
ONS	Office for National Statistics
OT	Overseas Territories
PAH	Polycyclic Aromatic Hydrocarbons
PAMs	Policies and Measures
PI	Pollution Inventory (of the Environment Agency of England & Wales)
POC	Port of call
PPC	Pollution Prevention and Control
PRODCOM	PRODuction COMmunautaire
PSDH	Project for the Sustainable Development of Heathrow
QA/QC	Quality Control/Quality Assurance
RASCO	Regional Air Services Co-ordination
RESTATs	Renewable Energy Statistics (published by DECC)
RTFO	Renewable Transport Fuels Obligation
SCCP	Short Chain Chlorinated Paraffins
SEPA	Scottish Environmental Protection Agency
SPRI	Scottish Pollutant Release Inventory
SWA	Scotch Whisky Association
THC	Total Hydrocarbons
TSP	Total Suspended Particulate
TRL	Transport Research Laboratory
TFEIP	Task Force on Emission Inventories and Projections
UEP	Updated Energy Projection (UK energy forecasts produced by DECC)
UKCCP	UK Climate Change Programme
UKMY	UK Minerals Yearbook
UKPIA	UK Petroleum Industries Association
UNECE	United Nations Economic Commissions for Europe
US EPA	United States Environment Protection Agency
ULSP	Ultra-low Sulphur Petrol
WML	Waste Management Licensing
WID	Waste Incineration Directive

Contents

GLOSSARY ... *ix*
Emission Units ... *ix*
Acronyms and Definitions ... *ix*

1 INTRODUCTION ... 1

1.1 AN INTRODUCTION/BACKGROUND TO EMISSION INVENTORIES ... 1
1.1.1 Nomenclature of the inventory ... *2*
1.2 THE UK NATIONAL ATMOSPHERIC EMISSIONS INVENTORY ... 2
1.2.1 International Commitments ... *3*
1.2.1.1 International Review ... 5
1.2.2 National Information ... *5*
1.2.3 Information Dissemination ... *8*
1.2.4 Methodology ... *10*
1.2.5 Mapping Emissions ... *11*
1.2.6 Projections ... *13*
1.2.7.1 REVIEW OF THE EMEP / EEA GUIDEBOOK AND EMEP REPORTING GUIDELINES ... 17
1.2.7.2 ROAD TRANSPORT ... 17
1.2.7.3 CEH AMMONIA REVIEW ... 19
1.2.7.4 INDUSTRIAL, COMMERCIAL & PUBLIC SECTOR COMBUSTION ... 19
1.2.7.5 HEAVY METALS ... 19
1.2.7.6 WASTE OIL USE AS FUEL ... 19
1.2.7.7 RAIL AND OFF ROAD MACHINERY ... 20
1.2.7.8 REVISIONS TO NAEI ENERGY DATA ... 20
1.2.7 Planned improvements ... *20*
1.3 UK POLLUTION INVENTORIES ... 24
1.3.1 The Environment Agency of England & Wales - Pollution Inventory ... *24*
1.3.2 The Scottish Environmental Protection Agency – SPRI Inventory ... *24*
1.3.3 The Northern Ireland Department of Environment – ISR Inventory ... *24*

2 AIR QUALITY POLLUTANTS ... 25

2.1 INTRODUCTION ... 25
2.1.1 Transboundary air pollution ... *26*
2.1.2 Local Air Quality ... *29*
2.2 AMMONIA ... 31
2.2.1 Key Source Description ... *31*
2.2.2 Total NH_3 Emissions ... *31*
2.2.3 Agricultural Sources ... *32*
2.2.4 Other Sources ... *32*
2.3 BENZENE ... 35
2.3.1 Key Source Description ... *35*
2.3.2 Total Benzene Emissions ... *35*
2.4 1,3-BUTADIENE ... 38
2.4.1 Key Source Description ... *38*
2.4.2 Total 1,3-Butadiene Emissions ... *38*
2.5 CARBON MONOXIDE ... 41
2.5.1 Key Source Description ... *41*
2.5.2 Total Carbon Monoxide Emissions ... *41*
2.5.3 Transport ... *44*
2.5.4 Other Sources ... *44*
2.6 HYDROGEN CHLORIDE ... 44
2.6.1 Key Source Description ... *44*
2.6.2 Total Hydrogen Chloride Emissions ... *44*
2.7 HYDROGEN FLUORIDE ... 47
2.7.1 Key Source Description ... *47*
2.7.2 Total HF Emissions ... *47*

2.8 NITROGEN OXIDES 49
2.8.1 *Key Source Description* 49
2.8.2 *Total NO_x Emissions* 49
2.8.3 *Transport* 52
2.8.4 *Power Generation* 54
2.8.5 *Industry* 54
2.9 NON-METHANE VOLATILE ORGANIC COMPOUNDS 55
2.9.1 *Key Source Description* 55
2.9.2 *Total NMVOC Emissions* 55
2.9.3 *Solvent Use and Production Processes* 58
2.9.4 *Transport* 58
2.9.5 *Other Sectors* 58
2.9.6 *Speciation of NMVOCs* 59
2.9.7 *Photochemical Ozone Creation Potential* 61
2.10 PARTICULATE MATTER 63
2.10.1 *Key Source Description* 63
2.10.2 *PM_{10}* 64
2.10.2.1 Sources of emissions 64
2.10.2.2 PM_{10} Emission estimates 65
2.10.3 *Finer Particulates: $PM_{2.5}$, $PM_{1.0}$ and $PM_{0.1}$* 68
2.10.3.1 $PM_{2.5}$ Emission estimates 68
2.10.4 *Black Smoke* 71
2.11 SULPHUR DIOXIDE 71
2.11.1 *Key Source Description* 71
2.11.2 *Total SO_2 Emissions* 71
2.11.3 *Power Generation* 74
2.11.4 *Industry* 74
2.11.5 *Transport* 74
2.11.6 *Other* 74
2.12 ACCURACY OF EMISSION ESTIMATES OF AIR QUALITY POLLUTANTS 75
2.12.1 *Ammonia* 75
2.12.2 *Benzene and 1,3-butadiene* 75
2.12.3 *Carbon monoxide* 75
2.12.4 *Hydrogen Chloride* 76
2.12.5 *Hydrogen Fluoride* 76
2.12.6 *Nitrogen oxides* 76
2.12.7 *Non-Methane Volatile Organic Compounds* 76
2.12.8 *Particulate Matter Estimates* 76
2.12.9 *Black Smoke Estimates* 77
2.12.10 *Sulphur Dioxide* 77

3 HEAVY METAL EMISSION ESTIMATES 78

3.1 INTRODUCTION 78
3.1.1 *UN/ECE Heavy Metals Protocol* 78
3.2 ARSENIC 81
3.3 BERYLLIUM 82
3.4 CADMIUM 83
3.5 CHROMIUM 84
3.5.1 *Speciation of Chromium* 86
3.6 COPPER 86
3.7 LEAD 88
3.8 MANGANESE 89
3.9 MERCURY 90
3.9.1 *Speciation of Mercury Emissions* 92
3.10 NICKEL 92
3.10.1 *Speciation of Nickel Emissions* 94
3.11 SELENIUM 94
3.12 TIN 95
3.13 VANADIUM 96

3.14 ZINC 98
3.15 SPATIAL DISAGGREGATION OF HEAVY METALS 100
3.16 ACCURACY OF EMISSION ESTIMATES OF HEAVY METALS 105

4 BASE CAPTIONS 106

4.1 INTRODUCTION 106
4.2 BACKGROUND....106
4.3 STATIONARY COMBUSTION OF FOSSIL FUELS 107
4.4 MINERAL EXTRACTION PROCESSES 107
4.5 PROCESSES IN THE MINERAL PRODUCTS INDUSTRY....108
4.6 INDUSTRIAL PROCESSES USING LIMESTONE, DOLOMITE AND SODA ASH 108
4.7 SOIL LIMING AND CULTIVATION IN AGRICULTURE 108
4.8 CONSTRUCTION ACTIVITIES....108
4.9 MOBILE SOURCES....108
4.10 CALCIUM 109
4.11 MAGNESIUM 110
4.12 SODIUM 111
4.13 POTASSIUM 112
4.14 ACCURACY OF EMISSION ESTIMATES OF BASE CATIONS....113

5 PERSISTENT ORGANIC POLLUTANTS 114

5.1 INTRODUCTION 114
5.1.1.1 Persistent Organic Pollutants (POPs)....114
5.2 POLYCYCLIC AROMATIC HYDROCARBONS (PAHS) 116
5.2.1 Dioxins and Furans (PCDD/F)....122
5.2.1.1 Introduction....122
5.2.1.2 Production and Emissions to Air....123
5.2.1.3 Emission Estimates 123
5.2.2 Polychlorinated biphenyls (PCBs)....127
5.2.2.1 Introduction....127
5.2.2.2 Production and Emissions to Air....127
5.2.2.3 Emission Estimates 127
5.2.3 Pesticide Emissions 129
5.2.3.1 Introduction....129
5.2.3.2 Production and Emissions to Air....129
5.2.3.3 Lindane (γ-HCH)....129
5.2.3.4 Pentachlorophenol (PCP)....131
5.2.3.5 Hexachlorobenzene (HCB) 132
5.2.4 Short Chain Chlorinated Paraffins (SCCP)....134
5.2.4.1 Introduction....134
5.2.4.2 Production and Emissions to Air....134
5.2.4.3 Emission Estimates 134
5.2.5 Polychlorinated Napthalenes (PCN)....134
5.2.5.1 Introduction....134
5.2.5.2 Production and Consumption....134
5.2.5.3 Emission Estimates 135
5.2.6 Polybrominated Diphenyl Ethers (PBDEs) 135
5.2.6.1 Introduction....135
5.2.6.2 Production and Releases to Air 135
5.2.6.3 Emission Estimate....136
5.3 ACCURACY OF EMISSION ESTIMATES OF POPS 137

6 STRATOSPHERIC OZONE DEPLETORS 138

7 GREENHOUSE GAS EMISSIONS 139

7.1 INTRODUCTION 139
7.2 CARBON DIOXIDE 142
7.2.1 Key Source Description 142
7.2.2 Total CO_2 Emissions....142
7.2.3 Electricity Supply Industry 145
7.2.4 Domestic....147

7.2.5 *Industrial* ... *147*
7.2.6 *Transport* ... *147*
7.2.7 *Agriculture/Forests/Land Use Change* ... *148*
7.3 METHANE ... 148
7.3.1 *Key Source Description* ... *148*
7.3.2 *Total CH_4 Emissions* ... *148*
7.3.3 *Landfill* ... *149*
7.3.4 *Agriculture* ... *149*
7.3.5 *Coal mining* ... *150*
7.3.6 *Leakage from the Gas Distribution System* ... *150*
7.3.7 *Offshore Oil and Gas* ... *150*
7.3.8 *Sewage Disposal* ... *150*
7.4 NITROUS OXIDE ... 153
7.4.1 *Key Source Description* ... *153*
7.4.2 *Total N_2O Emissions* ... *153*
7.4.3 *Agriculture* ... *154*
7.4.4 *Production Processes* ... *154*
7.4.5 *Power Generation* ... *154*
7.4.6 *Road Transport* ... *154*
7.5 HFCS, PFCS AND SF_6 ... 157
7.5.1 *Hydrofluorocarbons* ... *157*
7.5.2 *Perfluorocarbons* ... *158*
7.5.3 *Sulphur Hexafluoride* ... *159*
7.6 ACCURACY OF EMISSION ESTIMATES OF GREENHOUSE GASES ... 160

8 CROWN DEPENDENCIES AND OVERSEAS TERRITORIES ... 161

8.1 INTRODUCTION ... 161
8.2 REPORTING GREENHOUSE GASES ... 161
8.3 REPORTING AIR QUALITY POLLUTANTS ... 162
8.4 TABULATED EMISSIONS ... 163
8.4.1 *THE BAILIWICK OF JERSEY* ... *163*
8.4.2 *THE BAILIWICK OF GUERNSEY* ... *165*
8.4.3 *THE ISLE OF MAN* ... *167*

9 REFERENCES ... 169

ANNEX 1 DEFINITIONS OF UN/ECE SOURCE SECTORS...

1 Introduction

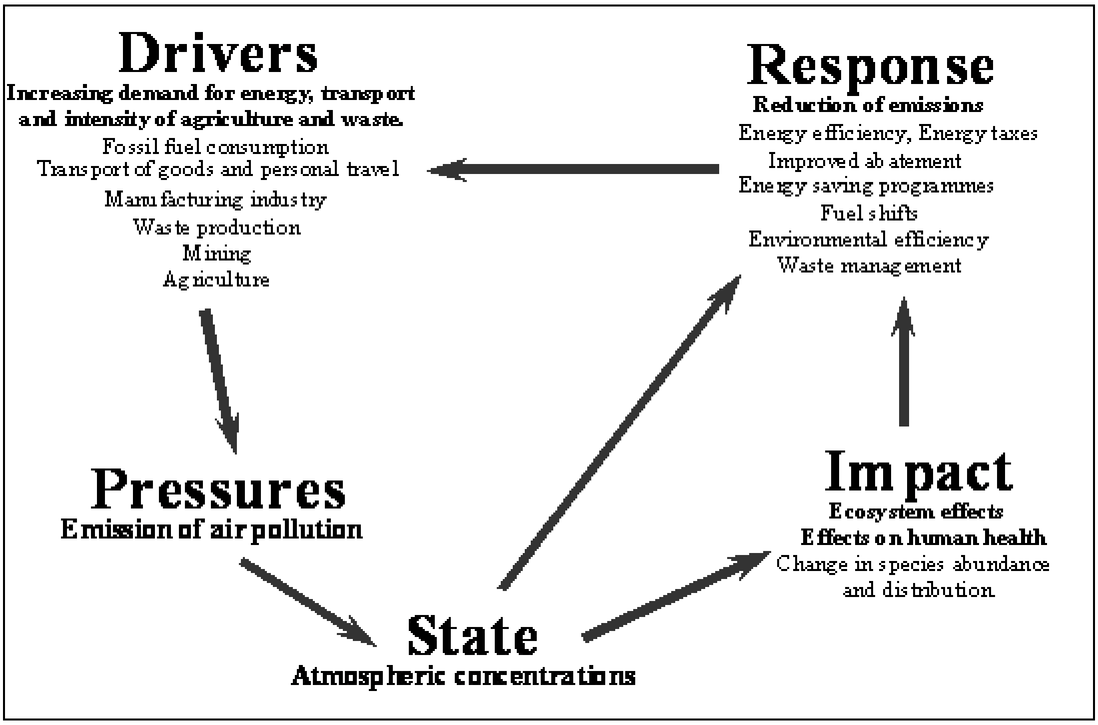
1.1 AN INTRODUCTION/BACKGROUND TO EMISSION INVENTORIES

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 economic sectors that emit pollutants are presented in the UK National Atmospheric Emission Inventory in the nomenclature for reporting (NFR) format (EMEP/CORINAIR (2002)) which gives a code to each sector. The exception to this is the processing of data to form maps of emissions, which is carried out by Selected Nomenclature for Air Pollution (SNAP) code (EMEP/CORINAIR (1997)). SNAP 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 for NECD reporting towards using the Convention on Long-Range Transboundary Air Pollution (LRTAP) which use NFR codes[3].

1.2 THE UK NATIONAL ATMOSPHERIC EMISSIONS INVENTORY

The UK emissions inventory is compiled by the UK Emissions Inventory Team, at AEA. 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 Quality and Industrial Pollution (AQIP) 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 1970-2007. However, for some pollutants, for example ammonia (NH_3) and persistent organic pollutants (POPs), there is insufficient information to produce a 1970-2007 time series and estimates are presented from 1990-2007.

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. 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 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

[3] 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 (UNECE). 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 UNECE 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 provided to international emission inventory activities such as the EC's CORINAIR and EUROSTAT inventories.

Table 1.1 Reporting requirements for the 2007 inventory

Legal Obligation	**Reporting requirement**		**2009 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)	1980-2007	15 February 2009
EU NECD (Directive 2001/81/EC)	Emissions of SO_2, NO_x, NMVOCs, NH_3	2004-2007, 2010	31 December 2008
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 2007, Air Quality Pollutants 2004-2007	15 January 2009 to European Commission 15 April 2009 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 EEA, EMEP and UNFCCC websites at:

http://www.eea.europa.eu and www.emep.int and www.unfccc.int

In addition to the national emission inventories derived from the NAEI, other emissions data and inventories covering specific industrial production and combustion activities are also submitted to international agencies as part of the UK's commitments to environmental regulatory and trading mechanisms:

- **The European Pollutant Release and Transfer Register (E-PRTR).** This multi-media inventory of environmental releases is submitted to the EU by Defra, using data derived from the Environment Agency's Pollution Inventory, the Scottish Pollutant Release Inventory from the Scottish Environmental Protection Agency, the Inventory of Statutory Releases from the Northern Ireland Environment Agency and an inventory of Local Authority-regulated installation compiled by Defra.
- **The European Union Emissions Trading Scheme (EU ETS**). Emissions of carbon dioxide from installations operating within the EU ETS are submitted annually to the Community Independent Transaction Log (CITL), as part of the trading system established across Europe to promote reductions of GHG emissions from the largest emitting sites in the EU area.

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 2008 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 5 countries. A number experts 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. From 2009, this review process will become compulsory.

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: www.defra.gov.uk/environment/airquality/strategy/index.htm, 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 (2007) for the most recent modelling method and results) and the Ozone Source Receptor model (OSRM) (Murrells et al, 2009) and many other UK air quality modelling communities ranging from urban dispersion models to regional scale chemistry transport models 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 three European Daughter Directives on air quality, now merged under the Air Quality Directive (AQD) and the 4th Daughter Directive, and extensively for scenario modelling to inform policy developments by the UK Government.

- 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.

- The NAEI team works closely with industrial and commercial Trade Associations to exchange emissions, activity and production data whilst managing issues of commercially confidentiality. This ensures that the NAEI/GHGI and the Trade Associations can arrive at emission estimates that are truly representative for specific economic sectors, but do not disclose specific company / farm scale activities.

- Emission factor data is provided for use by Local Authorities, academics and other consultants through the UK's Emission Factor Database on the NAEI website.

Table 1.2 Pollutants Covered by the Inventories

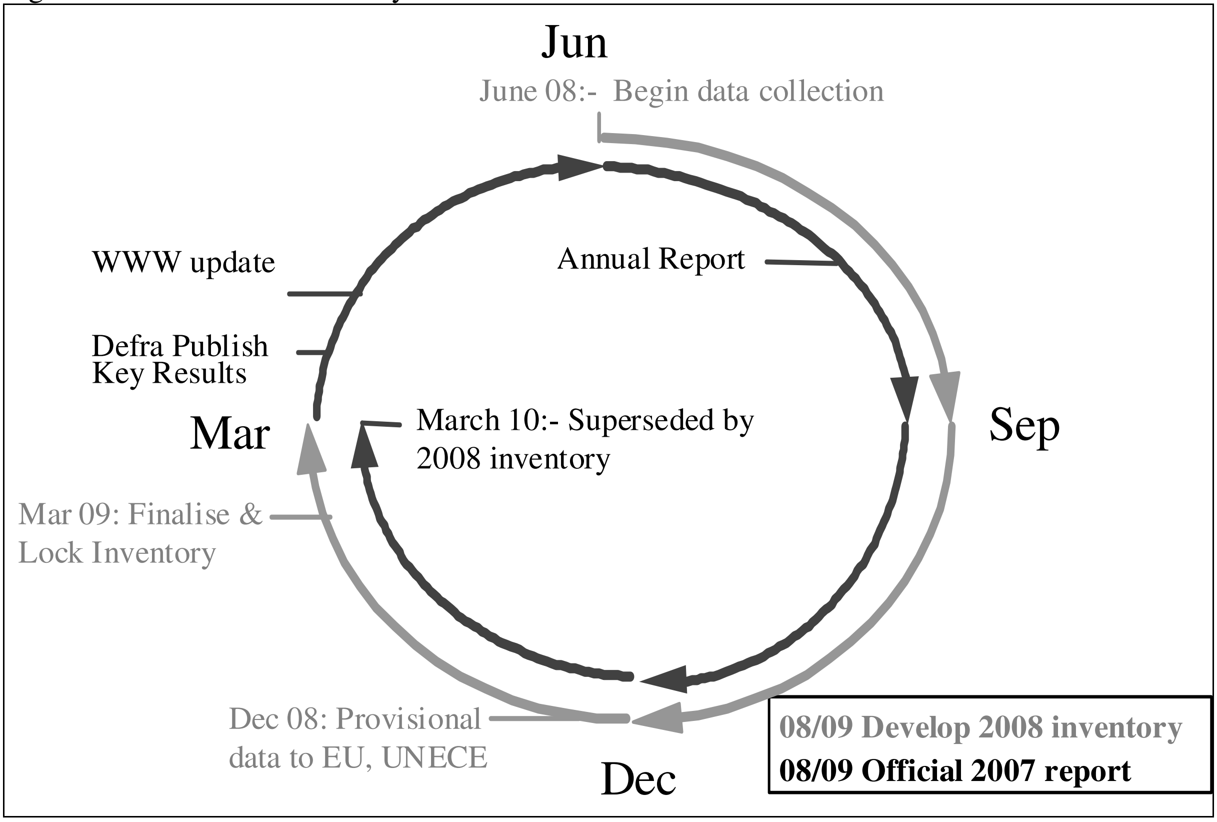
Pollutant		Range of Estimates[1]	Type of Pollutant[2]
Carbon Dioxide	CO_2	1970-2007	G
Methane	CH_4	1970-2007	G
Nitrous Oxide	N_2O	1990-2007	G
Hydrofluorocarbons	HFC	1990-2007	G
Perfluorocarbons	PFC	1990-2007	G
Sulphur Hexafluoride	SF_6	1990-2007	G
Nitrogen Oxides	NO_x (NO_2 + NO)	1970-2007	NAQS, AC, EU, IG, O
Sulphur Dioxide	SO_2	1970-2007	NAQS, AC, IG
Carbon Monoxide	CO	1970-2007	NAQS, O
Non-Methane Volatile Organic Compounds	NMVOC	1970-2007	NAQS, O, IG
Black Smoke	BS	1970-2007	NAQS
Particulates < 10 µm	PM_{10}	1970-2007	NAQS
Ammonia	NH_3	1990-2007	AC, EU
Hydrogen Chloride	HCl	1970-2007	AC
Hydrogen Fluoride	HF	1970-2007	AC
Lead	Pb	1970-2007	NAQS, HM
Cadmium	Cd	1970-2007	HM
Mercury	Hg	1970-2007	HM
Copper	Cu	1970-2007	HM
Zinc	Zn	1970-2007	HM
Nickel	Ni	1970-2007	HM
Chromium	Cr	1970-2007	HM
Arsenic	As	1970-2007	HM
Selenium	Se	1970-2007	HM
Vanadium	V	1970-2007	HM
Beryllium	Be	2000-2007	HM
Manganese	Mn	2000-2007	HM
Tin	Sn	2000-2007	HM
Polycyclic Aromatic Hydrocarbons	PAH	1990-2007	POP
Dioxins and Furans	PCDD/F	1990-2007	POP
Polychlorinated Biphenyls	PCB	1990-2007	POP
Lindane (gamma-HCH)	HCH	1990-2007	POP
Pentachlorophenol	PCP	1990-2007	POP
Hexachlorobenzene	HCB	1990-2007	POP
Short-chain chlorinated paraffins	SCCP	1990-2007	POP
Polychlorinated Napthalenes	PCN	NE	POP
Polybrominated diphenyl ethers	PBDE	SE	POP
Sodium	Na	1990-2007	BC
Potassium	K	1990-2007	BC
Calcium	Ca	1990-2007	BC
Magnesium	Mg	1990-2007	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** pollutant associated with acidification
EU pollutant associated with terrestrial and aquatic eutrophication
NAQS National Air Quality Standard/Local Air Quality Management pollutant
HM Heavy Metal
POP **Persistent Organic Pollutant**
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 2007 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, Dore et al 2007, Dore et al 2008). In addition, the NAEI also produces an annual GHG Report (Choudrie *et al* 2009).

Methodology appendices are not now included with this report, but more detailed information on the methodology can be accessed from the NAEI webpage (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:

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:

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

and

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

1.2.4 Methodology

Emission estimates for pollutant releases from all anthropogenic sources in the UK are estimated by combining an activity statistic with an emission factor:

Emission = Emission Factor × Activity

e.g.

Carbon Emission from coal use in domestic heating (in 2007)	=	Carbon content of domestic coal (in 2007)	×	Coal consumption in the domestic sector (in 2007)

The source data used to derive estimates in the NAEI are taken from many hundreds of different data sources, ranging from National Statistics (such as the UK energy balance data within the annual DECC publication *The Digest of UK Energy Statistics*), to emissions data from UK environmental regulators, source-specific emissions research and international resources of emission factors.

The same activity data is commonly used to calculate emissions of all pollutants (i.e. all air quality and GHG pollutants) for a specific emission source. In the example above, “coal consumption in the domestic sector” is the activity data which can be taken from the DECC UK energy statistics; estimates of different pollutants from domestic coal use can be estimated by applying emission factors that are cited as “emissions per unit coal use”, e.g. “sulphur dioxide per kilogramme of coal”.

Emission factors are typically derived from source measurements across a range of emission sources that are representative of a particular source sector. In the domestic sector example, this may cover source measurements taken from emissions tests from fireplaces, closed stoves, coal-fired boilers and so on; alternatively, emission factors may be derived from analysis of fuel content for specific chemicals such as carbon or sulphur. The resulting emission factor may then be applied to all emission sources within the sector.

For industrial installations (e.g. power stations, refineries, iron and steel plant, cement kilns etc.) that are regulated under environmental legislation such as EPR and IPPC, annual emission estimates are reported by plant operators to the UK environmental regulatory agencies: the Environment Agency of England and Wales, the Scottish Environment Protection Agency and the Northern Ireland Environment Agency. For the most significant sources these emission estimates are typically based on continuous or periodic stack emission monitoring using agreed sampling, analysis and reporting methods and protocols. Due to the well-established regulatory systems of emissions monitoring and data quality control systems used to manage the IPPC system, these point source data are regarded as high quality estimates; for most pollutants, these data are used directly within the NAEI estimates for these high-emitting sectors.

The NAEI estimates are generated using a combination of reported point source emissions, and emissions calculated using emission factors.

Where point source emission data are unavailable, emissions are estimated from other activity data such as fuel consumption, distance travelled, production or other statistical data that are related to the emissions. Emission estimates are calculated by applying an emission factor to an appropriate activity statistic.

Fossil fuel combustion is a major source of emissions in the UK for many air quality pollutants, and therefore the Digest of UK Energy Statistics published annually by DECC is a key activity dataset that underpins many emission estimates across the NAEI. 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 Energy and Climate Change's annual Digest of UK Energy Statistics (DUKES) as the 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, livestock numbers and motor fuel sales are appropriate.

In other cases, where emissions are more complex, further refinements or an alternative methodology is required. For example, in the estimation of emissions from road transport activity, the distance travelled by UK vehicles is a key data input; however, emissions per unit distance travelled are influenced by: vehicle type, vehicle age, engine size, fuel type, average speed and other parameters such as abatement technologies (e.g. catalytic converters, by type and according to abatement penetration rates across the fleet). To determine accurate emission estimates across the UK fleet, a complex calculation methodology is required in order to accommodate the wide range of parameters that influence pollutant emissions; 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 2007 (Choudrie et al, 2009).

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 dispersed and numerous source sectors such as agriculture, domestic heating and commercial boiler emissions 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:

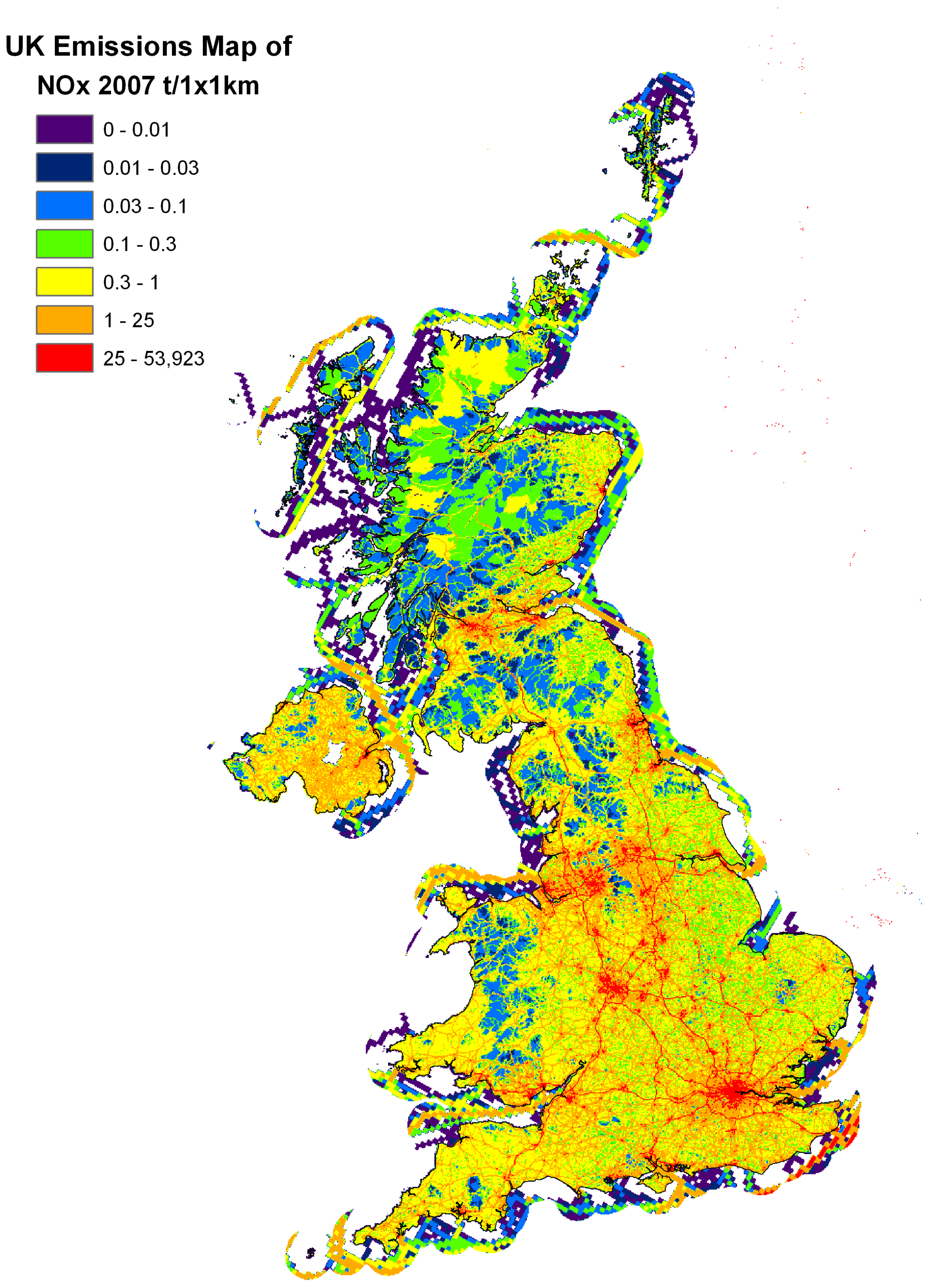
www.naei.org.uk/reports.php

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 the mass of emission per 1km grid squares. 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. The onshore emissions are contained within the black boarder of the map of the UK

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)



[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
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1.2.6 Projections

Projected emissions for the four National Emission Ceilings Directive (NECD) pollutants are compiled by the NAEI team in AEA to enable comparisons with international commitments to be made. A summary of the latest forecasts was submitted in December 2009 under the NECD reporting requirements. Emission projections are also submitted under the Long-range Transboundary Air Pollution (LRTAP) convention every 5 years, with the latest dataset being provided in February 2006.

The UK is required under the Gothenburg Protocol and the more stringent National Emission Ceilings Directive (NECD) to reduce emissions of NOx, SO_2, NMVOCs and NH_3 by 2010 and thereafter. The target emissions are provided in Table 1.3 below together with the UK's estimated emissions in 2007 (the latest year available). UK emissions of NMVOC and NH_3 were below the 2010 ceiling at the time of the 2007 inventory and only a further small SO_2 reduction is required. Further declines in emissions are however needed between 2007 and 2010 for NOx, if the UK is to meet its emission ceiling for all pollutants.

Table 1.3 The UK's emissions in 2007 (as reported to the NECD[5]) and targets for 2010

Pollutant	Emissions in 2007 (ktonnes)	Gothenburg Protocol target in 2010 (ktonnes)	Emissions ceiling target in 2010 (ktonnes)	Reduction required between 2007 and 2010 Emissions ceiling target
NOx	1,486	1,181	1,167	21%
SO_2	591	625	585	1%
NMVOCs	942	1,200	1,200	N/A
NH_3	289	297	297	N/A

Projections of UK emissions are compiled when significant 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. Regulations that have been taken into account include:

- The Large Combustion Plant Directive (LCPD)
- Integrated Pollution Prevention and Control Directive

[5] Covering the United Kingdom and Gibraltar

- The Solvent Emissions Directive
- MARPOL VI agreement requiring marine fuel oil to have a sulphur content less than 1.5%.
- Sulphur Content of Liquid Fuels Regulations 2007
- European Directives & UK Regulations 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 & UK Regulations on Non Road Mobile Machinery
- Introduction of sulphur-free fuels (petrol & diesel), under Directive 2003/17/EC.

A set of emission projections for the four National Emission Ceiling Directive (NECD) pollutants (NO_x, SO_2, NMVOC, NH_3) plus PM_{10} were compiled using the Department of Energy and Climate Change (DECC) updated energy paper 30 (UEP30) energy forecasts "central, central, central" scenario, which refers to central fuel and carbon prices, central economic growth forecasts and central policy impacts. These are regarded as the best current forecast for future energy use, taking account of current and firm and funded policy measures. 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).

The UK "central, central, central" projections, also referred to as "with measures" estimate assume that:

- All operators comply with new legislation;
- New abatement is applied by operators in order to meet the limits imposed by new regulations or in response to the impacts of trading mechanisms;
- Additional emission reductions by voluntary actions over and above regulatory requirements are not achieved, except for estimated responses to non-environmental factors. For example the projections include considerations of where older, more polluting plant will be replaced over time by newer technology on economic grounds.

Cases where the projections do include reductions that might be considered as 'voluntary' include:

- Projections from coating processes include the impact of product reformulation which in some cases may exceed the requirements of legislation;
- Power station emission projections are based on site or plant design-specific fuel projection data (from UEP37) and anticipated plant modifications (from consultation with operators) that in some cases may go over and above the minimum legislative requirements;
- Similarly for other heavy industry sectors, such as cement and iron & steel, the projections are based on site-specific emissions data and known plant closures & modifications.

The results were submitted under the National Emission Ceiling Directive reporting requirements in December 2008. Projections are provided for the year 2010. The forecasts were consistent with those published in the Government's Energy White Paper published in May 2007.

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 and the latest are provided in the February 2008 amended version of the Energy White Paper.
http://www.berr.gov.uk/files/file39580.pdf

The UK is required to submit greenhouse gas emission projections to the EU Monitoring Mechanism bi-annually. Further detail is provided at annex 8 of
http://www.eea.europa.eu/themes/climate/ghg-country-profiles

1.2.7 Continuous Improvement

The NAEI/GHGI operates a policy of continuous improvement, and reviews methodologies each year. The 2007 version of the NAEI/GHGI has seen a 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 2008 NAEI reports have been published.

1.2.7.1 Review of the EMEP / EEA Guidebook and EMEP reporting Guidelines

The Task Force on Emission Inventories and Projections revised the UNECE Guidelines for reporting emission data under the Convention on Long-Range Transboundary Air Pollution (LRTAP). The recommended changes apply to the UK Emission inventory within the transport sector (Shipping and Aviation).

Table 1.4 summarised the changes to the aviation and shipping sub-sectors that were included in the national total under LRTAP. The text in red highlights the sub-sectors that are now either included or excluded from the National total.

Table 1.4 Changes (highlighted in red) in aviation and shipping sub-sectors

	EU NECD	LRTAP Convention [a]	EU-MM/UNFCCC [b]
Air pollutants	NO_x, SO_x, NMVOCs, NH_3	NO_x, SO_x, CO, NMVOCs, NH_3, HMs, POPs, PM	NO_x, SO_x, NMVOCs, CO
Domestic aviation (landing and take-off cycle [LTO])	Included in national total	Included in national total	Included in national total
Domestic aviation (cruise)	*Not included in national total*	*Not included in national total*	Included in national total
International aviation (LTO)	Included in national total	Included in national total	*Not included in national total*
International aviation (cruise)	*Not included in national total*	*Not included in national total*	*Not included in national total*
National navigation (Domestic shipping)	Included in national total	Included in national total	Included in national total
International inland shipping	Included in national total	Included in national total	*Not included in national total*
Maritime international shipping	*Not included in national total*	*Not included in national total*	*Not included in national total*
Road transport	Emissions calculated based on fuel sold or consumed	Emissions calculated based on fuel sold[6]	Emissions calculated based on fuel sold

Note:
a) NFR = Nomenclature for reporting — sectoral classification system developed by UNECE/EMEP for the reporting of air emissions;
b) CRF = sectoral classification system developed by UNFCCC/IPCC for reporting of greenhouse gases.

1.2.7.2 ROAD TRANSPORT

Considerable improvements have been made to the 2007 version of the inventory. The changes have been driven by the availability of new DfT speed-emission factor functions developed by TRL and the availability of more detailed traffic activity data from DfT which we believe enables a more realistic representation of the mix of petrol and diesel cars on the road and also improves the spatial distribution of emissions undertaken in the mapping activity. The changes are summarised below:

Changes affecting AQ and GHG emissions

Speed data were updated after a review of speed data from various DfT sources for different road and area types. This improves consistency with road classifications used in mapping and for projections work done for Pollution Climate Mapping activities.

[6] The UK may choose to use the national emission total calculated on the basis of fuels used in the geographic area of the Party as a basis for compliance. (http://www.unece.org/env/documents/2008/EB/EB/ece.eb.air.97.e.pdf)

Vehicle km data

- Use of detailed traffic census data to improve split between vehicle km on different road types with different speeds.

- Use of new data from DfT on variation in car annual mileage and composition of car fleet by engine size.

- Fuel split on different road types – taking account of the fact that diesel cars do more annual mileage than petrol cars and use different petrol car/diesel car mix on different road types (it had previously been assumed the split was the same everywhere).

- Fleet composition changes – Northern Ireland fleet-specific data used for car fleet in Northern Ireland.

Changes affecting AQ emissions

NO_x and PM hot exhaust emission factors revised using new DfT speed-emission factor functions developed by TRL. Also uses:

- revised emission degradation with mileage functions
- revised effects of fuel quality on emissions

Effect of biofuels taken into account using biofuel consumption data and scaling factors for effects of different biofuels on air quality emissions based on recent AEA study

Prior to the 2008 compilation, Defra and AEA agreed to give priority to adopt the new DfT hot exhaust emission factors for NO_x and PM in the 2007 NAEI, even though the DfT had not completed the period of public consultation on the new factors. The NAEI took part in that consultation and made comments following an in-depth assessment of the factors. It is conceivable that some of the factors might be slightly changed in the future. However, it was considered crucial to include them in the 2007 version of the inventory so that the emissions could also be incorporated in the maps, the updated projections and subsequently the models used to calculate background NO_2 and PM_{10} concentrations in the PCM programme as these play a vital role in Defra's air quality policy and the various Local Air Quality Management tools currently being updated including the Defra Technical Guidance and DMRB. Omissions of updated factors in this year's inventory would mean missing an opportunity for another year of including them in these subsequent model datasets.

DfT hot exhaust emission factors

Under contract to DfT, TRL has completed a major review of emission factors and methodologies for modelling road transport emissions. A series of reports and a database of hot exhaust emission factors were made available for public consultation. That consultation period has expired and while DfT is still assessing feedback received, the proposed hot exhaust emission factors for NO_x and PM have already been incorporated into the NAEI road transport emissions model for calculating the 2007 version of the inventory. The urgency for updating the factors for these two pollutants reflects the policy importance of the NO_x and PM road transport inventories that feed into a number of Defra's air quality models such as the empirical models used in the Pollution Climate Mapping and tools used for Local Authority Review & Assessments. Time constraints meant that only the new DfT emission factors for NO_x and PM could be incorporated into the NAEI for the 2007 version of the inventory. During the next year, it will be necessary to include the new factors for NMVOCs, CO and fuel consumption.

1.2.7.3 CEH Ammonia review

CEH have been contracted to conduct a short review of the ammonia emission estimates in the NAEI. This work was completed in June 2008. As a result of the recommendations made, the emission estimates from non-agricultural sources will be reviewed in the second half of 2009 on an individual source by source basis. Improvements will be specifically targeted at the waste sector and production processes. The results of this review will feed into the 2008 Inventory.

1.2.7.4 Industrial, Commercial & Public Sector Combustion

Some improvements to the NAEI methodology have been incorporated during the 2007 cycle. To a large extent these have consisted of a general improvement in the use of data (e.g. ensuring that all relevant Pollution Inventory data are included) and improving the quality of assumptions (e.g. assumptions about fuel types burnt at individual sites have been based on EU ETS data wherever possible). Some more fundamental revisions to the methodology have also occurred. An important revision for the 2007 inventory has been to include stationary engines as a separate combustion type. These devices typically emit higher levels of NO_X than, for example industrial boilers and the inclusion of stationary engines as a separate category increases our estimates of NO_X emissions somewhat.

Revisions were made to NMVOC and methane factors for industrial use of pet coke as a fuel, with IPCC defaults now used rather than older literature-based factors.

1.2.7.5 Heavy Metals

In recent years it has become apparent that emission estimates of heavy metals made by different countries throughout Europe cover a wide range. Concerns were raised by the modelling community that there appeared to be a considerable difference between the quoted emission estimates in national inventories, and the emissions calculated by reverse modelling of concentration measurement data.

AQIP have invested money in reviewing and improving the UK emission estimates. This included a desktop review of the data being used in the UK emissions inventory (and comparison with other countries), modelling studies, and measurement of the metal content of different fuel types (including pet coke, fuel oils and gas oils). Output from these studies allowed several refinements to be made to the 2007 version of the heavy metal emissions, compiled in 2009.

1.2.7.6 Waste oil use as fuel

The methodology used to estimate the use of waste lubricants as a fuel has been updated for the 2007 version of the NAEI. This was necessary due to changes in the use of waste lubricants as a result of the Waste Incineration Directive (WID). This use of waste lubricants as fuel at power stations and at roadstone coating plant ended as a result of WID. The methodology was updated to reflect these changes and a number of other improvements were introduced at the same time. One result of these changes is that there is now a substantial tonnage of waste lubricant which might be recovered but for which there is no known use. It is possible that this lubricant is being disposed off in other ways e.g. by incineration or export but this needs further investigation as a priority.

1.2.7.7 Rail and off Road machinery

The methodologies for rail vehicles have been reviewed and slight modifications made to time series as new passenger km data was used.

Changes have been made to the methodology for reconciling NAEI estimates of gas oil use by off-road vehicles and mobile machinery with official UK energy statistics. The existing reallocation procedure created very low estimates of gas oil consumption by stationary industrial plant and would have resulted in a negative figure for 2005. The revised approach reallocates more gas oil from the public administration and commercial sectors with the result that estimates of gas oil use by stationary industrial plant appear more reliable.

1.2.7.8 Revisions to NAEI energy data

The NAEI relies upon the Digest of UK Energy Statistics (DUKES) to provide the fuel-use data that are used to calculate emissions. Total UK usage of any fuel should be the same in DUKES as in the NAEI. Many of the sector-specific fuel usage figures also tally, however, over the past 10 or 15 years the NAEI has had to abandon the use of DUKES data for certain sectors when alternative data sources showed that DUKES was inaccurate. Most importantly, the NAEI includes independent estimates of fuel oil burnt by power stations (based on AEA analysis of operators' fuel consumption) and all fuel types burnt at cement works (from the British Cement Association, and based on EUETS and other industry data) and at lime kilns (based on an AEA estimate). In addition, the NAEI includes our own estimates of the use of waste oils and petroleum coke as fuels.

NAEI estimates of renewable fuel use have been given increasing attention over the past 3 years and some new sources were introduced for the 2007 cycle. A wood-burning power station (Steven's Croft) commenced operation in 2007, and wood (e.g. short-rotation coppice) and other solid biomass such as shea, olive or palm residues has been co-fired in coal-fired power stations for a few years. Both types of biofuel usage were included in the NAEI. Some liquid biofuels such as tall oil have also been used for co-firing but the quantities to date have been small. Due to the need to complete the complex NAEI spreadsheets on time, the decision was taken this year not to try to redesign the relevant spreadsheets and power stations database to include this source, but it should be included next year.

As well as the revisions listed above, there have been a large number of 'updates' due to the availability of new data in the Pollution Inventory, Scottish Pollutant Release Inventory, Northern Ireland Inventory of Sources and Releases, Digest of UK Energy Statistics, and other sources.

1.2.7 Planned improvements

A number of improvements to the inventory are planned although it is anticipated that not all improvements will be incorporated for the next version of the inventory.

- **Road Transport**

  The future development of the road transport emission estimates will focus on:

  - Hot exhaust emission factors
  - Cold start and evaporative emission factors and methodologies
  - Development of an inventory for road transport based on fuel sales

- **Rail**

Research is recommended to develop a more detailed, comprehensive series of emission factors to better represent the full range of rail rolling stock. The current method and assumptions are in need of review given the ongoing development of the fleet. In addition, the method for estimating emissions from the freight stock ought to be developed to reflect the variable emissions from carrying variable loads. Alternative activity datasets used by the LAEI (ACTRAFFF) should also be evaluated to determine whether their use might lead to improved inventory estimates.

- **Emissions of Ammonia**

An improvement to the NAEI estimates from non-agricultural sources on an individual source by source basis as recommended by the CEH ammonia review, specifically targeted at the waste sectors and production processes. Also a review of other European emission inventories and the updated Guidebook should be conducted to indicate whether there is information available which could improve the UK emissions estimates and vice versa. This information will be important to provide context regarding international discussion on NEC compliance. This will feed into the 2008 NAEI.

- **Ultrafine Particles**

Method development is needed to incorporate ultrafine particulate data to address data needs of users and develop outputs in the most appropriate units. The current NAEI estimates of ultrafine mass emissions from combustion may be a conservative estimate; there is an increasing need for particle number-based data, mode size and surface area of particulates.

- **Comparison of the NAEI and the EMEP/CORINAIR Guidebook**

A review is recommended to identify areas where UK-specific metal emission factors differ significantly from those recommended in the latest UNECE Guidebook and to make recommendations for any changes needed.

- **Heavy Metals from Solid Fuels**

Metal emission factors for coal and smokeless fuels are based on very limited data and estimates are therefore very uncertain. A programme of fuel analyses would help to improve emission estimates. Metal content of coals are known to vary over a wide range; therefore it is likely that a very large number of analyses over an extended period will be needed, to significantly reduce uncertainty in this part of the inventory.

- **Re-suspension of Heavy Metals**

Further work on re-suspension of metal emissions from agricultural soils and from vehicle turbulence is recommended. In particular, there is a need for modelling of the contribution to measured concentrations of metals at roadsides from vehicle exhausts and tyre and brake wear, and for investigation of the metal content of fine particles released from soils.

- **Burning of Treated Wood**

A review is recommended to examine the feasibility of improving the methodology for emissions of chromium, copper and arsenic during the burning of wood treated with CCA timber preservatives. Current estimates are very uncertain, but it is not known whether data exists which could significantly reduce this uncertainty. Consultation with timber preservative manufacturers and other stakeholders will allow a better understanding of what development of the estimates is possible.

- **Heavy Metal Emissions Reported in the Pollution Inventory**

A consultation with Environment Agency experts to determine the methods used and accuracy associated with metal emissions data provided in the Pollution Inventory is proposed. As this task is likely to be resource-intensive, it is proposed that major sources of heavy metals (such as power stations) are prioritised for research.

- **Source Measurements**

Emission estimates for some industrial processes (e.g. foundries, glassworks) are based on literature-based emission factors; more representative emission factors may be derived through source measurement. A review of the inventory is needed to identify those sectors where source measurement might be beneficial and to generate a list of priority sources.

- **Heavy Metals from Accidental / Malicious Fires**

Currently the inventory does not include emission estimates for metals from accidental fires. Some serious fires probably have the potential to release significant quantities of metals to air. While it would require substantial research effort to generate a complete set of high quality emission estimates, an initial review should be undertaken to search the literature, consult with relevant organisations, and to produce an initial assessment of priority sectors for further research.

- **Industrial, Commercial & Public Sector Combustion**

It may be possible to extend the current approach used to estimate factors for NOx, CO and PM_{10}, to derive more accurate emission estimates of dioxins and benzo[a]pyrene. It is not certain whether the data exist to support their inclusion in this detailed methodology for the 2008 NAEI, and a review is proposed.

- **Revisions to DUKES Energy Data**

Sector-specific fuel use and fuel quality data within DUKES is periodically reviewed, impacting upon the NAEI emission estimates from combustion sources. The revisions to DUKES are expected to stem primarily from the increased availability of data on fuel use and quality from the EUETS reporting system. There are a number of areas that are known to require further attention:

- Use of liquid biofuels at power stations
- The treatment of coke use by industry needs to be revised
- More information is needed on fuels burnt in lime kilns
- Pet coke consumption estimates need to be reviewed and improved where possible
- Refinery fuel use data

- **Industrial Process Emissions**

Ongoing consultation with trade associations will continue to provide insights into factors affecting emissions of NMVOC, PM_{10}, CO, SO_2 & NOx from industrial processes reported in the PI, SPRI and ISR; in some cases, fluctuations in reported emissions require specific enquiry to ensure data quality.

- **Solvent Use**

Review and update of emission estimates from industrial solvent use is a considered a high priority, to maintain the quality of the estimates. Priorities include: (1) the use of solvents in adhesive coating processes, and (2) miscellaneous use of solvents that are not dealt with in specific source categories (e.g. solvents used in firelighters and barbeque fluids). Furthermore, a review of the estimates for non-aerosol consumer products may be useful particularly in the areas of household and car-care products where detailed activity statistics are not available, and the current method is based on extrapolation of out-dated information on the basis of growth in household numbers, population, or vehicle numbers.

- **Fireworks and Munitions**

A review of the factors used for PM_{10} emissions and the consideration for the inclusion of dioxin in the emission estimates is recommended. In addition, a scoping study to review the literature data for emissions of gaseous pollutants and metals that arise from munitions will enable assessment of the scale of such emissions to determine whether more detailed study is warranted for this source.

- **Persistent Organic Pollutants**

Several specific improvements are proposed to improve POPs inventories, which are coming under increased scrutiny through the development of reporting requirements:

- Development of a methodology to include emissions of dioxins and PAH from cigarette smoking, fireworks, barbeques, and green field drying, which are currently not included in the NAEI estimates.

- An improvement of emission estimates of PAH from cement kilns based on measurement data instead of the current estimates based on fuel consumption data and literature emission factors.

- A review to assess the decline in activity of small-scale waste burning, a source which has a very significant influence on POPs emission inventory estimates.

- Methodology review to account for imports, for estimating SCCP emissions.

- **Industrial Use of Coke and Petroleum Coke**

In order to better comply with GHG reporting guidance, the NAEI method is moving away from treating coke as an industrial combustion source, and towards treating it as a series of industrial processes. Some emissions from the use of coke are currently treated as process emissions but further revision of the methodology will be necessary in future cycles. The change in reporting will help to eliminate some potential double-counting of emissions in the NAEI, although it must be stressed that this double-counting will not be significant at a national level. A related-issue is that some lime kilns which were previously thought to burn coke, now appear to burn anthracite. More information is needed on the switch in fuels so that NAEI time series can be improved.

For the 2007 cycle, the use of petroleum coke by the cement and power sectors were sufficiently great that, assuming that DUKES' supply figures are correct, no pet coke would have been available for the domestic sector. This is highly unlikely since AEA obtained samples of pet coke from SSF supplies in early 2008 for the analysis of metals in fuels. Further work is needed on the petroleum coke estimates in the future.

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). EPER applies to certain emissions from 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 postcode interrogation, and may be found on the Environment Agency website: -

http://www.environment-agency.gov.uk/business/topics/pollution/32254.aspx

1.3.2 The Scottish Environmental Protection Agency – SPRI Inventory

The Scottish Environment Protection Agency (SEPA) compiles an emissions inventory for emissions reporting under the Integrated Pollution Prevention and Control (IPPC) Directive and the European Pollutant Emission Register (EPER and now EPRTR). The reporting of emissions is required for all activities listed in Annex I of the IPPC Directive. Industrial process emissions are reported to the Scottish Pollutant Releases Inventory (SPRI), and the data covers emissions in 2002 and from 2004 onwards. As with the data from the Environment Agency Pollution Inventory, the point source emissions data provided via the SPRI is used within the NAEI in the generation of emission totals, emission factors and mapping data. The SEPA inventory can be found at:

http://www.sepa.org.uk/air/process_industry_regulation/pollutant_release_inventory.aspx

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:

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 (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 2007 UK estimated emissions are summarised in Table 2.2.

Table 2.2 Estimated total UK Emissions of Acidifying Pollutants and Ozone Precursors in 2007

Pollutant	**Total 2007 emission (ktonnes)**
Nitrogen oxides (as NO_2)	1,486
Sulphur dioxide	591
Hydrogen chloride	14
Non-methane volatile organic compounds (NMVOC)	942
Ammonia	289
Hydrogen fluoride	4.4

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^{o}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 now met the 2000, 2005 and 2010 target. In 2007, emissions were 88% lower than in 1980.

The NMVOC Protocol required the UK to achieve a 30% reduction of anthropogenic NMVOC emissions by 1999 from a 1988 baseline. Emissions excluding those from forests fell from 2,492 ktonnes in 1988 to 1,519 ktonnes in 1999 - a reduction of 39%, indicating that this was achieved. 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 11% lower in 1994 than in 1987 and have fallen substantially since 1994.

The UNECE Protocol to Abate Acidification, Eutrophication and Ground-level Ozone was adopted in Gothenburg in December 2000, where it was signed and ratified (8/12/05) 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.

More detailed information on the Convention on Long-range Transboundary Air Pollution may be found at the UN/ECE web site: 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[7]	**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. The European Commission is currently preparing for a revision of the NECD containing ceiling for 2020 as part of the implementation of the European Commission's Thematic Strategy on Air Pollution[8].

[7] The territory under the NECD includes England, Scotland, Wales, Northern Ireland, Gibraltar
[8] http://ec.europa.eu/environment/air/pollutants/rev_nec_dir.htm

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 (Defra, 2007). A number of policies are currently in place in an attempt to improve air quality, these are described in the Air Quality Strategy for England, Scotland, Wales and Northern Ireland.

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). The directives are currently being reviewed and expected to enter into force in 2008.

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. 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). The most recent strategy was published in 2007 (Defra 2007).

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.

Defra and the Devolved Administrations commission evaluations of the review and assessment appraisal process and the support services (including the help desk and website) provided to local authorities in England, Northern Ireland, Scotland and Wales. The evaluations led to recommendations to which Defra and the Devolved Administrations respond after careful consideration on how the review and assessment process can reasonably be improved.

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 2007 emissions of the 9 priority pollutants covered by the AQS for ESWNI.

Table 2.4 Total UK Emissions of AQS Pollutants

Pollutant	**Total 2007 emission (ktonnes)**
PM_{10}	135
Carbon Monoxide	2,114
Benzene	16.8
1,3 Butadiene	2.38
Nitrogen oxides	1,486
Sulphur dioxide	591
Tropospheric Ozone	NS[1]
Lead	0.07
PAH[2]	1.28

[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 5.2).

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). It also acts as a precursor to secondary particulate matter, therefore contributing to the related health impacts. 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 estimates.

Emissions in 2007 represent a decrease of 20.6% 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.

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

	NFR Codes	1990	1995	2000	2003	2004	2005	2006	2007	2010[2]	2007 %
BY UN/ECE											
Stationary Combustion	1A1, 1A2	5.5	4.1	3.6	2.9	2.8	2.6	2.8	3.0		1%
Passenger cars	1A3bi	0.7	8.4	11.3	10.0	9.2	8.2	7.3	6.2		2%
Other Transport	1A3bii-iv, A3ai(i)-1A3aii(i), 1A3c-1A3eii, 1A4bii, 1A4cii, 1A5b	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.3		0%
Production Processes	1B, 2, 3	8.8	8.9	5.2	4.7	4.6	6.8	6.6	6.4		2%
Cattle	4B1	153.7	150.2	143.5	139.2	139.5	137.4	137.2	133.9		46%
Poultry	4B9	39.5	36.3	38.2	36.7	37.1	34.4	34.6	31.7		11%
Direct Soil Emissions	4D1	65.1	48.5	35.1	34.5	40.4	40.0	38.7	42.6		15%
Other Livestock	4B2-4B8, 4B13	77.9	75.8	66.9	57.4	57.7	55.9	58.6	54.1		19%
Waste\Other	6, 7, 4F	12.6	11.9	12.0	11.9	11.7	11.5	11.1	10.8		4%
BY FUEL											
Solid		5.2	3.5	2.6	1.8	1.8	1.5	1.6	1.7		1%
Petroleum		1.0	8.8	11.8	10.5	9.7	8.7	7.7	6.6		2%
Gas		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0%
Non-Fuel		357.9	332.1	301.8	285.3	292.0	287.0	288.0	280.8		97%
Total		**364.0**	**344.3**	**316.2**	**297.6**	**303.5**	**297.2**	**297.2**	**289.1**	**297**	**100%**
MEMO Items											
Wild Animals & Humans		8.2	8.2	8.2	8.3	8.3	8.3	8.4	8.4		

[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 2007 were dominated by agricultural sources where emissions from livestock production and their wastes comprising 76.7% 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 Inventory of Ammonia (NH_3) Emissions from UK Agriculture 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. 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* 2008).

As well as emissions from livestock, the agriculture inventory includes emissions from fertiliser use, crops and decomposition of agricultural vegetation. These estimates from crops and vegetation 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 numbers of cattle, sheep and pigs. In addition, there is a decline in fertiliser use, which also leads to decreasing emissions.

2.2.4 Other Sources

The non-agricultural sources comprise a number of diverse sources and equal 23.3% (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 2008).

Emissions of NH_3 from road transport although relatively small increased between 1990 and 2000 as a result of the increasing number of three way catalytic converters in the vehicle fleet. However, emissions are now falling as the second generation of catalysts (which emit less NH_3 than first generation catalysts) penetrate the vehicle fleet.

Figure 2.1 shows estimated UK emissions of NH_3 from 1990 to 2007. The 2010 target emission ceiling (under the NECD) is also shown.

Figure 2.1 Time Series of NH_3 Emissions (ktonnes)

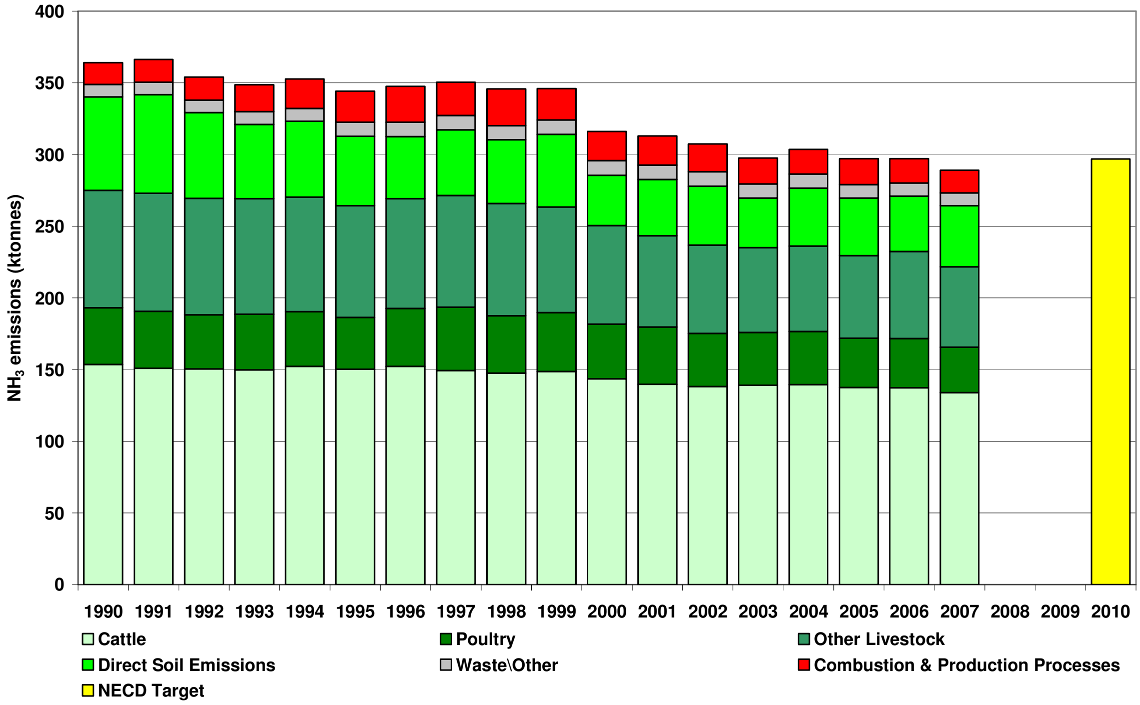
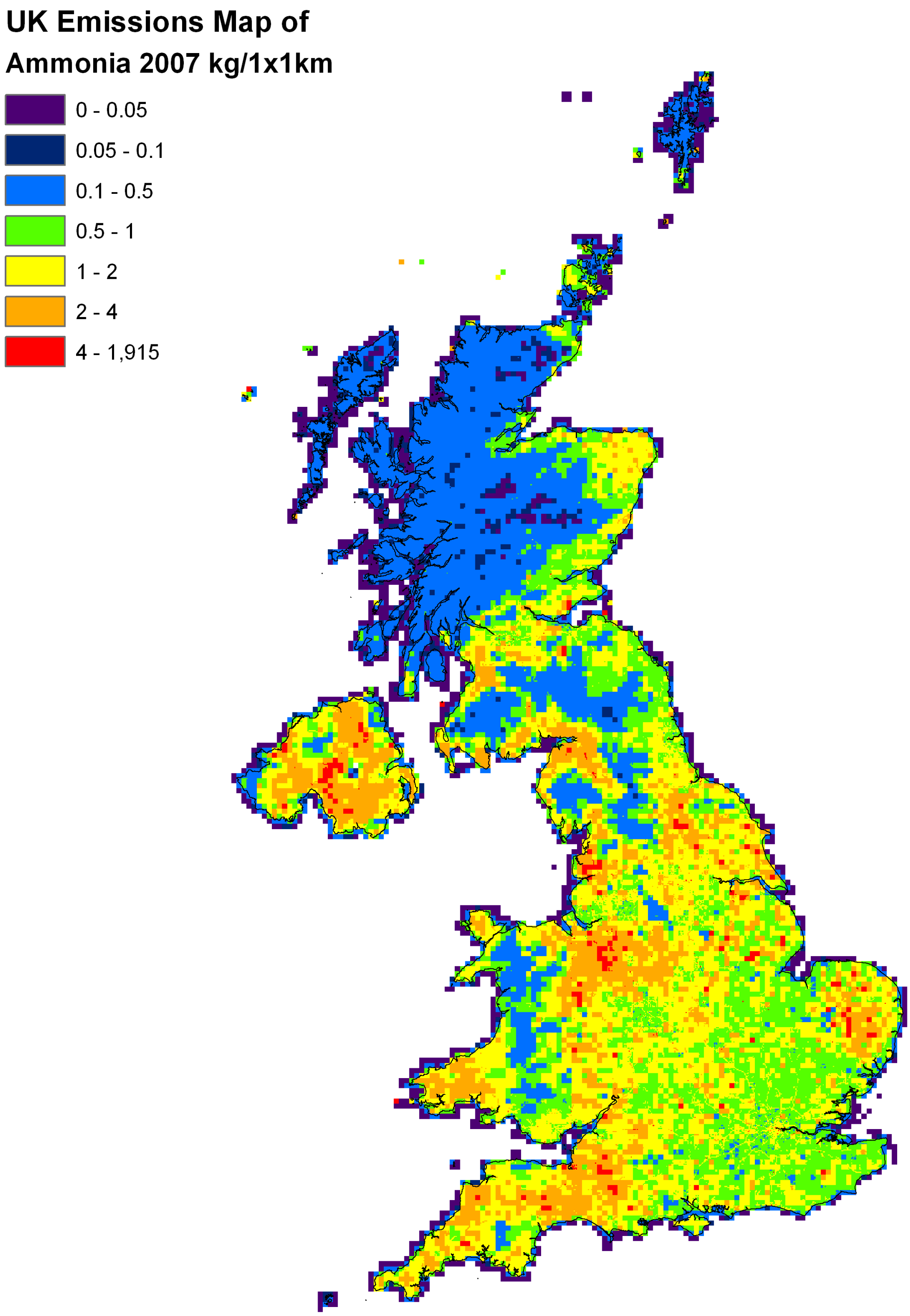


Figure 2.2 shows mapped NH_3 emissions. High emission densities are observed in agricultural areas, for example East Anglia, the South West and the North of England and Northern Ireland. Non-agricultural emissions are also noted to give rise to high emission densities in major urban areas such as London. 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 48% of UK emissions in 2007. 13% of the 2007 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 1970 to 2007 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

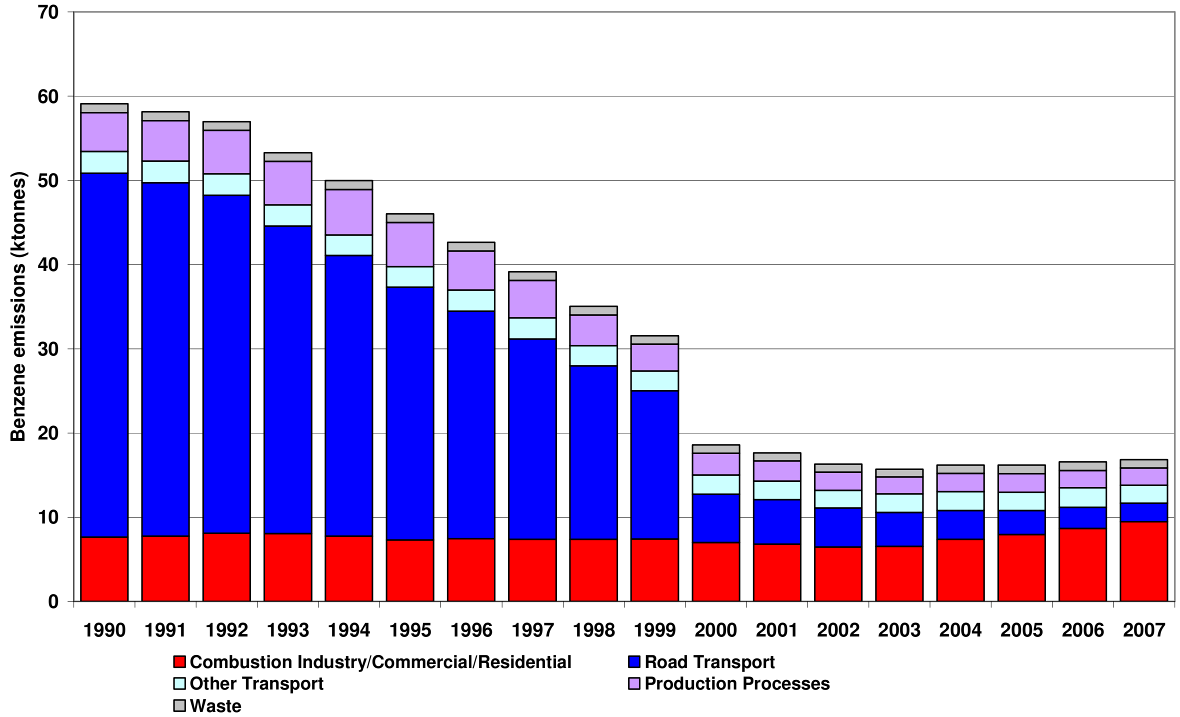
Benzene emissions have been steadily decreasing since 1990. The most noticeable decrease between 1999 and 2007 arises from the road transport sector. This is because the benzene content of petrol was substantially decreased between 1999 and 2007, resulting in a corresponding decrease in emissions and due to the introduction of cars equipped with three-way catalytic converters since 1991.

Table 2.6 UK emissions of Benzene by aggregated UN/ECE Source Category and Fuel (ktonnes)

	NFR Codes	1970	1980	1990	2000	2003	2004	2005	2006	2007	2007%
BY UN/ECE CATEGORY[1]											
Combustion Industry/Commercial/Residential	1A1, 1A2a, 1A4	16.8	9.27	6.54	5.76	5.42	6.28	6.94	7.69	8.48	50%
Other Industrial Combustion	1A2f	0.96	1.00	1.11	1.22	1.11	1.08	0.98	0.98	0.98	6%
Road Transport: Passenger cars	1A3bi	26.5	29.90	36.24	4.95	3.39	2.90	2.37	2.10	1.84	11%
Other Road Transport	1A3bii-v	3.99	6.10	6.95	0.79	0.63	0.54	0.48	0.41	0.38	2%
Waste	6	0.88	0.88	1.05	0.99	0.92	0.99	1.01	1.03	0.99	6%
Production Processes	1B1, 1B2, 2	0.68	0.53	4.60	2.60	1.99	2.17	2.20	2.07	2.04	12%
Other off Road Transport (Rail, Aviation, Navigation)	1A3ai(i)-1A3aii(i), 1A3c-1A3e, 1A4ci, 1A5b	2.05	1.88	2.58	2.27	2.22	2.22	2.19	2.28	2.12	13%
BY FUEL TYPE											
Solid				6.2	5.3	4.9	5.8	6.4	7.1	8.0	47%
Petroleum				46.5	8.8	7.0	6.4	5.8	5.5	5.1	31%
Gas				0.7	0.8	0.8	0.8	0.8	0.7	0.7	4%
Non-Fuel				5.7	3.7	3.0	3.2	3.2	3.1	3.1	18%
Total		**51.8**	**49.6**	**59.1**	**18.6**	**15.7**	**16.2**	**16.2**	**16.6**	**16.8**	**100%**

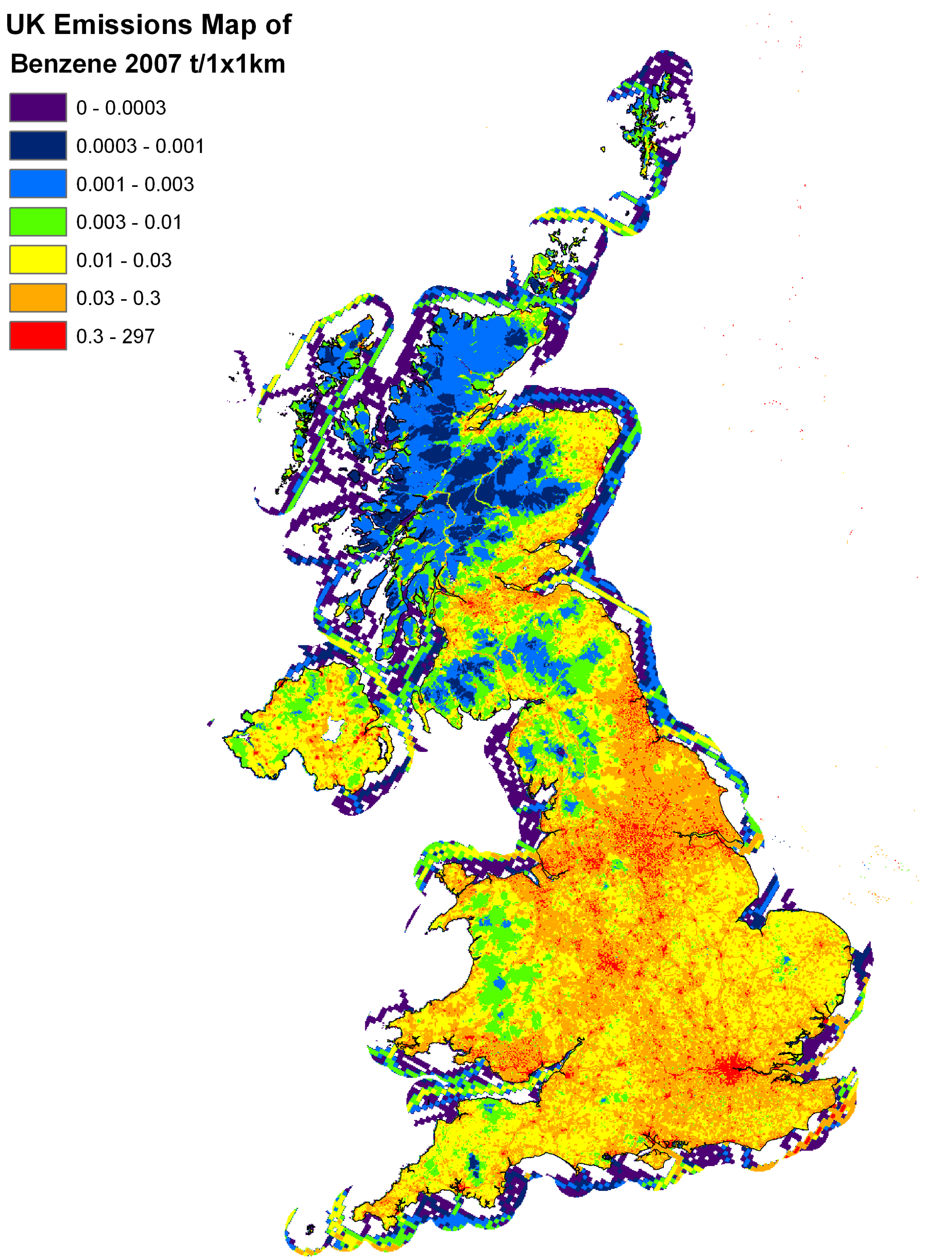
[1] See Annex 1 for definition of UN/ECE Categories

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, 2008) have been incorporated into the NAEI.

2.4.2 Total 1,3-Butadiene Emissions

The road transport sector dominates the UK emissions in 2007, contributing 53% of the total. Emissions of 1,3-butadiene for 1990 to 2007 are given in Table 2.7 and Figure 2.5 below.

As with benzene, the introduction of three-way catalytic converters in 1991 has had a significant impact on the emissions from the road transport sector, causing an 89% reduction in road transport emissions and a decline in total emissions of 81% between 1990 to 2007. 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 NO_x emissions provided in

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	2003	2004	2005	2006	2007	2007%
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	5.50	6.22	7.55	2.38	1.19	0.91	0.69	0.56	0.46	19%
Road Transport / Others	1A3bii&iv	0.72	1.06	0.99	0.40	0.29	0.25	0.23	0.20	0.19	8%
Road Transport / Heavy Duty Vehicle	1A3biii	2.45	2.74	2.61	1.07	0.79	0.74	0.68	0.65	0.62	26%
Industrial off-road mobile machinery	1A2f	0.22	0.21	0.25	0.25	0.25	0.25	0.24	0.24	0.24	10%
Other Transport	1A3ai(i) - 1A3aii(i), 1A3c-1A5b	0.68	0.61	0.61	0.54	0.51	0.51	0.49	0.47	0.46	19%
Production Processes	1B2aiv, 1B2av	0.16	0.20	0.79	0.52	0.39	0.39	0.39	0.40	0.41	17%
Waste Treatment and Disposal	6A	0.00	0.00	0.03	0.02	0.01	0.02	0.02	0.02	0.02	1%
BY FUEL CATEGORY											
Solid				0	0	0	0	0	0	0	0%
Petroleum				11.99	4.64	3.03	2.66	2.34	2.13	1.96	82.3%
Gas				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0%
Non-Fuel				0.83	0.53	0.41	0.42	0.40	0.42	0.42	17.7%
Total		**9.74**	**11.03**	**12.82**	**5.17**	**3.43**	**3.08**	**2.74**	**2.54**	**2.38**	**100%**

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

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

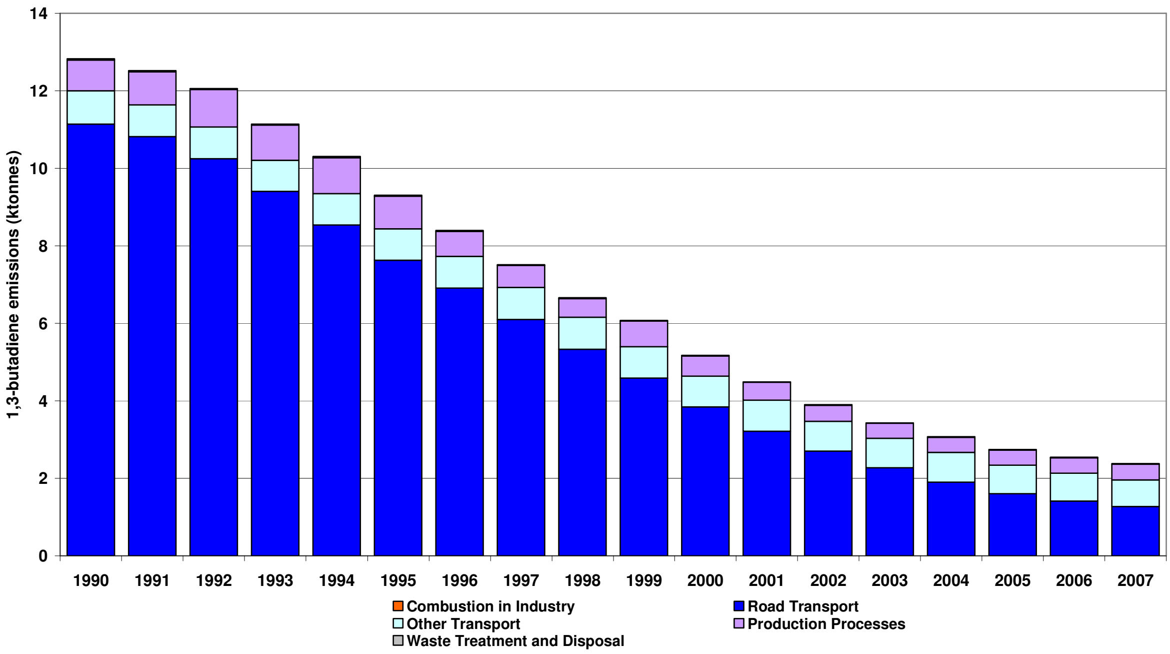
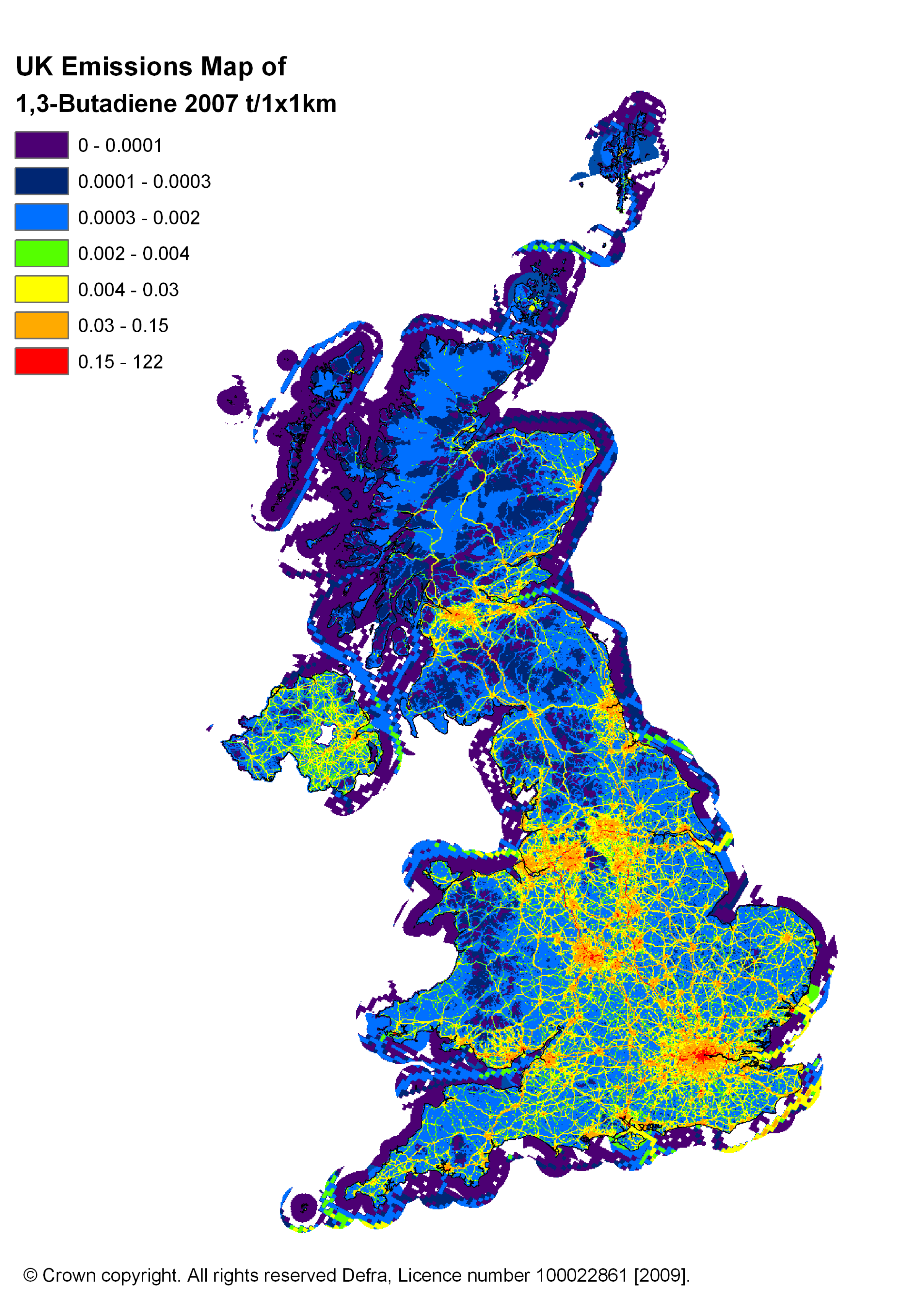


Figure 2.6 Spatially Disaggregated UK Emissions of 1,3-butadiene Map



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

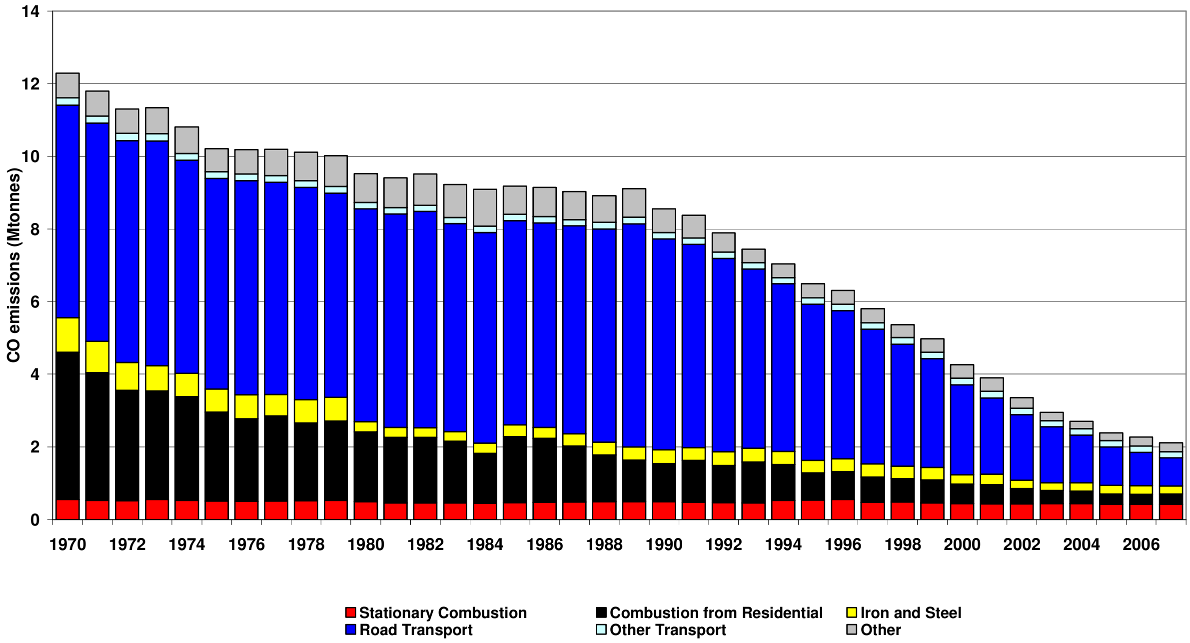
The UK emissions of carbon monoxide are shown in Figure 2.7 and Table 2.8 disaggregated by source and fuel. Over the period 1970-2007 emissions decreased by 83% reflecting significant reductions in emissions from road transport, agricultural field burning and the domestic sector.

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

	NFR Codes	1970	1980	1990	2000	2003	2004	2005	2006	2007	2007 %
BY UN/ECE CATEGORY[2]											
Public Electricity and Heat Production	1A1a	142	121	113	67	71	72	73	80	81	4%
Combustion in Industry/Commercial	1A1b&c, 1A2b, 1A4ci	79	51	45	47	46	47	50	43	43	2%
Iron and Steel	1A2a	948	283	384	253	212	233	240	239	217	10%
Other industrial combustion	1A2f	331	313	334	324	317	323	297	299	298	14%
Passenger cars	1A3bi	5247	5079	4857	2084	1303	1105	881	760	639	30%
Other Road Transport	1A3bii-iv	605	782	943	395	238	201	177	157	146	7%
Other Transport	1A3ai(i) - 1A3aii(i), 1A3c-1A3eii, 1A4bii, 1A4cii, 1A5b	204	180	175	184	173	178	182	180	164	8%
Combustion from Residential plants	1A4bi	4054	1922	1047	540	363	340	275	266	279	13%
Production Processes	1B1, 1B2, 2A&B	172	168	153	127	68	56	51	56	59	3%
Metal Production	2C	183	140	195	199	109	110	114	147	146	7%
Other[3]	4, 5, 6, 7	324	485	309	45	46	44	43	43	42	2%
BY FUEL TYPE											
Solid		5243	2372	1572	854	634	630	548	546	537	25%
Petroleum		6286	6241	6198	2878	1925	1700	1462	1320	1171	55%
Gas		34	77	90	132	135	139	133	127	128	6%
Non-Fuel		726	833	696	400	252	239	240	277	279	13%
Total		**12289**	**9524**	**8555**	**4264**	**2946**	**2707**	**2383**	**2270**	**2114**	**100%**

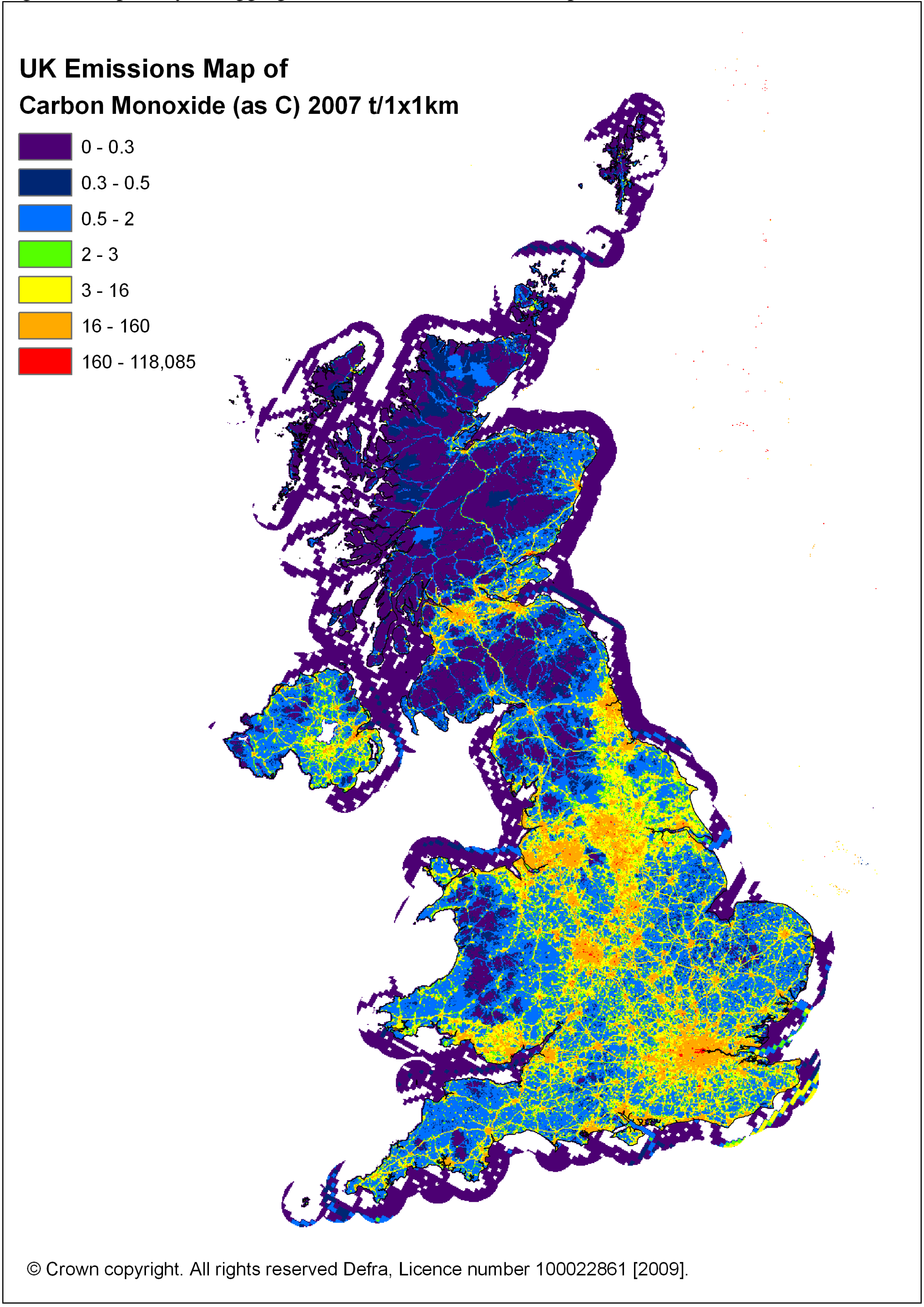
[1] UK emissions reported in IPCC format (Choudrie *et al*, 2009) differ slightly due to the different source categories used.
[2] See Annex 1 for definition of UN/ECE Categories
[3] Field Burning of agriculture waste, forest and grassland conversion, waste incineration, other waste and others

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 remained consistent between 1970 and 1990 but since then have declined significantly. This is due primarily to the increased use of three-way catalytic converters and to a lesser extent to fuel switching from petrol cars to diesel cars.

A significant fraction of emissions are from off-road sources which include those from 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 57% 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. In 2007, power generation accounts for only 4 % 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 chlorine; the UK emission inventory for hydrogen chloride is 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 96% since 1970. The main source of these emissions is coal combustion and the fall is a result of the decline in coal use. The installation of flue gas desulphurisation (FGD) at Drax, Ratcliffe-on-Soar, and other power stations since 1993, and a general trend towards the use of coal with lower chlorine contents at non-FGD plants has had an impact. The dip in emissions as a result 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	2003	2004	2005	2006	2007	2007 %
BY UN/ECE CATEGORY[2]											
Public Electricity and Heat Production	1A1a	222.3	257.8	238.8	72.5	31.4	20.3	12.3	11.3	8.4	60%
Stationary Combustion	1A1b-c, 1A2b, 1A4ci	61.8	26.9	13.6	5.2	2.9	2.6	1.9	1.7	1.9	14%
Iron and Steel	1A2a	3.0	0.8	0.8	0.7	0.7	0.7	0.4	0.3	0.3	2%
Other Industrial Combustion	1A2f	38.3	12.8	10.8	3.7	3.8	3.5	3.6	3.4	3.0	21%
Production Processes	2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	1%
Commercial / Institutional	1A4a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Road & Other Transport	1A3b, 1A3dii, 1A4bii	0.4	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0%
Waste	6	6.9	6.9	5.3	0.1	0.1	0.1	0.2	0.2	0.2	1%
BY FUEL TYPE											
Solid		323.55	297.37	261.18	80.63	37.47	25.76	17.24	16.11	13.02	93%
Petroleum		0.66	0.59	0.19	0.02	0.03	0.03	0.03	0.02	0.03	0%
Gases		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0%
Non Fuel		8.70	7.90	8.34	1.73	1.49	1.65	1.42	1.09	1.04	7%
Total		**332.9**	**305.9**	**269.7**	**82.4**	**39.0**	**27.4**	**18.7**	**17.2**	**14.1**	100%

[1] UK emissions reported in IPCC format (Choudrie *et al*, 2009) 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)

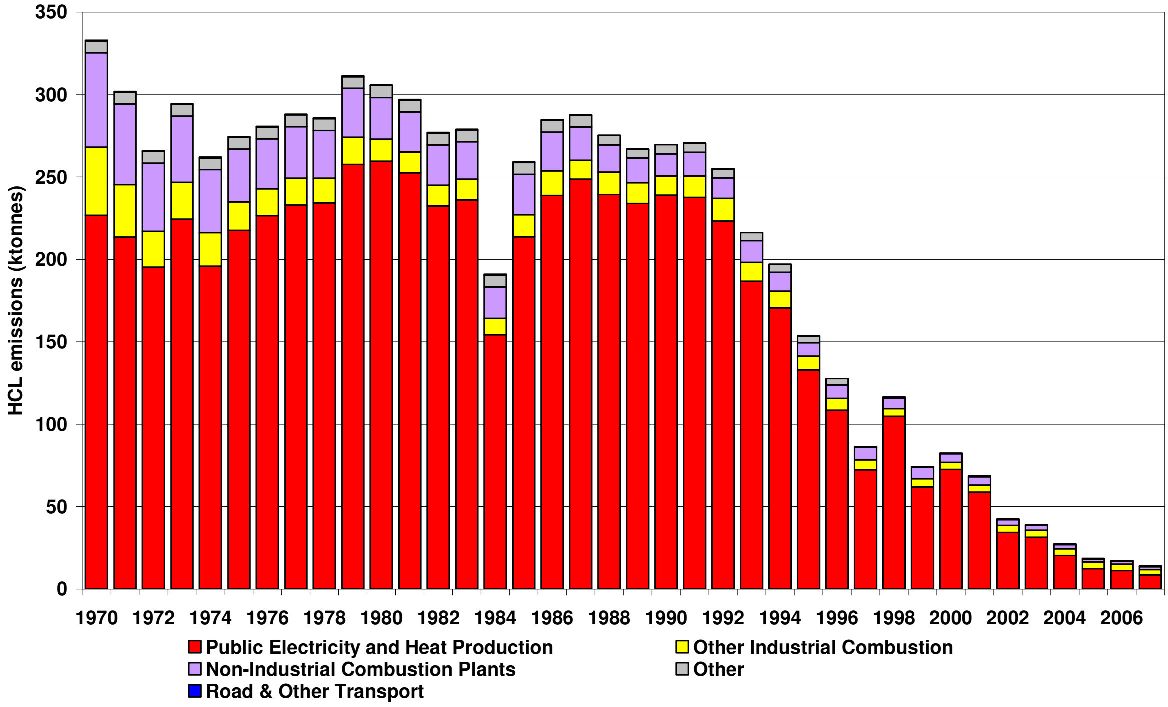
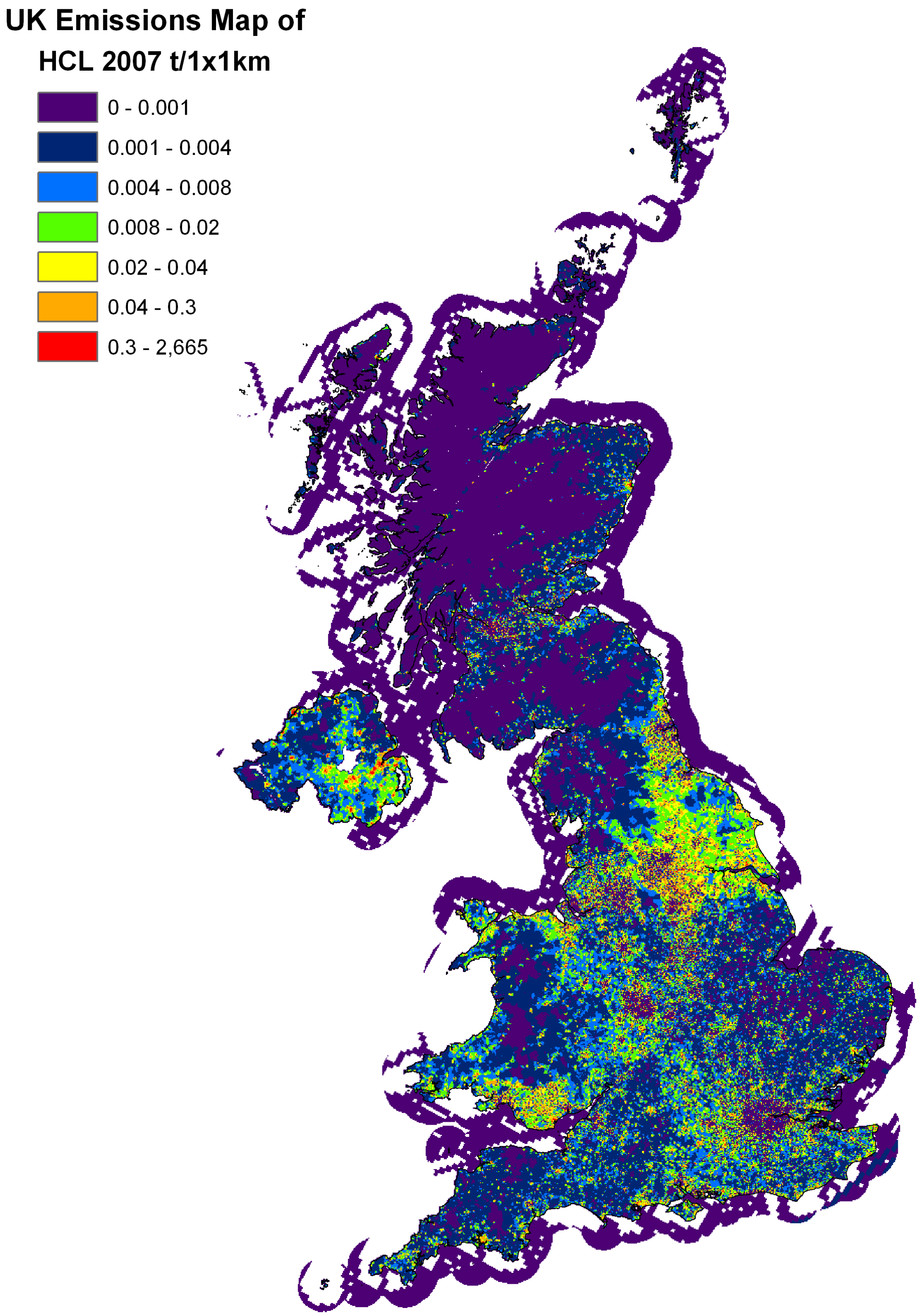


Figure 2.10 Spatially Disaggregated UK Emissions of HCl Map



2.7 HYDROGEN FLUORIDE

2.7.1 Key Source Description

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

2.7.2 Total HF Emissions

The emissions of hydrogen fluoride display a similar source pattern to hydrogen chloride (see Section 2.6). Like hydrogen chloride, power generation is the most significant source contributing 62% of total hydrogen fluoride emissions in 2007 (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 hydrogen fluoride 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. The impact of the miners strike in 1984 is again apparent.

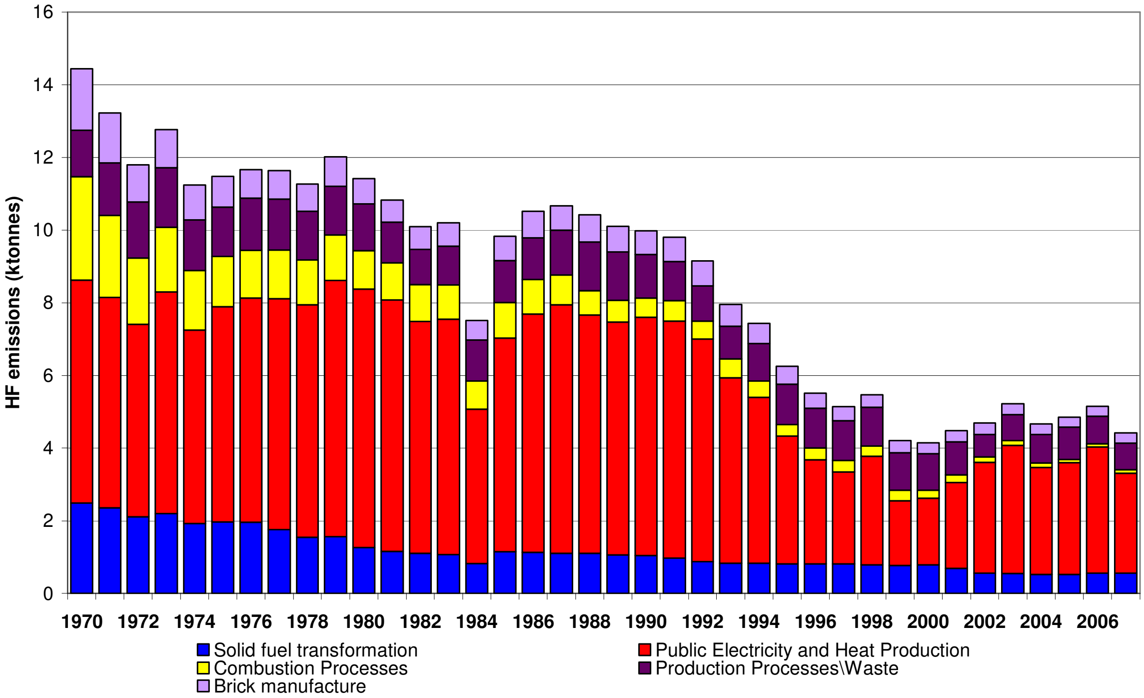
Between 2000 and 2006, UK emissions of hydrogen fluoride have increased, primarily driven by emissions from coal-fired power generation. In 2006, total hydrogen fluoride emissions were 24% higher than in 2000, due to an 89% increase in emissions from coal-fired power plant. Between 2006 and 2007, however, a decline in coal-fired power generation has dropped the hydrogen fluoride emissions to 85% of those in 2006 (with the coal-fired power emissions at 150% of the 2000 value). Interestingly this trend is not noted for hydrogen chloride (which exhibits a decrease of 79% from 1999 to 2006). This is because the hydrogen chloride emission per unit of coal consumed decreased between 1999 and 2006, whereas that for hydrogen fluoride 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	2003	2004	2005	2006	2007	2007%
BY UN/ECE CATEGORY											
Public Electricity and Heat Production	1A1a	6.13	7.11	6.56	1.83	3.52	2.94	3.07	3.47	2.75	62%
Stationary Combustion Processes	1A1c-1A2b, 1A4	2.85	1.05	0.53	0.22	0.13	0.12	0.09	0.09	0.10	2%
Brick manufacture	1A2f	1.70	0.69	0.66	0.30	0.31	0.29	0.29	0.28	0.28	6%
Solid fuel transformation	1B1b	2.49	1.26	1.04	0.79	0.55	0.52	0.53	0.56	0.56	13%
Production Processes	2	1.23	1.25	1.16	1.00	0.71	0.78	0.88	0.75	0.73	17%
Waste	6	0.04	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0%
BY FUEL TYPE											
Solid		13.29	10.16	8.83	3.16	4.57	3.94	4.04	4.47	3.77	85%
Petroleum		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0%
Gas		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0%
Non-Fuel		1.15	1.26	1.15	0.99	0.65	0.73	0.81	0.68	0.65	15%
TOTAL		**14.4**	**11.4**	**10.0**	**4.1**	**5.2**	**4.7**	**4.8**	**5.2**	**4.4**	**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 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.

Road Transport is the largest source of NO_x in the UK with Stationary Combustion and Power Generation also forming a significant source. Approximately one third of the UK NO_x emissions arise from road transport, 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 50%, 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 46% as a result of a 53% reduction from power stations and 59% decrease from road transport. The National Emissions Ceilings Directive target for 2010 is also shown.

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 (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_x) by aggregated UN/ECE[1] Category & Fuel (ktonnes)

	NFR Codes	1970	1980	1990	2000	2003	2004	2005	2006	2007	2010[3]	2007%
BY UN/ECE CATEGORY[2]												
Public Electricity and Heat Production	1A1a	813	862	775	347	382	358	374	392	360		24%
Stationary Combustion	1A1b-c, 1A2a	695	161	144	140	135	141	138	126	119		8%
Other industrial combustion	1A2f	539	424	359	284	267	265	256	244	230		15%
Passenger cars	1A3bi	282	403	650	357	236	206	180	158	137		9%
Heavy duty vehicles	1A3biii	249	288	346	306	281	276	265	259	248		17%
Other Road Transport	1A3bii, iv	44	55	88	85	77	73	69	61	56		4%
Other Transport	1A3ai(i)-1A3aii(i), 1A3c-1A3eii, 1A4bii, 1A4cii, 1A5b	187	214	240	225	214	216	223	247	229		15%
Residential plants	1A4bi	100	100	99	110	110	113	108	104	99		7%
Other	1B-6	35	47	43	11	8	8	8	7	7		0%
BY FUEL TYPE												
Solid		958	899	784	324	359	329	346	367	330		22%
Petroleum		1325	1317	1607	1140	953	922	884	865	802		54%
Gas		535	210	233	347	349	357	346	325	316		21%
Non-Fuel		127	127	120	56	48	49	46	40	38		3%
Total		**2945**	**2553**	**2744**	**1867**	**1710**	**1657**	**1622**	**1597**	**1486**	**1167**	**100%**

[1] UK emissions reported in IPCC format (Choudrie *et al*, 2009) 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)

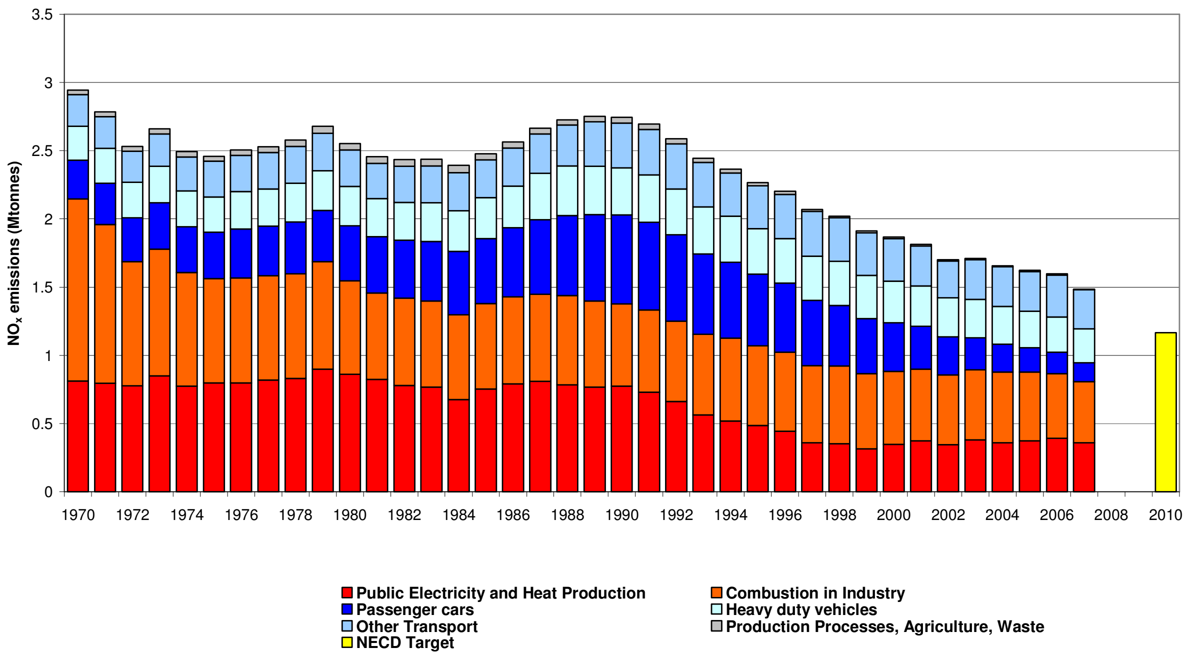
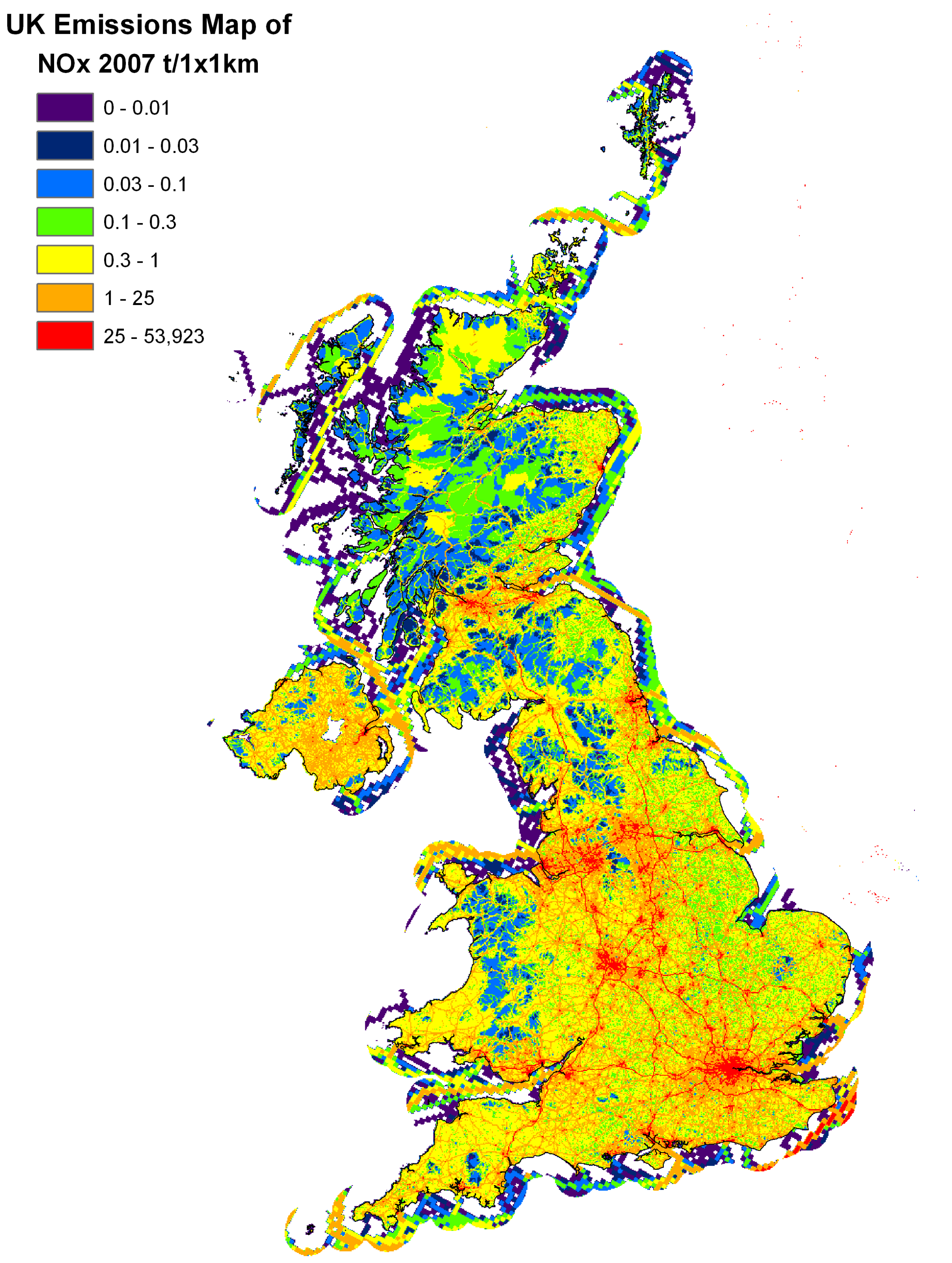


Figure 2.13 Spatially Disaggregated UK Emissions of NO_x Map



2.8.3 Transport

In 2007 the largest source of NO_x emissions in the UK is the transport sector with road vehicles and off-road vehicles contributing 30% and 15%, respectively, to total emissions. 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 120% compared to the 1970 level and emissions from diesel consumption rose by 48%.

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 three-way catalytic converters on petrol cars and stricter regulations on truck emissions.

Figure 2.14 Emissions of NO_x from Road Transport by Vehicle Type (ktonnes) and projections to 2010.

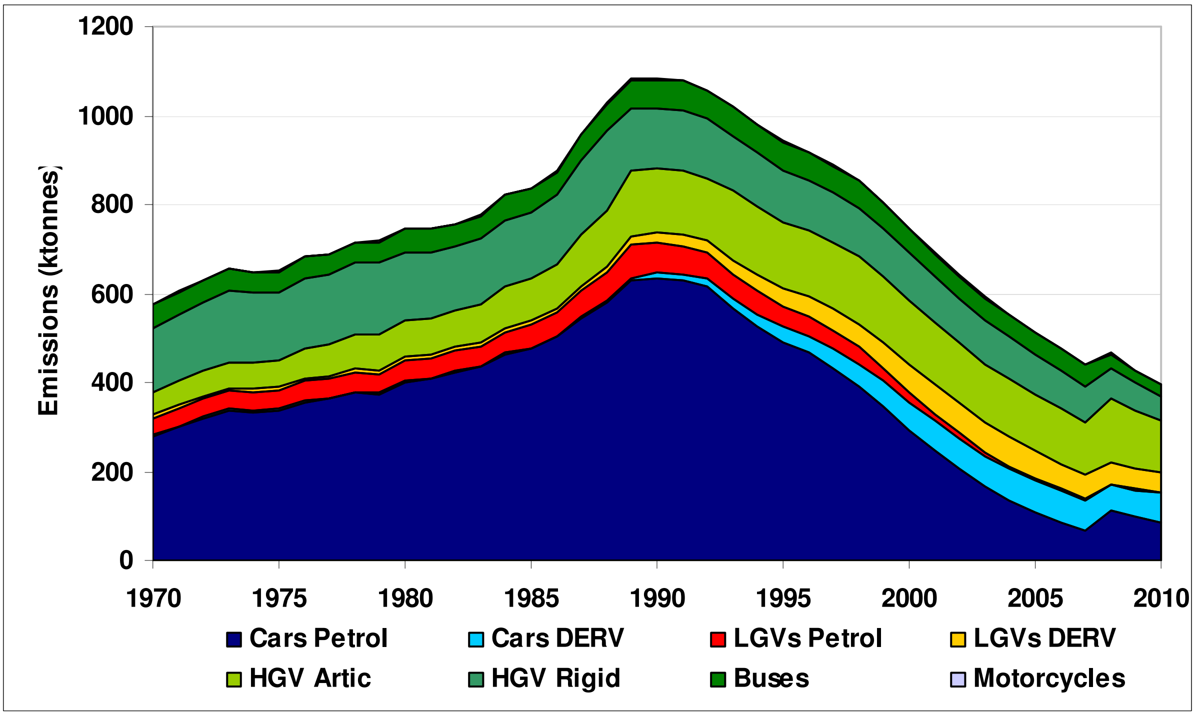


Figure 2.15 shows the average NO_x emissions per vehicle kilometre for different vehicle types between 1970 and 2010. Various emission regulations on new petrol cars, which have come into effect in stages since 1976, have led to the gradual reduction in NO_x emissions from petrol cars. The more rapid 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 NO_x Emissions per Vehicle km by Vehicle Type (1970-2007)

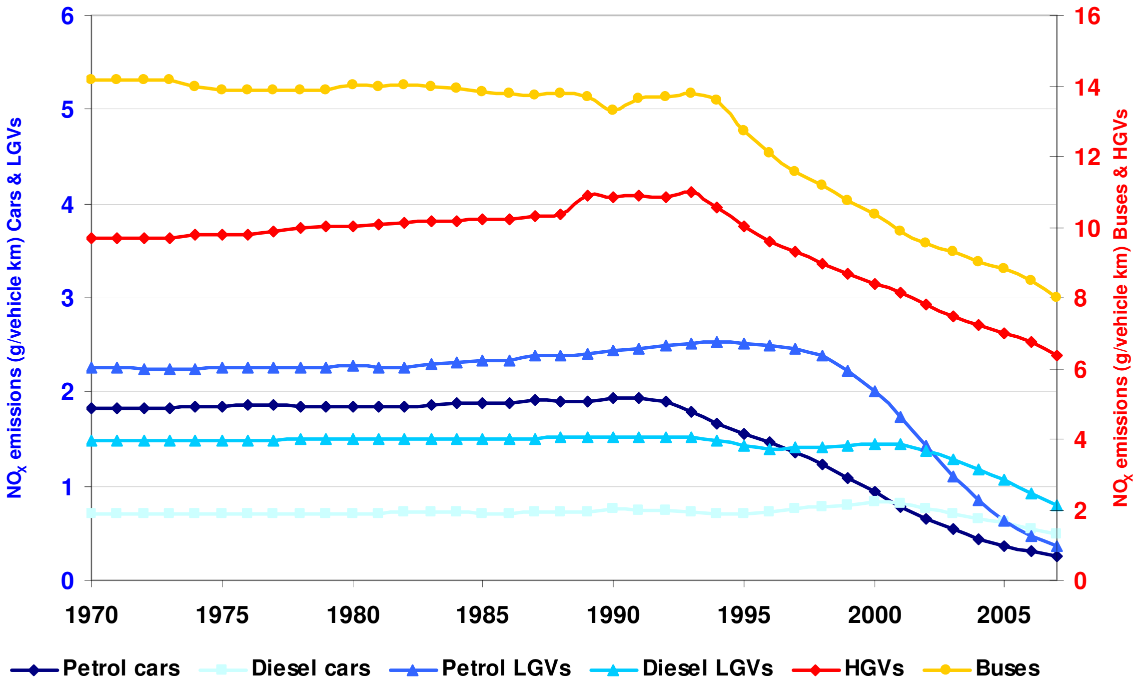
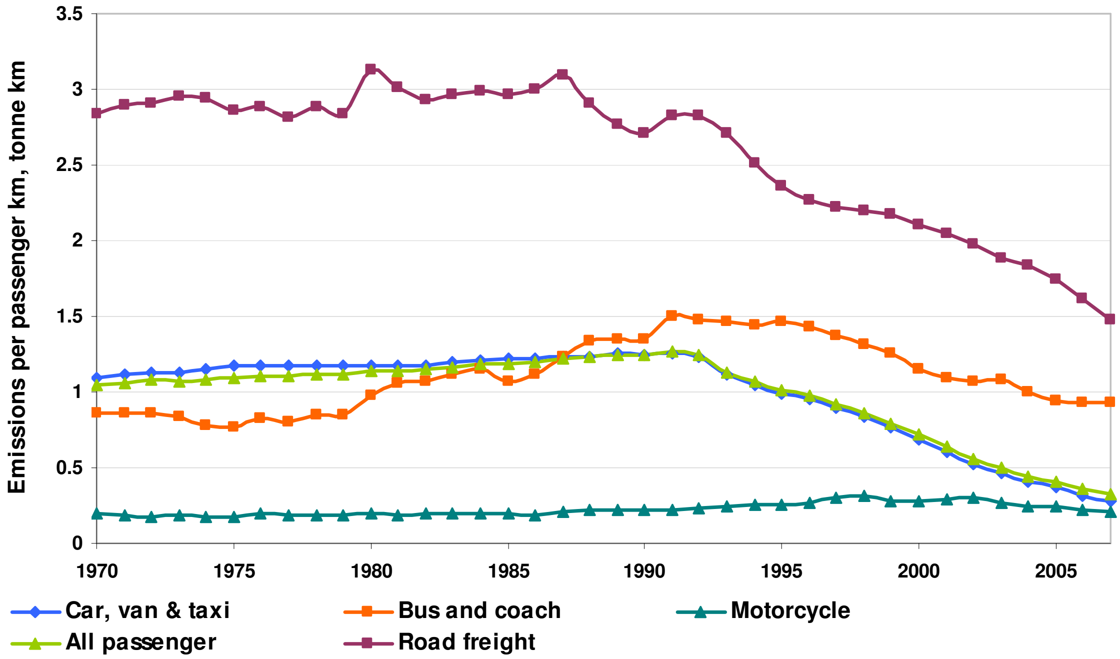


Figure 2.16 shows emissions per passenger km and by tonne km of freight. Technological improvements to HGVs have led to emissions per tonne of freight moved has almost halved in 2007 compared with 1970. Emissions per passenger km from cars, vans and taxis have significantly decreased since 1970 due mainly to the introduction of three-way catalytic converters in 1992 now penetrating the car fleet. Per passenger km emissions from buses and coaches increased between 1970 and 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 (grams) by Passenger Kilometre or Freight Tonne Kilometre (1970-2007)



In 2007 other transport and machinery contributed a further 15% to total UK NO_x emissions. This has also steadily gown over the period 1970 to 2007 (domestic and international take-off and landing cycles up to an altitude of 1,000 m are considered here in accordance with UN/ECE guidelines. Emissions arising from domestic and international cruise are not included).

2.8.4 Power Generation

Emissions from power stations have declined over the period 1970-2007 by 56%. 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. The increased use of nuclear generation and the introduction of CCGT (Combined Cycle Gas Turbine) plant burning natural gas over the past two decades (See Section 7.2.3) have further reduced NO_x emissions. The emissions from the low NO_x turbines used in CCGT plants are much lower than those of pulverised coal fired plant even when fitted with low NO_x burners, so changes in the mix of fuels used to generate electricity have a significant impact on NO_x emissions. For example, the use of coal increased between 2004 and 2006, while gas use decreased. 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 (NFR code 1A2) have declined by 72% since 1970 and they currently contribute 15% 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

Non-Methane Volatile Organic Compounds (NMVOCs) are organic compounds, which may differ widely in their chemical composition. These organic compounds are often grouped together as NMVOCs within environmental regulations and reports, 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 20% 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 an increase in emissions between 1970 and 1990 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. The data shows that NMVOC emissions in 2007 were well below the 2010 ceiling.

Figure 2.17 Time Series of NMVOC Emissions (Mtonnes) and the NECD ceiling for 2010.

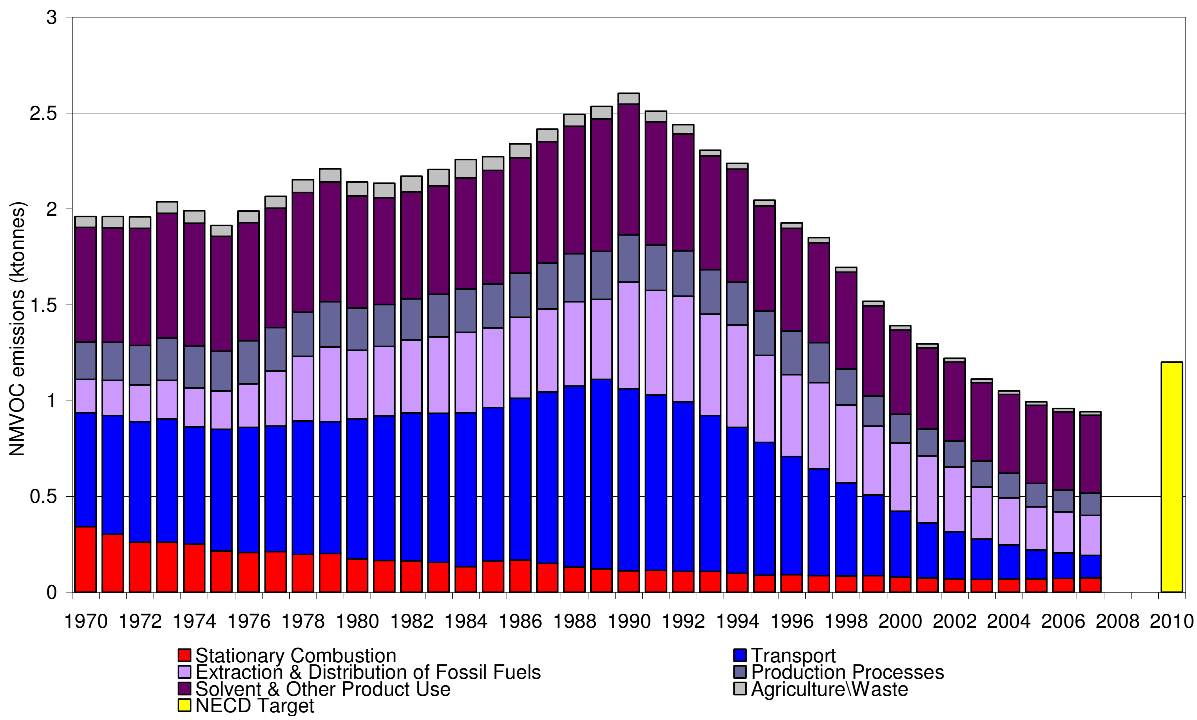


Table 2.12 UK Emissions of NMVOCs by aggregated UN/ECE[1] Source Category and Fuel (ktonnes)

	NFR Codes	1970	1980	1990	2000	2003	2004	2005	2006	2007	2010[3]	2007%
BY UN/ECE CATEGORY[2]												
Stationary Combustion	1A1, 1A2, 1A4a, 1A4bi, 1A4ci	342	174	113	78	67	70	69	72	75		8%
Road Transport	1A3b	559	652	906	307	175	144	118	101	88		9%
Other Transport	1A3ai(i), 1A3aii(i), 1A3c, 1A3eii, 1A4bii, 1A4cii, 1A5b	35	39	43	38	35	34	33	33	30		3%
Extraction & Distribution of Fossil Fuels	1B	173	356	556	356	272	246	225	214	208		22%
Production Processes	2A-2C	117	135	171	69	55	48	44	38	38		4%
Processes in wood, paper pulp, food, drink industries	2D	78	86	78	79	80	80	79	78	79		8%
Solvent & Other Product Use	3	598	584	679	440	409	410	407	407	405		43%
Agriculture\Waste	4, 6	56	73	59	23	19	18	18	18	18		2%
BY FUEL TYPE												
Solid		315	146	81	43	34	36	36	40	43		5%
Petroleum		617	752	972	369	233	201	173	156	139		15%
Gases		3	6	6	11	10	10	10	9	9		1%
Non Fuel		1025	1237	1545	969	836	804	774	755	750		79%
Total		**1960**	**2141**	**2604**	**1391**	**1113**	**1051**	**993**	**960**	**942**	**1200**	**100%**
MEMO Items												
Natural Emissions[4]		91	91	92	92	93	92	92	92	92		
Other Transport[5]		19	9	10	11	10	12	12	13	13		

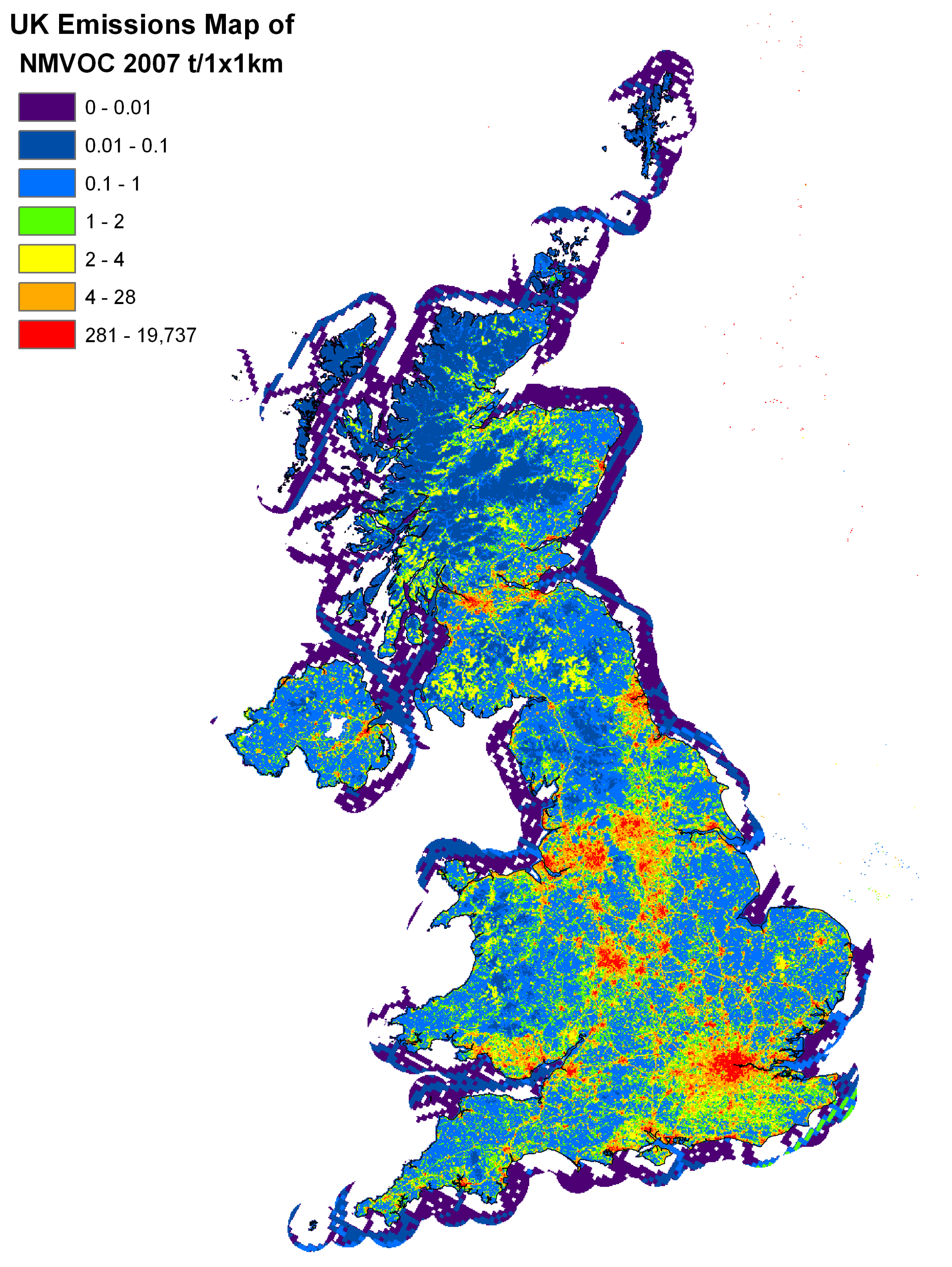
[1] UK emissions reported in IPCC format (Choudrie *et al*, 2009) differ slightly due to the different source categories used.
[2] See Annex 1 for definition of UN/ECE Categories
[3]Total emissions value shown for 2010 is the ceiling set under the NECD
[4] Primarily emissions from forests, but also includes accidental biomass fires
[5]Includes Domestic/International Aviation (Cruise) and International Navigation

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 43% and 12.5%, respectively, of the 2007 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 1981, 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 40 % 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 1990, 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 18% since 1994.

Emissions from the food and drink industry comprised 8.4% (79 ktonnes) of the total NMVOC emission in 2007. 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 12.5% of NMVOC emissions of which 9.3% 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 90% owing to the increased use of three-way catalytic converters and fuel switching from petrol to diesel cars.

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 source of NMVOC emissions is tanker loading.

Emissions from gas leakage currently comprise around 4% of the total NMVOC emission. 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 4% of national NMVOC emissions.

The contribution from domestic heating has fallen by 86% between 1970 and 2007 as the use of coal for domestic and commercial heating has declined. It now accounts for just 4.5% of the UK emissions.

NMVOC emissions from waste treatment and disposal contribute 2% to national emissions. Data from the Environment Agency (2008) 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 Top 50 NMVOC Mass Emissions in 2007 (tonnes)

	Stationary combustion			Production Processes	Extraction and distribution of fossil	Solvent Use	Road transport	Other transport[3]	Waste treatment and disposal	Other Sources	**Total (Tonnes)**
	Energy production	Commerc residential	Industrial								
ethanol		6,552	54	55,044		41,527			630		**103,808**
butane	186	1,314	291	2,936	41,243	19,314	4,667	228	53		**70,234**
ethane	242	3,778	95	1,195	29,762	0	1,282	221	5,956		**42,531**
methanol				1,486	0	28,719			163		**30,369**
propane	140	1,530	139	1,594	20,396	3,777	430	152	5,642		**33,800**
toluene	94	689	89	3,392	165	10,766	5,431	1,792	364		**22,782**
ethylene	49	7,186	107	3,570	24		6,107	3,734	1,013		**21,790**
acetone	18	6	15	1,560		18,078	578	48	3		**20,305**
pentane	125	713	320	1,593	15,446	434	2,866	135	46		**21,679**
2-methylbutane	57	1,241	112	929	7,613	48	6,095	318	34		**16,448**
m-xylene	460	102	41	1,916	58	12,319	1,658	540	167		**17,261**
hexane	124	105	51	3,226	8,004	2,612	2,613	84	240		**17,061**
benzene	88	8,213	339	1,584	541	0.043	2,218	2,853	985		**16,821**
formaldehyde	2,002	673	527	292	39	24	3,815	2,511	3,761		**13,644**
trichloroethene				575		12,335			132		**13,043**
2-methylpropane	17	447	12	210	9,084	973	1,998	120	17		**12,878**
2-butanone				636		11,677	176	8	30		**12,527**
dichloromethane				2,086		9,983			148		**12,217**
decane	0.107	16		681	20	8,284	562	1,345			**10,906**
butyl acetate				193		10,132			47		**10,372**
propylene	59	1,322	29	3,690	14	0.009	2,547	1,092	58		**8,812**
1,2,4-trimethylbenzene	0.107	0.003		464	4	5,408	1,906	453			**8,234**
ethylbenzene	134	35	25	1,538	17	4,717	1,278	348	270		**8,363**
2-propanol		4		561		7,717			36		**8,317**
ethyl acetate				1,166		7,010			50		**8,226**
heptane	18	281	1	284	7,857	1,472	620	102			**10,634**
4-methyl-2-pentanone				673		5,806					**6,478**
octane	0.214	27		182	6,907	1,277	274	37			**8,705**
p-xylene	3	79	18	819	12	3,314	1,282	417	130		**6,074**
o-xylene	102	58	13	660	27	3,091	1,432	468	95		**5,946**
tetrachloroethene				119		5,661			272		**6,052**
nonane	0.107	23		425	51	4,994	140	338			**5,972**
undecane	0.107	0.003		354		4,317		639			**5,310**
1-butanol				213		4,163			15		**4,391**
2-methylpropene	0	59		575	178		1,718	1,344	11		**3,884**
acetylene	15	7	57	625	11	0.177	2,109	876			**3,699**
acetaldehyde	0.321	0.009		681			1,940	1,281			**3,902**
1-propanol				60		3,535			86		**3,681**
2-butoxyethanol				96		3,360					**3,456**
2-methylpentane	3	5	7	876	1,389	1,236		6	114		**3,635**
dipentene				13		3,364					**3,377**
1,3,5-trimethylbenzene	0.214	0.006		164		1,873	721	255			**3,013**
methyl acetate				3,061							**3,061**
1-methoxy-2-propanol				93		2,879					**2,971**
methylethylbenzene				225		2,657					**2,882**
1,2,3-trimethylbenzene	0.107	0.003		155		1,874	438	215			**2,682**
4-methyldecane				206		2,514					**2,720**
1,3-butadiene	1			402	5		1,267	693	16		**2,383**
3-methylpentane	2	3	5	599	755	964			77		**2,405**
1-methoxy-2-propyl acetate				48		2,216					**2,264**
Total Top 50	**3,941**	**34,468**	**2,348**	**103,726**	**149,621**	**276,424**	**58,169**	**22,651**	**20,661**		**672,009**
Other VOCs	239	2,290	103	18,809	3,051	91,024	9,206	4,883	3,463		**133,067**
Other grouped species	2	257	2	19,928	5,609	7,785	19,596	21,632	2,856		**77,666**
unspeciated	1,297	7,706	2	31,274	735	8,929	789	2,216	4,333	1,516	**58,796**
Total VOC	**5,479**	**44,721**	**2,455**	**173,737**	**159,016**	**384,163**	**87,759**	**51,381**	**31,312**	**1,516**	**941,538**

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 based on values proposed by Jenkin et al 2000 (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	Other Sources	Total (Mass Emissions)	Total (POCCP weighted)	Total (POCCP weighted %)
ethanol	39.90	a	6,606	55,044		41,527			630		103,808	41,419	9.7%
butane	35.20	a	1,792	2,936	41,243	19,314	4,667	228	53		70,234	24,722	5.8%
ethane	12.30	a	4,115	1,195	29,762	0	1,282	221	5,956		42,531	5,231	1.2%
propane	17.60	a		1,486	0.002	28,719			163		30,369	5,345	1.2%
toluene	63.70	a	1,809	1,594	20,396	3,777	430	152	5,642		33,800	21,531	5.0%
methanol	14.00	a	872	3,392	165	10,766	5,431	1,792	364		22,782	3,189	0.7%
ethylene	100.00	a	7,342	3,570	24		6,107	3,734	1,013		21,790	21,790	5.1%
2-methylbutane	40.50	a	39	1,560		18,078	578	48	3		20,305	8,224	1.9%
pentane	39.50	a	1,158	1,593	15,446	434	2,866	135	46		21,679	8,563	2.0%
acetone	9.40	a	1,410	929	7,613	48	6,095	318	34		16,448	1,546	0.4%
hexane	48.20	a	603	1,916	58	12,319	1,658	540	167		17,261	8,320	1.9%
m-xylene	110.80	a	281	3,226	8,004	2,612	2,613	84	240		17,061	18,904	4.4%
2-methylpropane	30.70	a	8,640	1,584	541	0.043	2,218	2,853	985		16,821	5,164	1.2%
formaldehyde	51.90	a	3,202	292	39	24	3,815	2,511	3,761		13,644	7,081	1.7%
trichloroethene	32.50	a		575		12,335			132		13,043	4,239	1.0%
benzene	21.80	a	476	210	9,084	973	1,998	120	17		12,878	2,807	0.7%
propylene	112.30	a		636		11,677	176	8	30		12,527	14,068	3.3%
dichloromethane	6.80	a		2,086		9,983			148		12,217	831	0.2%
2-butanone	37.30	a	16	681	20	8,284	562	1,345			10,906	4,068	0.9%
butyl acetate	26.90	a		193		10,132			47		10,372	2,790	0.7%
decane	38.40	a	1,411	3,690	14	0.009	2,547	1,092	58		8,812	3,384	0.8%
ethylbenzene	73.00	a	0	464	4	5,408	1,906	453			8,234	6,011	1.4%
1,2,4-trimethylbenzene	127.80	a	194	1,538	17	4,717	1,278	348	270		8,363	10,688	2.5%
2-propanol	18.80	a	4	561		7,717			36		8,317	1,564	0.4%
heptane	49.40	a		1,166		7,010			50		8,226	4,064	0.9%
ethyl acetate	20.90	a	300	284	7,857	1,472	620	102			10,634	2,223	0.5%
o-xylene	105.30	a		673		5,806					6,478	6,822	1.6%
p-xylene	101.00	a	27	182	6,907	1,277	274	37			8,705	8,792	2.1%
octane	45.30	a	100	819	12	3,314	1,282	417	130		6,074	2,751	0.6%
tetrachloroethene	2.90	a	173	660	27	3,091	1,432	468	95		5,946	172	0.0%
4-methyl-2-pentanone	49.00	a		119		5,661			272		6,052	2,966	0.7%
acetylene	8.50	a	23	425	51	4,994	140	338			5,972	508	0.1%
nonane	41.40	a	0.110	354		4,317		639			5,310	2,198	0.5%
2-methylpropene	62.70	a		213		4,163			15		4,391	2,753	0.6%
undecane	38.40	a	59	575	178		1,718	1,344	11		3,884	1,491	0.3%
methyl acetate	5.90	a	79	625	11	0.177	2,109	876			3,699	218	0.1%
1-butanol	62.00	a	0.330	681			1,940	1,281			3,902	2,419	0.6%
acetaldehyde	64.10	a		60		3,535			86		3,681	2,359	0.6%
2-methylpentane	42.00	a		96		3,360					3,456	1,452	0.3%
2-butoxyethanol	48.30	a	15	876	1,389	1,236		6	114		3,635	1,756	0.4%
1,3,5-trimethylbenzene	138.10	a		13		3,364					3,377	4,664	1.1%
1-propanol	56.10	a	0.220	164		1,873	721	255			3,013	1,690	0.4%
1,3-butadiene	85.10	a		3,061							3,061	2,605	0.6%
dipentene	74.54	b		93		2,879					2,971	2,215	0.5%
2-butene	113.90	a		225		2,657					2,882	3,283	0.8%
1-methoxy-2-propanol	35.50	a	0.110	155		1,874	438	215			2,682	952	0.2%
1,2,3-trimethylbenzene	126.70	a		206		2,514					2,720	3,446	0.8%
methylethylbenzene	94.10	c	1	402	5		1,267	693	16		2,383	2,243	0.5%
4-methyldecane	37.67	b	10	599	755	964			77		2,405	906	0.2%
2-pentene	111.90	a		48		2,216					2,264	2,534	0.6%
Total Top 50			40,758	103,726	149,621	276,424	58,169	22,651	20,661		672,009	298,962	69.7%
Other VOC	0.38[a]		2,631	18,809	3,051	91,024	9,206	4,883	3,463		133,067	50,854	11.9%
Other grouped species	0.63[a]		261	19,928	5,609	7,785	19,596	21,632	2,856		77,666	48,767	11.4%
unspeciated	51.30	c	9,005	31,274	735	8,929	789	2,216	4,333	1,516	58,796	30,162	7.0%
Total VOC			52,655	173,737	159,016	384,163	87,759	51,381	31,312	1,516	941,538	428,745	100%

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 www.airquality.co.uk/archive/index.php).

For many years the monitoring of particulate levels in the UK 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 originally calibrated against Total Suspended Particulate (TSP) mass concentrations for domestic coal smoke and more recently to include the 1980s contribution of vehicle exhaust to the metric. With the original calibration 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 mass concentrations of particulates in the atmosphere. Furthermore, the measurements used for deriving emission factors of black smoke were conducted several decades ago. when the relative importance of sources were very different. 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 report from the Air Quality Expert Group Report on particulate matter in the UK (AQEG, 2005), which can be found on

www.airquality.co.uk/archive/index.php and

http://www.defra.gov.uk/environment/quality/air/airquality/publications/particulate-matter/index.htm

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 engine 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. Combustion of wood, gas oil and natural gas also all contributing significantly to UK emissions of PM_{10}. 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 245 ktonnes (50% of the total emission) in 1970 to 18 ktonnes (14%) in 2007.

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	2003	2004	2005	2006	2007	2007 %
BY UNECE CATEGORY[1]											
Combustion in Energy and Transformation Industry	1A1	83	83	74	26	11	11	12	13	11	8%
Combustion in Manufacturing Industry/Commercial	1A2	23	9	8	5	5	5	5	4	5	4%
Industrial off-road mobile machinery	1A2f	41	27	25	19	16	16	14	13	12	9%
Residential plants	1A4bi	232	100	49	23	16	16	15	16	18	13%
Passenger cars	1A3bi	3	4	8	7	6	6	6	6	6	4%
Light duty vehicles	1A3bii	4	5	9	7	6	5	5	5	4	3%
Heavy duty vehicles	1A3biii	13	15	17	9	7	6	6	5	5	3%
Other Transport	1A3biv&vi, 1A3ai(i)-1A3aii(i), 1A3c-1A3eii, 1A4bii, 1A4cii, 1A5b	19	21	24	23	22	23	23	25	24	17%
Production Processes	1B1-3	53	43	47	30	28	29	28	28	30	22%
Agriculture	4	11	12	13	14	14	14	13	13	13	9%
Waste/Other	6, 7	10	10	9	8	8	8	8	8	8	6%
By FUEL TYPE											
Solid		331	185	126	47	26	27	26	29	29	21%
Petroleum		73	67	71	54	45	45	43	43	40	30%
Gas		1	2	2	3	4	4	4	4	4	3%
Non-Fuel		86	76	84	66	64	63	62	61	63	46%
TOTAL		**492**	**330**	**283**	**170**	**139**	**138**	**135**	**137**	**135**	**100%**

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

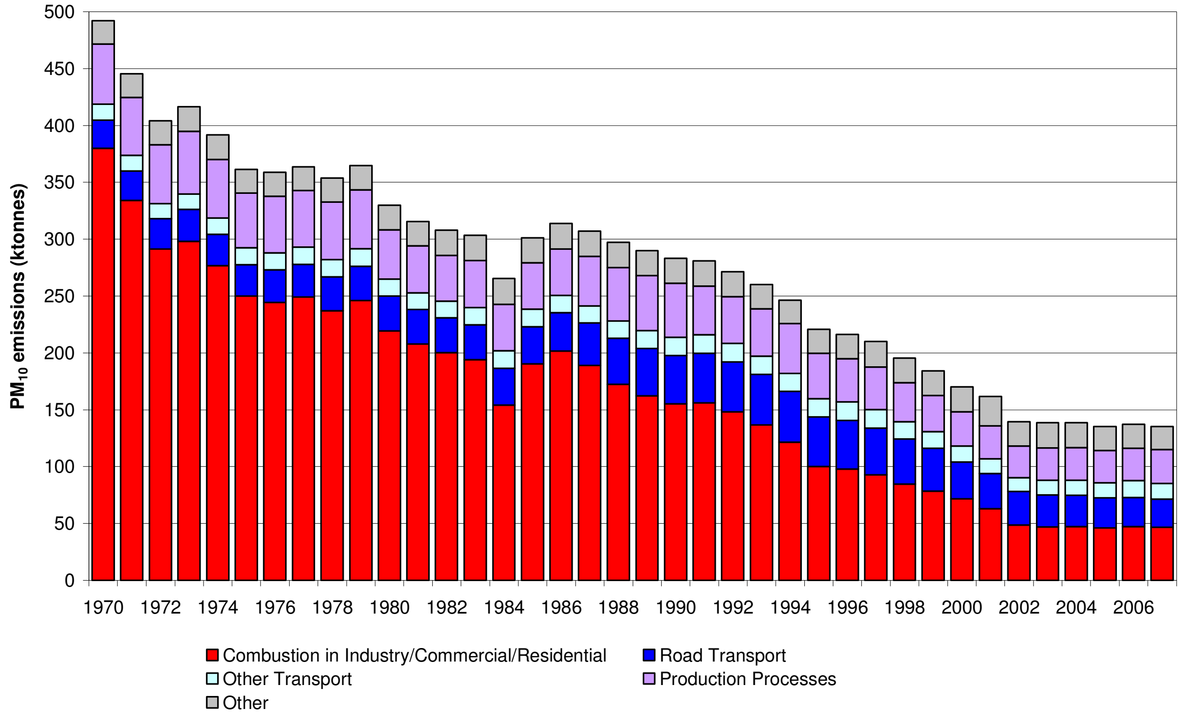
Table 2.16 PM_{10} Emission Estimates from Resuspension (ktonnes)

	1970	1980	1990	2000	2001	2002	2003	2004	2005	2006	2007
Resuspension from Road Transport	8.2	11.2	16.9	19.4	19.7	20.2	20.3	20.7	20.7	21.1	21.3

The geographical disaggregation of emissions is shown in Figure 2.19. There is a clear distinction between the important sources in rural and urban areas. The sources of PM emissions are diverse and many of the sources do not occur inside towns and cities. However, road transport is a major source in urban areas and while contributing to only 18% of national emissions of PM10, it can account for a much higher proportion (as much as 50%) in urban areas such as London (AQEG, 2005).

Emissions from electricity generation have also recently been declining (since 1990) despite a significant growth in the electricity generated between 1970 and 2007. 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 some power stations has reduced particulate emissions further.

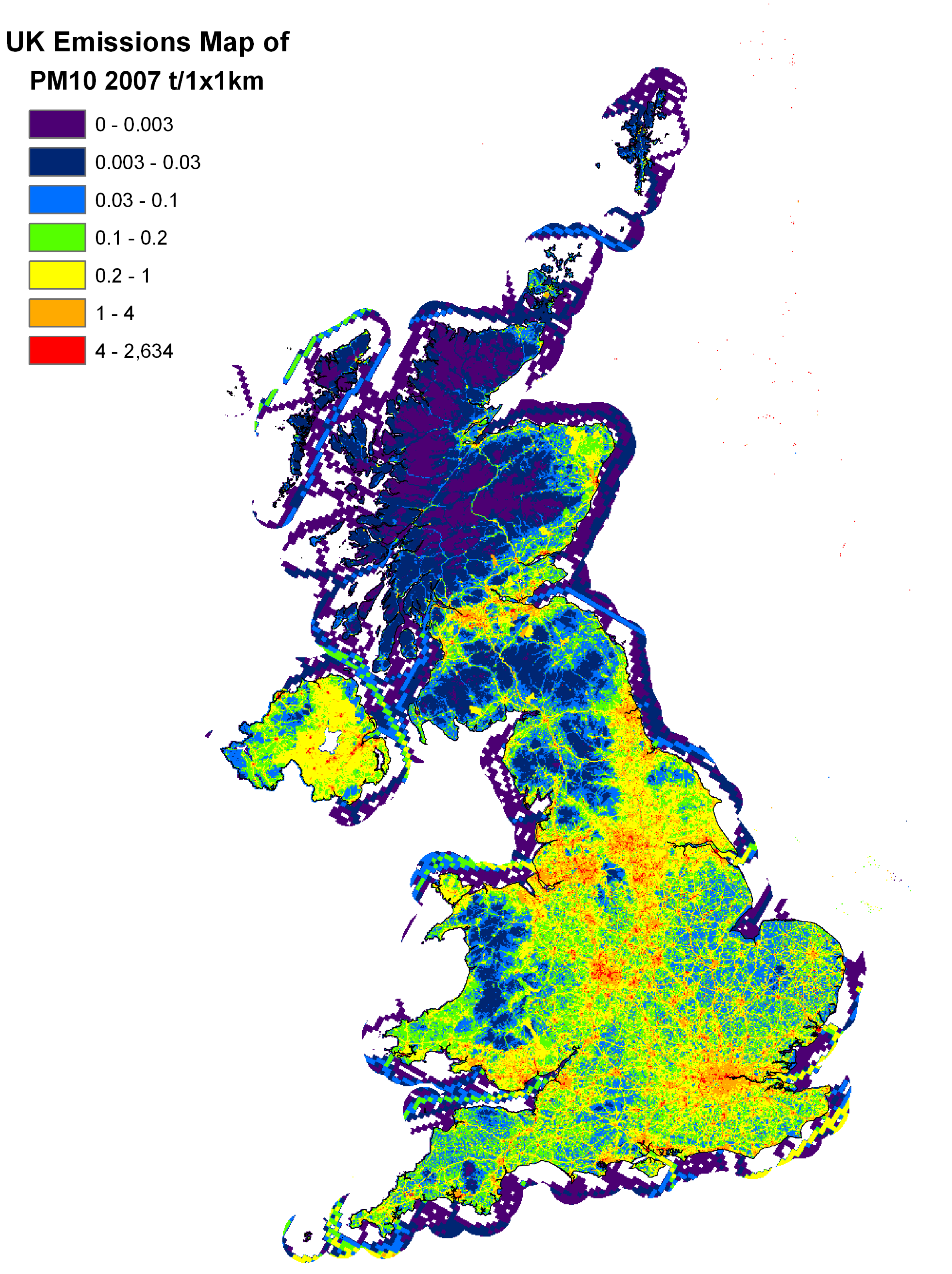
Figure 2.19 Time Series of PM_{10} Emissions (ktonnes)



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 5% in 1970 to 18% in 2007. 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.

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 although recently it has been declining slowly since 1994. 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 2007, UK emissions of PM_{10} fell by 52%, whereas emissions of $PM_{2.5}$ fell by 48%, $PM_{1.0}$ by 46% and $PM_{0.1}$ by 45%. 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 2007, it accounted for 18% of PM_{10} emissions, but 37% 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 21 ktonnes in 1990 to 11 ktonnes in 2007.

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	2003	2004	2005	2006	2007	2007%
Combustion in Energy and Transformation Industry	1A1	38	38	34	12	6	6	7	7	6	8%
Combustion in Manufacturing Industry/Commercial	1A2	11	5	4	3	3	3	3	3	3	4%
Industrial off-road mobile machinery	1A2f	28	19	17	13	12	12	11	10	9	11%
Residential plants	1A4bi	87	38	20	10	8	8	8	9	10	12%
Passenger cars	1A3bi	2	3	7	6	6	6	6	5	5	6%
Light duty vehicles	1A3bii	3	4	8	6	5	5	5	4	4	5%
Heavy duty vehicles	1A3biii	12	14	15	8	6	6	5	5	4	5%
Other Transport	1A3biv & vi, 1A3ai(i) - 1A3aii(i), 1A3c-1A3eii, 1A4bii, 1A4cii, 1A5b	15	16	18	17	16	17	17	19	18	22%
Production Processes	1B1-3	31	25	26	15	14	14	14	14	14	17%
Agriculture	4	2	3	2	2	2	2	2	2	2	3%
Waste/Other	6, 7	8	8	8	6	6	6	6	6	6	7%
Total		**238**	**173**	**159**	**100**	**84**	**84**	**83**	**84**	**82**	**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	2003	2004	2005	2006	2007	2007%
Combustion in Energy and Transformation Industry	1A1	19	18	16	6	4	4	4	4	4	7%
Combustion in Manufacturing Industry/Commercial	1A2	7	3	3	2	2	2	2	2	2	3%
Industrial off-road mobile machinery	1A2f	17	13	12	11	9	9	9	8	8	13%
Residential plants	1A4bi	69	29	14	7	5	5	5	5	6	10%
Passenger cars	1A3bi	2	3	6	6	5	5	5	5	5	8%
Light duty vehicles	1A3bii	3	4	7	6	5	5	4	4	4	6%
Heavy duty vehicles	1A3biii	11	13	14	8	6	5	5	4	4	7%
Other Transport	1A3biv & vi, 1A3ai(i) - 1A3aii(i), 1A3c-1A3eii, 1A4bii, 1A4cii, 1A5b	11	13	13	12	11	11	12	13	12	20%
Production Processes	1B1-3	22	18	17	9	9	9	9	8	9	14%
Agriculture	4	2	3	2	2	2	2	2	2	2	3%
Waste/Other	6, 7	6	6	6	5	5	5	5	5	5	8%
Total		**170**	**122**	**112**	**73**	**63**	**62**	**61**	**62**	**60**	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	2003	2004	2005	2006	2007	2007%
Combustion in Energy and Transformation Industry	1A1	7	7	6	3	2	2	2	2	2	8%
Combustion in Manufacturing Industry	1A2a	8	4	3	2	2	2	2	2	2	9%
Industrial off-road mobile machinery	1A2f	5	4	3	3	3	3	2	2	2	9%
Passenger cars	1A3bi	1	1	3	3	3	3	3	3	3	13%
Light duty vehicles	1A3bii	1	2	4	3	3	3	3	2	2	10%
Heavy duty vehicles	1A3biii	7	8	8	5	3	3	3	3	2	10%
Other Transport	1A3biv & vi, 1A3ai(i) - 1A3aii(i), 1A3c-1A3eii, 1A4bii, 1A4cii, 1A5b	3	3	3	3	3	3	3	3	3	13%
Production Processes	1B1-3	10	7	7	3	3	3	3	3	3	13%
Agriculture	4	2	2	2	2	2	2	2	2	2	9%
Waste/Other	6, 7	1	1	1	1	1	1	1	1	1	5%
Total		**44**	**38**	**41**	**28**	**24**	**24**	**24**	**23**	**22**	**100%**

Figure 2.21 Time Series of $PM_{2.5}$ Emissions (ktonnes)

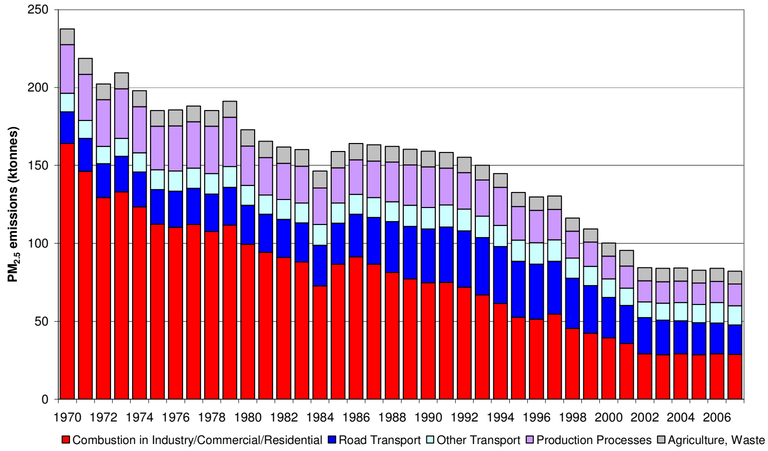


Figure 2.22 Time Series of $PM_{1.0}$ Emissions (ktonnes)

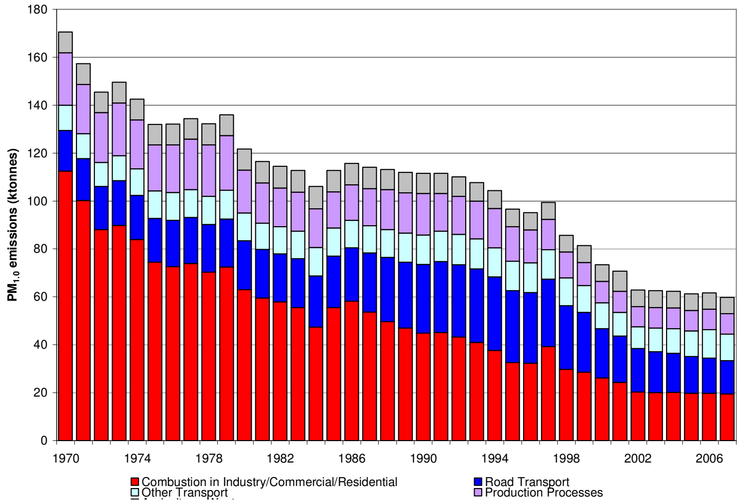
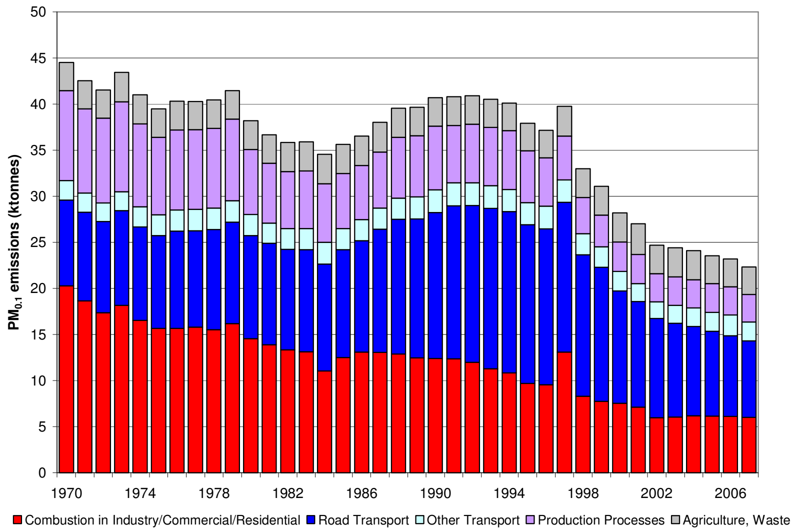


Figure 2.23 Time Series of $PM_{0.1}$ Emissions (ktonnes)



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	2006	2007
TOTAL	1095	626	457	334	294	292	291	252	241	220	211	201	189	185	180

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 than 93% of UK SO_2 emissions in 2007 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 (BERR, 2008), published sulphur contents of liquid fuels (Watson, 2007) 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 90% in SO_2 emissions. The emission profile exhibits a steady decline between 1970 and 2007 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 2007.

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 91% since 1970 and those from petroleum by 93%. 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 2007 there has been a 99% reduction in emissions.

Figure 2.24 Time Series of SO_2 Emissions (Mtonnes) and the ceiling to be achieved in 2010.

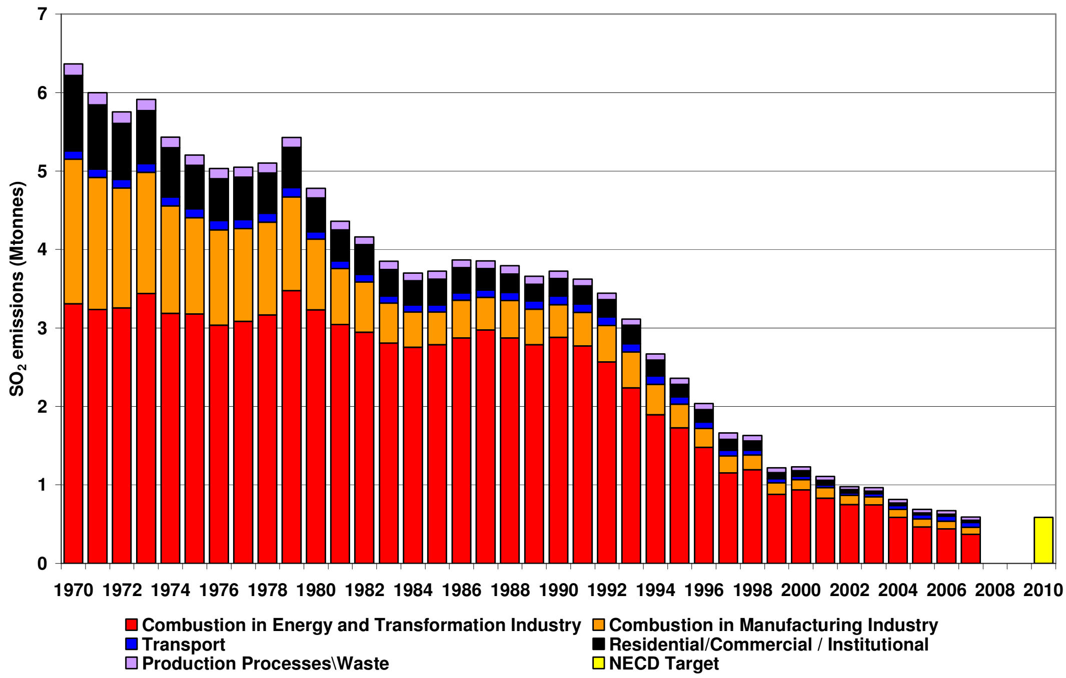


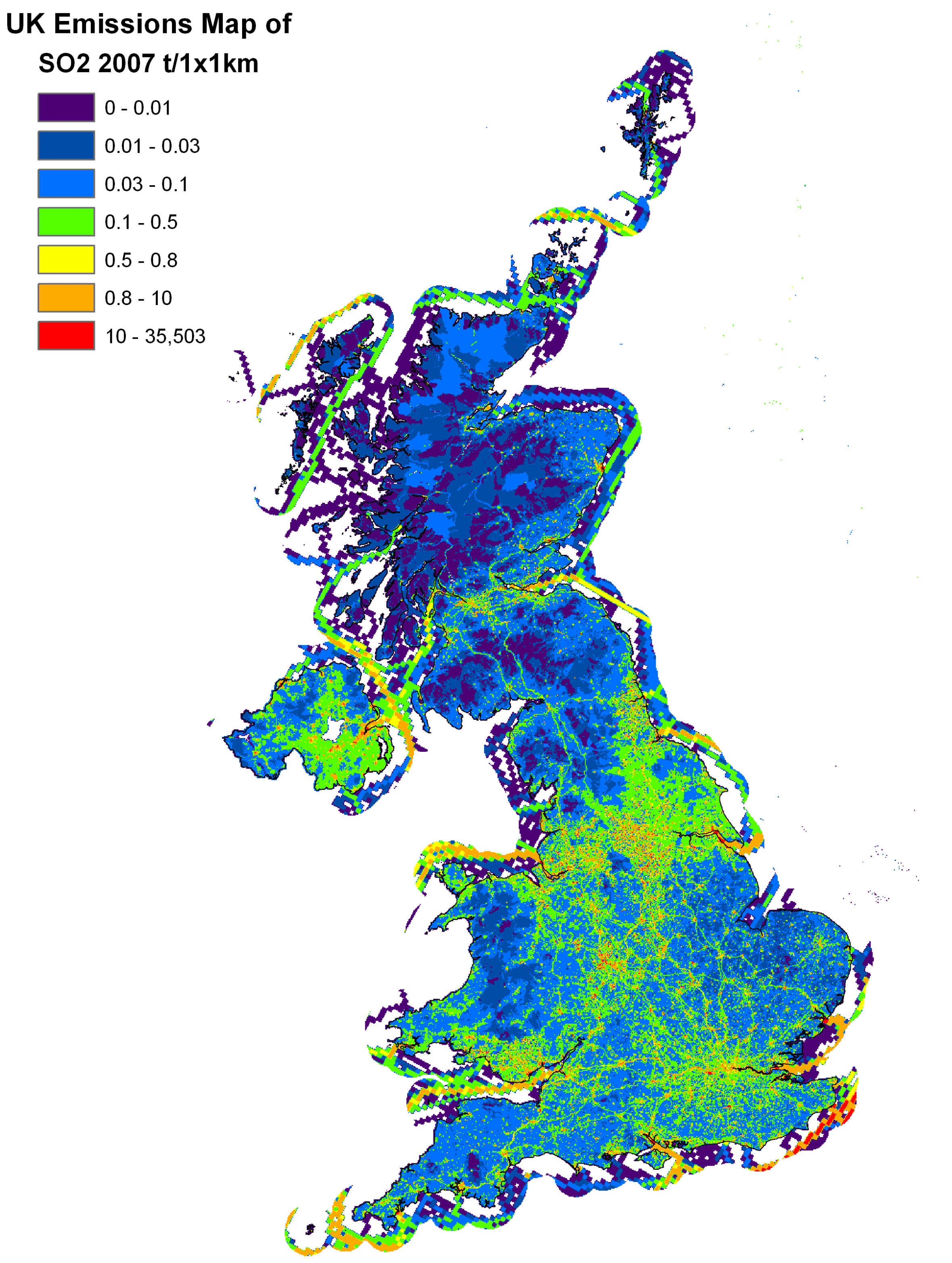
Table 2.21 UK Emissions of SO_2 by aggregated UN/ECE[1] Source Category and Fuel (ktonnes)

	NFR Codes	1970	1980	1990	2000	2003	2004	2005	2006	2007	2010[3]	2007 %
BY UN/ECE CATEGORY[2]												
Public Electricity and Heat Production	1A1a	2921	3014	2736	856	677	509	385	361	285		48%
Petroleum refining	1A1b	199	197	138	73	63	70	73	75	79		13%
Stationary Combustion	1A1c, 1A2a, 1A2b, 1A4a, 1A4ci	958	318	119	43	21	23	23	25	25		4%
Other industrial combustion (Autogenerators, Brick Manufacture)	1A2f	1514	811	388	112	93	92	91	81	76		13%
Transport	1A3ai(i), 1A3aii(i), 1A3b, 1A3c, 1A3eii, 1A4bii, 1A4cii, 1A5b	81	70	82	19	15	16	15	15	14		2%
National Navigation	1A3dii	23	25	28	20	24	31	37	50	49		8%
Residential plants	1A4bi	521	226	143	57	30	27	20	22	22		4%
Production Processes\Waste	1B1, 2, 6	147	120	91	51	43	44	43	42	41		7%
BY FUEL CATEGORY												
Solid		3730	3157	2757	954	753	585	457	432	354		60%
Petroleum		2461	1474	837	186	136	152	159	175	175		30%
Gas		19	10	9	15	10	11	10	10	11		2%
Non-Fuel		156	139	120	76	67	64	61	54	50		8%
Total		**6365**	**4781**	**3724**	**1231**	**966**	**813**	**687**	**671**	**591**	**585**	**100%**

[1] UK emissions reported in IPCC format (Choudrie *et al*, 2009) 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 48% of the total in 2007. 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 90%. 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 plants and the use of Combined Cycle Gas Turbine (CCGT) stations and other gas fired plants. 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, 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 2007 emissions from combustion sources have fallen by 95% 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 1970-2007, 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 to +30
Benzene	-30 to + 50
1,3-butadiene	-20 to +40
PM_{10}	-20 to +30
$PM_{2.5}$	-20 to +30
$PM_{1.0}$	-20 to +30
$PM_{0.1}$	-20 to +30
Black smoke	-30 to +50
Sulphur dioxide	+/- 4
Nitrogen oxides	+/- 10
Non-Methane Volatile Organic Compounds	-9 to +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 extrapolation of limited experimental data to the UK agricultural sector 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

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

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, although they are calculated using measured emission factors, 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 for 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 24% of emissions, and a further 28 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 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} underwent considerable revision over the 2003, 2004 and 2005 versions of the NAEI and must now 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 that are controlled under the Heavy metals protocol of the UNECE under the Convention on Long-range Transboundary Air Pollution- Heavy Metals.

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: www.unece.org/env/lrtap/. The UK has signed this protocol.

The UN/ECE Protocol on Heavy Metals targets three particularly harmful elements: 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 (Best Available Technique) for obtaining emission reductions from these sources, such as filters or scrubbers for combustion sources or mercury-free processes. The protocol also required 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 summarised 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 2007 are shown in Table 3.1 below.

Table 3.1 Total UK Emissions of Heavy Metals in 2007

Pollutant (Heavy metals)	**Total 2007 UK emission (tonnes)**
• Arsenic	14
• Beryllium	6
• Cadmium	3
• Chromium	29
• Copper	58
• Lead	70
• Manganese	32
• Mercury	7
• Nickel	80
• Selenium	35
• Tin	30
• Vanadium	474
• Zinc	292

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) and every year since the 1996 NAEI. 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 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 (BERR 2008). 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 last reviewed in 2002 (Passant *et al,* 2002a) and numerous changes were made.

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). The emissions from coal and oil fired power stations are based on estimates reported in the Pollution Inventory (Environment Agency, 2008) 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 was undertaken in Spring 2008. This has improved the certainty of many of the emission estimates and the results have been incorporated into the 2007 NAEI.

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 from new plant (Environment Agency, 2008).

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.

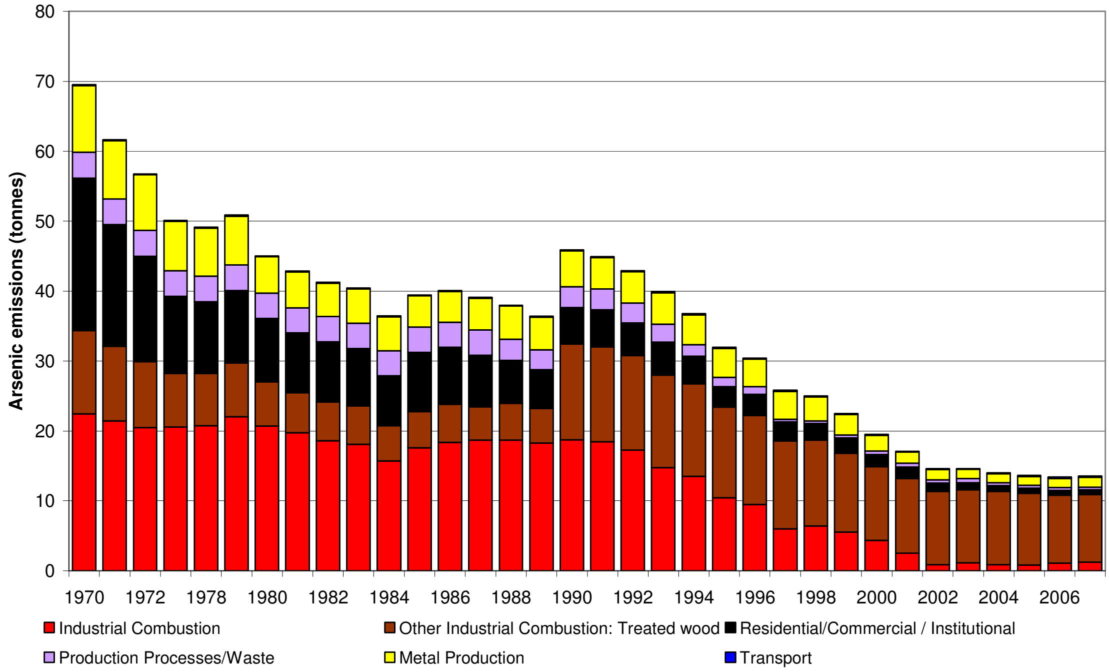
Table 3.2 and Figure 3.1 summarise the UK emissions of arsenic. Emissions have declined by 81% since 1970. Historically the largest source of emissions was coal combustion with other sources being very small by comparison. However, coal use has declined over time, in favour of natural gas use and emissions from the industrial sector are typically now greater than emissions from public power generation. 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	2003	2004	2005	2006	2007	2007%
BY UN/ECE CATEGORY[1]											
Public Electricity and Heat Production	1A1a	18.2	19.2	18.2	4.1	0.9	0.6	0.6	0.9	1.0	7%
Other Stationary Industrial Combustion	1A1b-c	2.8	1.2	0.3	0.1	0.1	0.1	0.1	0.1	0.2	1%
Iron and Steel	1A2a	1.4	0.4	0.2	0.1	0.1	0.1	0.1	0.1	0.1	1%
Other Industrial Combustion: Treated wood	1A2f	11.9	6.3	13.7	10.5	10.5	10.4	10.3	9.7	9.7	71%
Transport	1A3ai(i)-1A3aii(i), 1A3b, 1A3c-1A5b	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	2%
Residential/Commercial / Institutional	1A4	21.8	9.1	5.2	1.7	1.0	0.9	0.7	0.7	0.7	5%
Production Processes/Waste	1B1-2B, 6	3.7	3.6	3.0	0.5	0.6	0.4	0.4	0.4	0.4	3%
Metal Production	2C	9.5	5.2	5.2	2.3	1.3	1.3	1.2	1.3	1.4	10%
BY FUEL											
Solid		45.3	29.3	31.9	15.1	11.4	10.9	10.6	10.8	10.8	80%
Petroleum		7.8	4.3	2.7	0.6	0.5	0.5	0.6	0.6	0.6	4%
Gases		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Non Fuel		16.4	11.5	11.3	3.8	2.8	2.7	2.4	2.0	2.1	16%
Total		**69.5**	**45.1**	**45.9**	**19.5**	**14.6**	**14.0**	**13.6**	**13.4**	**13.6**	**100%**

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

Figure 3.1 Time Series of Arsenic Emission (tonnes)



3.3 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 3.3 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.

Table 3.3 UK Emissions of Beryllium by aggregated UN/ECE Category and Fuel (Ktonnes)

	NFR Codes	2000	2001	2002	2003	2004	2005	2006	2007	2007%
BY UN/ECE CATEGORY										
Combustion in Energy and Transformation Industry	1A1	0.7	0.6	0.6	0.6	0.6	0.5	0.5	0.7	9%
Combustion in Manufacturing Industry	1A2	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.7	10%
Passenger cars	1A3bi	0.7	0.8	0.8	0.9	1.0	1.0	1.1	0.7	19%
Light duty vehicles	1A3bii	0.4	0.4	0.4	0.5	0.6	0.6	0.6	0.4	10%
Heavy duty vehicles	1A3biii	1.2	1.2	1.3	1.3	1.2	1.3	1.3	1.2	23%
Other Transport	1A3c-eii, 1A4bii, 1A4cii, 1A5b	0.4	0.4	0.5	0.5	0.5	0.6	0.5	0.4	9%
Residential/Commercial/Institutional	1A4a, bii, ci	2.8	1.9	1.5	1.4	1.0	0.9	1.0	2.8	17%
Production Processes/Waste	1B1b, 2, 6	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.2	3%
By FUEL TYPE										
Solid		3.2	3.1	2.1	1.8	1.7	1.2	1.2	1.3	22%
Petroleum		3.8	3.9	3.9	4.0	4.1	4.3	4.3	4.4	76%
Gas		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Non-Fuel		0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	2%
TOTAL		**7.0**	**7.1**	**6.1**	**5.9**	**5.9**	**5.7**	**5.6**	**5.8**	**100%**

3.4 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 3.4 and Figure 3.2 summarise the UK emissions of cadmium. Emissions have declined by 92% 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 have declined across the time-series, primarily due to the closure of a lead-zinc smelting plant in 2003 and a secondary copper processing facility in 1999.

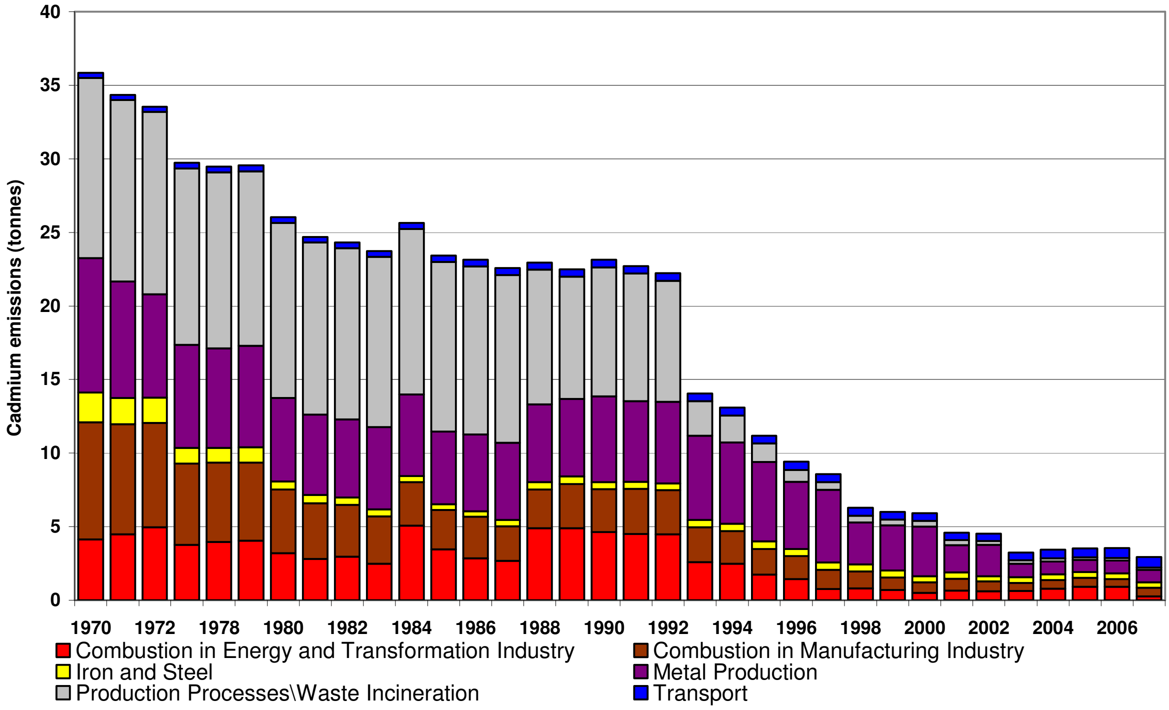
The overall decline in UK cadmium emissions is a result of the general fall in coal combustion and the decline in fuel oil combustion in power generation. The large reduction observed from waste emissions is due to improved controls on Municipal Solid Waste (MSW) incinerators from 1993 onwards and their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

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

	NFR Codes	1970	1980	1990	2000	2003	2004	2005	2006	2007	2007 %
BY UN/ECE CATEGORY[1]											
Public Electricity and Heat Production	1A1a	4.0	3.1	4.6	0.5	0.6	0.7	0.9	0.9	0.2	6%
Other Stationary Combustion	1A1b-c, 1A2b, 1A4a, 1A4bi, 1A4ci	2.7	1.3	1.4	0.3	0.2	0.2	0.2	0.2	0.2	8%
Iron and Steel	1A2a	2.0	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	13%
Other industrial combustion	1A2f	5.5	3.2	1.5	0.5	0.4	0.4	0.4	0.3	0.4	14%
Road Transport	1A3b	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	14%
Other Transport	1A3ai(i), 1A3aii(i), 1A3c, 1A3dii, 1A3eii, 1A4bii, 1A4cii, 1A5b	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.3	9%
Production Processes\Waste	1B1b, 2A7, 2B5, 6	12.3	11.9	8.8	0.4	0.2	0.2	0.2	0.2	0.2	6%
Metal Production	2C	9.1	5.7	5.8	3.4	0.9	0.9	0.8	0.9	0.8	29%
By FUEL TYPE											
Solid		3.1	2.5	2.1	0.5	0.5	0.7	0.7	0.8	0.3	9%
Petroleum		10.4	5.6	3.3	1.1	1.0	1.1	1.2	1.2	1.1	38%
Gas		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Non-Fuel		22.3	18.0	17.7	4.3	1.7	1.7	1.6	1.6	1.5	53%
Total		**35.9**	**26.0**	**23.1**	**5.9**	**3.2**	**3.4**	**3.5**	**3.6**	**2.9**	**100%**

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

Figure 3.2 Time Series of Cadmium Emissions (tonnes)



3.5 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.

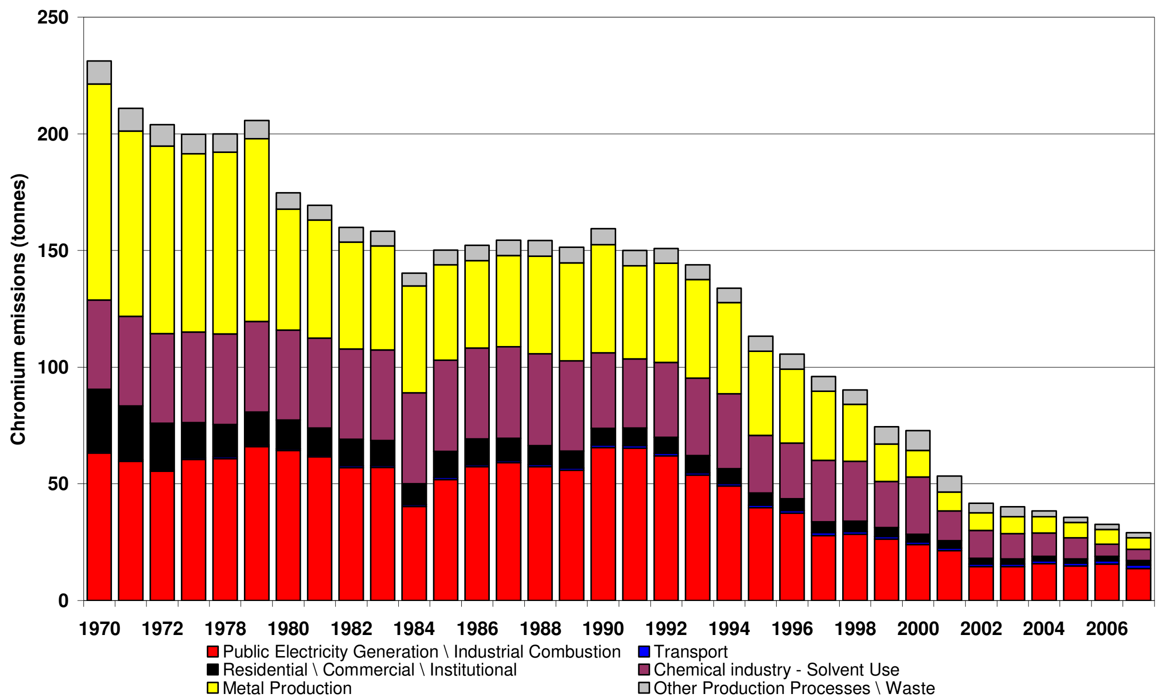
Table 3.5a and Figure 3.3 summarise the UK emissions of chromium. Emissions have fallen by 87% since 1970. The largest sources are various forms of coal combustion, iron and steel production in integrated works and in electric arc furnaces and the production of chromium-based chemicals. More recently 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 3.5a UK Emissions of Chromium by aggregated UN/ECE Category and Fuel (tonnes)

	NFR Codes	1970	1980	1990	2000	2003	2004	2005	2006	2007	2007 %
BY UN/ECE CATEGORY[1]											
Public Electricity and Heat Production	1A1a	50.3	57.5	53.1	13.4	3.9	4.1	4.5	4.8	2.8	**10%**
Industrial Combustion	1A1b-c	0.9	0.7	0.3	0.2	0.4	0.5	0.2	0.2	0.3	**1%**
Iron and Steel	1A2a	2.1	0.5	0.2	0.1	0.1	0.1	0.1	0.1	0.1	**0%**
Other Industrial Combustion: Treated wood	1A2f	9.9	5.6	12.0	10.2	10.1	11.1	10.0	10.6	10.5	**36%**
Transport	1A3b, 1A3ai(i), 1A3aii(i), 1A3c, 1A3dii, 1A3eii, 1A4bii, 1A4cii, 1A5b	0.6	0.8	1.0	1.1	1.2	1.3	1.3	1.4	1.4	**5%**
Residential\Commercial / Institutional	1A4a-bi	26.7	12.3	7.1	3.3	2.1	2.0	1.8	1.8	1.9	**7%**
Gas Mains Leakage	2B5	10.0	7.0	6.8	8.5	4.2	2.3	2.2	2.2	2.3	**8%**
Metal Production	2C	38.2	38.6	32.4	24.6	10.8	9.9	8.9	5.3	4.8	**17%**
Other Production Processes\Waste	1B1b, 2A7	92.6	51.8	46.3	11.3	7.3	7.1	6.6	6.3	4.9	**17%**
By FUEL TYPE											
Solid		76.4	69.1	68.5	24.9	14.3	15.2	14.3	14.8	12.6	**43%**
Petroleum		12.4	6.7	3.5	2.0	1.6	1.7	1.6	1.6	1.6	**5%**
Gas		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0%**
Non-Fuel		142.4	98.9	87.3	46.0	24.1	21.4	19.8	16.3	14.9	**51%**
Total		**231.3**	**174.7**	**159.4**	**72.9**	**40.2**	**38.4**	**35.7**	**32.7**	**29.1**	**100%**

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

Figure 3.3 Time Series of Chromium Emissions (tonnes)



3.5.1 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 3.4b

Table 3.5b Speciated Emissions of Chromium (tonnes)

BY aggregated UN/ECE CATEGORY[1]	NFR Codes	Cr3+	Cr6+	Total (2007)
Combustion in Energy and Transformation Industry	1A1	2.8	0.4	3.1
Combustion in Manufacturing Industry	1A2, 1A4ci	9.7	1.0	10.7
Combustion in Dom/Inst/Com	1A4a, 1A4bi	1.7	0.2	1.9
Production Processes	1B1b, 2	9.8	2.1	11.9
Road Transport	1A3b	0.9	0.2	1.1
Off-road Vehicles and Other Machinery	1A3ai(i)-1A3aii(i), 1A3c-1A3eii, 1A4bii, 1A4cii, 1A5b	0.3	0.1	0.3
Waste Incineration	6	0.1	0.0	0.1
TOTAL		25.2	3.9	29.1

[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).

3.6 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.

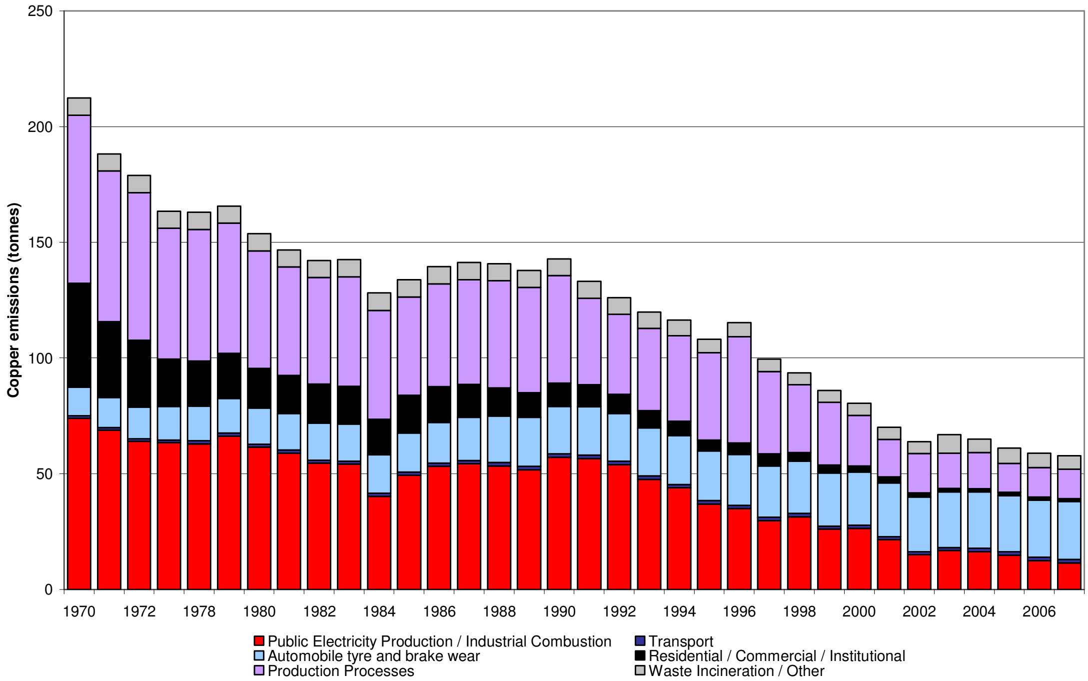
Table 3.6 and Figure 3.4 summarise the UK emissions of copper. Emissions have declined by 73% since 1970. The main sources are from tyre and break wear, metal production, combustion of lubricants in industry and coal combustion. Emissions have declined over the period due to the decline in coal combustion 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 3.6 UK Emissions of Copper by aggregated UN/ECE Category and Fuel (tonnes)

	NFR Codes	1970	1980	1990	2000	2003	2004	2005	2006	2007	2007 %
BY UN/ECE CATEGORY[1]											
Public Electricity and Heat Production	1A1a	39.3	44.5	41.2	13.7	3.0	3.7	3.3	3.4	2.1	4%
Industrial Combustion	1A1b-c, 1A2b	11.6	4.5	1.1	0.5	2.4	0.8	0.7	0.6	0.8	1%
Iron and Steel	1A2a	5.5	1.7	2.2	2.0	1.8	1.8	1.8	1.6	1.6	3%
Other industrial combustion: Lubricants	1A2f	17.6	10.8	12.5	10.3	9.6	10.1	8.9	6.8	6.9	12%
Transport	1A3b, 1A3ai(i), 1A3aii(i), 1A3c, 1A3dii, 1A3eii, 1A4bii, 1A4cii, 1A5b	1.1	1.3	1.5	1.4	1.4	1.4	1.5	1.6	1.6	3%
Automobile tyre and brake wear	1A3bvi	57.2	32.8	30.7	25.6	25.5	25.8	25.8	26.0	26.3	46%
Other Production Processes	1B1b, 2A7	3.0	2.8	3.6	4.9	2.6	3.3	3.0	2.6	2.7	5%
Metal Production	2C	69.6	48.0	42.8	17.0	12.6	12.4	9.5	10.0	9.9	17%
Waste Incineration\Other	6, 7	7.4	7.4	7.2	5.2	8.0	5.8	6.5	6.2	5.8	10%
By FUEL TYPE											
Solid		94.5	64.1	56.2	20.6	9.3	10.4	9.3	9.5	8.2	14.2%
Petroleum		17.2	10.5	6.1	3.7	4.9	3.5	3.6	3.4	3.6	6.2%
Gases		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
Non Fuel		100.7	79.2	80.6	56.2	52.6	51.1	48.1	46.0	46.0	79.6%
Total		**212.3**	**153.8**	**142.8**	**80.5**	**66.9**	**65.0**	**61.1**	**58.9**	**57.7**	**100%**

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

Figure 3.4 Time Series of Copper Emissions (tonnes)



3.7 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 3.7 and Figure 3.5 summarises the UK emissions of lead from 1970 to 2007. Emissions have declined by 99% since 1970. The largest source of lead until 1999 was 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. From 1987 sales of unleaded petrol increased, particularly as a result of the increased use of cars fitted with three-way catalyst and 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.

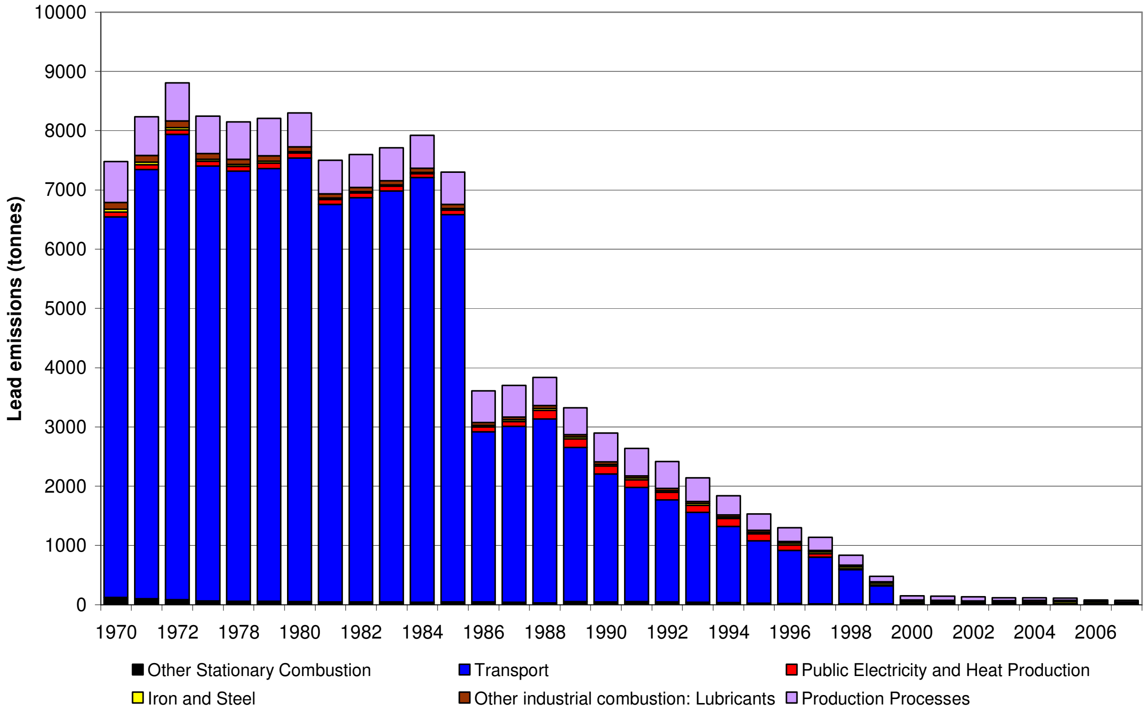
Currently major sources of lead are iron and steel combustion, metal production and combustion of lubricants in industry. There has been some reduction in emissions from iron and steel production processes due to improved abatement measures. Emissions have also declined as a result of the decreasing use of coal.

Table 3.7 UK Emissions of Lead by aggregated UN/ECE Category and Fuel (tonnes)

	NFR Codes	1970	1980	1990	2000	2003	2004	2005	2006	2007	2007 %
BY UN/ECE CATEGORY[1]											
Public Electricity and Heat Production	1A1a	82	89	133	18	12	13	12	11	3	4%
Other Combustion in Industry	1A1b-c	11	4	1	1	1	1	1	1	1	2%
Iron and Steel	1A2a	48	16	30	27	25	25	32	29	28	40%
Other industrial combustion: Lubricants	1A2f	118	82	39	18	20	26	18	5	6	9%
Residential /Commercial / Institutional	1A4a, 1A4bi, 1A4ci	109	47	47	10	6	5	5	4	5	7%
Transport	1A3b, 1A3ai(i), 1A3aii(i), 1A3c, 1A3eii, 1A4bii, 1A4cii, 1A5b	6421	7486	2158	3	3	3	3	4	3	4%
Other Production Processes	1B1b, 2A7	327	321	245	6	4	4	4	4	4	5%
Chemical industry	2B5	92	92	93	11	13	14	14	4	3	4%
Metal Production	2C	271	159	145	56	33	27	21	20	18	26%
By FUEL TYPE											
Solid[2]		216	141	109	29	19	19	15	15	8	11%
Petroleum		6508	7552	2182	6	6	6	8	7	6	9%
Gas		0	0	0	0	0	0	0	0	0	0%
Non-Fuel		756	604	603	115	91	92	86	60	56	80%
TOTAL		**7479**	**8298**	**2893**	**150**	**116**	**118**	**109**	**82**	**70**	**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)



3.8 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 3.8 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.

Table 3.8 UK Emissions of Manganese by aggregated UN/ECE Category and Fuel (tonnes)

	NFR Codes	2000	2001	2002	2003	2004	2005	2006	2007	2007 %
BY UN/ECE CATEGORY[1]										
Public Electricity and Heat Production	1A1a	21.2	16.4	5.9	5.8	6.0	6.7	6.8	8.1	25%
Industrial combustion: Wood	1A2f	8.3	7.4	7.1	7.3	7.4	3.9	3.6	3.4	11%
Other Combustion	1A1b,c -1A2a	1.9	1.8	1.5	1.6	1.7	1.7	1.8	1.9	6%
Road Transport	1A3b	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	3%
Residential/Commercial/Institutional	1A4a, bii, ci	3.4	3.2	2.3	2.0	1.9	1.6	1.5	1.5	5%
Metal Production	2C	28.4	21.1	16.9	16.7	16.2	13.4	13.1	13.6	43%
Solid fuel transformation	1B1b	3.1	2.7	2.2	2.1	2.0	2.0	2.2	2.2	7%
Other Transport	1A3c-eii\1A4bii\1A4cii\1A5b	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	1%
Other	6C	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0%
By FUEL TYPE										
Solid		32.6	27.0	15.2	15.0	15.1	11.4	12.5	13.6	43%
Petroleum		1.8	2.0	1.5	1.4	1.6	2.3	1.9	2.2	7%
Gas		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Non-Fuel		32.7	24.6	20.1	20.0	19.6	16.6	15.7	16.0	50%
TOTAL		**67.2**	**53.5**	**36.8**	**36.4**	**36.2**	**30.3**	**30.1**	**31.8**	**100%**

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

3.9 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.

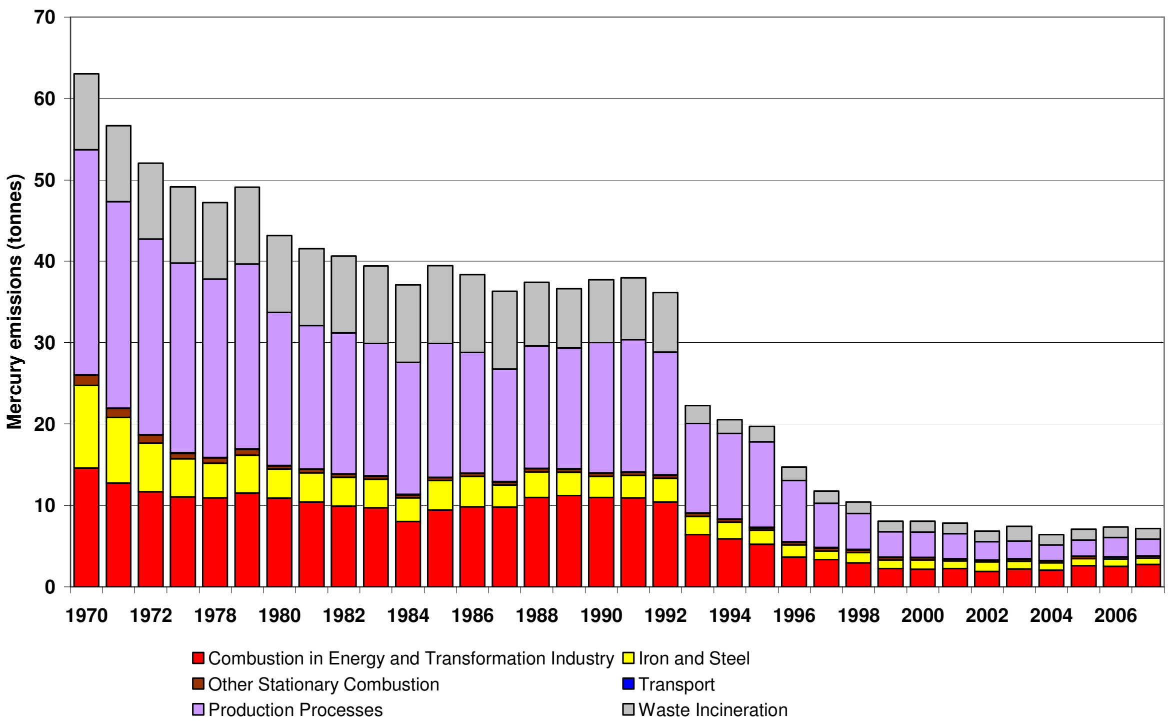
Table 3.9a and Figure 3.6 summarises the UK emissions of mercury. Emissions have declined by 89% since 1970. The main sources are public electricity and heat production, iron and steel production, waste incineration, the manufacture of chlorine in mercury cells, coal and other forms of industrial combustion. 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 re-classification following their conversion to power generating plant.

Table 3.9a UK Emissions of Mercury by aggregated UN/ECE Category and Fuel (tonnes)

	NFR Codes	1970	1980	1990	2000	2003	2004	2005	2006	2007	2007 %
BY UN/ECE CATEGORY[1]											
Public Electricity and Heat Production	1A1a	7.7	8.1	8.9	1.7	1.9	1.8	2.3	2.3	2.5	35%
Stationary Combustion	1A1b-c, 1A2b, 1A4a, 1A4bi, 1A4ci	6.9	2.8	2.1	0.5	0.3	0.3	0.3	0.2	0.2	3%
Iron and Steel	1A2a	17.7	9.0	8.3	1.9	1.2	0.9	1.0	1.1	1.2	16%
Other Industrial Combustion	1A2f	10.1	3.6	2.6	1.1	0.9	0.9	0.9	0.9	0.8	11%
Transport	1A3b, 1A3ai(i), 1A3aii(i), 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	0%
Chemical industry	2B5	11.1	10.1	8.0	1.4	1.2	1.2	1.1	1.5	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	1.4	0.9	1.0	0.9	0.9	13%
By FUEL TYPE											
Solid		24.0	13.7	11.0	2.8	2.7	2.5	2.8	2.8	2.8	41%
Petroleum		1.4	0.8	0.6	0.2	0.2	0.2	0.3	0.3	0.2	2%
Gas		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1%
Non-Fuel		37.6	28.6	26.2	5.1	4.5	3.7	4.0	4.2	3.9	57%
Total		**63.0**	**43.2**	**37.7**	**8.1**	**7.4**	**6.4**	**7.1**	**7.4**	**7.2**	**100%**

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

Figure 3.6 Time Series of Mercury Emissions (tonnes)



3.9.1 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 3.9b Speciated Emissions of Mercury (tonnes)

BY aggregated UN/ECE CATEGORY[2]	NFR Codes	Hg^0	Hg-p	RGM [1]	Total (2007)
Combustion in Energy and Transformation Industry	1A1	1.2	0.2	1.1	2.5
Combustion in Manufacturing Industry	1A2, 1A4ci	0.7	0.1	0.3	1.0
Combustion in Dom/Inst/Com	1A4a, 1A4bi	0.1	0.0	0.1	0.2
Production Processes	1B1b, 2	1.5	0.0	0.5	2.0
Road Transport	1A3b	0.0	0.0	0.0	0.0
Off-road Vehicles and Other Machinery	1A3ai(i)-1A3aii(i), 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		3.9	0.4	2.8	7.2

[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 if this uncertainty is to be reduced, particularly for major sources such as coal combustion, crematoria, clinical waste incinerators, sinter plant, chloralkali processes, and primary lead/zinc production.

3.10 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.

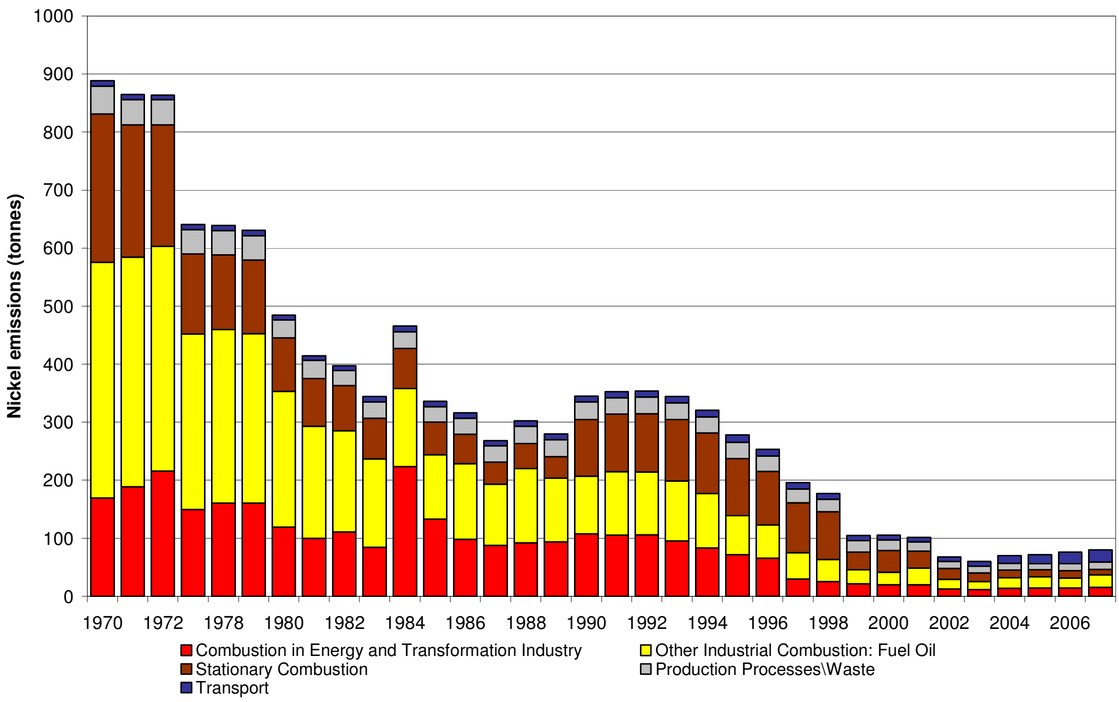
Table 3.10a and Figure 3.7 summarise the UK emissions of nickel. Emissions have declined by 91% since 1970. Currently the main source of nickel emissions is the combustion of heavy fuel oil, however in the past coal combustion was a major source. Emissions from both sources have declined since 1970 in 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 3.10a UK Emissions of Nickel by aggregated UN/ECE Category and Fuel (tonnes)

	NFR Codes	1970	1980	1990	2000	2003	2004	2005	2006	2007	2007 %
BY UN/ECE CATEGORY[1]											
Public Electricity and Heat Production	1A1a	145	97	96	12	4	5	5	6	4	5%
Petroleum refining	1A1b	23	22	12	8	8	9	9	9	11	14%
Other Stationary Combustion	1A1c	2	1	0	0	0	0	0	0	0	0%
Iron and Steel	1A2a	113	26	3	4	2	2	2	2	2	3%
Other Industrial Combustion: Fuel Oil	1A2f	406	234	99	21	13	18	19	17	21	27%
Transport	1A3b, 1A3ai(i), 1A3aii(i), 1A3c, 1A3eii, 1A4bii, 1A4cii, 1A5b	5	5	6	6	6	6	6	6	6	7%
National Navigation	1A3dii	5	3	4	2	3	8	10	14	15	19%
Residential /Commercial / Institutional	1A4a, 1A4bi, 1A4ci	143	65	95	33	13	11	10	10	8	9%
Production Processes\Waste	1B1b, 2, 6	48	31	31	18	11	11	10	12	13	16%
By FUEL TYPE											
Solid		60	47	103	33	11	11	10	10	7	9%
Petroleum		778	404	209	52	37	46	50	51	59	73%
Gas		0	0	0	0	0	0	0	0	0	0%
Non-Fuel		51	34	33	20	13	13	12	15	14	18%
TOTAL		**889**	**485**	**345**	**105**	**60**	**70**	**72**	**77**	**80**	**100%**

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

Figure 3.7 Time Series of Nickel Emissions (tonnes)



3.10.1 Speciation of Nickel Emissions

Nickel is emitted to air in 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 3.10b

Table 3.10b Speciated Emissions of Nickel 2007 (tonnes)

BY aggregated UN/ECE CATEGORY[1]	**NFR Code**	**MN**	**ON**	**SolN**	**NC**	**SU**	**Total (2007)**
Combustion in Energy and Transformation Industry	1A1	0.0	6.0	8.8	0.1	0.5	15.4
Combustion in Manufacturing Industry	1A2, 1A4ci	0.0	9.5	13.7	0.1	0.8	24.0
Combustion in Dom/Inst/Com	1A4a, 1A4bi	0.0	2.8	4.2	0.0	0.2	7.3
Production Processes	1B1b, 2	3.8	8.2	0.5	0.1	0.4	12.5
Road Transport	1A3b	0.7	0.5	0.8	0.0	0.1	2.1
Off-road Vehicles and Other Machinery	1A3ai(i)-1A3aii(i), 1A3c-1A3eii, 1A4bii, 1A4cii, 1A5b	0.0	7.4	10.9	0.1	0.6	19.0
Waste Incineration	6	0.0	0.0	0.0	0.0	0.0	0.1
TOTAL		4.4	34.5	39.0	0.4	2.5	80.3

[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 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.

3.11 SELENIUM

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

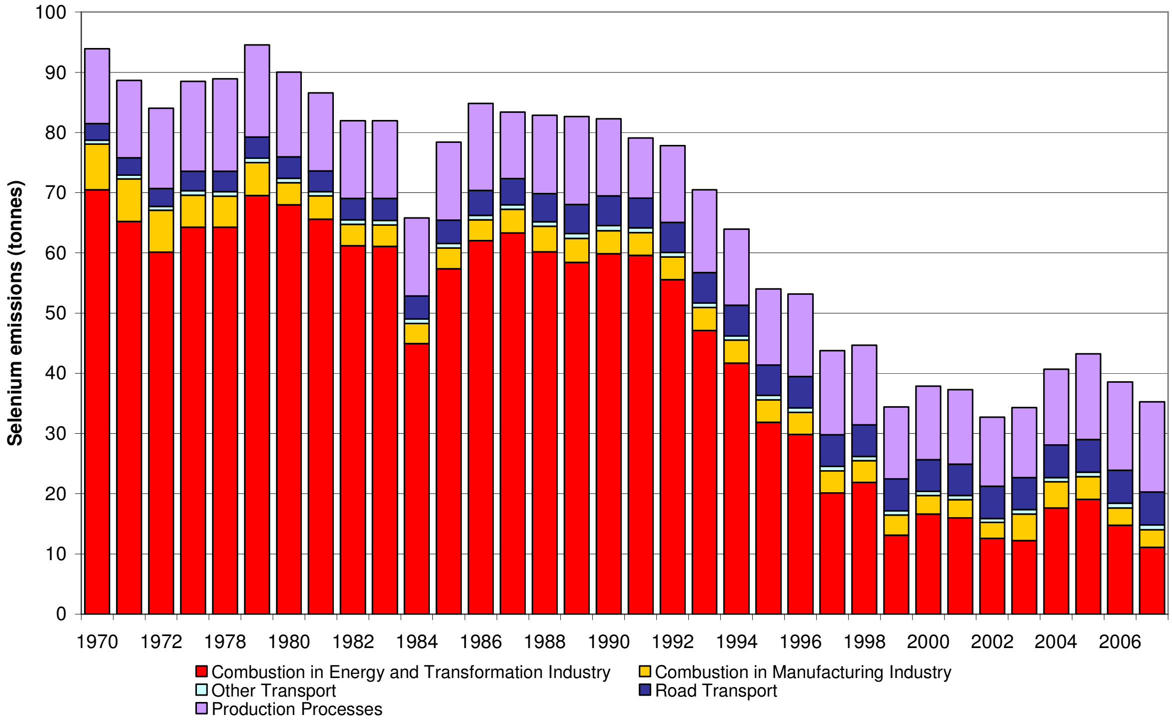
Table 3.11 and Figure 3.8 summarise the UK emissions of selenium. Emissions have declined by 62% since 1970. The main source of selenium emissions in earlier years was coal combustion. Only trace amounts are emitted by the combustion of petroleum based fuels. Glass production and combustion for public electricity and heat production are currently the most significant sources. The estimates for the manufacture of the various types of glass products (flat glass, container glass etc.) are uncertain.

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

	NFR Codes	1970	1980	1990	2000	2003	2004	2005	2006	2007	2007%
BY UN/ECE CATEGORY[1]											
Public Electricity and Heat Production	1A1a	53.0	59.9	55.3	14.5	10.9	16.3	17.9	13.3	9.6	27%
Other Stationary Combustion	1A1b-c\1A4a\1A2b-f\1A4a-bi\1A4ci	21.4	10.5	6.3	3.4	4.0	3.9	3.1	2.6	2.8	8%
Iron and Steel	1A2a	3.6	1.2	2.1	1.8	1.7	1.7	1.8	1.7	1.6	5%
Passenger cars	1A3bi	1.8	2.5	3.3	3.5	3.5	3.5	3.5	3.5	3.5	10%
Heavy duty vehicles	1A3bii	0.7	0.8	1.2	1.2	1.3	1.3	1.2	1.3	1.3	4%
Other Transport	1A3bii&iv\1A3ai(i)\1A3aii(i)\1A3c-eii\1A4bii\1A4cii\1A5b	0.9	1.0	1.3	1.2	1.3	1.3	1.4	1.5	1.5	4%
Production of Glass	2A7	11.6	13.7	12.4	11.9	11.3	12.2	13.8	14.3	14.6	41%
Other Production Processes	1A5b\2B5\2C	0.8	0.4	0.5	0.3	0.3	0.4	0.4	0.4	0.4	1%
By FUEL TYPE											
Solid		66.4	65.3	58.1	15.2	12.6	17.4	16.3	12.9	9.4	27%
Petroleum		11.7	9.3	9.0	8.5	8.3	8.9	10.8	9.1	8.9	25%
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	15.2	14.2	13.5	14.4	16.1	16.5	17.0	48%
Total		**93.9**	**90.0**	**82.3**	**37.8**	**34.3**	**40.7**	**43.2**	**38.5**	**35.3**	**100%**

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

Figure 3.8 Time Series of Selenium Emissions (tonnes)



3.12 TIN

Heavy or prolonged exposure to tin oxide may cause a disease of the lungs called stannosis. Table 3.12 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.

Table 3.12 UK Emissions of Tin by aggregated UN/ECE Category and Fuel (tonnes)

	NFR Codes	2000	2001	2002	2003	2004	2005	2006	2007	2007 %
BY UN/ECE CATEGORY[1]										
Public Electricity and Heat Production	1A1a	3.2	3.5	3.2	3.5	3.5	3.5	3.9	3.5	12%
Other Combustion	1A1b, c-1A2a	17.6	13.6	16.1	14.9	14.7	17.4	19.1	16.1	55%
Industrial Combustion: Lubricants	1A2f	1.7	1.9	1.5	1.4	1.5	1.6	1.2	1.3	4%
Road Transport	1A3b	4.7	4.9	5.1	5.4	5.6	5.9	6.1	6.4	22%
Other Transport	1A3c-eii, 1A4bii, 1A4cii, 1A5b	0.9	0.9	0.8	1.0	1.0	1.1	1.2	1.1	4%
Residential/Commercial/Institutional	1A4a, bii, ci	2.6	1.9	1.4	1.2	1.1	1.1	1.1	1.0	3%
Other	2C, 6C	1.2	1.2	0.2	0.2	0.1	0.1	0.1	0.1	0%
By FUEL TYPE										
Solid		5.4	4.9	4.3	4.5	4.3	4.3	4.7	4.2	14%
Petroleum		25.1	21.4	23.6	22.7	22.8	26.0	28.0	25.1	85%
Gas		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Non-Fuel		1.5	1.4	0.5	0.4	0.4	0.4	0.2	0.2	1%
TOTAL		**31.9**	**27.8**	**28.4**	**27.6**	**27.6**	**30.7**	**32.8**	**29.5**	**100%**

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

3.13 VANADIUM

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

Table 3.13 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 81% since 1970. The major source of emissions is the road transport sector accounting for 56%. Fuel oils accounted for some 37% of the estimated emission in 2007 and 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, which accounted for 1% of 2007 emissions, 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.

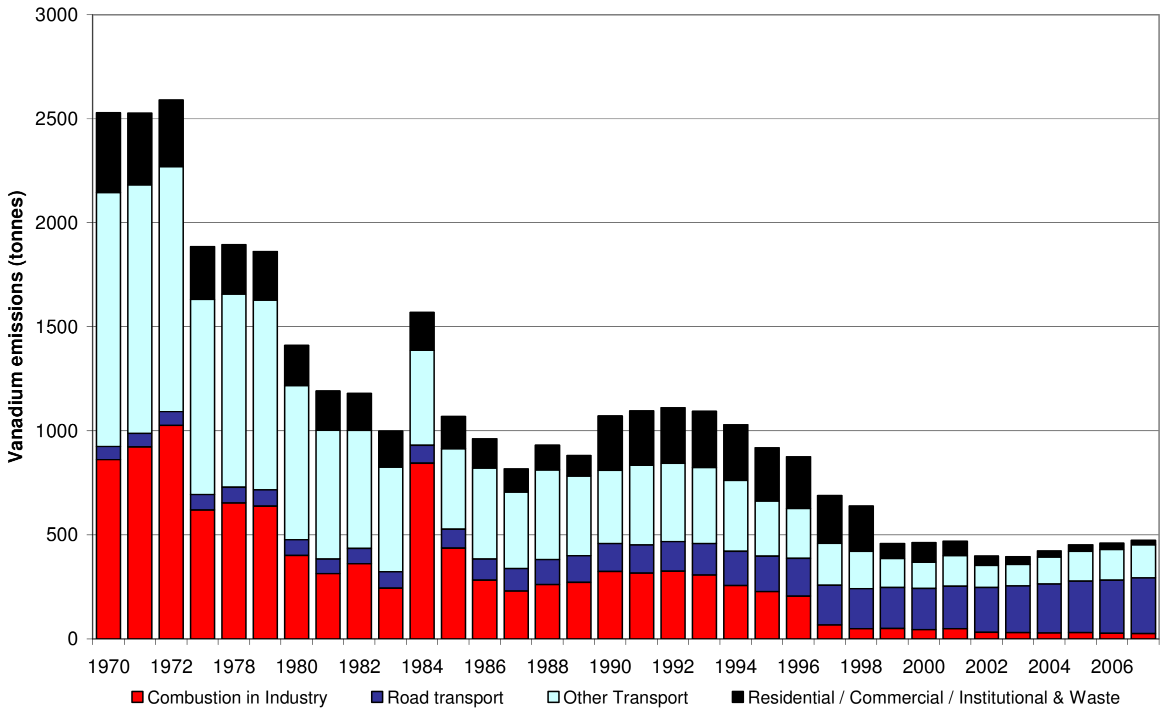
Since 2003 emissions of Vanadium have started to rise again, increasing by 20% between 2003 and 2007. This is due to a sharp increase in the number of diesel cars in the UK fleet.

Table 3.13 UK Emissions of Vanadium by aggregated UN/ECE Category and Fuel (tonnes)

BY UN/ECE CATEGORY[1]	NFR Codes	1970	1980	1990	2000	2003	2004	2005	2006	2007	2007%
Combustion in Industry	1A1, 1A2a	861.0	401.2	323.3	43.7	29.3	28.5	30.8	26.9	25.1	5%
Industrial off-road mobile machinery	1A2f	1170.1	691.1	299.9	82.3	57.4	69.7	77.7	66.9	79.0	17%
Passenger cars	1A3bi	1.6	2.5	12.7	58.6	73.1	80.5	86.8	92.2	97.7	21%
Light duty vehicles	1A3bii	3.2	4.7	16.2	33.1	39.0	42.8	49.7	50.5	52.8	11%
Heavy duty vehicles	1A3biii	59.3	67.3	106.5	107.0	113.1	112.1	110.5	113.4	117.4	25%
Other Transport	1A3c-eii, 1A4bii, 1A4cii, 1A5b	49.8	49.3	52.0	44.3	45.8	58.9	65.4	78.7	79.6	17%
Residential/Commercial/Institutional	1A4a, bii, ci	374.5	190.2	253.9	86.9	33.1	26.7	26.4	25.8	17.6	4%
Production processes	2	9.4	4.2	6.9	6.2	4.6	4.6	4.5	4.7	4.8	1%
BY FUEL TYPE											
Solid		50.5	43.9	205.8	70.8	21.2	19.6	18.2	18.6	9.6	2%
Petroleum		2465.2	1359.1	855.8	383.3	368.6	398.5	428.4	435.4	459.3	97%
Gas		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Non-Fuel		13.2	7.5	9.9	7.9	5.7	5.6	5.4	5.1	5.1	1%
TOTAL		**2528.9**	**1410.5**	**1071.5**	**462.1**	**395.4**	**423.7**	**452.0**	**459.1**	**474.0**	**100%**

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

Figure 3.9 Time series of Vanadium Emissions (tonnes)



3.14 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.

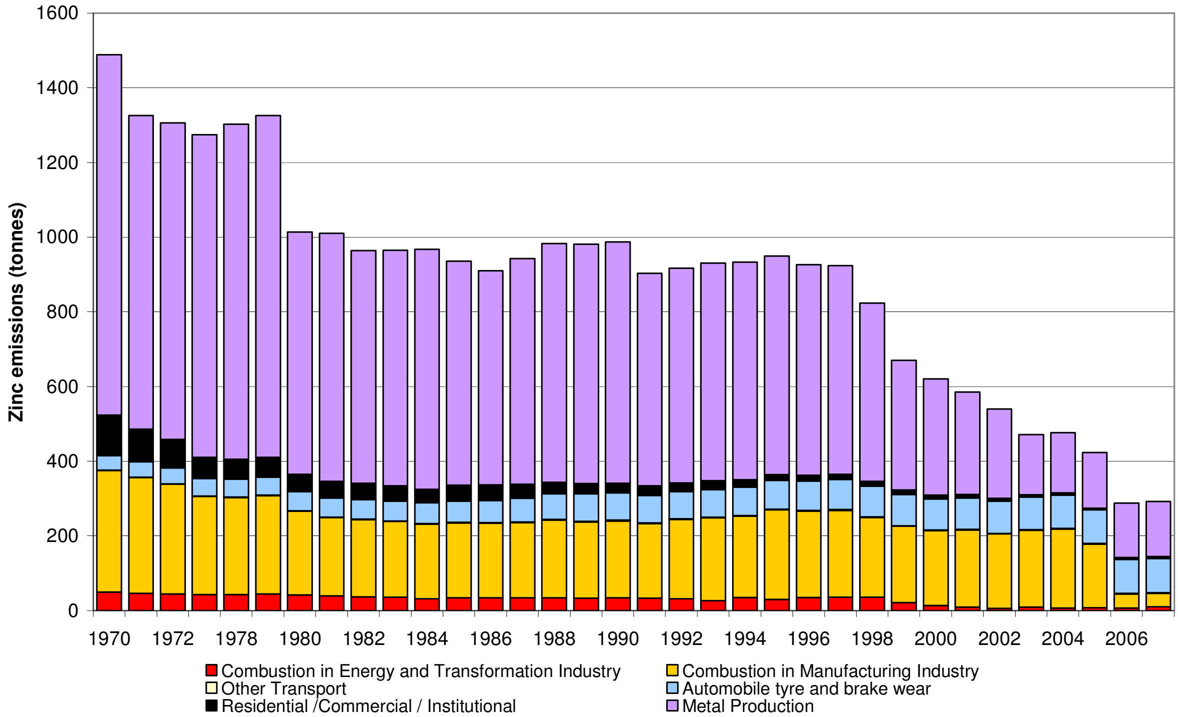
Table 3.14 and Figure 3.10 summarise the UK emissions of zinc. Emissions of zinc have declined by 80% since 1970. The main sources are metal production and combustion in industry. Emissions arising from road transport are also significant. 31% of total zinc emissions arise due to tyre wear. This arises 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 3.14 UK Emissions of Zinc by aggregated UN/ECE Category and Fuel (tonnes)

	NFR Codes	1970	1980	1990	2000	2003	2004	2005	2006	2007	2007 %
BY UN/ECE CATEGORY[1]											
Combustion in Energy and Transformation Industry	1A1	49.2	42.0	33.9	14.1	9.1	7.2	7.5	7.3	10.5	4%
Combustion in Manufacturing Industry	1A2	325.6	224.2	206.4	200.1	205.8	211.5	170.9	37.2	35.4	12%
Residential /Commercial / Institutional	1A4a, 1A4bi, 1A4ci	108.7	46.1	25.8	9.6	5.9	5.4	4.7	4.6	4.7	2%
Other Transport[2]	1A3ai(i), 1A3aii(ii), 1A3c-eii, 1A4bii, 1A4cii, 1A5b	0.9	0.9	1.0	0.8	0.8	1.0	1.1	1.3	1.3	0%
Road Transport	1A3bi-iv	0.4	0.6	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0%
Automobile tyre and brake wear	1A3bvi	38.8	50.9	72.9	83.6	87.6	89.3	89.3	90.7	92.1	31%
Metal Production	2C	913.1	599.8	614.3	293.3	153.8	153.5	142.7	139.7	141.1	48%
Other Production Processes / Waste	1B1-2B5, 6	51.6	49.5	32.3	18.2	7.5	7.6	6.4	6.2	6.6	2%
By FUEL TYPE											
Solid		182.1	90.7	63.3	22.1	12.4	12.4	10.6	13.9	14.2	5%
Petroleum		41.4	25.3	14.1	5.9	5.9	7.3	7.9	7.3	7.8	3%
Gas		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Non-Fuel		1264.9	898.1	910.0	592.5	453.1	456.5	404.8	266.4	270.5	92%
TOTAL		**1488.4**	**1014.1**	**987.3**	**620.5**	**471.4**	**476.2**	**423.4**	**287.7**	**292.4**	**100%**

[1] See Annex 1 for definition of UN/ECE Categories
[2] Including railways, shipping, naval vessels, military aircraft and off-road sources

Figure 3.10 Times Series of Zinc Emissions (tonnes)



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 2007 arises from public power generation and industries, 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 iron and steel combustion 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 2007 were waste incineration, public electricity and heat production 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 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 road transport, shipping, refineries 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 iron and steel production processes, combustion in industry 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 2007

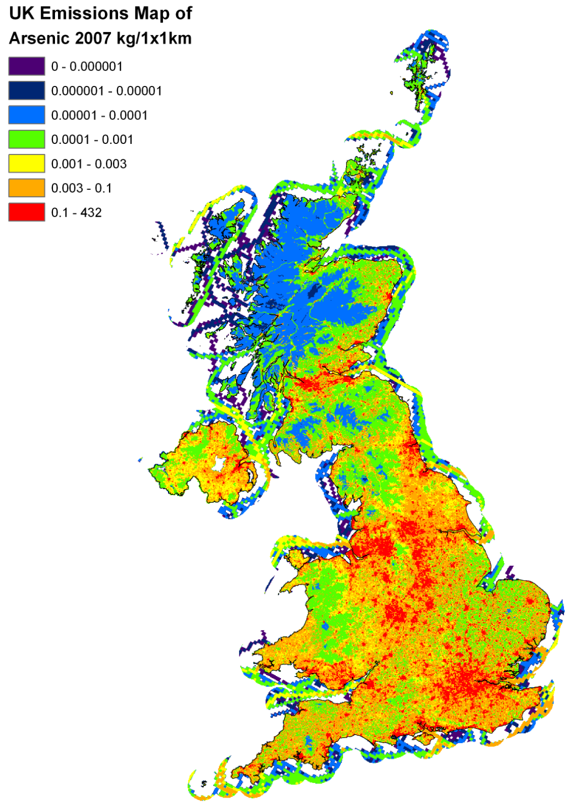


Figure 3.12 UK Emissions Map of Cadmium 2007

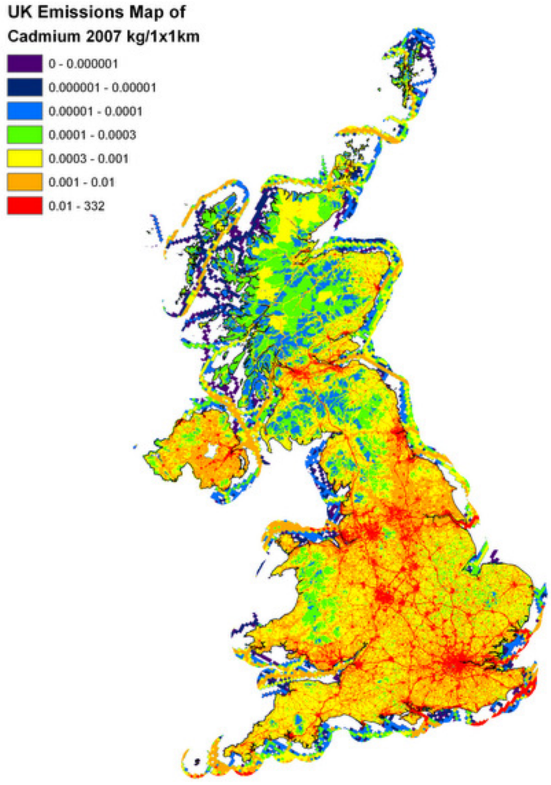


Figure 3.13 UK Emissions Map of Chromium 2007

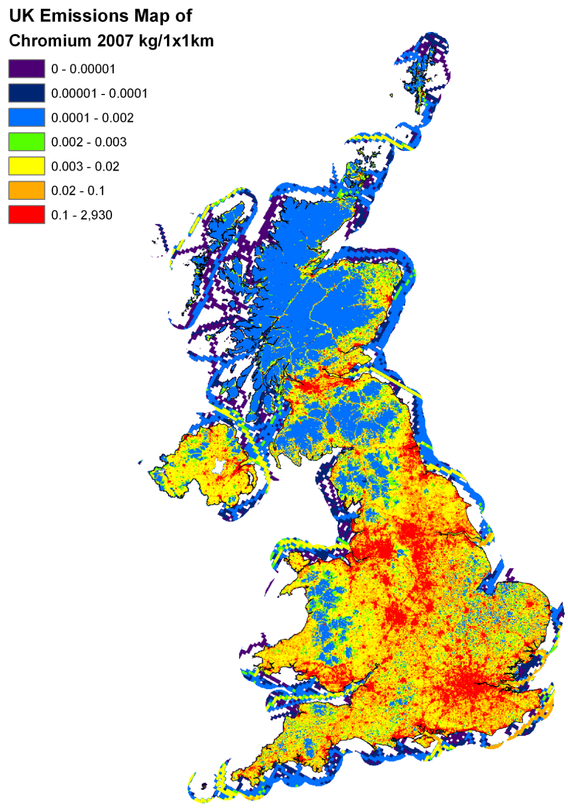


Figure 3.14 UK Emissions Map of Copper 2007

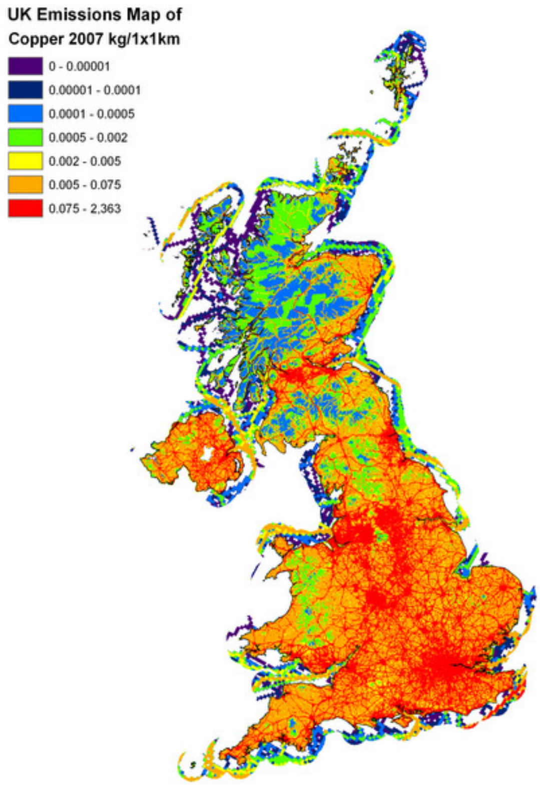


Figure 3.15 UK Emissions Map of Lead 2007

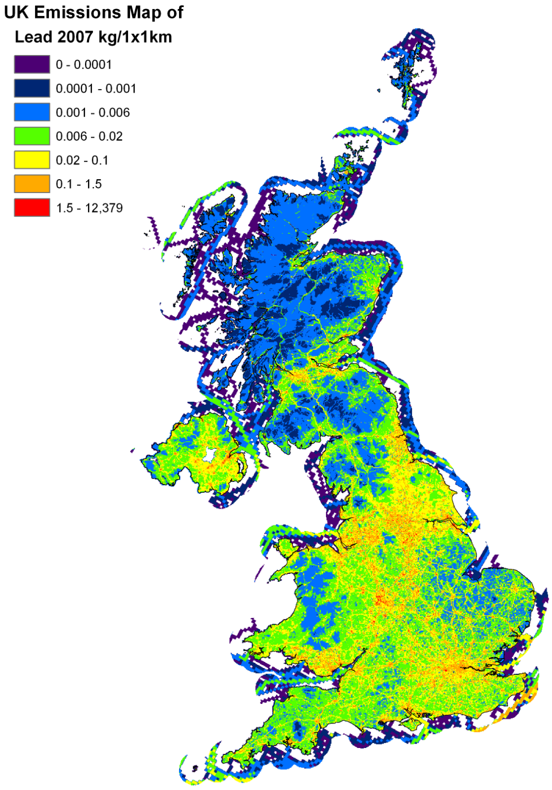


Figure 3.16 UK Emissions Map of Mercury 2007

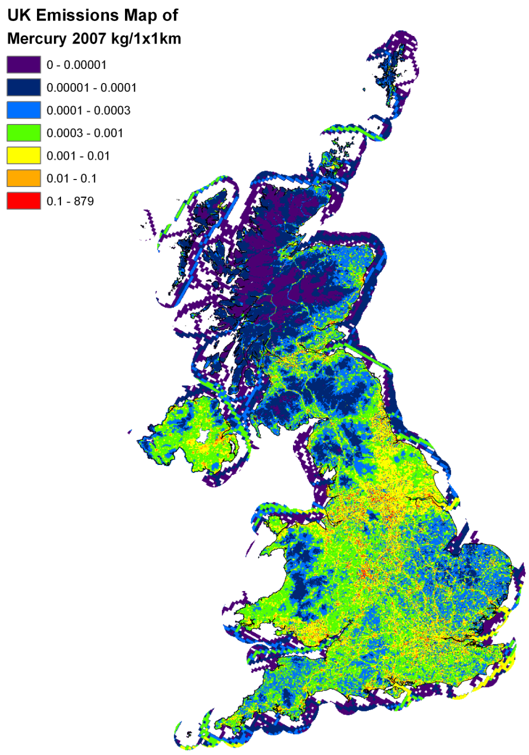


Figure 3.17 UK Emissions Map of Nickel 2007

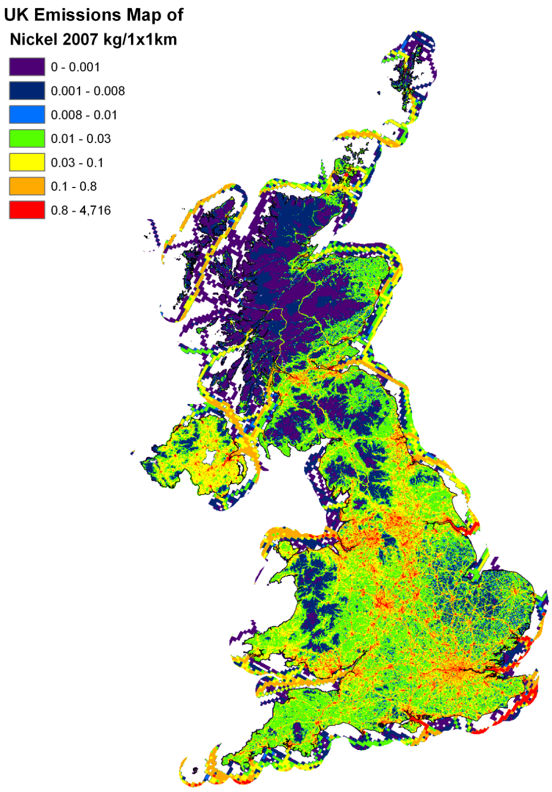


Figure 3.18 UK Emissions Map of Selenium 2007

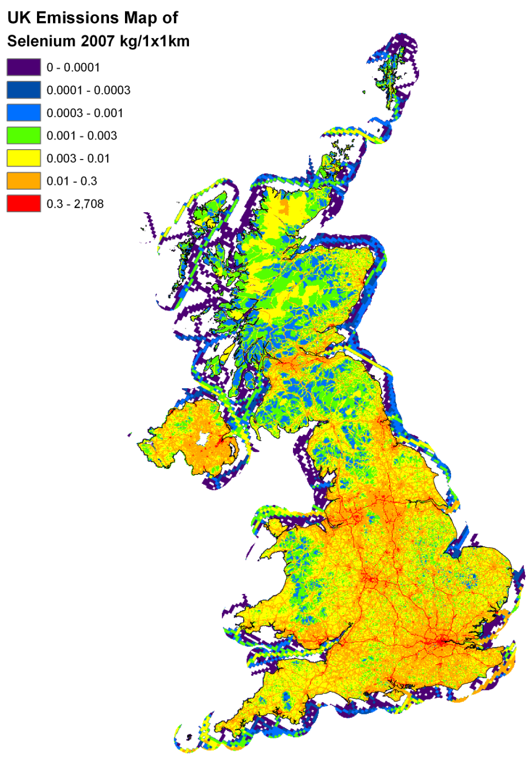


Figure 3.19 UK Emissions Map of Vanadium 2007

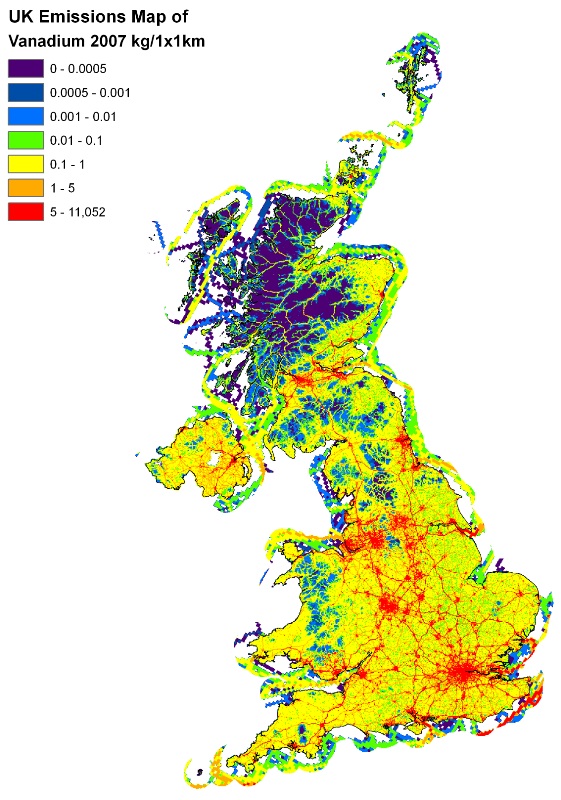
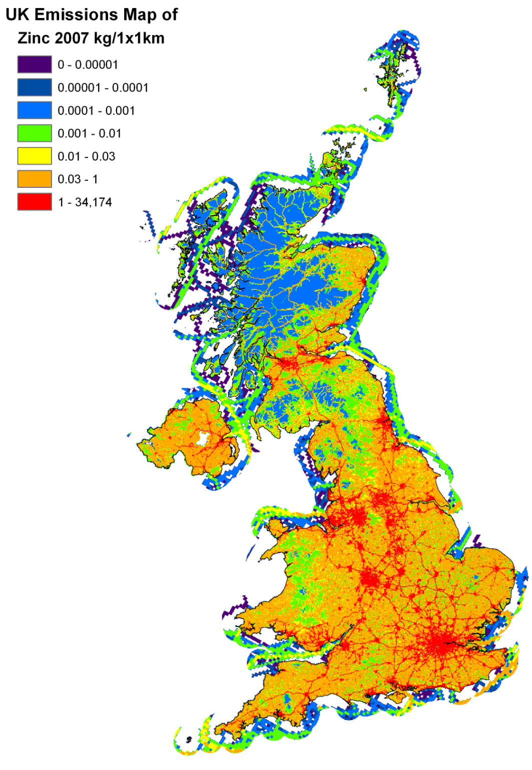


Figure 3.20 UK Emissions Map of Zinc 2007



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	-60 to +200
Cadmium	-20 to +50
Chromium	-30 to +70
Copper	-40 to +80
Lead	-30 to +50
Mercury	-30 to +40
Nickel	-30 to +50
Selenium	-20 to +30
Vanadium	-20 to +30
Zinc	-30 to +60
Beryllium	-40 to +80
Manganese	-30 to +40
Tin	-80 to +300

Among the metal inventories, those for selenium and vanadium are currently judged as least uncertain, followed by the inventories for cadmium, mercury, nickel, lead, manganese and zinc. Those for chromium, arsenic, copper, beryllium and tin are most uncertain. This ranking of the inventories reflects the relative contributions made by sources that can be estimated with more certainty, such as emissions from fuel combustion and chemicals manufacture, compared with the contributions made by sources for which estimates are very uncertain, such as burning of impregnated wood.

Comparison of measurements of heavy metals in the atmosphere around the UK with the emission estimates suggests that the concentrations measured in the atmosphere are considerably higher than those which would be expected from the emission inventory. This may be an indication of uncertainty in the emission inventory or of the contribution of resuspended soils and such sources outside the emission inventory to measured concentrations.

4 Base Captions

4.1 INTRODUCTION

Base caption emission estimates for the UK are presented in this chapter. The emission estimates cover the period 1990-2007 for Calcium (Ca), Magnesium (Mg), Sodium (Na) and Potassium (K). These estimates are highly uncertain.

A base caption 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 captions are important in the environment for two reasons.

- First, their deposition has an impact on surface soil pH. The deposition of base captions 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 captions (Na^+, K^+, Ca^{2+}, Mg^{2+}) are known to be present in ambient air and in precipitation. The deposition of these base captions 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 caption deposition that has been observed in Europe and North 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 captions is mainly confined to Ca, K and Mg. It has long been assumed that the major source of these base captions 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 caption 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 caption 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 captions emitted from stationary combustion arise from the trace concentrations of the captions found in the fuels. The base captions 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 captions 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 (2008).

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 captions from the iron and steel industry and the glass industry are based on the PM_{10} inventory combined with emission factors for captions 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 1990-2007) 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 captions 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 became available since autumn 1999 and was the main source of potassium emissions from vehicle exhausts. Emissions were estimated from UK LRP sales in 1999 (calculated as a fraction of leaded petrol sales) to 2006 given by the Digest of United Kingdom Energy Statistics (DECC, 2008). In 2006 the LRP sales accounted for only 0.1% of the combined LRP/super premium unleaded figure and from 2007 DUKES stopped reporting the sales of the two fuels separately. An assumption that from 2007 LRP sales were zero is used.

4.10 CALCIUM

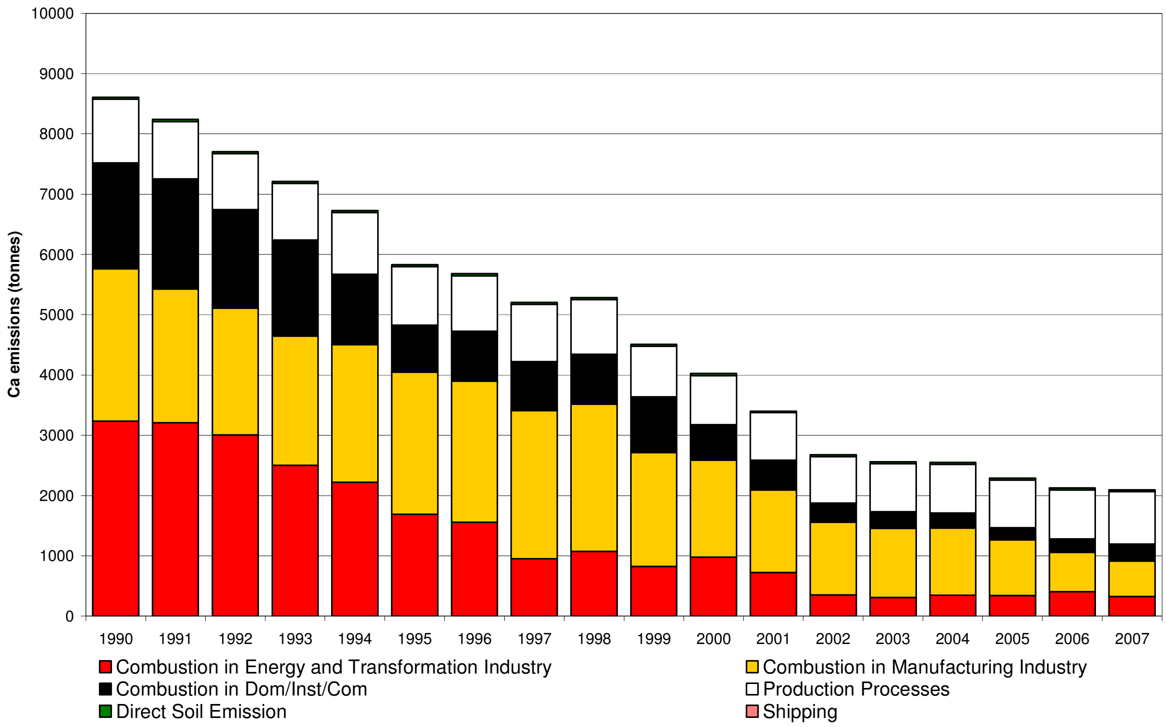
Combustion in industry and production processes contributes the most emissions of calcium. Within the latter sector glass production, quarrying, cement production and lime production are the most significant contributors. However, more recently the introduction of abatement measures has ensured reductions 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	2006	2007	2007 %
BY UN/ECE CATEGORY[1]											
Combustion in Energy and Transformation Industry	1A1	3.2	1.0	0.7	0.3	0.3	0.3	0.3	0.4	0.3	15%
Combustion in Manufacturing Industry	1A2	2.5	1.6	1.4	1.2	1.1	1.1	0.9	0.6	0.6	28%
Combustion in Dom/Inst/Com	1A4	1.8	0.6	0.5	0.3	0.3	0.3	0.2	0.2	0.3	13%
Other Production Industry	2A1\2C	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	11%
Glass Production	2A7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	30%
Direct Soil Emission	4D1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1%
Shipping	1A3dii	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
TOTAL		**4.0**	**3.4**	**2.7**	**2.6**	**2.6**	**2.3**	**2.3**	**2.1**	**2.1**	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 fireworks. The quarrying of dolomite, used as an aggregate, is another significant source. This emission falls within the production processes sector. Quarrying is also a significant source. Domestic coal burning was responsible for 78 tonnes, and coal burning power stations released 102 tonnes in 2007.

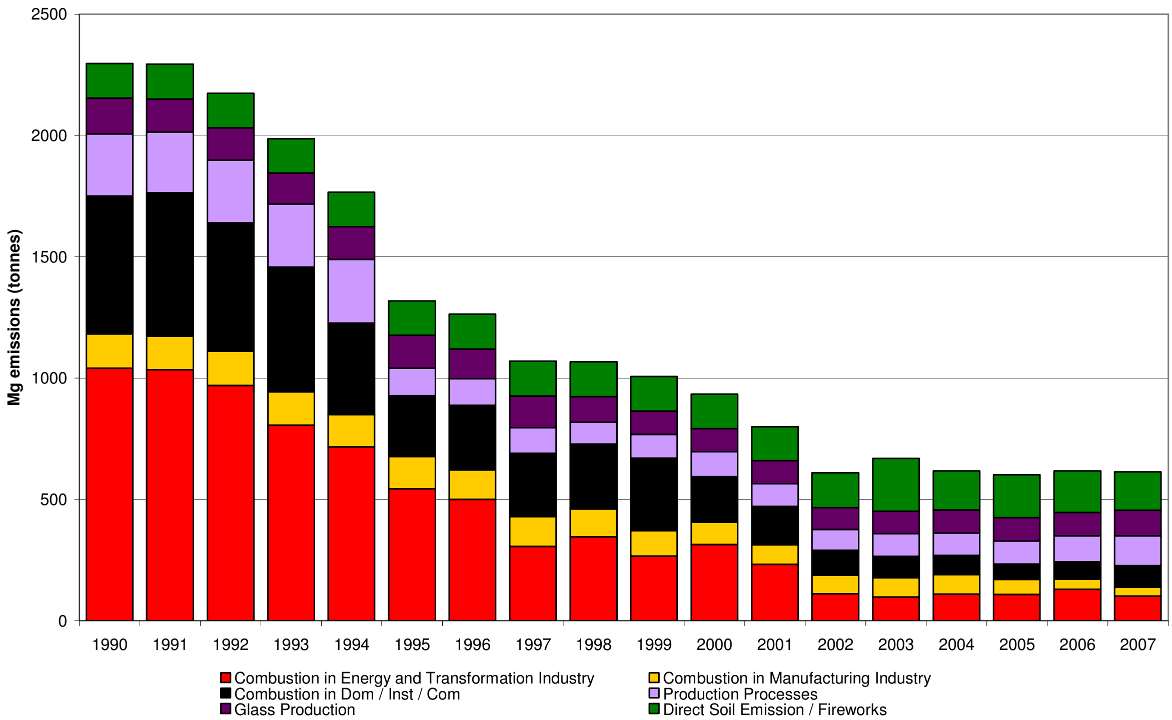
Estimates for slag cement grinding, fireworks and burning of waste lubricants have all been included in the emission estimates.

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

	NFR Codes	1990	2000	2001	2002	2003	2004	2005	2006	2007	2007 %
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	0.1	0.1	17%
Combustion in Manufacturing Industry	1A2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	6%
Combustion in Dom/Inst/Com	1A4	0.6	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	14%
Production Processes	2A1, 2C	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	20%
Glass Production	2A7	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	17%
Direct Soil Emission	4D1	0.0	0.0	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	0.2	0.1	0.2	0.2	0.1	24%
TOTAL		**2.3**	**0.9**	**0.8**	**0.6**	**0.7**	**0.6**	**0.6**	**0.6**	**0.6**	**100%**

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

Figure 4.2 Time Series of Magnesium Emissions (tonnes)



4.12 SODIUM

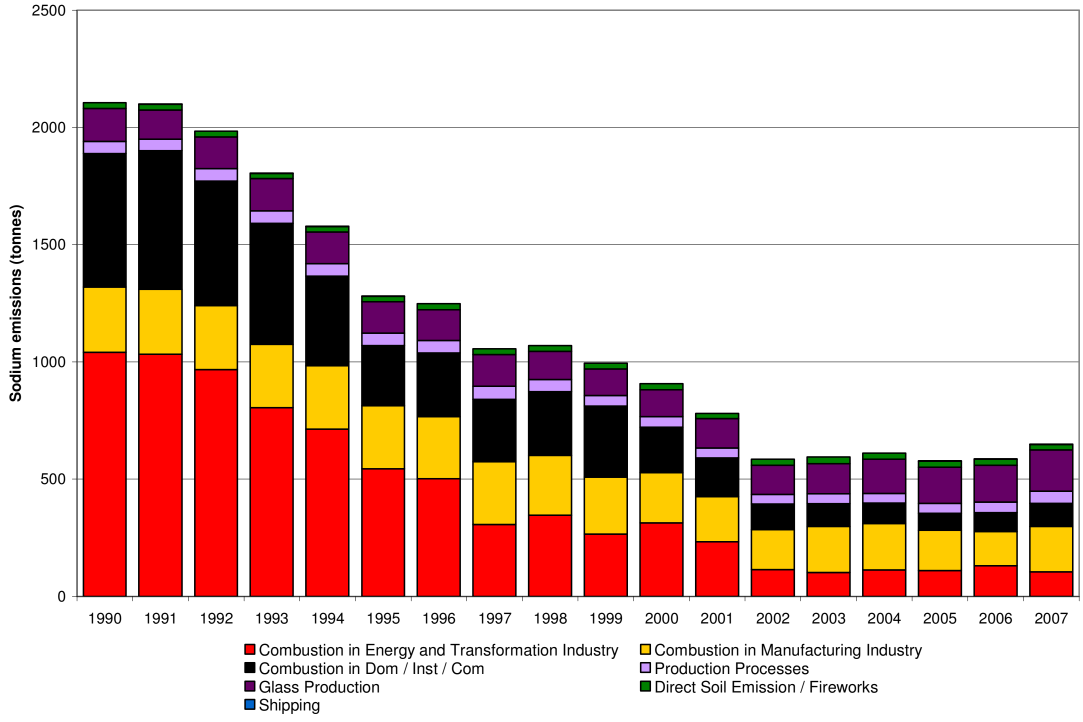
Iron and steel production from sinter plants is responsible for the greatest single emission of sodium with 169 tonnes emitted in 2007. Domestic coal burning emissions contributed 77 tonnes and coal burning power stations 101 tonnes. Other sources include glass manufacture and the food manufacture/preparation sectors.

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

	NFR Codes	1990	2000	2001	2002	2003	2004	2005	2006	2007	2007 %
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	0.1	0.1	16%
Combustion in Manufacturing Industry	1A2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2	30%
Shipping	1A3dii	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Combustion in Dom/Inst/Com	1A4	0.6	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	15%
Production Processes	2A1, 2B5, 2C	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	8%
Glass Production	2A7	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	27%
Direct Soil Emission\Fireworks	4D1, 7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4%
TOTAL		2.1	**0.9**	**0.8**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**100%**

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

Figure 4.3 Time Series of Sodium Emissions (tonnes)



4.13 POTASSIUM

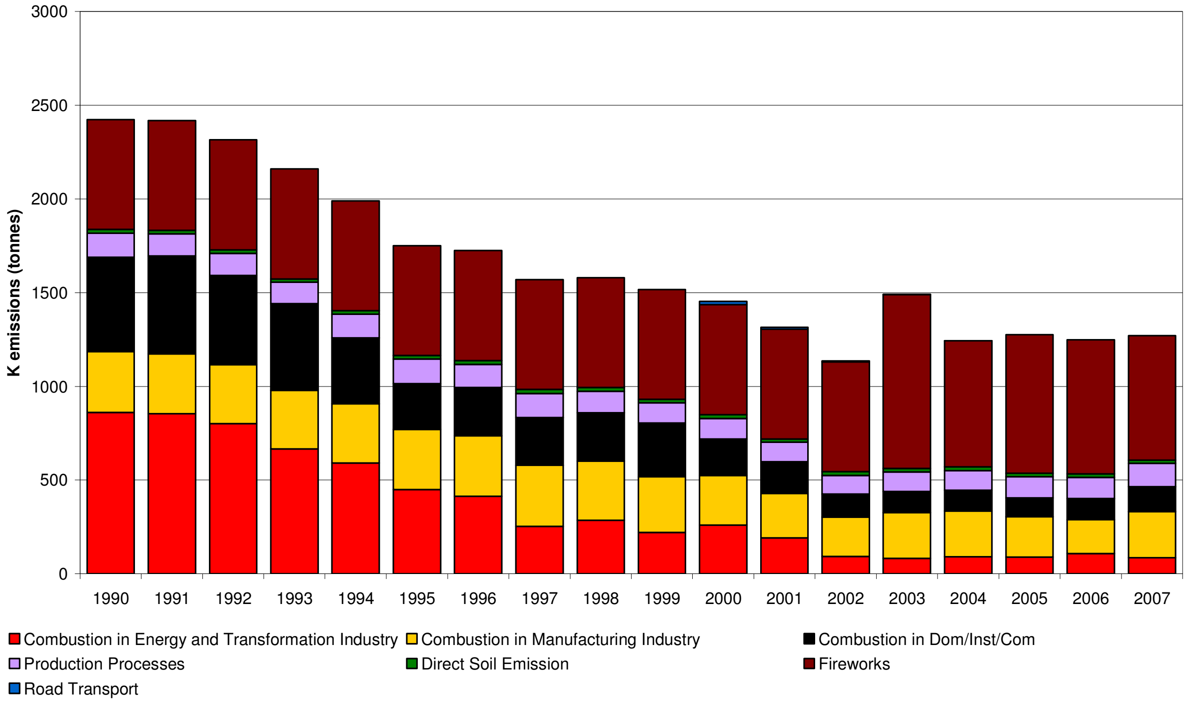
Fireworks are the largest source of potassium emissions, accounting for 665 tonnes. Iron and steel production was the second largest source, with emissions of 225 tonnes in 2007. Coal burning power stations were the third main contributor, causing the emissions of 84 tonnes of potassium.

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

BY UN/ECE CATEGORY[1]	NFR Codes	1990	2000	2001	2002	2003	2004	2005	2006	2007	2007%
Combustion in Energy and Transformation Industry	1A1	0.9	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	7%
Combustion in Manufacturing Industry	1A2	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	19%
Road Transport	1A3bi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Combustion in Dom/Inst/Com	1A4	0.5	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	10%
Production Processes	2	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	10%
Direct Soil Emission	4D1	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1%
Fireworks	7	0.0	0.6	0.6	0.6	0.9	0.7	0.7	0.7	0.7	52%
TOTAL		**2.4**	**1.5**	**1.3**	**1.1**	**1.5**	**1.2**	**1.3**	**1.2**	**1.3**	**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	-30% to +70%
Magnesium	-30% to +60%
Sodium	-40% to +100%
Potassium	-60% to +100%

Inventories for base captions 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 agreements on Persistent Organic Pollutants (POPs) of the UN/ECE under the Convention on Long-Range Transboundary Air Pollution and the UNEP Stockholm Convention on POPs.

5.1.1 International Agreements controlling POPs ReleasesProtocols

The Convention on Long-range Transboundary Air Pollution has been extende 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. Annexes IV and V to the Protocol on POPs are currently under review.

The Aarhus Protocol contains annexes which contain different levels of control for substances deemed to be considered as a persistent organic pollutant Annex I Bans substances, Annex II restricts their use, Annex III limits unintentional releases.

Similarly the Stockholm Convention of 2004 also has annexes (a- banned, b – restricted and c limit unintentional release). The two conventions are independent of one another but address similar lists of pollutants.

The EU POPs regulation came into effect when the EU ratified to the Stockholm Convention. This requires EU member states to report information to the European Commission. As of May 2009, nine additional POPs were added to the annexes of Stockholm, of which five are already covered by the UNECE Protocol and the EU POPs regulation (Chlordecone, Hexabromobiphenyl, alpha HCH, beta HCH and Lindane). This is likely to require changes to the EU POPs regulation to allow the EU to ratify the amendment to the Stockholm Convention. Pentachlorobenzene, an unintentional POP with similar sources to dioxins and furans was added to annex c of the Stockholm Convention and will require a multi-media release inventory to be developed.

5.1.1.1 Persistent Organic Pollutants (POPs)

Persistent organic pollutants (POPs) are organic compounds 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 and ecosystem 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 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 however although further emission reductions are expected projections indicate that there will continue to be exceedences of the objective for PAHs well after 2010 in some urban areas, industrial locations and alongside some busy roads. 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/m3. As a consequence of the national objective and the target value there is a continued drive to decrease PAH emissions from the major sources.

Table 5.1 lists POPs included in the current inventory together with their total UK emissions in 2007. Each of the pollutant classes are considered in more detail in the following sections.

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 2007 UK emission	
Persistent organic compounds (POPs)		
• Polycyclic aromatic hydrocarbons (PAHs)	1,280	tonnes (USEPA16)[1]
• Dioxins and Furans (PCDD/F)	190	grams I-TEQ [2]
• Polychlorinated biphenyls (PCBs)	0.984	tonnes
• Pesticides		
- lindane (>99% γ-HCH)	11.2	tonnes
- pentachlorophenol (PCP)	404	tonnes
- hexachlorobenzene (HCB)	0.81	tonnes
• Short Chain Chlorinated Paraffins (SCCPs)	1.49	kg
• Polychlorinated Napthalenes (PCNs)	NE[3]	
• Polybrominated Diphenyl Ethers (PBDEs)	7	tonnes

[1] See Table 5.3 for different PAHs included under different groupings.
[2] TEQ- "Toxic Equivalents" is a way of weighting emissions according to their toxicity. See Table 5.5
[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 of the EPA 16 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 1995 (contributing nearly half of the total PAH emission). Emissions since then have declined and in 2007 these sources accounted for less then 1% of the total PAH emissions. This is a consequence of the closure of the plant at Kinlochleven and investment in abatement equipment by the aluminium smelter operators following from the authorisation regime implementing the Environmental Protection Act 1990.

Road transport combustion is currently the largest source of PAH emissions contributing 58% of the emissions in 2007. 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 the very high uncertainty results. The next largest sources of emissions in 2007 were domestic combustion and paint application.

Overall, emissions of BaP increased slightly between 2006 and 2007 due to increases in throughput at coke works and the amount of domestic coal burned.

The most notable trends in the BaP inventory include significantly reduced emissions from some industrial sources and 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. However uncertainties associated with the emissions estimates of PAHs are still 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	2006	2007	2007%
BY UN/ECE CATEGORY[2]												
Public Electricity and Heat Production	1A1a	68	45	35	38	36	39	38	39	44	40	3%
Other Industrial Combustion	1A1b-c, 1A2	27	27	21	19	19	19	19	19	19	17	1%
Passenger cars	1A3bi	141	151	185	184	185	184	186	187	180	171	13%
Light duty vehicles	1A3bii	311	454	419	411	386	372	361	348	321	310	24%
Heavy duty vehicles - buses and coaches	1A3biii	1885	1295	634	530	455	396	350	311	290	258	20%
Other Transport	1A3biv, 1A3c-1A4cii	9	8	9	9	9	10	9	10	9	10	1%
Residential/Commercial / Institutional	1A4a, 1A4bi, 1A4ci	710	397	339	302	250	240	260	269	304	348	27%
Metal Production	2C	3492	2308	34	38	34	13	12	3	6	2	0%
Other (Paint Application/Waste)	1B1, 2A5, 2B5, 3, 4, 6	1118	165	144	158	147	148	120	118	122	123	10%
Total		**7761**	**4850**	**1819**	**1688**	**1521**	**1421**	**1354**	**1304**	**1293**	**1280**	**100%**

[1] The PAHs selected are listed above in Table 5.3
[2] See Annex 1 for definition of UN/ECE Categories

Figure 5.1 Time Series of 16 PAHs Emissions (tonnes)

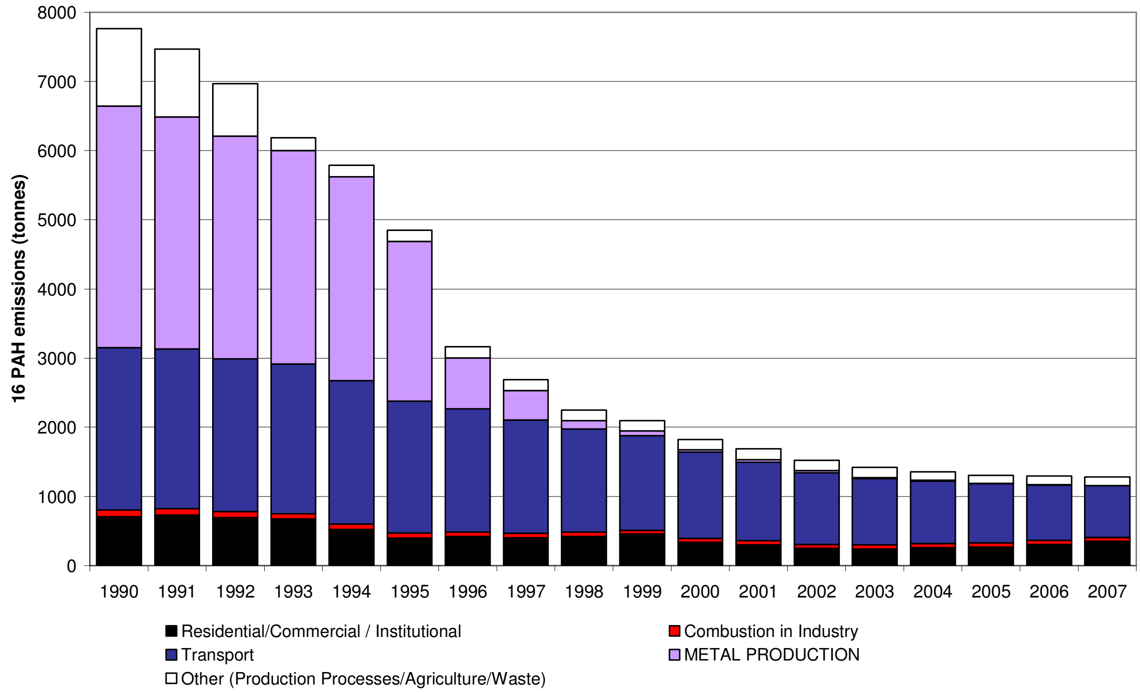


Table 5.4b UK Emissions of BaP[1] by aggregated UNECE Source Category (Kg)

	NFR Codes	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2007%
BY UN/ECE CATEGORY[2]												
Combustion in Industry	1A1, 1A2	373	309	217	251	371	269	235	219	167	162	4%
Passenger cars	1A3bi	4615	1525	378	304	252	207	177	156	141	130	3%
Light&Heavy Duty Vehicles	1A3bii, iii	661	520	304	269	238	215	198	183	169	157	4%
Other Transport	1A3biv, 1A3c-1A4cii	140	99	89	91	94	104	98	103	101	105	3%
Residential/Commercial / Institutional	1A4a, 1A4bi, 1A4ci	5840	3007	2492	2166	1706	1608	1681	1679	1896	2202	55%
Production Processes	1B1b-3A	24985	16595	966	971	899	474	442	263	335	314	8%
Waste Incineration	6C	663	663	662	1044	662	662	662	662	662	662	16%
Other (Agricultural & Other Waste)	4, 6D, 7	28657	335	296	306	309	324	290	283	285	285	7%
Total		**65933**	**23052**	**5404**	**5403**	**4532**	**3865**	**3783**	**3545**	**3754**	**4016**	**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)

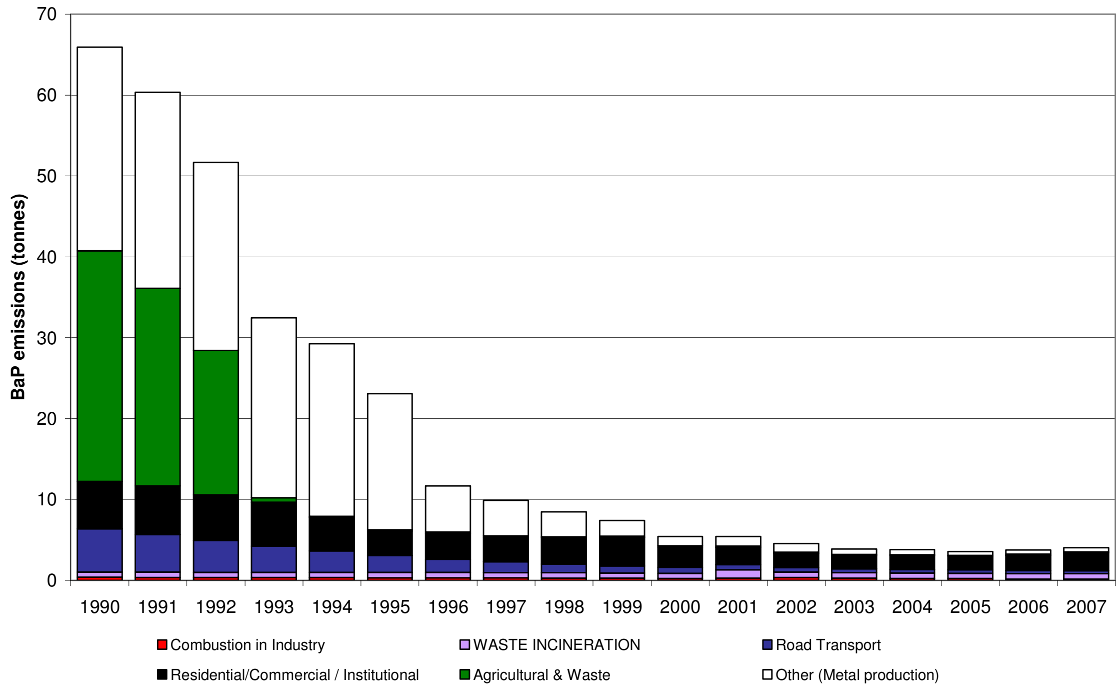
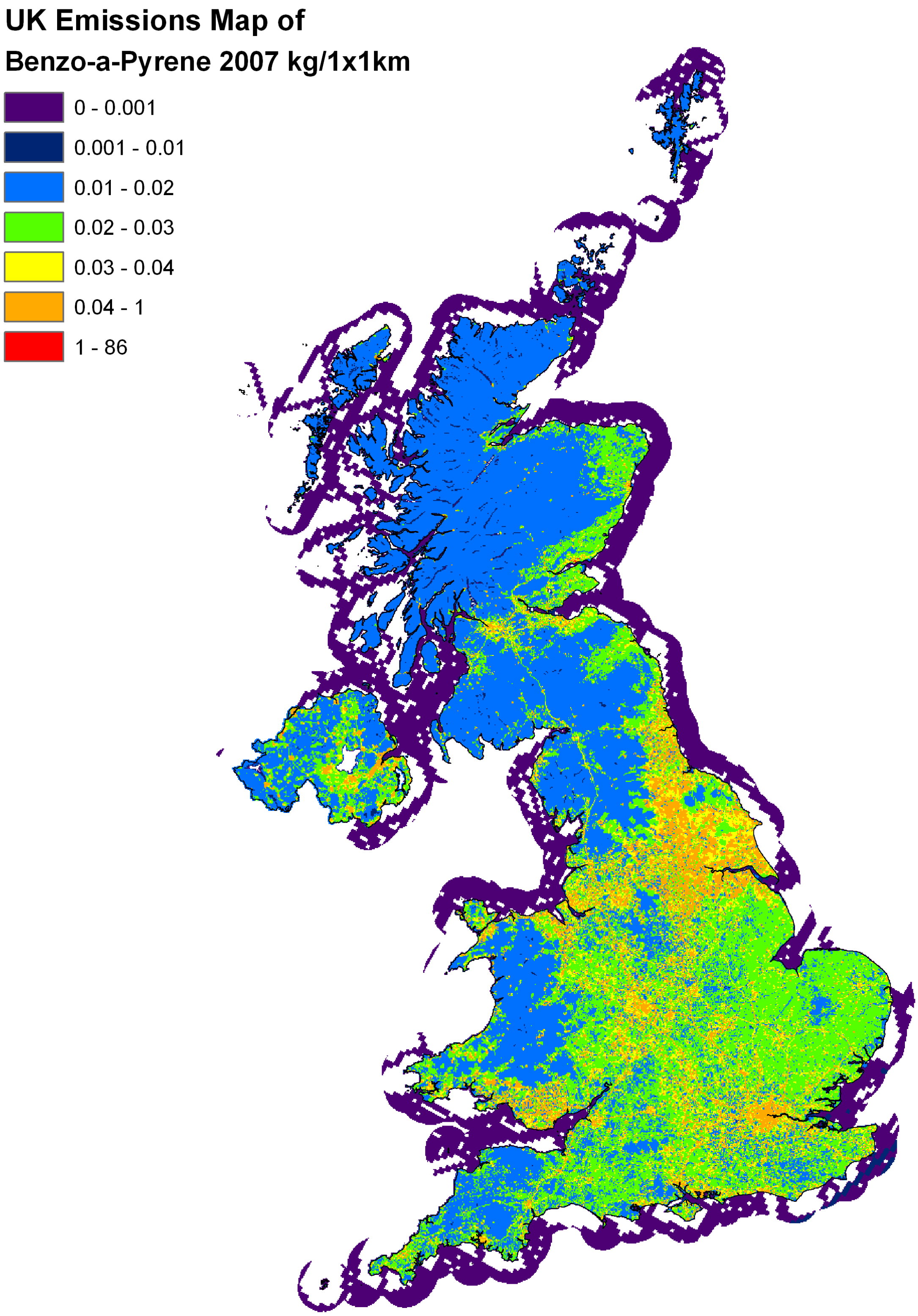


Figure 5.3 Spatially Disaggregated UK Emissions of Benzo[a]pyrene Map



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 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 7 PCDDs and 10 PCDFs which as a result of their common 2,3,7,8 chlorine substitution are thought to lead to dioxin-like toxicity. The emissions of these substances are weighted by factors called Toxic Equivalence Factors (TEF) to estimate the quantity of the most toxic congener, 2,3,7,8-TetraChloroDibenzo-*p*-Dioxin, 17 which would have the same effect as the mixture emitted this is the known as a Toxic Equivalent (TEQ). The NATO/CCMS (Committee on the Challenges of Modern Society 1988) scheme known as the International toxic equivalent (I-TEQ) scheme widely used in UK and European legislation is used in the NAEI.

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 published TEFs for certain PCBs which have dioxin-like toxicity which allows PCDD/F and PCB TEQs to be combined 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 for human exposure (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 thermal processes 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 following use of chlorinated 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 as pentachlorophenol treated wood which have the potential on disposal to be sources of PCDD/Fs e.g. from the combustion of the treated wood further the pentachlorophenol in the treated wood can lead to dioxin emission.

5.2.1.3 Emission Estimates

Estimated PCDD/F emissions for 1990-2007 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)

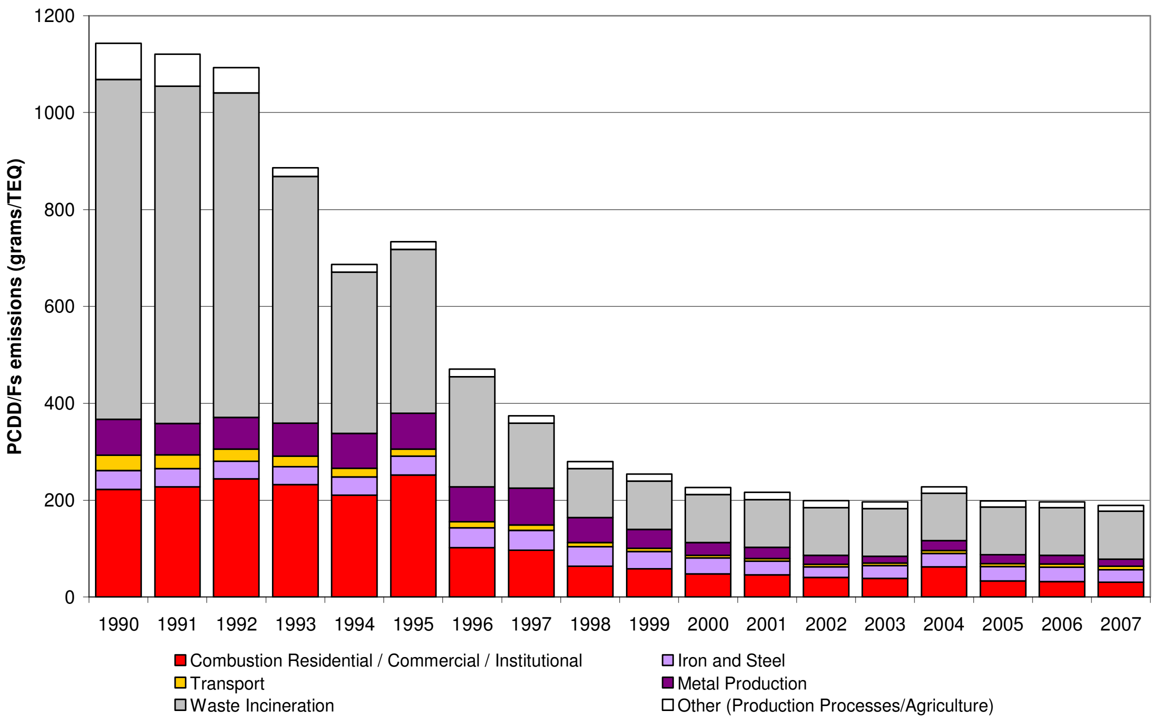
	NFR Codes	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2007 %
BY UN/ECE CATEGORY[1]												
Combustion in Industry	1A1	109.1	164.8	7.5	6.6	7.2	7.1	6.3	7.6	6.6	6.0	3%
Iron and Steel	1A2a	39.1	38.7	32.9	27.9	22.1	26.2	27.5	29.4	30.4	25.6	14%
Other industrial combustion: Wood&Coal	1A2f	40.3	45.4	24.7	24.6	20.1	19.4	44.2	14.2	13.2	12.9	7%
Transport[2]	1A3b, 1A3c-1A4cii	31.5	15.2	5.2	5.1	5.1	5.0	5.8	6.1	6.7	6.9	4%
Residential/Commercial / Institutional	1A4a, 1A4bi, 1A4ci	72.5	41.7	15.7	15.0	13.3	12.5	12.2	11.6	11.7	12.1	6%
Production Processes	1B1b, 2A&B&D	5.5	3.5	2.0	1.9	1.7	1.8	1.5	1.6	1.7	1.8	1%
Metal Production	2C	74.8	73.6	26.6	23.7	18.7	13.8	20.6	18.4	17.7	14.9	8%
Agriculture\Other	4, 7	63.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	4%
Waste Incineration & Other Waste	6	706.1	343.5	104.6	104.6	104.2	104.2	102.2	102.5	101.8	102.5	54%
Total		**1142.7**	**733.2**	**226.0**	**216.2**	**199.1**	**196.7**	**227.1**	**198.3**	**196.6**	**189.5**	**100%**

[1] See Annex 1 for definition of UN/ECE Categories
[2] Including railways, shipping, naval vessels, military aircraft, off-road sources and road transport

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 81% between 1993 and 2007. 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. All remaining MSW incinerators are now classified as public power plant burning MSW as they all generate electricity. 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.

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



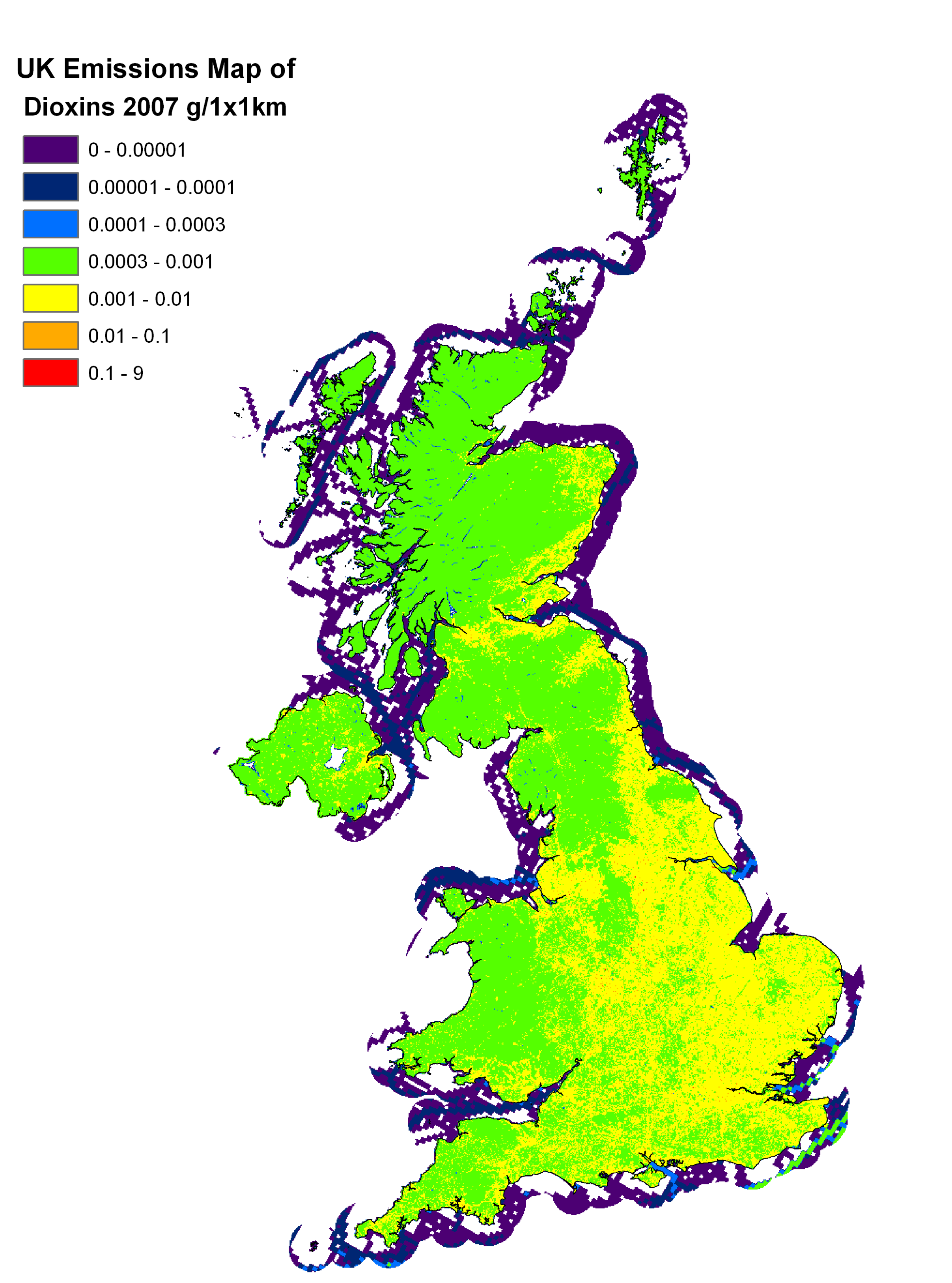
Emissions from power stations are low because the combustion is efficient and the post-combustion fly ash temperatures are rapidly reduced to increase energy efficiency. The emission factors associated with industrial and domestic coal combustion are significantly higher and even though the coal consumption in this sector is much smaller the emissions are thought to be larger. 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 at integrated iron and steel works. Emissions from iron and steel plants are probably underestimated since only emissions from electric arc furnaces are considered. Scrap used in electric arc furnaces and secondary non-ferrous metal production may contain chlorinated impurities such as plastics and cutting oil which contribute to PCDD/F formation.

It is thought that the major source of PCDD/F emissions from road transport are the 1,2-dichloroethane scavengers previously added to leaded petrol as a scavenger to remove lead from the cylinder. Consequently the emissions of PCDD/F from this sector are thought to have decreased following the decline in use then the removal from sale of leaded petrol. Unleaded petrol and diesel is likely to contain only trace quantities of chlorinated impurities. For 2007, the contribution to the PCDD/F emission total from road transport fuel was 1%.

Figure 5.5 Spatially Disaggregated UK Emissions of PCDD/F Map



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 may 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 2007, 57% 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

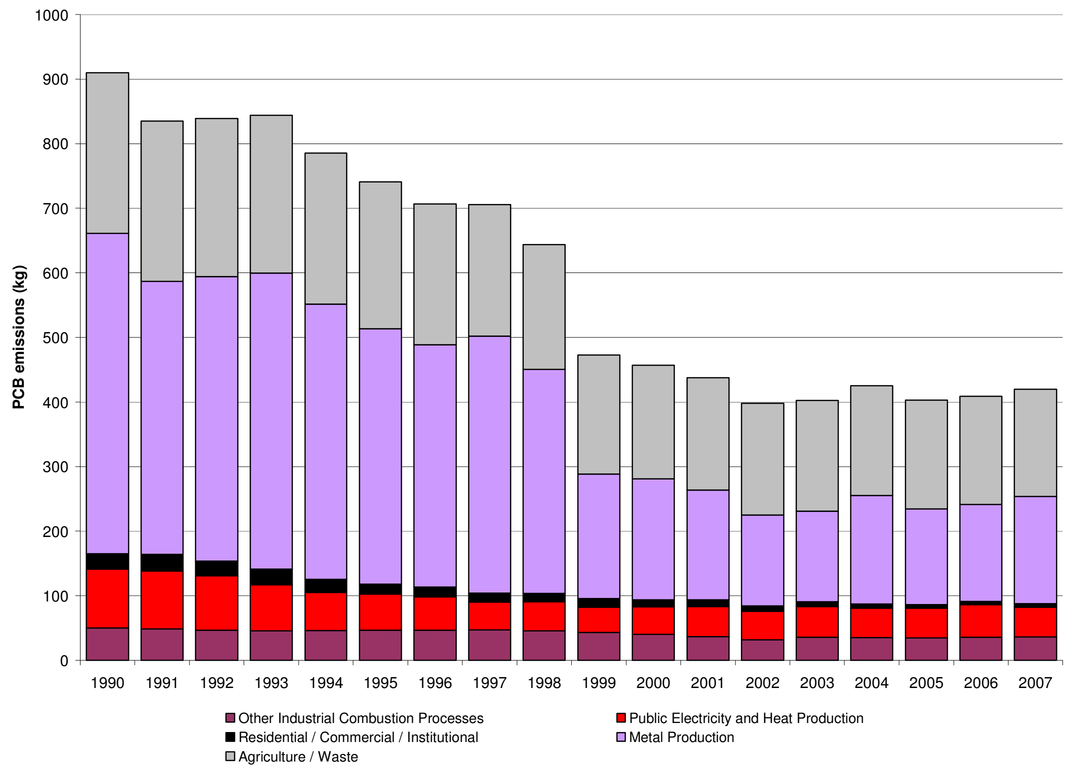
PCB speciation has been incorporated into the emission estimates since the 1998 inventory report. A summary of the total PCB emission estimates for 1990 to 2007 is given below in Table 5.7.

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	2006	2007	2007 %
BY UN/ECE CATEGORY[1]												
Public Electricity and Heat Production	1A1a	91	56	43	47	44	48	46	46	50	46	5%
Residential/Commercial / Institutional	1A4a, 1A4bi, 1A4ci	24	15	11	10	8	7	7	5	5	6	1%
Metal Production	2C	496	395	188	170	141	141	168	148	150	166	17%
Agriculture\Waste	4, 6	249	228	175	174	173	171	170	169	167	166	17%
Other	1A1b-c, 1A2, 1A4ci, 1B1b	50	46	40	37	32	36	35	35	36	36	4%
Evaporation from Capacitors, Fragmentisers, Transformers	2G	5670	4150	847	793	746	703	663	626	594	564	57%
Total		**6580**	**4891**	**1304**	**1231**	**1144**	**1105**	**1088**	**1029**	**1003**	**984**	**100%**

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

Figure 5.6 Time Series of PCBs Emissions (kg)



Sales of PCBs in the UK were stopped in 1986. It is thought that they are still manufactured in some countries. The total PCB emission in 1990 was dominated by leaks from capacitors (79% of total emission), and this is the case for 2007.

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 5.8a, Table 5.9b and Table 5.10show the estimated emissions of lindane (>99% 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. The emission estimates, presented in Table 5.8a, were made assuming that emissions arise from: the application of lindane to treated wood and agricultural and domestic use. In 2007 lindane emissions were solely due to emissions from treated wood. Emissions from previously wood preserving have fallen since 1990.

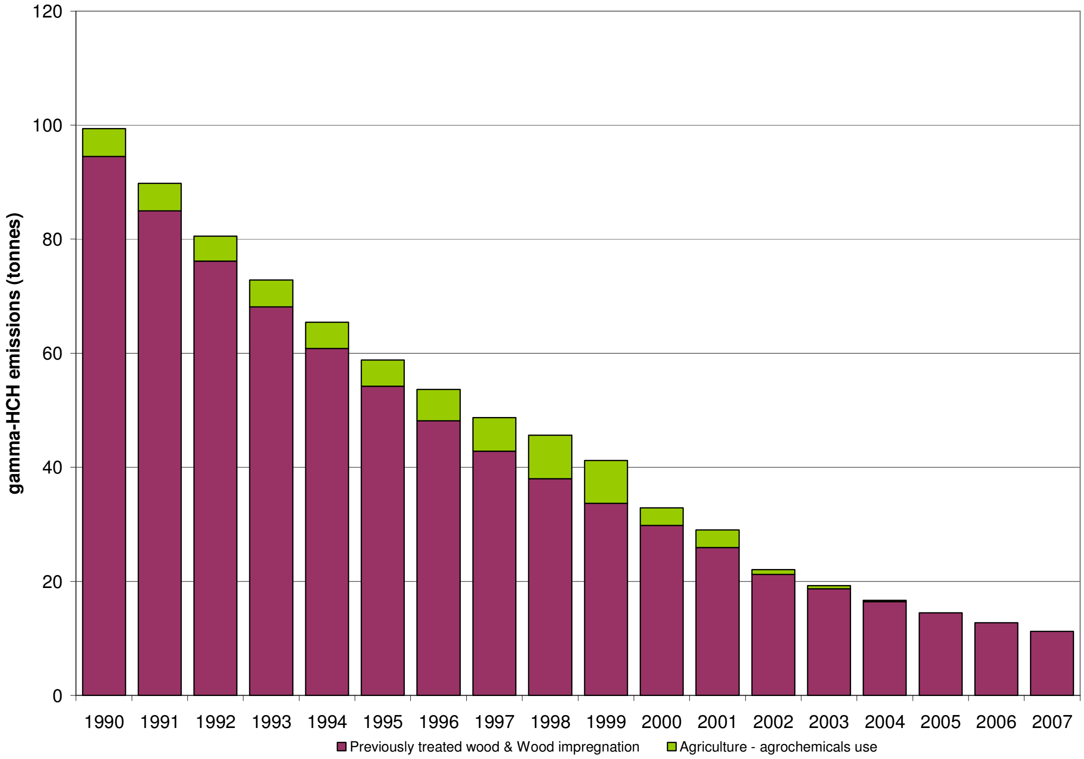
Emissions from agricultural pesticide activities accounted for around 9% of total 2000 lindane emissions. However, since 2006 there has been no emission from this sector. These emissions are based on statistics on the use of pesticides containing lindane, obtained from personal communication with the Central Science Laboratory's (now the Food and Environment Research Agency's) Pesticide Usage Survey Team. The emission factors used 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	2006	2007	2007 %
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	12.7	11.2	100.0%
Agriculture - agrochemicals use	4G	4.9	4.6	3.1	3.0	0.8	0.6	0.3	0.0	0.0	0.0	0.0%
Total		**99.4**	**58.8**	**32.9**	**29.0**	**22.0**	**19.3**	**16.7**	**14.5**	**12.7**	**11.2**	**100%**

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

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



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

Table 5.9b UK Emissions of γ-HCH by aggregated UN/ECE Source Category (tonnes).

		1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2007 %
BY UN/ECE CATEGORY[1]												
Solvent use - treated wood & wood impregnation	3D	95.5	54.7	30.1	26.2	21.4	18.9	16.6	14.6	12.9	11.3	100.0%
Agriculture - agrochemicals use	4G	4.9	4.7	3.1	3.1	0.8	0.6	0.3	0.0	0.0	0.0	0.0%
Total		**100.4**	**59.4**	**33.2**	**29.3**	**22.3**	**19.5**	**16.9**	**14.6**	**12.9**	**11.3**	**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 2007 are given in Table 5.10. 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 2007 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.

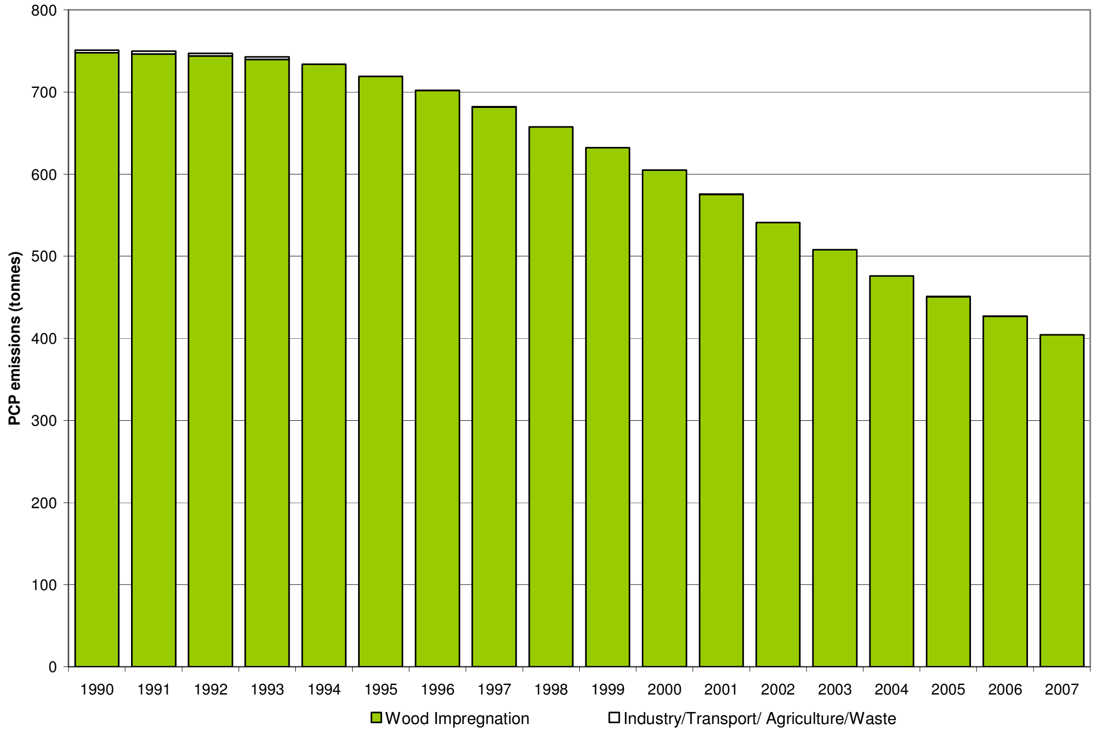
PCP has been used in the agricultural sector as the active ingredient in disinfecting wooden trays used in mushroom farming (classified as solvent use). Usage statistics are reliable coming from the Pesticide Usage Survey Group (MAFF, 1991a,b,c;1992a,b,c,d). The emission factor assumes 30% loss due to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

Table 5.10 UK Emissions of PCP by aggregated UN/ECE[1] Source Category (tonnes)

	NFR Codes	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2007
Wood Impregnation	3D	748	719	605	576	541	508	476	451	427	404	100%
Other	1A, 2, 3C, 6	3	0	0	0	0	0	0	0	0	0	0%
Total		**751**	**719**	**605**	**576**	**541**	**508**	**476**	**451**	**427**	**404**	**100%**

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

Figure 5.8 Times Series of PCP Emissions (tonnes)



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

5.2.3.5 Hexachlorobenzene (HCB)

Very little information is available on the health effects of HCB via ingestion. 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 2007. 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).

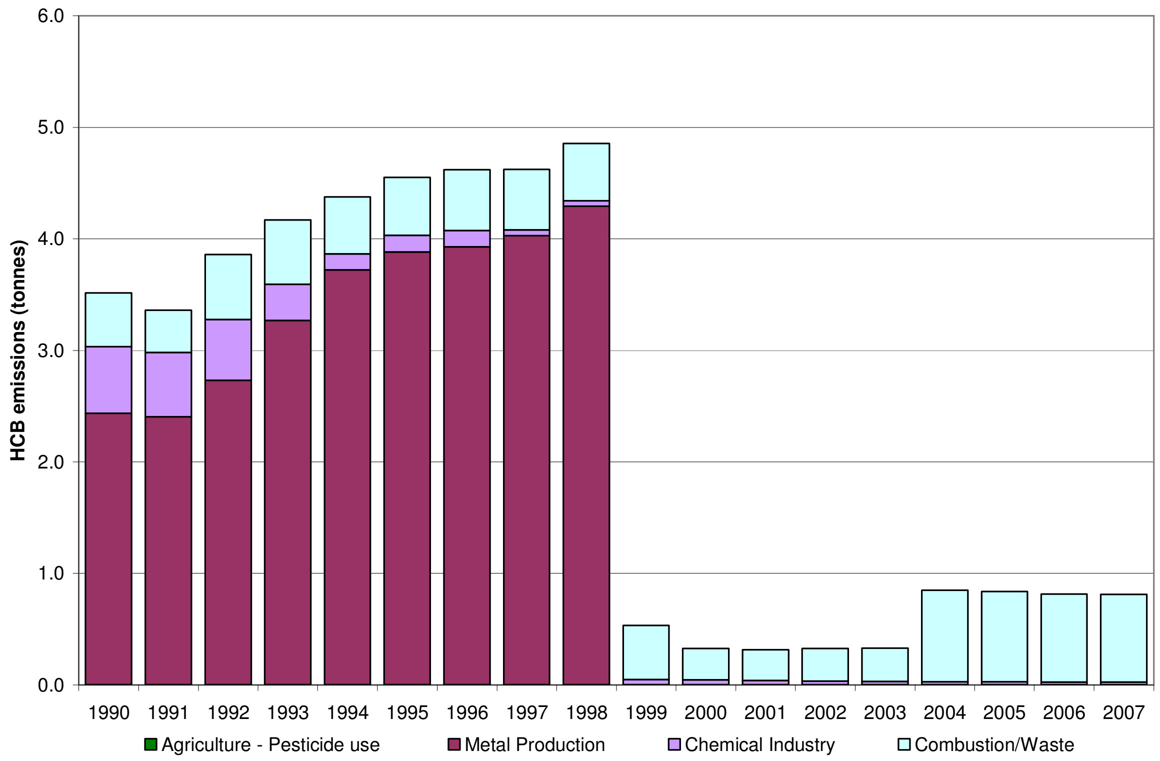
Emissions from pesticide application and chlorinated solvent production now account for virtually all of the UK HCB emissions (Table 5.10). For 2007, these two sources are estimated to account for 97% and 3%, respectively, of the total HCB emissions. This represents a change in the relative contributions 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.

Table 5.11 UK Emissions of HCB by aggregated UN/ECE[1] Source Category (kg)

	NFR Codes	1990	1995	2000	2003	2004	2005	2006	2007	2007 %
BY UN/ECE CATEGORY										
Chemical Industry	2B5	596.2	148.9	43.5	28.5	25.8	24.7	23.4	23.4	3%
Metal Production	2C	2435.0	3881.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
Agriculture - Pesticide use	4G	482.2	517.5	279.9	298.4	821.8	811.5	787.5	786.3	97%
Other[2]	1A1a, 1A4a, 6c	2.0	2.0	1.9	2.2	2.1	2.1	2.3	2.3	0%
Total		**3515.4**	**4549.4**	**325.2**	**329.1**	**849.6**	**838.3**	**813.2**	**812.0**	**100%**

[1] See Annex 1 for definition of UN/ECE Categories
[2]Public Electricity and Heat Production, Commercial / Institutional fuel combustion and waste incineration

Figure 5.9 Time Series of HCB Emissions (tonnes)



5.2.4 Short Chain Chlorinated Paraffins (SCCP)

5.2.4.1 Introduction

Short chain chlorinated paraffins (SCCPs) are a range of commercially available chlorinated paraffins with 10-13 carbon atoms. The commercial products are usually mixtures of different carbon chain length 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. The chlorine content of SCCPs generally range from 30 to 70% by weight. Current consumption in the UK is estimated to be approximately 286 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

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 5.12 UK Emissions of SCCPs (tonnes)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007
TOTAL	47.2	23.8	3.1	0.2	1.0	0.6	0.4	0.0007	0.0007	0.0015

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 to 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 over all years, as 150,000 tonnes. Similar assumptions can be made to derive UK production, which is estimated to have been 6,650 tonnes over the period of production.

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 5.9 tonnes (Penta-BDE: 0.7t, Octa-BDE: 0.2t, Deca-BDE: 5.0t) per year.

There are a number of improvements that could be made to the UK emission estimate for PBDEs. The current approach concentrates on the releases from foam materials during their use. Resources could be focused on:

- Emission from manufacturing sites
- Release from materials during and following disposal
- Release from other materials that contain PBDEs

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	-60 to +200
Dioxins and furans	-50 to +200
Polychlorinated biphenyls	-40 to + 90
Pentachlorophenol	-80 to +200
Hexachlorohexane	-100 to +400
Hexachlorobenzene	-80 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 inventory for polychlorinated biphenyls is 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 the 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	Sector 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 (no 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 AEA (Choudrie *et al*, 2009).

The 2007 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).

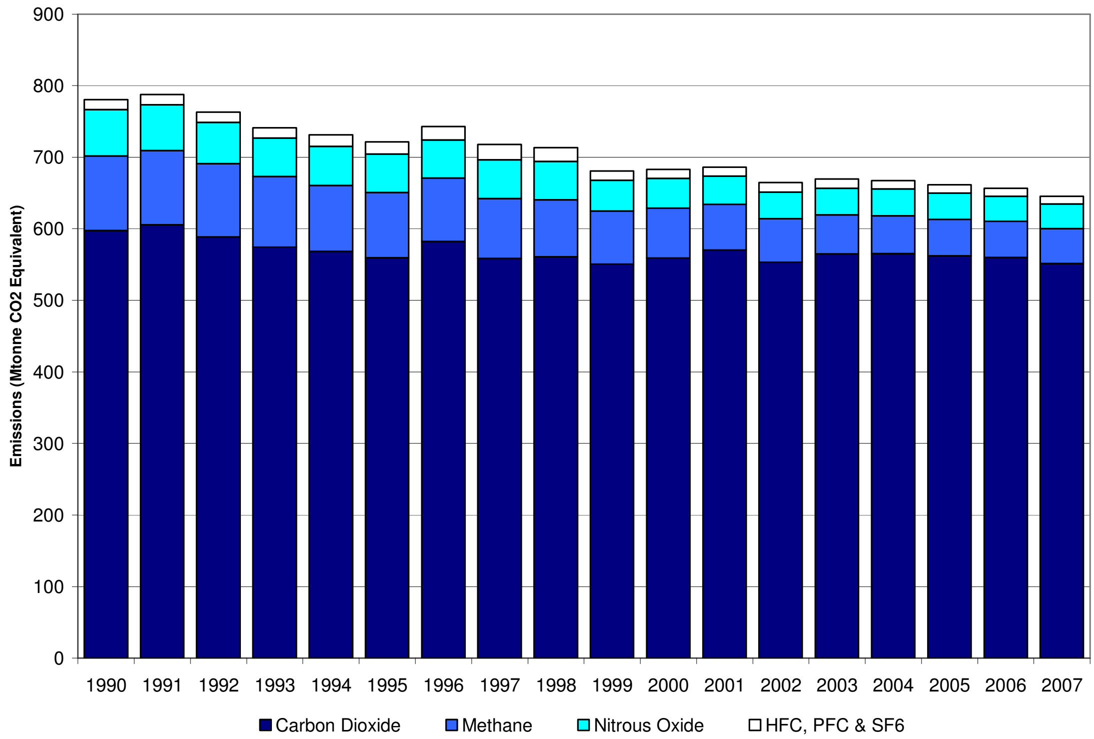
Table 7.1 GWP for UK Emissions of Greenhouse Gases in 2007

Direct GHG	Emissions (ktonnes) in 2007	GWP (100 years)	Global Warming Equivalence (equivalent kt of CO_2)
CO_2 (as carbon) [1]	149,092	3.7	551,640
CH_4	2,326	21	48,846
N_2O	110	310	34,100
HFCs [2]	5.6	140 - 11,700	2,613
PFCs [2]	0.03	6,500 - 9,200	59
SF_6	0.03	23,900	216

[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 1990-2007, there has been a decrease in UK emissions of CO_2, CH_4, N_2O, HFC, PFC and SF_6, meaning that there 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[9] for 1990 to 2007. 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 1990-2007 (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. Emissions of other pollutants from biomass combustion are included in the appropriate

[9] 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.

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 (Choudrie *et al*, 2009) as discussed 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 less than 2% of the total 2007 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 (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 the Department for Business Enterprise and Regulatory Reform (BERR) Digest of United Kingdom Energy Statistics (BERR, 2008). The fuel consumption data used to calculate the pollutant emission totals in the NAEI are given in Table 7.3; fuels that 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

UK carbon dioxide emissions have declined by 20% between 1970 and 2007, 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 thought 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	2003	2004	2005	2006	2007	2007 %
BY UN/ECE CATEGORY[2]											
Public Electricity and Heat Production	1A1a	58.6	60.0	55.8	43.3	47.3	47.1	47.1	49.4	48.3	32.4%
Combustion Industry/Commercial/Residential	1A1b&c, 1A2a, 1A4	64.1	44.8	43.8	46.3	44.9	45.2	44.0	41.6	40.3	27.1%
Other Industrial Combustion	1A2f	38.0	27.8	20.4	19.6	18.1	17.6	17.7	17.0	16.4	11.0%
Road Transport:											
Passenger cars	1A3bi	11.1	14.8	19.6	21.2	21.2	21.5	21.3	21.2	21.1	14.1%
Other Road Transport	1A3bii-iv	5.4	6.5	10.2	10.4	11.0	11.1	11.4	11.7	12.1	8.1%
Other Transport (off Road)[3]	1A3ai(i)-1A3aii(i), 1A3c-1A3eii, 1A4bii, 1A4cii, 1A5b	4.0	4.4	4.9	4.4	4.5	4.6	4.7	5.0	5.0	3.4%
Production Processes	1B1, 1B2, 2	4.8	7.0	5.6	5.0	4.6	4.7	4.9	4.5	4.8	3.2%
Agriculture\Other Sources & Sinks	4\5	0.0	0.0	0.5	0.3	0.4	0.3	0.3	0.3	0.3	0.2%
Waste & Others	6\7	0.8	0.8	0.8	0.6	0.6	0.6	0.6	0.6	0.6	0.4%
Emission by fuel											
Solid		92.9	72.5	62.8	33.6	36.6	35.0	35.0	38.1	35.3	23.6%
Petroleum		67.4	54.9	53.5	46.9	46.6	47.3	48.2	47.9	47.5	31.9%
Gas		21.7	31.5	39.3	65.0	64.0	65.0	63.3	60.2	61.0	40.9%
Non-Fuel		4.8	7.1	5.9	5.6	5.4	5.4	5.5	5.2	5.3	3.5%
Total		**186.6**	**166.1**	**161.5**	**151.1**	**152.6**	**152.7**	**152.0**	**151.4**	**149.1**	**100%**

[1] UK emissions reported in IPCC format (Choudrie *et al*, 2009) 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)

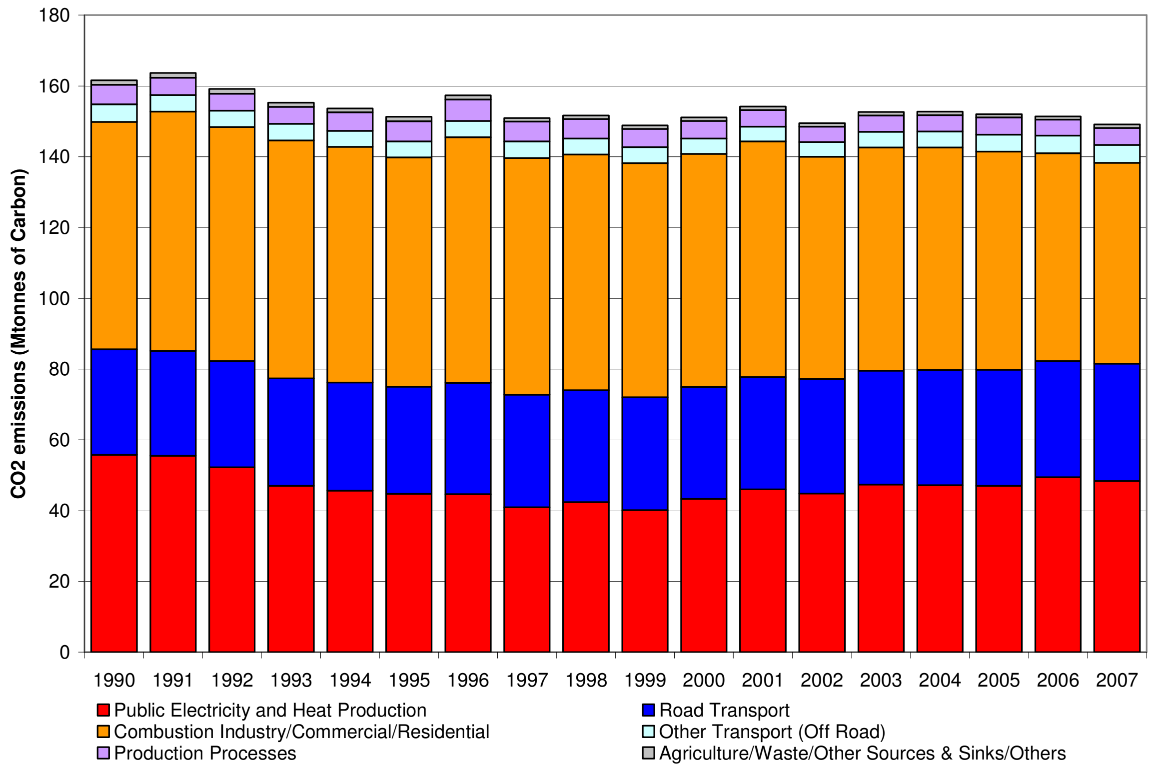
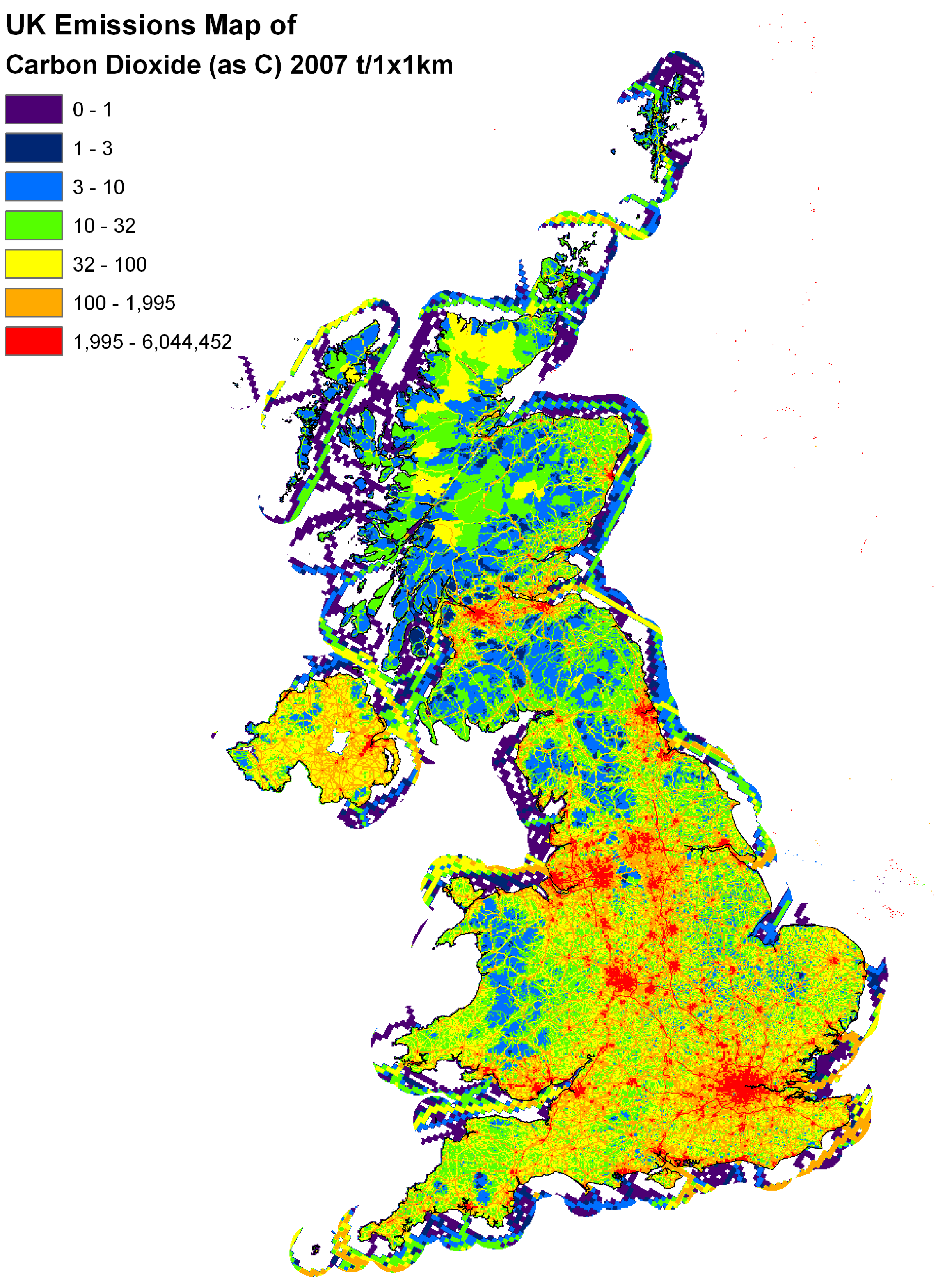


Figure 7.3 Spatially Disaggregated UK Emissions of CO_2 as Carbon Map



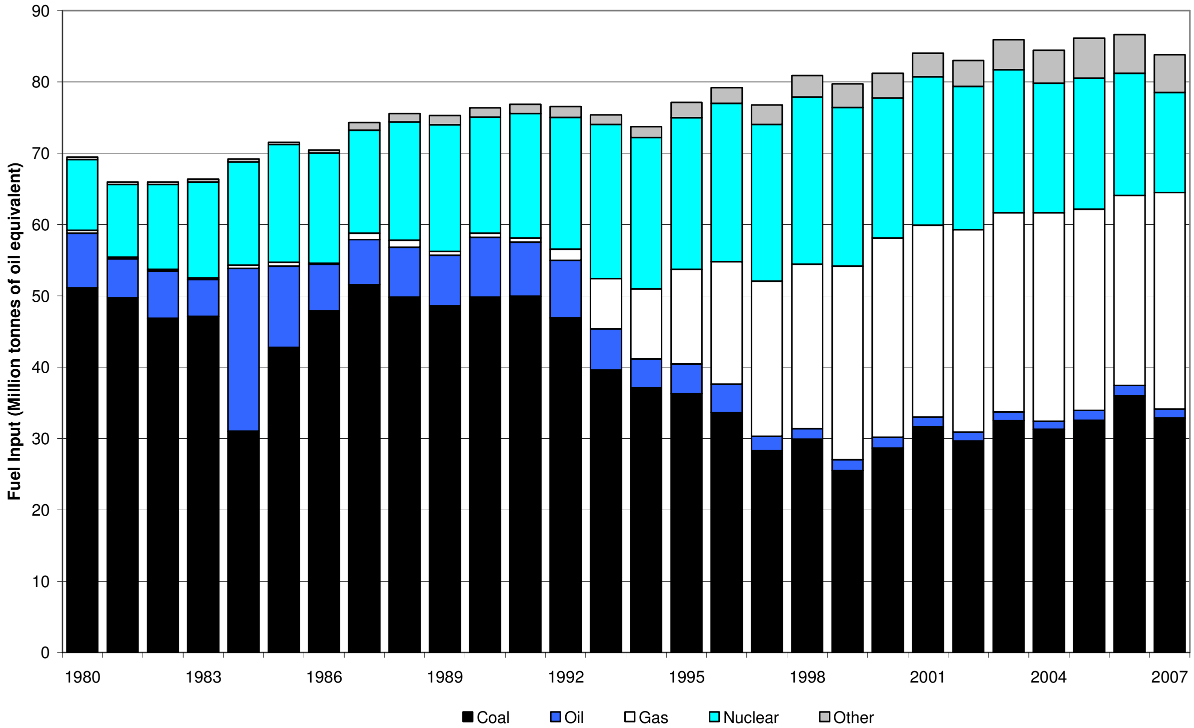
7.2.3 Electricity Supply Industry

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 2007, 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 150 and further increases may be expected as and when more CCGT stations come on line.

Table 7.3 UK Fuel Consumption, 1970-2007

Fuel	Consumer	Units	1970	1980	1990	2000	2003	2004	2005	2006	2007
Coal	Domestic	Mt	20	9	4	2	1	1	1	1	1
Coal	Industry	Mt	22	8	8	4	4	4	4	4	4
Coal	Major Power Producers	Mt	77	90	83	45	51	49	51	56	51
Coal	Others	Mt	13	5	3	1	1	0	0	0	0
Other Solid Fuels	All Consumers	Mt	17	6	4	2	1	1	1	1	1
Motor Spirit	Road Transport	Mt	0	0	0	0	0	0	0	0	0
Gas Oil	Industry	Mt	6	5	3	3	3	3	3	3	3
Gas Oil	Others	Mt	7	7	5	4	4	3	4	4	3
DERV	Road Transport	Mt	5	6	11	16	18	19	19	20	21
Fuel Oil	Industry	Mt	20	10	4	1	0	1	1	1	1
Fuel Oil	Major Power Producers	Mt	12	6	7	1	1	1	1	1	1
Fuel Oil	Others	Mt	5	2	1	0	0	0	0	1	1
Fuel Oil	Refineries	Mt	4	4	2	1	2	2	2	1	1
Orimulsion	Major Power Producers	Mt	0	0	0	0	0	0	0	0	0
Burning Oil	Domestic	Mt	1	1	2	2	2	2	2	2	2
Burning Oil	Others	Mt	4	0	0	1	1	2	2	2	1
Aviation Turbine Fuel	Air Transport	Mt	1	1	1	1	1	1	1	1	1
Other Petroleum Products	All Consumers	Mt	1	1	1	2	1	1	2	2	2
Petroleum Gases	Others	Mth	690	710	672	697	815	786	782	813	771
Petroleum Gases	Refineries	Mth	1011	987	1303	1308	1137	1264	1305	1142	1074
Natural Gas	Domestic	Mth	627	8420	10251	12622	13188	13526	13103	12449	11941
Natural Gas	Industry	Mth	718	6622	7015	10756	10295	9944	9624	9242	8791
Natural Gas	Major Power Producers	Mth	60	55	3	9683	9713	10390	10088	9490	10913
Natural Gas	Others	Mth	2206	2188	3019	4645	4402	4499	4362	4149	4006
Other Gases	All Consumers	Mth	7009	1126	1284	1082	902	878	899	925	929

Figure 7.4 Generating Mix (1980-2007) Million Tonnes Oil Equivalent (Mtoe).

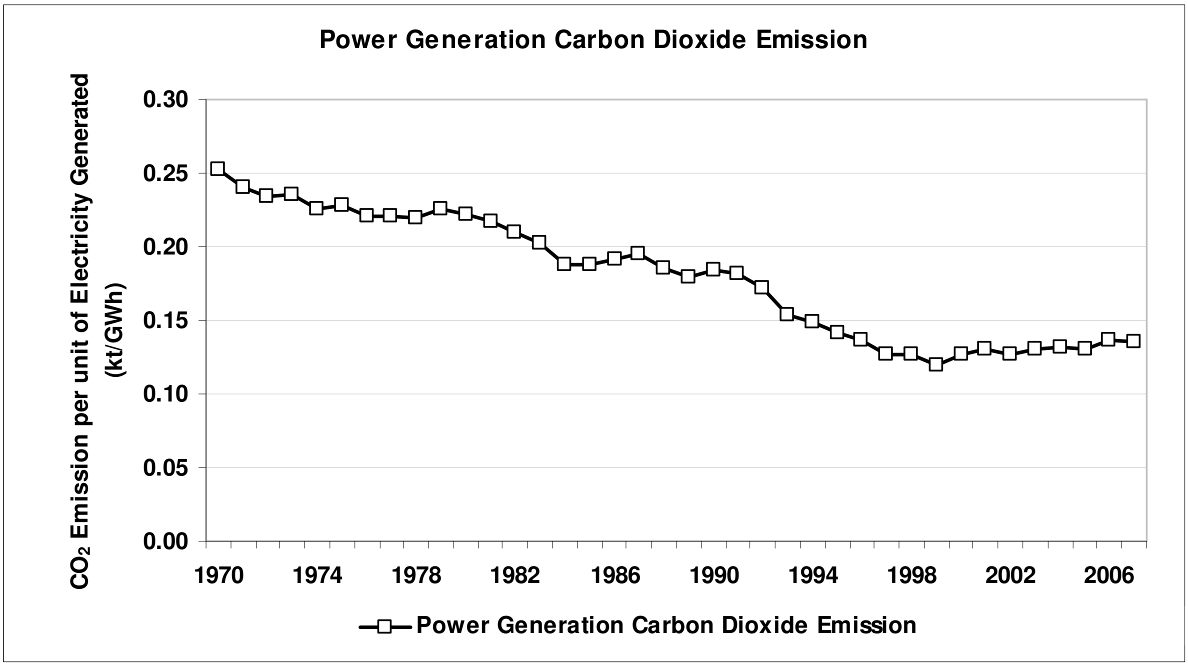


The effect of these changes in the power sector is clearly reflected in the carbon dioxide emissions. Since 1970 electricity generation has substantially increased but emissions have decreased by just under 18%. This is due specifically to:

- The greater efficiency of the CCGT stations compared with conventional coal fired stations - around 47% as opposed to 36%.
- The calorific value of natural gas (per unit mass of carbon) being higher than that of coal and oil (the inventory takes account of unrefined gas or sour gas used by some plant).
- and to a lesser extent, the proportion of nuclear generated electricity increasing to 20%.

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 135 tonnes/GWh in 2007. 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 7.5.

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 of 95% between 1970 and 2007. 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 2007 industrial emissions show a decrease of 53% 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 2007.

7.2.6 Transport

Total emissions from the transport sector have steadily increased since 1970. Of these, road transport emissions have risen by approximately 102% and currently account for 87% of the total transport/mobile machinery emissions in 2007. 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 2007. The increased use of private motor vehicles led to an increase in the consumption of petrol from 1970 to 2007. However, petrol consumption has declined by 28% 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 318% 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 (Choudrie *et al*, 2009) for the years 1990-2007. 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 (Thompson, 2008).

Table 7.4 Emissions & Removals of CO_2[1] (as CO_2) from Land Use Change & Forestry (2007)

Sources	**Net CO_2 emissions /removals (ktonnes)[1,2]**
A. Forest Land	-14173
B. Cropland	15288
C. Grassland	-7967
D. Wetlands	IE, NE, NO
E. Other [3]	5037
Total	**-1815**

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.
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

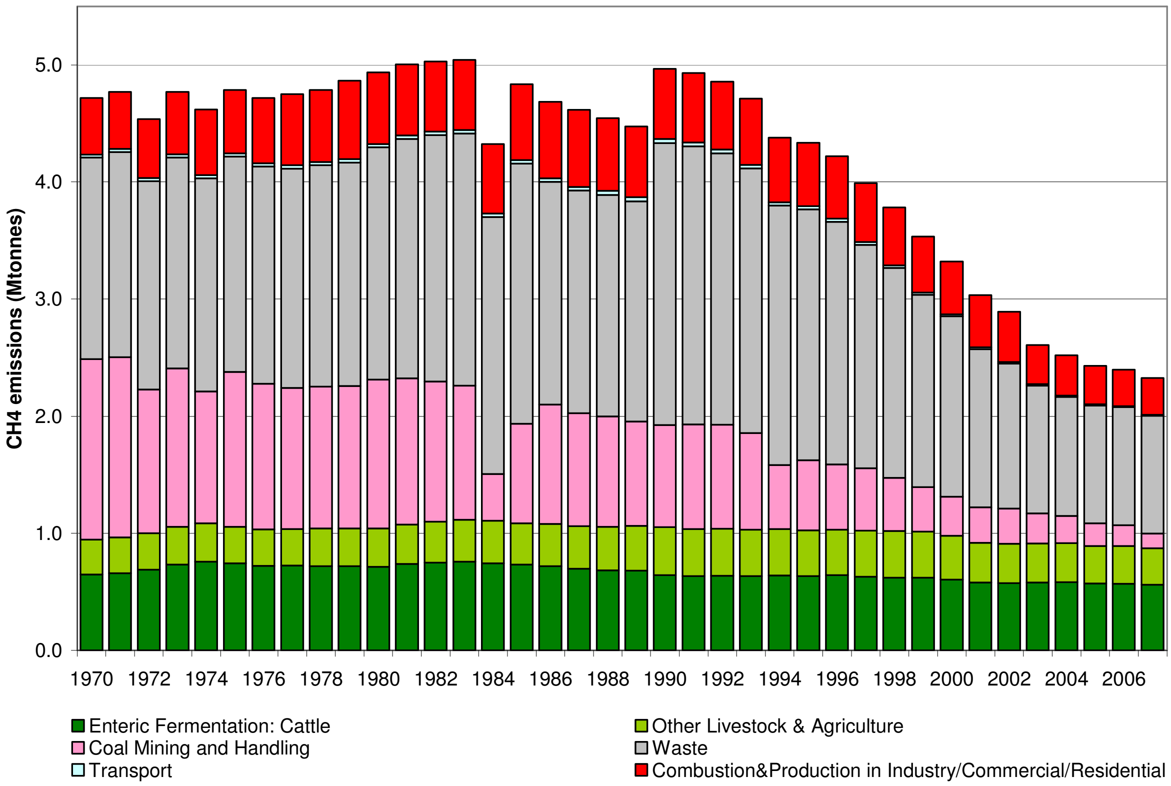
7.3.1 Key Source Description

The largest source of methane (CH_4) emissions in the UK arises from landfills. The agricultural sector where the emissions arise primarily from enteric fermentation in the guts of ruminant animals and from animal wastes 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 51%, 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 41% of the UK's methane emissions in 2007. 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 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 that 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

Methane emissions from the agriculture sector are dependent on the numbers and types of farm animals, with dairy cattle being the most significant source. The decline since 1984 results from a 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 emissions 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	2002	2003	2004	2005	2006	2007	2007 %
BY UN/ECE CATEGORY[2]											
Combustion Industry, Commercial & Residential	1A1, 1A2	366	165	98	54	53	52	49	48	50	2.1%
Road Transport	1A3b	25	28	33	12	11	9	8	8	7	0.3%
Other Transport (Rail, Aviation, Navigation)[3]	1A3ai(i)-1A3aii(i), 1A3c-1A3eii, 1A4bii, 1A4cii, 1A5b	1	1	1	1	1	1	1	1	1	0.0%
Coal Mining and Handling	1B1a	1540	1269	870	301	259	234	194	180	126	5.4%
Production Processes	1B1ab-2C	27	92	123	58	57	61	50	46	57	2.4%
Natural gas	1B2b	88	354	379	317	223	231	230	218	208	8.9%
Enteric Fermentation: Cattle	4A1	648	712	645	576	581	582	572	569	561	24.1%
Enteric Fermentation: Sheep	4A10	128	150	209	174	173	173	166	166	161	6.9%
Other Livestock & Agriculture	4A3-9, 4B	170	181	200	163	159	160	154	156	152	6.5%
Waste	6	1723	1984	2410	1236	1089	1017	1006	1006	1005	43.2%
By FUEL TYPE											
Solid		332	141	67	20	18	17	15	16	18	**0.8%**
Petroleum		35	36	39	16	15	13	12	11	11	**0.5%**
Gas		26	18	26	30	31	31	30	28	28	**1.2%**
Non-Fuel		4323	4741	4835	2826	2544	2459	2373	2342	2270	**97.6%**
TOTAL		**4716**	**4936**	**4967**	**2892**	**2607**	**2521**	**2431**	**2398**	**2326**	**100%**

[1] UK emissions reported in IPCC format (Choudrie *et al*, 2009) 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 2007 this had reduced to just 5%. 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. Historically emissions were estimated based on the throughput of gas and hence were 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.

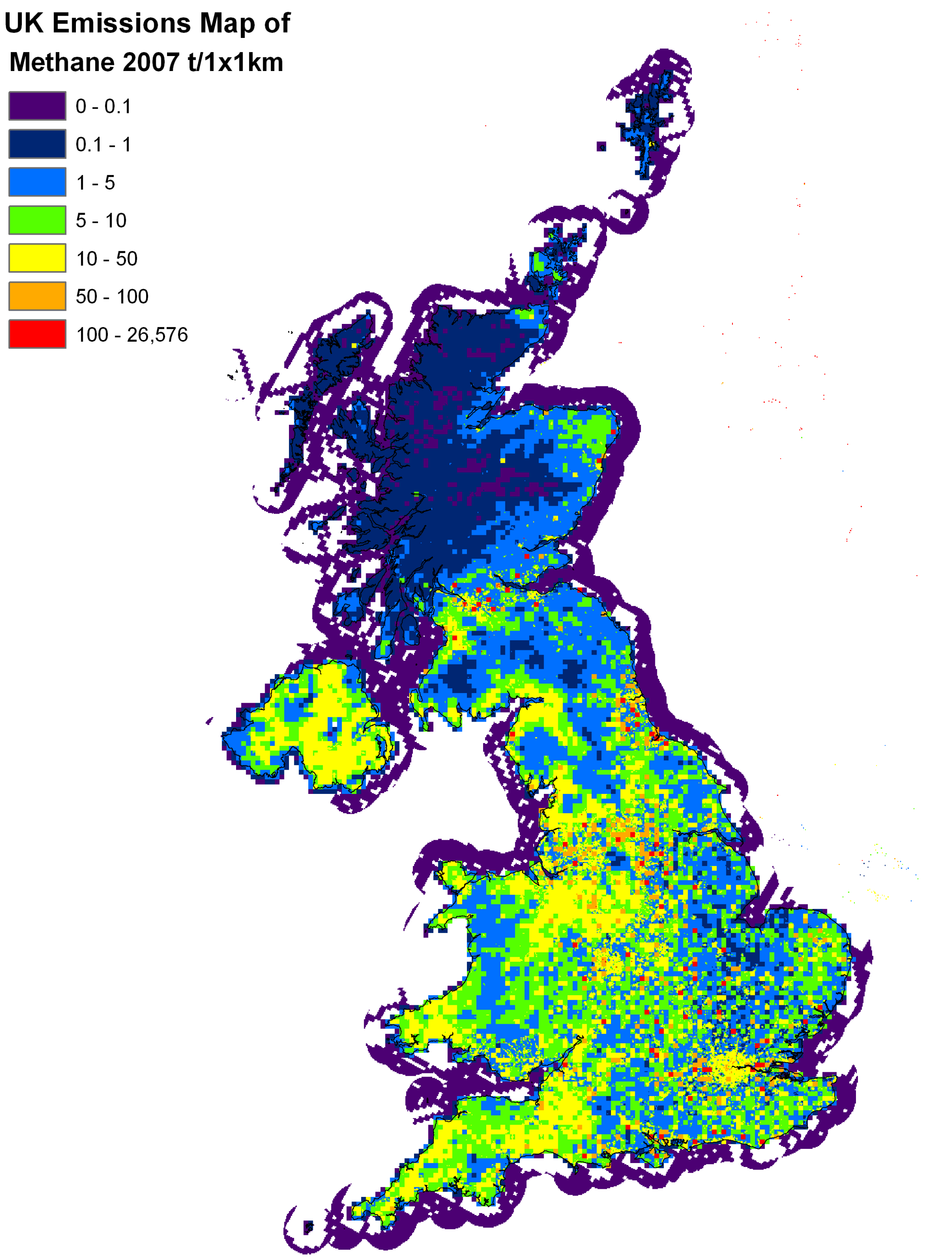
7.3.7 Offshore Oil and Gas

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 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 is 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).

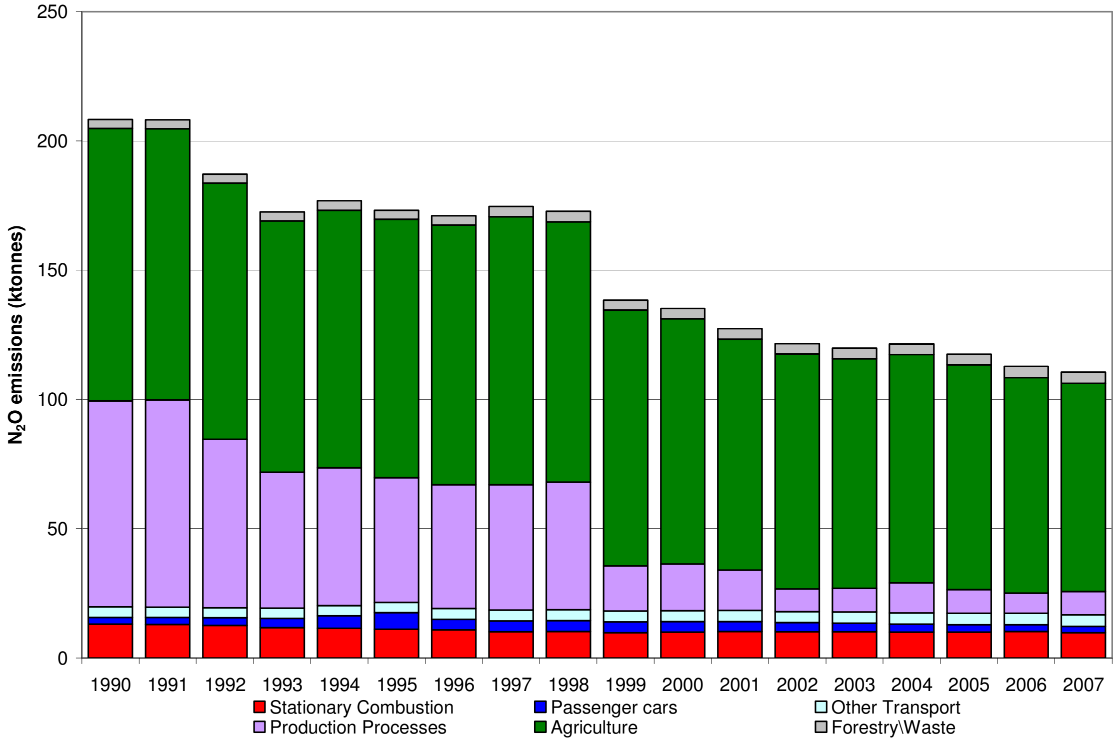
7.4.2 Total N_2O Emissions

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	2003	2004	2005	2006	2007	2007%
BY UN/ECE CATEGORY[2]											
Public Electricity and Heat Production	1A1a	5.2	5.8	5.4	3.1	3.5	3.4	3.5	3.9	3.6	3%
Stationary Combustion	1A1b-c, 1A2a	6.4	3.2	2.8	2.9	2.7	2.6	2.5	2.4	2.2	2%
Industrial off-road mobile machinery	1A2f	8.2	4.8	4.8	4.0	3.9	4.0	4.0	4.0	4.0	4%
Passenger cars	1A3bi	1.3	1.8	2.7	4.1	3.3	3.1	2.8	2.7	2.5	2%
Road Transport	1A3b	0.9	1.0	1.1	1.4	1.5	1.5	1.5	1.5	1.6	1%
Other Transport[(3)]	1A3ai(i)-1A3aii(i), 1A3c-1A3eii, 1A4bii, 1A4cii 1A5b	2.6	2.8	2.9	2.9	2.9	2.9	2.9	2.9	2.8	3%
Production Processes	1B, 2	14.3	16.1	79.7	18.1	9.2	11.7	9.2	7.8	9.0	8%
Direct Soil Emission	4D1	62.0	92.1	98.1	88.4	82.8	82.4	81.3	77.8	75.1	68%
Other Agriculture	4B, 4F, 4G	7.2	7.7	7.3	6.5	5.9	5.8	5.7	5.6	5.5	5%
Forestry\Waste	5, 6	3.9	3.9	3.5	4.0	4.1	4.1	4.1	4.2	4.2	4%
By Fuel Type											
Solid		15.2	9.64	7.92	4.03	4.22	4.04	4.10	4.40	4.10	3.7%
Petroleum		8.9	9.09	10.57	12.12	11.38	11.28	11.12	11.06	10.77	9.8%
Gas		0.5	0.70	1.21	2.02	1.98	1.93	1.86	1.69	1.61	1.5%
Non-Fuel		87.3	119.8	188.6	117.0	102.2	104.2	100.4	95.6	94.0	85.1%
TOTAL		111.9	139.3	208.3	135.2	119.8	121.4	117.5	112.7	110.5	100%

[1] UK emissions reported in IPCC format (Choudrie *et al*, 2009) 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 improved 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 68% 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 8% of the total nitrous oxide emissions in 2007. 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 2007 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 2007 the proportion of vehicle kilometres travelled by cars equipped with catalytic converters has increased from <1% to 99% of petrol cars (Figure 7.9) and therefore 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.

Figure 7.9 The Growth in the Number of Car Kilometres from Cars with Catalytic Converters

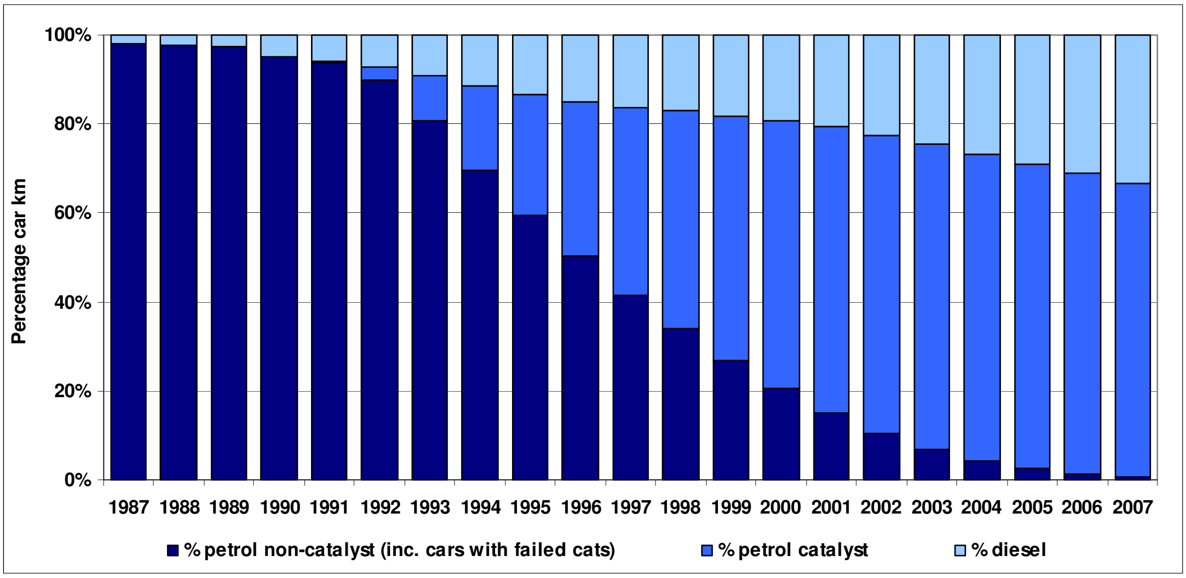
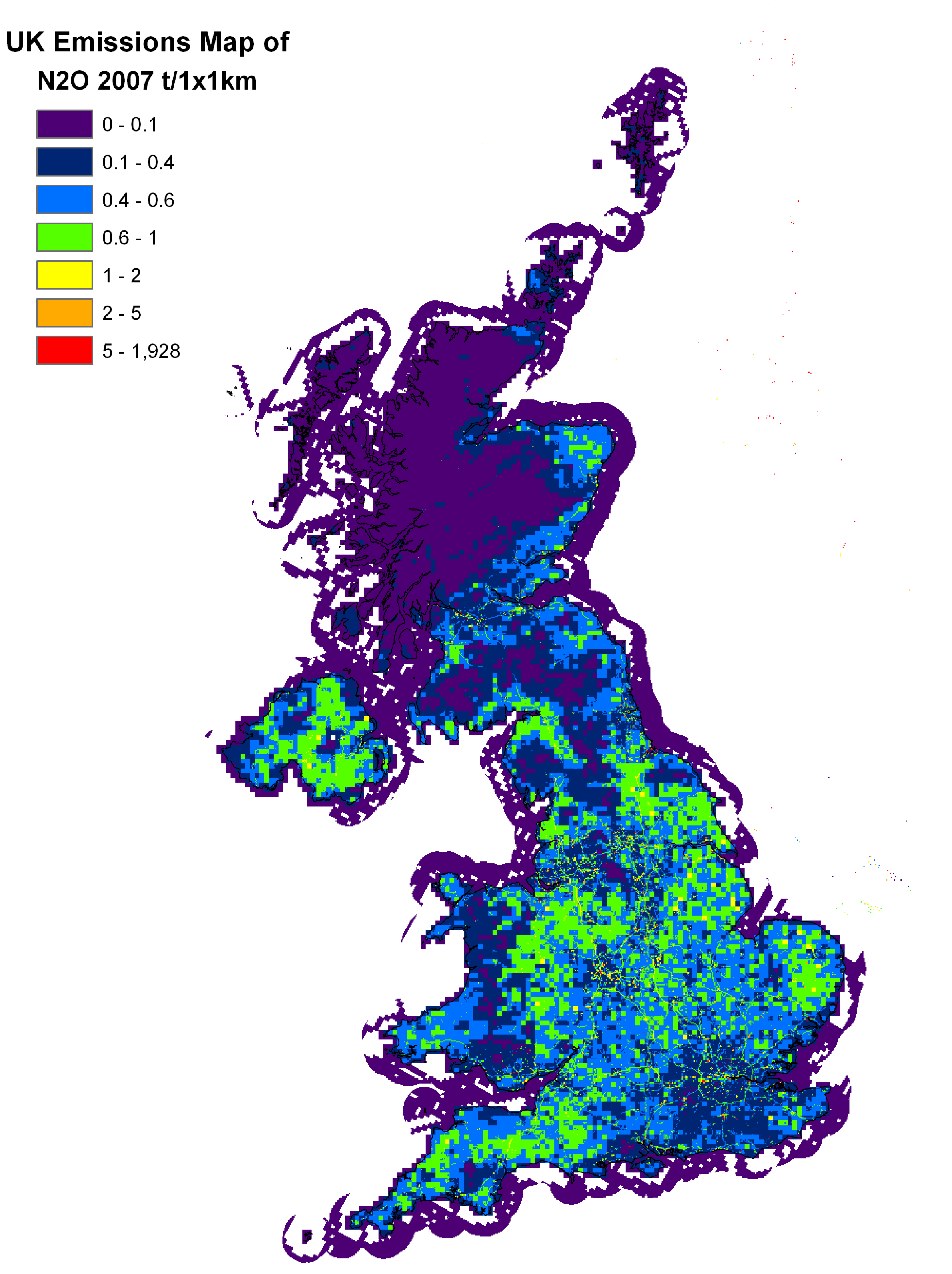


Figure 7.10 Spatially Disaggregated UK Emissions of N_2O Map



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. 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 (Choudrie *et al,* 2009) 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 50% of the total HFC emissions in 2007. Emissions arise due to leakage from refrigeration and air conditioning equipment during its lifetime, 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 2007, 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 20% of the total emission.

The total UK emission of HFC (in C equivalent) has decreased by 16% over 1990-2007 and is characterised by the increasing use of HFCs but offset by the large reduction in emissions from halocarbon production between 1998 and 2007.

Table 7.7 UK Emissions of HFCs (ktonnes C equivalent)

	NFR Codes	1990	2000	2001	2002	2003	2004	2005	2006	2007	2007 %
METAL PRODUCTION	2C	0	0	0	0	0	0	1	1	1	0.0%
Production Processes	2E1	3102	714	651	555	540	121	121	106	48	1.8%
Halocarbons use	2F	3	2003	2267	2452	2560	2595	2646	2608	2565	98.1%
Total		3105	2718	2918	3007	3100	2717	2767	2714	2614	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 2007, representing 41% 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 94% 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 33% of the UK total in 2007.

Table 7.8 UK Emissions of PFCs (ktonnes C equivalent)

	NFR Codes	**1990**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2007 %**
METAL PRODUCTION	2C	363	70	59	41	30	42	16	35	22	37.9%
Halocarbons production (by-product)	2E2	3	6	15	16	15	25	30	25	15	25.3%
Halocarbons use	2F	16	59	40	29	29	26	23	23	22	36.8%
Total		**382**	**136**	**115**	**86**	**74**	**92**	**70**	**82**	**59**	**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 directly. Emissions from this sector accounted for 64% of the UK total in 2007.

The other main sources are from uses as a cover gas from the magnesium sector (19% of UK total) and manufacture of trainers (15% of UK total). The use of SF_6 as a cushioning agent in trainers will be phased out in the near future. Emissions from 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 to date. It is expected that users will take great care over future fluid recovery, so that emissions will be minimised. SF_6 emissions have decreased by 23% since 1990.

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

	NFR Codes	1990	2000	2001	2002	2003	2004	2005	2006	2007	2007 %
METAL PRODUCTION	2C	116	298	206	231	183	106	69	49	40	18.7%
Halocarbons use	2F	165	192	182	181	178	202	233	189	176	81.3%
Total		**281**	**490**	**389**	**412**	**361**	**308**	**303**	**238**	**216**	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 2007 Inventory.

Table 7.10 Uncertainty of the Emission Inventories

Pollutant	**Estimated Uncertainty %**
Carbon Dioxide	+/- 2.0
Methane	+/- 22
Nitrous Oxide	+/- 231
HFCs	+/- 15
PFCs	+/- 6
SF_6	+/- 24

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 2007 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[10]
- The Isle of Man
- The Falkland Islands
- The Cayman Islands
- Bermuda
- Montserrat
- Akrotiri and Dhekhelia[11]
- Gibraltar

[10] The Bailiwick of Guernsey includes: Guernsey itself as well as Alderney, Sark and Herm.
[11] 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 2007 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 2007'[12].

[12] 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	2006	2007
1	Energy - Power stations and small combustion sources	0.92	0.89	1.19	1.06	1.34	1.12	1.09	0.99	1.07	0.96	0.63	0.52	0.47	0.33	0.40	0.32	0.32	0.45
	Energy - other mobile sources	0.18	0.16	0.15	0.14	0.15	0.16	0.16	0.16	0.17	0.19	0.24	0.23	0.22	0.22	0.21	0.22	0.20	0.21
	Energy - road transport	0.93	0.94	0.91	0.88	0.89	0.87	0.78	0.77	0.75	0.69	0.63	0.59	0.53	0.47	0.41	0.37	0.36	0.33
2	Industrial processes	0	0	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	0	0
4	Agriculture	0	0	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	0	0
6	Waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	**2.02**	**1.99**	**2.25**	**2.09**	**2.39**	**2.15**	**2.03**	**1.92**	**1.99**	**1.84**	**1.49**	**1.34**	**1.22**	**1.01**	**1.03**	**0.91**	**0.88**	**1.00**

Table A 1.2 Jersey CO emissions (ktonnes)

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1	Energy - Power stations and small combustion sources	1.09	1.09	0.66	0.93	0.77	0.76	0.79	0.65	0.65	0.56	0.52	0.48	0.39	0.35	0.36	0.33	0.29	0.26
	Energy - other mobile sources	6.85	5.31	4.95	5.00	6.90	7.37	7.46	8.31	8.38	10.47	12.93	15.01	12.12	9.13	9.14	11.03	8.01	6.92
	Energy - road transport	7.18	7.03	6.62	6.12	5.78	5.36	4.77	4.25	3.68	3.31	2.52	2.07	1.69	1.43	1.14	0.95	0.79	0.68
2	Industrial processes	0	0	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	0	0
4	Agriculture	0	0	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	0	0
6	Waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	**15.12**	**13.43**	**12.24**	**12.05**	**13.45**	**13.48**	**13.01**	**13.21**	**12.71**	**14.34**	**15.96**	**17.56**	**14.20**	**10.91**	**10.64**	**12.31**	**9.09**	**7.86**

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	2006	2007
1	Energy - Power stations and small combustion sources	3.56	3.23	4.22	3.92	4.49	3.77	3.95	2.78	3.16	2.71	1.43	0.83	0.65	0.30	0.37	0.25	0.26	0.36
	Energy - other mobile sources	0.01	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	Energy - road transport	0.05	0.04	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	0.00	0.00
2	Industrial processes	0	0	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	0	0
4	Agriculture	0	0	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	0	0
6	Waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	**3.62**	**3.28**	**4.28**	**3.98**	**4.56**	**3.83**	**4.00**	**2.83**	**3.20**	**2.74**	**1.46**	**0.86**	**0.67**	**0.32**	**0.39**	**0.27**	**0.29**	**0.38**

Table A 1.4 Jersey NMVOC emissions (ktonnes)

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1	Energy - Power stations and small combustion sources	0.01	0.01	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
	Energy - other mobile sources	0.21	0.18	0.15	0.16	0.16	0.16	0.15	0.17	0.15	0.18	0.21	0.24	0.19	0.15	0.15	0.18	0.13	0.12
	Energy - road transport	0.98	0.97	0.92	0.85	0.82	0.76	0.66	0.59	0.50	0.44	0.34	0.28	0.22	0.18	0.14	0.12	0.10	0.08
2	Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Solvent use	1.12	1.03	0.94	0.85	0.80	0.73	0.70	0.66	0.62	0.60	0.59	0.58	0.56	0.55	0.53	0.52	0.51	0.50
4	Agriculture	0	0	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	0	0
6	Waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	**2.32**	**2.19**	**2.02**	**1.87**	**1.79**	**1.66**	**1.53**	**1.43**	**1.28**	**1.23**	**1.14**	**1.10**	**0.98**	**0.89**	**0.83**	**0.82**	**0.74**	**0.71**

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	2006	2007
1	Energy - Power stations and small combustion sources	0.65	0.75	0.61	0.67	0.81	0.68	0.71	0.76	0.75	0.76	0.72	0.25	0.25	0.27	0.23	0.32	0.50	0.44
	Energy - road transport	0.79	0.82	0.77	0.77	0.73	0.74	0.69	0.73	0.66	0.68	0.63	0.60	0.46	0.43	0.37	0.38	0.46	0.43
	Energy - other mobile sources	0.00	0.03	0.07	0.07	0.09	0.10	0.12	0.13	0.13	0.16	0.21	0.22	0.19	0.18	0.18	0.17	0.16	0.16
2	Industrial processes	0	0	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	0	0
4	Agriculture	0	0	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	0	0
6	Waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	1.46	1.61	1.46	1.52	1.64	1.53	1.52	1.62	1.55	1.60	1.56	1.08	0.92	0.89	0.79	0.88	1.13	1.03

Table A 2.2 Guernsey CO emissions (ktonnes)

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1	Energy - Power stations and small combustion sources	0.09	0.11	0.10	0.10	0.10	0.10	0.11	0.10	0.12	0.13	0.13	0.05	0.05	0.06	0.05	0.06	0.09	0.06
	Energy - road transport	4.44	4.16	3.75	3.37	3.14	3.02	2.68	2.66	2.26	2.18	1.73	1.51	1.09	0.96	0.83	0.74	0.64	0.53
	Energy - other mobile sources	0.00	3.35	8.82	8.42	12.33	13.24	13.35	14.93	15.28	19.89	24.98	28.52	23.57	20.84	20.35	20.07	16.67	16.07
2	Industrial processes	0	0	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	0	0
4	Agriculture	0	0	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	0	0
6	Waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	**4.53**	**7.62**	**12.67**	**11.89**	**15.57**	**16.36**	**16.14**	**17.68**	**17.66**	**22.19**	**26.84**	**30.09**	**24.72**	**21.86**	**21.23**	**20.88**	**17.41**	**16.66**

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	2006	2007
1	Energy - Power stations and small combustion sources	2.63	2.81	2.20	2.55	2.76	2.33	2.60	2.36	2.52	2.30	2.00	0.43	0.37	0.36	0.25	0.34	0.59	0.42
	Energy - other mobile sources	0.00	0.00	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02
	Energy - road transport	0.05	0.05	0.05	0.05	0.05	0.04	0.03	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	Industrial processes	0	0	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	0	0
4	Agriculture	0	0	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	0	0
6	Waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	**2.68**	**2.87**	**2.26**	**2.61**	**2.83**	**2.39**	**2.65**	**2.41**	**2.56**	**2.33**	**2.03**	**0.46**	**0.39**	**0.39**	**0.28**	**0.37**	**0.62**	**0.45**

Table A 2.4 Guernsey NMVOC emissions (ktonnes)

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1	Energy - Power stations and small combustion sources	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Energy - other mobile sources	0.00	0.09	0.21	0.20	0.24	0.25	0.23	0.26	0.26	0.32	0.38	0.44	0.36	0.32	0.32	0.31	0.25	0.24
	Energy - road transport	0.67	0.64	0.58	0.52	0.48	0.46	0.40	0.39	0.33	0.31	0.25	0.22	0.16	0.13	0.11	0.10	0.09	0.07
2	Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Solvent use	0.48	0.45	0.42	0.38	0.37	0.36	0.35	0.35	0.33	0.32	0.33	0.32	0.32	0.31	0.31	0.31	0.31	0.31
4	Agriculture	0	0	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	0	0
6	Waste	0.03	0.03	0.04	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02
	Total	**1.19**	**1.23**	**1.25**	**1.14**	**1.14**	**1.10**	**1.03**	**1.04**	**0.96**	**1.00**	**0.99**	**1.00**	**0.85**	**0.78**	**0.76**	**0.75**	**0.68**	**0.65**

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	2006	2007
1	Energy - Power stations and small combustion sources	0.68	0.67	0.64	0.70	0.87	0.72	0.75	0.85	0.88	0.93	0.76	0.35	0.34	0.34	0.44	0.44	0.43	0.43
	Energy - other mobile sources	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.05	0.07	0.07	0.08	0.08	0.08	0.09	0.09	0.09
	Energy - road transport	0.68	0.69	0.67	0.63	0.58	0.61	0.93	0.86	0.90	0.84	0.73	0.78	0.80	0.84	0.82	0.77	0.73	0.68
2	Industrial processes	0	0	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	0	0
4	Agriculture	0	0	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	0	0
6	Waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	**1.39**	**1.39**	**1.34**	**1.35**	**1.49**	**1.37**	**1.72**	**1.75**	**1.82**	**1.81**	**1.56**	**1.20**	**1.22**	**1.25**	**1.34**	**1.31**	**1.25**	**1.20**

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	2006	2007
1	Energy - Power stations and small combustion sources	0.10	0.10	0.10	0.11	0.11	0.11	0.12	0.11	0.15	0.17	0.15	0.10	0.11	0.11	0.11	0.11	0.11	0.10
	Energy - other mobile sources	0.47	0.61	0.47	0.61	0.40	0.70	2.23	2.88	3.30	2.05	0.43	0.11	0.13	0.24	4.30	4.84	6.50	0.06
	Energy - road transport	4.51	4.39	4.21	3.68	3.30	3.09	4.32	3.40	3.18	2.74	1.54	1.74	1.58	1.42	1.25	1.07	0.82	0.73
2	Industrial processes	0	0	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	0	0
4	Agriculture	0	0	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	0	0
6	Waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	**5.07**	**5.10**	**4.79**	**4.40**	**3.81**	**3.91**	**6.67**	**6.39**	**6.63**	**4.96**	**2.12**	**1.94**	**1.82**	**1.77**	**5.66**	**6.02**	**7.44**	**0.89**

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	2006	2007
1	Energy - Power stations and small combustion sources	2.91	2.68	2.36	2.69	3.02	2.53	2.84	2.65	2.95	2.87	2.05	0.54	0.43	0.42	0.35	0.39	0.38	0.35
	Energy - other mobile sources	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01
	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	0.00	0.00
2	Industrial processes	0	0	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	0	0
4	Agriculture	0	0	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	0	0
6	Waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	**2.96**	**2.72**	**2.41**	**2.73**	**3.06**	**2.56**	**2.89**	**2.69**	**2.98**	**2.89**	**2.06**	**0.55**	**0.44**	**0.43**	**0.36**	**0.40**	**0.40**	**0.35**

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	2006	2007
1	Energy - Power stations and small combustion sources	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
	Energy - other mobile sources	0.04	0.04	0.02	0.03	0.02	0.03	0.06	0.07	0.09	0.06	0.02	0.02	0.02	0.02	0.08	0.09	0.11	0.01
	Energy - road transport	0.62	0.62	0.59	0.52	0.46	0.44	0.61	0.49	0.45	0.39	0.23	0.26	0.23	0.21	0.18	0.16	0.13	0.12
2	Industrial processes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Solvent use	0.44	0.42	0.40	0.38	0.36	0.35	0.34	0.35	0.34	0.35	0.36	0.37	0.37	0.38	0.38	0.39	0.40	0.41
4	Agriculture	0	0	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	0	0
6	Waste	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00
	Total	**1.13**	**1.11**	**1.05**	**0.96**	**0.87**	**0.84**	**1.04**	**0.93**	**0.91**	**0.82**	**0.64**	**0.66**	**0.65**	**0.63**	**0.66**	**0.65**	**0.65**	**0.55**

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Annex 1

Definitions of UN/ECE Source Sectors

CONTENTS

1. UN/ECE Classification of Emission Sources
Table A1 Mapping of NAEI Base Categories to NFR

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 in day to day contact 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), (BERR, 2008). 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
1A3ai(i)	1 A 3 a i Civil Aviation (International, LTO)
1A3aii(i)	1 A 3 a ii Civil Aviation (Domestic, LTO)
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(ii)	International Aviation (Cruise)
1A3aii(ii)	Domestic 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
1A3ai(i)	1 A 3 a i Civil Aviation (International, LTO)	Aircraft – international take off & landing
1A3ai(i)	1 A 3 a i Civil Aviation (International, LTO)	Aircraft engines
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
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
1A3bi	1 A 3 b i R.T., Passenger cars	Road Transport - cars Dioxins/PCP

NFR Code	NFR Name	Source Name
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
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

NFR Code	NFR Name	Source Name
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
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

NFR Code	NFR Name	Source Name
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
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

NFR Code	NFR Name	Source Name
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
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

NFR Code	NFR Name	Source Name
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
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

NFR Code	NFR Name	Source Name
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
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

NFR Code	NFR Name	Source Name
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_1A3aii(ii)	Domestic Aviation- Cruise (Memo)	Aircraft – domestic cruise
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
z_5E	Other (Memo)	Road transport - resuspension
z_5E	Other (Memo)	Wild birds wastes
z_5E	Other (Memo)	Wild other animal wastes