

# UK Greenhouse Gas Inventory, 1990 to 2004

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**Annual Report for submission under the Framework  
Convention on Climate Change**

## ***Issue 2***

**Main authors**

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**With contributions  
from**

Adams M, Dore C, Goodwin J, Li Y, Manning A, Murrells T,  
Wagner A, Walker C

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*August 2006*

*This work forms part of the Global Atmosphere Research Programme of the Department  
for Environment, Food and Rural Affairs.*

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### *Issue 2*

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*August 2006*

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## Preface

This is the second edition of the United Kingdom's National Inventory Report (NIR) submitted in 2006 to the United Nations Framework Convention on Climate Change (UNFCCC). It contains national greenhouse gas emission estimates for the period 1990-2004, and the descriptions of the methods used to produce the estimates. The report is compiled in accordance with the Inventory Reporting Guidelines agreed by the UNFCCC Conference of Parties at its eighth session (COP8), and set out in document FCCC/CP/2002/8. A Compact Disk on the inside of the back flap of this report contains tabular data in the Common Reporting Format (CRF) covering the United Kingdom's greenhouse gas emissions for the same period.

This second edition of the NIR supercedes the first edition, published in April 2006, and provides updated data to take account of:

- the decision of Gibraltar to join the UK's instrument of ratification of the Kyoto Protocol;
- revised estimates of methane emissions from landfill, which adopt a factor of 0.1 for the proportion of methane oxidised in the cap covering the landfill. This is in response to a reassessment by the UK of the evidence on landfill emissions following the UNFCCC review of the inventory conducted in 2005. This increases the UK methane estimate in 1990 by about 12% and applies throughout the time series so the trend in emissions is not much affected.

The estimates for other source categories in the inventory remain unchanged. However, some of the emissions in the CRF, that were originally reported in Sector 7, have been reallocated to Sectors 1 to 6. This improves the transparency of the reporting, and ensures that all emissions are reported in one of the categories specified in Annex A of the Kyoto Protocol, and can therefore be included in the UK's Assigned Amount. .. Further details of these changes are documented in **Chapter 9**.

The greenhouse gas inventory (GHGI) is based on the same data sets used by the UK in the National Atmospheric Emissions Inventory (NAEI) for reporting atmospheric emissions under other international agreements. The GHGI is therefore consistent with the NAEI where they overlap.

This inventory is compiled on behalf of the UK Department for Environment, Food & Rural Affairs (Defra) Global Atmosphere Division, by the National Environmental Technology Centre (NETCEN). We acknowledge the positive support and advice from Defra throughout the work, and we are grateful for the help of all those who have contributed to this NIR. A list of the contributors can be found in **Chapter 12**.

The GHGI is compiled according to IPCC 1996 Revised Guidelines and Good Practice Guidance (IPCC, 1997; 2000 and 2003). Each year the inventory is updated to include the latest data available. Improvements to the methodology are backdated as necessary to ensure a consistent time series. Methodological changes are made to take account of new data sources, or new guidance from IPCC, relevant work by CORINAIR, and new research, sponsored by Defra or otherwise.



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## Units and Conversions

Emissions of greenhouse gases presented in this report are given in Gigagrammes (Gg), Million tonnes (Mt) and Teragrammes (Tg). GWP weighted emissions are also provided. To convert between the units of emissions, use the conversion factors given below.

### Prefixes and multiplication factors

Multiplication factor	Abbreviation	Prefix	Symbol
1,000,000,000,000,000	$10^{15}$	peta	P
1,000,000,000,000	$10^{12}$	tera	T
1,000,000,000	$10^9$	giga	G
1,000,000	$10^6$	mega	M
1,000	$10^3$	kilo	k
100	$10^2$	hecto	h
10	$10^1$	deca	da
0.1	$10^{-1}$	deci	d
0.01	$10^{-2}$	centi	c
0.001	$10^{-3}$	milli	m
0.000,001	$10^{-6}$	micro	$\mu$

1 kilotonne (kt) =  $10^3$  tonnes = 1,000 tonnes  
1 Mega tonne (Mt) =  $10^6$  tonnes = 1,000,000 tonnes

1 Gigagramme (Gg) = 1 kt  
1 Teragramme (Tg) = 1 Mt

### Conversion of carbon emitted to carbon dioxide emitted

To convert emissions expressed in weight of carbon, to emissions in weight of carbon dioxide, multiply by 44/12.

### Conversion of Gg of greenhouse gas emitted into Gg CO<sub>2</sub> equivalent

Gg (of GHG) \* GWP = Gg CO<sub>2</sub> equivalent

The GWP is the Global Warming Potential of the greenhouse gas. The GWPs of the greenhouse gases are given in **Table 1.1** of **Chapter 1**.

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## Abbreviations for Greenhouse Gases and Chemical Compounds

Type of greenhouse gas	Formula or abbreviation	Name
Direct	CH <sub>4</sub>	Methane
Direct	CO <sub>2</sub>	Carbon dioxide
Direct	N <sub>2</sub> O	Nitrous oxide
Direct	HFCs	Hydrofluorocarbons
Direct	PFCs	Perfluorocarbons
Direct	SF <sub>6</sub>	Sulphur hexafluoride
Indirect	CO	Carbon monoxide
Indirect	NMVOC	Non-methane volatile organic compound
Indirect	NO <sub>x</sub>	Nitrogen oxides (reported as nitrogen dioxide)
Indirect	SO <sub>2</sub>	Sulphur oxides (reported as sulphur dioxide)

HFCs, PFCs and SF<sub>6</sub> are collectively known as the ‘F-gases’



## ES.1

The UK ratified the United Nations Framework Convention on Climate Change (UNFCCC) in December 1993, and the Convention came into force in March 1994. Parties to the Convention are committed to develop, publish and regularly update national emission inventories of greenhouse gases (GHGs).

This is the second edition of the UK's National Inventory Report (NIR) submitted in 2006. It contains GHG gas emissions estimates for the period 1990 to 2004, and describes the methodology on which the estimates are based. This report and the attached Common Reporting Format (CRF) have been compiled in accordance with UNFCCC reporting guidelines on annual inventories contained in document FCCC/CP/2002/8 and Decision 18/CP.8 of the Conference of Parties.

The UK's GHG inventory is compiled under contract to the UK Department for the Environment, Food and Rural Affairs (Defra) by the National Environmental Technology Centre (NETCEN) of AEA Technology. NETCEN also compiles the UK's National Atmospheric Emissions Inventory, used for reporting emissions to other international agreements. Most of the underlying information is held on common databases and this helps ensure consistency between the inventories. Emissions from the agricultural sector (Sector 4) are provided by Defra's Sustainable Agriculture Strategy on the basis of a contract with the Institute of Grassland and Environmental Research (IGER), and estimates for Land-Use, Land Use Change and Forestry (LULUCF) (Sector 5) are produced on behalf of Defra by the Centre for Ecology and Hydrology (CEH). Defra also funds research contracts to provide improved emissions estimates for certain sources such as fluorinated gases, landfill methane, and to provide estimates for sources such as methane emissions from closed coal mines, which first appeared in the 2005 NIR.

The inventory covers the six direct greenhouse gases under the Kyoto Protocol. These are:

- Carbon dioxide
- Methane
- Nitrous oxide
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulphur hexafluoride (SF<sub>6</sub>)

These gases contribute directly to climate change owing to their positive radiative forcing effect. Also reported are four indirect greenhouse gases:

- Nitrogen oxides (reported as NO<sub>2</sub>)
- Carbon monoxide
- Non-Methane Volatile Organic Compounds (NMVOC)
- Sulphur oxides (reported as SO<sub>2</sub>)

**Chapter 1** of the report provides an introduction and background information on greenhouse gas inventories. **Chapter 2** provides a summary of the emission trends for aggregated

greenhouse gas emissions by source and gas. **Chapters 3 to 9** discuss each of the main source categories in detail and **Chapter 10** presents information on recalculations, improvements and a summary of responses to review processes. There are also **Annexes** to provide key source analysis and other detailed information as set out in the Guidelines. Unless otherwise specified percentage contributions and changes quoted refer to net emissions (i.e. emissions minus removals).

The inventory provides data to assess progress with the UK's commitments under the Kyoto Protocol, and also progress towards the domestic goal to reduce CO<sub>2</sub> emissions by 20% below 1990 level by 2010. Geographical coverage<sup>1</sup> of these two targets differs to some extent, because:

1. The 20% goal is for CO<sub>2</sub> has the historical coverage of the UK inventory (the UK and the Crown Dependencies of Jersey, Guernsey and the Isle of Man);
2. The Kyoto commitment extends coverage also to Overseas Territories that have ratified the Kyoto Protocol or seem likely to do so (the Cayman Islands, the Falkland Islands, Bermuda, Monserrat and Gibraltar), and to non-CO<sub>2</sub> greenhouse gas emissions from the Crown Dependencies.

Coverage 1 has been used for all UK inventory submissions in the past. Coverage 2 is used for the data in the present CRF tables because of the emerging needs of reporting under the Kyoto Protocol. **Tables ES1 to ES3** show CO<sub>2</sub> and the direct greenhouse gases, disaggregated by gas and by sector for geographical coverage 1 and 2. Comparison between the Tables shows that the difference in total emissions and trends between geographical coverage 1 and 2 is small.

**Table ES4** has data on indirect greenhouse gas emissions, for geographical coverage 1. **Table ES5** shows the Kyoto basket of gases and LULUCF activities and for geographical coverage 2<sup>2</sup>. **Table ES6** shows total CO<sub>2</sub> emissions by sources minus removals by sinks for geographical coverage 1, which is the time series used relevant to the UK's 20% domestic goal to reduce CO<sub>2</sub> by 20% below the 1990 level by 2010.

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<sup>1</sup> The geographical coverage of the UK GHG inventory is explained in Section 1.9 with further details given in Chapter 9.

<sup>2</sup> LULUCF data are not yet available for the OTs, though the estimates are likely to be small.

## ES.1

**Table ES1a** Emissions of GHGs in terms of carbon dioxide equivalent emissions including all estimated GHG emissions from the Crown Dependencies and relevant Overseas Territories, 1990-2004

Table ES 1	Mt CO2 equivalent															% change
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	1990-2004
CO <sub>2</sub> (Emissions including LUCF emissions)	607.5	614.6	598.0	583.4	575.8	566.3	587.9	565.0	566.7	557.5	563.0	578.2	561.9	573.7	576.7	-5.1%
CH <sub>4</sub>	103.7	102.8	101.3	98.2	91.2	90.3	87.8	83.0	78.3	73.1	68.5	62.7	59.7	53.6	51.8	-50.0%
N <sub>2</sub> O	68.4	66.3	59.5	55.7	58.7	57.1	58.9	60.6	57.7	44.5	44.3	42.1	40.5	40.1	40.8	-40.3%
HFCs	11.4	11.9	12.3	13.0	14.0	15.5	16.7	19.2	17.3	10.8	9.1	9.7	9.9	10.2	8.9	-22.0%
PFCs	1.4	1.2	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.3	0.3	0.4	-74.9%
SF <sub>6</sub>	1.0	1.1	1.1	1.2	1.2	1.2	1.3	1.2	1.3	1.4	1.8	1.4	1.5	1.3	1.1	9.5%
Total (Emissions)	793.4	797.8	772.8	751.9	741.3	730.9	753.1	729.4	721.7	687.7	687.2	694.6	673.8	679.3	679.7	-14.3%
CO <sub>2</sub> (Removals)	-14.3	-14.6	-14.9	-15.2	-15.5	-15.5	-15.4	-15.4	-15.4	-15.4	-15.4	-15.4	-15.6	-16.0	-16.3	14.2%
CO <sub>2</sub> (Net Emissions)	593.23475	600.0	583.1	568.2	560.3	550.9	572.6	549.6	551.4	542.1	547.6	562.8	546.2	557.8	560.4	-5.5%
Total (Net Emissions)	779.1	783.3	757.9	736.7	725.9	715.4	737.8	714.0	706.3	672.2	671.8	679.1	658.1	663.3	663.407	-14.8%
CO <sub>2</sub> (Emission excluding LUCF)	590.3	597.3	580.8	567.1	559.4	549.8	571.7	549.1	551.4	542.3	548.0	563.4	547.3	558.9	562.4	
Total (Emissions excluding LUCF)	776.1	780.5	755.6	735.6	725.0	714.3	736.8	713.4	706.3	672.5	672.2	679.7	659.2	664.5	665.3	
CO <sub>2</sub> emissions from LUCF	17.2	17.4	17.2	16.3	16.4	16.5	16.3	15.9	15.4	15.2	15.0	14.8	14.5	14.8	14.4	
CO <sub>2</sub> removals from LUCF	-14.3	-14.6	-14.9	-15.2	-15.5	-15.5	-15.4	-15.4	-15.4	-15.4	-15.4	-15.4	-15.6	-16.0	-16.3	
CH <sub>4</sub> emissions from LUCF	0.014	0.013	0.013	0.010	0.011	0.012	0.014	0.014	0.015	0.018	0.019	0.023	0.019	0.018	0.017	
N <sub>2</sub> O emissions from LUCF	0.0014	0.0013	0.0013	0.0010	0.0011	0.0012	0.0014	0.0015	0.0015	0.0018	0.0020	0.0024	0.0020	0.0019	0.0017	

1. One Mt equals one Tg, which is 10<sup>12</sup> g (1,000,000,000,000 g) or one million tonnes
2. Net Emissions are reported in the Common Reporting Format
3. Geographical coverage of this table includes the Crown Dependencies Jersey, Guernsey and the Isle of Man, and the Overseas Territories which have joined, or are likely to join, the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol. These are the Cayman Islands, Falkland Islands, Bermuda, Montserrat and Gibraltar.

**Table ES1b** Emissions of GHGs in terms of carbon dioxide equivalent emissions including all estimated GHG emissions from the Crown Dependencies and excluding all estimated GHG emissions from relevant Overseas Territories, 1990-2004

<b>Table ES1b</b>	<b>Mt CO<sub>2</sub> equivalent</b>															<b>% change</b>
	<b>1990</b>	<b>1991</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>1990-2004</b>
CO <sub>2</sub> (Emissions including LUCF emissions)	606.4	613.5	596.8	582.2	574.6	565.2	586.8	563.8	565.5	556.2	561.7	576.9	560.6	572.4	575.4	-5.1%
CH <sub>4</sub>	103.4	102.7	101.1	98.1	91.0	90.1	87.7	82.8	78.2	72.9	68.4	62.6	59.6	53.5	51.7	-50.0%
N <sub>2</sub> O	68.3	66.3	59.5	55.6	58.6	57.0	58.8	60.5	57.6	44.4	44.2	42.1	40.4	40.1	40.7	-40.4%
HFCs	11.4	11.9	12.3	13.0	14.0	15.5	16.7	19.2	17.3	10.8	9.1	9.7	9.9	10.2	8.9	-22.1%
PFCs	1.4	1.2	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.3	0.3	0.4	-74.9%
SF <sub>6</sub>	1.0	1.1	1.1	1.2	1.2	1.2	1.3	1.2	1.3	1.4	1.8	1.4	1.5	1.3	1.1	9.5%
Total (Emissions)	792.0	796.5	771.4	750.6	740.0	729.5	751.8	728.0	720.3	686.2	685.7	693.1	672.3	677.8	678.2	-14.4%
CO <sub>2</sub> (Removals)	-14.3	-14.6	-14.9	-15.2	-15.5	-15.5	-15.4	-15.4	-15.4	-15.4	-15.4	-15.4	-15.6	-16.0	-16.3	14.2%
CO <sub>2</sub> (Net Emissions)	592.1	598.9	581.9	567.0	559.1	549.7	571.4	548.4	550.2	540.8	546.3	561.5	544.9	556.4	559.1	-5.6%
Total (Net Emissions)	777.7	781.9	756.5	735.4	724.5	714.0	736.4	712.6	704.9	670.8	670.3	677.6	656.6	661.8	661.9	-14.9%
CO <sub>2</sub> (Emission excluding LUCF)	589.2	596.1	579.6	565.9	558.3	548.6	570.5	547.9	550.2	541.0	546.8	562.1	546.0	557.6	561.0	
Total (Emissions excluding LUCF)	774.8	779.1	754.2	734.3	723.6	712.9	735.5	712.0	704.9	671.0	670.7	678.2	657.7	663.0	663.8	
CO <sub>2</sub> emissions from LUCF	17.2	17.4	17.2	16.3	16.4	16.5	16.3	15.9	15.4	15.2	15.0	14.8	14.5	14.8	14.4	
CO <sub>2</sub> removals from LUCF	-14.3	-14.6	-14.9	-15.2	-15.5	-15.5	-15.4	-15.4	-15.4	-15.4	-15.4	-15.4	-15.6	-16.0	-16.3	
CH <sub>4</sub> emissions from LUCF	0.014	0.013	0.013	0.010	0.011	0.012	0.014	0.014	0.015	0.018	0.019	0.023	0.019	0.018	0.017	
N <sub>2</sub> O emissions from LUCF	0.0014	0.0013	0.0013	0.0010	0.0011	0.0012	0.0014	0.0015	0.0015	0.0018	0.0020	0.0024	0.0020	0.0019	0.0017	

1. One Mt equals one Tg, which is 10<sup>12</sup> g (1,000,000,000,000 g) or one million tonnes
2. Net Emissions are reported in the Common Reporting Format

## ES2

**Table ES2a** Emissions of GHGs in terms of carbon equivalent emissions including all estimated GHG emissions from the Crown Dependencies and relevant Overseas Territories, 1990-2004

Table ES 2	Mt C equivalent															% change
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	1990-2004
CO <sub>2</sub> (Emissions including LUCF emissions)	165.7	167.6	163.1	159.1	157.0	154.5	160.3	154.1	154.6	152.0	153.5	157.7	153.2	156.5	157.3	-5.1%
CH <sub>4</sub>	28.3	28.0	27.6	26.8	24.9	24.6	24.0	22.6	21.4	19.9	18.7	17.1	16.3	14.6	14.1	-50.0%
N <sub>2</sub> O	18.6	18.1	16.2	15.2	16.0	15.6	16.1	16.5	15.7	12.1	12.1	11.5	11.0	10.9	11.1	-40.3%
HFCs	3.1	3.2	3.4	3.5	3.8	4.2	4.6	5.2	4.7	3.0	2.5	2.6	2.7	2.8	2.4	-22.0%
PFCs	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	-74.9%
SF <sub>6</sub>	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.5	0.4	0.4	0.4	0.3	9.5%
Total (Emissions)	216.4	217.6	210.8	205.1	202.2	199.3	205.4	198.9	196.8	187.5	187.4	189.4	183.8	185.3	185.4	-14.3%
CO <sub>2</sub> (Removals)	-3.9	-4.0	-4.1	-4.1	-4.2	-4.2	-4.2	-4.2	-4.2	-4.2	-4.2	-4.2	-4.3	-4.4	-4.5	14.2%
CO <sub>2</sub> (Net Emissions)	161.8	163.6	159.0	155.0	152.8	150.2	156.2	149.9	150.4	147.8	149.3	153.5	149.0	152.1	152.8	-5.5%
Total (Net Emissions)	212.5	213.6	206.7	200.9	198.0	195.1	201.2	194.7	192.6	183.3	183.2	185.2	179.5	180.9	180.9	-14.8%
CO <sub>2</sub> (Emission excluding LUCF)	161.0	162.9	158.4	154.7	152.6	150.0	155.9	149.7	150.4	147.9	149.5	153.6	149.3	152.4	153.4	
Total (Emissions excluding LUCF)	211.7	212.9	206.1	200.6	197.7	194.8	201.0	194.6	192.6	183.4	183.3	185.4	179.8	181.2	181.5	
CO <sub>2</sub> emissions from LUCF	4.7	4.7	4.7	4.4	4.5	4.5	4.4	4.3	4.2	4.1	4.1	4.0	4.0	4.0	3.9	
CO <sub>2</sub> removals from LUCF	-3.9	-4.0	-4.1	-4.1	-4.2	-4.2	-4.2	-4.2	-4.2	-4.2	-4.2	-4.2	-4.3	-4.4	-4.5	
CH <sub>4</sub> emissions from LUCF	0.004	0.003	0.004	0.003	0.003	0.003	0.004	0.004	0.004	0.005	0.005	0.006	0.005	0.005	0.005	
N <sub>2</sub> O emissions from LUCF	0.0004	0.0003	0.0004	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004	0.0005	0.0005	0.0006	0.0005	0.0005	0.0005	

1. One Mt equals one Tg, which is 10<sup>12</sup> g (1,000,000,000,000 g) or one million tonnes
2. Net Emissions are reported in the Common Reporting Format
3. Geographical coverage of this table includes the Crown Dependencies Jersey, Guernsey and the Isle of Man, and the Overseas Territories which have joined, or are likely to join, the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol. These are the Cayman Islands, Falkland Islands, Bermuda, Montserrat and Gibraltar.

**Table ES2b** Emissions of GHGs in terms of carbon equivalent emissions including all estimated GHG emissions from the Crown Dependencies and excluding emissions from relevant Overseas Territories, 1990-2004

<b>Table ES2b</b>	<b>Mt C equivalent</b>															<b>% change</b>
	<b>1990</b>	<b>1991</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>1990-2004</b>
CO <sub>2</sub> (Emissions including LUCF emissions)	165.4	167.3	162.8	158.8	156.7	154.1	160.0	153.8	154.2	151.7	153.2	157.3	152.9	156.1	156.9	-5.1%
CH <sub>4</sub>	28.2	28.0	27.6	26.7	24.8	24.6	23.9	22.6	21.3	19.9	18.6	17.1	16.2	14.6	14.1	-50.0%
N <sub>2</sub> O	18.6	18.1	16.2	15.2	16.0	15.5	16.0	16.5	15.7	12.1	12.1	11.5	11.0	10.9	11.1	-40.4%
HFCs	3.1	3.2	3.4	3.5	3.8	4.2	4.6	5.2	4.7	3.0	2.5	2.6	2.7	2.8	2.4	-22.1%
PFCs	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	-74.9%
SF <sub>6</sub>	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.5	0.4	0.4	0.4	0.3	9.5%
Total (Emissions)	216.0	217.2	210.4	204.7	201.8	198.9	205.0	198.5	196.4	187.2	187.0	189.0	183.4	184.8	185.0	-14.4%
CO <sub>2</sub> (Removals)	-3.9	-4.0	-4.1	-4.1	-4.2	-4.2	-4.2	-4.2	-4.2	-4.2	-4.2	-4.2	-4.3	-4.4	-4.5	14.2%
CO <sub>2</sub> (Net Emissions)	161.5	163.3	158.7	154.6	152.5	149.9	155.8	149.6	150.0	147.5	149.0	153.1	148.6	151.8	152.5	-5.6%
Total (Net Emissions)	212.1	213.3	206.3	200.6	197.6	194.7	200.8	194.3	192.2	182.9	182.8	184.8	179.1	180.5	180.5	-14.9%
CO <sub>2</sub> (Emission excluding LUCF)	160.7	162.6	158.1	154.3	152.3	149.6	155.6	149.4	150.0	147.6	149.1	153.3	148.9	152.1	153.0	
Total (Emissions excluding LUCF)	211.3	212.5	205.7	200.3	197.3	194.4	200.6	194.2	192.2	183.0	182.9	185.0	179.4	180.8	181.0	
CO <sub>2</sub> emissions from LUCF	4.7	4.7	4.7	4.4	4.5	4.5	4.4	4.3	4.2	4.1	4.1	4.0	4.0	4.0	3.9	
CO <sub>2</sub> removals from LUCF	-3.9	-4.0	-4.1	-4.1	-4.2	-4.2	-4.2	-4.2	-4.2	-4.2	-4.2	-4.2	-4.3	-4.4	-4.5	
CH <sub>4</sub> emissions from LUCF	0.004	0.003	0.004	0.003	0.003	0.003	0.004	0.004	0.004	0.005	0.005	0.006	0.005	0.005	0.005	
N <sub>2</sub> O emissions from LUCF	0.0004	0.0003	0.0004	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004	0.0005	0.0005	0.0006	0.0005	0.0005	0.0005	

1. One Mt equals one Tg, which is 10<sup>12</sup> g (1,000,000,000,000 g) or one million tonnes
2. Net Emissions are reported in the Common Reporting Format

### ES.3

**Table ES3** summaries the trends in aggregated direct greenhouse gas emissions covered by FCCC/CP/2002/8 by sector for the years 1990-2004 for the following sectors:

- Energy
- Industrial Processes
- Solvents
- Agriculture
- Land-use Change and Forestry (LULUCF)
- Waste

**Table ES3a** Aggregated emission trends per source category, including all estimated GHG emissions from the Crown Dependencies and selected relevant Overseas Territories (Mt CO<sub>2</sub> equivalent)

<b>Table ES3</b>	<b>Aggregated emission trends per source category (Mt CO<sub>2</sub> equivalent)</b>														
<b>Source Category</b>	<b>1990</b>	<b>1991</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>
1. Energy	611.4	620.6	604.5	589.2	574.6	565.7	586.1	562.9	563.7	553.3	558.1	574.5	558.8	566.8	569.6
2. Industrial Processes	56.4	52.8	46.7	44.0	48.3	48.2	51.4	54.3	50.0	30.7	29.7	27.7	24.9	25.9	25.8
3. Solvents and other product use <sup>a</sup>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4. Agriculture	53.7	53.1	51.6	50.9	51.7	51.5	51.9	52.5	51.5	50.9	49.0	46.1	46.4	45.8	45.5
5. Land-use Change and Forestry (emissions)	17.2	17.4	17.2	16.3	16.4	16.5	16.3	15.9	15.4	15.2	15.0	14.9	14.5	14.8	14.4
5. Land-use Change and Forestry (removals)	-14.3	-14.6	-14.9	-15.2	-15.5	-15.5	-15.4	-15.4	-15.4	-15.4	-15.4	-15.4	-15.6	-16.0	-16.3
6. Waste	52.9	52.0	50.9	49.5	48.4	46.9	45.5	41.7	39.0	35.6	33.4	29.4	27.0	23.9	22.3
7. Other	1.8	1.9	1.9	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.1	2.1	2.1
<b>Total</b>	<b>793.4</b>	<b>797.8</b>	<b>772.8</b>	<b>751.9</b>	<b>741.3</b>	<b>730.9</b>	<b>753.1</b>	<b>729.4</b>	<b>721.7</b>	<b>687.7</b>	<b>687.2</b>	<b>694.6</b>	<b>673.8</b>	<b>679.3</b>	<b>679.7</b>
(emissions only)															
<b>Total</b>	<b>779.1</b>	<b>783.3</b>	<b>757.9</b>	<b>736.7</b>	<b>725.9</b>	<b>715.4</b>	<b>737.8</b>	<b>714.0</b>	<b>706.3</b>	<b>672.2</b>	<b>671.8</b>	<b>679.1</b>	<b>658.1</b>	<b>663.3</b>	<b>663.4</b>
(net CO <sub>2</sub> – sum of emissions and removals)															

Footnotes:

<sup>a</sup> Solvents and other product use emissions occur as NMVOC and so do not appear in this Table which covers direct greenhouse gases

Geographical coverage of this table includes the Crown Dependencies Jersey, Guernsey and the Isle of Man, and the Overseas Territories which have joined, or are likely to join, the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol. These are the Cayman Islands, Falkland Islands, Bermuda, Montserrat and Gibraltar.



**Table ES3b** Aggregated emission trends per source category, including all estimated GHG emissions from the Crown Dependencies and excluding all estimated GHG emissions from relevant Overseas Territories

<b>Table ES3b</b>	<b>Aggregated emission trends per source category (Mt CO<sub>2</sub> equivalent)</b>														
<b>Source Category</b>	<b>1990</b>	<b>1991</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>
1. Energy	610.2	619.5	603.3	588.1	573.4	564.4	584.9	561.6	562.5	552.0	556.8	573.2	557.5	565.4	568.3
2. Industrial Processes	56.4	52.8	46.7	44.0	48.3	48.2	51.4	54.3	50.0	30.7	29.6	27.7	24.9	25.9	25.8
3. Solvents and other product use <sup>a</sup>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4. Agriculture	53.5	53.0	51.4	50.7	51.5	51.4	51.7	52.4	51.4	50.7	48.9	45.9	46.3	45.6	45.3
5. Land-use Change and Forestry (emissions)	17.2	17.4	17.2	16.3	16.4	16.5	16.3	15.9	15.4	15.2	15.0	14.9	14.5	14.8	14.4
5. Land-use Change and Forestry (removals)	-14.3	-14.6	-14.9	-15.2	-15.5	-15.5	-15.4	-15.4	-15.4	-15.4	-15.4	-15.4	-15.6	-16.0	-16.3
6. Waste	52.8	52.0	50.8	49.5	48.4	46.9	45.5	41.7	39.0	35.6	33.4	29.4	27.0	23.9	22.3
7. Other	1.8	1.9	1.9	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.1	2.1	2.1
<b>Total</b> (emissions only)	<b>792.0</b>	<b>796.5</b>	<b>771.4</b>	<b>750.6</b>	<b>740.0</b>	<b>729.5</b>	<b>751.8</b>	<b>728.0</b>	<b>720.3</b>	<b>686.2</b>	<b>685.7</b>	<b>693.1</b>	<b>672.3</b>	<b>677.8</b>	<b>678.2</b>
<b>Total</b> (net CO <sub>2</sub> – sum of emissions and removals)	<b>777.7</b>	<b>781.9</b>	<b>756.5</b>	<b>735.4</b>	<b>724.5</b>	<b>714.0</b>	<b>736.4</b>	<b>712.6</b>	<b>704.9</b>	<b>670.8</b>	<b>670.3</b>	<b>677.6</b>	<b>656.6</b>	<b>661.8</b>	<b>661.9</b>

Footnotes:

<sup>a</sup> Solvents and other product use emissions occur as NMVOC and so do not appear in this Table which covers direct greenhouse gases

The largest contribution to greenhouse gas emissions arises from the energy sector. In 2004 this contributed 86% to the total emissions including relevant OTs. Emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O also arise from this sector. Since 1990, emissions from the energy sector have declined by about 7%.

The second largest source of greenhouse gases is the agricultural sector. Emissions from this sector arise for both CH<sub>4</sub> and N<sub>2</sub>O. Since 1990, emissions from this sector have declined by 15%, due to a decline in emissions from enteric fermentation and agricultural waste disposal (related to lower livestock numbers) and agricultural soils (due to changes in agricultural practices, including a decline in emissions from enteric fermentation, and a decline in the emissions from the use of synthetic fertiliser).

Industrial processes make up the third largest source of greenhouse gases in the UK, contributing 4% to the national total in 2004. Emissions of all six direct greenhouse gases occur from this sector.

Land Use, Land-use Change and Forestry contributes 2% to the national total in 2004. Emissions from this source occur for CO<sub>2</sub>, N<sub>2</sub>O and CH<sub>4</sub>. LULUCF contains sinks as well as sources of CO<sub>2</sub> emissions.

The remaining source that contributes to direct greenhouse gas totals is waste. In 2004 this contributed 3.4% to the national total. Emissions arise for CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O, with emissions occurring from waste incineration, solid waste disposal on land and wastewater handling. Emissions from this sector have steadily declined and in 2004 are 58% below 1990 levels.

## ES.4

ES.4 lists the indirect greenhouse gases for which the UK has made emissions estimates. Nitrogen oxides, carbon monoxide and NMVOCs are included in the inventory because they can produce increases in tropospheric ozone concentrations and this increases radiative forcing. Sulphur oxides are included because they contribute to aerosol formation.

**Table ES4** Emissions of Indirect Greenhouse Gases in the UK, 1990-2004 (in kt)

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
NO <sub>x</sub>	2,932	2,803	2,719	2,545	2,455	2,355	2,277	2,121	2,052	1,936	1,856	1,799	1,693	1,685	1,621
CO	8,280	8,128	7,668	7,261	6,856	6,338	6,189	5,723	5,328	5,010	4,283	4,108	3,614	3,099	2,919
NMVOC	2,394	2,313	2,247	2,138	2,076	1,936	1,830	1,764	1,615	1,461	1,346	1,250	1,173	1,071	1,022
SO <sub>2</sub>	3,699	3,522	3,430	3,085	2,649	2,343	1,999	1,635	1,591	1,202	1,173	1,111	994	973	833

Footnotes:

Geographical coverage of the emissions in the table includes emissions from the Crown Dependencies, but does not include emissions from the Overseas Territories.

Since 1990, emissions of all indirect gases have decreased. The largest source of emissions for all the indirect gases is the energy sector. For NO<sub>x</sub>, CO and SO<sub>2</sub>, over 90% of emissions for each gas arise from activities within this sector. For NMVOC, 46% of emissions are energy related, with other significant contributions from both the industrial processes and solvent sectors.

### ES.5

ES.5 provides the time series of the UK Kyoto basket of emissions. The table shows the emissions making up the base year and subsequent years, and also estimated the emissions and removals from:

- ▶ **Article 3.3**, the net emissions or removals of Aforestation, Reforestation and Deforestation (ARD) since 1990;
- ▶ **Article 3.4**, the net flux due to forest management since 1990 (the UK has elected forest management from the choices of: cropland management, grassland management, forest management and revegetation);
- ▶ **Article 3.7**, emissions in 1990 only from deforestation, added to the base year for Kyoto reporting (only applicable for countries where there is a net LULUCF emission in 1990, which is the case for the UK).

## Executive Summaries

**Table ES5a** Kyoto basket of emissions, and emissions associated with Articles 3.3, 3.4 and 3.7, 1990-2004 (in Mt C equivalent)

Table ES5	Mt C equivalent																%changes	
	Base year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	1990-2004	Base Year - 2004
CO2 (excluding all LULUCF emissions and removals)	161.0	161.0	162.9	158.4	154.7	152.6	150.0	155.9	149.7	150.4	147.9	149.5	153.6	149.3	152.4	153.4	-4.7%	-4.7%
CH4	28.3	28.3	28.0	27.6	26.8	24.9	24.6	24.0	22.6	21.4	19.9	18.7	17.1	16.3	14.6	14.1	-50.0%	-50.0%
N2O	18.6	18.6	18.1	16.2	15.2	16.0	15.6	16.1	16.5	15.7	12.1	12.1	11.5	11.0	10.9	11.1	-40.3%	-40.3%
HFC C equiv	4.2	3.1	3.2	3.4	3.5	3.8	4.2	4.6	5.2	4.7	3.0	2.5	2.6	2.7	2.8	2.4	-22.0%	-42.7%
PFC C equiv	0.1	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	-74.9%	-25.2%
SF6 C equiv	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.5	0.4	0.4	0.4	0.3	9.5%	-9.0%
<b>Grand Total</b>	<b>212.6</b>	<b>211.7</b>	<b>212.9</b>	<b>206.1</b>	<b>200.6</b>	<b>197.7</b>	<b>194.8</b>	<b>201.0</b>	<b>194.6</b>	<b>192.6</b>	<b>183.4</b>	<b>183.3</b>	<b>185.4</b>	<b>179.8</b>	<b>181.2</b>	<b>181.5</b>	<b>-14.3%</b>	<b>-14.7%</b>
Article 3.3		0.06	0.10	0.11	0.08	0.05	-0.01	-0.07	-0.13	-0.19	-0.24	-0.28	-0.31	-0.37	-0.42	-0.48		
Article 3.4 (capped at -0.37 MTC)		-0.37	-0.37	-0.37	-0.37	-0.37	-0.37	-0.37	-0.37	-0.37	-0.37	-0.37	-0.37	-0.37	-0.37	-0.37		
Article 3.7	0.1																	
<b>KP total</b>	<b>212.7</b>	<b>211.4</b>	<b>212.6</b>	<b>205.8</b>	<b>200.3</b>	<b>197.4</b>	<b>194.4</b>	<b>200.5</b>	<b>194.1</b>	<b>192.1</b>	<b>182.8</b>	<b>182.7</b>	<b>184.7</b>	<b>179.1</b>	<b>180.4</b>	<b>180.6</b>	<b>-14.6%</b>	<b>-15.1%</b>

**Footnotes:**

Emissions and removals associated with LULUCF enter the table only through the rows labelled Article 3.3, Article 3.4 and Article 3.7. The UK has chosen to account only for forest management under Article 3.4.

Geographical coverage of this table includes the Crown Dependencies Jersey, Guernsey and the Isle of Man, and the Overseas Territories which have joined, or are likely to join, the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol. These are the Cayman Islands, Falkland Islands, Bermuda, Montserrat and Gibraltar.

**Table ES5b** Kyoto basket of emissions, and emissions associated with Articles 3.3, 3.4 and 3.7, 1990-2004 (in Mt CO<sub>2</sub> equivalent)

<b>Table ES5</b>	<b>Mt CO<sub>2</sub> equivalent</b>																<b>%changes</b>	
	<b>Base year</b>	<b>1990</b>	<b>1991</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>1990-2004</b>	<b>Base Year - 2004</b>
CO <sub>2</sub> (excluding all LULUCF emissions and removals)	590.3	590.3	597.3	580.8	567.1	559.4	549.8	571.7	549.1	551.4	542.3	548.0	563.4	547.3	558.9	562.4	-4.7%	-4.7%
CH <sub>4</sub>	103.6	103.6	102.8	101.3	98.2	91.2	90.2	87.8	83.0	78.3	73.0	68.5	62.7	59.7	53.6	51.8	-50.0%	-50.0%
N <sub>2</sub> O	68.4	68.4	66.3	59.5	55.7	58.7	57.1	58.9	60.6	57.7	44.5	44.3	42.1	40.5	40.1	40.8	-40.3%	-40.3%
HFC C equiv	15.5	11.4	11.9	12.3	13.0	14.0	15.5	16.7	19.2	17.3	10.8	9.1	9.7	9.9	10.2	8.9	-22.0%	-42.7%
PFC C equiv	0.5	1.4	1.2	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.3	0.3	0.4	-74.9%	-25.2%
SF <sub>6</sub> C equiv	1.2	1.0	1.1	1.1	1.2	1.2	1.2	1.3	1.2	1.3	1.4	1.8	1.4	1.5	1.3	1.1	9.5%	-9.0%
<b>Grand Total</b>	<b>779.5</b>	<b>776.1</b>	<b>780.5</b>	<b>755.6</b>	<b>735.6</b>	<b>725.0</b>	<b>714.3</b>	<b>736.8</b>	<b>713.4</b>	<b>706.3</b>	<b>672.5</b>	<b>672.2</b>	<b>679.7</b>	<b>659.2</b>	<b>664.5</b>	<b>665.3</b>	<b>-14.3%</b>	<b>-14.7%</b>
Article 3.3		0.2	0.36	0.42	0.31	0.17	-0.04	-0.24	-0.49	-0.71	-0.87	-1.03	-1.14	-1.34	-1.55	-1.76		
Article 3.4 (capped at -0.37 MTC)		-1.36	-1.36	-1.36	-1.36	-1.36	-1.36	-1.36	-1.36	-1.36	-1.36	-1.36	-1.36	-1.36	-1.36	-1.36		
Article 3.7	0.4																	
<b>KP total</b>	<b>779.9</b>	<b>775.0</b>	<b>779.5</b>	<b>754.6</b>	<b>734.6</b>	<b>723.8</b>	<b>712.9</b>	<b>735.2</b>	<b>711.6</b>	<b>704.2</b>	<b>670.2</b>	<b>669.8</b>	<b>677.2</b>	<b>656.5</b>	<b>661.6</b>	<b>662.2</b>	<b>-14.6%</b>	<b>-15.1%</b>

## Footnotes:

Emissions and removals associated with LULUCF enter the table only through the rows labelled Article 3.3, Article 3.4 and Article 3.7. The UK has chosen to account only for forest management under Article 3.4.

Geographical coverage of this table includes the Crown Dependencies Jersey, Guernsey and the Isle of Man, and the Overseas Territories which have joined, or are likely to join, the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol. These are the Cayman Islands, Falkland Islands, Bermuda, Montserrat and Gibraltar.

**Table ES6** Net emissions of carbon including all estimated carbon emissions from the Crown Dependencies but excluding emissions from relevant Overseas Territories

<b>Table ES6</b>	<b>Mt C Equivalent</b>														
	<b>1990</b>	<b>1991</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>
Net CO2 emissions	161.5	163.3	158.7	154.6	152.5	149.9	155.8	149.6	150.0	147.5	149.0	153.1	148.6	151.8	152.5
% Change relative to 1990	0.0%	1.1%	-1.7%	-4.2%	-5.6%	-7.2%	-3.5%	-7.4%	-7.1%	-8.7%	-7.7%	-5.2%	-8.0%	-6.0%	-5.6%

Footnotes:

Geographical coverage of the emissions in the table includes emissions from the Crown Dependencies, but does not include emissions from the Overseas Territories.

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## Contacts

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## Document revision history

Issue	Revision history
<b>Issue - Draft</b>	<ul style="list-style-type: none"><li>• Reviewed by Defra, IGER and CEH</li><li>• Revision following these comments</li></ul>
<b>1.0</b>	<ul style="list-style-type: none"><li>• Submission to the UNFCCC Secretariat on 15.iv.2006</li></ul>
<b>1.1</b>	<ul style="list-style-type: none"><li>• Correction of Waste Sector 6A – flare downtime has remained at 85% and not decreased to 75%</li></ul>
<b>1.1.1</b>	<ul style="list-style-type: none"><li>• Typographical error corrected in the footnote to Table 9.4.</li></ul>
<b>1.2</b>	<ul style="list-style-type: none"><li>• Table A7.4b Sectoral Uncertainties updated</li><li>• NETCEN address updated</li></ul>
<b>2.0 - draft</b>	<ul style="list-style-type: none"><li>• Includes emissions from Gibraltar and revised landfill methane estimates</li><li>• Reviewed by Defra</li></ul>
<b>2.0</b>	<ul style="list-style-type: none"><li>• Revisions following Defra comments on the <b>2.0 - draft</b></li><li>• Includes emissions from Gibraltar and revised landfill methane estimates</li></ul>



# 1. Introduction

## 1.1 BACKGROUND INFORMATION ON GREENHOUSE GAS INVENTORIES

### 1.1.1 Reporting of the UK greenhouse gas inventory

The UK ratified the United Nations Framework Convention on Climate Change (UNFCCC) in December 1993 and the Convention came into force in March 1994. Parties to the Convention are committed to develop, publish and regularly update national emission inventories of greenhouse gases (GHGs).

This report provides annual emission estimates submitted by the UK to the UNFCCC for the period 1990 to 2004. This report and the attached Common Reporting Format (CRF) tables comprise the UK's National Inventory Report (NIR) and are in accordance with Decision 18/CP.8 and other relevant decisions of the Conference of Parties. The UK also reports emissions under other international agreements. These estimates are provided in the UK's National Atmospheric Emissions Inventory (NAEI), which is also compiled by NETCEN. The greenhouse gas inventory and the NAEI share underlying data, which are extended as necessary to cover the additional sources required for UNFCCC reporting. This helps ensure consistency between the inventories. Emissions and removals from land use change and forestry are provided by the Centre of Ecology and Hydrology (CEH) Edinburgh, and agricultural emissions by the Institute of Grassland and Environmental Research (IGER), both under separate contracts to the UK government Department of Environment, Food and Rural Affairs (Defra). Defra also funds research contracts to provide improved emissions estimates for certain sources, and estimates for previously unreported sectors, for example estimates of methane from closed mines which were first included in the 2005 NIR.

This report and the CRF tables have been prepared according to UNFCCC guidelines contained in FCCC/CP/2002/8 and are provided to fulfil the UK's reporting obligations to UNFCCC. The estimates are consistent with the IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories (IPCC, 1997a, b, c) and Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000, 2003).

There are some differences in the allocation of indirect GHGs emissions to IPCC sectors between the NIR and the CRF in this submission, although the total emissions of each GHG are identical. This approach was necessary to circumvent software problems encountered with early versions of the new CRF reporting software. The differences occur in the reporting of emissions from UK Overseas Territories<sup>3</sup> (OTs), and Crown Dependencies<sup>4</sup> (CDs). In the CRF, emissions of GHGs from these OTs and CDs are reported in sub-categories under IPCC

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<sup>3</sup> The Overseas Territories are: the Cayman Islands, Falkland Islands, Bermuda, Montserrat and Gibraltar.

<sup>4</sup> The Crown Dependencies are: the Bailiwick of Jersey, the Bailiwick of Guernsey and the Isle of Man.

Sector 7 (“other emissions”), whereas these emissions are allocated to the appropriate IPCC sectors in this NIR.

This is the second edition of the UK NIR to be published. It provides updated data to take account of:

- the decision of Gibraltar to join the UK’s instrument of ratification of the Kyoto Protocol, and,
- revised estimates of methane emission from landfill, which adopt an factor of 0.1 for the proportion of methane oxidised in the cap covering the landfill. This is in response to a reassessment by the UK of the evidence on landfill emissions following the UNFCCC review of the inventory conducted in 2005. This increases the UK methane estimate in 1990 by about 12% and applies throughout the time series so the trend in emissions is not much affected.

The estimates for the other source categories in the inventory remain unchanged

### **1.1.2 Nomenclature of the inventory period reported**

This report is the UK National Inventory Report of 2006 (second edition). It contains revised emissions estimates for the years 1990 to 2004 inclusive.

### **1.1.3 Structure of the UK National Inventory Report**

The structure of this report meets the specification set out by the UNFCCC in document FCCC/CP/2002/8. This document specifies guidelines on reporting and review of greenhouse gas inventories from parties included in Annex I to the Convention. An Annex of FCCC/CP/2002/8 specifies the sections that should be included in a National Inventory Report, and the contents of each of the sections.

The main part of the report presents greenhouse gas emissions for the years 1990-2004, and discusses the reasons for the trends and any changes in the estimates due to revisions made since the last inventory. Tables in **Annex 9** present the UK summary emissions for these years and the IPCC Sectoral Tables are also given for the individual years 1990 and 2004. The Annexes provide supplementary detail of the methodology of the estimates, and explain how the Greenhouse Gas Inventory relates to the IPCC Guidelines and the NAEI. It contains mappings between IPCC, NAEI source categories and fuel types as well as some emission factors and references to the technical literature. The Annexes also include sections on the estimation of uncertainties and atmospheric verification of the inventory, and additional detail of the methods used to estimate emissions of GHGs. The IPCC Good Practice Guidance (IPCC, 2000) requires that certain sets of activity data are reported as well as the Common Reporting Format Tables. These datasets are included on a CD ROM attached to this report.

### **1.1.4 Reporting of greenhouse gas emissions and background data in the CRF**

The CRF consists of a series of detailed spreadsheets, with one set for each year. The CRF reports much more detail than the IPCC Sectoral Tables, in that it contains additional tables of activity data as well as updated versions of the IPCC Sectoral Tables. A copy of the CRF accompanies this report on a CD ROM.

### **1.1.5 Reporting of CO<sub>2</sub> emissions from Land Use Change and Forestry**

The reporting of CO<sub>2</sub> emissions from Land Use Change and Forestry now complies with the reporting specified in the 2003 Good Practice Guidance. Further information is given in **Chapter 7, Section 7.9**.

### **1.1.6 Greenhouse gases reported in the UK inventory**

The greenhouse gases reported are:

#### ***Direct Greenhouse Gases***

- Carbon dioxide (CO<sub>2</sub>)
- Methane (CH<sub>4</sub>)
- Nitrous oxide (N<sub>2</sub>O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulphur hexafluoride (SF<sub>6</sub>)

#### ***Indirect Greenhouse Gases***

- Nitrogen oxides (NO<sub>x</sub>, as NO<sub>2</sub>)
- Carbon monoxide (CO)
- Non-Methane Volatile Organic Compounds (NMVOC)
- Sulphur dioxide (SO<sub>2</sub>)

These indirect gases have indirect effects on radiative forcing and are requested by the UNFCCC guidelines.

Emissions estimates are made using methodologies corresponding mostly to the detailed sectoral Tier 2/3 methods in the IPCC Guidelines.

Most sources are reported in the detail required by the CRF. The main exceptions are the emissions of individual halocarbon species, which cannot always be reported individually because some of these are considered commercially sensitive data. Consequently, emissions data have been aggregated to protect this information. It is however possible to report the total global warming potential of these gases and hence the total global warming potential of all UK greenhouse gases.

### 1.1.7 Global Warming Potentials of the greenhouse gases

The direct greenhouse gases have different effectiveness in radiative forcing. The Global Warming Potential (GWP) is a means of providing a simple measure of the relative radiative effects of the emissions of the various gases. The index is defined as the cumulative radiative forcing between the present and a future time horizon caused by a unit mass of gas emitted now, expressed relative to that of CO<sub>2</sub>. It is necessary to define a time horizon because the gases have different lifetimes in the atmosphere. **Table 1.1** shows GWPs defined on a 100-year horizon (IPCC, 1996). These are the GWP values required by FCCC/CP/2002/8, consistent with Decision 2/CP.3.

**Table 1.1** GWP of Greenhouse Gases on a 100-Year Horizon used in the UK NIR

Gas	GWP
Carbon Dioxide	1
Methane	21
Nitrous Oxide	310
HFCs	140-11,700
PFCs	6,500-9,200
SF <sub>6</sub>	23,900

A range of GWP values is shown for HFCs and PFCs because these refer to a number of species, each with its own GWP. By weighting the emission of a gas with its GWP it is possible to estimate the total contribution to global warming of UK greenhouse gas emissions.

GWPs of certain greenhouse gases have been updated in the IPCC Third Assessment Report (IPCC, 2001). However, it has been agreed internationally that these will not apply to the Kyoto targets under the first commitment period. All calculations and inventory submissions throughout this period will be based on the GWPs given in the Second Assessment Report (IPCC, 1996).

### 1.1.8 Climate change – The UK programme

The UK's Climate Change Programme published in March 2006, describes measures to ensure that the UK delivers its legally binding target under the Kyoto Protocol to reduce emissions of the basket of the six greenhouse gases to 12.5% below base year levels over the first commitment period 2008-2012, and to move the UK towards its domestic goal of a 20% reduction in carbon dioxide emissions below 1990 levels by 2010. The UK has additionally a long-term goal of putting itself on a path to cut CO<sub>2</sub> emissions by 60% by 2050, with real progress by 2020. This is described in the Energy White Paper published in February 2003, (DTI, 2003). The Climate Change Programme forms the basis of the UK's Fourth National Communication to the UNFCCC.

Further information on the UK's action to tackle climate change is provided to the public through the Defra website on [www.defra.gov.uk/environment/climatechange](http://www.defra.gov.uk/environment/climatechange)

## **1.2 INSTITUTIONAL ARRANGEMENTS FOR INVENTORY PREPARATION**

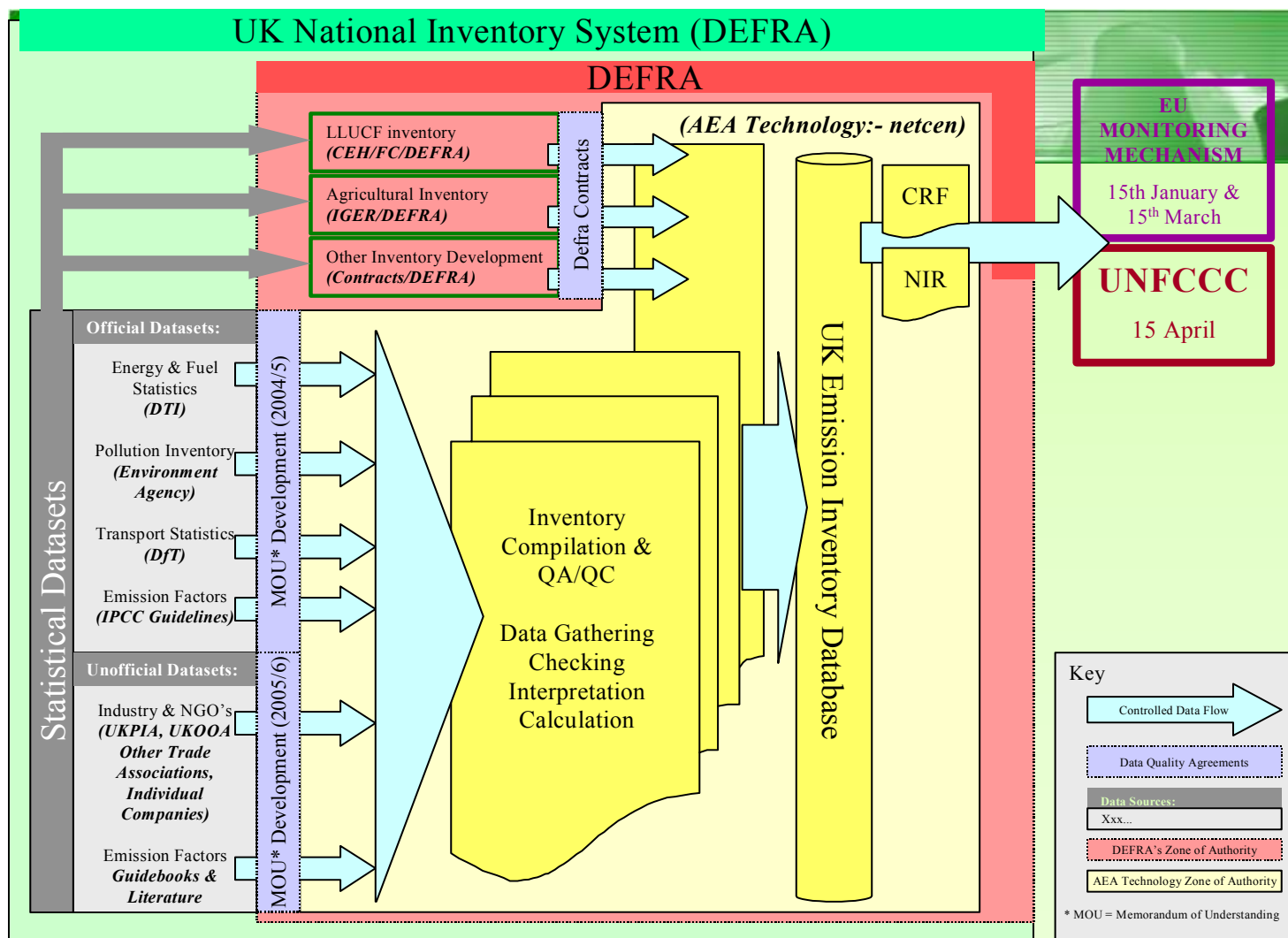
The UK Greenhouse Gas Inventory is compiled and maintained by the National Environmental Technology Centre (NETCEN) of AEA Technology plc – the **Inventory Agency** - under contract with the Global Atmosphere Division (GAD) in the UK Department for Environment, Food & Rural Affairs (Defra). NETCEN is directly responsible for producing the emissions estimates for CRF categories Energy (CRF sector 1), Industrial Processes (CRF sector 2), Solvent and Other Product Use (CRF sector 3), and Waste (CRF Sector 6). NETCEN is also responsible for inventory planning, data collection, QA/QC and inventory management and archiving. Agricultural sector emissions (CRF sector 4) are produced by the Defra's Sustainable Agriculture Strategy by means of a contract with the Institute of Grassland and Environmental Research (IGER). Land-Use Change and Forestry emissions (CRF sector 5) are calculated by the UK Centre for Ecology and Hydrology (CEH), under separate contract to GAD.

### **1.2.1 The UK Greenhouse Gas National Inventory System (UK NIS)**

The Marrakesh Accords of the Kyoto Protocol (Decision 20/CP7) define the requirements for National Inventory Systems (NIS), including the need to establish legal, procedural and institutional arrangements to ensure that all parties to the Protocol estimate and report their GHG emissions in accordance with relevant decisions of the COP, facilitate UNFCCC Reviews and improve the quality of their inventories. Under related EU legislation set out in Decision 280/2004/EC the UK was required to have in place its NIS by 31<sup>st</sup> December 2005. Many aspects of the UK NIS already meet the UNFCCC's requirements. The development of more formal agreements between Defra and Key Data Providers (KDPs) is ongoing and will specify the framework of data supply e.g. data quality, format, timeliness and security to underpin the GHG inventory.

**Figure 1.1a** shows the main elements the UK National Inventory System, including provision of data to the European Union under the terms of the EU Monitoring Mechanism. Defra is the **Single National Entity** responsible for submitting the UK's greenhouse gas inventory (GHGI) to the UNFCCC. NETCEN compiles the GHGI on behalf of Defra, and produces disaggregated estimates for the Devolved Administrations within the UK.

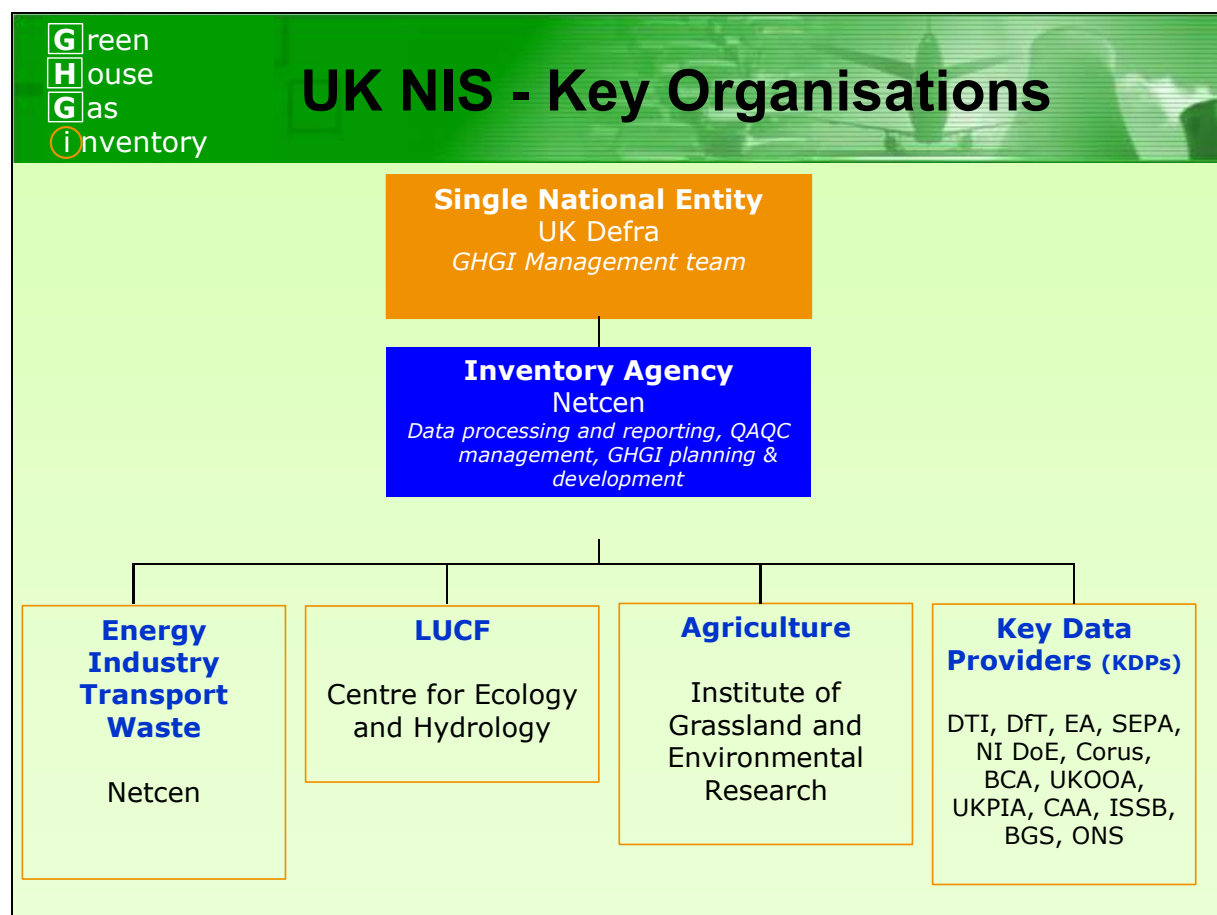
Key Data Providers include other Government Departments such as Department for Trade and Industry (DTI) and Department for Transport (DfT), Non-Departmental Public Bodies such as the Environment Agency for England and Wales (EA) and the Scottish Environmental Protection Agency (SEPA), private companies such as Corus, and business organisations such as UK Petroleum Industry Association (UKPIA) and UK Offshore Oil Association (UKOOA).

**Figure 1.1a** Main elements for the preparation of the UK greenhouse gas inventory

### 1.2.2 UK NIS - Organisational Structure

**Figure 1.1b** provides an overview of the organisational structure of the UK National Inventory System.

**Figure 1.1b** Key organisational structure of the UK National Inventory System



The following sections summarises the roles and responsibilities of key stakeholders in the UK NIS.

#### 1.2.2.1 Single National Entity - Defra

The UK Government Department for Environment, Food and Rural Affairs (Defra) has been appointed as the Single National Entity for the UK and this has been confirmed in writing to the UN Executive Secretary. Defra has overall responsibility for the UK Greenhouse Gas Inventory and the UK National System and carries out this function on behalf of Her Majesty's Government and the Devolved Administrations (Wales, Scotland and Northern Ireland). Defra is responsible for the institutional, legal and procedural arrangements for the national system and for the strategic development of the national inventory.

Within Defra, the Global Atmosphere (GA) Division administers this responsibility. GA coordinates expertise from across Government and manages research contracts to ensure that the UK Greenhouse Gas Inventory meets international standards set out in the UNFCCC

reporting guidelines, the Kyoto Protocol and the IPCC 1996 Guidelines and IPCC Good Practice Guidance.

As the designated Single National Entity for the UK GHG NIS, Defra has the following roles and responsibilities:

***National Inventory System Management & Planning***

- ▶ Overall control of the NIS development & function;
- ▶ Management of contracts & delivery of GHG inventory;
- ▶ Definition of performance criteria for NIS key organisations.

***Development of Legal & Contractual Infrastructure***

- ▶ Review of legal & organisational structure;
- ▶ Implementation of legal instruments and contractual developments as required to meet guidelines.

Defra manages three main contracts that underpin the preparation and development of the national inventory, covering greenhouse gas emissions and removals; these contracts are currently with Netcen, CEH and IGER.

**1.2.2.2 Inventory Agency - Netcen**

Netcen is contracted by Defra to perform the role of Inventory Agency and is responsible for all aspects of national inventory preparation, reporting and quality management. Netcen prepares the national atmospheric emissions inventory (NAEI) which is the core air emissions database from which the greenhouse gas inventory (GHGI) is extracted to ensure consistency in reporting across all air emissions for different reporting purposes (UNFCCC, UNECE etc). Activities include: collecting and processing data from a wide range of sources; selecting appropriate emission factors and estimation methods according to IPCC guidance; compiling the inventory; managing all aspects of inventory QA/QC including QC of raw data and data management tools, documentation and archiving, prioritisation of methodology and raw data improvements; carrying out uncertainty assessments; delivering the NIR (including CRF tables) by deadlines set to the EU Monitoring Mechanism (EUMM) and the UNFCCC on behalf of Defra; assisting with Article 8 reviews.

As the designated Inventory Agency for the UK GHG National Inventory System, Netcen has the following roles and responsibilities:

***Planning***

- ▶ Co-ordination with Defra to deliver the NIS;
- ▶ Review of current NIS performance and assessment of required development action;
- ▶ Scheduling of tasks and responsibilities to deliver GHG inventory and NIS.

***Preparation***

- ▶ Drafting of agreements with key data providers;
- ▶ Review of source data & identification of developments required to improve GHG inventory data quality.



***Management***

- ▶ Documentation & archiving;
- ▶ Dissemination of information regarding NIS to Key Data Providers;
- ▶ Management of inventory QA/QC plans, programmes and activities.

***Inventory Compilation***

- ▶ Data acquisition, processing and reporting;
- ▶ Delivery of NIR (including associated CRF tables) to time and quality.

CEH is currently responsible for the preparation and development of the LULUCF inventory, including both emissions and removals of GHGs. CEH conduct specific research in the LULUCF sector and provide finalised data to Netcen for inclusion within the UK GHG inventory dataset.

IGER is currently responsible for the preparation and development of the agriculture inventory. IGER conduct specific research in the agriculture sector and provide finalised GHG emissions data to Netcen for inclusion within the UK inventory dataset.

**1.2.2.3 Key Data Providers and Reference Sources**

The organisations that provide the raw data to the UK GHGI include a wide range of Government Departments, non-Departmental public bodies and Government Agencies, private companies and industrial trade associations.

Within the UK GHG National Inventory System, organisations that are Key Data Providers have the following roles and responsibilities:

***Data Quality, Format, Timeliness, Security***

- ▶ Delivery of source data in appropriate format and in time for inventory compilation, allowing for all required QA/QC procedures;
- ▶ Assessment of their data acquisition, processing & reporting systems, taking regard for QA/QC requirements;
- ▶ Identification of any required organisational or legal development and resources to meet more stringent NIS data requirements, notably the security of data provision in the future;
- ▶ Communication with Defra, Netcen and their peers / members to help to disseminate information regarding the GHG inventory and National System.

Energy statistics required for compilation of the GHGI are obtained from the Digest of UK Energy Statistics (DUKES). DUKES is compiled and published annually by the UK Government Department of Trade and Industry (DTI).

Information on industrial processes is provided either directly to Netcen by the individual plant operators or from:

- a) the Environment Agency's Pollution Inventory for England & Wales;
- b) the Scottish Environmental Protection Agency's European Pollution Emissions Register;
- c) the Northern Ireland Department of Environment Inventory of Statutory Releases.

Reporting to these UK inventories for the purposes of environmental regulation is a statutory requirement for industries covered by IPPC. The data from these inventory sources is also used to quality check data provided voluntarily by companies directly to Netcen.

The Institute of Grassland and Environmental Research (IGER) compiles the inventory for agricultural emissions using agricultural statistics from Defra.

The Centre for Ecology and Hydrology (CEH) compiles estimates of emissions and removals from LULUCF using land-use data and information on forestry from the Forestry Commission (a non-departmental public body), Defra itself, and from other sources.

Defra also funds research contracts to provide emissions estimates for certain sources. For example, AEA Technology, in consultation with industry, provides improved emission estimates of HFCs, PFCs and SF<sub>6</sub> (AEAT, 2004). Landfill methane emissions estimates were compiled by an independent consultancy (Golder Associates), in consultation with industry. A recent Defra-funded study has provided estimates for methane emissions from closed coal mines (Kershaw, 2005).

The GHGI is compiled according to IPCC Good Practice Guidance (IPCC, 2000; IPCC 2003). Each year the inventory is updated to include the latest data available. Improvements to the methodology are made and are backdated to ensure a consistent time series. Methodological changes are made to take account of new research and data sources, any new guidance from IPCC, relevant work or emission factors from EMEP-CORINAIR and the US EPA, or from specific research programmes sponsored by Defra.

### **1.2.3 Legal Framework**

The UK GHGI has been reported annually since 1994, and historically the acquisition of the required data has been based on a mixture of existing environmental and energy legislation and informal arrangements with industry contacts and trade associations.

The UK system of data collection has previously relied upon legislation set up for other purposes, such as:

- ▶ Integrated Pollution Prevention and Control (IPPC) regulations (industrial point source emission data from UK environmental regulatory agencies)
- ▶ Statistics of Trade Act (UK energy statistics from the DTI)

Recognising the fact that such a system of data collection might not meet the standards required under the Kyoto Protocol, the UK has introduced new legislation specifically for national inventory purposes which took effect from November 2005<sup>5</sup>. This legislation makes provision for Defra's Secretary of State to issue a notice in the event that information required for the inventory that has been sought voluntarily is not provided. This legislation is intended as a last resort once all other avenues to elicit the required data, in the format and to the timing specified have failed. The legislation includes penalties for failure to comply, and authority for entry to premises to obtain information required or verify information provided.

To ensure that the system works most effectively as it currently stands and to minimise the need for legislative action, Defra proposes to introduce data supply agreements with relevant organizations during 2006, to build upon existing relationships with data supply organisations. These agreements will formalise the acquisition of data and clarify the main requirements of quality, format, security and timely delivery of data for the national inventory.

#### **1.2.4 Roles and Responsibilities - Inventory Development**

**Table 1.2** and **1.3** below shows the main organisations engaged in the UK national system, and their roles and responsibilities in relation to the preparation and development of the national inventory. This table includes organisations from the following categories, many of which are classed as key data providers:

- ▶ Government Departments
- ▶ Government Agencies (e.g. environmental regulators)
- ▶ Industry bodies or associations
- ▶ Consultants

The UK GHG inventory Steering Committee will be established in 2006 to provide an independent review group to assist in the review & improvement of the UK inventory. The committee will assist the Defra GHG inventory management team to manage and prioritise the over-arching inventory QA and facilitate better communication between inventory stakeholders across Government Departments and Agencies. Special Advisors to the Steering Committee include the Inventory Agency team at Netcen, plus appropriate sector, legal and economic experts.

#### **1.2.5 Process for Official consideration and approval of the UK GHG inventory**

The national inventory is planned, prepared and managed according to the information provided in the annual National Inventory Report which is submitted to the EUMM and UNFCCC each year.

UN Expert Review Team reports in recent years all indicate that the UK submissions generally conform to international standards, although some of the recommended best practice

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<sup>5</sup> Greenhouse Gas Emissions Trading Scheme (Amendment) and National Emissions Inventory Regulations 2005, available at: <http://www.opsi.gov.uk/si/si2005/20052903.htm>

is not established in the UK system, such as the performance of a pre-submission review of inventory data by a review group independent of the main GHG inventory compilation process. This area is currently under consideration by Defra.

To meet the detailed requirements of a National System, as described within the Marrakech Accords and to address some of the identified gaps in best practice, Defra is establishing a formal cross-Government steering committee tasked with the official consideration and approval of the national inventory prior to submission to the UNFCCC. The Committee will assist in the review and improvement of the UK inventory and facilitate better communication between inventory stakeholders including Government Departments and Agencies. Special Advisors to the Steering Committee will include the Inventory Agency team at Netcen, other contractors, plus appropriate sector, legal and economic experts, forming expert panels. These panels will be responsible for reviewing methodologies, activity data, emission factors and emission estimates at a sectoral level and will report their findings and recommendations to the steering committee on a regular basis. The committee is responsible for ensuring that the inventory meets international standards of quality, accuracy and completeness, and is delivered on time each year to the EU Monitoring Mechanism and the UNFCCC.

These new arrangements primarily formalise a system to consolidate activities and review and improvement procedures that have been in place in the UK and working well for many years.

**Table 1.2** UK GHG National Inventory Steering Committee

<b>Organisation</b>	<b>Key Roles for the UK GHG inventory</b>	<b>General Responsibilities</b>
Defra, Global Atmosphere Division	<ul style="list-style-type: none"> <li>• Administer functions of Single National Entity for the UK National Inventory System</li> <li>• Overall responsibility for inventory development, compilation and reporting</li> <li>• Manage GHG inventory research contracts</li> <li>• Provide Secretariat to Steering Committee</li> </ul>	Management and administration of the UK National System to ensure that the UK GHG inventory conforms to international standards and is submitted on time to the EUMM and UNFCCC each year.
Defra, Sustainable Agriculture Strategy	<ul style="list-style-type: none"> <li>• Manage the agricultural inventory research contract</li> </ul>	Management and administration of the sub-contracted agriculture inventory, to ensure that it conforms to international standards and is submitted on time to Netcen each year.
Defra, Environmental Statistics and Indicators	<ul style="list-style-type: none"> <li>• Provide a statistical check of emissions data used to derive climate change indicators</li> </ul>	Publication of Defra climate change indicators each year.
Defra, National Climate Change Programme	<ul style="list-style-type: none"> <li>• Provide fuel use and fuel characterisation datasets from the EU-ETS for use by both DTI and the GHGI in the determination of industrial fuel use statistics and the resultant emissions of GHGs from combustion sources.</li> </ul>	Management of the UK's Climate Change Programme, including the maintenance and reporting of the EU Emissions Trading Scheme database of fuel use and emission estimates.
DTI, EA Regulator	<ul style="list-style-type: none"> <li>• Ensure that the UK environmental agencies meet data reporting requirements under IPPC regulations and that relevant details of industrial process plant design are made available to Inventory Agency.</li> </ul>	Regulation of the UK environmental regulatory agencies: the Environment Agency of England & Wales (EA), the Scottish Environmental Protection Agency (SEPA) and the Northern Ireland Department of Environment DoENI)
Department for Trade and Industry (DTI) – Offshore Regulator	<ul style="list-style-type: none"> <li>• Ensure that the offshore oil &amp; gas industry (via the trade association, UKOOA) produces annual activity and emissions data in the required format and timescale for inventory estimation and reporting.</li> </ul>	Regulation of the offshore oil & gas industry, including management of the EEMS reporting system of environmental emissions from that sector.

Organisation	Key Roles for the UK GHG inventory	General Responsibilities
DTI, Energy	<ul style="list-style-type: none"><li>• Provide energy statistics in the required format and timescale for inventory estimation and reporting.</li></ul>	Publication of the Digest of UK Energy Statistics each year, to meet DTI and National Statistics requirements.
Department for Communities and Local Government (DCLG)	<ul style="list-style-type: none"><li>• Provide housing statistics in the required format and timescale for inventory estimation and reporting</li></ul>	Responsible for publication of housing statistics each year.
DfT	<ul style="list-style-type: none"><li>• Provide transport statistics in the required format and timescale for inventory estimation and reporting.</li></ul>	Responsible for publication of transport statistics each year.
UK environmental regulators (EA, SEPA, DoENI)	<ul style="list-style-type: none"><li>• Provide the pollutant emission inventories for industrial processes regulated under IPC/IPPC (PI, SPRI, ISR) in the required format and timescale for inventory estimation and reporting</li></ul>	Responsible for the management, compilation, QAQC and reporting of pollutant emission inventories / registers under IPPC regulations.
Devolved Administrations	<ul style="list-style-type: none"><li>• Review aspects of the UK GHG inventory that correspond to devolved issues, ensuring the integration of local datasets and specific research where appropriate</li></ul>	Perform a review function for completeness and accuracy of the GHG inventory from a devolved perspective, integrating findings into local and regional policies and feeding local datasets into the UK inventory system.

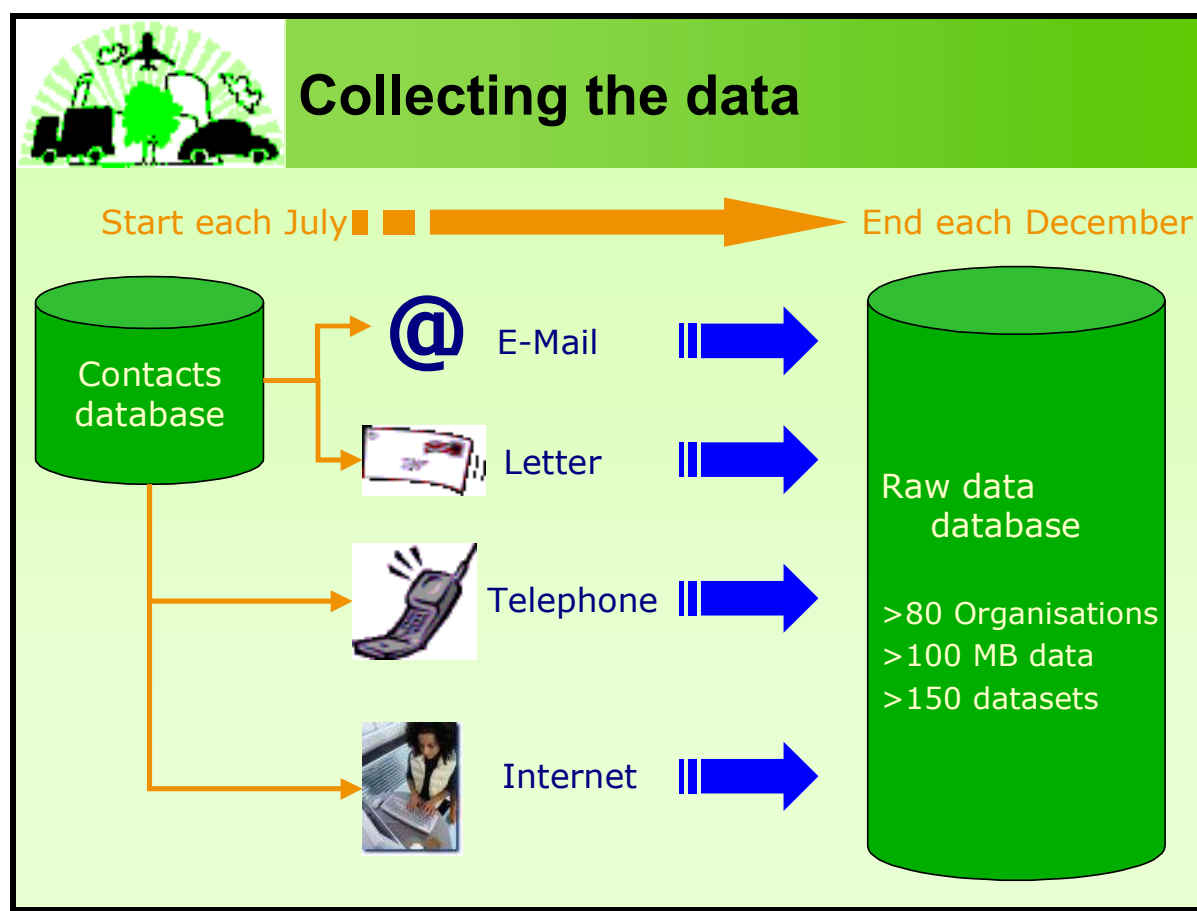
**Table 1.3** Special Advisors to the UK GHG National Inventory Steering Committee

<b>Organisation</b>	<b>Key Roles for the UK GHGI</b>	<b>General Responsibilities</b>
GHG Inventory Agency contractor (Netcen)	<ul style="list-style-type: none"> <li>Plan, prepare and manage all aspects of UK greenhouse gas inventory compilation and development, and deliver NIR and CRF on time to UN and EU each year</li> <li>Participate in sectoral expert panels as required</li> <li>Provide Secretariat support to Steering Committee</li> </ul>	Contractor responsible for national GHG inventory; activity data, methods, emission factors, emissions estimation, reporting and archiving
Agricultural inventory contractor (IGER)	<ul style="list-style-type: none"> <li>Prepare and develop agricultural inventory and deliver on time for incorporation into national inventory</li> <li>Participate in sectoral expert panels as required</li> </ul>	Contractor responsible for agricultural inventory; activity data, methods, emission factors and emissions estimation
LULUCF inventory contractor (CEH)	<ul style="list-style-type: none"> <li>Prepare and develop LULUCF inventory of emissions and removals and deliver on time for incorporation into national inventory</li> <li>Participate in sectoral expert panels as required</li> </ul>	Contractor responsible for LULUCF inventory; activity data, methods, emission factors, emissions and removals estimation
Defra – EPE	<ul style="list-style-type: none"> <li>Provide ad-hoc economic advice to the committee eg. in developing a risk register to enable the committee to review key risks to delivery of annual inventory and develop management strategies</li> </ul>	Ad-hoc economic advice
Defra - LEGAL	<ul style="list-style-type: none"> <li>Provide ad-hoc legal advice to the committee eg in developing data supply agreements with key data suppliers to specify timing, quality, security and format of data require for national inventory</li> </ul>	Ad-hoc legal advice
External reviewers & sector experts	<ul style="list-style-type: none"> <li>Provide a review function to improve &amp; develop the UK GHG inventory</li> </ul>	Ad-hoc feedback and advice on estimation methods, data sources and inventory improvements.

### 1.3 PROCESS OF INVENTORY PREPARATION

**Figure 1.2** outlines the main elements of the data collection system used in the UK inventory. The data acquisition task provides the fundamental activity data from which the GHG inventory is constructed. Starting in July, requests for data are issued. A database of contacts is used to track progress of the data acquired.

**Figure 1.2** Data collection for the UK greenhouse gas inventory



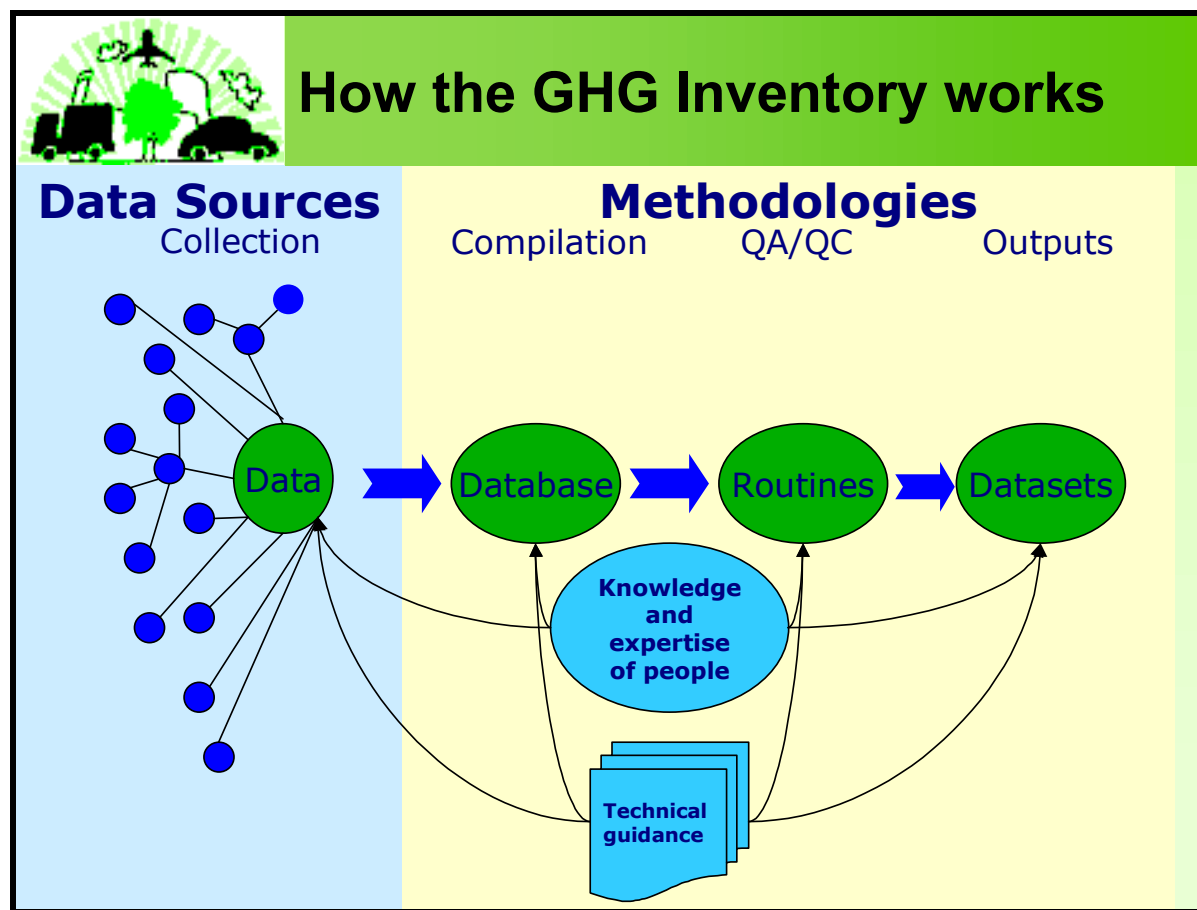
The following activities are carried out each year, in order, as the inventory is compiled:

- *Method Improvement.*  
Improvements to calculation methods are normally implemented before the inventory is compiled. These improvements are in part based on recommendations of UNFCCC (In Depth Reviews, In Country Reviews), peer reviews and relevant research sponsored by Defra or other organisations.
- *Data Requests.*  
Requests for activity data and background data are issued to a wide range of data suppliers. Each request is issued with a unique code, and a database is used to track the request and the data supplied from that request.



- *Data Verification.*  
Activity data received are examined. Anomalies are investigated, such as time series discrepancies, or large changes in values from the previous to the current inventory year.
- *Data Processing.*  
Data are prepared to allow emissions of direct and indirect GHG to be estimated.
- *Emission Estimation.*  
Provisional emissions are estimated using the most recent activity data available.
- *Emissions Review.*  
A series of internal reviews are carried out to detect anomalies in the estimates (time series variations and year to year changes). Errors and omissions are then rectified.
- *Emissions Reporting (including background data).*  
Estimates of emissions are prepared for the various reporting formats (e.g. IPCC, UNECE etc.).
- *Report Generation.*  
Draft reports are written to satisfy the reporting criteria of the various agencies, e.g. the IPCC.
- *Report Review.*  
The reports are reviewed: internally; by external contributing agencies; and by Defra. Errors and omissions are then rectified.
- *Report Publication.*  
Final reports and data sets are then submitted and published in print and on publicly available web sites.

The system outlined above complies with the Tier 1 QA/QC procedures outlined in **Table 8.1** of the Good Practice Guidance (IPCC, 2000).

**1.4 METHODOLOGIES AND DATA SOURCES****Figure 1.3** Data flow through the UK greenhouse gas inventory

The methods used to estimate emissions are described in detail in the relevant sections of this report. The direct and indirect GHGs reported are estimated using methodologies corresponding mostly to the detailed sectoral Tier 2/3 methods in the IPCC Guidelines. **Table 1.2** provides a brief summary of the methods used to estimate UK GHG emissions, which are described in more detail in the subsequent Chapters and Appendices.

**Table 1.4** Summary of methods used to estimate emissions of the direct greenhouse gases

CRF sector	Comments on methods
1A	Basic combustion module (see <b>Annex 3, Section A3.3.1</b> ) Transport model (see <b>Annex 3, Section A3.3.5</b> )
1B	Carbon Balance approach (See <b>Annex 3, Section A3.3.8.1.2</b> ) UKOOA EEMS inventory (See <b>Annex 3, Section A3.3.8.2</b> ) Transco gas leakage model (See <b>Annex 3, Section A3.3.8.2.6</b> )
2A	Cement production: IPCC Tier 2 approach (see <b>Chapter 4, Section 4.4.2</b> )
2B	Emissions calculated based on data from industry and the Pollution Inventory Carbon emissions from certain non-energy uses (NEU) of fuel reported here
2C	Iron and Steel - 2 stage carbon balance (see <b>Annex 3, Section A3.3.3.3 and A3.4.3.1</b> ) Spreadsheet model to estimate emissions of F-gases
2D	Emissions calculated based on USEPA Compilation of Air Emission Factors Emissions calculated based on Industry and Government data sources
2E, 2F	Spreadsheet model to estimate emissions of F-gases
3A	(No direct GHGs emitted from this sector)
3B	(No direct GHGs emitted from this sector)
3C	(No direct GHGs emitted from this sector)
3D	(No direct GHGs emitted from this sector)
4A	Emissions calculated based on animal population data and appropriate EFs
4B	Emissions calculated based on animal population data and appropriate EFs
4D	IPCC recommended methodology
4F	Emissions calculated based on IPCC methodologies and USEPA EFs
5	Spreadsheet model to estimate emissions from LULUCF
6	IPCC recommended methodologies and LQM Solid Waste Disposal model

The sources of data used are documented in the relevant sections of this NIR though much of the activity data are taken from the key publications listed in **Table 1.3**. All sources are updated annually.

**Table 1.5** Summary of sources of activity data used to estimate greenhouse gas emissions

Source (and publisher)	Relevant activity data contained in the source
<b>Digest of UK Energy Statistics</b> (UK Department for Trade and Industry)	<ul style="list-style-type: none"> <li>• Energy statistics for the UK (imports, exports, production, consumption, demand) of liquid, solid and gaseous fuels</li> <li>• Calorific values of fuels and conversion factors</li> </ul>
<b>Transport Statistics GB</b> (UK Department for Transport)	<ul style="list-style-type: none"> <li>• Vehicle km according to vehicle type and road type</li> <li>• Vehicle licensing statistics (split in vehicle km by fuel type)</li> <li>• Selected domestic and international civil aviation aircraft km flown</li> </ul>
<b>Northern Ireland Department of the Environment</b>	<ul style="list-style-type: none"> <li>• Traffic count and vehicle km data for Northern Ireland</li> <li>• Information on regulated processes in NI</li> </ul>
<b>Civil Aviation Authority</b>	<ul style="list-style-type: none"> <li>• Detailed domestic and international civil aviation aircraft km flown</li> </ul>
<b>Pollution Inventory</b> (Environment Agency)	<ul style="list-style-type: none"> <li>• Information on emissions from regulated processes in England and Wales</li> </ul>
<b>Scottish Environmental Protection Agency</b>	<ul style="list-style-type: none"> <li>• Information on regulated processes in Scotland</li> </ul>
<b>United Kingdom Petroleum Industry Association</b>	<ul style="list-style-type: none"> <li>• Refinery emissions,</li> <li>• Lead and sulphur contents of fuels, benzene content of petrol, RVP of petrol</li> </ul>
<b>United Kingdom Offshore Operators Association</b>	<ul style="list-style-type: none"> <li>• Detailed inventory of oil &amp; gas emissions</li> </ul>
<b>Iron and Steel Statistics Bureau</b>	<ul style="list-style-type: none"> <li>• Energy production and consumption in the Iron and Steel industry</li> <li>• Other statistics regarding the Iron and Steel industry</li> </ul>
<b>United Kingdom Minerals Yearbook</b> (British Geological Society)	<ul style="list-style-type: none"> <li>• Statistical data on minerals production, consumption and trade</li> </ul>
<b>Annual Abstract of Statistics</b> (Office for National Statistics)	<ul style="list-style-type: none"> <li>• Population data</li> </ul>

## 1.5 DESCRIPTION OF KEY SOURCE CATEGORIES

Key sources are defined as the sources of emissions that have a significant influence on the inventory as a whole, in terms of the absolute level of the emissions, the trend, or both. **Table 1.6a** and **1.6b** summarises the key source categories derived from the IPCC Tier 1 analysis. Details of the key source analysis are given in **Annex 1**.

**Table 1.6a** Key Source Categories (including LULUCF)

IPCC source category	Fuel/Activity	GHG	Reason (s)
1A	Natural Gas	CO <sub>2</sub>	Level
1A(stationary)	Oil	CO <sub>2</sub>	Level
1A3b	Auto Fuel	CO <sub>2</sub>	Level
5A	5A LULUCF	CO <sub>2</sub>	Level
5B	5B LULUCF	CO <sub>2</sub>	Level, Trend
5C	5C LULUCF	CO <sub>2</sub>	Level
5E	5E LULUCF	CO <sub>2</sub>	Level
4A	Enteric Fermentation	CH <sub>4</sub>	Level
6A	Solid Waste Disposal	CH <sub>4</sub>	Level, Trend
1A1&1A2&1A4&1A5	Other Combustion	N <sub>2</sub> O	Level, Trend
1A3b	Auto Fuel	N <sub>2</sub> O	Level, Trend
2B	Nitric Acid Production	N <sub>2</sub> O	Level, Trend
4B	Manure Management	N <sub>2</sub> O	Level, Trend
4D	Agricultural Soils	N <sub>2</sub> O	Level, Trend
6B	Wastewater Handling	N <sub>2</sub> O	Level, Trend
2	Industrial Processes	HFC	Level

**Table 1.6b** Key Source Categories (excluding LULUCF)

IPCC source category	Fuel/Activity	GHG	Reason (s)
1A	Natural Gas	CO <sub>2</sub>	Level
1A(stationary)	Oil	CO <sub>2</sub>	Level
1A3b	Auto Fuel	CO <sub>2</sub>	Level
4A	Enteric Fermentation	CH <sub>4</sub>	Level
6A	Solid Waste Disposal	CH <sub>4</sub>	Level, Trend
1A1&1A2&1A4&1A5	Other Combustion	N <sub>2</sub> O	Level, Trend
1A3b	Auto Fuel	N <sub>2</sub> O	Level, Trend
2B	Nitric Acid Production	N <sub>2</sub> O	Level, Trend
4B	Manure Management	N <sub>2</sub> O	Level, Trend
4D	Agricultural Soils	N <sub>2</sub> O	Level, Trend
6B	Wastewater Handling	N <sub>2</sub> O	Level, Trend
2	Industrial Processes	HFC	Level

## 1.6 QA/QC PLAN

This section presents the general QA/QC plan for the UK GHGI, including verification and treatment of confidentiality issues. The current system complies with the Tier 1 procedures outlined in the Good Practice Guidance (IPCC, 2000). The system is being developed and the range of activities extended so that the system complies with Tier 2.

Source specific QA/QC details are discussed in the relevant sections of this NIR. Where there is currently insufficient detail available to provide source specific QA/QC, more general information is given in the relevant section of the NIR.

### **1.6.1 Description of the QA/QC current system**

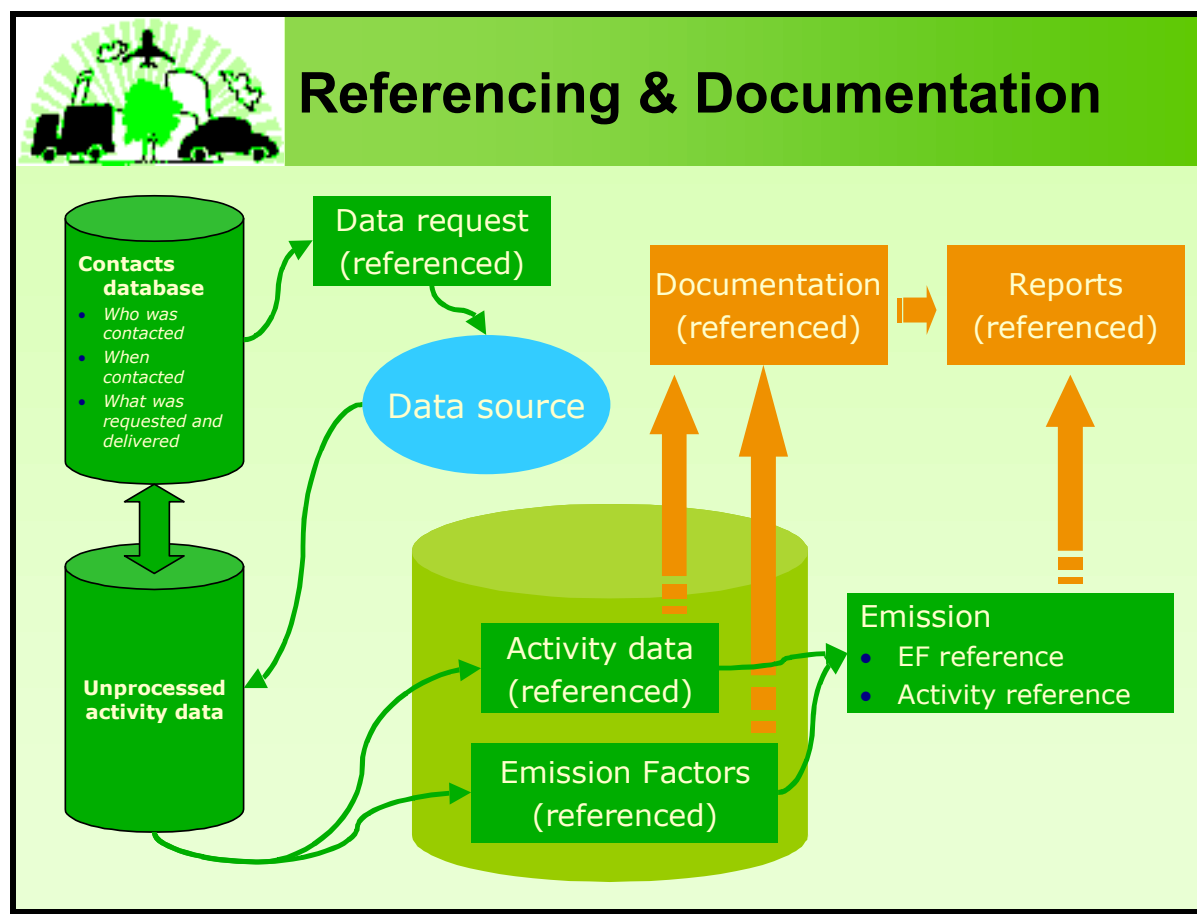
The National Atmospheric Emissions Inventory and the UK Greenhouse Gas Inventory are compiled and maintained by the National Environmental Technology Centre (Netcen), part of AEA Technology plc. The data compilation and reporting for some source sectors of the UK inventory are performed by other contractors (i.e. IGER compile the agriculture sector, CEH compile the land use, land use change and forestry sector), but Netcen is responsible for co-ordinating inventory-wide QA/QC activities.

UK emission estimates are prepared via a central database of activity data and emission factors, from which the UK emissions are extracted and reported in CRF format. The QC within this system has evolved over many years, and is illustrated in Figure 1.4 below.

Numerous stages of QA/QC procedures are built into the data processing system. These include checks before data are entered into the national database of GHG emissions, and when data are extracted from the database. The database contains activity data and emission factors for all the sources necessary to construct the UK GHG inventory.

The Inventory has been subject to ISO 9000 since 1994 and is now subject to BS EN ISO 9001:2000. It is audited by Lloyds and the AEA Technology internal QA auditors. The NAEI has been audited favourably by Lloyds on three occasions in the last ten years. The emphasis of these audits was on authorisation of personnel to work on inventories, document control, data tracking and spreadsheet checking, and project management. As part of the Inventory management structure there is a nominated officer responsible for the QA/QC system – *the QA/QC Co-ordinator*. The National Environmental Technology Centre is currently accredited to BS EN ISO 9001:2000, and was last audited in May 2003 by Lloyds.

**Figure 1.4** System of referencing and documentation used within UK greenhouse gas inventory



The system incorporates the following activities (see **Figure 1.4**), which are carried out each year as the inventory is compiled:

**1. Documentation**

- ▶ Source data received by Netcen are logged, numbered and are traceable back to their source from anywhere in the system, using a contacts database, spreadsheet notes and automated system of data referencing within the main NAEI database of activity data and emission factors.
- ▶ A database provides the mechanism by which all incoming and outgoing data from the inventory is logged and referenced in a transparent way that enables data flows to be traced back to source from any part of the data pathway. This database provides the central hub for data referencing and archiving and also provides a detailed record of data required for inventory compilation and the data source contacts, thereby ensuring both transparency of inventory data flows and consistency in source data acquisition across inventory cycles.
- ▶ Data processing spreadsheets each include a QA sheet in a standard format. This QA sheets provides summary details of source data, data processing activities for each sheet, the scope of activity and emission factor data outputs, relationships with other

processing spreadsheets (where inter-dependencies exist), links to internal consistency checks, plus records of authorship, version control and checking procedures.

- ▶ The inventory is held as a database of activity data and emission factors. Within the database these data fields are referenced to both the data source and the spreadsheet used to process source data. The database is populated via an automated system of querying specific spreadsheets, and data may only be uploaded to the database once it meets specified QAQC criteria of data checking, completion and consistency. The automation routines help to minimise potential human data transcription errors, and are also checked as part of the QA system.
- ▶ Annual reports to UNFCCC and UNECE provide full details of inventory estimation methodologies by source sector, and these reports include summaries of key data sources and significant revisions to methods and historic data, where appropriate.

## 2. ***Database***

- ▶ A consistency check between IPCC output and CORINAIR formatted output is made.
- ▶ Each activity or emission factor data point in the database includes the following information: origin processing sheet, date entered, the person uploading the data (which all ensure traceability and version control), source category, activity category, units (to ensure correct calculation), a code to indicate where there has been a revision from previous inventory versions (which ensures that recalculations of historic data can be easily traced and summarised).
- ▶ Data extracted from the NAEI database and entered into the new CRF Reporter tool are finally checked against the direct database output totals to ensure that any inconsistencies are identified and rectified prior to the CRF submission.

## 3. ***Checking***

- ▶ NETCEN's QA/QC system requires that spreadsheet calculations are checked and the checks applied are described. Also the data sources used for calculations must be referenced on the spreadsheet.
- ▶ All spreadsheets are subject to second-person checking prior to data uploading to the NAEI database.
- ▶ Source data used for calculations are referenced on the spreadsheet QA page with more detailed references (e.g. to a specific table within a referenced publication) noted throughout the processing spreadsheets to ensure transparency of data flows and consistency of inventory compilation.
- ▶ Mass balance checks are made to ensure that the total fuel consumptions in the GHG inventory are in accordance with those published in the official UK Energy Statistics from the DTI.
- ▶ Database output comparisons between different inventory cycles enable the investigation of the effects of recalculations and help identify any data processing errors. A designated auditor identifies sources where there have been significant changes or new sources. Inventory compilers are then required to explain these changes to satisfy the auditor.
- ▶ A final check is made on the inventory comparing the emissions of the latest year with those of the previous year (within the same version), and a complete time-series check is also conducted for selected key sources. A designated checker identifies sources where there have been significant changes. Inventory staff are required to explain



these changes in the inventory to satisfy the checker. This is somewhat more detailed than the recalculation explanations required by Table 8 in the CRF, as it is based on the more disaggregated source sectors used in the NAEI database.

4. ***Recalculation***

- ▶ Where changes are made to inventory estimation methodologies, or where source data are revised or errors in previous inventories identified, then the full time-series of emissions are recalculated. Where this occurs (or where a new source is added to the inventory), the database entries of activity and/or emission factors are labelled with a specific change code as appropriate.

5. ***Uncertainties***

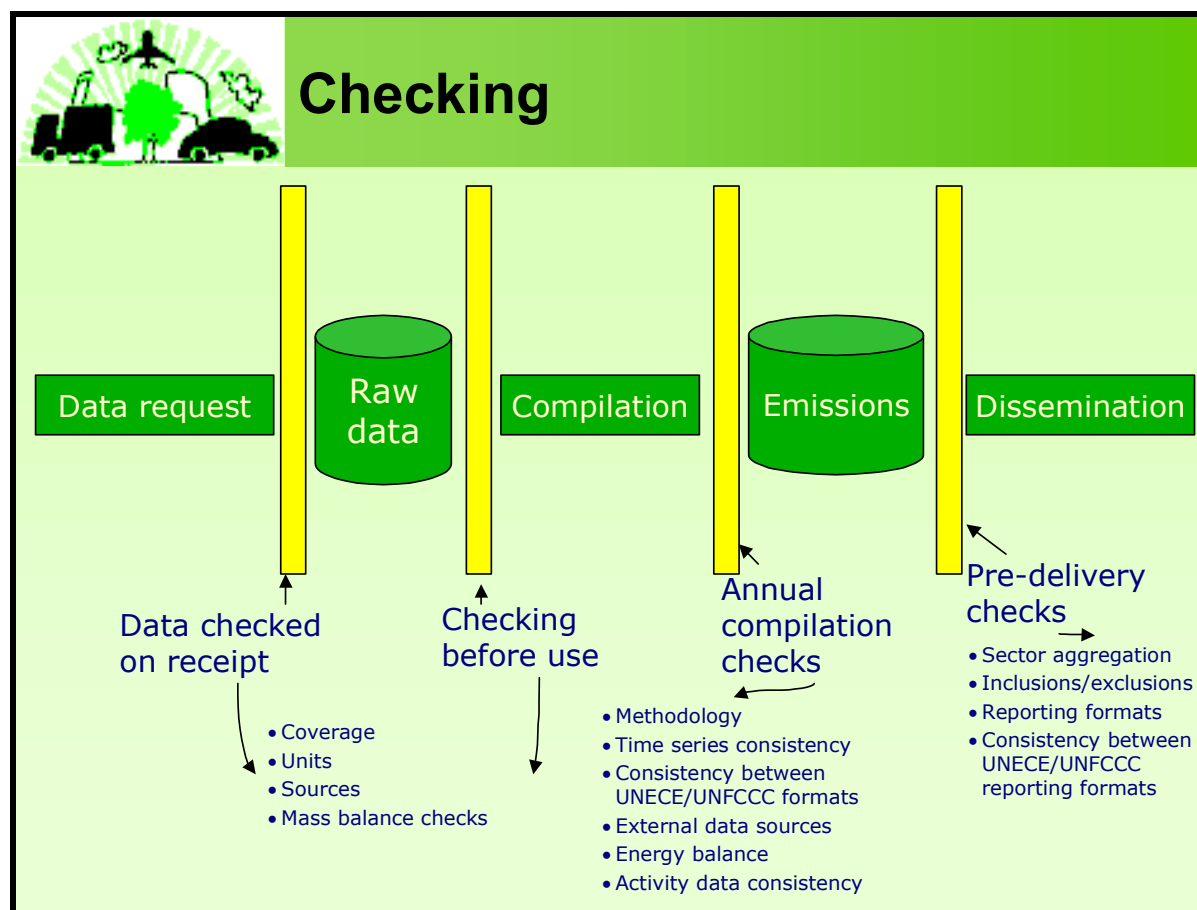
- ▶ Estimates are made of the uncertainties in the estimates according to Tier 1 and Tier 2 procedures set out in the IPCC GPG.
- ▶ A ranking exercise is performed according to Tier 1 procedures to identify key source categories and a Monte-Carlo uncertainty evaluation is conducted across the inventory.

6. ***Archiving***

- ▶ At the end of each reporting cycle, all the database files, spreadsheets, on-line manual, electronic source data, paper source data, output files are in effect frozen and archived. An annual report outlining the methodology of the inventory and data sources is produced. Electronic information is stored on hard disks that are regularly backed up. Paper information is being archived in a Lektreiver® or Roller Racking system and there is a simple database of all items in the archive.

The system outlined in the text above complies with the Tier 1 procedures outlined in Table 8.1 of the Good Practice Guidance (IPCC, 2000). A review of the QA/QC procedures was carried out in 2001 (Salway, 2001) and each year work continues to refine the procedures used.

**Figure 1.5** Summary of the system of data checks used within the UK greenhouse gas inventory  
(The yellow vertical bars symbolise ‘gates’ through which data should not pass until the appropriate checks have been performed)



### 1.6.2 Special QA/QC activities undertaken in 2005-2006

This section describes certain specific activities relating to QA/QC that were carried out during the latest inventory compilation cycle.

#### *Review of QA/QC Provisions and Engagement with Key Data Provider Organisations*

During 2005, UK Defra has focussed on the implementation of provisions to meet the requirements of the Kyoto guidelines for national systems set out in Decision 20/CP.7 of the Marrakesh Accords and corresponding requirements set out in EU Decision 280/2004/EC<sup>6</sup> on a mechanism for monitoring Community greenhouse gas emissions, and for implementing Kyoto Protocol quality and reporting requirements. In addition to the strengthening of legal provisions, Defra and Netcen have reviewed existing arrangements of major data providers regarding QA/QC of source data, and the timeliness and format of data delivered to the UK

<sup>6</sup> Decision No 280/2004/EC of the European Parliament and of the Council of 11 February 2004 concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol

GHG inventory. Through a programme of stakeholder workshops, meetings and email and telephone discussions, information on the development of the UK National Inventory System was disseminated to key data providers and information pertaining to current QA/QC provisions within those organisations was elicited for review.

During the latest inventory cycle, meetings have been held between Netcen and several key organisations to develop the UK National Inventory System and discuss specific quality issues and data sources, including:

- ▶ DTI energy statistics personnel that are responsible for the compilation of UK fuel use estimates across IPCC sectors;
- ▶ Climate change experts within the Devolved Administrations of the UK: the Scottish Executive, Welsh Assembly and Northern Ireland Department of Environment;
- ▶ The Institute of Grasslands and Environmental Research (IGER) as part of the agricultural review;
- ▶ Corus UK Ltd., the UK's main operator of iron & steel manufacturing installations;
- ▶ INVISTA, the UK's sole operator of adipic acid production plant;
- ▶ The British Cement Association.

The programme of stakeholder meetings is ongoing, with meetings planned with UKOOA (the trade association that represents the UK offshore oil & gas industry) and the newly formed businesses that operate within the UK gas supply market, following the division of UK Transco.

The review of existing QA/QC provisions within key data provider organisations identified a range of current practices, summarised below:

- ▶ Formal QA systems and established QC mechanisms exist to ensure the secure provision of assured source data from many Government Departments and Agencies, including: energy balance data from DTI, industrial point source emissions data from UK regulatory sources under IPPC and EU-ETS, housing, population and economic activity data from the Office of National Statistics, emissions from offshore oil & gas installations from UKOOA via the EEMS reporting system to DTI. Many of these data from government departments, agencies, research establishments or consultants meet the QA criteria required of National Statistics, including data from DTI, IGER and BGS.
- ▶ Within individual companies or trade organisations, formal QA systems are evident that have been established either to meet a mandatory reporting requirement or for voluntary internal company reporting procedures primarily regarding energy use, environmental emissions or production. Examples include: refinery emissions data from UKPIA, iron & steel process emissions and energy use data from Corus UK Ltd. & ISSB, mineral activity statistics from the British Geological Survey.
- ▶ We are still acquiring information about the QA/QC systems of several individual companies and trade associations. Where these organisations also reported emissions via an alternative mechanism (e.g. where total site emissions are reported via IPPC or ETS reporting mechanisms but for inventory purposes more detailed plant-specific

data is sought), then the source data can be verified to some extent through comparison with these alternative (mandatory) data sources.

- ▶ Several individual companies or trade associations appear to have limited QA/QC systems currently in place.
- ▶ The UK gas supply industry (formerly under a single organisation, National Grid Transco) has been undergoing a significant re-structuring programme during 2005 with the creation of several new companies to compete within the UK market. Although consistent data have been obtained for 2004 (pre-re-structuring and therefore not subject to issues of commercial confidentiality between the newly-formed companies), it has been impractical to critically assess the functions of the various QA/QC systems within these new organisations, and this is considered a priority for 2006.

Whether the QA/QC system is developed for a mandatory or voluntary reporting mechanism, in a few cases the resourcing and effectiveness of these systems within key data provider organisations could be significantly improved as they currently do not produce reliable data that are consistent across the inventory reporting time-series. Where appropriate, significant revisions of source data are conducted by Netcen during the inventory compilation process, in consultation with the source data organisation, to fill reporting gaps and address specific issues of apparent mis-reporting or inconsistent reporting over the time-series.

The development of documentation of data provider QA/QC systems is ongoing, with resources focussed on the most significant source sectors for the UK inventory. It is anticipated that through the ongoing development of more formal Data Supply Agreements with key organisations during 2006, improvements to source data quality will be achieved over time.

### ***Changes to Data Processing Systems of the Inventory Agency***

Several sector-specific data processing systems have been either replaced by new systems or significantly overhauled to improve the transparency of the data flow or in some cases in response to a change in the availability of source data.

Examples of these developments include:

- Complete review of the system used to calculate emissions from the road transport sector, via the development of a new database.
- Review of the method used to provide the time-series of fuel activity data for combustion sources in the petroleum sector, following a review of the source data leading to the withdrawal of some historic datasets on the grounds that they were deemed unreliable. This particularly affected the gas oil and fuel oil sectors and lead to a complete recalculation of sector-specific fuel use allocations from 1990-2003.
- A revision of the source data used to derive emissions from the offshore oil & gas industry was conducted during autumn 2005 following a review by the UK trade association, UKOOA, in response to the development of the EU-ETS. Several significant changes to emission factors and in some cases gap-filling of activity data

lead to a significant revision of the full time-series of data back to 1990. The data processing spreadsheet was subsequently modified to accommodate the new format UKOOA dataset, and to improve the transparency of the emission estimates.

### **1.6.3 Future development of the QA/QC system**

The programme of UK inventory improvement will be reviewed by the UK GHG Inventory Steering Group Committee during 2006 and in light of UNFCCC ERT feedback and other inputs, inventory QA/QC priorities and improvements will be derived.

Specific sectors that are proposed for review during the next inventory cycle include:

- ▶ GHG emissions from waste water treatment, following a change to the reporting system of UK water companies to integrate GHG emission estimates into their annual reporting requirements;
- ▶ GHG emission estimates of the UKOOA dataset of emissions from the offshore oil & gas industry are to be reviewed via a formal audit of their revised EEMS reporting system during early 2006.

### **1.6.4 Compliance of National Statistical Agencies**

Many of the data received by NETCEN come from other government departments, agencies, research establishments or consultants. Some of these organisations (e.g. DTI, IGER and BGS) would qualify as the *National Statistical Agencies* referred to in the Guidance. Other organisations (e.g. CEH) compile significant parts of the Inventory; data compiled by other organisations are used to compile significant parts of the inventory (e.g. the Pollution Inventory). We are contacting these organisations and inviting them to show how their QA/QC systems comply with IPCC Good Practice Guidance.

### **1.6.5 Documentation and review**

The inventory is documented in the National Inventory Report. The NIR describes the methods used to estimate emissions and presents underlying activity and emission factor data. The Good Practice Guidance highlights the need for review of methodologies during inventory compilation. A list collating and prioritising improvements identified by the Inventory Agency, and from Expert and Peer Reviews, is maintained by the Inventory Agency. These improvements to the inventory are implemented as necessary.

### **1.6.6 External Peer Review and Internal Reviews**

#### ***External Peer Reviews***

Tier 2 of the Good Practice Guidance requires that key sources should be subjected to external peer review. During 2002, the UK implemented a programme of peer reviews by experts outside of the organisation responsible for the estimates. The first peer review on CO<sub>2</sub> emissions from fossil fuel has been completed (Simmons, 2002). Recommendations from this Peer Review, which have now been implemented, include: an improved method for estimating emissions from domestic and international civil aviation; a review of the carbon emission factors used in the UK GHG inventory; and a review of the proportion of recycled lubricants burnt.

The second Peer Review on agriculture was carried out in March 2005. The external reviewers were Prof. Ulrich Daemmgen (Institute of Agroecology, Germany) and Ulrike Doering (Federal Environmental Agency, Germany). Both Prof. Ulrich Daemmgen and Ulrike Doering are internationally recognised experts in the technical area of agriculture. The review team also included the GHG agricultural expert from UK IGER (Lorna Brown) and John Watterson and Chris Dore from NETCEN (representing the Inventory Agency). The review covered: the methods used to estimate agricultural emissions, including emissions from agricultural soils ( $\text{N}_2\text{O}$ ), manure management ( $\text{N}_2\text{O}$ ) and enteric fermentation ( $\text{CH}_4$ ); the underlying activity data and emission factors; uncertainties; and the QA/QC of the emission estimates. The recommendations of the review will be used to help improve the accuracy of the emission estimates from the agricultural sector.

### ***Internal Reviews***

#### **Base Year Review**

This task reviewed the base year emissions of the UK GHG inventory. The 2006 UK Greenhouse gas inventory will be used to set the Assigned Amount on which the reduction during the first commitment period (2008-2012) will be based. It is therefore important that the inventory contains emission estimates for the base year that are neither underestimates nor overestimates so far as can be judged. The work consisted of the following elements:

- ▶ A consideration of the accuracy of emissions from existing sources
- ▶ A review of non- $\text{CO}_2$  emission factors and conversions
- ▶ A review of any missing sources
- ▶ A review of the allocation of emissions and fuels to IPCC sectors
- ▶ A review of the treatment of stored carbon and emissions from the non-energy use of fuels
- ▶ A review of the list of recommendations made by Peer Reviews and following FCCC in-country, centralised and desk reviews.

#### **Review of Non-Energy Uses of Fuel and Stored Carbon**

Previously, the UK Inventory has not used the IPCC default methodology for stored carbon because it was not clear what processes it encompassed or whether it was applicable to the UK. The procedure adopted was to report emissions from the combustion of fuels whilst emissions from the non-energy use (NEU) of fuels were assumed to be zero (i.e. the carbon is sequestered as products) unless a specific process emission was identified.

As part of our review of the base year GHGI estimates, the UK has reviewed the treatment of stored carbon in the UK GHG inventory and the fate of carbon from the NEU of products and the breakdown of those products. This appraisal included a review of the National Inventory Reports (NIRs) of other countries. The US NIR contained a detailed methodology of the approach used in the US inventory to estimate emissions of stored carbon, and the US NIR presents 'storage factors' for a range of products. Some of these factors have been used in the new UK method.

The UK Inventory Agency has conducted a series of calculations to estimate the fate of carbon contained in those petroleum products shown in the 'non-energy use' line of the UK commodity balance tables. The analysis indicates that most of the carbon is 'stored', although a significant quantity does appear to be emitted. Some of the emitted carbon has been included in previous versions of the GHG inventory, e.g. carbon from chemical waste incinerators; most has not. A summary of the estimates of emitted/stored carbon has been produced and this will be presented in a separate technical report. The study also provides subjective, qualitative commentary regarding the quality of the estimates.

The analysis also includes an assessment of the fate of carbon from the use of coal tars and benzoles. Benzoles and coal tars are shown as an energy use in DUKES and up until the 2002 version of the GHGI, the carbon was included in the coke ovens carbon balance as an emission of carbon from the coke ovens.

When the carbon balance methodology was improved for the 2003 GHGI, the UK inventory treated it as a non-emissive output from the coke ovens. However, we were not sure what the ultimate fate of the carbon was but were unable to research this in time for the 2003 GHGI. It was therefore treated as an emission from the waste disposal sector - thus ensuring that total UK carbon emissions were not altered until we had sufficient new information to judge what the fate of the carbon was.

New information from Corus UK Ltd (the sole UK operator of coke ovens) indicates that the benzoles & coal tars are recovered and sold on for other industrial uses, the emissions from which are already covered elsewhere within the inventory. Hence the carbon content from these coke oven by-products is now considered as stored and the carbon emissions included in previous inventories has been removed from the new version of the GHGI.

The analysis estimates emissions from:

- the 'energy' uses of coal tars and benzoles;
- the 'non-energy' uses of petroleum products

Since emissions of carbon are estimated, carbon which is not emitted (i.e. 'stored') can be calculated from DUKES consumption data by difference. The analysis divides the various fossil fuels into six categories:

1. coal tars & benzoles
2. lubricants
3. petroleum coke
4. petroleum waxes
5. bitumen
6. chemical feedstocks (ethane, propane, butane, other gases, naphtha, industrial spirit, white spirit, middle distillate feedstock)

After considering the magnitude of the source in relation to the national totals, the uncertainty associated with emissions, and the likely forthcoming IPCC reporting requirements in the

2006 Guidelines, emissions of carbon from the following additional sources have been included in the 2004 GHG inventory:

- ▶ Petroleum waxes
- ▶ Carbon emitted during energy recovery - chemical industry
- ▶ Carbon in products - soaps, shampoos, detergents etc.
- ▶ Carbon in products - pesticides

A full time series of emissions has been included. For transparency, these emissions are reported in Sector 7 in the CRF rather than aggregating emissions with other sectors.

### **1.6.7 Verification**

Verification is covered as part of the QA/QC checks and by the background research undertaken by Defra. In addition, GAD contributes support and analysis of the continuous high-frequency observations of the Kyoto gases at the Mace Head Atmospheric Research Station on the Atlantic Ocean coastline of Ireland. The UK Met Office employs the Lagrangian dispersion model NAME (Numerical Atmospheric dispersion Modelling Environment) driven by 3D synoptic meteorology from the Unified Model to sort the observations made at Mace Head into those that represent northern hemisphere baseline air masses and those that represent regionally-polluted air masses arriving from Europe. The Lagrangian dispersion model is then used to estimate the magnitude and spatial distribution of the European emissions that best support the observations. The technique has been applied to 2-yearly rolling subsets of the data.

The complete results of this verification and a more detailed description of the modelling method used are given in **Annex 8**.

### **1.6.8 Treatment of confidentiality**

Nearly all of the data necessary to compile the UK inventory are publicly available. The main exception relates to the reporting of emissions from PFCs and HFCs from some sources. For example, private companies that have provided data to estimate emissions of these gases from training shoes have provided data on condition that the data remains confidential, and it is therefore not possible to report emissions of PFC or HFC species from this source in isolation. Therefore, a number of sources are reported in combination, and estimates of the total GWP of emissions in the main IPCC categories are provided.

In addition, industrial production data are commercially sensitive in a handful of cases, such as cement production and adipic acid production. For these sectors, whilst emissions data are reported openly, the production data (required within the CRF to derive Implied Emission Factors to enable cross-party benchmarking) are estimates made by the Inventory Agency.

The UK National Inventory Reports from the 1999 NIR onwards and estimates of emissions of GHGs are all publicly available on the web; see <http://www.naei.org.uk>



## **1.7 GENERAL UNCERTAINTY EVALUATION**

The UK GHG inventory estimates uncertainties using both the Tier 1 and Tier 2 methods described by the IPCC. The Tier 1 approach provides estimates of uncertainties by pollutant according to IPCC sector. The Tier 2 approach provides estimates according to GHG (1990, base year and latest reporting year) and has now been extended to provide emissions by IPCC sector.

The uncertainty in the combined GWP weighted emission of all the greenhouse gases in 2004 was estimated as 14% and in 1990 as 14% also. The trend in the total GWP weighted emissions expressed as the fall between 1990 and 2004 is -14%, with 95% of the values found to lie within the range -11% and -19%. The source making the major contribution to the overall uncertainty is 4D – Agricultural Soils. This source shows little change over the years, but other sources have fallen since 1990.

A full description of the uncertainty analysis is presented in **Annex 7**. The uncertainty estimates for all gases are summarised in **Table A7.4a**.

## **1.8 GENERAL ASSESSMENT OF COMPLETENESS**

The UK GHG inventory aims to include all anthropogenic sources of GHGs. **Table 1.8** shows sources of GHGs that are not estimated in the UK GHG inventory, and the reasons for those sources being omitted. This table is taken from the CRF; Table “Table9s1”. There is more information about the completeness of the GHG inventory in **Annex 5**.

**Table 1.8** Sources not considered in the UK greenhouse gas inventory

GHG	CRF sector	Source/sink category	Reason
CO <sub>2</sub>	2. Industrial Processes	2A5/6 Asphalt Roofing/Paving	No methodology available
CO <sub>2</sub>	3. Solvent and Other Product Use		Carbon equivalent of solvent use not included in total - provided for information
CO <sub>2</sub>	5. Land-Use Change and Forestry	5C2/5C4 Abandonment of Managed Lands	Considered negligible
CH <sub>4</sub>	2. Industrial Processes	2B1 Ammonia Production	Manufacturers do not report emission - believed negligible
CH <sub>4</sub>	2. Industrial Processes	2C1 Iron and Steel	EAF emission and flaring only estimated - methodology not available for other sources
CH <sub>4</sub>	2. Industrial Processes	2C2 Ferroalloys	Methodology not available
CH <sub>4</sub>	2. Industrial Processes	2C3 Aluminium	Methodology not available
CH <sub>4</sub>	6. Waste	6B1 Industrial Waste Water	Activity data unavailable - most waste water treated in public system- believed small
N <sub>2</sub> O	3. Solvent and Other Product Use	3D Other - Anaesthesia	Activity not readily available - believed small

## 1.9 GEOGRAPHICAL COVERAGE OF THE UK GREENHOUSE GAS INVENTORY

A major source of activity data for the UK inventory is provided by the UK DTI through their publication the Digest of UK Environmental Statistics (DUKES) (see **Table 1.3**), and the geographical coverage of DUKES helps define the geographical coverage of the inventory.

The DTI advises that the geographical coverage of the statistics is the United Kingdom (DTI, 2005). Shipments to the Channel Islands and the Isle of Man from the United Kingdom are not classed as exports, and supplies of solid fuel and petroleum to these islands are therefore included as part of the United Kingdom inland consumption or deliveries.

The definition of the UK used by the DTI accords with that of the "economic territory of the United Kingdom" used by the UK Office for National Statistics, which in turn accords with the definition required to be used under the European System of Accounts (ESA95).

The geographical coverage of the UK inventory presented in this NIR has been extended to include emissions from the UK's Crown Dependencies (CDs) and the UK's Overseas Territories (OTs)<sup>7</sup> who have joined, or are likely to join, the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol.

<sup>7</sup> These OTs are the Cayman Islands, Falkland Islands, Bermuda, Montserrat and Gibraltar

The UK has three types of associated territories, which are:

- ▶ Crown Dependencies (CDs)

The Crown Dependencies are the Isle of Man and the Channel Islands. They are not part of the the United Kingdom, and are largely self-governing with their own legislative assemblies and systems of law. The British Government, however, is responsible for their defence and international relations.

- ▶ Overseas Territories (OTs, formerly called Dependent Territories)

The Overseas Territories are constitutionally not part of the United Kingdom. They have separate constitutions, and most Overseas Territories have elected governments with varying degrees of responsibilities for domestic matters. The Governor, who is appointed by, and represents, Her Majesty the Queen, retains responsibility for external affairs, internal security, defence, and in most cases the public service.

- ▶ Sovereign Bases (SBs)

The Sovereign Bases are a subset of Overseas Territories.

The UK submits the same GHG inventory to the European Monitoring Mechanism and the UNFCCC.

## **2. Trends in Greenhouse Gas Emissions**

### **2.1 EMISSION TRENDS FOR AGGREGATED GREENHOUSE GAS EMISSIONS**

As already described in **Chapter 1**, there are six direct greenhouse gases, each with different global warming potentials. In 2004, the total direct greenhouse gas emissions (including LULUCF emissions) in the UK were approximately 663.4 Mt CO<sub>2</sub> equivalent. This was approximately 14.8% below the 1990 level. There was a reduction of about 15.1% relative to the base year under the Kyoto Protocol, which includes F gas emissions for 1995 rather than 1990.

The following sections summarise the emission trends between 1990-2004 for the aggregated greenhouse gases, both by gas and by source. For a detailed breakdown on emission trends for all gases in all sectors, refer to **Annex 6**. Unless otherwise indicated, percentages quoted are relative to net emissions (i.e. emissions including removals from LULUCF).

The percentage changes presented in this chapter are calculated from emission estimates held at full precision within a database. The emissions quoted in Table ES3 and other tables relevant to this Chapter are values rounded from estimates in the database. The percentages that could be calculated from these tables may therefore differ slightly from percentages that can be calculated from the emission estimates held at full precision.

### **2.2 EMISSION TRENDS BY GAS**

The tables shown in **ES2** together with **Figure 2.1** show that the largest contributor to global warming is carbon dioxide at 85% of the weighted emission. Methane contributes 8% and nitrous oxide 6.2%. In spite of their high GWPs the contribution of halocarbons is small at around 1.6% of the total. This is because their mass emissions are very small. Overall the total weighted emission has fallen by 14.8% since 1990 (15.1% relative to the base year under the Kyoto Protocol), with all gases declining.

In 2004, CO<sub>2</sub> emissions were 560.4 Mt CO<sub>2</sub> equivalent, 5.5% below the 1990 level. A small increase in emissions was observed between 2000 and 2001 due to reduced nuclear output, higher coal burn relative to gas and lower outside temperatures.

Methane is the second most significant greenhouse gas in the UK after CO<sub>2</sub>. In 2004, methane emissions were 51.8 Mt CO<sub>2</sub> equivalent. Unlike most of the other major pollutants in the Greenhouse Gas Inventory, fuel combustion is not the predominant source of methane.

The major sources are agriculture, waste disposal, leakage from the gas distribution system and coal mining. Since 1990, emissions of methane have decreased by 50%.

Emissions of nitrous oxide are uncertain because there are many small sources, both natural and anthropogenic. The main anthropogenic sources are agriculture, transport, industrial processes, and coal combustion. In 2004, emissions of nitrous oxide were 40.8 Mt CO<sub>2</sub> equivalent. Emissions have declined 40% since 1990. This decline is due to decreases in emissions from both the agricultural and industrial sectors.

Emissions of the F-gases (HFCs, PFCs, and SF<sub>6</sub>) totalled 10.4 Mt CO<sub>2</sub> equivalent in 2004. Since 1990 the overall decrease in their emissions has been 25%. Improved data from trade associations for the use of SF<sub>6</sub> as a cover gas have led to a complete time series revision. This now shows a decreasing trend in SF<sub>6</sub> emissions as opposed to the increase reported in 2003. This has had a marked effect on the overall F-gases totals. Sources of F-Gases within the UK include: refrigeration and air conditioning, halocarbon production, aerosols and Metered Dose Inhalers (MDI), aluminium production and electronics.

### **2.3 EMISSION TRENDS BY SOURCE**

Weighted greenhouse gas emissions broken down by sector are shown in **Figure 2.2**. Clearly, the largest contribution is from the energy sector, which contributes 86% to the total emissions. Within this category the largest contributions arise from the energy industries (30%) and transport (22%). Category 1A4 (other sectors) and 1A2 (Manufacturing, Industry and construction) also have a significant impact on the emissions of this sector. Energy sector emissions have declined by about 7% since 1990, due to fuel switching, and reduced energy intensity of the economy.

The next largest contribution comes from the agricultural sector. This contributes approximately 7% to the total emissions. The emissions from this sector have shown an overall decrease of 15% since 1990, reflecting trends in livestock numbers and emissions from fertiliser application.

The industrial processes sector (sector 2) contributes 4% to total greenhouse gas emissions. Emissions from this sector include non-energy related emissions from mineral products, chemical industry and metal production as well as emissions from the F-gases. Since 1990, this category has seen a decline in emission of 54%, mostly due to a change in the emissions from the chemical industry

Emissions from the land-use change and forestry (sector 5) contributes 2% to total greenhouse gas emissions in 2004. Emissions from this sector have decreased by 16% since 1990, due to changes in the pattern of land use. Removals due to the forest sink are currently about 2% of gross emissions.

Emissions from the waste sector contributed 3.4% to greenhouse gas emission in 2004. Emissions consist of CO<sub>2</sub>, N<sub>2</sub>O and CH<sub>4</sub> from waste incineration, and CH<sub>4</sub> and N<sub>2</sub>O from both

solid waste disposal on land and wastewater handling. Overall emissions from the waste sector have decreased by 58% since 1990 and this is mostly due to the implementation of methane recovery systems.

## **2.4 EMISSION TRENDS FOR INDIRECT GREENHOUSE GASES AND SO<sub>2</sub>**

The indirect greenhouse gases in the UK consist of Nitrogen Oxides (NO<sub>x</sub>), Carbon Monoxide (CO), Non-Methane Volatile Organic Compounds (NMVOC) and Sulphur dioxide (SO<sub>2</sub>). Of these, NO<sub>x</sub>, CO and NMVOC can increase tropospheric ozone concentration and hence radiative forcing. Sulphur dioxide contributes to aerosol formation in the atmosphere. This is believed to have a negative net radiative forcing effect, tending to cool the surface. Emission trends for the indirect greenhouse gases are shown in **Figure 2.3**.

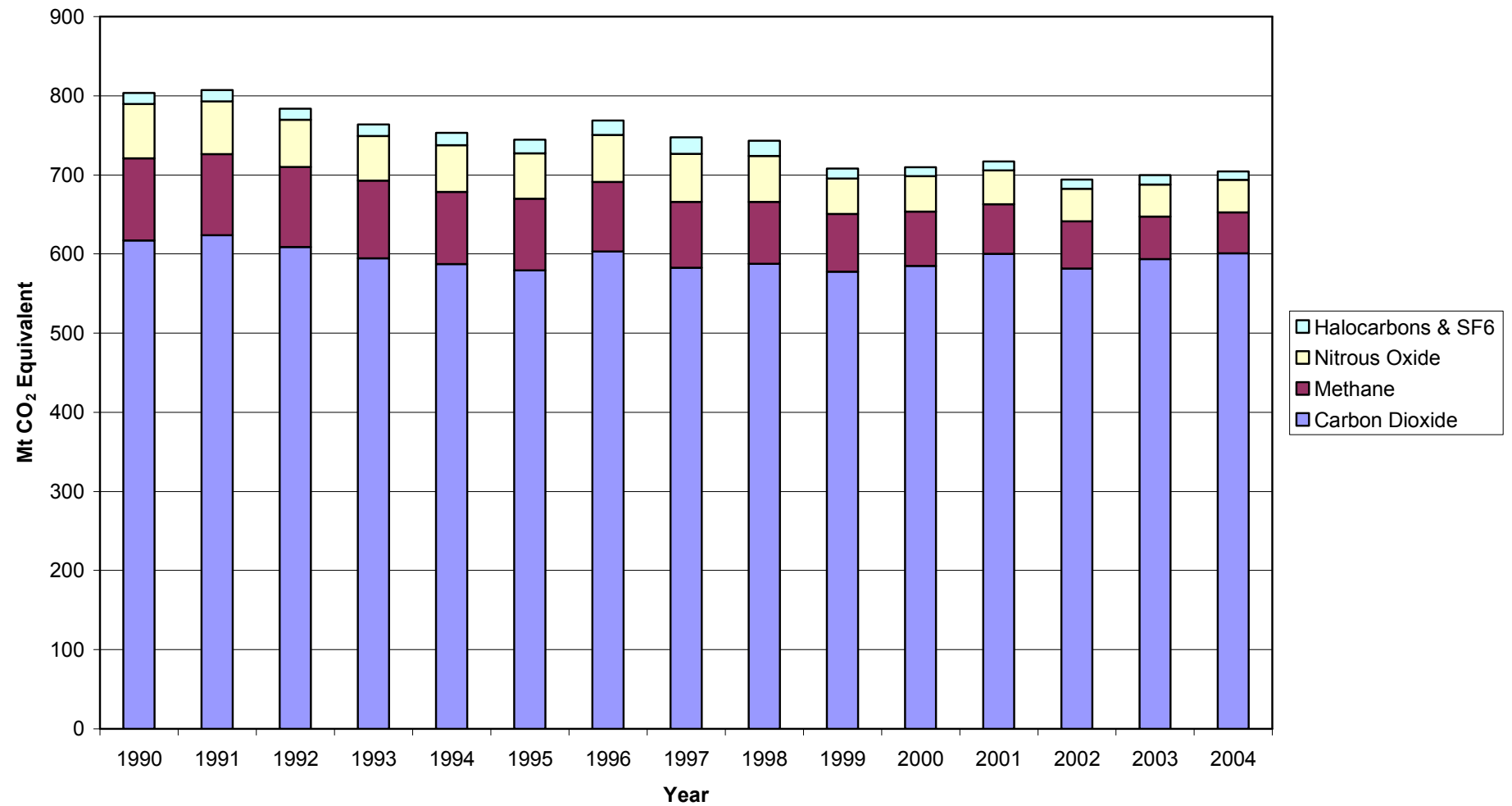
The main source of NO<sub>x</sub> in the UK is fuel combustion. These emissions are complex as the nitrogen can be derived from both the fuel and the combustion air. Emissions also depend on the conditions of combustion, which can vary considerably. In 2004, the total emissions were 1621 Gg, with 99.7% of these emissions arising from the energy sector. Since 1990, emissions have decreased by 45%, mostly as a result of abatement measures on power stations, three-way catalytic converters fitted to cars and stricter emission regulations on trucks.

Carbon monoxide arises from incomplete fuel-combustion. In 2004, the total emissions were 2919 Gg, of which 94% were from the energy sector. Since 1990, emissions of CO have decreased by 65%. This is mostly as a result of the increase in use of catalytic converters although a proportion is a consequence of fuel switching from petrol cars to diesel cars. The other significant reduction arises from in the agricultural section due to the cessation of agricultural stubble burning in 1993.

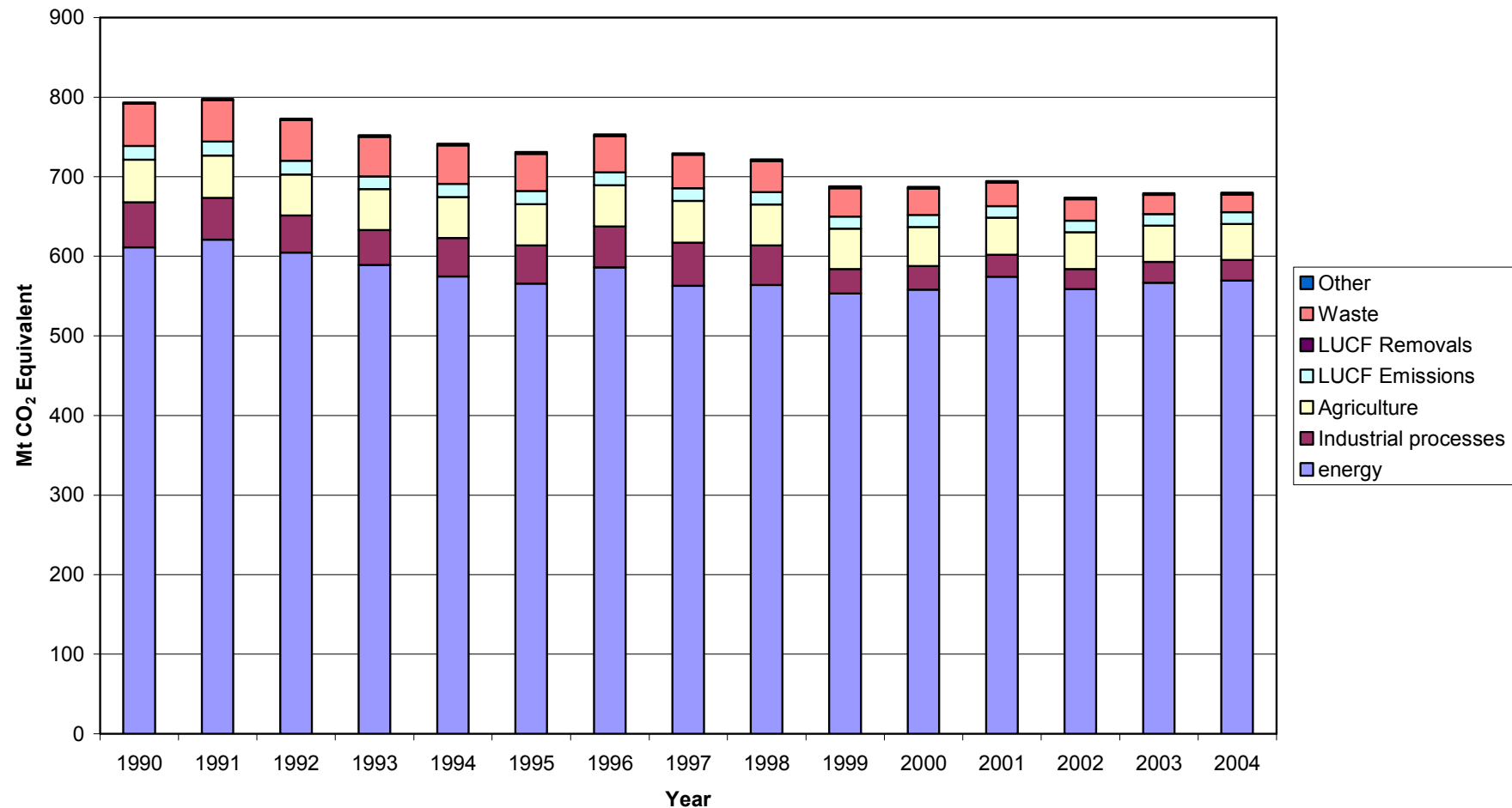
In 2004, total emissions of NMVOCs were 1022 Gg, of which 45.5% were from the energy sector, with other significant contributions from solvent and other product use and industrial processes. The development of an accurate emission inventory for NMVOCs is complex. The diversity of processes emitting NMVOC is large. Often emissions from sources are small individually, but important collectively. A good example of this is leakage from valves, flanges and other connections in petrochemical plants. Since 1990, overall emissions of NMVOCs have decreased by 57%. This decrease in emissions can, in part be attributed to the increased use of catalytic converters on cars as well as the switching from petrol to diesel cars.

Total SO<sub>2</sub> emissions in 2004 were 833 Gg. Of this, 96% of emissions were from the energy sector, with the remaining emissions arising from the industrial processes sector and a small proportion from the waste sector. Since 1990, emissions of SO<sub>2</sub> from the energy sector have decreased by 77%. The decrease has been as a result of the increase in the proportion of electricity generated in nuclear plant and the use of Combined Cycle Gas Turbine (CCGT) stations and other gas fired plant.

**Figure 2.1: UK Net Emissions of Greenhouse Gases Weighted by GWP**

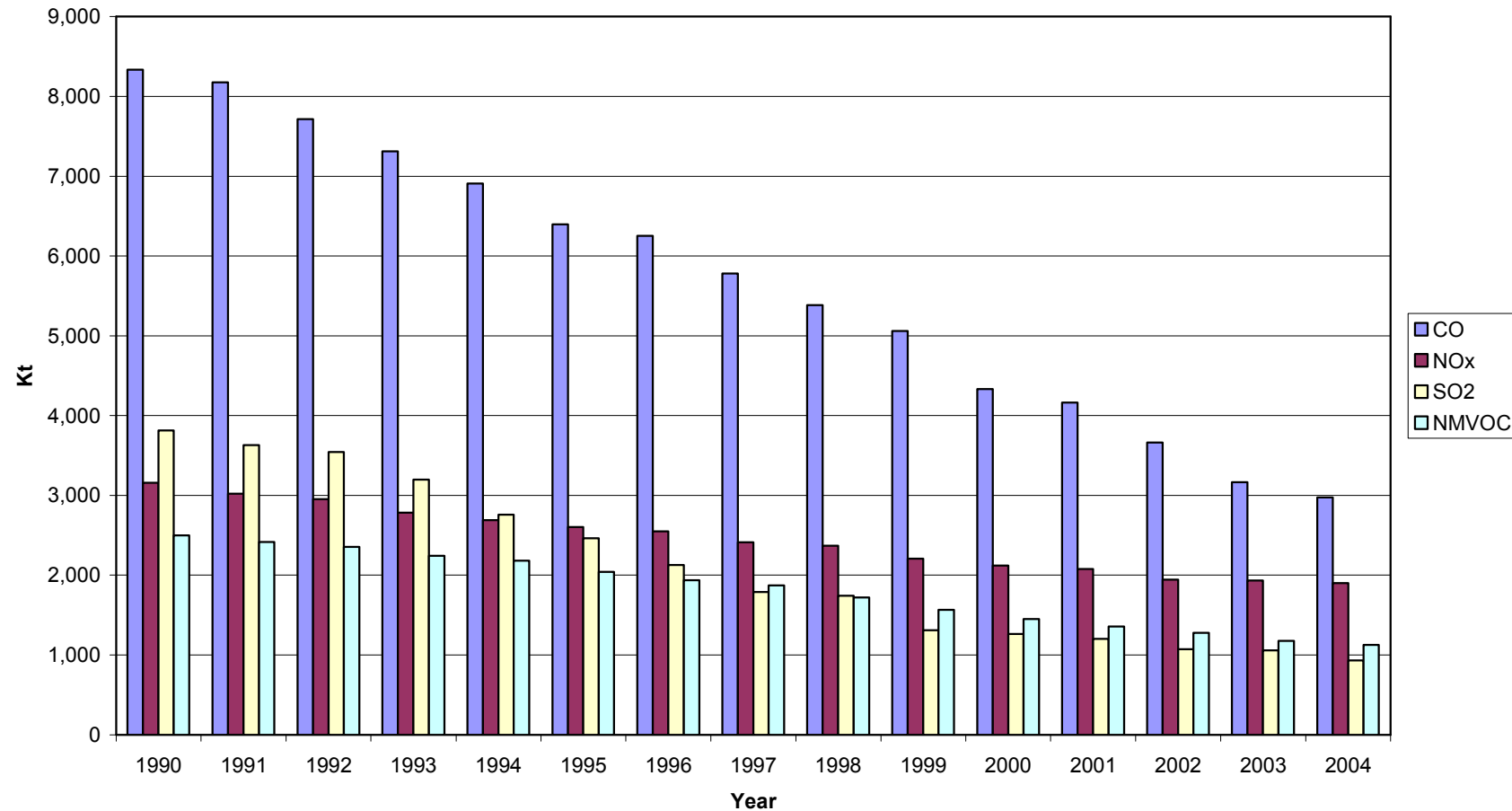




**Figure 2.2: UK Net Emissions of Greenhouse Gases by Source**

'Solvent and Other Product Use' is not shown in Figure 2.2 as it has zero emissions for all years.

**Figure 2.3: UK Net Emissions of Indirect Greenhouse Gases**



## **3. Energy (CRF sector 1)**

### **3.1 OVERVIEW OF SECTOR**

The energy sector is the largest emitter of greenhouse gases in the U.K. As noted in **Section 2.3**, in 2004, 86% of direct greenhouse gas emissions came from this sector. Major sources include power stations, road transport, combustion from industrial sources and provision of building services. Fugitive emissions are also accounted for in this sector. These are emissions that arise from the production, extraction of coal, oil and natural gas, and their storage, processing and distribution.

**Annex 3.3** contains more detailed descriptions of the methods used to estimate emissions in this sector.

### **3.2 SOURCE CATEGORY 1A1 – ENERGY INDUSTRIES**

#### **3.2.1 Source category description**

This source category includes: electricity generation, the use of fossil fuels for petroleum refining, and the production of coke and solid smokeless fuels.

The main fossil fuels used by the UK electricity supply industry are bituminous coal and natural gas. Approximately 48 mtonnes of coal was burnt at 17 power stations during 2004, while 10,330 Mtherms of natural gas was consumed at 37 large power stations and 9 small regional stations (mostly Combined-Cycle Gas Turbines, CCGTs). Heavy fuel oil is the main fuel at 5 facilities, and gas oil is used by 16 small power stations.

Bio-fuels are burnt at an increasing number of power generation sites as electricity generators strive to meet Government targets for renewable energy production. Four established sites use poultry litter as the main fuel and another site burns straw, whilst several coal-fired power stations have increased the use of other biofuels such as short-rotation coppice to supplement the use of fossil fuels.

Electricity is also generated at 19 Energy from Waste plant (EfW) plant in the UK. Formerly referred to as municipal solid waste (MSW) incinerators, all such plant are now required to be fitted with boilers to raise power and heat, and their emissions are therefore reported under CRF source category 1A1 (electricity generation) and 1A4 (heat generation), rather than 6C (Waste Incineration). This has been the case since 1997; prior to that year at least some MSW was burnt in older plant without energy recovery. Emissions from these incinerators were reported under 6C.

The UK has 12 oil refineries, 3 of these being small specialist refineries employing simple processes such as distillation to produce solvents or bitumens only. The remaining 9 complex refineries are much larger and produce a far wider range of products including refinery gases, petrochemical feedstocks, transport fuels, gas oil, fuel oils, lubricants, and petroleum coke.

The crude oils processed, refining techniques, and product mix will differ from one refinery to another and this will influence the level of emissions from the refinery, for example by dictating how much energy is required to process the crude oil.

Most UK coke is produced at coke ovens associated with integrated steelworks, although one independent coke manufacturer also exists. At the end of 2004, there were four coke ovens at steelworks and one independent coke oven. A further three coke ovens have closed in the last two years, due to closure of associated steelworks or closure of other coke consumers. Solid smokeless fuels (SSF) can be manufactured in various ways but only those processes employing thermal techniques are included in the inventory since these give rise to significant emissions. Currently, there are three sites manufacturing SSF using such processes.

### **3.2.2 Methodological issues**

Most emissions are estimated from information such as fuel consumption data and estimates for a particular source sector are calculated by applying an emission factor to an appropriate statistic (see **Annex 3, Section A3.3** for details). This method is applied to estimating emissions from this sector for direct greenhouse gases. General fuel consumption statistics taken from DUKES (DTI, 2005) are applied to emission factors to give an estimation of the emission. Some emissions of indirect greenhouse gases are also estimated in this way (see **Table 3.1** for details).

Some alterations are made to the basic fuel consumption statistics available from DUKES. This is done in order to ensure consistency between the GHGI and fuel usage data reported by certain process operators. Overall fuel consumption in the GHGI is, however, still consistent with DUKES. One of these alterations has been introduced for the first time in this version of the inventory: coal usage by power stations has been reduced in order to allocate that coal to cement works. This is done because DUKES does not report sufficient coal for this sector compared with the coal usage reported by UK cement kiln operators directly to Netcen.

A further reallocation concerns fuel oil consumed in power stations. DUKES reports less fuel oil burnt by major power producers than is reported directly to Netcen. Therefore fuel oil is reallocated from industry to power stations to ensure consistency with operator data. This reallocation was introduced to the inventory in previous versions but some input data have been revised for this version, leading to changes in the estimated fuel use.

For some sectors, emissions data are available for individual sites, either from the Environment Agency for England and Wales (EA, via the Pollution Inventory), from the Scottish Environment Protection Agency (SEPA, via the Scottish Pollutant Release Inventory) or from the Inventory of Statutory Releases (ISR) of the Department of the Environment in Northern Ireland (DOENI). In such cases, the emission for a particular sector can be calculated as the sum of the emissions from these point sources. However, in order to make an estimate of emissions from non-point sources in the sector, an independent estimate of fuel consumption associated with these point sources needs to be made, to ensure no double counting occurs (See **Annex 3, Section A3.3**). This method is applied to emissions of indirect greenhouse gases for sectors as shown in **Table 3.1**. Detailed tables of emission factors for both direct and indirect greenhouse gases can be found in **Annex 3, Tables A3.3.1–A3.3.4 and A3.3.6**.

**Table 3.1** Methods used for deriving emission estimates for direct and indirect greenhouse gases for CRF Source Category 1A1

Pollutant	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO	NO <sub>x</sub>	SO <sub>2</sub>	NMVOC
Power Stations	F	F	F	R	R	R	R
MSW incineration	F	F	F	R	R	R	R
Refineries	F	F	F	F/R	F/R	F/R	F
Coke ovens	F	F	F	F/R	F/R	R	F/R
SSF Manufacture	F	F	F	R	R	F	F

Key:

- F national emission estimates derived from emission factors and fuel consumption statistics (mostly DUKES)  
R national emission estimates derived from emission estimates reported by process operators to regulators  
F/R national emission estimates derived from either emission factors and fuel consumption statistics or emission estimates reported by process operators to regulators, depending upon fuel type.

### 3.2.2.1 Uncertainties and time-series consistency

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

Most of the core activity data for this source category is derived from the DTI publication the Digest of UK Energy Statistics. **Section 3.15** provides further general information about the time series consistency of activity data in this publication, and provides more general comments on the approaches used to ensure time series consistency in source category 1A.

Combustion emissions from the NAEI category ‘Gas separation plant’ are reported under category 1A1c (see **Annex 3, Table A3.2**). Background energy data for the calculation of these emissions are taken from the most up to date version of the Digest of UK Energy Statistics. In the DUKES published in 2002, the DTI stopped collecting the activity data about oil and gas extraction previously used to estimate these emissions. Therefore, for data from 2001 onwards, the amount of propane and ethane has been extrapolated from historical data, as advised through discussions with DTI.

**Table 3.2** Time series consistency of emission factors (EFs) of direct GHGs used in source category 1A1

GHGs	Source category	Fuel types	Comments on time series consistency
Carbon	1A1	All fuels	<ul style="list-style-type: none"> <li>EFs vary somewhat across the time series based on comprehensive carbon factor review in 2004.</li> <li>Key sources of carbon EF data include: UKPIA, Association of Electricity Producers, Powertech, Transco.</li> </ul>
CH <sub>4</sub> , N <sub>2</sub> O	1A1	All fuels	<ul style="list-style-type: none"> <li>Nearly all EFs are constant over the entire time series, with limited use of time-varying EFs due to fuel variability or technological developments.</li> <li>Increased availability of data from emissions of combustion of poultry litter has resulted in variable EFs across the time-series for both CH<sub>4</sub> and N<sub>2</sub>O.</li> </ul>

### **3.2.3 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

The core publication for Activity Data is the annual DTI publication “The Digest of UK Energy Statistics” which is produced in accordance with QA/QC requirements stipulated within the UK Government’s “National Statistics Code of Practice” and as such is subject to regular QA audits and reviews.

Where emissions data are provided by plant operators to the UK environmental regulatory agencies (EA, SEPA, DOENI) and reported via their respective inventories of pollutant releases (and then used in the UK’s GHG emission inventory) the data is subject to audit and review within established QA systems. Within England & Wales, the operator emission estimates are initially checked & verified locally by their main regulatory contact (Site Inspector), and then passed to a central Pollution Inventory team where further checks are conducted prior to publication. Specific checking procedures include: benchmarking across sectors, time-series consistency checks, checks on estimation methodologies and the use and applicability of emission factors used within calculations. Similar systems are being developed by SEPA and DOENI, with some routine checking procedures already in place.

### **3.2.4 Source-specific recalculations**

The most significant recalculation has been the revision to coal consumption data for power stations. This has been done to allow coal to be reallocated to the cement sector thereby maintaining consistency between the GHGI and cement kiln operators’ data.

Some recalculations for indirect greenhouse gases have been made following a review of the data available for calculating emissions from power stations. The existing methodology continues to be used but input data and assumptions used for the calculations have been updated and supplemented. The methodology for estimating emissions of CO and NO<sub>x</sub> from SSF manufacture has been changed, with estimates now based on operators’ reported data rather than on literature emission factors.

#### **3.2.4.1 Recalculation by gas**

The following section describes the main changes that have occurred in sector 1A1 per pollutant since the publication of the 2003 inventory (2005 NIR). Comparisons are made between the current inventory (1990-2004) and the previous inventory (1990-2003) for the year 2003.

##### **3.2.4.1.1 Carbon Dioxide (CO<sub>2</sub>)**

- Overall there has been a decrease in estimated emissions of 4409 Gg CO<sub>2</sub> from sector 1A1. This decrease has been caused by both energy statistics revisions and emission factor changes. The more major causes of this decrease are described below.
- There has been an increase in estimated emissions of 325 Gg CO<sub>2</sub> from fuel oil from power stations due to a revision in the energy statistics.



### 3.3 SOURCE CATEGORY 1A2 – MANUFACTURING INDUSTRIES AND CONSTRUCTION

#### 3.3.1 Source Category Description

This source category covers the use of fossil fuels by industrial processes, including the use of fuels to generate electricity in cases where the generation of electricity is not the principal activity of the process operator (“autogenerators”). The GHGI separately reports emissions from autogenerators, cement clinker manufacture, lime manufacture, and iron & steel processes. Only those iron & steel industry emissions from the use of fossil fuels in boilers and heat treatment furnaces, the use of coke in sinter plant and the use of coke oven gas, blast furnace gas and natural gas in the hot stoves used to heat air for blast furnaces are reported under 1A2. Other sources such as emissions of carbon from basic oxygen furnaces are reported under 2C1. Emissions from fuel used by other industrial sectors (e.g. chemicals, non-ferrous metals, food & drink) are reported as 'other industry'.

An estimate of CO emissions from manufacture of soda ash is also reported under 1A2. This emission arises due to the burning of coke as part of the process but, due to the nature of that process, CO emissions are considerably higher than would be the case for burning of coke in conventional combustion plant.

#### 3.3.2 Methodological Issues

Emissions of direct greenhouse gases are estimated using the principles of the basic combustion model, as described in **Annex 3, Section A3.3.1**. The DUKES publication is used to obtain relevant activity statistics, as well as data collected from industry. There are a number of sources of emission factors and these can be found in **Annex 3, Tables A3.3.1–A3.3.4**. Methods used to calculate emission estimates for both direct and indirect gases are summarised in **Table 3.3**.

**Table 3.3** Methods for calculation of direct and indirect greenhouse gas emissions from 1A2

Sector/pollutant	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO	NO <sub>x</sub>	SO <sub>2</sub>	NMVOC
Cement Fuel Combustion	Emission factors and fuel consumption data			No emissions reported			
Cement Clinker production	No emissions reported			Emissions data reported by process operators to regulators			
Lime Manufacture	Emission factors and fuel consumption data			Emissions data from regulators		Emission factors and fuel consumption data	
Autogenerators <sup>1</sup>	Emission factors and fuel consumption data						
Other Industry	Emission factors and fuel consumption data <sup>2</sup>						
Sinter Plant	Emission factors and fuel consumption data			Emissions estimates for individual sites provided by process operators			

<sup>1</sup> For the largest coal fired autogenerator, emissions data from the Pollution Inventory is used for CO, NO<sub>x</sub>, SO<sub>2</sub>

<sup>2</sup> Emission estimated for NO<sub>x</sub> based on a combination of reported data for large combustion plant and literature based emissions factors and fuel consumption for small plant



### 3.3.3 Uncertainties and time-series consistency

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

Most of the core activity data for this source category is derived from the DTI publication the Digest of UK Energy Statistics. **Section 3.15** provides further general information about the time series consistency of activity data in this publication, and provides more general comments on the approaches used to ensure time series consistency in source category 1A.

**Table 3.4** summarises the time series consistency of emission factors used in source category 1A2.

**Table 3.4** Time series consistency of emission factors of direct GHGs used in source category 1A2

GHGs	Source category	Fuel types	Comments on time series consistency
Carbon	1A2	All fuels	<ul style="list-style-type: none"> <li>EFs vary somewhat across time series based on comprehensive carbon factor review in 2004, with UKPIA providing new CEF data for many fuels used in this sector.</li> </ul>
CH <sub>4</sub> , N <sub>2</sub> O	1A2	All fuels	<ul style="list-style-type: none"> <li>Nearly all EFs are constant over the entire time series, with limited use of time-varying EFs due to fuel variability or technological developments.</li> </ul>

### 3.3.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Allocations of fuel use are primarily derived from DTI publications that are subject to established QA/QC requirements, as required for all UK National Statistics. For specific industry sectors (iron & steel, cement, lime, autogeneration) the quality of these data are also checked by the Inventory Agency through comparison against operator-supplied information and un-verified Emission Trading Scheme baseline datasets (covering 1998 to 2003). As discussed above, there have been instances where such information has led to amendments to DTI-reported fuel allocations (through fuel re-allocations between sectors).

### 3.3.5 Source-specific recalculations

Amendments to fuel (gas oil, DERV) consumption estimates for agricultural vehicles and mobile machinery (see **Section 3.5** for details) have had a knock-on effect on the estimates of gas oil use in stationary plant by industry, the public and commercial sectors and other sectors. Changes across sectors have been made to maintain consistency with the total UK consumption of gas oil reported in DUKES.

As already described in **Section 3.2.2**, a reallocation of coal from the power sector to the cement sector has been made to ensure that the coal use data in the GHGI matches that provided by the British Cement Association (2005). The BCA provided new datasets for recent years, based on information reported by each cement kiln operator in the derivation of Emission Trading Scheme baseline data. This new dataset has prompted revisions of a range

of fuel data (primarily coal & petcoke). All such revisions were agreed following consultation with the DTI, and indeed it transpired that the DTI has some evidence of coal sales between power generators and cement operators that would further support the changes made.

### **3.3.5.1 Recalculation by gas**

The following section describes the main changes that have occurred in sector 1A2 per pollutant since the publication of the 2003 inventory (2005 NIR). Comparisons are made between the current inventory (1990-2004) and the previous inventory (1990-2003) for the year 2003.

#### **3.3.5.1.1 Carbon Dioxide (CO<sub>2</sub>)**

- Estimated emissions of CO<sub>2</sub> from 1A2 have decreased by 1533 Gg although there have been a number of very significant revisions to estimates for individual sources including both large increases and large decreases in estimates. Details of the more major changes are given below.
- Estimated emissions from combustion of gas oil in stationary industrial plant have decreased by 9073 Gg CO<sub>2</sub> due to the reallocation of gas oil consumption to off-road vehicles and mobile machinery. Estimated emissions from off-road vehicles and machinery operated by industry have increased by 5267 Gg CO<sub>2</sub> as a result of the reallocation. Gas oil has also been reallocated to sectors reporting to 1A4.
- Emission estimates for carbon from cement kilns have increased by 1221 Gg in 2003 as a result of the replacement of fuel usage estimates based on DUKES with actual fuel usage data supplied by kiln operators.
- Estimated emissions from combustion of natural gas by the iron and steel industry have decreased by 1631 Gg CO<sub>2</sub>, and estimated emissions from combustion of fuel oil by the same sector have increased by 519 Gg CO<sub>2</sub>, both due to activity data revisions.
- Estimated emissions from combustion of natural gas by industry have increased by 1211 Gg CO<sub>2</sub> due to revisions to energy data.

#### **3.3.5.1.2 Nitrous oxide (N<sub>2</sub>O)**

- Estimated emissions from industrial off-road vehicles and mobile machinery have increased by 2 Gg due to revisions to the estimates of gas oil usage by this sector. Estimates for emissions from stationary industrial plant have decreased by 0.1 Gg as gas oil usage from this sector has been reallocated to the off-road sector.

#### **3.3.5.1.3 Nitrogen Oxides (NO<sub>x</sub>)**

- Estimated emissions from industrial off-road vehicles and mobile machinery have increased by 72 Gg due to revisions to the estimates of gas oil usage by this sector. Estimates for emissions from stationary industrial plant have decreased by 11 Gg as gas oil usage from this sector has been reallocated to the off-road sector.
- Estimated emissions from natural gas combustion by the iron and steel industry have decreased by 10 Gg due to revisions to energy statistics.

#### 3.3.5.1.4 Carbon Monoxide (CO)

- Estimated emissions from industrial off-road vehicles and mobile machinery have increased by 29 Gg due to revisions to the estimates of gas oil usage by this sector. Estimates for emissions from stationary industrial plant have decreased by 1 Gg as gas oil usage from this sector has been reallocated to the off-road sector.
- Estimated emissions from natural gas combustion by the iron and steel industry have decreased by 10 Gg due to revisions to energy statistics.
- Estimated emissions from industrial wood combustion have increased by 7 Gg due to revisions to energy statistics.
- Emission estimates for coke use in sinter strands have increased by 6 Gg. This is due to revision of the emission factor, following the provision of new data by UK process operators.

#### 3.3.5.1.5 Sulphur Dioxide (SO<sub>2</sub>)

- Estimated emissions from industrial off-road vehicles and mobile machinery have increased by 5 Gg due to revisions to the estimates of gas oil usage by this sector. Estimates for emissions from stationary industrial plant have decreased by 9 Gg as gas oil usage from this sector has been reallocated to the off-road sector.
- Estimated emissions from industrial coal combustion increased by 9 Gg due to changes in both activity data and emission factors.

#### 3.3.5.1.6 Volatile Organic Compounds (VOC)

- Estimated emissions from industrial off-road vehicles and mobile machinery have increased by 11 Gg due to revisions to the estimates of gas oil usage by this sector. Estimates for emissions from stationary industrial plant have decreased by only 0.1 Gg despite gas oil usage from this sector being reallocated to the off-road sector. This reflects the considerably higher emission factors for off-road vehicles compared with stationary plant.

### 3.3.6 Source-specific planned improvements

Emission factors and activity data will be kept under review. Fuel characterisation data from verified Emission Trading Scheme datasets will be considered in future GHGI cycles.

## 3.4 SOURCE CATEGORY 1A3 – TRANSPORT

### 3.4.1 Source Category Description

This source category reports the emissions of pollutants from transport. Emissions from aviation, railways, road transport, and shipping are covered by this category. Aircraft support vehicles are also covered under 1A3e. Road transport is by far the largest contributor to transport emissions and estimations are made for a wide variety of vehicle types using both petrol and diesel fuel.

The UK GHGI reports emissions from both stationary and mobile sources for railways. Stationary emissions are reported under category 1A4a. Mobile emissions, which are reported under 1A3c cover estimates from diesel trains as freight, intercity and regional.

Emission estimates from the navigation section (1A3d) cover coastal shipping and international marine.

### 3.4.2 Methodological Issues

The IPCC requires an estimate of emissions from 1A3ai International Aviation and 1A3Aii Domestic to include emissions from the cruise phase of the flight as well as the LTO<sup>8</sup>. Emissions from aviation comprise emissions from the landing and take-off phases and the cruise phase of the flight. An improved technique to estimate emissions and fuel use for civil aircraft in the UK has been developed and is now used. The approach follows the IPCC Tier 3 method. The method estimates emissions from both domestic and international aviation. Details can be found in **Annex 3, Section A3.3.5.1**.

Emissions from road transport are calculated either from a combination of total fuel consumption data and fuel properties or from a combination of drive related emission factors and road traffic data. Details are discussed in **Annex 3, Section 3.3.5.3**.

Details on emission estimates from railways can be found in **Annex 3, Section 3.3.5.2**.

Emission estimates for coastal shipping are estimated according to the base combustion module (**Annex 3, Section A3.3.1**) using emission factors given in **Table A3.9**. For International marine, fuel consumption data are assumed to be the marine bunkers total minus the naval consumption. Emission factors are used from **Table A3.9**

### 3.4.3 Uncertainties and time-series consistency

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

Some of the core activity data for this source category are derived from the DTI publication the Digest of UK Energy Statistics. **Section 3.15** provides further general information about the time series consistency of activity data in this publication, and provides more general

<sup>8</sup> As distinct from the NAEI category air transport which gives an estimation of emissions within a 1000 m ceiling of landing and take-off (LTO), because of the reporting requirements of other international treaties.

comments on the approaches used to ensure time series consistency in source category 1A. Other important sources of activity data are UK Department for Transport publication Transport Statistics Great Britain and fuel consumption data supplied by the Ministry of Defence (Defence Fuels Group). Transport Statistics Great Britain is an established publication and the compilers of the activity data strive to use consistent methods to produce the activity data.

**Table 3.5** Time series consistency of emission factors of direct GHGs used in source category 1A3

GHGs	Source category	Fuel types	Time series consistency
Carbon	1A3	Liquid fuels and gaseous fuels	<ul style="list-style-type: none"> <li>Time-series of EFs used based on carbon content of UK fuels available for each year from 1990 from UK sources and so appropriate for the UK</li> </ul>
CH <sub>4</sub> , N <sub>2</sub> O	1A3	Fuel types used in the UK	<ul style="list-style-type: none"> <li>For road transport, time varying EFs used appropriate to emission standards in force and age profile of vehicle fleet</li> </ul>

### 3.4.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

### 3.4.5 Source-specific recalculations

#### 3.4.5.1 Recalculation by gas

The following section describes the main changes that have occurred in sector 1A3 per pollutant since the publication of the 2003 inventory. Comparisons are made between the current inventory (1990-2004) and the previous inventory (1990-2003) for the year 2003.

##### 3.4.5.1.1 Carbon Dioxide (CO<sub>2</sub>)

- Emissions from 1A3 Transport have increased by 1316 Gg CO<sub>2</sub>, due primarily to a significant revision of gas oil activity data.
- Estimated emissions from category 1A3b Road Transport decreased by 920 Gg CO<sub>2</sub>. This is primarily due to the re-allocation of lubricating oil combustion emissions across other transport sectors.
- Estimated emissions from Railways (1A3c) have increased by 1417 Gg CO<sub>2</sub> due to changes in the fuel consumption data for gas oil.
- Emissions from shipping increased by 447 Gg CO<sub>2</sub> due to the revision in gas oil fuel statistics and the allocation of emissions from lubricant oil combustion (previously allocated entirely to road transport sources).
- There has been a slight increase of 28 Gg CO<sub>2</sub> in emissions from domestic aviation due primarily to the inclusion of emissions from overseas territories emissions from which have been included within the national inventory for the first time this year.

#### 3.4.5.1.2 Methane (CH<sub>4</sub>)

- There is no significant change in this year's estimate for 2003 compared with last year's estimate. The small change is due to improved vehicle kilometre data being obtained for Northern Ireland. The decrease in emission estimates from 2003 to 2004 is due to increased penetration of cleaner vehicles.

#### 3.4.5.1.3 Nitrogen Oxides (NO<sub>x</sub>)

- The decrease in emission estimates from 2003 to 2004 is due to increased penetration of cleaner vehicles.

#### 3.4.5.1.4 Carbon Monoxide (CO)

- Two things have caused modifications to the emission estimates for CO in 2003. These are an improvement to the methodology for calculating cold start emissions and improved vehicle kilometre data being obtained for Northern Ireland.
- The decrease in emission estimates from 2003 to 2004 is due to increased penetration of cleaner vehicles.

#### 3.4.5.1.5 Non-Methane Volatile Organic Compounds (NMVOC)

- As with CO, two things have caused modifications to the emission estimates in 2003. These are an improvement to the methodology for calculating cold start emissions and improved vehicle kilometre data being obtained for Northern Ireland.
- The decrease in emission estimates from 2003 to 2004 is due to increased penetration of cleaner vehicles.

### 3.4.6 Source-specific planned improvements

Emission factors and activity data will be kept under review. If appropriate, fuel characterisation data from verified Emission Trading Scheme datasets will be considered in future GHGI cycles.

## 3.5 SOURCE CATEGORY 1A4 – OTHER SOURCES

### 3.5.1 Source Category Description

The emissions that are included in this source category arise from the following sectors:

- *Commercial/Institutional* – emissions from fuel combustion in commercial and institutional buildings
- *Residential* – emissions from fuel combustion in households
- *Agriculture/Forestry/Fishing* – emissions from fuel combustion in these sectors

Emissions from the burning of municipal solid waste (MSW) to generate heat are reported under CRF source category 1A4. Emissions from stationary railway sources are reported under 1A4a Commercial/Institutional. Stationary railway sources include emissions from the combustion of burning oil, fuel oil and natural gas used by the railway sector.

### 3.5.2 Methodological Issues

The methodology used for emissions from the burning of MSW to generate heat is identical to that used for burning of MSW to generate electricity (see **Section 3.2.2**) and the emission factors are therefore the same.

Emissions of both direct and indirect greenhouse gases for other sources are primarily calculated using national activity data, taken from DUKES, and emission factors. Emissions from off-road mobile sources including agricultural and other machinery are estimated based on recent research by Netcen, which includes some minor modifications to fuel use allocations from DUKES. See **Section A.3.3.7** for further details.

Use of peat as a domestic fuel is a new source that has been included for the first time in 1A4 in the 1990–2004 dataset, based on peat consumption data from the Centre for Ecology and Hydrology (Mobbs, 2005).

### 3.5.3 Uncertainties and time-series consistency

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

Most of the core activity data for this source category is derived from the DTI publication the Digest of UK Energy Statistics. **Section 3.15** provides further general information about the time series consistency of activity data in this publication, and provides more general comments on the approaches used to ensure time series consistency in source category 1A.

**Table 3.6** summarises the time series consistency of emission factors used in source category 1A4.

**Table 3.6** Time series consistency of emission factors of direct GHGs used in source category 1A4

GHGs	Source category	Fuel types	Comments on time series consistency
Carbon	1A4	All fuels	<ul style="list-style-type: none"> <li>EFs vary somewhat across time series based on the UK carbon factor review in 2004.</li> </ul>
CH <sub>4</sub> , N <sub>2</sub> O	1A4	All fuels	<ul style="list-style-type: none"> <li>Nearly all EFs are constant over the entire time series, with limited use of time-varying EFs due to fuel variability or technological developments.</li> </ul>

### 3.5.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

### 3.5.5 Source-specific recalculations

Changes have been made to the way that consumption of DERV and gas oil by agricultural vehicles and mobile machinery is calculated (See **Section A3.3.7** for details). These changes have also impacted upon the estimates of gas oil use in stationary plant by industry, public & commercial and other sectors, which have been revised to maintain consistency with total UK consumption of gas oil given in DUKES.

#### 3.5.5.1 Recalculation by gas

The following section describes the main changes that have occurred in sector 1A4 per pollutant since the publication of the 2003 inventory (2005 NIR). Comparisons are made between the current inventory (1990-2004) and the previous inventory (1990-2003) for the year 2003.

##### 3.5.5.1.1 Carbon Dioxide (CO<sub>2</sub>)

- Estimated emissions of CO<sub>2</sub> from 1A4 have increased by 5055 Gg CO<sub>2</sub>. Details of the main source-specific recalculations are given below.
- A new emission estimate of 450 Gg CO<sub>2</sub> has been introduced into the inventory for domestic combustion of peat.
- Estimated emissions from combustion of gas oil in stationary, commercial, agricultural or public sector plant have decreased by 1608 Gg CO<sub>2</sub> due to the reallocation of gas oil use from these sectors to agricultural vehicles and mobile machinery. Estimated emissions from agricultural vehicles have increased by 3845 Gg CO<sub>2</sub> as a result of the reallocation. Gas oil has also been reallocated from sectors in 1A2.
- Estimated emissions from domestic fuel use have increased by 1915 Gg CO<sub>2</sub> due to revisions to energy statistics for burning oil, coke, anthracite, coal and natural gas.
- Estimated emissions from combustion of natural gas by the commercial sector have increased by 612 Gg CO<sub>2</sub> due to a revision of fuel use statistics.

##### 3.5.5.1.2 Methane (CH<sub>4</sub>)

- Minor revisions to fuel use data and emission factors have led to an estimated increase in emissions from 1A4 of 7 Gg across all fuels.

##### 3.5.5.1.3 Nitrous Oxide (N<sub>2</sub>O)

- Minor revisions to fuel use data and emission factors have led to an estimated increase in emissions from 1A4 of 2 Gg across all fuels.

##### 3.5.5.1.4 Nitrogen Oxides (NO<sub>x</sub>)

- Estimated emissions agricultural vehicles were revised up by 57 Gg due to revisions to the fuel usage estimates for this sector.
- Estimated emissions from combustion of natural gas by public sector and by commercial/institutional combustion plant have both been revised up by 2 Gg due to the use of updated emission factors and changes in energy statistics.



#### 3.5.5.1.5 Carbon Monoxide (CO)

- Estimated emissions agricultural vehicles were revised up by 19 Gg due to revisions to the fuel usage estimates for this sector.
- An emission estimate of 17 Gg has been introduced into the inventory for domestic combustion of peat.
- Estimated emissions from domestic combustion of coal and anthracite were revised up by 29 Gg and 20 Gg respectively, due to changes in energy statistics.

#### 3.5.5.1.6 Non-Methane Volatile Organic Compounds (NMVOC)

- Estimated emissions agricultural vehicles were revised up by 8 Gg due to revisions to the fuel usage estimates for this sector.
- An emission estimate of 6 Gg has been introduced into the inventory for domestic combustion of peat.
- Estimated emissions from domestic combustion of coal was increased by 2 Gg due to revisions to energy statistics.

### 3.5.6 Source-specific planned improvements

Emission factors and activity data will be kept under review. If appropriate, fuel characterisation data from verified Emission Trading Scheme datasets will be considered in future GHGI cycles.

## 3.6 SOURCE CATEGORY 1A5 – OTHER

### 3.6.1 Source Category Description

This category includes emissions from military aircraft and naval vessels. Both are reported under category 1A5b: mobile emissions.

### 3.6.2 Methodological Issues

Methods of estimation for both military aircraft and naval vessel emissions are discussed in the transport section of **Annex 3 (Section A3.3.5)**.

### 3.6.3 Uncertainties and time-series consistency

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

Military fuel consumption data are supplied by the Ministry of Defence Fuels Group. The MOD have supplied a time-series of fuel consumption data since 1990 and we believe the time series consistency of the fuel use data is good.

**Table 3.7** Time series consistency of emission factors of direct GHGs used in source category 1A5

GHGs	Source category	Fuel types	Comments on time series consistency
Carbon	1A2	All fuels	<ul style="list-style-type: none"> <li>EFs vary somewhat across time series based on the UK carbon factor review in 2004.</li> </ul>
CH <sub>4</sub> , N <sub>2</sub> O	1A2	All fuels	<ul style="list-style-type: none"> <li>Nearly all EFs are constant over the entire time series, with limited use of time-varying EFs due to fuel variability or technological developments.</li> </ul>

### 3.6.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

### 3.6.5 Source-specific recalculations

#### 3.6.5.1 Recalculation by gas

The following section describes the main changes that have occurred in sector 1A5 per pollutant since the publication of the 2003 inventory. Comparisons are made between the current inventory (1990-2004) and the previous inventory (1990-2003) for the year 2003.

##### 3.6.5.1.1 Carbon Dioxide (CO<sub>2</sub>)

- Estimated emissions from category 1A5 (Military aircraft) have increased by 22 Gg CO<sub>2</sub> due to a revision to fuel use data for aviation turbine fuel.

### 3.6.6 Source-specific planned improvements

Emission factors and activity data will be kept under review. If appropriate, fuel characterisation data from verified Emission Trading Scheme datasets will be considered in future GHGI cycles.

## 3.7 INTERNATIONAL BUNKER FUELS (MEMO ITEM)

International bunker emissions (international aviation and shipping) are not included in the national total but are reported separately. For the U.K. they are approximately 7% of the national total of CO<sub>2</sub>. In 2004, the shipping emission contributed 15% to total bunker emissions, with aviation contributing the remaining 85%. Since 1990, estimated emissions from international aviation have more than doubled. These estimates are consistent with the revised Tier 3 method now adopted for aviation and described in **Annex 3** section under **Appendix 3, Section 3.3.5.1**.

### **3.8 FEEDSTOCKS AND NON-ENERGY USE OF FUELS**

Natural gas is used as a feedstock for the manufacture of ammonia (for fertiliser), methanol and acetic acid. This process is described in **Section 4.9.1**.

### **3.9 CAPTURE AND STORAGE OF CO<sub>2</sub> FROM FLUE GASES**

Currently in the UK, CO<sub>2</sub> emitted from flue gases is not captured and stored.

### **3.10 COMPARISON OF SECTORAL AND REFERENCE APPROACHES**

This comparison is documented and described in **Annex 4**.

Summary Table 7B includes the IPCC Reference Inventory total for carbon dioxide. This is a 'top-down' inventory calculated from national statistics on production, imports, exports and stock changes of fossil fuels. All other Sectoral Tables report emissions of pollutants estimated using a 'bottom-up' approach with emissions estimated from activity statistics (mostly fuel consumption) in the various economic sectors and processes.

In principle the IPCC Reference Total can be compared with the IPCC Table 1A Total plus the emissions arising from fuel consumption in 1B1 Solid Fuel Transformation and Table 2 Industrial Processes (Iron and Steel and Ammonia Production). The IPCC Reference totals range between 1% lower to 3 % higher than the comparable bottom up totals, largely because they are based on a different set of statistics. Reasons for the differences between the two estimates are discussed in **Annex 4**.

Over the period (1990 to 2004), emissions estimated by the Reference Approach have fallen by 2.9 % compared with 4.6 % for the comparable 'bottom-up' totals.

A detailed comparison between the IPCC Reference Inventory, the UK Greenhouse Gas Inventory and the UK Inventory based on the IPCC Default Methodology is given by Salway (1998a).

### **3.11 COUNTRY SPECIFIC ISSUES**

Country specific issues have been identified under other headings or as they occur.

### **3.12 SOURCE CATEGORY 1B1 – SOLID FUELS**

#### **3.12.1 Source Category Description**

This source category covers emissions which occur during the production, transportation or use of solid fuels but which are not due to the combustion of those fuels to support of a productive activity. These emissions will include the release of methane contained within

coal and emissions of carbon and organic compounds during the transformation of coal into coke and solid smokeless fuels. Emissions will also occur from the flaring of any waste gases from coke or SSF manufacture.

### **3.12.2 Methodological Issues**

Carbon emissions from coke ovens are based on a carbon balance approach (discussed in **Annex 3, Section A3.3.8.1.2.1**) with calculations arranged so that the total carbon emission, plus carbon in products and wastes, corresponds to the carbon content of the input fuels. For process emissions from coke ovens for other pollutants, emissions are estimated either on the basis of total production of coke or the coal consumed. Emission factors are provided in **Annex 3, Table A3.3.25**.

Emissions of carbon from Solid Smokeless Fuel (SSF) production are also based on a carbon balance approach, as discussed in **Annex 3, Section A3.3.8.1.2.2**. For other pollutants, estimates are either made based on operators' reported emissions or on production data and emission factors as provided in **Table A3.3.25**.

Methane emissions from closed coal mines are accounted for within Sector 1B1a of the UK inventory, with estimates based on the findings of a recent study funded by Defra (Kershaw, 2005). This study has derived emission estimates for the years 1990 to 2004 using a relationship between emissions and the quantity of the underlying methane gas within the abandoned mine workings. More details of the estimation methodology are provided in **Annex 3, Section A3.3.8.1.1**.

### **3.12.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

Most of the core activity data for this source category is derived from the DTI publication the Digest of UK Energy Statistics. **Section 3.15** provides further general information about the time series consistency of activity data in this publication, and provides more general comments on the approaches used to ensure time series consistency in source category 1B.

The time series consistency of emission factors used in this source category is discussed in **Annex 3, Section A3.3.8.1.1**.

### **3.12.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

### **3.12.5 Source-specific recalculations**

#### **3.12.5.1 Recalculation by gas**

The following section describes the main changes that have occurred in sector 1B1 per pollutant since the publication of the 1990-2003 inventory. Comparisons are made between the current inventory (1990-2004) and the previous inventory (1990-2003) for the year 2003.

**3.12.5.1.1 Methane (CH<sub>4</sub>)**

- Estimated emissions from category 1B1 have increased by 32 Gg CH<sub>4</sub>. This change has mostly been caused by the increase of emissions from deep mined coal (33 Gg CH<sub>4</sub> increase) and has occurred due to a change in both emission factors and activity data. A small decrease of 1 Gg CH<sub>4</sub> occurred from coal storage and transport.

**3.12.6 Source-specific planned improvements**

Emission factors and activity data will be kept under review.

**3.13 SOURCE CATEGORY 1B2 – OIL AND NATURAL GAS****3.13.1 Source Category Description**

This source category covers emissions which occur during the production, transportation, or use of liquid and gaseous fuels but which are not due to the combustion of those fuels to support a productive activity. Emissions occur from oil and gas production facilities, gas and oil terminals, gas processing facilities, oil refineries, gas transmission networks, and storage and distribution of petrol.

Oil & gas production facilities are sources of CO<sub>2</sub>, CH<sub>4</sub>, CO, N<sub>2</sub>O, NO<sub>x</sub>, SO<sub>2</sub>, and VOC. Organic pollutants are emitted as a result of venting from processes for reasons of safety and from leakages from process plant. Flaring of waste streams gives rise to emissions of all seven pollutants. Most of the UK's oil and gas production occurs offshore but there are a number of mostly small onshore production sites as well.

Offshore oil and gas has to be transported to processing plant and pipelines are used for gas and a proportion of the oil produced. The remaining oil is transferred to shore using marine tankers and emissions of CH<sub>4</sub> and VOC occur during loading of oil into the ship's tanks. Some oil transported to shore by pipeline is subsequently reloaded into marine tankers for distribution to refineries and emissions of CH<sub>4</sub> and VOC will occur during this loading stage as well. Emissions of VOC occur from storage tanks located at oil terminals.

Emissions of carbon, CH<sub>4</sub>, CO, N<sub>2</sub>O, NO<sub>x</sub>, SO<sub>2</sub>, and VOC occur at refineries due to venting of process plant for reasons of safety, from flaring of waste products, leakages from process plant, evaporation of organic contaminants in refinery wastewater, regeneration of catalysts by burning off carbon fouling, and storage of crude oil, intermediates, and products at refineries.

Petrol distribution begins at refineries where petrol may be loaded into rail or road vehicles. Petrol is distributed to approximately 60 petrol terminals where it is stored prior to loading into road tankers for distribution to petrol stations. At petrol stations it is stored and then dispensed into the fuel tanks of road vehicles. Emissions of VOC occur from each storage stage and from each transfer stage.

**3.13.2 Methodological Issues**

Emissions estimates for the offshore oil & gas industry are based on data provided by the trade organisation, UKOOA, through their annual emissions reporting mechanism to UK

regulators, the Environmental Emissions Monitoring System (EEMS). This system provides a detailed inventory of point source emissions estimates, based on operator returns for the years 1995-2004. Additional, more detailed data on CO<sub>2</sub> emissions from some offshore combustion processes has become available as a result of the development of the industry's National Allocation Plan pertaining to the EU Emission Trading Scheme. Therefore, for the main combustion sources in the offshore oil & gas sector, the UKOOA data from 1998 onwards is sourced via NAP estimates, superseding any historic estimates previously reported via EEMS. The time-series of data has been revised for the 1990-2004 inventory submission to ensure that consistent carbon emission factors have been applied to activity data back to 1990, to reflect the updated factors derived under the ETS and provide a consistent emissions dataset.

For years prior to 1995 (i.e. pre-EEMS), emission totals are based on an internal UKOOA summary report produced in 1998. These data were revised and reported with the 1995-2004 datasets in the latest UKOOA submission to the inventory. Review by the Inventory Agency of the UKOOA datasets from the mid-90s (notably for 1995 & 1996) identified several gaps or apparent mis-reports within the EEMS data. Through consultation with UKOOA, these data have been amended as appropriate, using emission factors from more recent datasets to provide more representative emission estimates for specific activities. In addition, where the detailed split of emissions for 1990-1994 was previously based on 1995 EEMS data, the uncertainty regarding this (first ever) and the 1996 EEMS datasets has prompted a change in methodology in the latest inventory cycle; the 1990-1994 detailed estimates are now based on (1) total emission estimates and limited activity data (for 1990-1994) from the 1998 UKOOA summary report, and (2) the detailed split of emissions from the 1997 EEMS dataset.

The 1998 UKOOA report presented data from detailed industry studies in 1991 and 1995 to derive emission estimates for 1990 from available operator estimates. Emission estimates for 1991-1994 were then calculated using production-weighted interpolations. Only limited data was available from operators in 1990-1994, and emission totals could only be estimated in broadly aggregated sectors of: drilling (offshore), production (offshore), loading (offshore) and total emissions onshore. Estimates of the more detailed oil & gas processing source sectors for 1990-1994 are therefore based on applying the fraction of total emissions derived from the 1997 data from EEMS (as the gaps and inconsistencies within the 1995 and 1996 datasets indicate that these early years of the EEMS dataset are somewhat unreliable).

Emission estimates for onshore oil and gas facilities are based on emissions data reported by process operators to the UK environmental regulatory agencies (the Environment Agency of England & Wales and the Scottish Environmental Protection Agency) under IPC/IPPC regulations. Emissions data for Scottish plant have become available since the late 1990s, whilst in England & Wales the Pollution Inventory of the EA holds emissions data from industrial plant from around 1995 onwards.

Emission estimates for all pollutants from the nine complex UK refineries (see **Section 3.2.1**) are provided annually by the UK Petroleum Industry Association (UKPIA) and are incorporated directly into the GHGI. The UKPIA estimates are compiled by the refinery operators using agreed industry standard methods.

Petrol distribution emissions are calculated using petrol sales data taken from the Digest of UK Energy Statistics and emission factors calculated using the UK Institute of Petroleum's

protocol on estimation of emissions from petrol distribution. This protocol requires certain other data such as average temperatures, Reid Vapour Pressure (RVP) of petrol and details of the level of abatement in place. Central England Temperature (CET) data, obtained from the Met Office, is used for the temperature data, while UKPIA supply RVP estimates for summer and winter blend petrols and estimates of the level of control are based on statistics given in the Institute of Petroleum's annual petrol retail survey.

For further details on all processes covered under 1B2 including emission factors and detailed methodological descriptions, see **Annex 3, Section 3.3.8.2**.

### **3.13.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

The emission estimates for the offshore industry are based on the UKOOA EEMS dataset for 1995-2003. Emission estimates from 1990-1994 (i.e. pre-EEMS) are estimated from specific UKOOA studies of 1991 and 1998, using production data as a basis for interpolation of data between 1990 and 1995. The new dataset provided in 2005 by UKOOA now provides a more consistent time-series of data for the range of activities within this sector. Full details are given in **Annex 3 A3.3.8.2**.

### **3.13.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. UKOOA provides emission estimation guidance for all operators to assist in the completion of EEMS returns to the UK environmental regulators, including the provision of appropriate default emission factors for specific activities, where installation-specific factors are not available.

### **3.13.5 Source-specific recalculations**

The 2005 UKOOA dataset incorporates minor recalculations of CO<sub>2</sub> emissions data between 1998-2003, where carbon emission factors have been revised in light of the EU-ETS National Allocation Plans. A number of emission estimates in 1995 and 1996 have been amended to resolve apparent data gaps or mis-reports identified by the Inventory Agency following review of some site-specific estimates (notably for acid gas stripping facilities and oil loading activities). The detailed split of emission estimates for 1990-1994 have been amended as 1997 has now been identified as the most reliable and appropriate EEMS dataset upon which to base the sector-specific splits.

#### **3.13.5.1 Recalculation by gas**

The following section describes the main changes that have occurred in sector 1B2 per pollutant since the publication of the 1990-2003 inventory. Comparisons are made between the current inventory (1990-2004) and the previous inventory (1990-2003) for the year 2003.

#### 3.13.5.1.1 Carbon Dioxide (CO<sub>2</sub>)

- Estimated emissions from category 1B2 have increased by 25 Gg CO<sub>2</sub>. This change is due to a revision of the emission factor used for offshore flaring emissions, due to updated emissions data from UKOOA.

#### 3.13.5.1.2 Methane (CH<sub>4</sub>)

- Estimated emissions from category 1B2 have decreased by 19 Gg CH<sub>4</sub>. This change is primarily due to revised estimates of methane leakage from the UK gas distribution system, provided by UK Transco, which have been reduced by 22 Gg CH<sub>4</sub>. Slight increases in emission estimates from offshore oil & gas processes are also evident.

### 3.13.6 Source-specific planned improvements

The trade association, UKOOA, did review some aspects of the EEMS dataset during 2005, but not all matters that have been raised previously by the Inventory Agency were addressed, and there are a number of areas where further clarifications are required. In particular, significant step-changes in emission factors are apparent for some pollutants and sources across the time series, suggesting that updated guidance and emission factors have been provided to plant operators, but historic recalculations may not have been thoroughly conducted. Ongoing consultation between the Inventory Agency, Single National Entity, UKOOA and the offshore industry regulator (the Department of Trade & Industry) is planned for summer 2006 to co-ordinate action on further improvements to the EEMS dataset. Access to verified ETS data for 2005 may provide some useful clarifications.

## 3.14 GENERAL COMMENTS ON QA/QC

### 3.14.1 DTI Energy Balance Data

The DTI provides the majority of the energy statistics required for compilation of the NAEI and the GHGI. These statistics are obtained from the DTI publication “The Digest of UK Energy Statistics” which is produced in accordance with QA/QC requirements stipulated within the UK Government’s “National Statistics Code of Practice” and as such is subject to regular QA audits and reviews.

The DTI includes a number of steps to ensure the energy statistics are reliable. At an aggregate level, the energy balances are the key quality check with large statistical differences used to highlight areas for further investigation. Prior to this, the DTI tries to ensure that individual returns are as accurate as possible. A two-stage process is used to achieve this. Initially the latest data returns are compared with those from previous months or quarters to highlight any anomalies. Where data are of a seasonal nature comparison is also made with corresponding data for the same month or quarter in the previous year. The DTI also uses an energy balance approach to verify that individual returns are sensible. Any queries are followed up with the reporting companies. The DTI depends on data from a range of companies, and work closely with these reporting companies to ensure returns are completed as accurately as possible and in good time for the annual publications of statistics.



The data collection system used by the DTI to collect and calculate sector-specific estimates of the use of petroleum-based fuels has been changed, and since January 2005 a new electronic system of reporting has been introduced. This development should lead to more consistent returns from petroleum industries, reducing mis-allocations and transcription errors that may have occurred under the previous paper-based system, but these impacts will not be evident until the publication of DUKES 2006. Sector-specific allocations of gas oil and fuel oil have been significantly revised in the latest inventory cycle, following the removal of historic detailed datasets by DTI once uncertainties inherent in their estimation came to light.

### **3.14.2 Industrial Point-Source Emissions Data**

Where emissions data are provided by plant operators to the Environment Agency's Pollution Inventory and then used in the UK's GHG emission inventory, the data is subject to audit and review within the Agency's QA procedures. The operator emission estimates are initially checked & verified locally by their main regulatory contact (Site Inspector), and then passed to a central Pollution Inventory team where further checks are conducted prior to publication. Specific checking procedures include: benchmarking across sectors, time-series consistency checks, checks on estimation methodologies and the use and applicability of emission factors used within calculations.

Sector-specific guidance regarding estimation of annual emissions by plant operators are under development by the Environment Agency. A rolling programme of guidance publication for different sectors until 2007 is planned, and it is anticipated that this will lead to a gradual improvement of the consistency and accuracy of operator returns to the Pollution Inventory. The development of the SEPA and NI DoE reporting systems is anticipated to adopt these QA/QC mechanisms also.

## **3.15 GENERAL COMMENTS ON TIME SERIES CONSISTENCY**

The UK GHG inventory seeks to ensure time series consistency of its emission estimates. In general, the time series consistency of emissions will depend on:

- consistency in the techniques used to compile activity data
- correct choice of source and fuel specific emission factors for each year of the inventory
- consistency in the techniques used to estimate emissions from the activity data and emission factors.

Much of the core activity data for the sources reported in CRF sector 1 (Energy) is derived from the DTI publication the Digest of UK Energy Statistics. This is a long running publication and the compilers of the activity data for DUKES strive to use consistent methods to produce the activity data. This helps to ensure good time-series consistency. Revisions of activity data may be made up to two years behind the latest reported year, but such revisions are clearly noted in DUKES and are incorporated into the GHG inventory when the inventory is updated each year. Where activity data other than that presented in DUKES are required for a source category, we have made quantitative and qualitative comments about the quality of the time series if possible.

The emission factors used are typically fuel- and source-specific, and any comments on the time series consistency of the emission factors are made in the sections on “uncertainties and time-series consistency” in this chapter. Comments are restricted to the emission factors of the direct greenhouse gases.

In nearly all cases in the UK GHGI, a single method is used to estimate a time series of emissions from a specific source category. The technique of splicing two or more methods is rarely used. If a more sophisticated method is used to replace a simpler one, the entire time series of emissions is updated using the new method. Occasionally, there are insufficient data to produce a complete time series of emissions from the chosen method. Here, extrapolations and interpolations, use of surrogate data, and use of constant estimates of emission factors or activity data may be used to provide a complete time series. The same options can be used when splicing methodologies, and in addition, it may also be necessary to overlap of methodologies (Rypdal *et al.*, 2000).

## **4. Industrial Processes (CRF sector 2)**

### **4.1 OVERVIEW OF SECTOR**

UK industry includes many processes that give rise to direct or indirect greenhouse gases. Important sectors include cement and lime production, glass manufacture, steel production, secondary non-ferrous metal production, chemicals manufacture and food and drink manufacture. Primary non-ferrous metal production is now limited to the production of primary aluminium at three sites and the UK paper and pulp industry is relatively small compared with many other Northern European countries.

**Annex 3.4** contains more detailed descriptions of the methods used to estimate emissions in this sector.

### **4.2 SOURCE CATEGORY 2A1 – CEMENT PRODUCTION**

#### **4.2.1 Source category description**

Cement is produced by grinding a mixture of calcium carbonate ( $\text{CaCO}_3$ ), silica, alumina and iron oxides, either in a wet or dry process, and then heating the ground material in a kiln. In the kiln, the calcium carbonate breaks down into calcium oxide ( $\text{CaO}$ ) and carbon dioxide (a process known as calcination). The calcium oxide subsequently reacts with the other raw materials to form clinker. The clinker is cooled and, after addition of other raw materials, ground to make cement.

Emissions of carbon dioxide result both from calcination of the calcium carbonate, but also from fuels burnt to provide the heat for calcination and clinkering. Fuels used include coal, petroleum coke and waste materials plus small quantities of oil. Emissions of  $\text{CO}_2$  from fuel combustion are reported under CRF source category 1A2f while emissions from calcination are reported under category 2A1.

Fuel combustion also gives rise to emissions of  $\text{NO}_x$  and  $\text{N}_2\text{O}$  while emissions of methane, NMVOC,  $\text{SO}_2$  and  $\text{CO}$  also occur, both due to fuel combustion but also due to the evaporation of organic or sulphurous components present in the raw materials. The UK GHGI currently reports emissions both from fuels and from raw materials under 1A2f.

The UK had 18 sites producing cement clinker during 2004.

#### **4.2.2 Methodological issues**

The methodology used for estimating  $\text{CO}_2$  emissions from calcination is the IPCC Tier 2 approach (IPCC, 2000). The emission was estimated from the annual UK production of clinker (British Cement Association, 2005). The British Cement Association have also

provided an estimate of the average CaO content of cement clinker (63%) and that the use of non-carbonate CaO can be assumed to be zero. The clinker production data are revised up to take account of losses in the form of kiln dust, by assuming that these losses are 2% of clinker production. This is also based on an estimate provided by the British Cement Association. Based on these data, an emission factor of 137.6 t C/kt clinker was calculated according to the IPCC Tier 2 method. This is around 2.5% lower than the emission factor used in the 1999 Inventory, which was based on IPCC default values.

#### **4.2.3 Uncertainties and time-series consistency**

The emission was estimated from the annual UK production of clinker, with data provided by the British Cement Association. The time-series consistency of these activity data is very good due to the continuity in data provision by the British Cement Association.

#### **4.2.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in Section 1.6.

#### **4.2.5 Source-specific recalculations**

No recalculations have been required for this version of the inventory.

#### **4.2.6 Source-specific planned improvements**

The British Cement Association provided an alternative estimate of carbon from calcination, based on calculations of process-related CO<sub>2</sub> emissions by individual site operators. These data have not been incorporated into this version of the GHGI but, following assessment of the data, may be used in future versions of the inventory.

### **4.3 SOURCE CATEGORY 2A2 – LIME PRODUCTION**

#### **4.3.1 Source category description**

Lime (CaO) is manufactured by the calcination of limestone (CaCO<sub>3</sub>) and dolomite (CaCO<sub>3</sub>MgCO<sub>3</sub>) in kilns fired by coal, coke or gas. The calcination results in the evolution of carbon dioxide. It is necessary to distinguish between processes where lime is produced for use off-site and where carbon dioxide is emitted to atmosphere, and those processes where lime is produced so that the carbon dioxide and lime can be used on-site in the process. In these processes, which include sugar refining and the production of sodium carbonate using the Solvay process, most of the carbon dioxide is not emitted to atmosphere.

Lime was produced at 15 UK sites during 2004. Two of these produce lime for use on-site in the Solvay process and five produce lime for use on-site in sugar manufacturing.

#### **4.3.2 Methodological issues**

The UK bases estimation of lime production on limestone and dolomite consumption data, which are readily available (British Geological Survey, 2005). The use of consumption data rather than production data is simpler and probably more reliable since it is not necessary to

consider the different types of lime produced. An emission factor of 120 t carbon/kt limestone was used based on the stoichiometry of the chemical reaction assuming pure limestone. For dolomite an emission factor of 130 t carbon/kt dolomite would have been appropriate; however dolomite calcination data are not given explicitly but included in the limestone data, which will have caused a small under-estimate of emissions. Dolomite calcination is believed to be a small proportion of the total hence the underestimation is unlikely to be significant. The limestone calcination data exclude limestone calcined in the chemical industry since a large proportion of this is used in the Solvay process, which does not release CO<sub>2</sub>. The calcination of limestone in the sugar industry is also excluded.

#### **4.3.3 Uncertainties and time-series consistency**

Uncertainty in both the activity data and emission factor used for this source are judged to be low. The use of an emission factor applicable to limestone calcination for estimating emissions of both limestone and dolomite will lead to a slight underestimation in emissions. The exclusion of limestone used by the chemicals industry and sugar production will also lead to a small underestimation since not all CO<sub>2</sub> is consumed by the processes and, in the case of chemicals, some lime may be used in processes other than the Solvay process. Time-series consistency of activity data is very good due to the continuity in data provided by the British Geological Survey.

The British Geological Survey data for 2004 does not include an estimate of the quantity of limestone used by the chemical industry, thus this has had to be estimated by Netcen. This means that the estimate for 2004 is somewhat more uncertain than estimates for other years.

#### **4.3.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in Section 1.6.

#### **4.3.5 Source-specific recalculations**

No recalculations have been required for this version of the inventory

#### **4.3.6 Source-specific planned improvements**

Section 4.3.3 describes possible areas for improvement, though the impact on the trend is likely to be relatively small.

### **4.4 SOURCE CATEGORY 2A3 – LIMESTONE & DOLOMITE USE**

#### **4.4.1 Source category description**

Limestone and dolomite are added to sinter where they are calcined, the products subsequently acting as slag formers in blast furnaces. Some limestone or dolomite may be added directly to blast furnaces instead of sintered first, but this is ignored for the GHGI with all emissions being assumed to occur from the sinter strand instead. Limestone and dolomite are also used as sources of CaO and MgO in the manufacture of soda-lime glasses, as fluxing agents for basic oxygen furnaces, and for the liming of soils by the agricultural sector. Agricultural use

is covered in **Chapter 5** of this report. Use of limestone and dolomite in sinter production, basic oxygen furnaces and glass manufacture results in the evolution of carbon dioxide, which is emitted to atmosphere. Limestone is also used in flue-gas desulphurisation (FGD) plant, used to abate SO<sub>2</sub> emissions from combustion processes. The limestone reacts with the SO<sub>2</sub> and is converted to gypsum, with CO<sub>2</sub> being evolved.

The UK had three operational steel-making sites during 2004 and approximately 18 large glassworks manufacturing soda-lime type glasses. FGD was operational on three UK power stations during 2004.

#### **4.4.2 Methodological issues**

Emissions are calculated using emission factors of 120 t carbon/kt limestone and 130 t carbon/kt dolomite, in the case of glass processes involving calcinations, and 69 t carbon/kt gypsum produced in the case of FGD processes. These factors are based on the assumption that all of the carbon dioxide is released to atmosphere. Data on the usage of limestone and dolomite for glass and steel production are available from the British Geological Survey (2005) and the Iron & Steel Statistics Bureau (2005), respectively and gypsum produced in FGD plant is available from the British Geological Survey (2005).

Corus UK Ltd has provided analytical data for the carbon content of limestones and dolomites used at their steelworks and these have been used to generate emission factors of 111 t carbon/kt limestone and 123 t carbon/kt dolomite for sintering and basic oxygen furnaces.

#### **4.4.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

Uncertainty in both the activity data and emission factor used for this source are judged to be low. Time-series consistency is also very good due to the continuity in data provision by the British Geological Survey and the Iron & Steel Statistics Bureau.

#### **4.4.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

#### **4.4.5 Source-specific recalculations**

A correction was necessary to the activity data for dolomite use by the glass industry during 2000 and 2003. This was due to dolomite usage being omitted from the inventory in previous versions. Estimated emissions of CO<sub>2</sub> increase by 57 Gg as a result.

Revised emission factors have been used for sintering and basic oxygen furnaces as described in section 4.6.2, leading to a decrease in estimated emissions of 73 Gg CO<sub>2</sub>.

#### **4.4.6 Source-specific planned improvements**

Emission factors and activity data will be kept under review.

## **4.5 SOURCE CATEGORY 2A4 – SODA ASH USE**

### **4.5.1 Source category description**

Soda ash (sodium carbonate,  $\text{Na}_2\text{CO}_3$ ) is used in the manufacture of soda-lime glasses. The soda ash decomposes in the melt to  $\text{Na}_2\text{O}$ , which is incorporated into the glass, and  $\text{CO}_2$ , which is released to atmosphere. Other uses of soda ash can also result in the emission of  $\text{CO}_2$ , including use in food and drink manufacture and pharmaceuticals, however the consumption of soda ash for these applications is small. Only the emissions from soda-lime glasses are reported in 2A4.

The UK has approximately 18 large glassworks manufacturing soda-lime type glasses.

### **4.5.2 Methodological issues**

Emission estimates are based on estimates of the consumption of soda ash in the production of soda-lime glass (British Glass, 2004). This is assumed to be 20% of the mass of glass produced. An emission factor of 113 kt carbon/Mt soda ash is used. The estimate of soda ash consumption is based on the production of container glass, flat glass and domestic glass. Other types of glass, such as glass fibres, glass wool and special glasses are not soda-lime glasses and do not involve the use of large quantities of soda ash. The glass production data are corrected for the amount of recycled glass (cullet) and the soda ash consumption is therefore estimated as 20% of the new glass melted and not total glass melted.

### **4.5.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

The calculation of soda ash consumption is subject to uncertainties linked to:

- glass production data, which are themselves estimates subject to moderate uncertainty
- estimate of the rate of soda ash production per tonne of glass, which is an approximate figure.

The emission factor is based on the stoichiometry of the chemical reaction undergone by the soda ash and will be accurate. The time-series required some interpolation of data from year to year.

### **4.5.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

### **4.5.5 Source-specific recalculations**

No recalculations have been made for this version of the inventory.

#### **4.5.6 Source-specific planned improvements**

Estimates for this sector could be improved either through collection of actual soda ash consumption data or through more detailed estimation of soda ash consumption at sub-sector level (e.g. separately for flat glass, container glass etc. using glass composition data.) Currently the sector is probably not a priority for further improvements, since emissions are relatively minor compared to the UK total.

### **4.6 SOURCE CATEGORY 2A5 – ASPHALT ROOFING**

Emissions of CO<sub>2</sub> are not estimated from this source as there is no methodology available. Emissions from this source category are likely to be extremely small in relation to national emissions.

### **4.7 SOURCE CATEGORY 2A6 – ROAD PAVING WITH ASPHALT**

#### **4.7.1 Source category description**

Bitumen is used in the preparation of road surfaces. Different types of surface dressing are used and some contain kerosene as well as bitumen. The kerosene partially evaporates and is emitted to atmosphere. Emissions are reported under 2A6.

#### **4.7.2 Methodological issues**

Emissions of CO<sub>2</sub> are not estimated from this source, as there is no methodology available. Emissions from this source category are likely to be extremely small in relation to national emissions.

The inventory reports emissions of NMVOC from the use of bitumen emulsions, cut-back bitumens, and cut-back fluxes used in road construction using emission factors of 7, 87.5 and 700 kg NMVOC/ tonne for each component respectively (Refined Bitumen Association, 1990). These estimates are based on the assumption that only 70% of the kerosene is emitted, the remainder being fixed in the road material. Estimates of the usage of these surface dressings are based on a set of consumption data for one year only, provided by the Transport and Road Research Laboratory (1989) and are extrapolated to other years using data for annual bitumen consumption given in the Digest of UK Energy Statistics (DTI, 2005).

#### **4.7.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

The estimates of NMVOC from road paving are quite uncertain, due particularly due the long-term extrapolation of a single set of consumption data. The use of bitumen consumption may well represent a good indicator of road construction but it is unclear whether the rate of use of the specialised products containing kerosene will change to a similar extent.



**4.7.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in Section 1.6.

**4.7.5 Source-specific recalculations**

A recalculation has been required for this version of the inventory, due to revisions in the bitumen consumption data given by DTI, 2005. This leads to an estimated increase in emissions of 1 Gg NMVOC in 2003.

**4.7.6 Source-specific planned improvements**

Emissions are small compared with national totals and the sector has been a low priority for further improvement. Nonetheless, new solvent consumption data currently being collected may provide more accurate estimates of recent kerosene usage for road construction, allowing the time series to be improved for the next version of the inventory.

**4.8 SOURCE CATEGORY 2A7 – OTHER MINERAL PRODUCTS****4.8.1 Source category description**

Emissions from Fletton brickworks, manufacture of glass fibres and glass wool, and manufacture of coated roadstone are reported under 2A7.

Fletton bricks are manufactured at three sites in Southern England using the Lower Oxford clay. This clay contains a high level of carbonaceous material, which acts as a fuel during firing, leading to emissions of carbon dioxide, carbon monoxide, methane, and NMVOC. The clay also contains sulphurous material, which can result in SO<sub>2</sub> emissions as well.

Glass fibres are manufactured at two sites in the UK and glass wool at nine sites. Both process types involve the attenuation of molten glass into fine fibres, which are then cooled and coated with organic materials. The coating processes give rise to some emissions of NMVOC.

Coated roadstone is produced at numerous sites. The stone is quarried, crushed and then coated with bitumen. Emissions of NMVOC from these processes are relatively trivial.

**4.8.2 Methodological issues**

Emissions data for Fletton brickworks during recent years are available from the Pollution Inventory (Environment Agency, 2005). These data include emissions both from the burning of the carbonaceous and sulphurous material in the clay but also from the burning of coal and gas used as support fuel. Emissions from the clay materials were estimated by estimating the likely emissions from coal and gas combustion in the manufacture of the bricks and then subtracting these estimates, which are included in source category 1A2f, from the emissions reported in the Pollution Inventory. This gave an estimated of emission from the clay which are reported here. The recent emissions data are extrapolated back using estimates of Fletton brick production. The sole company involved in the manufacture of Fletton bricks has been

approached previously but did not provide any additional data; this will increase the uncertainty of the estimates of emissions from earlier years.

Emissions of NMVOC from glass fibre and glass wool processes in recent years are also available from the Pollution Inventory, although these do not include the two glass wool producers located in Scotland. The Pollution Inventory data are used to calculate emission factors, based on estimates of glass production and emissions can then be calculated both to include all processes and, by extrapolation, to include other years.

Emissions of NMVOC during manufacture of coated roadstone are estimated using production data from TSO, 2005 and an emission factor of 8.73 g/t coated roadstone, which is the average of emission factors given by US EPA, 2005 for various types of batch roadstone coating plant.

### **4.8.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

The estimates for all of these processes are very uncertain. However, the glass and roadstone coating processes are very minor sources of NMVOC and are not considered further. Estimates for Fletton bricks, carbon in particular, are sensitive to the assumptions made about supplementary fuel use and so the estimates could be improved were fuel consumption data available.

The time-series involves some extrapolation of data using brick production estimates and this will introduce further uncertainty within the earlier part of the time series.

### **4.8.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

### **4.8.5 Source-specific recalculations**

There have been only very minor recalculations for this version of the inventory and these do not lead to any significant change in emission estimates.

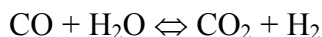
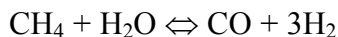
### **4.8.6 Source-specific planned improvements**

Emissions estimates related to Fletton brick production could be significantly improved on the basis of better information on the usage of supplementary fuels and this will be sought.

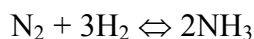
## **4.9 SOURCE CATEGORY 2B1 – AMMONIA PRODUCTION**

### **4.9.1 Source category description**

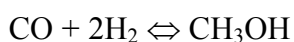
Ammonia is produced using the Haber process, which starts with the steam reforming of natural gas to make hydrogen. The simplified reactions are:



The hydrogen is then reacted with nitrogen from air to form ammonia



If there is no use of the by-products CO and CO<sub>2</sub> formed, then these are emitted to atmosphere. Ammonia plants can be integrated with methanol and/or acetic acid manufacture for greater efficiency. Thus, hydrogen formed as a by-product from acetic acid manufacture is used as the feedstock for ammonia manufacture. Some carbon monoxide and carbon dioxide from the reforming process is used to manufacture methanol:



One ammonia plant sells CO<sub>2</sub> to the food industry and nuclear industry. Because this CO<sub>2</sub> is still ultimately emitted to atmosphere, it is included in the emissions reported here. This is judged more reliable than trying to identify carbon emissions at the point of final use since CO<sub>2</sub> will also be emitted from other processes such as fermentation.

Ammonia was being produced at four UK sites by the end of 2004, one of which also produced acetic acid. Methanol production, which was carried out at a different UK site, ceased in 2001.

#### **4.9.2 Methodological issues**

Emissions from ammonia production and the associated production of methanol and acetic acid are reported under two inventory source categories. The first category is reserved for emissions of CO<sub>2</sub> from natural gas used as a feedstock in the ammonia and other processes. The second category includes emissions of CO<sub>2</sub> and other pollutants from the combustion of natural gas to produce the heat required by the reforming process.

Emissions of CO<sub>2</sub> from feedstock use of natural gas were calculated by combining reported data on CO<sub>2</sub> produced, emitted and sold by the various ammonia processes. Where data were not available, they have been calculated from other data such as plant capacity or natural gas consumption. The ammonia plant utilising hydrogen by-product from acetic acid manufacture does not need to be included since there are no process emissions of CO<sub>2</sub>.

A correction has to be made for CO<sub>2</sub> produced at one site where some of this CO<sub>2</sub> is subsequently 'recovered' through sequestration in methanol. This carbon is calculated from methanol capacity data based on the stoichiometry of the chemical reaction. (This only applies to estimates for 1990-2001, after which this correction is not required as the methanol plant ceased operation.)

The use of natural gas as a feedstock was calculated by combining:

1. natural gas equivalent to carbon sequestered in methanol (see above)
2. natural gas equivalent to the CO<sub>2</sub> emitted from ammonia manufacture

### 3. natural gas usage of the acetic acid plant, available from the process operator

For the first two parts of the calculation, the default carbon emission factor for natural gas was used to convert between carbon and natural gas. The total feedstock use of natural gas was estimated as the sum of items 1-3 and a CO<sub>2</sub> emission factor can be calculated from the CO<sub>2</sub> emission estimate already generated.

Emissions of CO<sub>2</sub> and other pollutants from natural gas used as a fuel are calculated using estimates of natural gas usage as fuel supplied by the operators and emission factors. Factors for NO<sub>x</sub> are back-calculated from reported NO<sub>x</sub> emissions data, while emission factors for carbon, methane, CO, N<sub>2</sub>O and NMVOC are default emission factors for industrial gas combustion.

#### **4.9.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

A consistent time series of activity data has usually been reported from the manufacturers of ammonia, and this results in good time series consistency of emissions. For 2001 to 2004, no new ammonia production data were received from one plant operator. Production estimates from 2000 and annual plant emissions data from the Environment Agency Pollution Inventory have been used to estimate production & emissions from this plant in 2001-2004.

#### **4.9.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

#### **4.9.5 Source-specific recalculations**

The method for emissions estimation was improved in the compilation of the 2004 inventory, to use a time-series of natural gas carbon emission factors rather than a single factor across the time-series, as previously. This has led to a very slight revision of emissions across the full time-series.

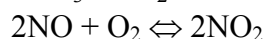
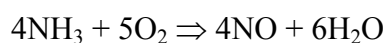
#### **4.9.6 Source-specific planned improvements**

Emission factors and activity data will be kept under review.

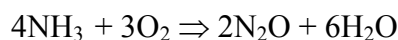
### **4.10 SOURCE CATEGORY 2B2 – NITRIC ACID PRODUCTION**

#### **4.10.1 Source category description**

Nitric acid is produced by the catalytic oxidation of ammonia:



Nitrous oxide is also formed by oxidation of ammonia:



Nitrous oxide is emitted from the process as well as a small percentage of the  $\text{NO}_x$ . Nitric acid was being manufactured at 4 UK sites at the end of 2004. One of the sites has nitrous oxide abatement fitted to all nitric acid process plant since commissioning (all pre-1990). The three other sites have no nitrous oxide abatement fitted to any units.

#### **4.10.2 Methodological issues**

Across the 1990-2004 time-series, the availability of emissions and production data for UK Nitric Acid (NA) plant is inconsistent, and hence a range of methodologies have had to be used to provide estimates and derive emission factors for this sector.

For plant in England, emissions data are available for all sites from 1998 onwards. For the plant (now closed) in Northern Ireland, emissions data became available from 2001.

Site-specific production estimates are largely based on production capacity reported directly by the plant operators. This approach may overestimate actual production. No data are available for two sites operating between 1990 and 1994, and production at these sites is calculated based on the difference between estimates of total production and the sum of production at the other sites.

Emission estimates for  $\text{N}_2\text{O}$  are derived for each NA site using:

- a) emissions data provided by the process operators directly or via the Pollution Inventory (1998 onwards for plant in England, 2001 onwards for plant in N Ireland);
- b) site-specific emission factors derived from reported emissions data for the same site for another year (1990-1997 for some plant in England, 1994-1997 for other plant in England, 1990-2000 for plant in N Ireland);
- c) a default emission factor of 6 ktonnes  $\text{N}_2\text{O}$  /Mt 100% acid produced in cases where no emissions data are available for the site (some sites in England, 1990-1993). This default factor is the average of the range quoted in IPCC Guidelines (IPCC, 1997) for medium pressure plant

Emissions of  $\text{NO}_x$  are derived for each nitric acid site using emissions data provided by the process operators directly or via the Pollution Inventory. No emissions data are available before 1994 and so a default  $\text{NO}_x$  emission factor of 3.98 tonne  $\text{NO}_x$  / ktonne of 100% acid produced and nitric acid production data (CIS, 1991) is used up to 1988 with emissions between 1989 and 1993 being calculated by linear interpolation. The default emission factor is an aggregate factor based on CORINAIR (1989) emission factors for the different types of processes ranging from 3-12 t/kt of 100% acid produced. The aggregate factor was based on data on UK manufacturing plant provided by the Nitric Acid Association for the year 1985 (Munday, 1990).

Some nitric acid capacity is associated with a process that manufactures adipic acid. For the years 1990-1993, its emissions are reported combined with those from the adipic acid plant (see **Section 3.10**) and emissions from 1994 onwards are reported separately. This causes some inconsistency in between reporting categories, although total emissions are not affected.

#### **4.10.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

Emissions from nitric acid production are estimated based on a combination of emission factors and reported emissions data. The methodology used to estimate N<sub>2</sub>O for this sector does vary through the time-series depending upon the availability of data. The calculated N<sub>2</sub>O EF for UK nitric acid production facilities varies quite significantly across the time series, and this may be a reflection of the lack of availability of a consistent time-series of emissions data. However, the variable N<sub>2</sub>O EF for this sector is also a reflection of nitric acid production patterns across UK sites that utilise different process conditions with only one plant fitted with N<sub>2</sub>O abatement.

For all plants in England, emissions of N<sub>2</sub>O used in the GHG inventory are taken from emissions reported in the Pollution Inventory data from 1998 onwards. For the plant in Northern Ireland, reported emission data became available from 2001 onwards. Prior to these years in England, emissions of N<sub>2</sub>O are estimated using either plant-specific EFs (in terms of plant capacity) based on 1998 PI data and applied to known historic plant capacity, or by applying a default emission factor of 6 ktonnes N<sub>2</sub>O /Mt 100% acid produced for some plant in 1990-1993. A similar approach has been used for the nitric acid plant in Northern Ireland prior to 2001.

The nitric acid plant emissions data are considered to be reliable since they are subject to internal QA/QC checks by the plant operators and the Environment Agency before being reported in the Pollution Inventory. More details have been obtained regarding the abatement plant and N<sub>2</sub>O monitoring methodologies at the one UK plant with N<sub>2</sub>O abatement fitted, and this has clarified some previous uncertainties regarding their process emissions.

#### **4.10.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

#### **4.10.5 Source-specific recalculations**

2003 emission estimates have been revised for two of the four production sites following emissions data updates from the operators. No other recalculations have been made.

#### **4.10.6 Source-specific planned improvements**

Emission factors and activity data will be kept under review.

**4.11 SOURCE CATEGORY 2B3 – ADIPIC ACID PRODUCTION****4.11.1 Source category description**

Adipic acid is manufactured in a multi-stage process from cyclohexane via oxidation with nitric acid. Nitrous oxide is produced as a breakdown product from the nitric acid. A single company produces adipic acid in the UK.

**4.11.2 Methodological issues**

Production data and emission estimates have been estimated based on data provided by the process operator (Invista, 2005). The emission estimates are based on extrapolation of on-line measurement of the concentration of nitrous oxide in the flue gases, conducted for regulatory compliance monitoring purposes since 1998. Prior to 1998, the operators have provided estimates of emissions based on emission factors.

A small nitric acid plant is associated with the adipic acid plant that also emits nitrous oxide. From 1994 onwards this emission is reported as nitric acid production but prior to 1994 it is included under adipic acid production. This will cause a variation in reported effective emission factor for these years. This allocation reflects the availability of data.

In 1998 an N<sub>2</sub>O abatement system was fitted to the plant. The abatement system is a thermal oxidation unit and is reported by the operators to be 99.99% efficient at N<sub>2</sub>O destruction. In 2004 it was operational 92.6 % of the time (when compared to plant operation).

**4.11.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

Emissions of N<sub>2</sub>O from adipic acid production are now taken from emissions reported in the Pollution Inventory, with more process-specific details also provided directly by the plant operators. In the early 1990s, emissions were received direct from the plant operators.

The level of uncertainty associated with reported emissions of N<sub>2</sub>O is not currently known. However these data are considered to be reliable since they are subject to internal QA/QC checks within the company producing the adipic acid, and QA/QC checks by the Environment Agency before being reported in the Pollution Inventory.

Fluctuations in the N<sub>2</sub>O EF from this plant are apparent since the installation of the abatement plant. Following direct consultation with the plant operators, it has been determined that the variability of emissions is due to the varying level of availability of the abatement plant. A small change in the availability of the abatement system can have a very significant impact upon overall plant emissions and hence upon the annual IEF calculated.

**4.11.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. During summer 2005, consultation between Defra, Netcen, plant operators and the UK Metereological Office was conducted to discuss factors affecting emissions from the

adipic acid plant, including: plant design, abatement design, abatement efficiency and availability, emission measurement techniques, historic stack emission datasets and data to support periodic fluctuations in reported emissions. These discussions were intended to clarify the relationship between annual emission totals reported by the plant operators and emissions verification work conducted by the Met Office using ambient N<sub>2</sub>O concentration measurements from the Mace Head observatory in Ireland. The meeting prompted exchange of detailed plant emissions data and recalculation of back-trajectory emission models.

#### **4.11.5 Source-specific recalculations**

No recalculations have been required for this version of the inventory.

#### **4.11.6 Source-specific planned improvements**

Emission factors and activity data will be kept under review.

### **4.12 SOURCE CATEGORY 2B4 – CARBIDE PRODUCTION**

This category does not occur in the UK.

### **4.13 SOURCE CATEGORY 2B5 – OTHER**

#### **4.13.1 Source category description**

The UK has a large chemical manufacturing sector and emissions of methane, carbon monoxide, NO<sub>x</sub>, SO<sub>2</sub>, and NMVOC in the inventory are treated in some detail to reflect the many different types of process. All of these emission sources are reported under 2B5.

Chemical manufacturing processes are a significant source of NMVOC emissions. Due to the complexity of the sector and the difficulty of separating emissions from different chemical processes, almost all emissions are reported using a single, general, category.

Emissions of the remaining pollutants are less significant compared with national totals but are reported in more detail.

Methane emissions are reported separately for production of ethylene and production of methanol, these chemicals being suggested as sources by the IPCC Guidelines for National Greenhouse Gas Inventories. Ethylene was manufactured on four sites at the end of 2003 while the only methanol plant closed in 2001. The IPCC Guidelines also suggested that methane might be emitted from manufacture of carbon black, styrene and dichloroethylene however no evidence of any emissions of methane from these processes has been found and no estimates have been made. However, methane is emitted from other UK chemical processes and these emissions are reported as third, general, source category.

Emissions of other pollutants are reported under the following source categories:

- Chemical industry - CO, SO<sub>2</sub>, NMVOC
- Chemical industry (carbon black) - CO, SO<sub>2</sub>



- Chemical industry (nitric acid use) - NO<sub>x</sub>
- Chemical industry (pigment manufacture) - SO<sub>2</sub>
- Chemical industry (reforming) - CO
- Chemical industry (soda ash) - CO
- Chemical industry (sulphuric acid use) - SO<sub>2</sub>
- Chemical industry (titanium dioxide) - CO
- Coal, tar and bitumen processes - NMVOC
- Solvent and oil recovery - NMVOC
- Ship purging - NMVOC
- Sulphuric acid production - SO<sub>2</sub>

The first source listed is the general category used where emissions occur from processes, which do not fit elsewhere. The remaining categories are specific and often relate to small numbers of sites. Carbon black is produced at two sites by partially burning petroleum feedstocks to produce finely divided soot. The categories 'chemical industry (nitric acid use)' and 'chemical industry (sulphuric acid use)' refer to processes using these acids and emitting NO<sub>x</sub> and SO<sub>2</sub> respectively. Manufacture of nitric acid (see **Section 4.10**) and sulphuric acid are treated separately from use. Sulphuric acid was being produced at four sites at the end of 2004. Pigment manufacture relates to a single plant where sulphur is burnt as part of the manufacturing process. The sulphur oxides produced are largely consumed in the process, although some emissions do occur.

Reforming processes convert natural gas or other light hydrocarbons into hydrogen and carbon monoxide for use in further chemical processes, and can result in emissions of CO. Soda ash manufacture also results in some emissions of CO, which is formed during the lime manufacturing stage and then passes through the chemical processes before being emitted. These emissions are not included in the inventory category 'Lime (combustion)'. Titanium dioxide is manufactured by two routes in the UK, but one involves the use of coke as a reductant and is carried out on two sites. Carbon monoxide is emitted to atmosphere from the process. The remaining three source categories are reserved for minor sources of NMVOC. Processes involving coal-based chemicals and bitumen-based products are reported under 'coal, tar & bitumen processes', the recovery of solvents and other organic chemicals by distillation is reported under 'oil & solvent recovery', and the venting of chemical vapours from ships' tanks where cross-contamination of cargoes must be avoided, is reported under 'ship purging'.

#### **4.13.2 Methodological issues**

Emissions data for chemical processes located in England and Wales are available in the Pollution Inventory (Environment Agency, 2005). Reporting generally started in 1994 or 1995, and few data exist for the years prior to 1994. Data for ethylene production processes in Scotland and additional data for some of the methane-emitting processes in England and Wales have been obtained from process operators and from the Scottish Pollutant Release Inventory (SEPA, 2005). The Scottish Environment Protection Agency has also, on previous occasions, supplied some data on emissions of NMVOC from individual Scottish chemical processes and additional NMVOC data for processes located in both Scotland and Northern Ireland have been obtained from process operators. The National Sulphuric Acid Association (NSAA, 2003) have provided historical emissions data for sulphuric acid production

processes. Emissions from ship purging are based on a single estimate given by Rudd *et al* (1996), which is applied to all years.

All of the data available are in the form of emission estimates, usually generated by the process operators and based on measurements or calculated based on process chemistry. Emission factors and activity data are not required, although emission factors are back-calculated in the process of extrapolation of emissions back to the years prior to 1994. The extrapolation is usually linked to changes in the level of output from the chemicals manufacturing sector as measured by the 'index of output' figures published by the Office of National Statistics (2005). In a few cases, such as the figures for methane from ethylene production and SO<sub>2</sub> from sulphuric acid production, actual emissions data are available or can be estimated for individual plant based on actual plant capacities.

Some gaps exist in the reported data. For example, emissions from a given process will be reported for some years but not others, even though the process is known to have been operating. These gaps are presumably due to the fact that either the process operator was not required to submit emissions data or that emissions data was not or could not be supplied when requested. Most of the gaps occur in the early years of the pollution inventory. These gaps have been filled by copying emissions data from the nearest year for which emissions data were reported.

#### **4.13.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

Emission estimates for 1994 onwards are mostly based on data reported by process operators and might therefore be considered accurate. However, in the absence of any detailed assessment of the methods used by individual process operators to estimate emissions, it is not possible to come to a definite conclusion. Emission estimates for NMVOC are more uncertain than the estimates for other pollutants because of the way in which these emissions are reported in the Pollution Inventory. As a result, the data have to be interpreted using expert judgement.

Emission estimates for the period prior to 1994 are also more uncertain, with the exceptions of sulphuric acid production and methane emissions. This is due to the need for extrapolation of emissions data for 1994, or later, backwards, using general indicators of chemical industry output.

The reliability of emission estimates from 2002 onwards may deteriorate for at least some of the sources included in this sector. This is due to changes in the reporting requirements for the Pollution Inventory with the *de minimis* limits for reporting of emissions of some pollutants being raised, and greater use made of extrapolation based on drivers.

#### **4.13.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

#### **4.13.5 Source-specific recalculations**

Some recalculation of emissions has occurred since the last inventory. This is due to a number of factors including:

- changes to the emissions data given in the Pollution Inventory and other sources;
- the influence of emissions data for 2004, available for the first time, with subsequent changes to the extrapolations necessary for filling 'gaps' in the data (for example, gaps in reported data for 2003 might previously been filled using emissions reported for 2002, whereas now the mean of the 2002 and 2004 emissions would be used).

The various recalculations have usually resulted in very small changes in emissions from these sources compared with values in the last version of the inventory. These changes are summarised below by gas.

##### **4.13.5.1 Recalculation by gas**

The following section describes the main changes that have occurred in sector 2A5 per pollutant since the publication of the 2003 inventory (2005 NIR). Comparisons are made between the current inventory (1990-2004) and the previous inventory (1990-2003) for the year 2003.

###### **4.13.5.1.1 Non Methane Volatile Organic Compounds (NMVOCs)**

- Estimated emissions from 2B5 have decreased by 4 Gg for NMVOC. This is largely due to revisions in the emission factors for the chemicals and manmade fibres section of the industry due to updates in available data.

#### **4.13.6 Source-specific planned improvements**

Estimates of emissions from this sector are subject to uncertainty although this uncertainty is not well understood. The estimates of NMVOC are certainly subject to considerable uncertainty and have been considered as a priority for improvement for some years. However, the methods used to generate emission estimates for all of these sources are complex and require a significant effort each year in terms of data gathering, data interpretation and extrapolation. Changes in the methodology are likely to be required from year to year in order to deal with changes in the data available. The intention behind these changes is to try to maintain the quality of estimates at current levels but improvement of the estimates would almost certainly require radical and resource-intensive changes to the procedures used to generate emission estimates.

### **4.14 SOURCE CATEGORY 2C1 – IRON AND STEEL PRODUCTION**

#### **4.14.1 Source category description**

UK iron and steel production may be divided into integrated steelworks, electric arc steelworks, downstream processes such as continuous casting and rolling of steel, and iron & steel foundries.

Integrated steelworks convert iron ores into steel using the three processes of sintering, pig iron production in blast furnaces and conversion of pig iron to steel in basic oxygen furnaces. For the purposes of the inventory, emissions from integrated steelworks are estimated for these three processes, as well as other minor processes such as slag processing.

Sintering involves the agglomeration of raw materials for the production of pig iron by mixing these materials with fine coke (coke breeze) and placing it on a travelling grate where it is ignited. The heat produced fuses the raw materials together into a porous material called sinter. Emissions of CO<sub>2</sub>, CH<sub>4</sub>, CO, NO<sub>x</sub>, SO<sub>2</sub>, and NMVOC from sintering are reported under CRF category 1A2.

Blast furnaces are used to reduce the iron oxides in iron ore to iron. They are continuously charged with a mixture of sinter, fluxing agents such as limestone, and reducing agents such as coke. Hot air is blown into the lower part of the furnace and reacts with the coke, producing carbon monoxide, which reduces the iron ore to iron. Gas leaving the top of the blast furnace has a high heat value because of the residual CO content, and is used as a fuel in the steelworks. Molten iron and liquid slag are withdrawn from the base of the furnace. Subsequent cooling of the slag with water can cause emissions of SO<sub>2</sub>. The most significant greenhouse gas emissions to occur directly from the blast furnace process are the combustion gases from the 'hot stoves' used to heat the blast air. These generally use blast furnace gas, together with coke oven gas and/or natural gas as fuels. These emissions are reported under CRF category 1A2. Gases emitted from the top of the blast furnace are collected and emissions should only occur when this gas is subsequently used as fuel. These emissions are allocated to the process using them. However, some blast furnace gas is lost and the carbon content of this gas is reported under CRF category 2C1.

Pig iron has a high carbon content derived from the coke used in the blast furnace. A substantial proportion of this must be removed to make steel and this is done in the basic oxygen furnace. Molten pig iron is charged to the furnace and oxygen is blown through the metal to oxidise carbon and other contaminants. As a result, carbon monoxide and carbon dioxide are emitted from the furnace and are collected for use as a fuel. As with blast furnace gases, some losses occur and these losses are reported with blast furnace gas losses under CRF category 2C1.

Electric arc furnaces produce steel from ferrous scrap, using electricity to provide the high temperatures necessary to melt the scrap. Emissions of carbon dioxide occur due to the breakdown of the graphite electrodes used in the furnace and NO<sub>x</sub> is formed due to oxidation of nitrogen in air at the high temperatures within the furnace. Emissions of NMVOC and CO occur due to the presence of organic contaminants in the scrap, which are evaporated and partially oxidised. Emissions from electric arc furnaces are reported under CRF category 2C1.

The inventory contains estimates of NMVOC emissions from rolling mills. Lubricants are needed and contain organic material, some of which evaporates. These emissions are reported under 2C1. A more significant emission from rolling mills and other downstream processing of steel are those emissions from use of fuels to heat the metal. These emissions are reported under 1A2.

#### **4.14.2 Methodological issues**

The methodology for the prediction of carbon dioxide emissions from fuel combustion, fuel transformation, and processes at integrated steelworks is based on a detailed carbon balance (this methodology is described in more detail within the section on CRF sector 1A2a). Carbon emissions from electric arc furnaces are calculated using an emission factor provided by BISPA (1997). For other pollutant emissions from blast furnaces, emissions are partly based on the methodology described in IPCC (1997), with some revisions made to the SO<sub>2</sub> factors based on data available from industry. Details of all methodologies are provided in **Annex 3, Section A3.4.2**, which also provides details on emissions from electric arc furnaces. Energy related emissions from foundries are included in category 1A2a but any process emissions from foundries of direct GHGs are likely to be very small and are not estimated.

#### **4.14.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

Much of the activity data used to estimate emissions from this source category come from the Iron and Steel Statistics Bureau (ISSB) and the DTI publication DUKES. Time-series consistency of these activity data are very good due to the continuity in data provided in these two publications.

#### **4.14.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

#### **4.14.5 Source-specific recalculations**

Some minor recalculations have been made as a result of the inclusion of new data from Corus UK Ltd, who operate UK integrated steelworks. These recalculations include the reporting of emissions of CO<sub>2</sub> from ladle arc furnaces for the first time (12 Gg CO<sub>2</sub> in 2003) and the revision of the emission factor for CO<sub>2</sub> emissions from electric arc furnaces (a decrease of 15 Gg CO<sub>2</sub> in 2003). Other revisions to emission estimates include a decrease of 23 Gg CO from basic oxygen furnaces and a decrease of 8 Gg SO<sub>2</sub> for blast furnaces.

#### **4.14.6 Source-specific planned improvements**

Emission factors and activity data will be kept under review. Where appropriate, fuel characterisation data from verified Emission Trading Scheme datasets will be considered in future GHGI cycles.

### **4.15 SOURCE CATEGORY 2C2 – FERROALLOYS PRODUCTION**

This category is not relevant to the UK since the early 1990s. Prior to then, some ferroalloys were produced however emissions are likely to have been trivial.

**4.16 SOURCE CATEGORY 2C3 – ALUMINIUM PRODUCTION****4.16.1 Source category description**

Aluminium is produced by the electrolytic reduction of alumina, currently at three sites in the UK. A fourth process closed in mid 2000. All of the operational sites use the pre-baked anode process, whereas the closed plant used the Soderberg Cell process. This distinction is important because of large differences in emission rates for some pollutants.

Both process types make use of carbon anodes and these anodes are consumed as the process proceeds, resulting in emissions of CO<sub>2</sub>, CO, NMVOC and SO<sub>2</sub>. The high temperatures necessary in the process mean that NO<sub>x</sub> is also emitted. Finally, the PFC species tetrafluoromethane (CF<sub>4</sub>) and hexafluoroethane (C<sub>2</sub>F<sub>6</sub>) are formed if the alumina content of the electrolyte falls too low. Computerised control of alumina addition to the cells is a feature of modern plant and has helped to reduce PFC emissions from aluminium production.

**4.16.2 Methodological issues**

Emissions of carbon were estimated based on the production of aluminium for each type of process and emission factors. The carbon emission factors reflect current practice, and higher emission factors were used for earlier years.

All emissions of PFCs occur during the aluminium smelting process. The estimates were based on actual emissions data provided by the aluminium-smelting sector. There are two main aluminium smelting operators in the UK. One operator uses a Tier 2 methodology Smelter-specific relationship between emissions and operating parameters based on default technology-based slope and over-voltage coefficients, using the default factors for the CWPB (Centre Worked Prebaked) plant. However, in the near future they are looking to move to Tier 3b methodology, once on-site equipment is in place to make the relevant field measurements. The other operator uses a Tier 3b methodology (as outlined in the IPCC guidance) Smelter-specific relationship between emissions and operating parameters based on field measurements. The methodology used for estimating emissions, based on IPCC Good Practice Guidance (2000), was 'Tier 2 Method – smelter-specific relationship between emissions and operating parameters based on default technology-based slope and over-voltage coefficients'. Emissions estimates were based on input parameters, including frequency and duration of anode effects, and number of cells operating. Emission factors were then used to derive the type of PFC produced. All emissions occur during manufacturing.

The type of smelter design has a large effect on the rate of PFC emissions. The UK industry has previously made major investment to improve their technology and all UK plants now use point feeder prebake. A more detailed description of the methodology used to calculate emission estimates for this sector is provided in AEAT (2004). A minor methodology change was made in 2005 concerning the conversion of emissions reported in tonnes by industry into CO<sub>2</sub> equivalent units. Details of this are provided in the section 'sector-specific recalculations' below.

For other pollutants, some emissions data are available from the Environment Agency's Pollution Inventory for the two largest processes in England & Wales, whilst data for the plant located in Scotland were obtained by direct contact with the plant operators, derived from

emission factors calculated from the England & Wales plant emissions, or obtained from the Scottish Pollutant Release Inventory, produced by the Scottish Environmental Protection Agency (SEPA).

#### **4.16.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

The source of activity data, from 1990 to the current inventory year, is from data compiled by the British Geological Survey (production of primary aluminium). This is a long running publication and the compilers of the activity data strive to use consistent methods to produce the activity data. This helps to ensure good time series consistency of the emission estimates.

#### **4.16.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

#### **4.16.5 Source-specific recalculations**

Emissions of PFCs reported in kt CO<sub>2</sub>eq have undergone a minor recalculation this year. In previous years a weighted GWP value (6770 i.e. 90% CF<sub>4</sub>, 10% C<sub>2</sub>F<sub>6</sub>) was used for all years to convert the emissions reported by industry in tonnes into CO<sub>2</sub> equivalent units. This methodology was corrected this year so that the value of emissions reported in CO<sub>2</sub> equivalent units now reflects the relative ratio of CF<sub>4</sub> and C<sub>2</sub>F<sub>6</sub> emissions reported by industry.

#### **4.16.6 Source-specific planned improvements**

Emission factors and activity data will be kept under review. Where appropriate, fuel characterisation data from verified Emission Trading Scheme datasets will be considered in future GHGI cycles.

### **4.17 SOURCE CATEGORY 2C4 – SF<sub>6</sub> USED IN ALUMINIUM AND MAGNESIUM FOUNDRIES**

#### **4.17.1 Source category description**

SF<sub>6</sub> is used in the magnesium alloy and casting industry as a cover gas, to prevent molten magnesium oxidising when exposed to air. All SF<sub>6</sub> used in this way is released to the atmosphere unless capture/recycle technologies are employed. SF<sub>6</sub> is non-flammable and non-toxic, and is therefore a safe gas to use. In the UK, SF<sub>6</sub> has been used as an alternative cover gas to SO<sub>2</sub> in magnesium alloy production and sand and die-casting since the early 1990s. Magnesium alloy production and casting are therefore significant emitters of SF<sub>6</sub> in the UK.

In the UK, there is one large magnesium alloy producer and six smaller casting operators (three die-casting and 3 sand-casters (one of which closed during 2003/4). Alloy production involves the use of primary magnesium ingots, recycled scrap material and second-generation magnesium materials (i.e. material already made into alloys) for the production of different

alloys. Both die and sand casters use these magnesium alloys to produce specific components for a wide range of industries. For the casting industry, SF<sub>6</sub> is used for casting specific magnesium alloys where other cover gases, such as argon, are not suitable.

#### Methodological issues

For magnesium alloy production, emissions from 1998-2004 were estimated based on the emission data reported by the company to the UK's Pollution Inventory. This data is considered reasonably robust whilst earlier data (pre-1998) are estimated based on consultation with the manufacturer. In 2004, for the first time, one of the main industry users has implemented a cover gas system using HFC134a as a cover gas for some of its production capacity. There has not been a complete switch to HFC 134a, although the operator is considering this on an ongoing basis depending on suitability for the different alloys produced. In addition to having a significantly lower GWP than SF<sub>6</sub> (and thus reducing emissions on a CO<sub>2</sub> equivalent basis), use of HFC134a is further advantageous in that a significant fraction of it is destroyed by the high process temperatures thus reducing the fraction of gas emitted as a fugitive emission. It is assumed 90% of the used HFC cover gas is destroyed in the process (CSIRO 2005). As this is obviously a key assumption that affects the level of reported emissions, this factor for HFC destruction will be kept under review and the possibility of obtaining a UK-specific factor will be investigated in the future.

For the casting operations, emission estimates made in previous years (as documented in AEAT (2004)) used a previous model from the March (1999) study for the casting sector. In order to improve the quality of this data this estimate has been revised based on consultation with all of the casting operators. Each operator was asked to supply annual SF<sub>6</sub> usage data for 1990 – 2004 – all responded to this request. The data supplied has been aggregated with the magnesium alloy production sector, to produce a single estimate for the whole sector, thus avoiding disclosure of company specific data.

Note that actual emissions of SF<sub>6</sub> for this sector are reported for practical reasons under 2C5 'Other metal production'. This is because the CRF Reporter does not allow reporting of HFC emissions under the 2C4 sector category.

#### **4.17.2 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

The following information on uncertainty associated with time-series data for this sector should not be confused with the formal IPCC uncertainty analysis in **Annex 7**.

For the period 1990-1997, the estimated uncertainty in the time series data was +/- 30%. The main area of uncertainty is regarding emissions of SF<sub>6</sub> from casting based on discussions with the sector Trade Association. Data from the main magnesium alloy producer is also uncertain for this period. For the period 1998-2004, the uncertainty of the time-series emissions is estimated to be significantly lower (+/- 10%). Data received from the main magnesium alloy producer is considered to be reasonably robust and accurate.



#### **4.17.3 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

#### **4.17.4 Source-specific recalculations**

Emission data for this sector (primarily for magnesium casting activities) has been revised since last year's submission to UNFCCC. A description of the changes made is provided above in the methodology section. The recalculation is considered to lead to an improved estimate for casting activities, as previous estimates were based on modelled data from earlier work (March 1999), whereas now actual SF<sub>6</sub> consumption statistics have been obtained from industry..

#### **4.17.5 Source-specific planned improvements**

Emission factors and activity data will be kept under review.

### **4.18 SOURCE CATEGORY 2C5 – OTHER METAL PRODUCTION**

#### **4.18.1 Source category description**

UK production of many non-ferrous metals has been relatively small for many years and has declined further in recent years with the closure of the only primary lead/zinc producer in 2003 and the only secondary copper production process in 1999. A number of secondary lead processes exist, although the capacity of one lead refinery has been significantly reduced following the closure of the primary lead/zinc producer, which used to supply it with lead bullion. The two closed processes and some of the secondary lead processes use coke as a reductant and emissions from these processes should be reported under 2C5. Currently, emissions of carbon from use of this coke are included with estimates for other industrial combustion (see **Section A3.4.3**) while emissions of CO from the lead/zinc smelter, copper refinery and secondary lead producers are reported under 2C5. Two of the secondary lead producers also emit SO<sub>2</sub> from the automotive batteries that they recover lead from. Copper wire rod plants use natural gas burners to create a slightly reducing atmosphere in the melting furnace, which helps to maintain a high conductivity product. Emissions of CO are reported under 2C5. Carbon monoxide is also used by the only UK nickel refinery and is produced by reforming of butane. Emissions from this process have been included in the NAEI estimates for chemical industry reforming processes and are reported under 2B5.

As described in the preceding section, (2C4 SF<sub>6</sub> used in Aluminium and Magnesium Foundries) actual emissions of SF<sub>6</sub> and HFC134a for this sector are reported under 2C5 for practical reasons under 2C5 'Other metal production' as the CRF Reporter does not allow reporting of HFC emissions under the 2C4 sector category.

#### **4.18.2 Methodological issues**

Emission estimates for these processes are derived from emissions data available from the Pollution Inventory (Environment Agency, 2005). For earlier years, where no emissions data

are available, emission estimates are made by extrapolation based on production of the relevant type of metal.

#### **4.18.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

Emissions of direct greenhouse gases from this source category will be minor and are currently not estimated. No comments are currently made here on the time series consistency of the indirect GHGs.

#### **4.18.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

#### **4.18.5 Source-specific recalculations**

No major recalculations

#### **4.18.6 Source-specific planned improvements**

Emission factors and activity data will be kept under review.

### **4.19 SOURCE CATEGORY 2D1 – PULP AND PAPER**

#### **4.19.1 Source category description**

The UK paper industry is mainly confined to the production of pulp from recycled material and the production of papers using either imported virgin pulp, recycled pulp or a combination of the two. Production of virgin pulp is limited to a few processes producing mechanical or neutral sulphite semi-chemical pulp. Emissions from UK paper processes consist largely of emissions from the associated combustion processes, which supply steam and power to the papermaking processes. These emissions are reported under CRF category 1A2. Other atmospheric emissions of greenhouse gases from UK paper and pulp processes will be minor and are currently not estimated.

Emissions of NMVOC from the manufacture of chipboard, fibreboard and oriented strand board (OSB) are reported under 2D1. These products differ in the type of wood material that is made into board. Chipboard is made from assorted wood shavings, dust & chippings etc., while fibreboard is made from mechanically pulped wood fibres and OSB is made from long, thin wafers of wood with fairly uniform dimensions. All three processes involve steps for drying of the wood particles and hot pressing of the formed board and both steps give rise to some NMVOC emissions.

#### **4.19.2 Methodological issues**

Emissions are estimated using emission factors derived from those available in the USEPA Compilation of Air Emission Factors (USEPA, 2005). Production of the wood products is

estimated from data published by the Office of National Statistics. These data are given as areas or volumes of product depending upon the type of product and must be converted to a mass basis by making assumptions about the thickness and/or density of the products.

#### **4.19.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

#### **4.19.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

#### **4.19.5 Source-specific recalculations**

No recalculations have been required for this version of the inventory.

#### **4.19.6 Source-specific planned improvements**

Emission factors and activity data will be kept under review.

### **4.20 SOURCE CATEGORY 2D2 – FOOD AND DRINK**

#### **4.20.1 Source category description**

A number of food and drink manufacturing processes give rise to emissions of NMVOC. Most significant are emissions of ethanol from whisky maturation. Whisky is matured for a period of years in wooden barrels. This process develops the character of the whisky but an inevitable consequence is that spirit evaporates from the barrel. Other spirit manufacturing stages such as fermentation, distillation, casking (whisky only) and drying of spent grains also give rise to NMVOC emissions although these emissions are relatively small in comparison with those from maturation. Whisky manufacture is confined mainly to Scotland, which has 7 large grain distilleries and approximately 90 smaller, malt distilleries. There is a single small whisky distillery in Wales and a large whiskey distillery in Northern Ireland. Scotland is also a major source of other distilled spirits such as gin and vodka, as is England. Malt production also creates emissions of NMVOC. Malting is occasionally carried out by distilleries but most malt, both for distillers and breweries, is produced by specialist maltsters. Brewing processes such as fermentation and wort boiling and fermentation for production of cider and wine are all very minor sources of NMVOC.

Bread manufacture involves fermentation reactions and ethanol is released as a result. Most bread in the UK is made in large mechanised bakeries, of which there are about 70. The remainder is made in small ‘craft bakeries’. Some other baked products include a fermentation stage and also emit ethanol. Heating of food products can cause reactions that produce organic emissions, and so processes such as drying of vegetable matter, preparation of compounded animal foods and cooking of meat and fish can cause NMVOC emissions. Finally, the processing of oils and fats is also a source of emissions, although emissions of

hexane, a solvent used to extract vegetable oil from rape and other oilseeds is included in estimates of solvent use rather than as a food industry emission.

#### **4.20.2 Methodological issues**

Emissions of NMVOC from food and drink manufacture are all calculated using emission factors and activity data obtained from either industry or Government sources. In the case of whisky maturation, data are available for volumes of whisky in storage at the end of each year from the Scotch Whisky Association (2004), and so emissions can be calculated by applying an annual emission rate factor with the average volume of whisky in storage for each year. This is more accurate than using an overall emission factor applied to whisky production since whiskies are stored for varying lengths of time and stock levels will rise or fall depending upon production, demand and changes in the length of maturation required.

#### **4.20.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

Emissions of direct greenhouse gases from this source category will be minor and are currently not estimated.

#### **4.20.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

#### **4.20.5 Source-specific recalculations**

A minor recalculation has been made to the estimated emission of NMVOC from the maturation of alcoholic drinks other than Scotch Whisky following the receipt of new data – emission estimates are 2 Gg higher than previously.

#### **4.20.6 Source-specific planned improvements**

Emission factors and activity data will be kept under review.

### **4.21 SOURCE CATEGORY 2E – PRODUCTION OF HALOCARBONS AND SF<sub>6</sub>**

#### **4.21.1 Source category description**

Emissions arise from the UK manufacture of HFCs, PFCs and HFC 23 (as a by-product formed during HCFC 22 production). There are two single manufacturers of HFCs and PFCs respectively in the UK, and two companies currently operate HCFC 22 plants. Species data from these sectors have been aggregated to protect commercial confidentiality. There is no UK production of SF<sub>6</sub>.

In terms of their global warming impact (expressed as kt CO<sub>2</sub> eq.), HFC 23 emissions are responsible for the substantial majority of emissions from this manufacturing sector. HFC 23 is emitted as a by-product of HCFC 22 production. It has a high GWP, and traditionally is

emitted at levels of 3-5% of the amount of HCFC 22 produced. The market for HCFC 22 is presently made up of three elements:

- end user markets, refrigerants for refrigeration and air-conditioning equipment (subject to phasing out under the Montreal Protocol)
- export markets
- feedstock for production of certain plastic products, especially PTFE.

## **4.21.2 Methodological issues**

Emissions for this sector were calculated using the same emission model as used for the UK's previous submission. A full description of the emission model and associated methodology used is contained in AEAT (2004). Within the model, manufacturing emissions from UK production of HFCs, PFCs and HFC 23 (by-product of HCFC 22 manufacture) are estimated from reported data from the respective manufacturers. Manufacturers have reported both production and emissions data, but only for certain years, and for a different range of years for different manufacturers. Therefore the emissions model is based on implied emission factors, and production estimates are used to calculate emissions in those years for which reported data was not available. Two of the three manufacturers are members of the UK greenhouse gas Emissions Trading Schemes. As a requirement of participation in the scheme, their reported emissions are verified annually via external and independent auditors.

Under an agreement on confidentiality, the three UK manufacturers have provided speciated data for certain years on the condition that only aggregated data are reported. As described in Section 4.21.1, there is only one UK manufacturer of HFCs, a different sole manufacturer of PFCs and two manufacturers of HCFC22. The UK inventory team will continue to investigate to establish whether it will be possible to report emissions by species in future.

## **4.21.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in Annex 7, shown in Table A7.5a and Table A7.5b, provides estimates of uncertainty according to IPCC source category and fuel type.

There is a significant decrease in HFC emissions in 1998/1999. This step-change in emissions is due to the installation of thermal oxidiser pollution abatement equipment at one of the UK manufacturing sites. Fugitive HFC emissions from both an HCFC22 plant and HFC manufacturing plant (run by the same operator) are treated using the same thermal oxidiser unit. Emissions also decrease in 2004, reflecting the installation of a thermal oxidiser at the second of the UK's HCFC22 manufacturing sites. This was installed in late 2003, and went fully online in 2004.

A significant increase in PFC emissions from the production of halocarbons is observed from 1992 to 1996 (with the trend changing after 1996). The increase in emissions was due to increasing production levels at the single UK manufacturing plant during this period. Since 1996, the level of emissions have changed each year which broadly reflects the demand (and hence production levels) for PFCs. In 2004, emissions reported by the company have increased compared with the preceding 3 years of fairly stable emission levels 2001-2003.

The following information on uncertainty associated with time-series data for this sector has been derived from the study that produced the emission estimates (AEAT, 2004) based on an

understanding of the uncertainties within the sector and from discussion with industry, and should not be confused with the formal IPCC uncertainty analysis in Annex 7. An uncertainty range of +/- 15% was estimated for the time-series emissions.

#### **4.21.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**, and details of verification of emissions of HFC-134a and HFC-152a are given in **Annex 8**. Additionally, as described above in **Section 4.21.2**, two of the UK manufacturing plants also have their emissions externally validated as part of the requirements of the UK Emissions Trading Scheme.

#### **4.21.5 Source-specific recalculations**

In the current submission, some recalculations have been performed since the previous submission, although the overall significance of these is small. Manufacturing and fugitive emissions of HFCs for 2002 and 2003 have been updated to reflect new data received from industry (which replaces values that were previously estimated using modelled data). The timeseries of PFC emissions has also been revised for some years again reflecting updated information reported by industry to the UK's Pollution Inventory. This data affects the calculated average implied emission factors used in the emissions model to estimate emissions in years where reported data on the actual level of emissions is not available. .

#### **4.21.6 Source-specific planned improvements**

There are no source-specific improvements planned.

### **4.22 SOURCE CATEGORY 2F1 – REFRIGERATION AND AIR CONDITIONING EQUIPMENT**

#### **4.22.1 Source category description**

HFCs and HFC blends have been widely used as replacement refrigerants across virtually all refrigeration sub-sectors. They generally share many of the properties of CFC and HCFC refrigerants, namely low toxicity, zero and/or varying degrees of flammability and acceptable materials compatibility. Emissions of HFCs can occur at various stages of the refrigeration/air-conditioning product life-cycle:

- during the refrigeration equipment manufacturing process;
- over the operational lifetime of the refrigeration or air-conditioning unit; and
- at disposal of the refrigeration or air-conditioning unit.

This emission category contains aggregated emission estimates from the following sector sub-divisions:

- Domestic refrigeration (including refrigerators, chest freezers, upright freezers and fridge-freezers)

- Other small hermetic refrigeration units (including through the wall air-conditioners, retail equipment, drinking water coolers etc)
- Small commercial distributed systems (including pub cellar coolers, small chill and cold stores)
- Supermarket systems
- Industrial systems
- Building air conditioning systems (direct use of refrigerant)
- Building air-conditioning chillers (indirect use of refrigerant)
- Refrigerated transport (refrigerated lorries, containers etc) using conventional refrigeration technology
- Mobile air conditioning (air-conditioning systems for cars and other vehicles).

#### **4.22.2 Methodological issues**

Emissions for this sector were calculated using the same emission model as used for the UK's previous submission. A full description of the emissions and associated methodology used is contained in AEAT (2004). The general methodology used was based on that of March (1999). The calculation methodology within the model is considered to provide a relatively conservative approach to the estimation of emissions. The bank of fluid is estimated by considering the consumption of fluid in each sector, together with corrections for imports, exports, disposal and emissions. Once the size of the bank in a given year is known, the emission can be estimated by application of a suitable emission factor. Emissions are also estimated from the production stage of the equipment and during disposal. The methodology corresponds to the IPCC Tier 2 'bottom-up' approach. Data are available on the speciation of the fluids used in these applications; hence estimates were made of the global warming potential of each fluid category.

Emissions from the domestic refrigeration sector were estimated based on a bottom-up approach using UK stock estimates of refrigerators, fridge-freezers, chest-freezers and upright freezers from the UK Market Transformation Programme (MTP, 2002). For the commercial refrigeration sub-sectors, emissions for these sectors were based on the activity data supplied by industry and used in previous emission estimates by March (1999) and WS Atkins (2000). Consultation with a range of stakeholders was used to determine appropriate country-specific emission factors; these generally fell within the ranges given in IPCC guidance (IPCC 2000). A full list of emission factors and assumptions used for the domestic and commercial refrigeration sub-sectors is provided in AEAT (2004).

Emissions of HFCs from mobile air conditioning systems were also derived based on a bottom-up analysis using UK vehicle statistics obtained from the UK Society of Motor Manufacturers and Traders, and emission factors determined in consultation with a range of stakeholders. A full account of the assumptions and data used to derive emission estimates for the MAC sub-sector is in AEAT (2004).

#### **4.22.3 Uncertainties and time-series consistency**

The following information on uncertainty associated with time-series data for this sector has been derived from the study that produced the emission estimates (AEAT, 2004), and should not be confused with the formal IPCC uncertainty analysis in **Annex 7**.

Estimates of the uncertainties associated with time-series data for this sector were made in AEAT (2004), based on an understanding of the uncertainties within the sector and from discussion with industry. An uncertainty range of +/- 20% was estimated for the aggregated time-series emissions from the domestic and commercial refrigeration sectors, and +/- 10% for the mobile air conditioning sector.

#### **4.22.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Details of verification of emissions of HFC-134a and HFC-152a are given in **Annex 8**.

#### **4.22.5 Source-specific recalculations**

There have been no significant recalculations made to the emissions data for this sector since the previous submission.

#### **4.22.6 Source-specific planned improvements**

Emission factors and activity data will be kept under review.

### **4.23 SOURCE CATEGORY 2F2 – FOAM BLOWING**

#### **4.23.1 Source category description**

Prior to the Montreal Protocol, a wide range of foams was produced using CFC blowing agents. As use of these chemicals was banned, the industry moved to alternatives including HCFCs. For applications such as packaging and cushioning, the use of HCFCs was banned under the EC Regulation on Substances that Deplete the Ozone Layer (EC 3093/94) and these sectors moved to blowing agents such as water or CO<sub>2</sub>. Use of HCFC was still permitted in rigid insulating foams and integral skin foams for safety applications, but a new EC Regulation on Substances that Deplete the Ozone Layer (EC 2037/2000) has or will shortly ban all HCFC use in these remaining sectors.

Emissions of HFCs from foams can occur:

- during the manufacturing process
- over the lifetime of the foam; rigid foams are closed cell foams and the blowing agent is designed to remain in the foam and contributes to its performance. Loss of HFCs is undesirable as it may affect the performance of the foam but is estimated to occur, albeit at a low rate
- at disposal of the foam.

Emissions at each point vary according to the type of foam. Typically, of the HFC used in the production process, less than 10% is emitted during manufacture (although emissions may be as high as 40 to 45 % for some types of foam), less than 1% per year over the useful lifetime of the product and the remainder on disposal.



### **4.23.2 Methodological issues**

Emissions for this sector were calculated using the same emission model as used for the UK's previous submission. A full description of the emissions and associated methodology used is contained in AEAT (2004). The emissions for the years 1990 to 2002 are based on data from March (1999). Emissions data for recent years (2003 onward) were obtained from UK industry experts. The methodology used estimates the bank of fluid used by considering the consumption of fluid in each foam sub-sector, together with corrections for imports, exports, disposal and emissions. Once the size of the bank in a given year is known, the emission can be estimated by application of a suitable emission factor. Emissions are also estimated from the production stage of the equipment and during disposal. The methodology corresponds to the IPCC Tier 2 'bottom-up' approach.

### **4.23.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

The following information on uncertainty associated with time-series data for this sector has been derived from the study that produced the emission estimates (AEAT, 2004), and should not be confused with the formal IPCC uncertainty analysis in **Annex 7**.

Estimates of the uncertainties associated with time-series data for this sector were made in AEA Technology (2004), based on an understanding of the uncertainties within the sector and from discussion with industry. Time-series data was estimated to have an uncertainty range of +/- 30% for this sector.

### **4.23.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Details of verification of emissions of HFC-134a and HFC-152a are given in **Annex 8**.

### **4.23.5 Source-specific recalculations**

There have been no significant recalculations made to the emissions data for this sector since the previous submission.

### **4.23.6 Source-specific planned improvements**

Emission factors and activity data will be kept under review.

## **4.24 SOURCE CATEGORY 2F3 – FIRE EXTINGUISHERS**

### **4.24.1 Source category description**

In the UK, manufacturers of fixed suppression systems for fire fighting have been using HFCs as an alternative to Halons for the past 7-8 years. Fluorocarbons currently take up some 25% of the market that would have previously been covered by Halons. This is primarily due to the specific requirements of certain industries where the use of HFCs is seen as necessary to

reduce fire risks. Such systems have much faster discharge and suppression times, and do not damage equipment.

The systems are also compact and take up minimal space. The HFCs themselves are non-toxic. It is the combination of speed, space and safety that makes HFCs important alternatives to Halon in those applications where these properties are required. HFC-based systems are used for the protection of electronic and telecommunications equipment, and in military applications, records offices, bank vaults and oil production facilities.

The main HFC used in UK fixed systems is HFC 227, with some use of HFC 23 and HFC 125. The majority of emissions of HFCs will occur when the system is discharged, either when triggered accidentally or during a fire. Minimal emissions may also occur during filling or maintenance of the systems. The rest of the market for fixed system applications uses inert gases or non-gaseous agents, such as water mist, and non-extinguishing early warning systems.

As well as HFCs being used to replace halon-based systems in the mid-1990s, a small quantity of PFC (mainly  $C_4F_{10}$ ) was imported by a US company into the EU to be used as an alternative fluid in fire fighting fixed systems. The main application of these PFC-based fixed systems is for fire protection of flooding closed rooms (e.g. control rooms). Imports for new systems stopped in 1999, as this application of PFCs was not regarded as an essential use. For purposes of recharge, PFCs are still supplied. By 2010 there will probably be no fixed systems using PFCs in the EU. Emissions of PFCs from these systems are thought to be insignificant relative to other PFC emission sources.

Portable extinguishers have moved away from Halons, with most manufacturers using water, dry powder and carbon dioxide as the replacement. A small number of niche applications use HFCs, but emissions from such applications are thought to be insignificant.

## **4.24.2 Methodological issues**

Emissions for this sector were calculated using the same emission model as used for the UK's previous submission. Emissions estimates were obtained from March (1999) for years 1990-1996 and for subsequent years from the representative UK trade organisation, the Fire Industry Council (FIC). The emissions data are based on estimates of installed capacity and an annual emission rate of approximately 5% per annum until 2000 and decreasing to 4% in 2004 (an assumption based on literature studies (Verdonik and Robin 2004). The latter has been based on discussion with the industry, and with reference to the 1998 UNEP Halon Technical Options Committee (HTOC) report. There are no emissions from HFC prior to 1995. A full description of the associated methodology used is contained in AEAT (2004).

## **4.24.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

The following information on uncertainty associated with time-series data for this sector has been derived from the study that produced the emission estimates (AEAT, 2004), and should not be confused with the formal IPCC uncertainty analysis in **Annex 7**.

Estimates of the uncertainties associated with time-series data for this sector were made in AEAT (2004), based on an understanding of the uncertainties within the sector and from discussion with industry. Uncertainties in emissions over the 1990-2004 period were estimated to be +/- 5-10%.

#### **4.24.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Details of verification of emissions of HFC-134a and HFC-152a are given in **Annex 8**.

#### **4.24.5 Source-specific recalculations**

There have been no significant recalculations made to the emissions data for this sector since the previous submission.

#### **4.24.6 Source-specific planned improvements**

Emissions have been recalculated for the years 2001-2003. This has occurred as a result of work undertaken to review emission factors from this sector. Information received from discussion with the UK Fire Protection System industry and literature studies suggested the previous emission factor assumed for those years (5%) was too high, and that a transition from 5% leakage (including releases) in 2000, decreasing to 4% leakage in 2004 was appropriate.

### **4.25 SOURCE CATEGORY 2F4 – AEROSOLS/ METERED DOSE INHALERS**

#### **4.25.1 Source category description**

In the UK, HFCs are generally used as propellants in specific aerosols where the use of HFCs is considered critical, i.e. where safe alternative propellants are not available. Historically many types of aerosols were formulated with CFCs as propellants. However, for the vast majority of aerosols, the use of CFCs ceased at the end of 1989 on account of concerns regarding their role in ozone destruction. Aerosol manufacturers could then choose between a number of options to replace CFCs, including hydrocarbons, dimethyl ether (DME), compressed gases or HFCs.

The vast majority of aerosols use hydrocarbon propellants, with a relatively small proportion of the market favouring DME. Compressed gases are used in very few aerosols since they suffer from a number of disadvantages compared with liquefied gas propellants such as DME and hydrocarbons. HFCs are used only in a few specialist applications, which can be categorised as industrial or non-industrial. Most of these are considered critical (as defined by BAMA (British Aerosol Manufacturers Association) and agreed by Defra) with regard to the use of HFCs as propellants. The most important industrial applications in volume terms are air dusters and pipe freezing products; other applications include specialised lubricants and surface treatments, and specialised insecticides. The main non-industrial applications in the UK are novelty products, such as 'silly string', where the use of HFC is considered critical due to the need for non-flammable propellants. The use of HFCs for novelty applications is

proposed to be eliminated in the future, under the proposed EC Regulation on fluorinated greenhouse gases.

Metered dose inhalers (MDIs) are used to deliver certain pharmaceutical products as an aerosol. For patients with respiratory illnesses, such as asthma and chronic obstructive pulmonary disease (COPD), medication needs to be delivered directly to the lungs. MDIs are one of the preferred means of delivering inhaled medication to patients with these illnesses. MDIs originally used CFC propellants but, as with industrial aerosols, concern over ozone destruction led to attempts to replace CFCs with HFCs. HFCs have been identified as the only viable replacement for CFCs in MDIs as no other compound has met the stringent criteria for a medical gas to be used for inhalation by patients. Criteria include the need for the gas to be non-flammable, non-toxic, liquefied, chemically stable, compatible with range of medicines, acceptable to patients, and to have appropriate density and solvent properties. This switch from CFCs to HFCs has resulted in increasing emissions of HFCs from this sector (although a saving in terms of CO<sub>2</sub> equivalent).

#### **4.25.2 Methodological issues**

Emissions for this sector were calculated using the same emission model as used for the UK's previous submission. A full description of the emissions and associated methodology used is contained in AEAT (2004). Aerosol HFC emission estimates have been derived on the basis of fluid consumption data provided by BAMA. Estimates of emissions from HFC-filled aerosols were derived by estimating the amount of fluid used annually in their manufacture. An average product lifetime of one year for all aerosols containing HFC has been assumed, based on discussions with BAMA, although this may be shorter or longer depending on the specific aerosol application. The number of HFC-based aerosols that are used in the UK is derived from data from BAMA, based on assumptions concerning imports and exports. It is estimated that 1% of HFC emissions from aerosols occur during manufacture. The majority is released during the product lifetime (97%), with end of life emissions accounting for the other 2%. These emission factors are the same as those estimated in previous work by March (1999). The lifetime and end of life emissions are calculated after import and exports have been taken into account.

The MDI methodology was based on a Tier 2 bottom-up analysis, deriving the number of units (inhalers) used annually and estimating the amount of HFC in each inhaler. Although the amount of HFC in each inhaler differs between manufacturers, an average amount was assumed. MDIs were assumed to emit 96% of total HFC contained during the lifetime usage: 2% of emissions occur during manufacture and 2% at end-of-life. Import and export levels have been based on data provided by manufacturers, and estimates of the UK market for MDI usage.

#### **4.25.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

The following information on uncertainty associated with time-series data for this sector has been derived from the study that produced the emission estimates (AEAT, 2004), and should not be confused with the formal IPCC uncertainty analysis in **Annex 7**.

Estimates of the uncertainties associated with time-series data for this sector were made in AEAT (2004), based on an understanding of the uncertainties within the sector and from discussion with industry. The uncertainty for aerosol emissions was estimated to be +/- 15-20%, based on uncertainties surrounding the estimation of import and export markets, and reliance on estimates from previous work (March 1999). For MDIs, the uncertainty was estimated to be +/- 30-40%, a relatively high uncertainty due to the use of approximations of the use of HFCs in MDIs for research work, and assumptions that had to be made concerning the import / export market, domestic market and number of doses used in the UK annually.

#### **4.25.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Details of verification of emissions of HFC-134a and HFC-152a are given in **Annex 8**.

#### **4.25.5 Source-specific recalculations**

Estimates of emissions from aerosols for the years 2001-2003 have been updated based on new data received from BAMA, the British aerosols sector trade association. They have provided new estimates for these years derived from a confidential survey of UK aerosol filling companies including BAMA members and non-members.

#### **4.25.6 Source-specific planned improvements**

Emission factors and activity data will be kept under review.

### **4.26 SOURCE CATEGORY 2F5 – SOLVENTS**

#### **4.26.1 Source category description**

HFCs can be used as solvents in a range of applications such as precision cleaning to replace CFCs, HCFCs or 1,1,1-trichloroethane, the use of all of which have been or will be phased out as a result of the Montreal Protocol. In recent years, HFCs have been developed that are used for precision cleaning in sectors such as aerospace and electronics. CFCs were used as solvents in precision cleaning before being replaced by certain HCFCs, namely HCFC-141-b. As an ozone depleting substance, this HCFC has started to be replaced by HFC-43-10mee, albeit slowly. Due to only being used as a replacement in recent years, the amount of this HFC being sold in the UK market at present is thought to be insignificant relative to other UK sources of HFCs. However, future growth could be high, depending on their use as a replacement to HCFC-141b over the next 10 years.

#### **4.26.2 Methodological issues**

Emissions for this sector were calculated using the same emission model as used for the UK's previous submission. A full description of the emissions and associated methodology used is contained in AEAT (2004). UK estimates of emissions from this source were based on a recent European evaluation of emissions from this sector (Harnisch and Schwarz, 2003), subsequently disaggregated to provide a top-down UK estimate.

### **4.26.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

The following information on uncertainty associated with time-series data for this sector has been derived from the study that produced the emission estimates (AEAT, 2004), and should not be confused with the formal IPCC uncertainty analysis in **Annex 7**.

Estimates of the uncertainties associated with time-series data for this sector were made in AEAT (2004), based on an understanding of the uncertainties within the sector and from discussion with industry. There is a relatively high uncertainty estimated for emissions from this sector (+/- 25%).

### **4.26.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Details of verification of emissions of HFC-134a and HFC-152a are given in **Annex 8**.

### **4.26.5 Source-specific recalculations**

There have been no significant recalculations made to the emissions data for this sector since the previous submission.

### **4.26.6 Source-specific planned improvements**

Emission factors and activity data will be kept under review.

## **4.27 SOURCE CATEGORY 2F6 – SEMICONDUCTOR MANUFACTURE**

### **4.27.1 Source category description**

PFCs and SF<sub>6</sub> are released from activities in this source sector.

Emissions of PFCs from semiconductor manufacturing are combined with emissions from training shoes in source category 2F8b for reasons of commercial confidentiality. This source category is described in **Section 4.30**.

Emissions of SF<sub>6</sub> from semiconductor manufacturing are combined with emissions from training shoes and electrical insulation in source category 2F8b for reasons of commercial confidentiality. This source category is described in **Section 4.30**.

**4.28 SOURCE CATEGORY 2F7 – ELECTRICAL EQUIPMENT****4.28.1 Source category description**

SF<sub>6</sub> is released from activities in this source sector.

Emissions of SF<sub>6</sub> from electrical equipment (insulation in electrical transmission and distribution – e.g. switchgear) are combined with emissions from training shoes and semiconductor manufacture in source category 2F8b for reasons of commercial confidentiality. This source category is described in **Section 4.30**.

**4.29 SOURCE CATEGORY 2F8A – ONE COMPONENT FOAMS****4.29.1 Source category description**

One Component Foams (OCFs) are used by tradesmen (and in the home improvement sector to a lesser extent) to mount doors and windows, and to insulate different types of open joints and gaps. As an insulator, OCF helps improve energy efficiency, due to the insulating properties of the PU foam and because the foam adheres to the building materials providing air tightness. Therefore, use of OCFs could contribute to savings of CO<sub>2</sub> through improved energy efficiency. When used as an OCF propellant, HFC (134a, 152a) is blended with various flammable gases. HFC escapes from the foam on application, leaving small residues, which remain in the hardened foam for up to a year. These products are not manufactured in the UK, although they are imported.

**4.29.2 Methodological issues**

Emissions for this sector were calculated using the same emission model as used for the UK's previous submission. A full description of the emissions and associated methodology used is contained in AEAT (2004). UK estimates of emissions from this source were based on a recent European evaluation of emissions from this sector (Harnisch and Schwarz, 2003), subsequently disaggregated by GDP to provide a top-down UK estimate.

**4.29.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

The following information on uncertainty associated with time-series data for this sector has been derived from the study that produced the emission estimates (AEAT, 2004), and should not be confused with the formal IPCC uncertainty analysis in **Annex 7**.

Estimates of the uncertainties associated with time-series data for this sector were made in AEAT (2004), based on an understanding of the uncertainties within the sector and from discussion with industry. Emissions from this sector are estimated to fall within an uncertainty range of 10-25%.

**4.29.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Details of verification of emissions of HFC-134a and HFC-152a are given in **Annex 8**.

**4.29.5 Source-specific recalculations**

There have been no significant recalculations made to the emissions data for this sector since the previous submission.

**4.29.6 Source-specific planned improvements**

Emission factors and activity data will be kept under review.

**4.30 SOURCE CATEGORY 2F8B – SEMICONDUCTORS, ELECTRICAL AND PRODUCTION OF TRAINERS****4.30.1 Source category description**

SF<sub>6</sub> has been used as a cushioning agent in sports-shoes. It is well suited to this application because it is chemically and biologically inert and its high molecular weight means it cannot easily diffuse across membranes. This means the gas is not released until the training shoe is destroyed at the end of its useful life. SF<sub>6</sub> has also been used for filling tennis balls, but this practice has now ceased.

SF<sub>6</sub> has been used in electrical transmission and distribution high and medium voltage switchgear and transformers since the mid-1960s because the physical properties of the gas make it very effective as an arc-quenching medium and as an insulator. Consequently it has gradually replaced equipment using older technologies, namely oil filled and air blast equipment.

The electronics industry is one of the largest sources of PFC emissions in the UK, accounting for 36% of emissions in 2000.

The main uses of PFCs are:

- cleaning of chambers used for chemical vapour deposition (CVD) processes
- dry plasma etching
- vapour phase soldering and vapour phase blanketing
- leak testing of hermetically sealed components
- cooling liquids, e.g. in supercomputers or radar systems.

In addition SF<sub>6</sub> is used in etching processes for polysilicon and nitrite surfaces, and there is some usage of CHF<sub>3</sub> and NF<sub>3</sub>. The first two of these processes (cleaning and etching during semiconductor manufacture) account for the majority of emissions from the sector, with cleaning accounting for around 70% and etching 30%.



### 4.30.2 Methodological issues

Emissions from these sectors have been combined for reasons of commercial confidentiality. Emissions for this sector were calculated using the same emission model as used for the UK's previous submission. A full description of the emissions and associated methodology used is contained in AEAT (2004). Estimates of emissions from sports-shoes were based on a bottom-up Tier 2 estimate, using activity data supplied in confidence by the manufacturer.

SF<sub>6</sub> emission from electrical transmission and distribution were based on industry data from BEAMA (for equipment manufacturers) and the Electricity Association (for electricity transmission and distribution), who provided emission estimates based on Tier 3b, but only for recent years. Tier 3a estimates were available for the electricity distribution and transmission industry for 1995. In order to estimate a historical time series and projections, these emission estimates together with fluid bank estimates provided by the utilities were extrapolated using the March study methodology (March, 1999). This involved estimating leakage factors based on the collected data and using the March model to estimate the time series. Emissions prior to 1995 used the March SF<sub>6</sub> consumption data to extrapolate backwards to 1990 from the 1995 estimates.

Emissions of PFC and SF<sub>6</sub> emissions from electronics are based on data supplied by UK MEAC – the UK Microelectronics Environmental Advisory Committee. UK MEAC gave total PFC consumption for the UK electronics sector based on purchases of PFCs as reported by individual companies. Emissions were then calculated using the IPCC Tier 1 methodology, which subtracts the amount of gas left in the shipping container (10%), the amount converted to other products (between 20% and 80% depending on the gas) and the amount removed by abatement (currently assumed to be zero). Emissions for previous years were extrapolated backwards assuming an annual 15% growth in the production of semiconductors in the UK up until 1999.

### 4.30.3 Uncertainties and time-series consistency

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and fuel type.

The following information on uncertainty associated with time-series data for this sector has been derived from the study that produced the emission estimates (AEAT, 2004), and should not be confused with the formal IPCC uncertainty analysis in **Annex 7**.

Estimates of the uncertainties associated with time-series data for this sector were made in AEAT (2004), based on an understanding of the uncertainties within the sector and from discussion with industry. Estimated uncertainties in individual sectors: sports-shoes: +/- 20-50%, electronics +/- 30%, and electrical transmission and distribution +/- 20%.

### 4.30.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Details of the verification of the greenhouse gas inventory are given in **Annex 8**.

### **4.30.5 Source-specific recalculations**

There have been no significant recalculations made to the emissions data for this sector since the previous submission.

### **4.30.6 Source-specific planned improvements**

Emission factors and activity data will be kept under review.

## 5. Solvent and Other Product Use (CRF sector 3)

### 5.1 OVERVIEW OF SECTOR

Solvents are used in a wide range of processes and products and the GHGI gives detailed estimates to reflect this diversity. Significant quantities of solvent are used both for industrial applications (mainly coatings and cleaning solvents), but also for non-industrial applications (mainly aerosols, decorative paints and consumer products).

**Annex 3.5** contains more detailed descriptions of the methods used to estimate emissions in this sector.

### 5.2 SOURCE CATEGORY 3A – PAINT APPLICATION

#### 5.2.1 Source category description

Emissions of solvents from the use of both industrial and decorative paints are reported under CRF source category 3A. Both types of paint are further sub-divided in the GHGI:

**Table 5.1** Paints and their applications in the UK

Type of paint	Application
Decorative paint: Retail decorative Trade decorative	'DIY' decorative coatings mainly sold directly to the public 'Professional' decorative coatings mainly sold to decorating contractors
Industrial coatings: ACE Aircraft Coil Commercial vehicles Drum High performance Marine  Metal and plastic Metal packaging OEM Vehicle refinishing Wood	Coatings for agricultural, construction and earthmoving equipment Coatings for aircraft & aircraft components Coatings for steel and aluminium coil Coatings for new, non-mass produced vehicles Coatings for new and reclaimed metal drums Coatings for large structures such as bridges, offshore installations etc. Coatings for the exteriors and interiors of ships and yachts including both new and old vessels  Coatings for metal and plastic substrates not covered elsewhere Coatings for food and beverage cans and other small metal packaging Coatings for new mass-produced road vehicles Coatings for the refinishing of road vehicles Coatings for wooden substrates

### **5.2.2 Methodological issues**

Emission estimates for most types of coatings are based on annual consumption data and emission factors provided by the British Coatings Federation (BCF, 2005). Emission estimates for drum coatings, metal packaging and OEM coatings are estimated instead using a combination of consumption data and emission factors and estimates made on a plant by plant basis using information supplied by the Metal Packaging Manufacturers Association (MPMA, 2000) and the regulators of individual sites.

### **5.2.3 Uncertainties and time-series consistency**

This source does not affect the overall total or trend in UK emissions of direct greenhouse gases and is not included in the Tier 1 or Tier 2 uncertainty analysis.

The data used to estimate emissions from paint application are mostly provided by the British Coating Federation (BCF) and the data is thought to be consistent. Estimates for the drum coating, car coating, and metal packaging coating sectors are based on emissions data collected from regulators for the latter part of the time series with extrapolation to earlier years on the basis of BCF coating consumption data. This extrapolation is not thought likely to introduce significant problems with the accuracy of estimates.

### **5.2.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

### **5.2.5 Source-specific recalculations**

Recalculations have been made to reflect new data provided by the British Coatings Federation (2005). These recalculations lead to an overall increase in estimated emissions of NMVOC of 16 Gg in 2003.

### **5.2.6 Source-specific planned improvements**

Emission factors and activity data will be kept under review.

## **5.3 SOURCE CATEGORY 3B – DEGREASING AND DRY CLEANING**

### **5.3.1 Source category description**

This sector covers the use, predominantly of chlorinated solvents, for cleaning and degreasing of surfaces, dry cleaning of clothing and textiles and degreasing of leather.

Chlorinated solvents, including trichloroethene, tetrachloroethene and dichloromethane are widely used in industry to clean metallic, plastic and other surfaces, often using the process of vapour degreasing. Objects to be cleaned are suspended above boiling solvent. Solvent vapour condenses on the object and removes grease and other surface contamination. Cooling tubes at the top of the tank minimise emissions but some solvent is emitted. Cold cleaning is also used with objects being dipped in cold solvent and larger objects may be hand cleaned with solvent-soaked cloths. Historically, 1,1,1-trichloroethane was also used as a

cleaning solvent but this was prohibited due to this solvent's contribution to ozone depletion and use ceased by 1999.

Hydrocarbons and oxygenated solvents are also used as cleaning solvents, generally being used for hand cleaning or cold cleaning of objects.

Dry cleaning involves the use of tetrachloroethene to clean clothes and textiles in special equipment. The solvent is largely recovered and recycled within the machine but emissions do occur, especially in older 'open' machines, where the final drying stage involves venting of solvent-laden vapour to atmosphere.

Sheepskins must be degreased due to their high fat content. Degreasing can be done using either hydrocarbon or chlorinated solvents.

### **5.3.2 Methodological issues**

Emission estimates for surface cleaning processes are based on estimates of annual consumption and emission factors. Consumption estimates are based on data from UK industry sources and UK and European trade associations, together with some published data. Some extrapolation of data is necessary, using Index of Output data produced annually by the Office for National Statistics (ONS), although this is not expected to introduce significant uncertainty into the estimates. Emission factors assume that all hydrocarbon and oxygenated solvent is emitted, while emission factors for chlorinated solvents are lower, reflecting the fact that some solvent is sent for disposal rather than emitted.

Emission estimates for dry cleaning are based on estimates of solvent consumption by the sector. Industry-sourced data are available for some years and estimates for the remaining years are based on a model of the sector, which takes account of changes in the UK population and the numbers of machines of different types and with different emission levels.

Emission estimates for leather degreasing are based on a single estimate of solvent use extrapolated to all years using the Index of Output for the leather industry, which is produced annually by the ONS.

### **5.3.3 Uncertainties and time-series consistency**

This source does not affect the overall total or trend in UK emissions of direct greenhouse gases and is not included in the Tier 1 or Tier 2 uncertainty analysis.

The time series for degreasing emissions uses a consistent methodology, although the activity data used are not of uniform quality for each year, some extrapolation of data being required. This extrapolation is not thought likely to introduce significant problems with the accuracy of estimates. Although perhaps more uncertain than estimates for 3A and 3C, the estimates for source category are still expected to be good.

### **5.3.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

### **5.3.5 Source-specific recalculations**

No significant recalculations were necessary for this sector.

### **5.3.6 Source-specific planned improvements**

Emission factors and activity data will be kept under review.

## **5.4 SOURCE CATEGORY 3C – CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING**

### **5.4.1 Source category description**

This sector includes the manufacture of coatings, the coating of films, leather, paper and textiles, and the use of solvents in the manufacture of tyres and other rubber products.

Coating manufacture includes the manufacture of paints, inks, and adhesives, plus specialist coatings for films, leather, paper and textiles.

Film coating includes the manufacture of photographic film, data storage films, hot stamping films and other specialist products. Processes manufacturing hot stamping films are especially large users of solvents.

Leather is generally coated with products that are waterborne, although more solvent borne coatings were used historically. Coatings are used to provide protection or to enhance the appearance by improving colour or glossiness.

Textile coating processes include the manufacture of textiles, manufacture of tarpaulins and other heavy-duty textiles, and coating of textiles with rubber.

Solvents are used in the manufacture of tyres and other rubber products such as hose, belting and sports goods. The solvent is used for cleaning and also to increase the tackiness of the rubber during joining operations.

### **5.4.2 Methodological issues**

Emission estimates for coating of film, leather, and textiles as well as estimates for tyre manufacture are based on plant-by-plant emission estimates, made on the basis of information available from regulators.

Emissions from coating manufacture are calculated from the solvent contained in coatings produced in the UK, by assuming that an additional 2.5% of solvent was lost during manufacture.

Emissions from the manufacture of rubber goods other than tyres are based on solvent consumption estimates provided by the British Rubber Manufacturers Association (BRMA), which are extrapolated to other years on the basis of the Index of Output figures for the rubber industry which are published each year by the ONS.

### 5.4.3 Uncertainties and time-series consistency

This source does not affect the overall total or trend in UK emissions of direct greenhouse gases and is not included in the Tier 1 or Tier 2 uncertainty analysis.

Estimates for sources covered by source category 3C are estimating using a consistent methodology with relatively little extrapolation of data. As with the estimates for source categories 3A and 3B, extrapolation of data is not thought likely to introduce significant problems with the accuracy of estimates.

### 5.4.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

### 5.4.5 Source-specific recalculations

No significant recalculations were necessary for this sector.

### 5.4.6 Source-specific planned improvements

Emission factors and activity data for the category will be kept under review.

## 5.5 SOURCE CATEGORY 3D - OTHER

### 5.5.1 Source category description

This category covers a diverse group of sources including paper coating, printing processes, adhesives use, seed oil extraction, wood impregnation, agrochemicals use, aerosols, consumer products and miscellaneous solvent use.

Paper coating processes include solvent used in the manufacture of wallpapers, together with coating of other specialist paper products such as vehicle air filters or colour cards.

Printing processes differ in their requirement for solvent-borne inks and chemicals. Most solvent use occurs from the printing of flexible packaging using flexography and rotogravure printing with solvent-borne inks. Publication gravure printing for magazines and catalogues etc. also uses high solvent inks. Heatset web offset printing, coldset web offset, and sheetfed offset, used for printing magazines, newspapers and other publications, employ paste inks that contain high boiling point hydrocarbons which are driven off and burnt in the case of heatset web offset or absorb into the printed substrate in the case of the other two processes. Offset presses may use solvents in the 'damping solutions', which are used to ensure accurate reproduction of the image. Letterpress printing also uses paste inks that dry by adsorption and is little used now. Paper & board packaging are printed using flexography, rotogravure and offset although, unlike flexible packaging, the flexographic and gravure inks used are generally waterborne. Screen printing, used for high quality colour printing such as art reproduction, textile printing and point of sale printing can use either water or solvent-based inks. Other, specialist printing processes include printing of roll labels and printing of

securities both of which use a variety of printing techniques including offset, letterpress, copperplate (a form of gravure printing with paste inks), flexography, and screen printing. Solvent-borne varnishes may be applied over some printed materials.

Adhesives are used by many industries, although solvent-borne adhesives are becoming increasingly confined to a small number of industry sectors. Construction and pressure-sensitive tapes and labels are the largest users of solvent-borne adhesives. Other sectors include footwear, abrasives, and some furniture manufacture.

Seed oil extraction involves the use of hexane to extract vegetable oil from rape and other seed oils. The solvent is recovered and reused in the process.

Solvents are used in some wood preservatives, although consumption has fallen markedly in the last ten years. Emissions from use of creosote, which does not contain solvent, are also reported under 3D.

Agrochemicals can be supplied in many forms including solid or solutions and some are dissolved in organic solvents, which are emitted when the agrochemical is applied.

Aerosols use organic chemicals both as propellants and as solvents. All use of volatile organic materials in aerosols is reported under CRF source category 3D. Non-aerosol consumer products which contain or can contain significant levels of solvents include fragrances, nail varnish and nail varnish remover, hair styling products, slow release air fresheners, polishes, degreasers, screen wash, and de-icers.

Miscellaneous solvent use includes solvent usage not covered elsewhere and, current, little information is available on the types of uses included. However, it will include applications such as pharmaceutical processes, acetylene storage, flavour extraction, foam blowing, production of asbestos-based products, oil-field chemicals and foundry chemicals.

### **5.5.2 Methodological issues**

Emission estimates are based on one of three approaches:

1. Estimates are made based on activity data and emission factors supplied by industry sources (printing processes, consumer products, wood preservation)
2. Estimates are made for each process in a sector based on information provided by regulators or process operators (seed oil extraction, pressure sensitive tapes, paper coating)
3. Estimates are based on estimates of solvent consumption supplied by industry sources (adhesives, aerosols, agrochemicals, miscellaneous solvent use).

### **5.5.3 Uncertainties and time-series consistency**

This source does not affect the overall total or trend in UK emissions of direct greenhouse gases and is not included in the Tier 1 or Tier 2 uncertainty analysis.



Estimates for sources covered by source category 3D are estimating using a consistent methodology with relatively little extrapolation of data. Some extrapolation of activity data is required for some sources included in source category 3D as this will limit the accuracy of emission estimates for these sources e.g. industrial adhesives, other solvent use. Other sources included in 3D, including emission estimates for printing and paper coating are likely to be comparable in quality to the estimates for paint application or chemical products (source categories 3A and 3C). Overall, however, the estimate for source category 3D is likely to be more uncertain than those for 3A, 3B and 3C.

### **5.5.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

### **5.5.5 Source-specific recalculations**

Recalculations have been made to reflect new data provided by the British Coatings Federation (2005). These recalculations lead to an overall increase in estimated emissions of NMVOC of 3 Gg in 2003.

### **5.5.6 Source-specific planned improvements**

Emission factors and activity data for the category will be kept under review.

## **6. Agriculture (CRF sector 4)**

### **6.1 OVERVIEW OF SECTOR**

Emissions of GHGs from this sector include all anthropogenic emissions, except for emissions from fuel combustion and sewage. These emissions are included in Energy 1A and Waste 6B, respectively. Emissions from enteric fermentation, manure management, and agricultural soils are included in this CRF sector. Historical emissions from the field burning of agricultural residues are included here also, but field burning ceased in the UK in 1993.

**Annex 3.6** contains more detailed descriptions of the methods used to estimate emissions in this sector.

### **6.2 SOURCE CATEGORY 4A – ENTERIC FERMENTATION**

#### **6.2.1 Source category description**

Methane is produced as a by-product of enteric fermentation. Enteric fermentation is a digestive process whereby carbohydrates are broken down by micro-organisms into simple molecules. Both ruminant animals (e.g. cattle and sheep), and non-ruminant animals (e.g. pigs and horses) produce CH<sub>4</sub>, although ruminants are the largest source per unit of feed intake.

#### **6.2.2 Methodological issues**

A more detailed description of the method used and emission factors can be found in **Annex 3, Section A3.6.1**.

Emissions from enteric fermentation are calculated from animal population data collected in the June Agricultural Census and the appropriate emission factors. Data for earlier years are often revised so information was taken from the Defra agricultural statistics database. Apart from cattle, lambs and deer, the methane emission factors are IPCC Tier 1 defaults (IPCC, 1997) and do not change from year to year. The dairy cattle emission factors are estimated following the IPCC Tier 2 procedure (IPCC, 1997) and vary from year to year. For dairy cattle, the calculations are based on the population of the 'dairy breeding herd' rather than 'dairy cattle in milk'. The former definition includes 'cows in calf but not in milk'. The emission factors for beef and other cattle were also calculated using the IPCC Tier 2 procedure but do not vary from year to year. The enteric emission factors for beef cattle were almost identical to the IPCC Tier 1 default so the default was used in the estimates. The emission factor for lambs is assumed to be 40% of that for adult sheep (Sneath *et al.* 1997). In using the animal population data, it is assumed that the reported number of animals are alive for that whole year. The exception is the treatment of sheep where it is normal practice to slaughter lambs and other non-breeding sheep after 6 to 9 months. Hence it is assumed that breeding sheep are alive the whole year but that lambs and other non-breeding sheep are only alive 6 months of a given year (based on Smith and Frost, 2000). These assumptions for lamb

can not be improved at the present time as there are no direct measurements of methane emission by lambs in the UK.

### **6.2.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category.

Emissions are calculated from animal population data and appropriate emission factors. The animal population data are collected in an annual census, published by Defra. This is a long running publication and the compilers of the activity data strive to use consistent methods to produce the activity data. The time-series consistency of these activity data is very good due to the continuity in data provided.

### **6.2.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC procedures, which are discussed in **Section 6.9**.

### **6.2.5 Source-specific recalculations**

For calculation of methane from enteric fermentation in the dairy breeding herd, the digestibility of the diet has been increased from 65% to 74%, based on expert opinion of Bruce Cottrill (ADAS).

### **6.2.6 Source-specific planned improvements**

Emission factors and activity data will be kept under review.

## **6.3 SOURCE CATEGORY 4B – MANURE MANAGEMENT**

### **6.3.1 Source category description**

This category reports emissions of methane from animal manures as well as emissions from their manures arising during its storage.

### **6.3.2 Methodological issues**

#### **6.3.2.1 Methane emissions from animal manures**

A more detailed description of the method used and emission factors can be found in **Annex 3, Section A3.6**.

Methane is produced from the decomposition of manure under anaerobic conditions. When manure is stored or treated as a liquid in a lagoon, pond or tank it tends to decompose anaerobically and produce a significant quantity of methane. When manure is handled as a solid or when it is deposited on pastures, it tends to decompose aerobically and little or no methane is produced. Hence the system of manure management used affects emission rates. Emissions of methane from animal manures are calculated from animal population data (Defra, 2005a) in the same way as the enteric emissions. Apart from cattle, lambs and deer, these are all IPCC Tier 1 defaults (IPCC, 1997) and do not change from year to year. The

emission factors for lambs are assumed to be 40% of that for adult sheep (Sneath *et al.* 1997). Emission factors for dairy cattle were calculated from the IPCC Tier 2 procedure. There was a revision (in 2002) of the allocation of manure to the different management systems based on new data. This is detailed in **Section 6.3.2.2**. For dairy cattle, the calculations are based on the population of the ‘dairy breeding herd’ rather than ‘dairy cattle in milk’ used in earlier inventories. The former includes ‘cows in calf but not in milk’. The waste factors used for beef and other cattle are now calculated from the IPCC Tier 2 procedure but do not vary from year to year.

### **6.3.2.2 Nitrous Oxide emissions from Animal Waste Management Systems**

Animals are assumed not to give rise to nitrous oxide emissions directly, but emissions from their manures during storage are calculated for a number of animal waste management systems (AWMS) defined by IPCC. Emissions from the following AWMS are reported under the Manure Management IPCC category:

- Flushing anaerobic lagoons. These are assumed not to be in use in the UK.
- Liquid systems
- Solid storage and dry lot (including farm-yard manure)
- Other systems (including poultry litter, stables)

According to IPCC (1997) guidelines, the following AWMS are reported in the Agricultural Soils category:

- All applied animal manures and slurries
- Pasture range and paddock

Emissions from the combustion of poultry litter for electricity generation are reported under power stations.

The IPCC (1997) method for calculating emissions of N<sub>2</sub>O from animal waste management is followed.

The UK application of the methodology assumes that 20% of the total N emitted by livestock volatilises as NO<sub>x</sub> and NH<sub>3</sub> and therefore does not contribute to N<sub>2</sub>O emissions from AWMS. This is because in the absence of a more detailed split of NH<sub>3</sub> losses at the different stages of the manure handling process it has been assumed that NH<sub>3</sub> loss occurs prior to major N<sub>2</sub>O losses. Thus, the Nex factors used in the AWMS estimates exclude the fraction of N volatilising and are 20% less than if they were reported on the same basis as the ‘total’ Nex factors reported in the IPCC Guidelines. Values of total N excreted shown in the Common Reporting Format are not corrected in this way and are estimates of total N excreted from livestock. Nex factors for dairy cattle take account of the new animal weight values (1990–2001, Steve Walton, Defra, *pers. comm.*). The UK is currently looking into improving the link between the NH<sub>3</sub> and GHG inventories, and incorporating NO<sub>x</sub> in a study (desk/experimental) will review the current assumption of 20% of N lost as NH<sub>3</sub> and NO<sub>x</sub>.

The conversion of excreted N into N<sub>2</sub>O emissions is determined by the type of manure management system used. The distributions used were revised for cattle and poultry in the 2000 Inventory. The change related to the way that data on ‘no significant storage capacity’ of farmyard manure (FYM) were allocated. This could have a large effect on emissions because it amounted to around 50% of manure and the ‘Daily spread (DS)’ category has an emission factor of zero, compared to 0.02 for the ‘Solid storage and dry lot (SSD)’ category. Assigning this ‘stored in house’ manure to ‘daily spread’ is acceptable only if emissions from the housing phase are thought to be very small. Calculations were performed with the N<sub>2</sub>O Inventory of Farmed Livestock to compare housing and storage phases (Sneath *et al.* 1997). For pigs and poultry, the emission factor for housing is the same as or greater than that of storage. It would therefore lead to significant underestimation to use the daily spread emission factor. The FYM in this case has therefore been re-allocated to SSD or ‘other’ as appropriate.

For dairy and non-dairy cattle, the emission factor for the housing phase is around 10% of the storage phase, so the non-stored FYM has been split between SSD and DS to account for this.

Emissions from grazing animals (pasture range and paddock) and daily spread are calculated in the same way as the other AWMS. However, emissions from land spreading of manure that has previously been stored in a) liquid systems, b) solid storage and dry lot and c) other systems, are treated differently. These are discussed in **Annex 3, Section A3.6.3.7**.

### **6.3.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category.

Emissions are calculated from animal population data and appropriate emission factors. The animal population data are collected in an annual census, published by Defra. This is a long running publication and the compilers of the activity data strive to use consistent methods to produce the activity data. The time-series consistency of these activity data is very good due to the continuity in data provided.

### **6.3.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC procedures which are discussed in **Section 6.9**.

### **6.3.5 Source-specific recalculations**

For calculation of methane emission from manures of the dairy breeding herd (using Tier 2 methodology), the Methane Conversion Factor for cool climate liquid systems was increased from 10% to 39%, in line with IPCC (2000). Also for this cattle category, the digestibility of the diet has been increased from 65% to 74%, based on expert opinion of Bruce Cottrill (ADAS).

**6.3.6 Source-specific planned improvements**

Emission factors and activity data will be kept under review.

**6.4 SOURCE CATEGORY 4C – RICE CULTIVATION**

This source is not relevant in the UK.

**6.5 SOURCE CATEGORY 4D – AGRICULTURAL SOILS****6.5.1 Source category description**

Direct emissions of nitrous oxide from agricultural soils are estimated using the IPCC recommended methodology (IPCC, 1997) but incorporating some UK specific parameters. The IPCC method involves estimating contributions from:

- (i) The use of inorganic fertilizer
- (ii) Biological fixation of nitrogen by crops
- (iii) Ploughing in crop residues
- (iv) Cultivation of Histosols (organic soils)
- (v) Spreading animal manures on land
- (vi) Manures dropped by animals grazing in the field

In addition to these, the following indirect emission sources are estimated:

- (vii) Emission of N<sub>2</sub>O from atmospheric deposition of agricultural NO<sub>x</sub> and NH<sub>3</sub>
- (viii) Emission of N<sub>2</sub>O from leaching of agricultural nitrate and runoff

Descriptions of the methods used are described in **Section 6.5.2**.

**6.5.2 Methodological issues**

A more detailed description of the method used and emission factors can be found in **Annex 3, Section A3.6.3**.

**6.5.2.1 Inorganic Fertiliser**

Emissions from the application of inorganic fertilizer are calculated using the IPCC (1997) methodology and IPCC default emission factors.

Annual consumption of synthetic fertilizer is estimated based on crop areas (Defra, 2005a) and fertilizer application rates (BSFP, 2005).

**6.5.2.2 Biological Fixation of Nitrogen by crops**

Emissions of nitrous oxide from the biological fixation of nitrogen by crops are calculated using the IPCC (1997) methodology and IPCC default emission factors.

The data for the ratio residue/crop are default values found under Agricultural Soils or derived from Table 4.17 in Field Burning of Agricultural Residues (IPCC, 1997). Crop production data are taken from Defra (2005a, 2005b). The total nitrous oxide emission reported also includes a contribution from improved grass calculated using a fixation rate of 4 kg N/ha/year (Lord, 1997). It must be noted that for these source the calculation of the emission requires estimating the amount of N that is fixed and then the emission factor is applied to this value. The result being that the Implied Emission Factor reported in the old CRF which was derived from the ratio N<sub>2</sub>O emission:dry matter was different from the IPCC default value (0.013). In the new CRF this has been modified and the IEF coincides with the IPCC default value.

#### **6.5.2.3 Crop Residues**

Emissions of nitrous oxide from the ploughing in of crop residues are calculated using the IPCC (1997) methodology and IPCC default emission factors.

Production data of crops are taken from Defra (2005a, 2005b). Field burning has largely ceased in the UK since 1993. For years prior to 1993, field-burning data were taken from the annual MAFF Straw Disposal Survey (MAFF, 1995).

#### **6.5.2.4 Histosols**

Emissions from Histosols were estimated using the IPCC (2000) default factor of 8 kg N<sub>2</sub>O-N/ha/yr. The area of cultivated Histosols is assumed to be equal to that of eutric organic soils in the UK and is based on a FAO soil map figure supplied by SSLRC (now NSRI).

#### **6.5.2.5 Grazing Animals**

Emissions from manure deposited by grazing animals are reported under agricultural soils by IPCC. The method of calculation is the same as that for AWMS (**Section 6.3.2.2**), using factors for pasture range and paddock. However the value for the fraction of livestock N excreted and deposited onto soil during grazing is a country specific value of 0.52, much larger than the IPCC recommended value (0.23).

#### **6.5.2.6 Organic Fertilizers**

Emissions from animal manures and slurries used as organic fertilizers are reported under agricultural soils by IPCC. The calculation involves estimating the amount of nitrogen applied to the land and applying IPCC emission factors.

The summation is for all animal types and manure previously stored in categories defined as a) liquid, b) solid storage and dry lot and c) other.

#### **6.5.2.7 Atmospheric deposition of NO<sub>x</sub> and NH<sub>3</sub>**

Indirect emissions of N<sub>2</sub>O from the atmospheric deposition of ammonia and NO<sub>x</sub> are estimated according to the IPCC (1997) methodology but with corrections to avoid double counting N. The sources of ammonia and NO<sub>x</sub> considered are synthetic fertiliser application and animal manures applied as fertiliser.

The method used corrects for the N content of manures used as fuel but no longer for the N lost in the direct emission of N<sub>2</sub>O from animal manures as previously. The nitrogen excretion data in **Table A3.6.6** already exclude volatilisation losses and hence a correction is included for this.

#### **6.5.2.8 Leaching and runoff**

Indirect emissions of N<sub>2</sub>O from leaching and runoff are estimated according to the IPCC methodology but with corrections to avoid double counting N. The sources of nitrogen considered, are synthetic fertiliser application and animal manures applied as fertiliser.

#### **6.5.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category.

Emissions are calculated from a range of activity data and appropriate emission factors (see **A3.6.3**). Emissions of N<sub>2</sub>O from the use of fertilizers are important in this source category. The annual consumption of synthetic fertilizer is estimated based on crop areas (crop area data reported annually by Defra) and fertilizer application rates (reported annually in another Defra publication, the British Survey of Fertiliser Practice). These are both long running datasets and the compilers of the activity data strive to use consistent methods to produce the activity data. The time-series consistency of these activity data is very good due to the continuity in data provided.

#### **6.5.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC procedures, which are discussed in **Section 6.9**.

#### **6.5.5 Source-specific recalculations**

Peas green for market, error in percentage DM calculation, was 8% should have been 80% (S. Landrock-White, PGRO, *pers. comm.*)

#### **6.5.6 Source-specific planned improvements**

Emission factors and activity data will be kept under review.

### **6.6 SOURCE CATEGORY 4E – PRESCRIBED BURNING OF SAVANNAS**

This source is not relevant in the UK.

### **6.7 SOURCE CATEGORY 4F – FIELD BURNING OF AGRICULTURAL RESIDUES**

#### **6.7.1 Source category description**

This sector covers the emissions of non-CO<sub>2</sub> greenhouse gases from the burning (in the field) of crop residue and other agricultural waste on site.



### **6.7.2 Methodological issues**

The National Atmospheric Emissions Inventory reports emissions from field burning under the category agricultural incineration. The estimates are derived from emission factors calculated according to IPCC (1997) and from USEPA (1997).

The estimates of the masses of residue burnt of barley, oats, wheat and linseed are based on crop production data (e.g. Defra, 2005a) and data on the fraction of crop residues burnt (MAFF, 1995; ADAS, 1995b). Field burning ceased in 1993 in England and Wales. Burning in Scotland and Northern Ireland is considered negligible, as is grouse moor burning, so no estimates are reported from 1993 onwards. The carbon dioxide emissions are not estimated because these are part of the annual carbon cycle.

### **6.7.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category.

Field burning ceased in 1994, and emissions are reported as zero after this date.

### **6.7.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC procedures, which are discussed in **Section 6.9**.

### **6.7.5 Source-specific recalculations**

There have been no recalculations.

### **6.7.6 Source-specific planned improvements**

Emission factors and activity data will be kept under review.

## **6.8 SOURCE CATEGORY 4G - OTHER**

There are no emissions reported in the UK under this category

## **6.9 GENERAL COMMENTS ON QA/QC**

The livestock activity data used for constructing the inventory are supplied annually from the June census by the Defra Economics and Statistics Group, who adhere to documented QA procedures. Activity data on mineral fertiliser are calculated using application rates from Defra's annual British Survey of Fertiliser Practice (BSFP, 2005) multiplied by crop areas in Defra's Survey of Farming Incomes (June Census). Data from the June Census, in the form of \*.PDF files, can be downloaded from the Defra website ([www.defra.gov.uk](http://www.defra.gov.uk)) and incorporated into inventory spreadsheets without the need for manual data entry, eliminating the need for "double entry" procedures. Annual comparisons of emission factors and other coefficients used are made by contractors compiling the inventory on behalf of Defra and by Defra itself.

Any changes are documented in the spreadsheet and in the accompanying chapter of the National Inventory Report. Hardcopies of the submitted inventories, associated emails and copies of activity data are filed in Government secure files adhering to Government rules on document management.

Defra contractors who work on compiling the agricultural inventory, IGER, operate strict internal quality assurance systems with a management team for each project overseen by an experienced scientist with expertise in the topic area. A Laboratory Notebook scheme provides quality control through all phases of the research and these are archived in secure facilities at the end of the project. All experiments are approved by a consultant statistician at each of the planning, data analysis and interpretation and synthesis stages. A range of internal checks exists to ensure that projects run to schedule, and internal and external (*viz.* visiting group procedures, etc.) reviews ensure the quality of the outputs.

## **7. Land-Use, Land Use Change and Forestry (CRF Sector 5)**

### **7.1 OVERVIEW OF SECTOR**

This sector contains both sources and sinks of carbon dioxide. The sinks, (or *removals*), are presented as negative quantities. Net emissions from land use change and forestry were approximately 2% of the UK total in 2004 and are declining gradually.

Some revision of the data and methods used for this Sector has been made for the 2006 NIR, starting from the approaches described by Cannell *et al.* (1999) and Milne & Brown (1999), taking account of the requirements of IPCC (1997, 2003). **Annex 3.7** contains more detailed descriptions of the methods used to estimate emissions in this Sector.

The structure of this Chapter and of the main submission of CRF Tables is based on the Categories of the Common Reporting Format tables agreed at the 9<sup>th</sup> Conference of Parties to the UNFCCC and contained in FCCC/SBSTA/2004/8. The Sector 5 Report Tables in the CRF format for each year from 1990 to 2004 have been submitted using the CRF Reporter. The relationship of this reporting format to that used in previous NIRs from the UK is discussed in **Section 7.9**.

Net emissions in 1990 are estimated here to be 2915 Gg CO<sub>2</sub> compared to 2645 Gg CO<sub>2</sub> in the 2003 National Inventory Report. For 2003 a net removal of -1180 Gg CO<sub>2</sub> is estimated here compared to a net removal of -1489 Gg CO<sub>2</sub> in the 2003 Inventory.

### **7.2 CATEGORY 5A – FOREST LAND**

#### **7.2.1 Source/sink category description**

All UK forests are classified as temperate and about 65% of these have been planted since 1920 on land that had not been forested for many decades. This category is divided into Category 5.A.1 Forest remaining Forest Land and Category 5.A.2 Land converted to Forest Land.

The forests in existence since before 1920 are considered not to have significant long term changes in biomass stock. This is probably a conservative assumption. The estimates of changes in carbon stock in the biomass and soils of the forests established since 1920 are based on activity data in the form of annual planting areas of forest published by the UK Forestry Commission and the Northern Ireland Department of Agriculture (**Annex 3, Section A3.7.1**.)

For Category 5.A. (Forest Land) the data are disaggregated into 5.A.1 Forest Land remaining Forest Land and 5.A.2 Land converted to Forest Land. Category 5.A.1 is disaggregated into the four geographical areas of England, Scotland, Wales and Northern Ireland. Category 5.A.2

is disaggregated into afforestation of Cropland, Grassland and Settlements and further by a) the four geographical areas of England, Scotland, Wales and Northern Ireland and b) two time periods, 1920 – 1990 and 1991 onwards.

Direct N<sub>2</sub>O emissions from N fertilization from land use, land use change and forestry changes in Category 5A are not estimated as they have been assessed as small in the UK. N<sub>2</sub>O emissions from drainage of soils for land in Category 5A are not reported for the same reason (Skiba *et al.* 2005)

### **7.2.2 Methodological issues**

The carbon uptake by the forests planted since 1920 is calculated by a carbon accounting model (C-Flow) as the net change in the pools of carbon in standing trees, litter, soil and products from harvested material for conifer and broadleaf forests. The method can be described as Tier 3, as defined in the GPG LULUCF (IPCC 2003). The model calculates the masses of carbon in the pools of new even-aged plantations that were clear-felled and then replanted at the time of Maximum Area Increment.

A detailed description of the method used can be found in **Annex 3, Section 3.7.1** for biomass, dead mass and soil with additional information on harvested wood products in **Annex 3, Section 3.7.2**.

### **7.2.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to GPG source category and gas.

Activity data are obtained consistently from the same national forestry sources, which helps ensure time series consistency of estimated removals.

### **7.2.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC procedures, which are discussed in **Section 7.10**.

### **7.2.5 Source-specific recalculations**

The estimates of emissions and removals due to afforestation were updated with planting statistics for 2004.

The main revision was an adjustment in the forest planting calculations to take account of the impact of non-standard management practices in conifer forests, which were due to either deliberately shortened harvesting rotations or a response to forest disturbance. The conifer afforestation series in England and Wales were sub-divided into the standard Sitka spruce 59 year rotation (1921-2004), a 49 year rotation (1921-1950) and a 39 year rotation (1931-1940, England only). The areas of forest planting with non-standard management were small (8.8 kha in England, 20.0 kha in Wales), so the impact on forest removals reported here is less than  $\pm 0.1 \text{ Mt C a}^{-1}$  compared to removals reported in the previous NIR. Further details are given in **Annex 3, Section 3.7.1**.

There was a minor revision of the modelling of the emissions due to soil disturbance. This is now estimated within C-Flow using a time-step of 0.1 years, rather than as a separate calculation using an annual time-step as in the 2003 Inventory.

### **7.2.6 Source-specific planned improvements**

The method for estimating removals and emissions due to afforestation is being developed to provide data for grid cells of 20 x 20 km. Periodically updated forest inventory or grant application data will be used rather than annual planting data to drive the new version. This approach is being developed to meet the requirements of the Kyoto Protocol for more geographically explicit data than the national area for reporting removals due to afforestation and deforestation under Article 3.3. In addition, investigation will be extended into the effects of non-standard management, externally imposed disturbances on both conifer and broadleaved forests and the effect of alternative assumptions on species distribution.

## **7.3 CATEGORY 5B –CROPLAND**

The category is disaggregated into 5.B.1 Cropland remaining Cropland and 5.B.2 Land converted to Cropland. Category 5.B.1 is further disaggregated into the four geographical areas of England, Scotland, Wales and Northern Ireland.

Two activities are considered for 5.B.1: The effect of fenland drainage on soil carbon stocks (which occurs only in England) and carbon dioxide emissions from soils due to agricultural lime application to Cropland (which is also disaggregated into application of Limestone ( $\text{CaCO}_3$ ) and Dolomite ( $\text{CaMg}(\text{CO}_3)_2$ )).

Category 5.B.2 is disaggregated into conversions from Forest Land, Grassland and Settlements. These conversions are further disaggregated by a) the four geographical areas of England, Scotland, Wales and Northern Ireland and b) two time periods, 1920 – 1990 and 1991 onwards

$\text{N}_2\text{O}$  emissions from disturbance associated with land use conversion to Cropland are not reported as a study has shown these to be small (Skiba *et al.* 2005)

### **7.3.1 Source/sink category description**

#### **7.3.1.1 Changes in non-forest biomass resulting from yield improvements (5.B.1)**

This is the annual increase in the biomass of cropland vegetation in the UK that is due to yield improvements (from improved species strains or management, rather than fertilization or nitrogen deposition).

#### **7.3.1.2 Fenland drainage (5.B.1)**

Fenland areas of England were drained many decades ago for agriculture. The soils in these areas are still emitting  $\text{CO}_2$ , i.e. there is an ongoing change in soil carbon stock.

#### **7.3.1.3 Application of Lime (5.B.1)**

Emissions of carbon dioxide from the application of limestone, chalk and dolomite to cropland were estimated using the method described in the IPCC 1996 Guidelines (IPCC, 1997a, b, c). Data on the use of limestone, chalk and dolomite for agricultural purposes is

reported in BGS (2005). They also include ‘material for calcination’. In agriculture all three minerals are applied to the soil, and CO<sub>2</sub> emissions, weight for weight, from limestone and chalk will be identical since they have the same chemical formula. Dolomite, however, will have a slightly higher emission due to the presence of magnesium. Estimates of the individual materials have to be made each year as only their total is published because of commercial confidentiality rules for small quantities. It is assumed that all the carbon contained in the materials applied is released in the year of use.

#### **7.3.1.4 Changes in non-forest biomass stocks resulting from Land use change to Cropland(5.B.2)**

This is the annual change in the carbon stock in biomass of vegetation due to all land use change, excluding forests and woodland, to Cropland.

#### **7.3.1.5 Changes in soil carbon stocks due to Land use change to Cropland (5.B.2)**

Changes in soil stocks due to land use change to Cropland are estimated. All forms of land use change, including deforestation although this is found to be small, are considered together and both mineral and organic soils are included.

### **7.3.2 Methodological issues**

The method for assessing changes in soil carbon stock due to land use change links a matrix of change from land surveys to a dynamic model of carbon stock change. Matrices from the Monitoring Landscape Change project for 1947 and 1980 and the ITE/CEH Countryside Surveys of 1984, 1990 and 1998 are used. Land use in the UK was placed into 4 broad groups – Forestland, Grassland, Cropland, and Settlements by combining the more detailed categories for the two surveys. Area change data exist for the period up to 1998 and those from 1990 to 1998 are used to extrapolate to the years 1999 to 2004.

In Northern Ireland, less data are available to build matrices of land use change, but for 1990 to 1998 a matrix for the whole of Northern Ireland was available from the Northern Ireland Countryside Survey (Cooper & McCann 2002). The only data available pre-1990 for Northern Ireland is land use areas from The Agricultural Census and The Forest Service and processed by Cruickshank & Tomlinson (2000). Matrices of land use change had then to be estimated for 1970-80 and 1980-90 using area data. The basis of the method devised was to assume that the relationship between the matrix of land use transitions for 1990 to 1998 and the area data for 1990 is the same as the relationship between the matrix and area data for each of two earlier periods – 1970-79 and 1980-89. The matrices developed by this approach were used to extrapolate areas of land use transition back to 1950 to match the start year in the rest of the UK.

A database of soil carbon density for the UK based on information on soil type, land cover and carbon content of soil cores has been available since 1995. These densities included carbon to a depth of 1 m or to bedrock, whichever was the shallower, for mineral and peaty/mineral soils. Deep peat in the North of Scotland was identified separately and depths to 5 m are included. For the 2003 Inventory a complete re-evaluation of the database was carried out (Bradley *et al.* 2005). There are three soil survey groups covering the UK and the field data, and soil classifications and laboratory methods were harmonized to reduce

uncertainty in the final data. The depth of soil considered was also restricted to 1 m at maximum as part of this process. Further improvements of the information on carbon content and bulk density of organic soils in Scotland have been included in this year's Inventory.

In the dynamic model of carbon stock change, the change in equilibrium carbon density from the initial to the final land use during a transition is required. These are calculated for each land use category as averages for Scotland, England, Northern Ireland and Wales. The rate of loss or gain of carbon is dependent on the type of land use transition. A Monte Carlo approach is used to vary the rate of change, the area activity data and the values for soil carbon equilibrium (under initial and final land use) for all countries in the UK. The mean carbon flux for each region resulting from these imposed random choices was then reported as the estimate for the Inventory. A detailed description of the method be found in **Annex 3, Section 3.7.4**. An adjustment was made to these calculations for each country to remove increases in soil carbon due to afforestation, as a better value for this is found from the C-Flow model used for the Land converted to Forest Land Category (See **Section 7.2.2**).

Detailed descriptions of the methods and emission factors used for the activities, fenland drainage, application of lime and changes in non-forest biomass, can be found in **Annex 3, Sections 3.7.5 to 3.7.7**.

### **7.3.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to the GPG source category and gas.

#### **7.3.3.1 Changes in non-forest biomass due to yield improvement in Cropland**

Data are reported as a constant average value in each year.

#### **7.3.3.2 Fenland Drainage**

The emissions due to lowland drainage are obtained from a model driven by activity data from a single source that provides good time series consistency.

#### **7.3.3.3 Application of lime to Cropland**

Uncertainty in both the activity data and emission factor used for this source are judged to be low. The main source of uncertainty in the estimates is caused by non-publication of some data due to commercial restrictions although these are not judged to be very significant. Time-series consistency is underpinned by continuity in data source.

#### **7.3.3.4 Changes in non-forest biomass due to land use change to Cropland**

Data are reported as a constant average value in each year.

#### **7.3.3.5 Changes in soil carbon stocks due to land use change to Cropland**

Land use change activity data are obtained from several sources. The sources for Great Britain have separate good internal consistency, but there is poorer consistency between these sources and with the data for Northern Ireland. There may be carry-over effects on emission/removal estimates for the reported years due to the long time response of soil systems.

### **7.3.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC procedures, which are discussed in **Section 7.10**.

### **7.3.5 Source-specific recalculations**

#### **7.3.5.1 Changes in non-forest biomass due to yield improvements in Cropland**

There has been a complete revision of the activity data and methodology in this category. The increases in crop yield are now calculated separately from those resulting from land use change. These revisions are described in **Annex 3, Section 3.7.7**.

#### **7.3.5.2 Fenland drainage**

No recalculations were undertaken for this category.

#### **7.3.5.3 Application of lime to Cropland**

The estimates of emissions due to liming have been updated with 2004 data (BGS 2005).

#### **7.3.5.4 Changes in non-forest biomass due to land use change to Cropland**

Estimates of emissions and removals for this category are now made using the Countryside Survey Land Use Change matrix approach, with biomass densities weighted by expert judgment. Further details are given in **Annex 3, Section 3.7.7**.

#### **7.3.5.5 Changes in soil carbon stocks due to land use change to Cropland**

The Scottish soil carbon bulk densities have been updated, giving improved information on carbon content and the bulk density of organic rich soils. Estimates of emissions and removals have been updated to reflect these improvements in the data. Further details are given in **Annex 3, Section 3.7.4**.

### **7.3.6 Source-specific planned improvements**

Emission factors and activity data will be kept under review.

## **7.4 Category 5C – GRASSLAND**

### **7.4.1 Source/sink category description**

The Category is disaggregated into 5.C.1 Grassland remaining Grassland and 5.C.2 Land converted to Grassland. Category 5.C.1 is disaggregated into the four geographical areas of England, Scotland, Wales and Northern Ireland. Category 5.C.2 is disaggregated into conversions from Forest Land, Cropland and Settlements. Conversions from Cropland and Settlements to Grassland are further disaggregated by a) the four geographical areas of England, Scotland, Wales and Northern Ireland and b) two time periods, 1920 – 1990 and 1991 onwards. Biomass burning emissions due to conversion of Forest Land to Grassland is reported at the 5C level for all of the UK in two time periods, 1920-1990 and 1990 onwards.

Carbon dioxide emissions from agricultural lime application to Grassland is disaggregated into application of Limestone ( $\text{CaCO}_3$ ) and Dolomite ( $\text{CaMg}(\text{CO}_3)_2$ ).



The data reported for the UK in Sectoral Table 5 in the FCCC/SBSTA/2004/8 format the Information item “Forest Land converted to other Land-Use Categories” includes both changes in carbon stock in biomass (due to burning) and soils under “Net CO<sub>2</sub> emissions/removals”.

#### **7.4.1.1 Emissions from biomass burning (5C)**

These are emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O resulting from the burning of forest biomass when Forest Land is converted to Grassland. In the 2003 Inventory deforestation was assumed only to be a conversion to Settlements. A revised interpretation of the available data (described in **Annex 3, Section 3.7.3**) allows the emissions to be disaggregated into deforestation to Grassland and Settlements. Deforestation to Cropland is negligible.

#### **7.4.1.2 Peat Extraction (5.C.1)**

Peat is extracted in the UK for use as either a fuel or in horticulture. Previously estimates were made separately for each of these end uses. For 2004, peat use as a fuel is reported in the Energy Sector of the UK Inventory.

#### **7.4.1.3 Application of lime on Grassland (5.C.1)**

Emissions of carbon dioxide from the application of limestone, chalk and dolomite to agricultural soils were estimated using the method described in the IPCC 1996 Guidelines (IPCC 1997c, 1997a, 1997b). Data on the use of limestone, chalk and dolomite for agricultural purposes is reported in BGS (2005). They also include ‘material for calcination’. In agriculture all three minerals are applied to the soil, and CO<sub>2</sub> emissions, weight for weight, from limestone and chalk will be identical since they have the same chemical formula. Dolomite, however, will have a slightly higher emission due to the presence of magnesium. Estimates of the individual materials have to be made each year as only their total is published because of commercial confidentiality rules for small quantities. It is assumed that all the carbon contained in the materials applied is released in the year of use.

#### **7.4.1.4 Changes in non-forest biomass due to land use change to Grassland (5.C.2)**

This is the annual change in the carbon stock in biomass of vegetation due to all land use change, excluding forests and woodland, to Grassland.

#### **7.4.1.5 Changes in soil carbon stocks due to land use change to Grassland (5.C.2)**

Changes in soil stocks due to land use change to Grassland are estimated. All forms of land use change, including deforestation, are considered together and both mineral and organic soils are included.

### **7.4.2 Methodological issues**

#### **7.4.2.1 Emissions from biomass burning after conversion of Forest Land to Grassland**

The methodology for estimating emission due to conversion of Forest to Grassland is described in **Annex 3, Section 3.7.3**.

#### **7.4.2.2 Peat extraction**

A detailed description of the methods used and emission factors can be found in **Annex 3, Section 3.7.8**.

**7.4.2.3 Application of lime to Grassland**

Further information on application of the method used and emission factors can be found in **Annex 3, Section 3.7.5**.

**7.4.2.4 Changes in non-forest biomass due to land use change to Grassland**

A detailed description of the methods used and emission factors can be found in **Annex 3, Section 3.7.7**.

**7.4.2.5 Changes in soil stocks due to land use change to Grassland**

See **Section 7.3.2**. A detailed description of the methods used and emission factors can be found in **Annex 3, Section 3.7.4**.

**7.4.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to the GPG source category and gas.

**7.4.3.1 Emissions due to biomass burning after conversion of Forest Land to Grassland**

The time series consistency of emissions from this activity is only medium given that the two constituent data series are not both available for each year and the values for the period several years are partially derived from data in one region.

**7.4.3.2 Peat Extraction**

Activity data for peat extraction come from a number of sources, only some of which are reliable, which will have some effect on time series consistency.

**7.4.3.3 Application of lime to Grassland**

Uncertainty in both the activity data and emission factor used for this source are judged to be low. The main source of uncertainty in the estimates is the caused by non-publication of some data due to commercial restrictions although these are not judged to be very significant. Time-series consistency is underpinned by continuity in data source.

**7.4.3.4 Changes in non-forest biomass due to land use change to Grassland**

Data are reported as a constant average value in each year.

**7.4.3.5 Changes in soil stocks due to land use change to Grassland**

Land use change activity data are obtained from several sources. The sources for Great Britain have separate good internal consistency, but there is poorer consistency between these sources and with the data for Northern Ireland. There may be carry-over effects on emission/removal estimates for the reported years due to the long time response of soil systems.

**7.4.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC procedures, which are discussed in **Section 7.10**.

### **7.4.5 Source-specific recalculations**

#### **7.4.5.1 Emissions due to biomass burning after conversion of Forest Land to Grassland**

Areas deforested in non-rural areas have been revised for each year from 1990 and updated to 2004. Data on rural deforestation is only available up to 2002; therefore areas for 2003 and 2004 were estimated by extrapolation from earlier years.

#### **7.4.5.2 Peat extraction**

Only peat used in horticulture is now reported in this category. Peat used as a fuel is reported in the Energy Sector of the UK Inventory. This change results in reporting of 390 Gg CO<sub>2</sub> for 1990, compared to 792 Gg CO<sub>2</sub> in the previous NIR, and 355 Gg CO<sub>2</sub> in 2004, compared to 894 reported for 2003 in the previous NIR.

#### **7.4.5.3 Application of lime to Grassland**

The estimates of emissions due to liming have been updated with 2004 data (BGS 2005).

#### **7.4.5.4 Changes in non-forest biomass due to land use change to Grassland**

Estimates of emissions and removals due to carbon stock changes for this activity are now made using the Countryside Survey Land Use Change matrix approach, with biomass densities weighted by expert judgment. Further details are given in **Annex 3, Section 3.7.7**.

#### **7.4.5.5 Changes in soil carbon stocks due to land use change to Grassland**

The Scottish soil carbon bulk densities have been updated, giving improved information on carbon content and the bulk density of organic rich soils. Estimates of emissions and removals have been updated to reflect these improvements in the data. Further details are given in **Annex 3, Section 3.7.4**.

### **7.4.6 Source-specific planned improvements**

Future improvements of the method for biomass burning emissions will include collating Forestry Commission unconditional felling licence data for Scotland and Wales. Similar information for Northern Ireland has also become available recently and will be incorporated in next year's Inventory,

All emission factors and activity data will be kept under review.

## **7.5 CATEGORY 5D – WETLANDS**

### **7.5.1 Source/sink category description**

In the UK, Wetlands will either be saturated land (e.g. bogs, marshes) and, due to the classifications used in the Countryside Survey, will fall into the Grassland category or into open water (e.g. lakes, rivers, reservoirs), which is included in the Other Land category. Table 5.D. (Wetlands) is therefore completed with 'IE' (Included Elsewhere).

## **7.6 CATEGORY 5E –SETTLEMENTS**

### **7.6.1 Source/sink category description**

Category 5.E (Settlements) is disaggregated into 5.E.1 Settlements remaining Settlements and 5.E.2 Land converted to Settlements. The area of Settlements in Category 5.E.1 is considered not to have long term changes in carbon stock. Category 5.E.2 is disaggregated into conversions from Forest Land, Cropland and Grassland. These conversions are further disaggregated by a) the four geographical areas of England, Scotland, Wales and Northern Ireland and b) two time periods, 1920 – 1990 and 1991 onwards. Biomass burning emissions due to conversion of Forest Land to Settlements are reported at the 5C level for all of UK in two time periods, 1920-1990 and 1990 onwards.

The data reported for the UK in Sectoral Table 5 in the FCCC/SBSTA/2004/8 format the Information item “Forest Land converted to other Land-Use Categories” includes both changes in carbon stock in biomass (due to burning) and soils under “Net CO<sub>2</sub> emissions/removals”.

#### **7.6.1.1 Emissions from biomass burning after conversion of Forest Land to Settlements (5E)**

These are emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O resulting from the burning of forest biomass when Forest Land is converted to Settlements. In the 2003 Inventory deforestation was assumed only to be a conversion to Settlements. A revised interpretation of the available data (described in **Annex 3, Section 3.7.3**) allows the emissions to be disaggregated into deforestation to Grassland and Settlements. Deforestation to Cropland is negligible.

#### **7.6.1.2 Changes in non-forest biomass due to land use change to Settlements (5.E.2)**

This includes annual changes in the biomass of vegetation in the UK due to all land use change, excluding forests and woodland.

#### **7.6.1.3 Changes in soil carbon stocks due to land use change to Settlements (5.E.2)**

Changes in soil stocks due to land use change to Settlements are estimated. All forms of land use change, including deforestation, are considered together and both mineral and organic soils are included.

### **7.6.2 Methodological issues**

#### **7.6.2.1 Emissions from biomass burning after conversion of Forest Land to Settlements**

The methodology for estimating emission due to conversion of Forest to Settlements is described in **Annex 3, Section 3.7.3**.

#### **7.6.2.2 Changes in non-forest biomass due to land use change to Settlements**

A detailed description of the methods used and emission factors can be found in **Annex 3, Section 3.7.7**.

#### **7.6.2.3 Changes in soil carbon stocks due to land use change to Settlements**

See **Section 7.3.2**. A detailed description of the methods used and emission factors can be found in **Annex 3, Section 3.7.4**.

### **7.6.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to the GPG source category and gas.

#### **7.6.3.1 Emissions due to biomass burning after conversion of Forest Land to Settlements**

The time series consistency of emissions from this activity is only medium given that the two constituent data series are not both available for each year and the values for the period several years are partially derived from data in one region.

#### **7.6.3.2 Changes in non-forest biomass due to land use change to Settlements**

Data are reported as a constant average value in each year.

#### **7.6.3.3 Changes in soil carbon stocks due to land use change to Settlements**

Land use change activity data are obtained from several sources. The sources for Great Britain have separate good internal consistency, but there is poorer consistency between these sources and with the data for Northern Ireland. There may be carry-over effects on emission/removal estimates for the reported years due to the long time response of soil systems.

### **7.6.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC procedures, which are discussed in **Section 7.10**.

### **7.6.5 Source-specific recalculations**

#### **7.6.5.1 Emissions due to biomass burning after conversion of Forest Land to Settlements**

Areas deforested in non-rural areas have been revised for each year from 1990 and updated to 2004. Data on rural deforestation is only available up to 2002; therefore areas for 2003 and 2004 were estimated by extrapolation from earlier years.

#### **7.6.5.2 Changes in non-forest biomass due to land use change to Settlements**

Estimates of emissions and removals for this category are now made using the Countryside Survey Land Use Change matrix approach, with biomass densities weighted by expert judgment. Further details are given in **Annex 3, Section 3.7.7**.

#### **7.6.5.3 Changes in soil carbon stocks due to land use change to Settlements**

The Scottish soil carbon bulk densities have been updated, giving improved information on carbon content and the bulk density of organic rich soils. Estimates of emissions and removals have been updated to reflect these improvements in the data. Further details are given in **Annex 3, Section 3.7.4**.

### **7.6.6 Source-specific planned improvements**

Future improvements of the method for biomass burning emissions will include collating Forestry Commission unconditional felling licence data for Scotland and Wales. Similar

information for Northern Ireland has also become available recently and will be incorporated in next year's Inventory,

All emission factors and activity data will be kept under review

## **7.7 CATEGORY 5F – OTHER LAND**

### **7.7.1 Source/sink category description**

No emissions or removals are reported in this category. It is assumed that there are very few areas of land of other types that become bare rock or water bodies, which make up the majority of this type. Therefore Table 5.F. (Other Land) is completed with 'NO' (Not Occurring).

## **7.8 CATEGORY 5G – OTHER**

### **7.8.1 Source/sink category description**

Changes in stocks of carbon in harvested wood products are reported here.

### **7.8.2 Methodological issues**

The carbon uptake by the forests planted since 1920 is calculated by a carbon accounting model (C-Flow) as the net change in the pools of carbon in standing trees, litter, soil and products from harvested material for conifer and broadleaf forests. The method can be described as Tier 3, as defined in the GPG LULUCF (IPCC 2003). The model calculates the masses of carbon in the pools of new even-aged plantations that were clear-felled and then replanted at the time of Maximum Area Increment. Only products from UK forests planted since 1920 (i.e. those for which biomass and soil carbon stock changes are reported) are considered at present. It is not considered to be of high priority to consider decay of imported products etc. as there is no international agreement on a single methodology to be used for reporting

A detailed description of the method used and emission factors can be found in **Annex 3, Section 3.7.2.**

### **7.8.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and gas.

Activity data are obtained consistently from the same national forestry sources, which helps ensure time series consistency of estimated removals.

### **7.8.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC procedures, which are discussed in **Section 7.10.**

**7.8.5 Source-specific recalculations**

The estimates of emissions and removals due to afforestation were updated with planting statistics for 2004.

**7.8.6 Source-specific planned improvements**

This category will be kept under review. Further details are given in **Annex 3, Section 3.7.2**.

**7.9 SEPARATE REPORTING OF EMISSIONS AND REMOVALS**

In previous National Inventory Reports the UK provided data for the entire forest sink together and non-forest emissions and removals from soils in a separate group. This provided a broad separation of sinks and sources within the LUCF sector. **Tables 7.1, 7.2 and 7.3** show the activities concerned and how they have been combined for the two reporting approaches. The totals for emissions and removals for the LUCF Sector are the same in each approach but the information here allows the data in the main GHG Inventory Tables for this 2004 Inventory to be compared with those published in previous UK National Inventory Reports. In future Reports data will only be presented in the categories of the LULUCF GPG (FCCC/SBSTA/2004/8).

**Table 7.1** Comparison of sub-categories used for reporting emissions and removals in UNFCCC Common Reporting Format and previous UK National Inventory Reports

<b>IPCC 2003 GPG CRF</b>	<b>Previous UK NIR</b>
5A2 Cropland converted to Forest Land (living biomass)	5A2- Temperate Forests
5A2 Grassland converted to Forest Land (living biomass)	5A2 - Temperate Forests
5A2 Settlements converted to Forest Land (living biomass)	5A2 - Temperate Forests
5A2 Cropland converted to Forest Land (dead organic matter)	5A2 - Forest Soils
5A2 Grassland converted to Forest Land (dead organic matter)	5A2 - Forest Soils
5A2 Settlements converted to Forest Land (dead organic matter)	5A2 - Forest Soils
5A2 Cropland converted to Forest Land (soils)	5A2 - Forest Soils
5A2 Grassland converted to Forest Land (soils)	5A2 - Forest Soils
5A2 Settlements converted to Forest Land (soils)	5A2 - Forest Soils
5B1 Cropland remaining Cropland (Changes in stocks of Non-forest Biomass due to yield improvements)	5E - Other: Changes in Non-forest Biomass
5B1 Cropland remaining Cropland (Lowland drainage)	5E - Other: Lowland Drainage
5B1 Cropland remaining Cropland (Liming)	5D3 - Liming of Agricultural Soils
5B2 Land converted to Cropland (Changes in stocks of Non-forest Biomass)	5E - Other: Changes in Non-forest Biomass
5B2 Forest Land converted to Cropland (Change in soils due to LUC)	5D - Cultivation of Soils
5B2 Grassland converted to Cropland (Change in soils due to LUC)	5D - Cultivation of Soils
5B2 Settlements converted to Cropland (Change in soils due to LUC)	5D - Cultivation of Soils
5C1 Grassland remaining Grassland (Peat extraction)	5E - Other: Peat extraction
5C1 Grassland remaining Grassland (Liming)	5D3 - Liming of Agricultural Soils
5C2 Land converted to Grassland (Changes in stocks of Non-forest Biomass)	5E - Other: Changes in Non-forest Biomass
5C2 Land converted to Grassland (Deforestation)	5B2 - Deforestation
5C2 Forest Land converted to Grassland (Change in soils due to LUC)	5D - Cultivation of Soils
5C2 Cropland converted to Grassland (Change in soils due to LUC)	5D - Cultivation of Soils
5C2 Settlements converted to Grassland (Change in soils due to LUC)	5D - Cultivation of Soils
5E2 Land converted to Settlements (Changes in stocks of Non-forest Biomass)	5E - Other: Changes in Non-forest Biomass
5E2 Land converted to Settlements (Deforestation)	5B2 - Deforestation
5E2 Forest Land converted to Settlements (Change in soils due to LUC)	5D - Cultivation of Soils
5E2 Grassland converted to Settlements (Change in soils due to LUC)	5D - Cultivation of Soils
5E2 Cropland converted to Settlements (Change in soils due to LUC)	5D - Cultivation of Soils
5G Harvested Wood Products	5A5 - Harvested Wood



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**Table 7.2** Emissions and removals in categories with the Land Use Change and Forestry Sector as reported in the LULUCF GPG Common Reporting Format. (IE - Included Elsewhere.)

Gg CO <sub>2</sub> /year		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
<b>5</b>	<b>NET</b>	<b>2915</b>	<b>2782</b>	<b>2290</b>	<b>1082</b>	<b>889</b>	<b>1034</b>	<b>902</b>	<b>552</b>	<b>0</b>	<b>-234</b>	<b>-440</b>	<b>-596</b>	<b>-1120</b>	<b>-1180</b>	<b>-1942</b>
<b>5A</b>	<b>Forest-Land</b>	<b>-12203</b>	<b>-12715</b>	<b>-13340</b>	<b>-13714</b>	<b>-14193</b>	<b>-13948</b>	<b>-13720</b>	<b>-13512</b>	<b>-13406</b>	<b>-13504</b>	<b>-13805</b>	<b>-14348</b>	<b>-15045</b>	<b>-15646</b>	<b>-16302</b>
5A1	Forest-Land remaining Forest-Land	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5A2	Land converted to Forest-Land	-12203	-12715	-13340	-13714	-14193	-13948	-13720	-13512	-13406	-13504	-13805	-14348	-15045	-15646	-16302
<b>5B</b>	<b>Cropland</b>	<b>15842</b>	<b>16001</b>	<b>16004</b>	<b>15579</b>	<b>15632</b>	<b>15771</b>	<b>15802</b>	<b>15542</b>	<b>15427</b>	<b>15328</b>	<b>15339</b>	<b>15287</b>	<b>15314</b>	<b>15380</b>	<b>15329</b>
5B1	Cropland remaining Cropland	1805	1951	1940	1499	1536	1659	1673	1395	1262	1145	1136	1065	1073	1120	1050
5B2	Land converted to Cropland	14037	14050	14064	14080	14096	14112	14130	14147	14165	14183	14202	14222	14241	14260	14279
5B (liming)	Liming of Cropland	795	978	1003	599	673	832	883	642	546	465	493	445	474	543	496
<b>5C</b>	<b>Grassland</b>	<b>-6193</b>	<b>-6146</b>	<b>-6254</b>	<b>-6660</b>	<b>-6605</b>	<b>-6536</b>	<b>-6786</b>	<b>-6889</b>	<b>-7288</b>	<b>-7275</b>	<b>-7427</b>	<b>-7449</b>	<b>-7742</b>	<b>-7526</b>	<b>-7836</b>
5C1	Grassland remaining Grassland	1025	1190	1196	914	1081	1255	1107	1124	827	853	728	746	563	878	674
5C2	Land converted to Grassland	-7218	-7336	-7450	-7573	-7686	-7791	-7894	-8013	-8115	-8128	-8154	-8195	-8305	-8403	-8510
5C (liming)	Liming of Grassland	635	794	806	531	597	697	632	704	512	421	301	280	265	374	319
<b>5D</b>	<b>Wetland</b>	<b>IE</b>	<b>IE</b>	<b>IE</b>	<b>IE</b>	<b>IE</b>	<b>IE</b>	<b>IE</b>	<b>IE</b>	<b>IE</b>	<b>IE</b>	<b>IE</b>	<b>IE</b>	<b>IE</b>	<b>IE</b>	<b>IE</b>
5D1	Wetland remaining Wetland	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
5D2	Land converted to Wetland	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
<b>5E</b>	<b>Settlements</b>	<b>6925</b>	<b>6851</b>	<b>6799</b>	<b>6719</b>	<b>6688</b>	<b>6647</b>	<b>6627</b>	<b>6607</b>	<b>6573</b>	<b>6485</b>	<b>6402</b>	<b>6358</b>	<b>6306</b>	<b>6274</b>	<b>6248</b>
5E1	Settlements remaining Settlements	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5E2	Land converted to Settlements	6925	6851	6799	6719	6688	6647	6627	6607	6573	6485	6402	6358	6306	6274	6248
<b>5F</b>	<b>Other-Land</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>
5F1	Other-Land remaining Other-land	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5F2	Land converted to Other-Land	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<b>5G</b>	<b>Other activities</b>	<b>-1456</b>	<b>-1210</b>	<b>-920</b>	<b>-842</b>	<b>-633</b>	<b>-900</b>	<b>-1021</b>	<b>-1197</b>	<b>-1306</b>	<b>-1268</b>	<b>-950</b>	<b>-445</b>	<b>47</b>	<b>337</b>	<b>619</b>
	Harvested Wood Products	-1456	-1210	-920	-842	-633	-900	-1021	-1197	-1306	-1268	-950	-445	47	337	619
<b>5C2&amp;5E2</b>	<b>Deforestation Gg CH<sub>4</sub>/year</b>	<i>0.659</i>	<i>0.598</i>	<i>0.619</i>	<i>0.453</i>	<i>0.519</i>	<i>0.549</i>	<i>0.664</i>	<i>0.681</i>	<i>0.691</i>	<i>0.834</i>	<i>0.925</i>	<i>1.106</i>	<i>0.928</i>	<i>0.876</i>	<i>0.798</i>
<b>5C2&amp;5E2</b>	<b>Deforestation Gg N<sub>2</sub>O/year</b>	<i>0.0045</i>	<i>0.0041</i>	<i>0.0043</i>	<i>0.0031</i>	<i>0.0036</i>	<i>0.0038</i>	<i>0.0046</i>	<i>0.0047</i>	<i>0.0048</i>	<i>0.0057</i>	<i>0.0064</i>	<i>0.0076</i>	<i>0.0064</i>	<i>0.0060</i>	<i>0.0055</i>

# LULUCF (CRF sector 5) 7

**Table 7.3** Emissions and removals in sub-categories within the Land Use Change and Forestry Sector as reported in the format used in previous UK National Inventory Reports. (IE - Included Elsewhere.)

<i>NIR</i>	<b>Gg CO<sub>2</sub></b>	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	<i>Category</i>	
Temperate forest	Removal	-12203	-12715	-13340	-13714	-14193	-13948	-13720	-13512	-13406	-13504	-13805	-14348	-15045	-15646	-16302	5A2	Sum of Removals due to Changes in Forest biomass, Forest litter & soils
Harvested wood	Removal	-1456	-1210	-920	-842	-633	-900	-1021	-1197	-1306	-1268	-950	-445	47	337	619	5A5	Removals to Harvested wood
Deforestation	Emission	151	137	142	104	119	126	152	156	158	191	212	253	213	201	183	5B	Emissions (CO <sub>2</sub> ) due to Deforestation
Soils	Emission	15029	15206	15087	14258	14254	14377	14231	13937	13528	13241	13038	12862	12773	12853	12654	5D	Sum of Emissions from soils and Removals to soils due to Land use change (not forestry), and Liming of agricultural land
<i>Soils</i>	<i>Removal</i>	<i>-7366</i>	<i>-7486</i>	<i>-7603</i>	<i>-7718</i>	<i>-7830</i>	<i>-7940</i>	<i>-8047</i>	<i>-8153</i>	<i>-8255</i>	<i>-8356</i>	<i>-8455</i>	<i>-8552</i>	<i>-8647</i>	<i>-8740</i>	<i>-8831</i>		<i>Included in Emission</i>
Other	Emission	2040	2010	1966	1923	1987	2025	1905	1813	1671	1752	1710	1727	1538	1721	1550	5E	Sum of Emissions from soils due to Lowland drainage and Peat extraction
Other	Removal	-646	-646	-646	-646	-646	-646	-646	-646	-646	-646	-646	-646	-646	-646	-646	5E	Removals due to changes in Non-forest Biomass
<b>Total</b>	<b>Emission</b>	17220	17353	17195	16284	16360	16527	16289	15906	15358	15184	14960	14842	14524	14775	14387	5	Gross LULUCF Emissions
<b>Total</b>	<b>Removal</b>	-14304	-14571	-14905	-15202	-15471	-15494	-15387	-15354	-15358	-15418	-15401	-15439	-15643	-15954	-16329	5	Gross LUCF Removals
<b>Total</b>	<b>Net</b>	<b>2915</b>	<b>2782</b>	<b>2290</b>	<b>1082</b>	<b>889</b>	<b>1034</b>	<b>902</b>	<b>552</b>	<b>0</b>	<b>-234</b>	<b>-440</b>	<b>-596</b>	<b>-1120</b>	<b>-1180</b>	<b>-1942</b>	5	Net LULUCF Emissions



## 7.10 GENERAL COMMENTS ON QA/QC

CEH has put in place high quality assurance standards, and selects subcontractors from professional organisations who meet those standards. The general standards are:

- The use of professionally qualified staff
- The application of rigorous quality control procedures
- The use of modern equipment
- The use of validated methods
- The quality control and curation of databases
- The establishment of management procedures to ensure compliance

The particular quality control measures relevant to this report are as follows:

### *Databases*

The databases used to calculate carbon sources and sinks are all quality controlled at source by the responsible organisation, e.g. Centre for Ecology & Hydrology for land use, National Soils Resource Institute and Macaulay Institute for soils and Forestry Commission for forestry statistics.

### *Models*

All modelling is done by trained staff who now have many years' experience of simulating changes in soil and biomass carbon. The output of models is checked against quality assured data. Predictions of future sources and sinks are bench marked against predictions made by other researchers in Europe through various collaborative projects, research meetings and the scientific literature. An active role is taken in the Sinks Expert Group of the EU.

### *Output*

The integrity of results, the quality of the reports, the relationship to contracted deliverables and the punctuality of reporting are all subject to management vetting and tracking within CEH, through the Heads of Sections, Programme Directors and the Finance Administration. Additionally, all staff are required to publish as much non-confidential scientific information in the peer reviewed scientific literature, with the prior approval of the customer and customer acknowledgement.

### *Field measurements of sources and sinks*

All fieldwork, sampling and data handling is carried out by experienced and trained staff to defined protocols agreed to meet the objectives of the work. The procedures for flux measurement are fully documented and instruments are calibrated directly with primary standards.

### *Chemical analysis*

All chemical analyses are made at CEH Lancaster and are supported by full quality assurance and control procedures under BS 5750. The integrity of results is checked by conducting bi-monthly inter-laboratory comparisons (Aquachecks and the International Soil Exchange Scheme).

## **8. Waste (CRF sector 6)**

### **8.1 OVERVIEW OF SECTOR**

Emissions of GHGs from this sector occur from the disposal of waste. Solid wastes can be disposed of through landfilling, recycling, composting, incineration and waste-to-energy. The most important GHG produced in this sector is methane. In addition to methane, solid waste disposal sites can produce CO<sub>2</sub> and NMVOCs. The primary source of CO<sub>2</sub> release from waste is the decomposition of organic matter derived from biomass sources (e.g. crops and forests). These biomass sources are re-grown, and so, in accordance with the guidelines CO<sub>2</sub> emissions are not treated as emissions from waste. Emissions of CO<sub>2</sub> derived from fossil carbon by waste incineration are covered, together with other greenhouse gases, under category 6C (Waste incineration) or 1A if there is energy recovery.

Wastewater treatment produces methane and N<sub>2</sub>O. Emissions of NMVOCs are covered under sector 6B.

### **8.2 SOURCE CATEGORY 6A – SOLID WASTE DISPOSAL ON LAND**

#### **8.2.1 Source category description**

Methane (CH<sub>4</sub>) is emitted during the anaerobic decomposition of organic waste disposed of in solid waste disposal sites (SWDS). Organic waste decomposes at a diminishing rate over time.

The NAEI category Landfill maps directly on to IPCC category 6A1 Landfills (managed waste disposal on land) for methane emissions. Emissions are reported from managed landfills only, as open dumps and unmanaged landfills (unmanaged waste disposal sites) are considered insignificant sources in the UK.

#### **8.2.2 Methodological issues**

The UK method uses a first order decay (Tier 2) methodology based on estimates and historical data on waste quantities, composition and disposal practices over several decades. The AEA Technology model of methane generation from landfill sites was used until 2002 (Brown *et al*, 1999). This was updated and revised for Defra by the consultants Land Quality Management (LQM, 2003). Further revision of the LQM version of the model was made in 2005 by the consultants Golder Associates (Golder, 2005) and this reissue of the 2006 NIR and CRF contains results from the model has been re-run with the oxidation factor of 0.1 rather than the more complex treatment of oxidation used previously. This change was in response to previous UNFCCC reviews.

The UK method is based on Equations 4 and 5 in the Revised 1996 IPCC guidelines (IPCC, 1997) (pp 6.10-6.11), which are compatible with Equations 5.1 and 5.2 in the Good Practice Guidance (IPCC, 2000). A slightly modified version of Equation 5.1 is used, which takes into account the fact that the model uses a finite time interval (one year). The full derivation of the equations used is given in Appendix 6 of Golder (2005)

The UK method divides the waste stream into four categories of waste: rapidly degrading, moderately degrading, slowly degrading, and inert. These categories each have a separate decay rate. The decay rates were revised slightly for the 2002 version of the model (LQM, 2003) and have continued to be used. They now range from 0.046 (slowly degrading waste) to 0.076 (moderately degrading waste) to 0.116 (rapidly degrading waste), within the range of 0.030 to 0.200 quoted in the Good Practice Guidance.

The model uses data extending back to 1945, which gives a time period of around 4 half lives for the slowest of the three decay rates (0.046, half life 15 years). This lies within the range of 3 to 5 half-lives recommended by the Good Practice Guidance.

As recommended, the model takes account of changes in landfill practice over past decades using the method to estimate gas collection rate from estimated flare usage and landfill gas usage described below..

The estimates of historical waste disposal and composition data are based on various data sources, described fully in Brown *et al.* (1999), LQM (2003) and Golder (2005). Until 1994 the waste arisings data are the same as that used for the AEA model (Brown *et al.*, 1999) and is based on waste surveys in the UK using actual data combined with population data to interpolate where necessary. After 1994, data are based on a new study carried out by a UK consultancy ERM for input to the LQM model, which uses updated waste survey data gathered by the Environment Agency for 1999. Years between 1995 and 1998 inclusive are extrapolated backwards from the 1999 data and years after 1999 use a scenario of waste disposal from the Local Authority Waste Recycling and Disposal (LAWRRD) model (AEA Technology, 2005). The LAWRRD model provides arisings for England and so the data has been scaled upwards, assuming England represents 83% of the UK's total. A comparison between the LAWRRD data and actual waste arisings for 2002 and 2003 showed a discrepancy of 2% and 4%, respectively. These differences are considered insignificant and the LAWRRD model data were taken to be representative of the current situation.

As recommended in the Good Practice Guidance, the estimates of waste disposal quantities include commercial and industrial waste, demolition and construction waste sewage sludge disposal to landfill as well as municipal waste. There is greater uncertainty in both the amounts and composition of industrial and commercial wastes. Arisings for these categories were determined by Brown *et al.* (1999), are based on national estimates from a 1995 survey. Historical data are also taken from this survey. Waste quantities have been extrapolated to cover past years based on employment rates in the industries concerned. In the Golder (2005) model commercial and industrial arisings have been modified for 2002 (assumed constant thereafter) based on Environment Agency data; years 1999, 2000 and 2001 are scaled values between 1998 and 2002. The 2002 Environment Agency data are for England and Wales only and have been scaled upwards to include Scotland and Northern Ireland.

All sites in the UK are managed, and therefore have a methane correction factor of 1.0.

Degradable organic carbon (DOC) was estimated assuming that the DOC arises solely from the cellulose and hemi-cellulose content of the waste. Cellulose and hemicellulose make up approximately 91% of the degradable fraction, whilst other potential degradable fractions which may have a small contribution (such as proteins and lipids) are ignored (LQM 2003). The proportion of cellulose and hemi-cellulose in each waste component and the degradability of these fractions were based on a study by Barlaz *et al.* (1997).

Each waste component (paper, food, etc) was assigned a DOC value based on the cellulose and hemi-cellulose content. The component was then split into four fractions: rapidly degrading, moderately degrading, slowly degrading and inert, each of which was assigned the appropriate degradation rate. For example, paper was taken to be 25% moderately degrading and 75% slowly degrading. The DOC value for both components was assumed to be equal to the percentage by weight of cellulose and hemi-cellulose multiplied by a factor of 72/162 (to account for the carbon content). This was around 22% for household paper waste. Further details are provided in Annex 3, section A3.8.

The fraction of degradable organic carbon dissimilated ( $DOC_F$ ) is also derived from an analysis of the laboratory study by Barlaz *et al.* (1997). It varies from 35% (newspaper) to 98% (white office paper) depending on the particular component in the waste. The majority of the waste components are between 50% and 64% degradable. The IPCC recommended range quoted in the guidance is 50-60%.

The fraction of  $CH_4$  in landfill gas is generally taken to be 50%, which is in line with the Guidance. For old shallow sites it is taken to be 30% to reflect a higher degree of oxidation.

The fraction of methane recovered was derived from a survey of statistics on gas use for power generation, and a survey of installed flare capacity. Flares (other than those used to back up power generation, which are assumed to operate only when needed) are taken to have a load factor of 85% (ie 15% downtime), and 7% of flared are assumed to be replaced every year, so that the flare lifetime is about 15 years. This approach was taken because suitable metering data were not available. In 2004 the estimates were that 32% of generated methane was utilised and 44% was flared. Further details are provided in section A3.8 of the NIR.

The oxidation factor based on a model developed by LQM (2003) (which distinguishes between passage of methane through fissures and through the intact cap) is not used in this second issue of the 2006 inventory submission; the recommended IPCC Guidance value of 0.1 has been adopted. This was following a reassessment in response to previous UNFCCC reviews. Recovered methane is subtracted before applying the oxidation factor. This is in line with the IPCC Guidance.

Emissions from electricity generation are considered under Power Stations and emissions from heat generation are included under Miscellaneous and are discussed in **Annex 3**.

An estimate of NMVOC emissions from landfills was made using an emission factor of 0.01 t NMVOC/t methane produced which is equivalent to 5.65g NMVOC/m<sup>3</sup> landfill gas (Passant, 1993). The emissions of pollutants from the flare stacks are not estimated separately.

### 8.2.3 Uncertainties and time-series consistency

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and gas. There are many uncertainties inherent in estimating methane emissions from landfill sites. The model is particularly sensitive to the values assumed for the degradable organic carbon (DOC) present in different fractions of waste, and the amount of this that is dissimilable, as well as to the oxidation factor. Both of these parameters are poorly understood, and field and experimental observations exhibit wide variation, so uncertainties are inevitably high, and the uncertainty estimates in **Annex 7** are intended to reflect this as well as uncertainties in the other data and model parameters.

The estimates for all years have been calculated from the LQM model and thus the methodology is consistent throughout the time series. Estimates of waste composition and quantities have been taken from different sources – prior to 1995 they are from Brown *et al.* 1999, and after 1995 new estimates were made as part of the LQM study, based on more recent data. This has resulted in an increase in estimated MSW arisings from households from 25 million tonnes in 1994 to 28 million tonnes in 1995, against a background trend of an annual increase of around 1 million tonnes before and after 1995. Similarly estimates of industrial and commercial waste arising – from 108 million tonnes in 1995 to reach 169 million tonnes by 1999 (assuming a linear increase over this period). Arisings are roughly constant in the years before 1995 and after 1999.

### 8.2.4 Source-specific QA/QC and verification

The IPCC Tier 2 Solid Waste Disposal from Land model from the 2006 Inventory Guidelines (which are agreed by IPCC but still under consideration by UNFCCC) has been used for purposes of quality control. The model was used to compare emissions to the Golder (2005) model. A comparison of the results is shown in Table 8.1. Although the Golder model uses country specific DOC, DOC<sub>F</sub> and K (half-life) values, the way they are implemented against rapidly-, moderately- and slowly-degrading fractions of waste means that they are capable of changing with time through each waste stream. Consequently they were difficult to apply to the IPCC model, and hence, IPCC default values were used. The activity data, the methane correction factor, the fraction of methane, the oxidation factor and the amount recovered were identical between the two model runs which therefore show the effect of country specific values for DOC, DOC<sub>F</sub> and K (half-life). The results in **Table 8.1** show that although the Golder model initially estimates slightly lower emissions, in later years the estimates are higher. In general the two models provide similar emissions through the time-series. The Golder results are considered more representative of UK conditions and have therefore been used in the inventory



**Table 8.1** Amount of methane generated compared with the IPCC Tier 2 model.

Year	Mass of waste landfilled (Mt)			Golder model (oxidation factor 0.1) Methane emitted (kt)	IPCC Methane emitted (kt)
	MSW	C&I	Combined waste streams		
1990	18.19	81.83	100.02	2363	2432
1991	18.84	81.77	100.61	2329	2364
1992	19.47	81.72	101.19	2270	2275
1993	20.09	81.66	101.76	2212	2190
1994	20.71	81.61	102.32	2167	2121
1995	23.83	81.56	105.39	2099	2044
1996	24.76	78.17	102.93	2027	1979
1997	26.14	72.86	99.00	1866	1795
1998	25.94	65.63	91.57	1735	1628
1999	27.03	63.84	90.87	1577	1413
2000	27.54	62.05	89.59	1472	1262
2001	26.85	60.27	87.11	1277	1032
2002	27.17	58.48	85.64	1162	884
2003	26.39	58.48	84.87	1016	710
2004	25.47	58.48	83.94	943	615
<b>Total</b>	-	-	-	<b>26,514</b>	<b>24,745</b>

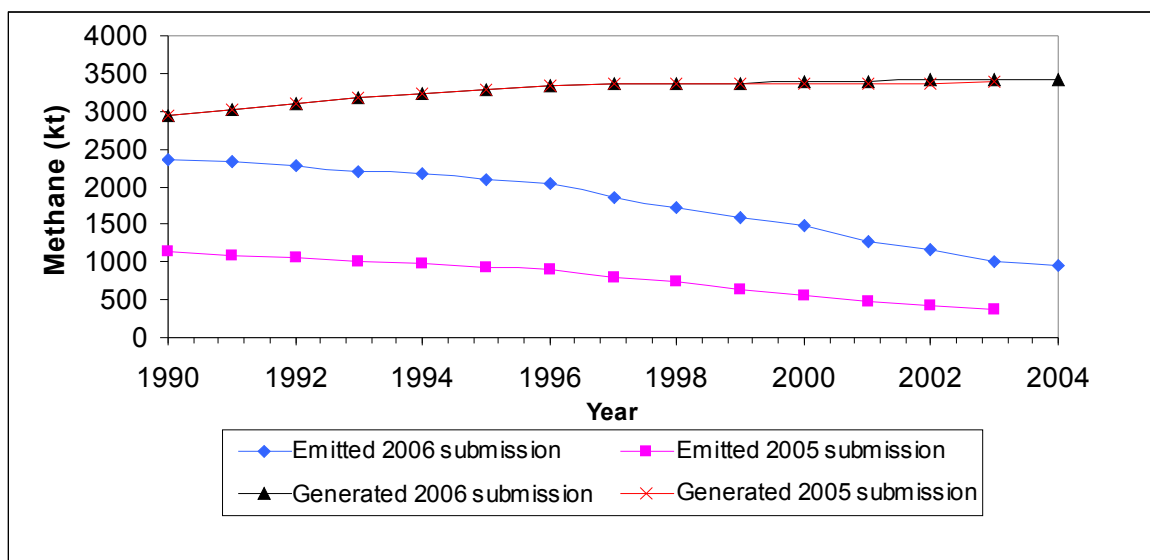
### 8.2.5 Source-specific recalculations

The 2005 Golder report describes changes that have had a significant affect on the methane emission values, and in addition (for this re-issue of the 2006 inventory submission) following the reassessment identified above, the oxidation factor which has been aligned to the IPCC Guidelines. Estimates for total waste arisings have been updated with real data where possible.

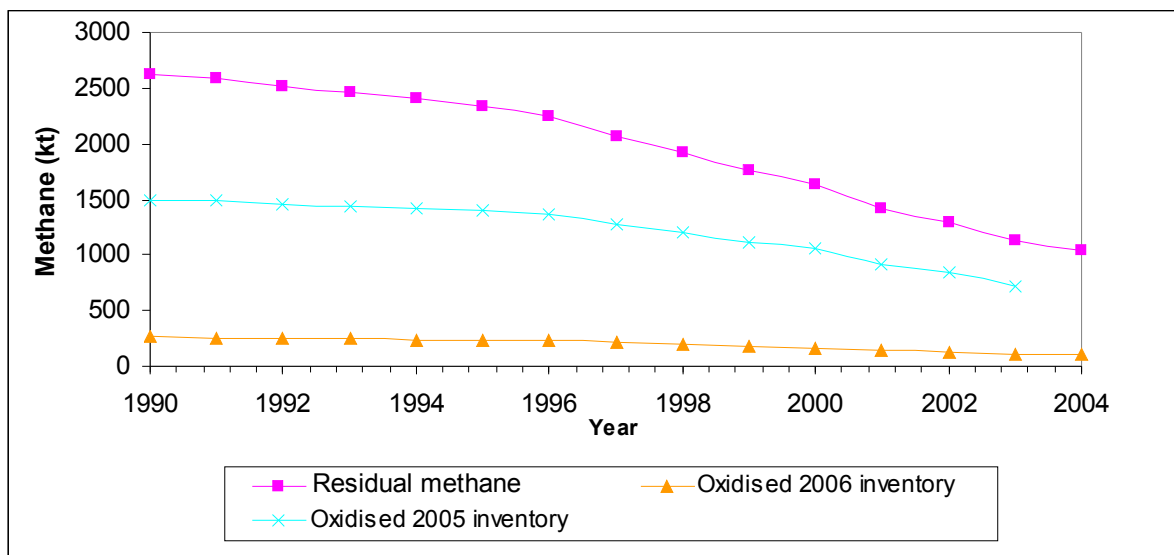
Updates to the inventory have resulted in an increase in methane emissions from solid waste disposal over the entire time series, although the difference between the two time series decreases with time (Figure 8.1). The increase in the methane from solid waste disposal emissions is directly related to the change in the oxidation parameter; oxidation is now in line with the IPCC guidelines at 10%. Although the waste composition activity data have been updated, after 1996, this has only a small effect on the amount of methane generated (see **Figure 8.1**). As the amount of methane generated is essentially the same, and the amount of gas utilised remains unchanged, the portion of residual methane (generated less utilised) is directly affected by the amount of methane that is oxidised (see **Figure 8.2**). **Figure 8.1** and **Figure 8.2** demonstrate that the amount emitted in the reissued 2006 inventory submission is directly proportional to the residual methane. In the 2005 submission, however, the percentage of residual methane oxidised increased with time (57% in 1990 to 65% in 2003), whereas methane oxidised remains constant at 10% in the reissued 2006 submission. These

factors have caused the gradual convergence of the two time series illustrated in **Figure 8.1** (diamond legend; 2006 reissued submission; .square legend, 2005 submission).

**Figure 8.1** Methane generated and methane emitted in the 2005 and 2006 inventory submission



**Figure 8.2** Residual (generated less utilised) methane compared to amount oxidised in the 2005 and 2006 inventory submission



## 8.2.6 Source-specific planned improvements

Emission factors, model parameters, and activity data will be kept under review.

## **8.3 SOURCE CATEGORY 6B – WASTEWATER HANDLING**

### **8.3.1 Source category description**

Emissions from this category cover those released from wastewater handling. Emissions are included for industrial, domestic and commercial wastewater.

Methane and nitrous oxide are produced from anaerobic decomposition of organic matter by bacteria in sewage facilities and from food processing and other industrial facilities during wastewater handling. Nitrous oxide may also be released from wastewater handling and human waste.

### **8.3.2 Methodological issues**

The NAEI category Sewage is mapped on to the IPCC category 6B2 Domestic and Commercial Wastewater.

The NAEI estimate is based on the work of Hobson *et al* (1996) who estimated emissions of methane for the years 1990-95. Subsequent years are extrapolated on the basis of population. Sewage disposed to landfill is included in landfill emissions.

The methodology of the UK model differs in some respects from the IPCC default methodology. The main differences are that it considers wastewater and sewage together rather than separately. It also considers domestic, commercial and industrial wastewater together rather than separately. Emissions are based on empirical emission factors derived from the literature expressed in kg CH<sub>4</sub>/tonne dry solids rather than the BOD default factors used by IPCC. The model complies with the IPCC Good Practice Guidance as a national model (IPCC, 2000).

The basic activity data are the throughput of sewage sludge through the public system. The estimates are based on the UK population connected to the public sewers and estimates of the amount of sewage per head generated. From 1995 onwards the per capita production is a projection (Hobson *et al*, 1996). The main source of sewage activity data is the UK Sewage Survey (DOE, 1993). Emissions are calculated by disaggregating the throughput of sewage into 14 different routes. The routes consist of different treatment processes each with specific emission factors. The allocation of sludge to the treatment routes is reported for each year on the CRF tables attached to this report as a CD ROM.

For more details on methodology and coverage of the Hobson model, see **Section A.3.8**.

Nitrous oxide emissions from the treatment of human sewage are based on the IPCC (1997c) default methodology. The most recent average protein consumption per person is based on the National Food Survey (Defra, 2004); see **Table A.3.8.3**. This is a household survey and may omit some consumption, but it is not thought that the effect on emissions would be significant.

### **8.3.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and gas.

The same methodology has been used to estimate emissions for all years, providing a good time series consistency. The population data needed to estimate emissions are provided by the Office of National Statistics (ONS). Time-series consistency of activity data is very good due to the continuity in data provided by the ONS.

### **8.3.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

### **8.3.5 Source-specific recalculations**

The time series of emissions from this sector has been recalculated to include emissions from the Crown Dependencies (CDs) of Guernsey, Jersey, the Isle of Man, and the Overseas Territories (OTs) of the Cayman Islands, the Falkland Islands, Montserrat and, Bermuda.

### **8.3.6 Source-specific planned improvements**

The methodology of the UK model is based on research, surveys and reports from the early 1990s. Significant changes to sewage treatment systems have been implemented in the intervening years, and hence a new estimation methodology is now required. In summer 2005, UK water companies adopted a new GHG emissions calculation system (developed by UK Water Industry Research) and in future will be required to submit annual emission estimates to the industry regulator, OFWAT. The Inventory Agency has not been given access to the UKWIR research findings, and hence the up-to-date emission factors and plant design knowledge could not be integrated into the UK GHG inventory in this cycle.

Water company GHG emissions data for 2005 will become publicly available from June 2006 and will be integrated into the next inventory cycle. In the prioritisation of inventory improvements and associated resource allocation for the 2004 inventory, access to this new dataset was identified as a key step forward but because access has not been granted to the new industry research, improvements to the method have been deferred to the 1990-2005 inventory cycle.

## **8.4 SOURCE CATEGORY 6C – WASTE INCINERATION**

### **8.4.1 Source category description**

This source category covers the incineration of wastes, excluding waste-to-energy facilities. For the UK, this means that all MSW incineration is excluded, being reported under CRF source category 1A instead. Incineration of chemical wastes, clinical wastes, sewage sludge and animal carcasses is included here. In-situ burning of agricultural waste e.g. crop residue burning is reported under category 4F.

There are approximately 70 plant incinerating chemical or clinical waste or sewage sludge and approximately 2600 animal carcass incinerators. Animal carcass incinerators are typically much smaller than the incinerators used to burn other forms of waste.

This source category also includes emissions from crematoria.

#### **8.4.2 Methodological issues**

Emissions of carbon, CO, NO<sub>x</sub>, SO<sub>2</sub>, and VOC from chemical waste incinerators are estimated based on analysis of data reported to the Environment Agency's Pollution Inventory. This only covers England and Wales and there may be some significant emissions from plant in Scotland and Northern Ireland but no emissions data are available from these plant. Emissions data are not available for all pollutants for all sites and so some extrapolation of data from reporting sites to non-reporting sites has been done, using estimates of waste burnt at each site as a basis. The gaps in reported data are usually for smaller plant and the extrapolation of data is unlikely to seriously reduce the quality of the estimates.

Emissions of CH<sub>4</sub>, CO, N<sub>2</sub>O, NO<sub>x</sub>, SO<sub>2</sub> and VOC from sewage sludge incinerators are estimated from a combination of data reported to the Environment Agency's Pollution Inventory, supplemented with the use of literature-based emission factors for those pollutants where the Pollution Inventory does not give information sufficient to derive estimates. Emissions of NO<sub>x</sub> are estimated using Pollution Inventory data while emissions of all other direct and indirect greenhouse gases are estimated from literature-based emission factors. The factor for N<sub>2</sub>O is the default factor given in the IPCC good practice guidance for UK sewage sludge incineration. Emission factors for other pollutants are taken from the EMEP/CORINAIR Emission Inventory Guidebook. The quantity of waste burnt annually is estimated, these estimates being based on estimates given in the literature.

Emissions of carbon, CH<sub>4</sub>, CO, N<sub>2</sub>O, NO<sub>x</sub>, SO<sub>2</sub>, and VOC from clinical waste incinerators are estimated using literature-based emission factors. The factor for carbon is the default factor given in the IPCC good practice guidance, while the factor for N<sub>2</sub>O is the default for UK MSW incineration given in the same source. Emission factors for other pollutants are largely taken from the EMEP/CORINAIR Emission Inventory Guidebook. The quantity of waste burnt annually is also estimated, these estimates being based on information given in literature sources.

Emission estimates for animal carcass incinerators are taken directly from a Defra-funded study (AEA Technology, 2002) and are based on emissions monitoring carried out at a cross section of incineration plant. No activity data are available and so the emission estimates given in this report are assumed to apply for all years.

Emissions of CO, NO<sub>x</sub>, SO<sub>2</sub> and VOC from crematoria are based on literature-based emission factors, expressed as emissions per corpse, and taken from US EPA (2005). Data on the annual number of cremations is available from the Cremation Society of Great Britain (2005).

### **8.4.3 Uncertainties and time-series consistency**

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5a** and **Table A7.5b**, provides estimates of uncertainty according to IPCC source category and gas.

### **8.4.4 Source-specific QA/QC and verification**

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

### **8.4.5 Source-specific recalculations**

No significant recalculations have been required for this version of the inventory.

### **8.4.6 Source-specific planned improvements**

Emission estimates for chemical waste incineration currently do not include the burning of chemical wastes in flares or the burning of chemical wastes as fuels. The estimates therefore underestimate actual emissions from combustion of chemical wastes. Further development of the methodology should allow at least some of these omitted sources to be included although this will not completely address this issue. Other possible areas for improvement include better activity data for clinical waste, animal carcass and sewage sludge incineration.

Improvements in the reporting of data from plant in Scotland (i.e. the development of the Scottish Pollutant Release Inventory) is anticipated to improve the coverage of industrial waste incineration plant for Scottish in future versions of the inventory.

## **8.5 SOURCE CATEGORY 6D – OTHER**

### **8.5.1 Source category description**

This category covers the release of greenhouse gas from other waste handling activities.

There are no emissions from this source category in the UK.

## 9. Other (CRF sector 7)

### 9.1 OVERVIEW OF SECTOR

Sector 7 has been used to extend coverage of emissions from the UK's Crown Dependencies (CDs) and Overseas Territories (OTs)<sup>9</sup> who have joined, or are likely to join, the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol. Sector 7 is also used for emissions from stored carbon and non-energy use of fuels. Because of time constraints linked to difficulties encountered with adding emissions data to early versions of the CRF Reporter, there are some differences on reporting of emissions in this sector between the NIR and the accompanying CRF. These differences occurred between the CRF and The NIR (issue 1) published in April 2006 and are summarised in **Table 9.1a** below. They do not affect the national total emissions, which agree between the CRF agree and the NIR.

Since issuing the first edition of the UK NIR, some of the emissions from Sector 7 have been reallocated in the CRF to Sectors 1-6. This is so there is no ambiguity and ensures that these emissions are included in the UK's Assigned Amount. These changes are highlighted in **Table 9.1b** below. Emissions of indirect greenhouse gases remain in Sector 7 in the revised CRF tables due to technical difficulties including them in the categories to which the direct greenhouse gases were moved. In most cases, moving the emissions from Sector 7 has made the allocation of emissions in the CRF tables consistent with those in the NIR. Reporting between the NIR and the CRF will be fully harmonised in the UK's submission for 2007.

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<sup>9</sup> These are the Cayman Islands, Falkland Islands, Bermuda, Montserrat and Gibraltar

**Table 9.1a** Differences between reporting of emissions in the 2006 NIR and the 2006 CRF submitted in April 2006

Source	Location in the NIR and IPCC sectoral tables presented in the NIR	Location in the CRF	Notes
Emissions of CO <sub>2</sub> from energy use in the UK Crown Dependencies. Emissions of N <sub>2</sub> O and CH <sub>4</sub> from stationary combustion of fuels within the geographical coverage of DUKES.	With the main UK categories	With the main UK categories	These emissions have been included in previous inventory submissions to the UNFCCC
Other emissions from the UK Crown Dependencies and Overseas Territories	Emissions allocated to the appropriate IPCC sector and category	Sector 7  Emissions are reported in following categories  <i>CDandOT_Sector1</i> <i>CDandOT_Sector2</i> <i>CDandOT_Sector3</i> <i>CDandOT_Sector4</i> <i>CDandOT_Sector5</i> <i>CDandOT_Sector5</i>	Emissions from sources included in the OTs and CDs have been aggregated to the top tier IPCC reporting level. No further sectoral breakdown is given in the CRF.



Source	Location in the NIR and IPCC sectoral tables presented in the NIR	Location in the CRF	Notes
New sources of carbon introduced into the GHG inventory following the review of stored carbon and the non-energy use of fuels.	Sector 7	<p>Sector 7</p> <p>Emissions are reported in the category</p> <p><i>Carbon_from_NEU_Products</i></p>	<p>This category contains estimates of carbon emissions from 1) carbon emitted during energy recovery in the chemical industry; 2) the release of carbon from the breakdown of selected products formed from the non-energy use of fossil fuels.</p> <p>Carbon emissions are included from: petroleum waxes (emissions from the use or breakdown of packaging materials, candles, construction materials, firelogs, hot melt adhesives); carbon emitted during energy recovery in the chemical industry (the use of chemical wastes as fuels, for example in steam-raising boilers); carbon released from the breakdown of products (soaps, shampoos, detergents etc.; and pesticides).</p> <p>For transparency, these emissions are reported in Sector 7 in the CRF rather than aggregating emissions with other sectors since the sources of these emissions do not match with the available IPCC reporting categories.</p>

**Table 9.1b** Summary of changes to the CRF tables between issue 1 and issue 2 of the NIR

Source	Category in Original CRF	Category in Revised CRF	Category in NIR	Notes
Power stations (All OTs, stations burning MSW from the CDs)	7: Other - CD and OT Sector 1	1A1a: Public Electricity and Heat Production (Other Fuels)	1A1a	Quantities of fuels consumed are currently not available in the detail required for the CRF, and are currently not reported. Therefore, emissions have been included under "other fuel" in the CRF in order to avoid introducing errors to the IEFs calculated from the mainland UK data. In most cases, the fuel used in gas or fuel oil.
Industrial Combustion (OTs only)	7: Other - CD and OT Sector 1	1A2f: Other - OT Industrial Combustion	1A2f	This has been included in the CRF as a separate category under 1A2f.
Road Transport (OTs only)	7: Other - CD and OT Sector 1	1A3b: Road Transport (Other Fuels)	1A3b	Quantities of fuels consumed are currently not available in the detail required for the CRF, and are currently not reported. Therefore, emissions from road transport have been included under "other fuel" in the road transport category. This enters emissions to the correct sector, without introducing errors to the IEFs from the existing data.
Aviation (OTs only)	7: Other - CD and OT Sector 1	1A3e: Other - OT Aviation	1A3a	It was not possible to include emissions from aviation under 1A3a in the CRF because there was no option to create another fuel category, and adding the OT emissions to the UK figures would affect the IEFs.
Residential and Commercial Combustion (OTs only)	7: Other - CD and OT Sector 1	1A4b: Residential (Other Fuels)	1A4b	This has been included as an "other fuel" in the CRF. Some emissions from the commercial sector are also included here, where it was difficult to disaggregate fuel use data.
Carbon from NEU Products	7: Other - Carbon from NEU Products	2B5: Other - Carbon from NEU Products	7	This has been included in the CRF as a separate category. Emissions of carbon from NEU products remain reported under Sector 7 in the NIR.
OT and CD F gases	7: Other - CD and OT Sector 2	2F9: Other - OT and CD F Gas Emissions	2F	This has been included in the CRF as a separate category for all F Gas emissions from the OTs and CDs.
OT and CD Enteric Fermentation	7: Other - CD and OT Sector 4	4A10: Other - OTs and CDs All Livestock	4A	A separate category for all livestock in the OTs and CDs has been introduced.
OT and CD Manure Management	7: Other - CD and OT Sector 4	4G: Other - OT and CD Emissions from Manure Management	4B	It was not possible to introduce a new category in which to put emissions of N <sub>2</sub> O from manure from the OTs and CDs into Sector 4B. A new category was therefore included in Sector 4G - Other.

Source	Category in Original CRF	Category in Revised CRF	Category in NIR	Notes
OT and CD Landfill	7: Other - CD and OT Sector 6	6A3: Other - OT and CD Landfill Emissions	6A	This has been included in the CRF as a separate category under 6A.
OT and CD Sewage Treatment	7: Other - CD and OT Sector 6	6B3: Other - OT and CD Sewage Treatment (all)	6B	This has been included in the CRF as a separate category under 6B.
OT and CD Waste Incineration	7: Other - CD and OT Sector 6	6C3: Other - OT and CD MSW Incineration	6C	This has been included in the CRF as a separate category under 6C.

## 9.2 EMISSIONS OF CARBON FROM PRODUCTS

Four new sources of carbon have been introduced into the 2004 inventory, and these are reported in **Sector 7** in both the NIR and the CRF. These new sources are emissions from:

- ▶ Petroleum waxes
- ▶ Carbon emitted during energy recovery - chemical industry
- ▶ Carbon in products - soaps, shampoos, detergents etc.
- ▶ Carbon in products - pesticides

**Section A3.3.9 in Annex 3** presents more information about the approach used to estimate emissions from stored carbon and the non-energy use of fuels, and this is not discussed further here. A full time series of emissions has been included in the inventory.

For transparency, these emissions of carbon are reported in Sector 7 in the CRF and IPCC sectoral tables in the NIR rather than aggregating emissions with other sectors.

## 9.3 EMISSIONS FROM THE UK'S CROWN DEPENDENCIES AND OVERSEAS TERRITORIES

Direct GHG emissions are included from those UK Crown Dependencies (CDs) and Overseas Territories (OTs) which have joined, or are likely to join, the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol<sup>10</sup>. The relevant CDs and OTs are:

- ▶ Guernsey
- ▶ Jersey
- ▶ The Isle of Man
- ▶ The Falkland Islands
- ▶ The Cayman Islands
- ▶ Bermuda
- ▶ Montserrat
- ▶ Gibraltar

Country specific data have been sought to estimate as emissions as accurately as possible. In general the data were requested by questionnaire asking for information on fuel use, the vehicle fleet, shipping movements, aircraft, livestock numbers and waste treatment. In some cases (such as for the Channel Islands) much of the data were readily available from government statistical departments, and indeed the inventory already included CO<sub>2</sub> from energy use in the CDs because of the coverage of the Digest of UK Energy Statistics. In these cases it was possible make estimates of the emissions using the same methodology as used for the UK inventory.

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<sup>10</sup> Emissions from the UK military bases in Cyprus are assumed to be included elsewhere – emissions from on-base activities are included within the military section of the UK greenhouse gas inventory, whereas any off-base activities will be included within the inventory submitted for Cyprus.

There were some difficulties obtaining information for some sectors in some of the OTs to estimate emissions using the same methods applied to the existing UK GHG inventory. Modifications were therefore made to the existing methods and surrogate data were used as necessary; this is discussed in the sections below. For sectors such as waste treatment in the Overseas Territories, no data were available and it was not possible to make any estimates of emissions.

Emissions of GHGs from fuel combustion in IPCC Sector 1 (but not waste incineration) were already included in the GHG inventory from the CDs of the Channel Islands and the Isle of Man, but emissions from agriculture and waste from these CDs were not previously estimated or included. **Table 9.2a** and **Table 9.2b** show the new emissions included according to source category.

**Table 9.2a** Source categories included in the 2006 NIR from Crown Dependencies

<b>Territory</b>	<b>GHG</b>	<b>Source category</b>	<b>Included in 2005 NIR?</b>	<b>Included in 2006 NIR?</b>
<i>Crown Dependencies</i>				
Jersey Guernsey Isle of Man	CO <sub>2</sub>	Stationary and Mobile Fuel Combustion	✓	✓
		1A1a Public Electricity&Heat Production (Waste Incineration)	×	✓
	CH <sub>4</sub>	Stationary Fuel Combustion	✓	✓
		1A1a Public Electricity&Heat Production (Waste Incineration)	×	✓
		4A10 Enteric Fermentation	×	✓
		6A1 Managed Waste Disposal on Land	×	✓
		6B2 Wastewater Handling	×	✓
	N <sub>2</sub> O	Stationary Fuel Combustion	✓	✓
		1A1a Public Electricity&Heat Production (Waste Incineration)	×	✓
		4B13 Manure Management	×	✓
		6B2 Wastewater Handling	×	✓
	F-gases	Not included	×	×

**Table 9.2b** Source categories included in the 2006 NIR from Overseas Territories

Territory	GHG	Source category	Included in 2005 NIR?	Included in 2006 NIR?
<i>Overseas Territories</i>				
Bermuda Cayman Islands Falkland Islands Montserrat	CO <sub>2</sub>	1A1a Public Electricity&Heat Production	x	✓
		1A2f Manufacturing Industry&Construction:Other	x	✓
		1A3aii Civil Aviation Domestic	x	✓
		1A3b Road Transportation	x	✓
		1A4b Residential	x	✓
		1A4cii Agriculture/Forestry/Fishing:Off-road	x	✓
		6C Waste Incineration	x	✓
	CH <sub>4</sub>	1A1a Public Electricity&Heat Production	x	✓
		1A2f Manufacturing Industry&Construction:Other	x	✓
		1A3aii Civil Aviation Domestic	x	✓
		1A3b Road Transportation	x	✓
		1A4b Residential	x	✓
		1A4cii Agriculture/Forestry/Fishing:Off-road	x	✓
		4A10 Enteric Fermentation Other	x	✓
		6A1 Managed Waste Disposal on Land	x	✓
		6B2 Wastewater Handling	x	✓
		6C Waste Incineration	x	✓
	N <sub>2</sub> O	1A1a Public Electricity&Heat Production	x	✓
		1A2f Manufacturing Industry&Construction:Other	x	✓
		1A3aii Civil Aviation Domestic	x	✓
		1A3b Road Transportation	x	✓
		1A4b Residential	x	✓
		1A4cii Agriculture/Forestry/Fishing:Off-road	x	✓
		4B13 Manure Management Other	x	✓
		6B2 Wastewater Handling	x	✓
		6C Waste Incineration	x	✓
	F-gases		x	✓

A summary of the emissions of the direct GHGs from the UK's Crown Dependencies and Overseas Territories are given in **Table 9.4** and **Table 9.6**.

## ■ CROWN DEPENDENCIES: THE CHANNEL ISLANDS AND THE ISLE OF MAN

The methods used to estimate emissions from the Channel Islands and the Isle of Man are summarised in **Table 9.3**; this table is located after **Section 9.3.1.3**. Data for these territories were obtained at the same time as the compilation of the UK GHG inventory which enabled checks to be made on the data and its veracity. Emissions are summarised in **Table 9.4**.

Emissions of CO<sub>2</sub> from fuel combustion were already included in the GHG inventory from the CDs of the Channel Islands and the Isle of Man because fuel consumptions from these areas are included in the DTI energy statistics. Emissions of CH<sub>4</sub> and N<sub>2</sub>O from these CDs were not previously included in the GHG inventory.

Estimates of the indirect GHGs have been made in addition to the direct GHGs (CO, NMVOC, NO<sub>x</sub>, and SO<sub>2</sub>) and additional, NH<sub>3</sub>.

### **9.3.1 Jersey**

The largest sources of carbon emissions for Jersey are transport, mainly shipping and aviation, and power generation. Emissions from power generation have decreased steadily across the time series due to imports of electricity from France.

Agricultural activity is the main source of methane emissions, although emissions have declined from 2002 onwards. Waste is incinerated, and so there are no methane emissions from landfill sites. Default factors from the EMEP/CORINAIR Guidebook were used to estimate emissions from waste incineration as there was not enough information available to assume similar technology in Jersey and the UK.

N<sub>2</sub>O emissions are mostly from off road transport sources and livestock manure management. Emissions from road transport increase across the time series in line with the increase in vehicle numbers and the introduction of catalysts to the vehicle fleet.

F-gas emissions are based on UK emissions, scaled by population or GDP. There are no emissions from industrial sources and so the F-gas emissions show a similar trend to the UK emissions from non-industrial sources. No estimates were made of emissions of N<sub>2</sub>O from agricultural soils as no data could be obtained or extrapolated for fertiliser use.

Estimates of emissions from fuel combustion are based on real data supplied for fuel use and vehicle movements, and we consider the uncertainty on these emissions to be low and probably similar in magnitude to the uncertainties on UK emissions from these sources. Emissions from livestock were based on an incomplete time series, and rely on extrapolated figures, introducing greater uncertainty for this sector. Emissions from sewage treatment are based on UK per capita emission factors, which may not be an accurate representation of the technology in use for Jersey.

### **9.3.2 The Isle of Man**

The main source of carbon emissions is power generation. Emissions from this source increased in 2004 as a new waste incinerator opened; previously waste generated on the Isle of Man was disposed to landfill. Some minor industrial sources of combustion emissions also exist; the sewage treatment plant and quarries.

The most significant methane source is agriculture, which accounted for 65% of methane emissions in 1990. The other major source was waste treatment and disposal to landfill until the incinerator replaced the landfill sites.

N<sub>2</sub>O emissions arise mainly from agricultural practices – livestock manure management. No estimate has been made of N<sub>2</sub>O from agricultural soils. Off road transportation and machinery is also a relatively important source.

The emissions for fuel combustion and transportation sources are based on real data and emission factors sourced from the existing GHG inventory, and so estimates have a fairly low uncertainty. Emissions from landfill, sewage treatment, and F-gas use rely on UK data scaled to population and therefore assume similar characteristics and usage patterns to the UK.

### **9.3.3 Guernsey**

At the beginning of the time series (towards 1990), the most important sources of carbon emissions were power generation and domestic fuel combustion. There is one power station on Guernsey. Emissions from power generation decreased from 1990 onwards as an increasing fraction of electricity was imported, so that in 2004, emissions from this source are only 37% of those in 1990. Emissions from off road transport and machinery are also significant, accounting for almost half of the emissions in 2004.

The largest methane source is from waste disposed to landfill. Emissions from most methane sources show a decrease across the time series, reflecting improved technology and a reduction in livestock numbers. Increased shipping activity has increased methane emissions. Shipping and off road machinery are also the largest source of N<sub>2</sub>O emissions.

The estimates of emissions of non-CO<sub>2</sub> emissions from fuel consumption for Guernsey are based on a number of assumptions. Fuel consumption figures for power generation were calculated based on electricity consumption figures, total fuel imports, and fuel consumption data for a few years taken from the power station statistical report. Domestic and commercial combustion figures also needed to be separated out from the total imports, and split into different fuel types based on data given in a previous inventory for Guernsey. Aviation, shipping and agriculture figures are based on incomplete time series and the missing data have been interpolated or extrapolated as necessary, and are therefore subject to greater uncertainty.



**Table 9.3** Isle of Man, Guernsey and Jersey – Summary of methodologies

Sector	Source name	Activity data	Emission factors	Notes
<b>1</b>	Energy - power stations and small combustion sources	Fuel use data supplied	2003 NAEI, EMEP/CORINAIR default factors used for waste incineration.	In some cases time series were incomplete - other years were based on extrapolated/interpolated values. Fuel imports for Guernsey were not always broken down into different fuel classes - this information was derived from data in a previous report (2002).
	Energy - road transport	Time series of vehicle numbers and fuel consumption supplied, age profile and vehicle km data calculated using UK figures	Factors for vehicle types based on UK figures	Breakdown of vehicle types not always detailed, some fuel use is based on extrapolated figures. Assumes the same vehicle age profile as the UK.
	Energy - other mobile sources	Aircraft and shipping movements supplied, and some data about off road machinery	Aircraft factors taken from EMEP/CORINAIR, shipping and off road machinery from 2003/2002 NAEI	Incomplete datasets were supplied in many cases - the time series were completed based on passenger number data or interpolated values. The off road machinery data was not in a detailed format - numbers for each type are best estimates
<b>2</b>	Industrial processes	Population and GDP	Some sources assumed zero. Per capita emission factors based on UK emissions, where appropriate.	Based on the assumption that activities such as aerosol use and refrigeration will be similar to the UK, whilst industrial sources will not be present. Industrial process emissions are assumed to be zero.
<b>3</b>	Solvent use	Population, GDP, vehicle and housing numbers	Per capita (or similar) emission factors based on UK emissions	Assumes that solvent use for activities such as car repair, newspaper printing, and domestic painting will follow similar patterns to the UK, whilst the more industrial uses will be zero.
<b>4</b>	Agriculture	Livestock statistics supplied	Ammonia and N <sub>2</sub> O from manure management are based on a time series of UK emissions. Methane emissions based on IPCC guidelines	Ammonia and N <sub>2</sub> O emissions assume similar farm management practices as for the UK. Some of the farming statistics time series were incomplete - other years were based on interpolated values
<b>5</b>	Land use change and forestry			Emissions Not Estimated (NE)
<b>6</b>	Waste - MSW	Landfill estimates based on population, incineration estimates based on limited data on the amount of waste incinerated	Time series of UK per capita emission factors used for land fill sites, 2003 NAEI emission factor used for incinerators	Estimates of amounts of incinerated waste are based on limited data and interpolated values. Using UK per capita emissions assumes the same management techniques as for the UK
	Waste - Sewage treatment	Population	Time series of UK per capita emission factors	Assumes the same sewage treatment techniques as for the UK. In practice, treatment not thought to be as comprehensive as UK, but no details available.

**Table 9.4** Isle of Man, Guernsey and Jersey – Emissions of Direct GHGs (Mt CO<sub>2</sub> equivalent)

Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1. Energy	2.07	2.11	2.18	2.16	2.16	2.24	2.36	2.39	2.46	2.38	2.27	1.97	1.96	1.92	1.93
2. Industrial Processes	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.03	0.03	0.03	0.03	0.03
3. Solvent and Other Products Use	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Agriculture	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.16	0.16	0.15	0.15	0.11	0.10
5. Land Use Change and Forestry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6. Waste	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.07	0.07	0.06	0.06	0.05	0.05	0.04	0.02
7. Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Total</b>	<b>2.31</b>	<b>2.35</b>	<b>2.42</b>	<b>2.39</b>	<b>2.40</b>	<b>2.48</b>	<b>2.60</b>	<b>2.62</b>	<b>2.71</b>	<b>2.62</b>	<b>2.51</b>	<b>2.20</b>	<b>2.18</b>	<b>2.10</b>	<b>2.09</b>

**Notes**

The estimates of greenhouse gas emissions from IPCC Sector 1 in **Table 9.4** include CO<sub>2</sub> derived from the data gathered directly from representatives in the CDs. These estimates are not used directly in the UK inventory to avoid double counting, because the main UK energy data already include the CDs.

▪ **OVERSEAS TERRITORIES: BERMUDA, FALKLANDS ISLANDS, MONTSERRAT, THE CAYMAN ISLANDS AND GIBRALTAR**

**Table 9.5** summarises the methods used to estimate emissions from the Falklands Islands, Montserrat and the Cayman Islands. Emissions from some sources are not estimated due to scarcity of data. Only estimates of the direct GHGs have been made for the OTs. Emissions are summarised in **Table 9.6**. The government of Bermuda has prepared its own GHG inventory estimates and methodological report, so **Table 9.5** only refers to the methodologies used for Falkland Islands, Montserrat and the Cayman Islands. **Table 9.6** does, however, include emissions estimates for Bermuda.

#### **9.3.4 Falklands Islands**

The most significant source of carbon is from power generation and domestic heating. There are no industrial combustion sources. The off road transportation figure includes aviation fuel supplied in the islands but no information was available on shipping or off road machinery.

Methane emissions are mostly from agriculture – there are around 700,000 sheep on the island. Agriculture is also a major source of N<sub>2</sub>O. Methane emissions from waste combustion are small, and as waste is burnt, the methane emissions from this source are small. Sewage is disposed of to sea.

The estimates of emissions from power generation are based on a complete time series of annual fuel consumptions, and can therefore be considered fairly reliable. Domestic fuel consumption statistics, however, were only provided for the last four years, so the time series was extrapolated back to 1990 based on population statistics. Vehicle numbers were also only provided for one year, and the time series was generated based on population statistics also. We consider the uncertainties associated with emissions from domestic fuel consumption and transport to be high, with the greatest uncertainties earlier in the time series.

#### **9.3.5 Montserrat**

Only limited activity data were supplied for Montserrat, so it was not possible to make estimates of GHG emissions from all source sectors. In addition half of the island is currently uninhabitable due to recent volcanic activity. Nevertheless a reliable time series of the island's population was supplied, and it was possible to use this to extend some of the time series of available emission estimates.

Estimates have been made for power generation, residential combustion, aviation, road transport and F-gases. No information was supplied about shipping. There was also no information supplied about the disposal of waste, treatment of sewage, or livestock numbers. Since emissions from different waste disposal and sewage treatment techniques vary greatly, there is no way of calculating a reliable estimate based on any surrogate statistics. It is also difficult to predict livestock figures without any indication of the importance of agriculture to the island.

Of the sectors calculated, road transport is the most important. However, only fuel consumption figures were supplied for this sector. Emissions were calculated based on the assumption that the vehicle fleet would be made up of old petrol and diesel cars, and emissions are therefore quite uncertain. It is assumed that emissions from some off road transport and machinery will be included in the figure calculated for the road transport sector. Power generation is the other major source.

### **9.3.6 Cayman Islands**

Relatively little data were available and it has only been possible to develop some basic estimates of emissions from fuel combustion sources. No estimates were made for off road transport, agriculture, domestic fuel consumption or waste treatment because there are no suitable surrogate statistics.

The major emission sources are power generation and vehicle emissions for carbon, methane and nitrous oxide. There are also significant industrial combustion emissions from the water desalination plant and the cement industry.

All estimates are based on surrogate statistics. Power generation emissions were calculated based on electricity consumption statistics sourced from the CIA world fact book; emissions from the desalination plant were derived from reported fuel use for a similar plant in Gibraltar, scaled by population; cement industry emissions were calculated by scaling UK emissions by GDP; and F-gas emissions were based on data from Gibraltar scaled by population. The only information supplied about road transport was a figure for total vehicle numbers, and an estimate of typical vehicle km. Emissions estimates were made based on road transport in Jersey, and scaled by the total number of vehicles, since the typical mileage was similar.

Since all of the data is based on assumptions and generalised statistics, the emissions calculated are all very uncertain.

### **9.3.7 Bermuda**

The Bermuda Department for Environmental Protection have produced their own greenhouse gas inventory, compiled according to the IPCC guidelines. Calculated emissions and the methodology used for Bermuda are detailed in Bermuda's Greenhouse Gas Inventory – Technical Report 1990-2000 (the Department of Environmental Protection, Government of Bermuda).

The major sources for carbon are road transport and power generation. Emissions from landfill were the main source of methane in 1990, but waste is now disposed of by incineration. N<sub>2</sub>O emissions arise mainly from sewage treatment.

**Table 9.5** Cayman Islands, Falklands Islands and Montserrat – Methodology (for estimates of carbon, CH<sub>4</sub> and N<sub>2</sub>O)

Sector	Source name	Activity data	Emission factors	Notes
<b>1</b>	Energy - power stations and small combustion sources	Fuel use data supplied (Falkland Islands and Montserrat), electricity consumption data (Cayman Islands)	NAEI 2003	Fuel data in most cases was only supplied for the latter part of the time series. Extrapolated figures based on population trends have been used to calculate fuel consumption for earlier years. The information supplied from the Cayman islands was limited to the type of fuel burned for electricity generation - electricity consumption statistics were obtained from the CIA World Factbook.
	Energy - road transport	Vehicle numbers and fuel use supplied for the Falkland Islands, vehicle numbers and vehicle kilometres for the Cayman Islands, fuel use for Montserrat.	Factors for vehicle types based on UK figures	Vehicle numbers have only been supplied for one year (time series are based on population), and the age profiles are based on UK figures - which may not be appropriate. Emissions for Montserrat are subject to a greater degree of uncertainty as there is no information about vehicle types or numbers - emissions have been calculated based on a fleet of old petrol and diesel cars.
	Energy - other mobile sources	Aircraft movements supplied for FI and Montserrat. Some off road machinery for Falklands also supplied.	EMEP/CORINAIR factors, off road machinery from NAEI 2002/2003	It has not been possible to make any estimates of emissions from shipping activities for any of these - no information was supplied, and the use of any surrogate statistics would not be suitable for this source. No estimates for the Cayman Islands have been made for other mobile sources.
<b>2</b>	Industrial processes	Population, GDP	Some sources assumed zero. Per capita emission factors based on UK/Gibraltar emissions.	Assumes activities such as aerosol use and refrigeration will be similar to the UK. In practice, this is unlikely, but there is no other data available. The Cayman Island estimates were based on figures calculated for Gibraltar rather than for the UK - it was assumed that trends in the use of air conditioning etc would be similar.
<b>3</b>	Solvent use	Population, GDP, vehicle and housing numbers.	Per capita (or similar) emission factors based on UK emissions	Assumes that solvent use for activities such as car repair, newspaper printing, and domestic painting will follow similar patterns to the UK, whilst the more industrial uses will be zero. In practice, for these overseas territories, this is unlikely. This source is not important for direct greenhouse gases.
<b>5</b>	Land use change and forestry			Emissions Not Estimated
<b>6</b>	Waste - MSW	Tonnes of waste incinerated (Falkland Islands), NE for Montserrat and Cayman Islands	US EPA factors for the open burning of municipal refuse, NAEI factors for clinical waste incineration	Information on the amount of waste incinerated was limited. No information about the type of waste treatment was available for Montserrat or the Cayman Islands.
	Waste - Sewage treatment	NO (Falkland Islands), NE (Cayman Islands and Montserrat)		Sewage from the Falkland Islands is disposed of to sea. Emissions Not Estimated (NE) for the Cayman Islands and Montserrat, as no information was available.

**Table 9.6** Cayman Islands, Falklands Islands, Bermuda and Montserrat – Emissions of Direct GHGs (Mt CO<sub>2</sub> equivalent)

Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1. Energy	1.02	1.03	1.04	1.06	1.07	1.09	1.09	1.09	1.09	1.12	1.14	1.16	1.17	1.18	1.19
2. Industrial Processes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
3. Solvent and Other Products Use	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Agriculture	0.17	0.17	0.16	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.17	0.17	0.16	0.15	0.15
5. Land Use Change and Forestry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6. Waste	0.07	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
7. Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.26	1.21	1.22	1.23	1.25	1.26	1.26	1.27	1.26	1.30	1.31	1.34	1.35	1.35	1.36
<b>Total</b>	<b>1.02</b>	<b>1.03</b>	<b>1.04</b>	<b>1.06</b>	<b>1.07</b>	<b>1.09</b>	<b>1.09</b>	<b>1.09</b>	<b>1.09</b>	<b>1.12</b>	<b>1.14</b>	<b>1.16</b>	<b>1.17</b>	<b>1.18</b>	<b>1.19</b>

### 9.3.8 Gibraltar Emissions

A greenhouse gas inventory for 2004 Gibraltar has been created which contains annual emission estimates from 1990 to 2004 inclusive and emissions for the Base Year. The year 1995 has been chosen as the Base Year for the fluorinated gases, in agreement with the year the UK has chosen, and in accordance with Article 3(8) of the Kyoto Protocol. Emission estimates of the indirect greenhouse gases have not been made.

At the time the 2006 NIR was written, Gibraltar had not made the decision to join the UK's instrument of ratification to the UNFCCC and the Kyoto Protocol. Emissions from Gibraltar were therefore not included in the first issues of the UK 2006 NIR or 2006 CRF. The decision has now been made that Gibraltar will join, and this issue of the NIR has been updated to report emissions from Gibraltar. The CRF has also been re-submitted to include total emissions from Gibraltar.

Gibraltar already reports emissions under other international agreements. During the compilation of the Gibraltar GHG inventory, steps have been taken to ensure the existing Gibraltar inventories and the GHG inventory share common activity data where appropriate.

Data specific to Gibraltar have been collected to estimate emissions as accurately as possible. In general the data were requested by questionnaire asking for information on fuel use, the vehicle fleet, shipping movements, aircraft, livestock numbers and waste treatment. Communications between the Gibraltar Environmental Agency and other companies is extremely good, allowing the acquisition of reliable data relating to the larger emission sources. The Gibraltar Environmental Agency was able to provide information from the government of Gibraltar statistics office, which holds much information relating to several source sectors. However, there are laws in Gibraltar restricting the data available from the Government statistics department. In general these were introduced to protect commercially sensitive information, which is more likely to occur in smaller administrations. For example it is not possible to obtain information on petrol sales from the eight petrol stations on Gibraltar without special dispensation. However, it is possible to obtain information on services that have no direct competitors (and hence the information is not regarded as being commercially sensitive).

There were some difficulties obtaining information for some sectors to estimate emissions using the same methods applied to the existing UK GHG inventory. Modifications were therefore made to the existing methods and surrogate data were used as necessary; this is discussed in the sections below. Where possible, emissions were estimated using same methods used in the UK inventory.

Emission factors for most sources are taken from the NAEI, to be consistent with the UK GHG inventory. Emissions from aircraft were calculated using default factors from the EMEP/CORINAIR guidebook, since the information available about aircraft movements from Gibraltar was limited.

Whilst the data availability was regarded as good for an administrative area the size of Gibraltar, there were a number of sources for which detailed activity data was not available. In

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these cases expert judgement was required to enable an emission estimate to be obtained. **Table 9.7** summarises the methodologies used to produce emission estimates for Gibraltar.

Emissions from LULUCF have not been estimated from Gibraltar but are believed to be very small or negligible.

Emissions from military activities in Gibraltar have been excluded from the totals. This is because the fuel used for these activities is likely to be sourced from the UK, and therefore to include emissions in the Gibraltar inventory would result in a double-count. All shipping and aviation emissions are currently classified as international, on the basis that Gibraltar has only one port and one airport.

A summary of the emissions of the direct GHGs from Gibraltar is given in **Table 9.8**.



**Table 9.7 Summary of methodologies used to estimate emissions from Gibraltar**

Sector	Source name	Activity data	Emission factors	Notes
<b>1</b>	Energy - power stations, domestic, and small combustion sources	Fuel use data supplied for the three power stations. No activity data available for domestic, commercial and institutional combustion and so estimates made. Some fuel use available for industrial combustion.	2003 NAEI, EMEP/CORINAIR default factors used for waste incineration. Carbon content of some industrial fuels supplied.	In some cases time series were incomplete - other years were based on extrapolated (on population)/interpolated values.
	Energy - road transport	Time series of vehicle numbers and typical annual vehicle km per car, age profile calculated using UK figures.	Factors for vehicle types based on UK figures.	Breakdown of vehicle types not always detailed, some fuel use is based on extrapolated figures. Assumes the same vehicle age profile as the UK.
	Energy - other mobile sources	Aircraft and shipping movements supplied, and some data about off-road machinery.	Aircraft factors taken from EMEP/CORINAIR, shipping and off-road machinery from 2003/2002 NAEI.	Incomplete datasets were supplied in many cases - the time series were completed based on passenger number data or interpolated values. The off road machinery data was not in a detailed format - numbers for each type are best estimates.
<b>2</b>	Industrial processes	No industrial processes identified with GHG emissions. Emissions of F-gases from air conditioning units are included in this sector.	Per capita (or similar) emission factors based on UK emissions.	Estimates of HFCs from air conditioning were based on percentages of homes, cars etc using the equipment, provided by the Environmental Agency.
<b>3</b>	Solvent use	Population, GDP, vehicle and housing numbers, air conditioning usage estimates.	Per capita (or similar) emission factors based on UK emissions.	Assumes that solvent use for activities such as car repair, newspaper printing, and domestic painting will follow similar patterns to the UK, whilst the more industrial uses will be zero. There are no direct GHG emissions from this sector.
<b>4</b>	Agriculture	No commercial agricultural activity. No emissions from this sector.		
<b>5</b>	Land use change and forestry			Emissions Not Estimated (NE).
<b>6</b>	Waste - MSW	Incineration estimates based on limited data on the amount of waste incinerated up to 2001. After 2001, waste transported to Spain to be land filled.	1990 NAEI emission factor used for old incinerator (used in 1990 only) 2003 NAEI emission factor used for new incinerator.	Estimates of waste incinerated between 1990 and 1993 are based on extrapolated values. Data for the remainder of the time series was provide. Emissions from this source are assumed zero after the closure of the incinerator in 2000.
	Waste - Sewage treatment	No emissions from this sector; all sewage is piped directly out to sea, with no processing.		

**Table 9.8** Emissions of Direct GHGs (kt CO<sub>2</sub> equivalent) from Gibraltar

Sector	Base year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1. Energy	112.2	112.2	123.0	131.6	107.5	122.6	121.3	120.3	126.2	128.6	135.0	140.4	143.1	144.8	148.6	157.8
2. Industrial Processes	1.13	0.01	0.02	0.02	0.21	0.65	1.13	1.67	2.17	2.87	3.50	4.14	4.75	5.21	5.53	5.94
3. Solvent and Other Products Use	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Agriculture	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5. Land Use Change and Forestry	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
6. Waste	5.68	5.68	4.66	4.66	4.66	5.37	5.40	5.49	5.52	5.77	5.77	6.85	0.00	0.00	0.00	0.00
7. Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Total</b>	<b>119.0</b>	<b>117.9</b>	<b>127.6</b>	<b>136.3</b>	<b>112.3</b>	<b>128.6</b>	<b>127.8</b>	<b>127.5</b>	<b>133.9</b>	<b>137.2</b>	<b>144.3</b>	<b>151.4</b>	<b>147.9</b>	<b>150.0</b>	<b>154.1</b>	<b>163.7</b>

**Notes**

No emissions from military activities, shipping or aviation are included in the above totals

## 10. Recalculations and Improvements

This section of the report summarises the recalculations and improvements made to the UK GHG inventory since the 2005 NIR (2003 inventory) was issued. It summarises material that has already been presented and discussed in more detail in **Chapter 3** to **Chapter 9**. Table 8(b) of the CRF for each year also contains a summary of the recalculations since the previous inventory was submitted. For a quantitative discussion of emissions estimated in the 2004 GHG inventory, please see **Annex 6**. This chapter has been updated to reflect the late addition of emissions from Gibraltar, and the updates to methane emissions from landfill.

Each year, the UK greenhouse inventory is:

- *updated* existing activity data and/or emissions factors may be revised;
- *extended* the inventory includes a new inventory year.

*Updating* often entails revision of emission estimates, most commonly because of revision to the core energy statistics presented in the Digest of UK Energy Statistics (DUKES). The inventory also makes use of other datasets (see **Table 1.3** for a summary), and these too may also be revised. Updating will also reflect adoption of revised methodologies, as has happened with the estimates of stored carbon and emissions from the non-energy use of fuels in this submission. Updating, particularly involving revised methodologies, may affect the whole time series, so estimates of emissions for a given year may differ from estimates of emissions for the same year reported previously. Therefore comparisons between submissions should take account of whether there have been changes to:

- the methodology used to estimate emissions, or
- the base activity data.

The time series of the inventory is *extended* by including a new inventory year - for example, the previous report covered the years up to and including 2003; this report gives emission estimates for 2003, and includes estimates for the year 2004 also.

The inventory may also be *expanded* to include emissions from additional sources if a new source has been identified within the context of the IPCC Guidelines and Good Practice Guidance, and there are sufficient activity data and suitable emission factors.

### 10.1 EXPLANATIONS AND JUSTIFICATIONS FOR RECALCULATIONS

**Table 10.1** summarises the recalculations that have occurred in estimates of the direct GHGs since the 2005 NIR (2003 inventory) was issued. It contains brief comments on the reasons behind the recalculations, and shows if a revision of the entire time series has occurred. The

changes in emissions are net changes (the sum of any increases and decreases) in the source category, for the year 2003.

Table8(a)s1 and Table8(a)s2 of the CRF also present details of recalculations of emissions between the current and the previous inventory. The emissions are expressed as GWP emissions, but are not shown to the sectoral detail in **Table 10.1**.

The percentage change, due to recalculation with respect to the previous submission, is calculated as

$$\text{Percentage change} = 100\% \times [(\text{LS}-\text{PS})/\text{PS}]$$

Where

LS = Latest Submission (2004 inventory; 2006 NIR)

PS = Previous Submission (2003 inventory, 2005 NIR)

The percentages expressed in this way are consistent with those calculated in the CRF in Table8(a)s1 and Table8(a)s1.

For changes in earlier years data the corresponding CRF tables for that year should be referred to.

**Table 10.1** Recalculations of direct GHG emissions for the year 2003 in the UK 2006 NIR (2004 inventory)

Source category and GHG	Change in emissions (GgCO <sub>2</sub> eq.) (Emissions in 2004 inventory minus emissions in 2003 inventory)	Change in emissions (%) (Percentage change relative to the 2003 inventory)	Brief description of reasons for recalculation
<b>1A1</b>			
CO <sub>2</sub>	-4,409	-2.1	<ul style="list-style-type: none"> <li>• Review of lubricant use - changes to both the total amount of lubricant assumed oxidised and the allocation of emissions to sectors, taking from road transport and adding to industrial and other transport sectors (1A1a).</li> <li>• Revision of UK energy statistics (1A1a, 1A1b, 1A1cii).</li> <li>• Review of cement industry fuel use. Driven by the development of the EU Emission Trading Scheme, improved cement industry-sourced estimates of fuel use have been used in the latest inventory cycle, which has been used to amend the DTI UK energy statistics which underestimate the use of coal in cement kilns. Re-allocations of coal use between 1A1a and 1A2f have been made for later years in the time-series, to reflect sales of coal between power generators and cement manufacturers, whilst for earlier years, coal is re-allocated between industrial sectors reporting to 1A2f. In previous versions of the GHG inventory, gas was assumed to be a significant fuel, but this gas use has now largely been re-allocated to other industrial sectors. The cement industry data also includes waste-derived fuels and petroleum coke. Although the revisions have no net impact on total coal or gas use, emission estimates have changed because of differences in carbon factors for different sectors and because of changes in the activity data and emissions for waste-derived fuels and petroleum coke.</li> <li>• Updated information from process operators regarding scrap tyre use in power generation in recent years has lead to a very small increase in the estimated emissions for IPCC Sector 1A1a.</li> <li>• Following consultation with the operator of all UK integrated steelwork's (Corus UK Ltd), several alterations were made to the carbon balance approach to fuel transformation processes associated with steelworks. Several re-allocations have been made between IPCC sectors but the overall impact on the UK inventory is quite small (1A1ci).</li> <li>• A comprehensive review of the emissions dataset from the offshore oil &amp; gas industry (1A1cii - see Section 10.6.3 <i>Major improvements to the current inventory</i>).</li> <li>• Inclusion of emissions from UK Overseas Territories (1A1a).</li> </ul>

Source category and GHG	Change in emissions (GgCO <sub>2</sub> eq.) (Emissions in 2004 inventory minus emissions in 2003 inventory)	Change in emissions (%) (Percentage change relative to the 2003 inventory)	Brief description of reasons for recalculation
CH <sub>4</sub>	-814	-84.3	<ul style="list-style-type: none"> <li>• Revision and reduction in the emission factors for emissions from landfill gas flares, together with reductions in the emission factors for combustion of natural gas and sludge gas (1A1a).</li> <li>• Reduction in reported emissions from offshore oil and gas own gas use stemming from revisions to the application of emission factors across the UK Offshore Oil Association dataset (1A1cii).</li> <li>• Inclusion of emissions from UK Overseas Territories (1A1a).</li> </ul>
N <sub>2</sub> O	-1,493	-53.2	<ul style="list-style-type: none"> <li>• The emission factors for N<sub>2</sub>O emissions from coal and natural gas combustion in this sector have been changed due to revisions in the time-series of the fuel calorific values. This has led to a significant reduction in N<sub>2</sub>O emission estimates from this source across the time-series (1A1a).</li> <li>• Emissions from offshore own gas use in the oil &amp; gas sector have been revised across the time-series due to changes to the default emission factors applied to operator activity data. This has reduced emission estimates from this sector across the time-series (1A1cii).</li> </ul>

Source category and GHG	Change in emissions (GgCO <sub>2</sub> eq.) (Emissions in 2004 inventory minus emissions in 2003 inventory)	Change in emissions (%) (Percentage change relative to the 2003 inventory)	Brief description of reasons for recalculation
<b>1A2</b>			
CO <sub>2</sub>	-1,533	-1.7	<ul style="list-style-type: none"> <li>• Review of lubricant use - changes to both the total amount of lubricant assumed oxidised and the allocation of emissions to sectors, taking from road transport and adding to industrial and other transport sectors (1A2f).</li> <li>• New estimates of gas oil usage by off-road vehicles and machinery and the rail sector have been introduced and the cement industry have provided data on their own use of gas oil. In order to maintain consistency with national statistics, gas oil activity data for stationary industrial, commercial and institutional combustion plant have been reduced. A small revision to DTI energy statistics occurs for 2003 (1A2f).</li> <li>• Revision of UK energy statistics (1A2a, 1A2f).</li> <li>• Review of cement industry fuel use. Driven by the development of the EU Emission Trading Scheme, improved cement industry-sourced estimates of fuel use have been used in the latest inventory cycle, which has been used to amend the DTI UK energy statistics which underestimate the use of coal in cement kilns. Re-allocations of coal use between 1A1a and 1A2f have been made for later years in the time-series, to reflect sales of coal between power generators and cement manufacturers, whilst for earlier years, coal is re-allocated between industrial sectors reporting to 1A2f. In previous versions of the GHG inventory, gas was assumed to be a significant fuel, but this gas use has now largely been re-allocated to other industrial sectors. The cement industry data also includes waste-derived fuels and petroleum coke. Although the revisions have no net impact on total coal or gas use, emission estimates have changed because of differences in carbon factors for different sectors and because of changes in the activity data and emissions for waste-derived fuels and petroleum coke.</li> <li>• Following consultation with the operator of all UK integrated steelwork's (Corus UK Ltd), several alterations were made to the carbon balance approach to fuel transformation processes associated with steelworks. Several re-allocations have been made between IPCC sectors but the overall impact on the UK inventory is quite small (1A2a, 1A2f).</li> <li>• Inclusion of emissions from UK Overseas Territories (1A2f).</li> </ul>
CH <sub>4</sub>	+48	+19.6	<ul style="list-style-type: none"> <li>• Inclusion of emissions from UK Overseas Territories (1A2f).</li> </ul>
N <sub>2</sub> O	+592	+78.5	<ul style="list-style-type: none"> <li>• Improvements to the derivation of activity data for gas oil use in the off-road transport sector has lead to increases in emission estimates across the time-series in this sector. Slight revisions to the emission factor have also been made (1A2fii).</li> </ul>

Source category and GHG	Change in emissions (GgCO <sub>2</sub> eq.) (Emissions in 2004 inventory minus emissions in 2003 inventory)	Change in emissions (%) (Percentage change relative to the 2003 inventory)	Brief description of reasons for recalculation
<b>1A3</b>			
CO <sub>2</sub>	+1316	+1.0	<ul style="list-style-type: none"> <li>Review of lubricant use - changes to both the total amount of lubricant assumed oxidised and the allocation of emissions to sectors, taking from road transport and adding to industrial and other transport sectors (1A3b, 1A3dii).</li> <li>New estimates of gas oil usage by off-road vehicles and machinery and the rail sector have been introduced and the cement industry have provided data on their own use of gas oil. In order to maintain consistency with national statistics, gas oil activity data for stationary industrial, commercial and institutional combustion plant have been reduced. A small revision to DTI energy statistics occurs for 2003 (1A3c, 1A3dii, 1A3e).</li> <li>Inclusion of emissions from UK Overseas Territories (1A3a, 1A3b).</li> </ul>
CH <sub>4</sub>	+5.1	+2.3	<ul style="list-style-type: none"> <li>Minor revisions to fuel consumption and emission factors (1A3aii, 1A3b, 1A3c, 1A3e).</li> </ul>
N <sub>2</sub> O	+224.3	+4.4	<ul style="list-style-type: none"> <li>Improvements to the derivation of activity data for gas oil use in the rail transport sector has lead to increases in emission estimates in later years of the time-series in this sector. Slight revisions to the emission factor have also been made (1A3c).</li> </ul>
<b>1A4</b>			
CO <sub>2</sub>	+4,533	+4.1	<ul style="list-style-type: none"> <li>Review of lubricant use - changes to both the total amount of lubricant assumed oxidised and the allocation of emissions to sectors, taking from road transport and adding to industrial and other transport sectors (1A4cii).</li> <li>New estimates of gas oil usage by off-road vehicles and machinery and the rail sector have been introduced and the cement industry have provided data on their own use of gas oil. In order to maintain consistency with national statistics, gas oil activity data for stationary industrial, commercial and institutional combustion plant have been reduced. A small revision to DTI energy statistics occurs for 2003 (1A4a, 1A4c).</li> <li>Revision of UK energy statistics (1A4a, 1A4b, 1A4ci).</li> <li>Following consultation with the operator of all UK integrated steelwork's (Corus UK Ltd), several alterations were made to the carbon balance approach to fuel transformation processes associated with steelworks. Several re-allocations have been made between IPCC sectors but the overall impact on the UK inventory is quite small (1A4b, 1A4ci).</li> <li>Peat combustion (re-allocation of emissions and update of method to estimate emissions). Emissions from this source were previously included in the inventory in Sector 5.</li> <li>Inclusion of emission from UK Overseas Territories (1A4b, 1A4c).</li> </ul>



Source category and GHG	Change in emissions (GgCO <sub>2</sub> eq.) (Emissions in 2004 inventory minus emissions in 2003 inventory)	Change in emissions (%) (Percentage change relative to the 2003 inventory)	Brief description of reasons for recalculation
CH <sub>4</sub>	+150	+31.5	<ul style="list-style-type: none"> <li>Revision and increase in methane emission factors from coal and gas use in the domestic sector have lead to the reported increased emission estimates across the time-series in IPCC sector 1A4b.</li> <li>Inclusion of emissions from UK Overseas Territories (1A4b, 1A4c).</li> </ul>
N <sub>2</sub> O	+496	+234	<ul style="list-style-type: none"> <li>Improvements to the derivation of activity data for gas oil use in the agricultural machinery sector has lead to increases in emission estimates across the time-series in this sector. Slight revisions to the emission factor have also been made (1A4cii).</li> </ul>
<b>1A5</b>			
CO <sub>2</sub>	+22	+0.8	<ul style="list-style-type: none"> <li>Minor revisions to fuel consumption data (gas oil used by naval shipping and aviation turbine fuel used by military aircraft).</li> </ul>
<b>1B1</b>			
CO <sub>2</sub>	-2	-2.2%	<ul style="list-style-type: none"> <li>Minor revisions to the quantities of coke oven gas used in the iron and steel sector (flaring) and associated EFs. Part of the carbon balance in the iron and steel sector.</li> </ul>
CH <sub>4</sub>	+667	+13.9	<ul style="list-style-type: none"> <li>An error in data processing was identified for this sector (a mis-report of methane emission estimates from deep-mined coal production sites), and a previous under-report has been rectified. This revision applies to 2003 only (1B1ai).</li> </ul>
<b>1B2</b>			
CO <sub>2</sub>	+25	+0.5	<ul style="list-style-type: none"> <li>A comprehensive review of the emissions dataset from the offshore oil &amp; gas industry (1B2ai, 1B2aii, 1B2ciii Flaring - see Section 10.6.3 <i>Major improvements to the current inventory</i>).</li> </ul>
CH <sub>4</sub>	-395	-6.4	<ul style="list-style-type: none"> <li>The UK Offshore Oil Association dataset for 1900-1994 has been changed due to a change in method, using the 1997 data as a template by which to split the total reported emissions, and hence some changes in individual sectors are reported here for methane emissions also. (1B2aii, 1B2ciii_Venting). The change in the 1990 data for 1B2aii stems from a revision to the emission estimates for offshore oil &amp; gas process sources.</li> <li>Methane emissions from natural gas losses from the UK gas distribution system were revised for the whole time-series, following consultation with UK Transco and other gas market operating companies. Losses from high pressure mains supplies were revised downwards from previous estimates, whilst losses from other sources such as "Above Ground Installations" were revised upwards. The overall change across the time-series is a reduction in estimates of the total methane emissions from these gas transmission losses (1B2bii).</li> </ul>
N <sub>2</sub> O	0.2	+0.6	<ul style="list-style-type: none"> <li>Revisions to The UK Offshore Oil Association dataset.</li> </ul>

Source category and GHG	Change in emissions (GgCO <sub>2</sub> eq.) (Emissions in 2004 inventory minus emissions in 2003 inventory)	Change in emissions (%) (Percentage change relative to the 2003 inventory)	Brief description of reasons for recalculation
<b>2A</b>			
CO <sub>2</sub>	-14	-0.2	<ul style="list-style-type: none"> <li>A revision to the data for dolomite use by the glass industry in recent years has lead to a very small change in the estimated emissions for IPCC Sector 2A3.</li> <li>Corus provided new country-specific carbon emission factors for limestone &amp; dolomite use at steelworks, leading to a reduction in emissions in IPCC sector 2A3.</li> </ul>
<b>2B</b>			
CH <sub>4</sub>	-8.9	-20.6	<ul style="list-style-type: none"> <li>Minor revisions to emissions associated with the chemical industry (2B5).</li> </ul>
N <sub>2</sub> O	-11	+0.4	<ul style="list-style-type: none"> <li>Minor revisions to emissions from nitric acid production (2B2).</li> </ul>
<b>2C</b>			
CO <sub>2</sub>	+4	+0.2	<ul style="list-style-type: none"> <li>Minor revisions to emissions associated with the iron and steel sector (2C1). Part of the iron and steel carbon balance.</li> </ul>
SF <sub>6</sub>	-236	-26.0	<ul style="list-style-type: none"> <li>Time series revision. Improved data for amount used in casting from trade associations (2C4).</li> </ul>
<b>2E</b>			
HFC	-339	-15.5	<ul style="list-style-type: none"> <li>From 2002 onwards, previous GHG inventory estimates (in 2E1) have been replaced with UK Pollution Inventory data (covering England and Wales). No emissions occur in Northern Ireland and Scotland.</li> </ul>
PFC	-3	-4.1	<ul style="list-style-type: none"> <li>Method improvements and removals of small contribution of emissions to water that were previously included (2E2). Previous inventory estimates have been replaced with UK Pollution Inventory data (covering England and Wales) for 2002 onwards.</li> </ul>
<b>2F</b>			
HFC	-159	-1.9	<ul style="list-style-type: none"> <li>Method change - revision in EF. Improved assumptions about operating leakage rates following industry consultation (2F3). From 2001 onwards.</li> <li>New data provided by industry (2F4). From 2001 onwards.</li> <li>Inclusion of emissions from UK Overseas Territories.</li> </ul>
<b>4A</b>			
CH <sub>4</sub>	+93	+0.6	<ul style="list-style-type: none"> <li>Methane emissions from the overseas territories have been inserted to the UK inventory for the first time in the 2006 submission (4A10 enteric fermentation).</li> </ul>

Source category and GHG	Change in emissions (GgCO <sub>2</sub> eq.) (Emissions in 2004 inventory minus emissions in 2003 inventory)	Change in emissions (%) (Percentage change relative to the 2003 inventory)	Brief description of reasons for recalculation
<b>4B</b>			
CH <sub>4</sub>	-25	-1.0	<ul style="list-style-type: none"> <li>Series of small revisions to emission factors and activity data associated with enteric fermentation.</li> </ul>
N <sub>2</sub> O	+47	+3.5	<ul style="list-style-type: none"> <li>Small revisions to emission factors (4B11, 4B12).</li> <li>Inclusion of emissions from UK Overseas Territories (4B13 – manure management).</li> </ul>
<b>4D</b>			
N <sub>2</sub> O	-181	-0.7	<ul style="list-style-type: none"> <li>Based on the findings of the Agricultural Review, a small revision to the emission factor for N<sub>2</sub>O emissions from agricultural soils have lead to reductions in N<sub>2</sub>O emission estimates from this source in later years of the time-series.</li> </ul>
<b>5</b>			
CO <sub>2</sub>	+356	-23.2	<ul style="list-style-type: none"> <li>Peat combustion (re-allocation of emissions and update of method to estimate emissions). Emissions from this source were previously included in the inventory in Sector 5.</li> </ul>
<b>6A</b>			
CO <sub>2</sub>	-554	emissions removed from the inventory	<ul style="list-style-type: none"> <li>Further information has been obtained regarding the use of coal tars and benzoles. These by-products of coke ovens are sold by Corus, and are subsequently used in various products such as anodes for the aluminium industry. Emissions from these applications are already included elsewhere in the inventory. The previous approach of assuming that the carbon in these coal tars and benzoles is emitted from the decay of treated products in landfills is therefore incorrect and these emissions have been removed from the inventory (6A1).</li> </ul>
CH <sub>4</sub>	+13,299	+165	<ul style="list-style-type: none"> <li>The most significant revision to the UK methane emissions inventory is the increase in estimates for methane emissions from landfills; this is a large increase compared to the previous inventory submission. The increase is due, primarily, to the revision of the oxidation factor in addition to the change in waste composition data used within the UK model.</li> <li>The incineration of municipal waste without energy recovery ceased in the UK during the 1990s, but for the early 1990s the estimates of methane emissions from this source were previously based on an emission factor of unknown origin, and this has been replaced with an IPCC default factor. This has lead to a small increase in methane emission estimates from this source.</li> <li>Inclusion of emissions from UK Overseas Territories (6A1).</li> </ul>

Source category and GHG	Change in emissions (GgCO <sub>2</sub> eq.) (Emissions in 2004 inventory minus emissions in 2003 inventory)	Change in emissions (%) (Percentage change relative to the 2003 inventory)	Brief description of reasons for recalculation
<b>6B</b>			
CH <sub>4</sub>	+13	+1.6	<ul style="list-style-type: none"> <li>Inclusion of emissions from UK Overseas Territories (6B2).</li> </ul>
N <sub>2</sub> O	+12	+1.0	<ul style="list-style-type: none"> <li>Small revision to activity data associated with waste water handling (6B2).</li> </ul>
<b>7</b>			
CO <sub>2</sub>	+2,088	new sources introduced into the inventory	<ul style="list-style-type: none"> <li>This category contains new estimates of carbon emissions from 1) carbon emitted during energy recovery in the chemical industry; 2) the release of carbon from the breakdown of selected products formed from the non-energy use of fossil fuels. Carbon emissions are included from: petroleum waxes (emissions from the use or breakdown of packaging materials, candles, construction materials, firelogs, hot melt adhesives); carbon emitted during energy recovery in the chemical industry (the use of chemical wastes as fuels, for example in steam-raising boilers); carbon released from the breakdown of products (soaps, shampoos, detergents etc.; and pesticides).</li> </ul>

## 10.2 IMPLICATIONS FOR EMISSION LEVELS

The implications for emission levels in the year 2003 are summarised by sector in **Table 10.1**, and the overall effect for individual years is shown in **Figure 10.2**.

## 10.3 IMPLICATIONS FOR EMISSION TRENDS, INCLUDING TIME SERIES CONSISTENCY

The effects of the recalculations and improvements made in the 2004 inventory are summarised in this section in a series of charts. The charts show the changes in the time series of emissions, or percentage changes in emissions, since the 2003 inventory.

**Figure 10.1** summarises the effect of the recalculations in the 2006 NIR (2003 inventory) in terms of the time series of GWP emissions. The chart shows the time series of differences in the annual GWP emissions of the basket of the 6 Kyoto GHGs between the inventories of 2003 and 2004, according to IPCC source sector. A negative difference indicates a decline in GWP emission between the inventory presented in the 2006 NIR (2004 inventory), and the inventory presented in the 2005 NIR (2003 inventory). The LULUCF totals are separated out into emissions and removals.

**Figure 10.2** summarises the effect of the recalculations in the 2005 NIR in terms of

- changes in the time series of total net UK GWP emissions (sum of emissions and removals), and,
- percentage changes in the time series of GWP emissions.

The chart shows the time series of changes in the basket of the 6 Kyoto GHGs between the inventories of 2003 and 2004.

The percentage change, due to recalculation with respect to the previous submission, has been calculated as

$$\text{Percentage change} = 100\% \times [(\text{LS}-\text{PS})/\text{PS}]$$

Where

LS = Latest Submission (2004 inventory; 2005 NIR)

PS = Previous Submission (2003 inventory, 2005 NIR)

The percentages expressed in this way are consistent with those calculated in the CRF in Table8(a)s1 and Table8(a)s1.

The current inventory incorporates a number of important revisions to both the methods used to estimate GHG emissions, and the emission factors used in these methods. The changes in the time series of GWP emissions in **Figure 10.2** reflect these enhancements. A summary of

the key reasons for the changes are given below. More detailed information is given in the sections describing the source-specific recalculations given in **Chapters 3 to 8**.

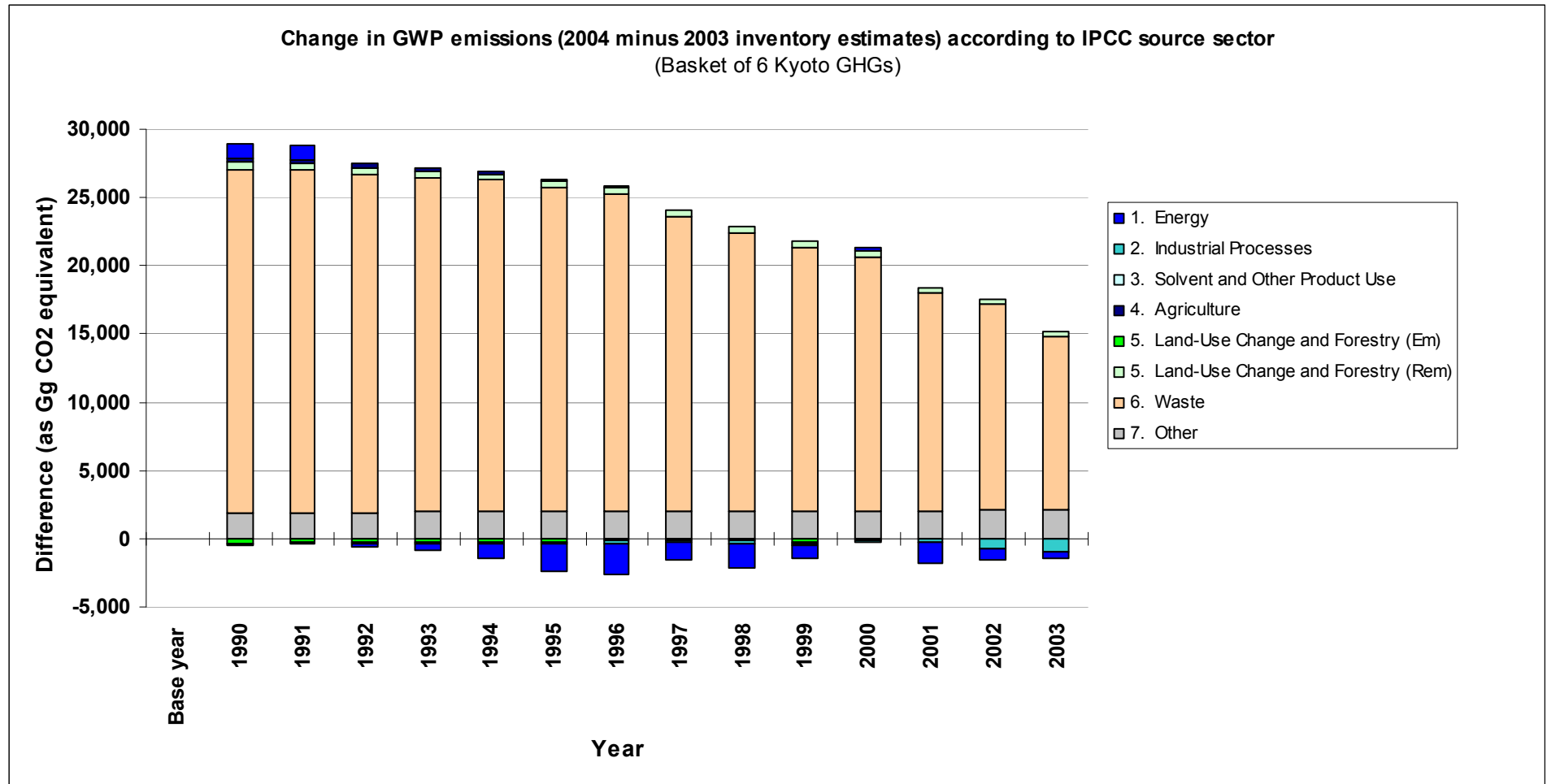
### *Reasons for changes in GWP emissions in 1990*

- The changes in GWP emissions are dominated by the changes in emissions of methane from landfill.
- The method to used estimate emissions from the consumption of waste lubricants has been revised.
- Four new sources of carbon have been included in the UK inventory.
- A new analysis concludes that we can treat all of the carbon emissions from the use of benzoles and tars as stored and so the carbon emission included in last years inventory has been removed from the new version of the GHG inventory.
- Estimates of emissions from Crown Dependencies (from sources other than fuel combustion – emissions from fuel combustion sources have always bee included) and Overseas Territories are now included in the inventory.
- Revised methods have been used to estimate emissions from LULUCF and this has affected both estimates of emissions and removals.

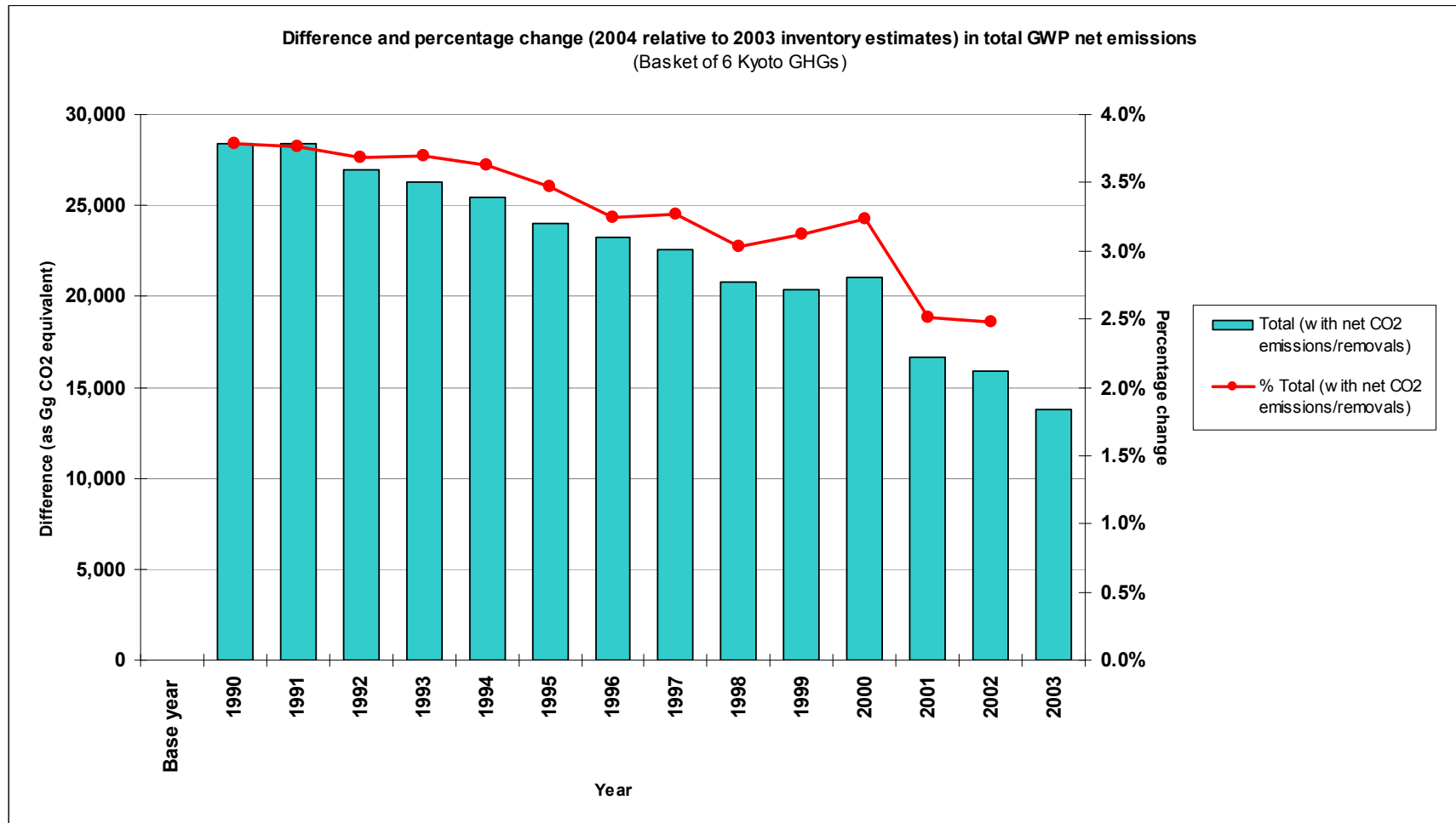
### *Reasons for changes in GWP emissions in 2003*

- The main reasons for the changes in 2003 are as given above for 1990, with the addition of the points below.
- The changes in GWP emissions are dominated by the changes in emissions of methane from landfill.
- There were a number of significant changes to the underlying activity data (energy statistics).

**Figure 10.1** Time series of changes in GWP emissions between the inventory presented in the current and the previous NIR, according to IPCC source sector



**Figure 10.2** Time series of changes in total net GWP emissions, and percentage changes in total net GWP emissions, between the inventory presented in the current and the previous NIR





## **10.4 RECALCULATIONS**

This section gives details of recalculations, including the response to the UNFCCC review process, and planned improvements to the inventory.

Recalculations are summarised in **Section 10.1 to Section 10.3**. Details of recalculations are given in Sections 3 to Sections 9, and are also shown in CRF Table8(a)s2 and Table8(b) for each year.

### **10.4.1 Response to the review process**

The UNFCCC Secretariat conducted a Centralized Review of the 2005 UK's greenhouse gas inventory submission, in accordance with decision 19/CP.8 of the Conference of the Parties. The review took place from 3 to 8 October 2005 in Bonn, Germany (FCCC ERT, 2005). This was the fourth Centralised Review of the UK greenhouse gas inventory. This review follows on from the third Centralised Review of the 2003 NIR (Bonn, 18 to 22 October 2004).

Most of the changes suggested in the Fourth Centralised Review have already been incorporated within this NIR. A few of the tasks suggested by the Expert Review Team (ERT) in the third Centralised Review are being carried over to 2007.

**Table 10.2** provides an overview of the actions taken to improve the NIR and the inventory in response to the comments made by the ERTs. Some comments have been carried over from the third Centralised Review of 2003, because of the time needed for the major improvements which have been incorporated in the current inventory. The table concentrates on the improvements that have been made to methods used to estimate emissions from the Key Categories and the steps taken to improve transparency of reporting from those Key Categories. Comments about improvements made to some non-Key Categories, general reporting and provision of background information are included also.

**Table 10.2** Brief details of improvements to the NIR and the inventory in response to FCCC reviews

ERT comment	Actions
<b><i>Second Centralised Review</i></b>	
Further explanation requested about feedstocks and non-energy use of fuels	A complete review has been conducted about the use of feedstocks and the non-energy use of fuels. Updated estimates of emissions are included in this NIR.
<b><i>Third Centralised Review</i></b>	
Improve documentation of method & results of key source analysis	<p>This year we have adjusted the aggregation of the Tier 1 uncertainty analysis so it is performed at the level of the IPCC source categories (as recommended in the GPG 2000), revised some uncertainty parameters and provided extra detail about the approach used in the uncertainty analysis.</p> <p>Additional work was completed last year: Two additional tables of information have been included to support the Tier 1 uncertainty analysis: the key source analysis based on level of emissions, and the key source analysis based on trend in emissions. The Tier 2 analysis has now been refined to present estimated uncertainties at the sectoral level as well as by gas.</p>
Include in NIR description of how AD and emissions data reported by companies are verified (e.g. description of QA of Pollution Inventory data)	A programme of meetings involving the Key Data Providers, UK Defra and the Inventory Agency continues. The aim of these meetings is understand QA/QC activities in place and suggest improvements where necessary.
Comment on lime production - data based on assumption that all lime is quicklime and that calcination of dolomite is minimal - review, confirm, improve text in NIR - provide documented evidence of assumptions.	Our best information at present is that the use of dolomite is small or negligible. This is still under review as it is proving difficult to obtain the necessary data.
<b><i>Fourth Centralised Review</i></b>	
The key category analysis with and without LULUCF should be conducted and presented separately to be consistent with the IPCC good practice guidance for LULUCF, and the aggregation level chosen should be reconsidered	The Key Category analysis has been performed with and without LULUCF (LULUCF in the new categories). We have modified the aggregation level so it is performed at the level of the IPCC source categories (as recommended in the GPG 2000).

ERT comment	Actions
The uncertainty estimation should be updated, and more analysis and discussion of uncertainties in the sectoral chapters of the NIR should be provided.	The uncertainty estimation has been updated by revising selected uncertainty parameters and provided extra detail about the approach used in the uncertainty analysis.
Consistency between the NIR and the CRF and within the NIR should be improved	This action has been noted. Difficulties with early versions of the CRF Reporter software have hindered this task in the 2006 submission.
Further explanations of the revised EFs used from enteric fermentation in the NIR.	Work is currently underway with the agricultural sector experts to improve the transparency of reporting for this sector.
Reporting of emissions from benzoles and tars.	Emissions from these sources were review as part of the stored carbon review – and are now treated as stored carbon.
Provide quantitative results and qualitative discussions of the sources of uncertainty in individual source categories in the sectoral chapters of the NIR	The collation of this information has taken longer than expected, but the UK National Inventory Compiler has reminded the sectoral experts of this requirement. Additional information has been provided in this NIR.
Revision of uncertainty estimation	There has been a review of the uncertainties associated with many source categories where major recalculations and improvements have occurred, including: carbon emission factors for solid, liquid and gaseous fuels; aviation; LULUCF; F-gases.
Review and revision of feedstocks and non-energy use of fuels	The UK has reviewed and revised the methods used to estimate emissions from feedstocks and the non-energy use of fuels. Details are provided in this NIR. This review extended to considering estimates of emissions from coke oven-derived benzoles and tars, lubricant oils, petcoke, petroleum waxes, bitumen, petroleum products use in the chemical industry, and carbon released from the breakdown of products derived from petroleum products.
Adipic acid production – there large inter-annual variations in the IEF not fully explained by changes in production levels, total N <sub>2</sub> O emissions, and the introduction of abatement technology in 1998	Clarification has been added to the NIR. Variability in the down time of the abatement plant in a given year is responsible for the variable IEF.
Improve the transparency of the reporting of methane EFs for lambs and ewes	Additional information from UK studies has been added to the NIR to justify the use of the current EFs.
Review assumption that 20 per cent of the total nitrogen emitted by livestock volatilizes as nitrogen oxide and ammonia and therefore does not contribute to N <sub>2</sub> O emissions from AWMS	The UK is looking into improving the link between the NH <sub>3</sub> and GHG inventories, and incorporating NO <sub>x</sub> in a study (desk/experimental) will review the current assumption of 20% of N lost as NH <sub>3</sub> and NO <sub>x</sub> .

ERT comment	Actions
Clarify choice of IEFs used to estimate direct and indirect soil emissions of N <sub>2</sub> O	This has been clarified in the NIR.
Improve the level of detail provided in the NIR to explain the methods used to estimate emissions from LULUCF	Additional detail has been added to the 2006 NIR and emissions are reported using the source categories recommended in the IPCC Good Practice Guidance for LULUCF.
Improve the level of detail provided in the NIR to explain the method used to estimate CH <sub>4</sub> emissions from solid waste disposal. Reconsider the use of certain EFs and other parameters in the used to estimate CH <sub>4</sub> emissions from solid waste disposal.	A review of the CH <sub>4</sub> oxidation factor has taken place and a modified factor will be used for the 2004 inventory submission. Additional detail has been added to the 2006 NIR to explain the large gap between the values of CH <sub>4</sub> generated and those reported as CH <sub>4</sub> emissions from solid waste disposal and to provide more information to justify the disaggregated DOC parameters and gas collection efficiencies used.
The value reported for protein consumption per capita for the entire time series in the 2005 submission was extremely low	This parameter was incorrectly reported, and a table of the correct protein consumptions per capita has been added to the NIR.
Improve level of detail in the NIR to explain the method used to estimate CH <sub>4</sub> emissions from waste-water handling	Further details have been provided.

## 10.4.2 Major improvements to the current inventory

The estimates of emissions in the current inventory will be used to determine the UK's Assigned Amount. To ensure that the UK GHG inventory was as complete and accurate as possible, a substantial effort has been invested in reviewing the base year emissions and implementing any outstanding method improvements identified either by the NIC or FCCC expert review teams.

During the compilation of this inventory, the NIC has concentrated on:

- ▶ Conducting a Peer Review of agriculture and reviewing the recommendations of previous Peer Reviews;
- ▶ completing expert reviews and stakeholder consultations, and,
- ▶ a review of the treatment of stored carbon and the non-energy uses of fuel in the inventory.

As a result of this programme of inventory reviews, many changes to source data and estimation methods have been made. The most significant recalculations conducted since the publication of the 1990-2003 UK GHG inventory dataset include:

- ▶ **Integration of EU ETS data & other industrial fuel use data.** For some key industry sectors, data provided directly by UK industry or from the UK database used within the EU-ETS system has been used to improve the time-series of industrial fuel use. Such modifications have been limited to a few industry sectors where specific problems have been identified with the DTI energy balance dataset during 2005, and in all cases the modifications have been conducted such that the total UK energy use reported via the GHG inventory is consistent with DTI UK energy statistics. For example, the UK cement industry use of coal, oil, gas, petcoke and substitute fuels such as tyres has been revised to coincide with estimates provided directly by the industry over 1998-2004. In addition, greater integration of datasets directly from Corus, the UK's main iron & steel producer, has led to improvements of estimated fuel use at the four integrated steelworks in the UK. The NIC and the DTI continues and aims to ensure that future UK Energy Statistic publications are more consistent with the EU-ETS reports and other industry-derived energy use datasets.
- ▶ **A revision to the time-series of methane emission estimates from waste disposal at landfills has been introduced.** This followed an FCCC expert review that recommended changes to the assumptions regarding the composition of waste arisings and methane oxidation factors.
- ▶ **A review of CO<sub>2</sub> emission estimates from solvent-derived NMVOC.** These sources have not previously been included in the inventory although estimates are calculated and reported annually. The estimation method has been improved during 2005, but the final emissions of CO<sub>2</sub> from this source have not been included within the final UK GHG inventory dataset. The forthcoming 2006 IPCC guidelines will recommend that CO<sub>2</sub> from this source is not included in national totals.
- ▶ **A review of the combustion of lubricating oils by vehicles and industrial machinery.** Analysis by UK experts in transport emissions and oil combustion have led to a revision to the assumptions regarding re-use or combustion of lubricating oils from vehicle and industrial machinery. A review of the estimation method and sector allocations within the 1990-2003 inventory has led to reductions in the estimated emissions and a re-allocation to other IPCC sectors from combustion within the 1A3d (Road Transport) sector.
- ▶ **A review to investigate the emissions of nitrous oxide from adipic acid and nitric acid production plant in the UK.** Through direct consultation with plant operators, an improved understanding of the plant design, abatement, emissions monitoring and reporting systems was developed. Minor revisions to activity data over recent years have been made, although total emissions reported via the Environment Agency Pollution Inventory and the UK GHG Inventory are unchanged. Some changes to Implied Emission Factors are evident, and a greater understanding of the variability of these factors has been gained.
- ▶ **A review of the fate of benzoles and coal tars.** Benzoles and coal tars are shown as an energy use in UK DTI energy statistics and up until the 2002 version of the GHGI,

the carbon was included in the coke ovens carbon balance as an emission of carbon from the coke ovens. In reality, the benzoles and coal tars are recovered and sold. Therefore, when the carbon balance methodology was improved for the 2003 GHG (2005 NIR) inventory, it was treated as a non-emissive output from the coke ovens. However, we were not sure what the ultimate fate of the carbon was but were unable to research this in time for the 2003 GHG inventory (2005 NIR). It was therefore treated as an emission from the waste disposal sector - thus ensuring that total UK carbon emissions were not altered until we had sufficient new information to judge what the fate of the carbon was. The new analysis concludes that we can treat all of the carbon as stored and so the carbon emission included in last years inventory has been removed from the new version of the GHG inventory.

- ▶ **A comprehensive review of the emissions dataset from the offshore oil & gas industry.** A review of these data across the full time-series was conducted during autumn 2005 by the UK trade association, UKOOA, in response to the development of the EU-ETS. Several significant changes to emission factors, and in some cases gap-filling of activity data lead to a significant revision of the full time-series of data back to 1990 within the UK GHG inventory. The 2005 revisions to UKOOA datasets from offshore oil & gas sources include:
  - Changes to carbon emission factors for some combustion sources, to ensure that emissions reported via the UK GHG inventory are consistent with those reported via the EU Emissions Trading Scheme.
  - The sector-specific splits for the 1990-1994 datasets have been re-allocated by benchmarking against the 1997 UKOOA dataset. Previously the 1990-1994 emission totals were split out based on 1995 data, but irreconcilable gaps in the 1995 and 1996 datasets have been identified that indicate that use of the 1997 dataset will provide a more accurate estimate for 1990-1994. The missing sources in 1995 and 1996 will lead to a slight under-report of GHG emissions in those years.
  - Changes to some historic emission estimates of methane and nitrous oxide where the application of emission factors has been identified as inconsistent across the time-series.
- ▶ **Emissions of peat have been re-allocated.** Emissions of domestic peat combustion were always included in the UK GHG inventory but were not allocated to the correct sector (LULUCF sector, category 5E in the 2005 NIR). A Tier 2 methodology drawing on default emission factors was developed and the emissions accounted within IPCC sector 1A4b.
- ▶ **Within the LULUCF emissions inventory, minor corrections and improvements have been made to the LULUCF model** used by CEH, leading to revisions across the reporting time series. Revisions to land use activity data, soil density assumptions and emission / sink factors for some land uses have been made, and the sectoral disaggregation of some emissions / sinks have been altered. Further details of the recalculations are given in the LULUCF chapter.

- ▶ **A review of the non-energy uses of carbon and stored carbon.** This review is summarised in the section immediately below, and provides more detail about some of the points in the listed above also.
- ▶ **A review of the estimation of emissions from rail (gas oil).** Gas oil consumption by trains is now estimated from data provided by the Association of Train Operating Companies, and from other research (Netcen, 2004). In the past, emissions were calculated based on the allocation of gas oil to the railways sector in DUKES (Dti, 2004). The new methodology improves the accuracy of the emissions estimates from this sector.

## 10.4.3 Review of Non-Energy Uses of Fuel and Stored Carbon

Previously, the UK GHG inventory has not used the IPCC default methodology for stored carbon because it was not clear what processes it encompassed or whether it was applicable to the UK. The procedure adopted was to report emissions from the combustion of fuels whilst emissions from the non-energy use (NEU) of fuels were assumed to be zero (i.e. the carbon is sequestered as products) unless a specific process emission was identified.

As part of our review of the base year GHG inventory estimates, the UK has reviewed the treatment of stored carbon in the UK GHG inventory and the fate of carbon from the NEU of products and the breakdown of those products. This appraisal included a review of selected National Inventory Reports (NIRs) of other countries. The US NIR contained a detailed methodology of the approach used in the US inventory to estimate emissions of stored carbon, and the US NIR presents 'storage factors' for a range of products. Some of these factors have been used in the new UK method.

The UK has conducted a series of calculations to estimate the fate of carbon contained in those petroleum products shown in the 'non-energy use' line of the UK commodity balance tables. The analysis indicates that most of the carbon is 'stored', although a significant quantity does appear to be emitted. Some of the emitted carbon has been included in previous versions of the GHG inventory, e.g. carbon from chemical waste incinerators; most has not. A summary of the estimates of emitted/stored carbon has been produced and this will be presented in a separate technical report. The study also provides subjective, qualitative commentary regarding the quality of the estimates.

The analysis also includes an assessment of the fate of carbon from the use of coal tars and benzoles. Benzoles and coal tars are shown as an energy use in the DTI Digest of UK Energy Statistics (DUKES) and up until the 2002 version of the GHG inventory (2004 NIR), the carbon was included in the coke ovens carbon balance as an emission of carbon from the coke ovens. When the carbon balance methodology was improved for the 2003 GHG inventory (2006 NIR), the UK inventory treated it as a non-emissive output from the coke ovens. However, we were not sure what the ultimate fate of the carbon was but were unable to research this in time for the 2003 GHG inventory. It was therefore treated as an emission from the waste disposal sector - thus ensuring that total UK carbon emissions were not altered until we had sufficient new information to judge what the fate of the carbon was.

New information from Corus UK Ltd (the sole UK operator of coke ovens) indicates that the benzoles & coal tars are recovered and sold on for other industrial uses, the emissions from which are already covered elsewhere within the inventory. Hence the carbon content from these coke oven by-products is now considered as stored and the carbon emissions included in previous inventories has been removed from the new version of the GHG inventory.

The analysis estimates emissions from:

- ▶ the 'energy' uses of coal tars and benzoles;
- ▶ the 'non-energy' uses of petroleum products.

Since emissions of carbon are estimated, carbon which is not emitted (i.e. 'stored') can be calculated from DUKES consumption data by difference. The analysis divides the various fossil fuels into six categories:

1. coal tars & benzoles
2. lubricants
3. petroleum coke
4. petroleum waxes
5. bitumen
6. chemical feedstocks (ethane, propane, butane, other gases, naphtha, industrial spirit, white spirit, middle distillate feedstock)

After considering the magnitude of the source in relation to the national totals, the uncertainty associated with emissions, and the likely forthcoming IPCC reporting requirements in the 2006 Guidelines, emissions of carbon from the following new sources have been included in the 2006 NIR:

- ▶ Petroleum waxes
- ▶ Carbon emitted during energy recovery - chemical industry
- ▶ Carbon in products - soaps, shampoos, detergents etc.
- ▶ Carbon in products - pesticides

A full time series of emissions has been included. For transparency, these emissions are reported in Sector 7 in the CRF rather than aggregating emissions with other sectors.

### 10.4.4 UNFCCC GHG inventory adjustment exercise

During the 2005 Centralised Review, the UK participated in a voluntary inventory adjustment exercise conducted by the UNFCCC. The Expert Review Team (ERT) indicated that a potential adjustment would be required to the methane emissions in IPCC sector 6.A.1 (managed solid waste disposal sites) if no action was taken to revise the emission estimates. No other sectors were identified as requiring potential adjustments.

The ERT commented that:

- ▶ the methane oxidation factor used was very high;



- ▶ methane recovery assumptions were very high and only calculated from capacities;
- ▶ the DOC was very low and the reporting of the DOC data was not transparent.

The ERT indicated that methane emissions from sector 6.A.1 were potentially overestimated, including emissions in 1990.

The ERT recommended that:

- ▶ the methane oxidation factor should be replaced with the IPCC default oxidation factor of 10%;
- ▶ the UK should justify gas collection efficiency with empirical data or replace the gas collection efficiency with a lower value (between 50-70%);
- ▶ the UK should use IPCC default DOC values as national values were not transparent.

The UK was already conducting a review of the method used to estimate methane emissions from managed solid waste disposal sites when this adjustment exercise was occurring, and a series of technical meetings were held within the UK during 2005 with waste sectoral experts and UK Defra. These meetings were held as part of the review of the UK base year emissions, and also considered comments from FCCC expert reviews of the waste sector of the UK GHG inventory. The sectoral experts reviewed the methane oxidation factors and gas collection efficiencies currently used in the model which produces estimates of methane from waste decomposition in landfills. The transparency of the technical report presenting the detailed methodology used to estimate the methane emissions from waste was discussed, and the reporting has been improved in this NIR. Tables of revised MSW waste stream parameters (including percentages of DOC) and DOC,  $DOC_f$  and methane oxidation factors were provided to the adjustment exercise review team together with a revised time series of methane emissions from managed solid waste disposal sites.

After considering the parameters to be used in the revised waste model, the ERT did not apply the adjustment as part of the exercise, because the UK revised the parameters questioned, in particular the oxidation factor, gas collection efficiency, and provided transparent DOC values. The review team noted that the oxidation factor for some landfill types is still high (50% compared to IPCC default 10%), but zero oxidation is assumed for other landfills.

# 11. References

References for the main chapters and the annexes are listed here and are organised by chapter and annex.

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**11.14 ANNEX 3, SECTOR 5**

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**Table 12.1** Contributors to this National Inventory Report and the CRF

Person	Technical work area and responsibility
<i>Main authors</i>	
Baggott, Sarah	Contributions to most chapters, lead author of energy sector text; management of both CRF and NIR compilation and submission. Technical support to Defra GAD in the development of the GHGI, including inclusion of the OT/CD dataset, managing integration of the CRF Reporter software and provision of ETS carbon emission factor datasets.
Brown, Lorna	Sector expert for agriculture; co-author of all sections on agriculture.
Cardenas, Laura	Sector expert for agriculture; co-author of all sections on agriculture. Compilation of Sector 4 of the CRF.
Downes, Melissa	Implementation of the CRF Reporter in the UK GHG inventory; contributing author to Chapter 9 (Overseas Territories and Crown Dependencies); contributing author to Chapter 2; development of GHG data processing and reporting systems; assistance Tier 2 uncertainty analysis; assistance with estimating emissions from road transport.
Garnett, Liz	Sector expert for Source Category 6a – Solid Waste Disposal On Land; responsible for the CRF for this source category.
Hobson, Melanie	Sector expert for mobile sources (transport – road transport and railways).
Jackson, Joanna	Main author of Chapter 9 (Overseas Territories and Crown Dependencies); Main author of Annex 6. QC of data tables throughout the report.
Milne, Ronnie	Team leader CEH LULUCF team; co-author of all sections on Land Use Change and Forestry
Mobbs, Deena	Co-author of all sections on Land Use Change and Forestry; compilation of Sector 5 of the CRF.
Passant, Neil	Author of selected sections on energy, industry and uncertainties; contributions to most chapters. Developments to the methods used to estimate GHG emissions from the non-energy use of fuels and stored carbon.
Thistlethwaite, Glen	Data acquisition manager for the UK inventory. Author of sections of Chapters 1, 2, 3, 4 and 10; compilation of industrial and offshore emissions data, author of responses to the UNFCCC Centralised Review of the 2003 NIR; QC of recalculation data; technical support to Defra GAD in the development of the UK National Inventory System.

Person	Technical work area and responsibility
Thomson, Amanda	Co-author of all sections on Land Use Change and Forestry. Compilation of Sector 5 of the CRF.
Watterson, John	Project Manager for the UK Greenhouse Gas Inventory with overall responsibility for the NIR and the CRF <sup>11</sup> . Contributing author to most chapters, primarily Chapter 1 and Chapter 10; co-ordination of the NIR compilation; internal QC for consistency between the CRF, IPCC reporting formats and the UK National Atmospheric Emissions Inventory database; manager of the review of base year emissions; Tier 1 uncertainty analysis.
<b>Contributors</b>	
Adams, Martin	Author of sections on F-gases; responsible for the CRF for this source category.
Dore, Chris	NAEI Project Manager. Assistance with compiling the UK National Atmospheric Emissions Inventory database; QA checks on time series consistency and sector consistency; assistance with the compiling the CRF; project manager for compiling the GHG emission estimates from the Overseas Territories and Crown Dependencies.
Goodwin, Justin	Internal QA checks for consistency between the CRF, IPCC reporting formats and the UK National Atmospheric Emissions Inventory database. NAEI database development and support.
Li, Yvonne	Contribution to Tier 1 uncertainty analysis. Assistance with road transport data compilation.
Manning, Alistair	Verification of the UK greenhouse gas inventory.
Murrells, Tim	NAEI transport manager. Contributing author to all sections on road transport. Compilation of the GHG emissions from mobile sources (road transport) and off-road mobile machinery.
Wagner, Anna	Assistance with compiling the CRF and tables of EFs for the NIR. Assistance with QC of the time series consistency.
Walker, Charles	Sector expert for aviation in the NAEI.
<b>Additional assistance</b>	
Aston, Clare	Assistance with compiling the Tier 1 uncertainty analysis documentation.
English, Linda	Editorial support
Grice, Susannah	Assistance with compiling the 2004 GHG inventory (gas oil and fuel oil use)
Hetherington, Pat	Editorial support
Kent, Val	Editorial and reprographic support
Penman, Jim <sup>12</sup>	Suggestions and improvements to draft versions of the NIR
Donaldson, Susan <sup>13</sup>	Suggestions and improvements to draft versions of the NIR
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<sup>12</sup> Global Atmosphere Division, Department for Environment, Food & Rural Affairs

<sup>13</sup> Global Atmosphere Division, Department for Environment, Food & Rural Affairs

**Table 12.2** Key Data Providers to the Greenhouse Gas Inventory

<b>Company</b>
UKPIA
UKOOA
Environment Agency
DTI
PowerTech
British Cement Association
Transco
Corus
DFT
UK Coal
Kemira
NIDoE
SEPA

# A1. ANNEX 1: Key Sources

## A1.1 KEY SOURCE ANALYSIS

In the UK inventory, certain source categories are particularly significant in terms of their contribution to the overall uncertainty of the inventory. These key source categories have been identified so that the resources available for inventory preparation may be prioritised, and the best possible estimates prepared for the most significant source categories. We have used the method set out in Section 7.2 of the IPCC Good Practice Guidance (2000) (*Determining national key source categories*) to determine the key source categories.

The results of the Key Source Category Analysis with and without LULUCF are summarised by sector and gas in **Table A1.5** and **Table A1.6** respectively. The analysis is based on the Tier 1 Level analysis and Trend analysis, performed using the data shown in **Tables A7.5a** and **A7.5 b**, and **Tables A7.6a** and **A7.6b** using the same categorisation and the same estimates of uncertainty. The table indicates whether a key source arises from the level assessment or the trend assessment. The factors that make a source a key source are:

- A high contribution to the total
- A high contribution to the trend
- High uncertainty.

For example, transport fuel (1A3b) is a key source for carbon dioxide because it is large; landfill methane (6A) is key because it is large, has a high uncertainty and shows a significant trend.

Both the Level and the Trend assessments were completed, following the procedure set out in the IPCC Good Practice Guidance (2000). A qualitative assessment was not conducted, but we do not anticipate that additional source categories would have been identified using such an assessment.

The results of the Level Assessment with and without LULUCF are shown in **Table A1.1** and **Table A1.2** respectively, with the key source categories shaded. The emission estimates were taken from the 2004 UK GHG inventory. The source categories (i.e. rows of the table) were sorted in descending order of magnitude based on the results of the “Level Parameter”, and then the cumulative total was included in the final column of the table. The key source categories are those whose contributions add up to 95% of the total uncertainty in the final column after this sorting process.

The results of the Trend Assessment with and without LULUCF are shown in **Table A1.3** and **Table A1.4** respectively, with key source categories shaded. The emission estimates were taken from the 2004 UK GHG inventory. The trend parameter was calculated using absolute value of the result. An absolute function is used since Land Use Change and Forestry contains

negative sources (sinks) and the absolute function is necessary to produce positive uncertainty contributions for these sinks. The source categories (i.e. rows of the table) were sorted in descending order of magnitude based on the results of the trend parameter, and then the cumulative total was included in the final column of the table. The key source categories are those whose contributions add up to 95% of the total uncertainty in the final column after this sorting process.

There have been a number of improvements to the key source analysis this year. These are partly in response to comments made in the Fourth Centralised Review to improve the transparency of the uncertainty analysis. The improvements are discussed in **Annex 7**.

There are changes in the Key Source categories, from those presented in 2005 NIR, since there have been revisions of uncertainty parameters assigned to activity data or emission factors. These changes are shown in **Table A1.7**. The table shows changes that have occurred in Key Sources (defined according to level and trend), and provides short reason for the change in Key Sources which were present in 2003 but are not now Key Sources in 2004, and visa versa.

**Table A1.1** Key Source Analysis Based on Level of Emissions (Including LULCUF)

IPCC category	Source category	Gas	Base year emissions	Year Y emissions	Combined uncertainty range as a % of source category	Level Parameter (used to order sources)	Level / Sum(Level)*100	Cumulative %
			Gg CO2 equiv. 1990	Gg CO2 equiv. 2004			%	
4D	Agricultural Soils	N2O	30,407.12	25,281.34	424.00	0.1615798	52.92166	
6A	Solid Waste Disposal	CH4	49,772.46	19,822.97	48.38	0.0144574	4.73517	57.65683
1A(stationary)	Oil	CO2	91,435.86	61,226.05	15.13	0.0139661	4.57425	62.23109
1A3b	Auto Fuel	N2O	1,025.19	5,037.74	170.02	0.0129111	4.22873	66.45982
5B	5B LUCF	CO2	15,841.67	15,329.12	50.01	0.0115556	3.78478	70.24459
2B	Nitric Acid Production	N2O	4,133.69	2,922.68	230.22	0.0101424	3.32189	73.56649
1A1&1A2&1A4&1A5	Other Combustion	N2O	4,522.79	3,388.91	195.00	0.0099613	3.26259	76.82908
5C	5C LUCF	CO2	- 6,192.80	- 7,835.52	70.01	0.0082686	2.70817	79.53725
4B	Manure Management	N2O	1,583.86	1,316.30	414.00	0.0082144	2.69044	82.22769
1A3b	Auto Fuel	CO2	109,638.07	119,614.06	4.48	0.0080815	2.64691	84.87459
6B	Wastewater Handling	N2O	1,033.64	1,209.29	401.12	0.0073119	2.39485	87.26944
5A	5A LUCF	CO2	- 12,202.57	- 16,302.00	25.02	0.0061482	2.01370	89.28314
4A	Enteric Fermentation	CH4	18,421.03	16,309.15	20.00	0.0049168	1.61040	90.89354
5E	5E LUCF	CO2	6,925.01	6,248.02	50.01	0.0047100	1.54264	92.43618
1A	Natural Gas	CO2	108,856.88	206,458.59	1.51	0.0047095	1.54247	93.97865
2	Industrial Processes	HFC	11,375.39	8,873.14	19.03	0.0025448	0.83348	94.81214
1A	Coal	CO2	248,419.66	144,359.44	1.08	0.0023437	0.76761	95.57975
7C	Other	CO2	1,843.69	2,092.72	53.85	0.0016987	0.55639	96.13613
1B2	Production, Refining & Distribution of Oil & Natural Gas	CH4	10,304.69	6,007.04	17.07	0.0015460	0.50635	96.64248
1B	Oil & Natural Gas	CO2	5,760.18	5,099.95	17.09	0.0013136	0.43025	97.07274
4B	Manure Management	CH4	2,923.20	2,567.51	30.00	0.0011611	0.38028	97.45301
1B1	Mining & Solid Fuel Transformation	CH4	18,289.71	4,933.13	13.03	0.0009690	0.31738	97.77040
1A	All Fuel	CH4	2,017.53	1,123.10	50.00	0.0008465	0.27725	98.04765
1A3	Other Diesel	N2O	260.58	346.06	140.01	0.0007304	0.23921	98.28686
1A3a	Aviation Fuel	CO2	1,309.49	2,331.56	20.27	0.0007124	0.23333	98.52019
1A	Other (waste)	CO2	812.62	1,921.15	21.19	0.0006136	0.20098	98.72117
6B	Wastewater Handling	CH4	709.70	799.30	50.01	0.0006025	0.19735	98.91852
2	Industrial Processes	SF6	1,029.95	1,127.56	20.02	0.0003404	0.11148	99.02999
5G	5G LUCF	CO2	- 1,455.88	618.82	30.02	0.0002800	0.09171	99.12170
2B	Adipic Acid Production	N2O	25,136.35	1,103.29	15.01	0.0002496	0.08175	99.20345
1A4	Peat	CO2	477.00	441.91	31.62	0.0002106	0.06899	99.27244
2B	Ammonia Production	CO2	1,321.67	1,329.20	10.11	0.0002026	0.06636	99.33880
2A1	Cement Production	CO2	6,659.34	5,455.65	2.42	0.0001987	0.06509	99.40389
2C1	Iron&Steel Production	CO2	2,309.83	2,088.87	6.12	0.0001927	0.06310	99.46699
1A3d	Marine Fuel	N2O	78.12	68.82	170.01	0.0001764	0.05776	99.52476
6C	Waste Incineration	N2O	47.90	48.30	230.11	0.0001675	0.05487	99.57962
1A	Lubricant	CO2	386.90	356.25	30.07	0.0001615	0.05288	99.63251
6C	Waste Incineration	CO2	1,205.27	451.80	21.19	0.0001443	0.04727	99.67977
1A3b	Auto Fuel	CH4	614.37	186.35	50.08	0.0001407	0.04607	99.72584
2A7	Fletton Bricks	CO2	166.69	127.98	72.80	0.0001404	0.04600	99.77184
1A3d	Marine Fuel	CO2	4,014.20	3,549.79	2.20	0.0001178	0.03860	99.81044
2A3	Limestone & Dolomite use	CO2	1,285.33	1,371.22	5.10	0.0001054	0.03452	99.84496
1A3	Other Diesel	CO2	2,201.39	2,919.73	2.20	0.0000969	0.03175	99.87670
1B2	Oil & Natural Gas	N2O	42.40	39.24	111.16	0.0000657	0.02153	99.89824
2A2	Lime Production	CO2	1,191.52	815.49	5.10	0.0000627	0.02053	99.91877
1A3a	Aviation Fuel	N2O	12.96	23.03	171.17	0.0000594	0.01946	99.93823
2	Industrial Processes	PFC	1,401.49	352.23	10.05	0.0000534	0.01748	99.95570
2A4	Soda Ash Use	CO2	167.32	179.59	15.13	0.0000410	0.01342	99.96912
2A7	Fletton Bricks	CH4	22.43	12.80	101.98	0.0000197	0.00644	99.97556
1B	Solid Fuel Transformation	CO2	856.42	168.09	6.01	0.0000152	0.00499	99.98055
2C	Iron & Steel	N2O	11.11	8.28	118.00	0.0000147	0.00482	99.98538
2B	Chemical Industry	CH4	136.17	32.97	28.28	0.0000141	0.00460	99.98998
2C	Iron & Steel Production	CH4	16.36	13.83	50.00	0.0000104	0.00342	99.99340
1A3d	Marine Fuel	CH4	7.62	6.71	50.03	0.0000051	0.00166	99.99505
5C2	5C2 LUCF	CH4	3.08	11.87	20.02	0.0000036	0.00117	99.99623
1B1	Coke Oven Gas	N2O	2.08	1.75	118.00	0.0000031	0.00102	99.99725
6C	Waste Incineration	CH4	134.43	3.30	50.49	0.0000025	0.00082	99.99807
1A3a	Aviation Fuel	CH4	2.66	2.77	53.85	0.0000022	0.00074	99.99880
1A3	Other Diesel	CH4	1.67	2.21	50.03	0.0000017	0.00054	99.99933
5E2	5E2 LUCF	CH4	10.76	4.88	20.02	0.0000015	0.00048	99.99983
5C2	5C2 LUCF	N2O	0.31	1.21	20.02	0.0000004	0.00012	99.99995
5E2	5E2 LUCF	N2O	1.09	0.50	20.02	0.0000001	0.00005	100.00000
4F	Field Burning	CH4	266.04	-	55.90	0.0000000	0.00000	100.00000
4F	Field Burning	N2O	77.76	-	231.35	0.0000000	0.00000	100.00000
		Sum -->	779,072.44	663,407.09		0.3053	100.00	



**Table A1.2** Key Source Analysis Based on Level of Emissions (Excluding LULUCF)

IPCC category	Source category	Gas	Base year emissions	Year Y emissions	Combined uncertainty range as a % of source category	Level Parameter (used to order sources)	Level / Sum(Level)*100	Cumulative %
			Gg CO2 equiv. 1990	Gg CO2 equiv. 2004			%	
4D	Agricultural Soils	N2O	30,407.12	25,281.34	424.00	0.1611127	58.89531	
6A	Solid Waste Disposal	CH4	49,772.46	19,822.97	48.38	0.0144156	5.26967	64.16497
1A(stationary)	Oil	CO2	91,435.86	61,226.05	15.13	0.0139257	5.09058	69.25555
1A3b	Auto Fuel	N2O	1,025.19	5,037.74	170.02	0.0128738	4.70606	73.96161
2B	Nitric Acid Production	N2O	4,133.69	2,922.68	230.22	0.0101130	3.69686	77.65847
1A1&1A2&1A4&1A5	Other Combustion	N2O	4,522.79	3,388.91	195.00	0.0099325	3.63086	81.28933
4B	Manure Management	N2O	1,583.86	1,316.30	414.00	0.0081907	2.99413	84.28346
1A3b	Auto Fuel	CO2	109,638.07	119,614.06	4.48	0.0080581	2.94568	87.22914
6B	Wastewater Handling	N2O	1,033.64	1,209.29	401.12	0.0072908	2.66517	89.89431
4A	Enteric Fermentation	CH4	18,421.03	16,309.15	20.00	0.0049026	1.79217	91.68649
1A	Natural Gas	CO2	108,856.88	206,458.59	1.51	0.0046958	1.71658	93.40307
2	Industrial Processes	HFC	11,375.39	8,873.14	19.03	0.0025374	0.92757	94.33063
1A	Coal	CO2	248,419.66	144,359.44	1.08	0.0023369	0.85426	95.18489
7C	Other	CO2	1,843.69	2,092.72	53.85	0.0016938	0.61919	95.80408
1B2	Production, Refining & Distribution of Oil & Natural Gas	CH4	10,304.69	6,007.04	17.07	0.0015415	0.56351	96.36758
1B	Oil & Natural Gas	CO2	5,760.18	5,099.95	17.09	0.0013098	0.47882	96.84640
4B	Manure Management	CH4	2,923.20	2,567.51	30.00	0.0011577	0.42320	97.26961
1B1	Mining & Solid Fuel Transformation	CH4	18,289.71	4,933.13	13.03	0.0009662	0.35321	97.62282
1A	All Fuel	CH4	2,017.53	1,123.10	50.00	0.0008440	0.30854	97.93136
1A3	Other Diesel	N2O	260.58	346.06	140.01	0.0007282	0.26621	98.19757
1A3a	Aviation Fuel	CO2	1,309.49	2,331.56	20.27	0.0007104	0.25967	98.45724
1A	Other (waste)	CO2	812.62	1,921.15	21.19	0.0006119	0.22366	98.68091
6B	Wastewater Handling	CH4	709.70	799.30	50.01	0.0006008	0.21962	98.90053
2	Industrial Processes	SF6	1,029.95	1,127.56	20.02	0.0003394	0.12406	99.02459
2B	Adipic Acid Production	N2O	25,136.35	1,103.29	15.01	0.0002489	0.09098	99.11557
1A4	Peat	CO2	477.00	441.91	31.62	0.0002100	0.07678	99.19235
2B	Ammonia Production	CO2	1,321.67	1,329.20	10.11	0.0002020	0.07385	99.26619
2A1	Cement Production	CO2	6,659.34	5,455.65	2.42	0.0001982	0.07244	99.33863
2C1	Iron&Steel Production	CO2	2,309.83	2,088.87	6.12	0.0001921	0.07023	99.40886
1A3d	Marine Fuel	N2O	78.12	68.82	170.01	0.0001759	0.06429	99.47314
6C	Waste Incineration	N2O	47.90	48.30	230.11	0.0001670	0.06106	99.53420
1A	Lubricant	CO2	386.90	356.25	30.07	0.0001610	0.05885	99.59305
6C	Waste Incineration	CO2	1,205.27	451.80	21.19	0.0001439	0.05260	99.64565
1A3b	Auto Fuel	CH4	614.37	186.35	50.08	0.0001403	0.05127	99.69693
2A7	Fletton Bricks	CO2	166.69	127.98	72.80	0.0001400	0.05119	99.74812
1A3d	Marine Fuel	CO2	4,014.20	3,549.79	2.20	0.0001175	0.04295	99.79107
2A3	Limestone & Dolomite use	CO2	1,285.33	1,371.22	5.10	0.0001051	0.03842	99.82949
1A3	Other Diesel	CO2	2,201.39	2,919.73	2.20	0.0000966	0.03533	99.86482
1B2	Oil & Natural Gas	N2O	42.40	39.24	111.16	0.0000656	0.02396	99.88878
2A2	Lime Production	CO2	1,191.52	815.49	5.10	0.0000625	0.02285	99.91163
1A3a	Aviation Fuel	N2O	12.96	23.03	171.17	0.0000592	0.02166	99.93328
2	Industrial Processes	PFC	1,401.49	352.23	10.05	0.0000532	0.01945	99.95273
2A4	Soda Ash Use	CO2	167.32	179.59	15.13	0.0000408	0.01493	99.96767
2A7	Fletton Bricks	CH4	22.43	12.80	101.98	0.0000196	0.00717	99.97484
1B	Solid Fuel Transformation	CO2	856.42	168.09	6.01	0.0000152	0.00555	99.98039
2C	Iron & Steel	N2O	11.11	8.28	118.00	0.0000147	0.00537	99.98576
2B	Chemical Industry	CH4	136.17	32.97	28.28	0.0000140	0.00512	99.99088
2C	Iron & Steel Production	CH4	16.36	13.83	50.00	0.0000104	0.00380	99.99468
1A3d	Marine Fuel	CH4	7.62	6.71	50.03	0.0000050	0.00185	99.99653
1B1	Coke Oven Gas	N2O	2.08	1.75	118.00	0.0000031	0.00113	99.99766
6C	Waste Incineration	CH4	134.43	3.30	50.49	0.0000025	0.00092	99.99857
1A3a	Aviation Fuel	CH4	2.66	2.77	53.85	0.0000022	0.00082	99.99939
1A3	Other Diesel	CH4	1.67	2.21	50.03	0.0000017	0.00061	100.00000
5A	5A LUCF	CO2	-	-	25.02	0.0000000	0.00000	100.00000
5B	5B LUCF	CO2	-	-	50.01	0.0000000	0.00000	100.00000
5C	5C LUCF	CO2	-	-	70.01	0.0000000	0.00000	100.00000
5E	5E LUCF	CO2	-	-	50.01	0.0000000	0.00000	100.00000
5G	5G LUCF	CO2	-	-	30.02	0.0000000	0.00000	100.00000
4F	Field Burning	CH4	266.04	-	55.90	0.0000000	0.00000	100.00000
5C2	5C2 LUCF	CH4	-	-	20.02	0.0000000	0.00000	100.00000
5E2	5E2 LUCF	CH4	-	-	20.02	0.0000000	0.00000	100.00000
4F	Field Burning	N2O	77.76	-	231.35	0.0000000	0.00000	100.00000
5C2	5C2 LUCF	N2O	-	-	20.02	0.0000000	0.00000	100.00000
5E2	5E2 LUCF	N2O	-	-	20.02	0.0000000	0.00000	100.00000
	Sum -->		776,141.77	665,330.19		0.2736	100.00	

**Table A1.3** Key Source Analysis Based on Trend in Emissions (Including LULUCF)

IPCC category	Source category	Gas	Base year emissions	Year Y emissions	Combined uncertainty range as a % of source category	Trend Parameter (used to order sources)	Trend / Sum(Trend)*100	Cumulative %
			Gg CO2 equiv. 1990	Gg CO2 equiv. 2004			%	
1A3b	Auto Fuel	N2O	1,025.19	5,037.74	170.02	0.0213119	28.63146	
4D	Agricultural Soils	N2O	30,407.12	25,281.34	424.00	0.0194563	26.13850	54.76996
6B	Wastewater Handling	N2O	1,033.64	1,209.29	401.12	0.0093739	12.59328	67.36324
6A	Solid Waste Disposal	CH4	49,772.46	19,822.97	48.38	0.0093488	12.55968	79.92292
2B	Nitric Acid Production	N2O	4,133.69	2,922.68	230.22	0.0056039	7.52851	87.45143
1A1&1A2&1A4&1A5	Other Combustion	N2O	4,522.79	3,388.91	195.00	0.0031125	4.18141	91.63284
4B	Manure Management	N2O	1,583.86	1,316.30	414.00	0.0009833	1.32097	92.95381
5B	5B LUCF	CO2	15,841.67	15,329.12	50.01	0.0008143	1.09402	94.04783
2B	Adipic Acid Production	N2O	25,136.35	1,103.29	15.01	0.0008095	1.08749	95.13532
1A(stationary)	Oil	CO2	91,435.86	61,226.05	15.13	0.0006743	0.90592	96.04124
1A3	Other Diesel	N2O	260.58	346.06	140.01	0.0004309	0.57885	96.62009
1B1	Mining & Solid Fuel Transformation	CH4	18,289.71	4,933.13	13.03	0.0003187	0.42811	97.04820
5G	5G LUCF	CO2	1,455.88	618.82	30.02	0.0002964	0.39823	97.44643
7C	Other	CO2	1,843.69	2,092.72	53.85	0.0002684	0.36052	97.80695
1A	All Fuel	CH4	2,017.53	1,123.10	50.00	0.0002633	0.35371	98.16066
1B2	Production, Refining & Distribution of Oil & Natural Gas	CH4	10,304.69	6,007.04	17.07	0.0001749	0.23491	98.39557
5E	5E LUCF	CO2	6,925.01	6,248.02	50.01	0.0001555	0.20884	98.60441
1A3b	Auto Fuel	CH4	614.37	186.35	50.08	0.0001495	0.20087	98.80529
1A	Other (waste)	CO2	812.62	1,921.15	21.19	0.0000977	0.13125	98.93654
1A3b	Auto Fuel	CO2	109,638.07	119,614.06	4.48	0.0000934	0.12543	99.06197
1A3a	Aviation Fuel	CO2	1,309.49	2,331.56	20.27	0.0000885	0.11887	99.18084
6B	Wastewater Handling	CH4	709.70	799.30	50.01	0.0000863	0.11596	99.29679
6C	Waste Incineration	N2O	47.90	48.30	230.11	0.0000704	0.09458	99.39137
1A3a	Aviation Fuel	N2O	12.96	23.03	171.17	0.0000622	0.08356	99.47493
2	Industrial Processes	HFC	11,375.39	8,873.14	19.03	0.0000521	0.07002	99.54496
6C	Waste Incineration	CH4	134.43	3.30	50.49	0.0000502	0.06739	99.61235
1A	Natural Gas	CO2	108,856.88	206,458.59	1.51	0.0000461	0.06195	99.67431
6C	Waste Incineration	CO2	1,205.27	451.80	21.19	0.0000457	0.06135	99.73565
4A	Enteric Fermentation	CH4	18,421.03	16,309.15	20.00	0.0000441	0.05927	99.79492
2	Industrial Processes	SF6	1,029.95	1,127.56	20.02	0.0000178	0.02389	99.81881
2	Industrial Processes	PFC	1,401.49	352.23	10.05	0.0000150	0.02020	99.83901
1A	Coal	CO2	248,419.66	144,359.44	1.08	0.0000138	0.01853	99.85755
2A7	Fletton Bricks	CO2	166.69	127.98	72.80	0.0000131	0.01760	99.87514
4B	Manure Management	CH4	2,923.20	2,567.51	30.00	0.0000125	0.01676	99.89190
1A3d	Marine Fuel	N2O	78.12	68.82	170.01	0.0000118	0.01581	99.90771
2B	Chemical Industry	CH4	136.17	32.97	28.28	0.0000118	0.01579	99.92350
2A7	Fletton Bricks	CH4	22.43	12.80	101.98	0.0000116	0.01558	99.93908
1B	Oil & Natural Gas	CO2	5,760.18	5,099.95	17.09	0.0000101	0.01354	99.95262
1B2	Oil & Natural Gas	N2O	42.40	39.24	111.16	0.0000069	0.00921	99.96183
1A4	Peat	CO2	477.00	441.91	31.62	0.0000063	0.00850	99.97033
1A	Lubricant	CO2	386.90	356.25	30.07	0.0000043	0.00576	99.97609
2B	Ammonia Production	CO2	1,321.67	1,329.20	10.11	0.0000037	0.00495	99.98104
1B	Solid Fuel Transformation	CO2	856.42	168.09	6.01	0.0000036	0.00483	99.98587
2C	Iron & Steel	N2O	11.11	8.28	118.00	0.0000029	0.00391	99.98978
2A4	Soda Ash Use	CO2	167.32	179.59	15.13	0.0000015	0.00202	99.99180
2A3	Limestone & Dolomite use	CO2	1,285.33	1,371.22	5.10	0.0000013	0.00171	99.99351
2A2	Lime Production	CO2	1,191.52	815.49	5.10	0.0000009	0.00123	99.99474
1A3	Other Diesel	CO2	2,201.39	2,919.73	2.20	0.0000009	0.00121	99.99594
2C1	Iron&Steel Production	CO2	2,309.83	2,088.87	6.12	0.0000008	0.00109	99.99703
5C2	5C2 LUCF	CH4	3.08	11.87	20.02	0.0000007	0.00088	99.99791
1A3	Other Diesel	CH4	1.67	2.21	50.03	0.0000003	0.00047	99.99838
5E2	5E2 LUCF	CH4	10.76	4.88	20.02	0.0000003	0.00041	99.99879
1A3a	Aviation Fuel	CH4	2.66	2.77	53.85	0.0000003	0.00035	99.99914
2A1	Cement Production	CO2	6,659.34	5,455.65	2.42	0.0000002	0.00030	99.99944
1A3d	Marine Fuel	CO2	4,014.20	3,549.79	2.20	0.0000001	0.00015	99.99959
1A3d	Marine Fuel	CH4	7.62	6.71	50.03	0.0000001	0.00013	99.99972
1B1	Coke Oven Gas	N2O	2.08	1.75	118.00	0.0000001	0.00009	99.99981
5C2	5C2 LUCF	N2O	0.31	1.21	20.02	0.0000001	0.00009	99.99990
2C	Iron & Steel Production	CH4	16.36	13.83	50.00	0.0000000	0.00006	99.99996
5E2	5E2 LUCF	N2O	1.09	0.50	20.02	0.0000000	0.00004	100.00000
5A	5A LUCF	CO2	12,202.57	16,302.00	25.02	0.0000000	0.00000	100.00000
5C	5C LUCF	CO2	6,192.80	7,835.52	70.01	0.0000000	0.00000	100.00000
4F	Field Burning	CH4	266.04	-	55.90	0.0000000	0.00000	100.00000
4F	Field Burning	N2O	77.76	-	231.35	0.0000000	0.00000	100.00000
		Sum -->	779,072.44	663,407.09		0.0744	100.00	

**Table A1.4** Key Source Analysis Based on Trend in Emissions (Excluding LULUCF)

IPCC category	Source category	Gas	Base year emissions	Year Y emissions	Combined uncertainty range as a % of source category	Trend Parameter (used to order sources)	Trend / Sum(Trend)*100	Cumulative %
			Gg CO2 equiv.	Gg CO2 equiv.				
			1990	2004			%	
4D	Agricultural Soils	N2O	30,407.12	25,281.34	424.00	0.0247279	31.49131	
1A3b	Auto Fuel	N2O	1,025.19	5,037.74	170.02	0.0210796	26.84522	58.33653
6A	Solid Waste Disposal	CH4	49,772.46	19,822.97	48.38	0.0093762	11.94076	70.27729
6B	Wastewater Handling	N2O	1,033.64	1,209.29	401.12	0.0091187	11.61276	81.89006
2B	Nitric Acid Production	N2O	4,133.69	2,922.68	230.22	0.0057693	7.34723	89.23729
1A1&1A2&1A4&1A5	Other Combustion	N2O	4,522.79	3,388.91	195.00	0.0032545	4.14467	93.38196
4B	Manure Management	N2O	1,583.86	1,316.30	414.00	0.0012449	1.58539	94.96736
2B	Adipic Acid Production	N2O	25,136.35	1,103.29	15.01	0.0008074	1.02827	95.99563
1A(stationary)	Oil	CO2	91,435.86	61,226.05	15.13	0.0006888	0.87721	96.87284
1A3	Other Diesel	N2O	260.58	346.06	140.01	0.0004217	0.53700	97.40984
1B1	Mining & Solid Fuel Transformation	CH4	18,289.71	4,933.13	13.03	0.0003187	0.40591	97.81575
1A	All Fuel	CH4	2,017.53	1,123.10	50.00	0.0002658	0.33852	98.15427
7C	Other	CO2	1,843.69	2,092.72	53.85	0.0002605	0.33171	98.48598
1B2	Production, Refining & Distribution of Oil & Natural Gas	CH4	10,304.69	6,007.04	17.07	0.0001765	0.22481	98.71079
1A3b	Auto Fuel	CH4	614.37	186.35	50.08	0.0001496	0.19056	98.90135
1A	Other (waste)	CO2	812.62	1,921.15	21.19	0.0000964	0.12277	99.02412
1A3b	Auto Fuel	CO2	109,638.07	119,614.06	4.48	0.0000903	0.11497	99.13909
1A3a	Aviation Fuel	CO2	1,309.49	2,331.56	20.27	0.0000871	0.11093	99.25001
6B	Wastewater Handling	CH4	709.70	799.30	50.01	0.0000837	0.10662	99.35663
6C	Waste Incineration	N2O	47.90	48.30	230.11	0.0000672	0.08558	99.44221
1A3a	Aviation Fuel	N2O	12.96	23.03	171.17	0.0000612	0.07798	99.52019
2	Industrial Processes	HFC	11,375.39	8,873.14	19.03	0.0000557	0.07098	99.59177
6C	Waste Incineration	CH4	134.43	3.30	50.49	0.0000500	0.06371	99.65488
6C	Waste Incineration	CO2	1,205.27	451.80	21.19	0.0000458	0.05829	99.71317
1A	Natural Gas	CO2	108,856.88	206,458.59	1.51	0.0000454	0.05785	99.77103
4A	Enteric Fermentation	CH4	18,421.03	16,309.15	20.00	0.0000363	0.04628	99.81731
2	Industrial Processes	SF6	1,029.95	1,127.56	20.02	0.0000172	0.02191	99.83921
2	Industrial Processes	PFC	1,401.49	352.23	10.05	0.0000150	0.01915	99.85836
1A	Coal	CO2	248,419.66	144,359.44	1.08	0.0000140	0.01777	99.87613
2A7	Fletton Bricks	CO2	166.69	127.98	72.80	0.0000139	0.01765	99.89378
2B	Chemical Industry	CH4	136.17	32.97	28.28	0.0000117	0.01496	99.90874
2A7	Fletton Bricks	CH4	22.43	12.80	101.98	0.0000117	0.01492	99.92366
4B	Manure Management	CH4	2,923.20	2,567.51	30.00	0.0000097	0.01239	99.93605
1A3d	Marine Fuel	N2O	78.12	68.82	170.01	0.0000094	0.01197	99.94803
1B	Oil & Natural Gas	CO2	5,760.18	5,099.95	17.09	0.0000083	0.01057	99.95860
1B2	Oil & Natural Gas	N2O	42.40	39.24	111.16	0.0000063	0.00798	99.96659
1A4	Peat	CO2	477.00	441.91	31.62	0.0000058	0.00737	99.97396
1A	Lubricant	CO2	386.90	356.25	30.07	0.0000039	0.00496	99.97892
1B	Solid Fuel Transformation	CO2	856.42	168.09	6.01	0.0000036	0.00457	99.98349
2B	Ammonia Production	CO2	1,321.67	1,329.20	10.11	0.0000035	0.00448	99.98797
2C	Iron & Steel	N2O	11.11	8.28	118.00	0.0000030	0.00387	99.99184
2A4	Soda Ash Use	CO2	167.32	179.59	15.13	0.0000015	0.00185	99.99369
2A3	Limestone & Dolomite use	CO2	1,285.33	1,371.22	5.10	0.0000012	0.00156	99.99525
2A2	Lime Production	CO2	1,191.52	815.49	5.10	0.0000009	0.00120	99.99644
1A3	Other Diesel	CO2	2,201.39	2,919.73	2.20	0.0000009	0.00112	99.99756
2C1	Iron&Steel Production	CO2	2,309.83	2,088.87	6.12	0.0000007	0.00091	99.99847
1A3	Other Diesel	CH4	1.67	2.21	50.03	0.0000003	0.00043	99.99891
2A1	Cement Production	CO2	6,659.34	5,455.65	2.42	0.0000003	0.00033	99.99924
1A3a	Aviation Fuel	CH4	2.66	2.77	53.85	0.0000002	0.00032	99.99955
1B1	Coke Oven Gas	N2O	2.08	1.75	118.00	0.0000001	0.00012	99.99968
1A3d	Marine Fuel	CO2	4,014.20	3,549.79	2.20	0.0000001	0.00012	99.99979
2C	Iron & Steel Production	CH4	16.36	13.83	50.00	0.0000001	0.00010	99.99990
1A3d	Marine Fuel	CH4	7.62	6.71	50.03	0.0000001	0.00010	100.00000
5A	5A LUCF	CO2	-	-	25.02	0.0000000	0.00000	100.00000
5B	5B LUCF	CO2	-	-	50.01	0.0000000	0.00000	100.00000
5C	5C LUCF	CO2	-	-	70.01	0.0000000	0.00000	100.00000
5E	5E LUCF	CO2	-	-	50.01	0.0000000	0.00000	100.00000
5G	5G LUCF	CO2	-	-	30.02	0.0000000	0.00000	100.00000
4F	Field Burning	CH4	266.04	-	55.90	0.0000000	0.00000	100.00000
5C2	5C2 LUCF	CH4	-	-	20.02	0.0000000	0.00000	100.00000
5E2	5E2 LUCF	CH4	-	-	20.02	0.0000000	0.00000	100.00000
4F	Field Burning	N2O	77.76	-	231.35	0.0000000	0.00000	100.00000
5C2	5C2 LUCF	N2O	-	-	20.02	0.0000000	0.00000	100.00000
5E2	5E2 LUCF	N2O	-	-	20.02	0.0000000	0.00000	100.00000
		Sum -->	776,141.77	665,330.19		0.0785	100.00	

**Table A1.5** Key Source Category Analysis Summary (Including LULUCF)

Quantitative Method Used: Tier 1		B	C	D	E
A			Category	If Column C is	
IPCC Source Categories		Gas	Key Source Category	Yes, Criteria for Identification	Comments
1A	Coal	CO2			
1A(stationary)	Oil	CO2		Level	
1A	Natural Gas	CO2		Level	
1A	Other (waste)	CO2			
1A	Lubricant	CO2			
1A3a	Aviation Fuel	CO2			
1A3b	Auto Fuel	CO2		Level	
1A3d	Marine Fuel	CO2			
1A3	Other Diesel	CO2			
1A4	Peat	CO2			
1B	Solid Fuel Transformation	CO2			
1B	Oil & Natural Gas	CO2			
2A1	Cement Production	CO2			
2A2	Lime Production	CO2			
2A3	Limestone & Dolomite use	CO2			
2A4	Soda Ash Use	CO2			
2A7	Fletton Bricks	CO2			
2B	Ammonia Production	CO2			
2C1	Iron&Steel Production	CO2			
5A	5A LUCF	CO2		Level	
5B	5B LUCF	CO2		Level, Trend	
5C	5C LUCF	CO2		Level	
5E	5E LUCF	CO2		Level	
5G	5G LUCF	CO2			
6C	Waste Incineration	CO2			
7C	Other	CO2			
1A	All Fuel	CH4			
1A3a	Aviation Fuel	CH4			
1A3b	Auto Fuel	CH4			
1A3d	Marine Fuel	CH4			
1A3	Other Diesel	CH4			
1B1	Coal Mining	CH4			
1B2	Oil & Natural Gas	CH4			
2A7	Fletton Bricks	CH4			
2B	Chemical Industry	CH4			
2C	Iron & Steel Production	CH4			
4A	Enteric Fermentation	CH4		Level	
4B	Manure Management	CH4			
4F	Field Burning	CH4			
5C2	5C2 LUCF	CH4			
5E2	5E2 LUCF	CH4			
6A	Solid Waste Disposal	CH4		Level, Trend	high uncertainty
6B	Wastewater Handling	CH4			
6C	Waste Incineration	CH4			
1A1&1A2&1A4&1A5	Other Combustion	N2O		Level, Trend	
1A3a	Aviation Fuel	N2O			
1A3b	Auto Fuel	N2O		Level, Trend	
1A3d	Marine Fuel	N2O			
1A3	Other Diesel	N2O			
1B1	Coke Oven Gas	N2O			
1B2	Oil & Natural Gas	N2O			
2B	Adipic Acid Production	N2O			
2B	Nitric Acid Production	N2O		Level, Trend	
2C	Iron & Steel	N2O			
4B	Manure Management	N2O		Level, Trend	high uncertainty
4D	Agricultural Soils	N2O		Level, Trend	high uncertainty
4F	Field Burning	N2O			
5C2	5C2 LUCF	N2O			
5E2	5E2 LUCF	N2O			
6B	Wastewater Handling	N2O		Level, Trend	
6C	Waste Incineration	N2O			
2	Industrial Processes	HFC		Level	
2	Industrial Processes	PFC			
2	Industrial Processes	SF6			

**Table A1.6** Key Source Category Analysis Summary (Excluding LULUCF)

Quantitative Method Used: Tier 1		B	C	D	E
A			Category	If Column C is	
IPCC Source Categories		Gas	Key Source Category	Yes, Criteria for Identification	Comments
1A	Coal	CO2			
1A(stationary)	Oil	CO2		Level	
1A	Natural Gas	CO2		Level	
1A	Other (waste)	CO2			
1A	Lubricant	CO2			
1A3a	Aviation Fuel	CO2			
1A3b	Auto Fuel	CO2		Level	
1A3d	Marine Fuel	CO2			
1A3	Other Diesel	CO2			
1A4	Peat	CO2			
1B	Solid Fuel Transformation	CO2			
1B	Oil & Natural Gas	CO2			
2A1	Cement Production	CO2			
2A2	Lime Production	CO2			
2A3	Limestone & Dolomite use	CO2			
2A4	Soda Ash Use	CO2			
2A7	Fletton Bricks	CO2			
2B	Ammonia Production	CO2			
2C1	Iron&Steel Production	CO2			
5A	5A LUCF	CO2			
5B	5B LUCF	CO2			
5C	5C LUCF	CO2			
5E	5E LUCF	CO2			
5G	5G LUCF	CO2			
6C	Waste Incineration	CO2			
7C	Other	CO2			
1A	All Fuel	CH4			
1A3a	Aviation Fuel	CH4			
1A3b	Auto Fuel	CH4			
1A3d	Marine Fuel	CH4			
1A3	Other Diesel	CH4			
1B1	Coal Mining	CH4			
1B2	Oil & Natural Gas	CH4			
2A7	Fletton Bricks	CH4			
2B	Chemical Industry	CH4			
2C	Iron & Steel Production	CH4			
4A	Enteric Fermentation	CH4		Level	
4B	Manure Management	CH4			
4F	Field Burning	CH4			
5C2	5C2 LUCF	CH4			
5E2	5E2 LUCF	CH4			
6A	Solid Waste Disposal	CH4		Level, Trend	high uncertainty
6B	Wastewater Handling	CH4			
6C	Waste Incineration	CH4			
1A1&1A2&1A4&1A5	Other Combustion	N2O		Level, Trend	
1A3a	Aviation Fuel	N2O			
1A3b	Auto Fuel	N2O		Level, Trend	
1A3d	Marine Fuel	N2O			
1A3	Other Diesel	N2O			
1B1	Coke Oven Gas	N2O			
1B2	Oil & Natural Gas	N2O			
2B	Adipic Acid Production	N2O			
2B	Nitric Acid Production	N2O		Level, Trend	
2C	Iron & Steel	N2O			
4B	Manure Management	N2O		Level, Trend	high uncertainty
4D	Agricultural Soils	N2O		Level, Trend	high uncertainty
4F	Field Burning	N2O			
5C2	5C2 LUCF	N2O			
5E2	5E2 LUCF	N2O			
6B	Wastewater Handling	N2O		Level, Trend	
6C	Waste Incineration	N2O			
2	Industrial Processes	HFC		Level	
2	Industrial Processes	PFC			
2	Industrial Processes	SF6			

**Table A1.7** Changes in Key Sources Based on Level and Trend of Emissions

LEVEL	Activity	Gas	AD uncertainty range	EF uncertainty range	Key Source?	Reason for change
<b>2003</b>						
1A	Coal	CO2	1.2	6	Yes	
1A (Stationary)	Oil	CO2	2	2	No	
<b>2004</b>						
1A	Coal	CO2	0.4	1	No	Both AD and EF uncertainties have been reduced following a review
1A (Stationary)	Oil	CO2	15	2	Yes - New Key Source	AD uncertainty value has been increased following a review

LEVEL	Activity		AD uncertainty range	EF uncertainty range	Key Source?	Reason for change
<b>2003</b>						
5A	LULUCF	CO2	1	30	Yes	
5B	LULUCF	CO2	30	40	No	
5C	LULUCF	CO2			-	
5D_em	LULUCF	CO2	1	60	Yes	
5E_em	LULUCF	CO2	1	50	No	
5E_rem	LULUCF	CO2	1	50	No	
<b>2004</b>						
5A Forest Land	LULUCF	CO2	1	25	Yes	No change
5B Cropland	LULUCF	CO2	1	50	Yes - New Key Source	LULUCF reporting nomenclature has been aligned with 2000 LULUCF GPG and differs from that used in the 2005 NIR
5C Grassland	LULUCF	CO2	1	70	Yes - New Key Source	LULUCF reporting nomenclature has been aligned with 2000 LULUCF GPG and differs from that used in the 2005 NIR
5D Wetland (NOT REPORTED)	LULUCF	CO2			-	
5E Settlements	LULUCF	CO2	1	50	Yes - New Key Source	LULUCF reporting nomenclature has been aligned with 2000 LULUCF GPG and differs from that used in the 2005 NIR
5F Other Land (NOT REPORTED)	LULUCF	CO2			-	
5G Other Activities	LULUCF	CO2	1	30	No	

TREND	Activity		AD uncertainty range	EF uncertainty range	Key Source?	Reason for change
<b>2003</b>						
4B	Manure Management	N2O	1	414	No	
<b>2004</b>						
4B	Manure Management	N2O	1	414	Yes - New Key Source	No change in the values of uncertainties assigned to the AD and EF for 4B, but uncertainties in other categories have decreased (e.g. for coal, aviation fuel and coal mining) so 4B Manure Management is now included within the 95% cut off limit.

## **A2. ANNEX 2: Detailed discussion of methodology and data for estimating CO<sub>2</sub> emissions from fossil fuel combustion**

Methodology for estimating CO<sub>2</sub> emissions from fossil fuel combustion is discussed together with the methodologies for other emissions in Annex 3. This is because the underlying methodology for such estimates apply to a range of pollutants and not just CO<sub>2</sub>.

## **A3. ANNEX 3: Other Detailed Methodological Descriptions**

This Annex contains background information about methods used to estimate emissions in the UK GHG inventory. This information has not been incorporated in the main body of the report because of the level of detail, and because the methods used to estimate emissions cut across sectors.

This Annex provides:

- Background information on the fuels used in the UK GHG inventory.
- Mapping between IPCC and NAEI source categories.

Detailed description of methods used to estimate GHG emissions, and emission factors used in those methods – presented in **Section A3.3** onwards.

### **A3.1 FUELS DATA**

The fuels data are taken from DUKES - the Digest of UK Energy Statistics (DTI, 2005), so the fuel definitions and the base source categories used in the NAEI reflect those in DUKES. Base categories for non-combustion sources generally reflect the availability of data on emissions from these sources.

IPCC Guidelines (IPCC, 1997a) lists fuels that should be considered when reporting emissions. **Table A3.1.1** lists the fuels that are used in the GHGI and indicates how they relate to the fuels reported in the NAEI. In most cases the mapping is obvious but there are a few cases where some explanation is required.

(i) *Aviation Fuels*

UK energy statistics report consumption of aviation turbine fuel and this is mapped onto jet kerosene in the GHGI. Aviation turbine fuel includes fuel that is described as jet gasoline using IPCC terminology. For non-CO<sub>2</sub> gases, emissions are estimated from data on numbers of landing-takeoff cycles, so jet kerosene and aviation gasoline emissions are combined.

(ii) *Coal*

The IPCC Guidelines (IPCC, 1997a) classify coal as anthracite, coking coal, other bituminous coal and sub-bituminous coal. In mapping the UK fuel statistics to these categories it is assumed that only the coal used in coke ovens is coking coal; and the rest is reported as either coal or anthracite. Most coal used in the UK is bituminous coal; anthracite is reported separately.



- (iii) *Coke Oven Coke*  
Gas works coke is no longer manufactured in the UK so all coke and coke breeze consumption is reported as coke oven coke.
- (iv) *Colliery Methane*  
The IPCC Guidelines do not refer to colliery methane but significant use is made of it as a fuel in the UK so emissions are included in the GHGI.
- (v) *Orimulsion*  
Orimulsion® is an emulsion of bitumen and water and was burnt in some power stations in the UK, however its use has now been discontinued
- (vi) *Slurry*  
This is a slurry of coal and water used in some power stations.
- (vii) *Sour Gas*  
Unrefined natural gas is used as a fuel on offshore platforms and in some power stations. It has a higher carbon and sulphur content than mains gas.
- (viii) *Wastes used as fuel*  
The following wastes are used for power generation: municipal solid waste, scrap tyres, poultry litter, meat and bone meal, landfill gas, sewage gas, and waste oils. Some waste oils and scrap tyres are burnt in cement kilns. Further waste oils are burnt by other industrial sectors, and it is assumed that between 40% and 50% of lubricants consumed in the UK are destroyed (burnt) in the vehicle.

**Table A3.1.1** Mapping of fuels used in the GHGI and the NAEI

	<b>GHGI</b>	<b>NAEI</b>
<b>Category</b>	<b>Subcategory</b>	<b>Subcategory</b>
Liquid	Motor Gasoline Aviation Gasoline Jet Kerosene Other Kerosene Gas/Diesel Oil Residual Fuel Oil Orimulsion Liquefied Petroleum Gas Naphtha Petroleum Coke Refinery Gas Other Oil: Other Other Oil: Other Lubricants	Petrol Aviation Spirit Aviation Turbine Fuel <sup>1</sup> (ATF) Burning Oil Gas Oil/ DERV Fuel Oil Orimulsion Liquefied Petroleum Gas (LPG) Naphtha Petroleum Coke Other Petroleum Gas (OPG) Refinery Miscellaneous Waste Oils Lubricants
Solid	Anthracite Coking Coal Coal Coal Coke Oven Coke Patent Fuel Coke Oven Gas Blast Furnace Gas	Anthracite Coal <sup>2</sup> Coal Slurry <sup>3</sup> Coke Solid Smokeless Fuel (SSF) Coke Oven Gas Blast Furnace Gas
Gas	Natural Gas Natural Gas Colliery Methane <sup>5</sup>	Natural Gas Sour Gas <sup>4</sup> Colliery Methane
Other Fuels	Municipal Solid Waste Industrial Waste: Scrap Tyres	Municipal Solid Waste Scrap Tyres
Biomass	Wood/Wood Waste Other Solid Biomass: Straw Other Solid Biomass: Poultry Litter, Meat & Bone Meal Landfill Gas Sludge Gas	Wood Straw Poultry Litter, Meat & bone meal  Landfill Gas Sewage Gas

1 Includes fuel that is correctly termed jet gasoline.

2 Used in coke ovens.

3 Coal-water slurry used in some power stations

4 Unrefined natural gas used on offshore platforms and some power stations

5 Not referred to in IPCC Guidelines (IPCC, 1997a) but included in GHGI.

## **A3.2 NAEI SOURCE CATEGORIES AND IPCC EQUIVALENTS**

**Tables A3.2.1 to A3.2.7** relate the IPCC source categories to the equivalent NAEI base categories. In most cases it is possible to obtain a precise mapping of an NAEI source category to a specific IPCC source category. In some cases the relevant NAEI source category does not correspond exactly to the IPCC source category and in a few cases an equivalent NAEI source category is not estimated or is defined quite differently. As a result, total annual emissions given in the NAEI and GHGI differ slightly. The source categories responsible for the differences between the GHGI and the NAEI are:

- 1A3a Civil Aviation
- 5 Land Use Change and Forestry
- Forests (NMVOC emission only reported in the NAEI)

**Tables A3.2.1 to A3.2.7** refer to NAEI base categories. Normally the NAEI is not reported in such a detailed form but in the summary UNECE/CORINAIR SNAP97, eleven-sector format or the new NRF (Nomenclature or Reporting) system used for submission to CORINAIR.

**Table A3.2.1** Mapping of IPCC Source Categories to NAEI Source Categories:  
IPCC Table 1A

IPCC Source Category	NAEI Source Category
1A1a Public Electricity and Heat Production	Power Stations
1A1b Petroleum Refining	Refineries (Combustion)
1A1ci Manufacture of Solid Fuels	SSF Production Coke Production
1A1cii Other Energy Industries	Collieries Gas Production Gas Separation Plant (Combustion) Offshore Own Gas Use Production of Nuclear Fuel Town Gas Production
1A2a Iron and Steel	Iron and Steel (Combustion) Iron and Steel (Sinter Plant) Iron and Steel (Blast Furnaces)
1A2b Non-Ferrous Metals 1A2c Chemicals 1A2d Pulp, Paper and Print 1A2e Food Processing, Beverages, Tobacco	Included under Other Industry (Combustion)
1A2fi Other	Other Industry (Combustion) Cement (Fuel Combustion) Cement (Non-decarbonising) Lime Production (Combustion) Autogenerators Ammonia (Combustion)
1A2fii Other (Off-road Vehicles and Other Machinery)	Other Industry Off-road
1A3a Civil Aviation	No comparable category
1A3b Road Transportation	Road Transport
1A3c Railways	Railways (Freight) Railways (Intercity) Railways (Regional)
1A3di International Marine	International Marine
1A3dii Internal Navigation	Coastal Shipping
1A3e Other Transport	Aircraft Support
1A4a Commercial/Institutional	Miscellaneous Public Services Railways (Stationary Sources)
1A4bi Residential	Domestic
1A4bii Residential Off-road	Domestic, House & Garden
1A4ci Agriculture/Forestry/Fishing (Stationary)	Agriculture
1A4cii Agriculture/Forestry/Fishing (Off-road Vehicles and Other Machinery)	Agriculture Power Units
1A4ciii Agriculture/Forestry/Fishing (Fishing)	Fishing
1A5a Other: Stationary	No comparable category-included in 1A4a
1A5b Other: mobile	Aircraft Military Shipping Naval

**Table A3.2.2** Mapping of IPCC Source Categories to NAEI Source Categories:  
IPCC Table 1B

IPCC Source Category	NAEI Source Category
1B1a Coal Mining i Mining activities	Deep-Mined Coal
1B1a Coal Mining ii Post mining activities	Coal Storage & Transport
1B1a Coal Mining ii Surface Mines	Open-Cast Coal
1B1b Solid Fuel Transformation	Coke Production (Fugitive) SSF Production (Fugitive) Flaring (Coke Oven Gas)
1B1c Other	Not Estimated
1B2a Oil i Exploration	Offshore Oil and Gas (Well Testing)
1B2a Oil ii Production	Offshore Oil and Gas
1B2a Oil iii Transport	Offshore Loading Onshore Loading
1B2a Oil iv Refining/Storage	Refineries (drainage) Refineries (tankage) Refineries (Process) Oil Terminal Storage Petroleum Processes
1B2a Oil vi Other	Not Estimated
1B2a Oil v Distribution of oil products	Petrol Stations (Petrol Delivery) Petrol Stations (Vehicle Refuelling) Petrol Stations (Storage Tanks) Petrol Stations (Spillages) Petrol Terminals (Storage) Petrol Terminals (Tanker Loading) Refineries (Road/Rail Loading)
1B2b i Natural Gas Production	Gasification Processes
1B2b ii Natural Gas. Transmission/Distribution	Gas Leakage
1B2ciii Venting: Combined	Offshore Oil and Gas (Venting)
1B2ciii Flaring: Combined	Offshore Flaring Refineries (Flares)

**Table A3.2.3** Mapping of IPCC Source Categories to NAEI Source Categories:  
IPCC Table 2

IPCC Source Category	NAEI Source Category
2A1 Cement Production	Cement (Decarbonising)
2A2 Lime Production	Lime Production (Decarbonising)
2A3 Limestone and Dolomite Use	Glass Production: Limestone and Dolomite Iron and Steel (Blast Furnace): Limestone and Dolomite Power Stations (FGD)
2A4 Soda Ash Production and Use	Glass Production: Soda Ash
2A5 Asphalt Roofing	Not Estimated
2A6 Road Paving with Asphalt	Road Construction
2A7 Other	Brick Manufacture (Fletton) Glass (continuous filament glass fibre) Glass (glass wool)
2B1 Ammonia Production	Ammonia Feedstock
2B2 Nitric Acid Production	Nitric Acid Production
2B3 Adipic Acid Production	Adipic Acid Production
2B4 Carbide Production	
2B5 Other	Sulphuric Acid Production Chemical Industry Chemical Industry (Carbon Black) Chemical Industry (Ethylene) Chemical Industry (Methanol) Chemical Industry (Nitric Acid Use) Chemical Industry (Pigment Manufacture) Chemical Industry (Reforming) Chemical Industry (Sulphuric Acid Use) Coal, tar and bitumen processes Solvent and Oil recovery Ship purging
2C1 Iron and Steel	Iron and Steel (other) Iron and Steel (Basic Oxygen Furnace) Iron and Steel (Electric Arc Furnace) Iron and Steel Flaring (Blast Furnace Gas) Rolling Mills (Hot & Cold Rolling)
2C2 Ferroalloys Productions	No Comparable Source Category
2C3 Aluminium Production	Non-Ferrous Metals (Aluminium Production)
2C4 SF <sub>6</sub> Used in Aluminium and Magnesium Foundries	SF <sub>6</sub> Cover Gas
2C5 Other	Non-Ferrous Metals (other non-ferrous metals) Non-Ferrous Metals (primary lead/zinc) Non-Ferrous Metals (secondary Copper) Non-Ferrous Metals (secondary lead)
2D1 Pulp and Paper	Wood Products Manufacture

IPCC Source Category	NAEI Source Category
2D2 Food and Drink	Brewing (barley malting, fermentation, wort boiling) Bread Baking Cider Manufacture Other Food (animal feed; cakes, biscuits, cereals; coffee, malting, margarine and other solid fats; meat, fish and poultry; sugar) Spirit Manufacture (barley malting, casking, distillation, fermentation, maturation, spent grain drying) Wine Manufacture
2E1 Halocarbon & SF6 By-Product Emissions	Halocarbons Production (By-Product and Fugitive)
2E2 Halocarbon & SF6 Fugitive Emissions	
2E3 Halocarbon & SF6 Other	Not Estimated
2F1 Refrigeration & Air Conditioning Equipment	Refrigeration Supermarket Refrigeration Mobile Air Conditioning
2F2 Foam Blowing	Foams
2F3 Fire Extinguishers	Fire Fighting
2F2 Aerosols	Metered Dose Inhalers Aerosols (Halocarbons)
2F5 Solvents	Not Occurring
2F8a One Component Foams	
2F8 Semiconductors, Electrical and Production of Trainers	Electronics Training Shoes Electrical Insulation

**Table A3.2.4** Mapping of IPCC Source Categories to NAEI Source Categories:  
IPCC Table 3

IPCC Source Category	NAEI Source Category
3A Paint Application	Decorative paint (retail decorative) Decorative paint (trade decorative) Industrial Coatings (automotive) Industrial Coatings (agriculture & construction) Industrial Coatings (aircraft) Industrial Coatings (Drum) Industrial Coatings (coil coating) Industrial Coatings (commercial vehicles) Industrial Coatings (high performance) Industrial Coatings (marine) Industrial Coatings (metal and plastic) Industrial Coatings (metal packaging) Industrial Coatings (vehicle refinishing) Industrial Coatings (wood)
3B Degreasing & Dry Cleaning	Dry Cleaning Surface Cleaning Leather Degreasing
3C Chemical Products, Manufacture & Processing	Coating Manufacture (paint) Coating Manufacture (ink) Coating Manufacture (glue) Film Coating Leather coating Other Rubber Products Tyre Manufacture Textile Coating
3D Other	Aerosols (Car care, Cosmetics & toiletries, household products) Agrochemicals Use Industrial Adhesives Paper Coating Printing Other Solvent Use Non Aerosol Products (household, automotive, cosmetics & toiletries, domestic adhesives, paint thinner) Seed Oil Extraction Wood Impregnation



**Table A3.2.5** Mapping of IPCC Source Categories to NAEI Source Categories:  
IPCC Table 4

IPCC Source Category	NAEI Source Category
4A1 Enteric Fermentation: Cattle	Dairy Cattle Enteric Other Cattle Enteric
4A2 Enteric Fermentation: Buffalo	Not Occurring
4A3 Enteric Fermentation: Sheep	Sheep Enteric
4A4 Enteric Fermentation: Goats	Goats Enteric
4A5 Enteric Fermentation: Camels & Llamas	Not Occurring
4A6 Enteric Fermentation: Horses	Horses Enteric
4A7 Enteric Fermentation: Mules & Asses	Not Occurring
4A8 Enteric Fermentation: Swine	Pigs Enteric
4A9 Enteric Fermentation: Poultry	Not Occurring
4A10 Enteric Fermentation: Other: Deer	Deer Enteric
4B1 Manure Management: Cattle	Dairy Cattle Wastes Other Cattle Wastes
4B2 Manure Management: Buffalo	Not Occurring
4B3 Manure Management: Sheep	Sheep Wastes
4B4 Manure Management: Goats	Goats Wastes
4B5 Manure Management: Camels & Llamas	Not Occurring
4B6 Manure Management: Horses	Horses Wastes
4B7 Manure Management: Mules & Asses	Not Occurring
4B8 Manure Management: Swine	Pigs Wastes
4B9 Manure Management: Poultry	Broilers Wastes Laying Hens Wastes Other Poultry
4B9a Manure Management: Other: Deer	Deer Wastes
4B10 Anaerobic Lagoons	Not Occurring
4B11 Liquid Systems	Manure Liquid Systems
4B12 Solid Storage and Dry Lot	Manure Solid Storage and Dry Lot
4B13 Other	Manure Other
4C Rice Cultivation	Not Occurring
4D 1 Agricultural Soils: Direct Soil Emissions 4D 2 Agricultural Soils: Animal Emissions 4D 4 Agricultural Soils: Indirect Emissions	Agricultural Soils Fertiliser Agricultural Soils Crops
4E Prescribed Burning of Savannahs	Not Occurring
4F1 Field Burning of Agricultural Residues: Cereals	Barley Residue Wheat Residue Oats Residue
4F5 Field Burning of Agricultural Residues: Other: Linseed	Linseed Residue
4G Other	Not Estimated

The LULUCF categories in the table below are the old reporting categories; these categories are still used in the NAEI database to allow comparisons with previous GHG inventories, but emissions in this NIR are reported used the reporting nomenclature specified in the LULUCF Good Practice Guidance. The categories will be modified in the 2005 database.

**Table A3.2.6** Mapping of IPCC Source Categories to NAEI Source Categories:  
IPCC Table 5

IPCC Source Category <sup>1</sup>	NAEI Source Category
5A Changes in Forest and Other Woody Biomass Stocks	Not estimated
5B Forest and Grassland Conversion	5B2 Deforestation
5C Abandonment of Managed Lands	Not estimated
5D CO <sub>2</sub> Emissions and Removals from Soil	Agricultural Soils: Limestone Agricultural Soils: Dolomite
5E Other	Not estimated

1 Categories 5A, 5B, 5C and 5E are not included in the NAEI because a time series back to 1970 is unavailable. They are included in the Green House Gas Inventory.

**Table A3.2.7** Mapping of IPCC Source Categories to NAEI Source Categories:  
IPCC Tables 6 & 7

IPCC Source Category	NAEI Source Category
6A1 Managed Waste Disposal on Land	Landfill
6A2 Unmanaged Waste Disposal on Land	Not Occurring
6A3 Other	Not Occurring
6B1 Industrial Wastewater 6B2 Domestic and Commercial Wastewater 6B3 Other	Sewage Sludge Disposal
6C Waste Incineration	Incineration: MSW Incineration: Sewage Sludge Incineration: Clinical Incineration: Cremation
6D Other Waste	Not estimated

## A3.3 ENERGY (CRF SECTOR 1)

The previous two sections defined the fuels and source categories used in the NAEI and the GHGI. This section describes the methodology used to estimate the emissions arising from fuel combustion for energy. These sources correspond to IPCC Table 1A.

There is little continuous monitoring of emissions performed in the UK; hence information is rarely available on actual emissions over a specific period of time from an individual emission source. In any case, emissions of CO<sub>2</sub> from fuel are probably estimated more accurately from fuel consumption data. The majority of emissions are estimated from other information such as fuel consumption, distance travelled or some other statistical data related to the emissions. Estimates for a particular source sector are calculated by applying an emission factor to an appropriate statistic. That is:

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

Emission factors are typically derived from measurements on a number of representative sources and the resulting factor applied to the UK environment.

For the indirect gases, emissions data are sometimes available for individual sites from databases such as the Environment Agency's Pollution Inventory (PI). Hence the emission for a particular sector can be calculated as the sum of the emissions from these point sources. That is:

$$\text{Emission} = \Sigma \text{ Point Source Emissions}$$

However it is still necessary to make an estimate of the fuel consumption associated with these point sources, so that the emissions from non-point sources can be estimated from fuel consumption data without double counting. In general the point source approach is only applied to emissions of indirect greenhouse gases for well-defined point sources (e.g. power stations, cement kilns, coke ovens, refineries). Direct greenhouse gas emissions and most non-industrial sources are estimated using emission factors.

### **A3.3.1 Basic combustion module**

For the pollutants and sources discussed in this section the emission results from the combustion of fuel. The activity statistics used to calculate the emission are fuel consumption statistics taken from DTI (2005). A file of the fuel combustion data used in the inventory is provided on a CD ROM attached to this report. Emissions are calculated according to the equation:

$$E(p,s,f) = A(s,f) \times e(p,s,f)$$

where

$$\begin{aligned} E(p,s,f) &= \text{Emission of pollutant } p \text{ from source } s \text{ from fuel } f \text{ (kg)} \\ A(s,f) &= \text{Consumption of fuel } f \text{ by source } s \text{ (kg or kJ)} \\ e(p,s,f) &= \text{Emission factor of pollutant } p \text{ from source } s \text{ from fuel } f \text{ (kg/kg or kg/kJ)} \end{aligned}$$

The pollutants estimated in this way are:

- Carbon dioxide as carbon
- Methane
- Nitrous oxide

- NO<sub>x</sub> as nitrogen dioxide
- NMVOC
- Carbon monoxide
- Sulphur dioxide

The sources covered by this module are:

- Domestic
- Miscellaneous
- Public Service
- Refineries (Combustion)
- Iron & Steel (Combustion)
- Iron & Steel (Blast Furnaces)
- Iron & Steel (Sinter Plant)
- Other Industry (Combustion)
- Autogenerators
- Gas Production
- Collieries
- Production of Nuclear Fuel
- Coastal Shipping
- Fishing
- Agriculture
- Ammonia (Combustion)
- Railways (Stationary Sources)
- Aircraft Military
- Shipping Naval

The fuels covered are listed in **Annex 3, Section 3.1**, though not all fuels occur in all sources.

Beginning with the 2003 inventory, a major change has been made to the estimation of CO & NO<sub>x</sub> emissions from industrial, commercial/institutional, and domestic sources. Whereas, previously, a single emission factor would be applied for a given source/fuel combination, the new methodology allows source/fuel combinations to be further broken down by a) thermal input of combustion devices; b) type of combustion process e.g. boilers, furnaces, turbines etc. Different emission factors are applied to these subdivisions of the source/fuel combination. Most of these emission factors are taken from literature sources, predominantly from US EPA, (2005), EMEP/CORINAIR (2003), and Walker *et al*, (1985). Some emissions data reported in the Pollution Inventory (Environment Agency, 2005) are also used to generate emission factors.

**Tables A3.3.1 to A3.3.4** list the emission factors used in this module. Emission factors are expressed in terms of kg pollutant/tonne for solid and liquid fuels, and g/TJ gross for gases. This differs from the IPCC approach, which expresses emission factors as tonnes pollutant/TJ based on the *net calorific value* of the fuel. For gases the NAEI factors are based on the *gross calorific value* of the fuel. This approach is used because the gas consumption data in DTI (2005) are reported in terms of energy content on a gross basis.

For most of the combustion source categories, the emission is estimated from fuel consumption data reported in DUKES and an emission factor appropriate to the type of combustion e.g. commercial gas fired boiler. However the DUKES category ‘Other Industries’ covers a range of sources and types, so the Inventory disaggregates this category into a number of sub-categories, namely:

- Other Industry
- Other Industry Off-road
- Ammonia Feedstock (natural gas only)
- Ammonia (Combustion) (natural gas only)
- Cement (Combustion)
- Lime Production (non-decarbonising)

Thus the GHGI category Other Industry refers to stationary combustion in boilers and heaters by industries not covered elsewhere (including the chemicals, food & drink, non-ferrous metal, glass, ceramics & bricks, textiles & engineering sectors). The other categories are estimated by more complex methods discussed in the sections indicated. For certain industrial processes (e.g. Lime production, cement production and ammonia production), the methodology is discussed in **Section A3.4** as the estimation of the fuel consumption is closely related to the details of the process. However, for these processes, where emissions arise from fuel combustion for energy production, these are *reported* under IPCC Table 1A. The fuel consumption of Other Industry is estimated so that the total fuel consumption of these sources is consistent with DUKES (DTI, 2005).

According to IPCC 1996 Revised Guidelines, electricity generation by companies primarily for their own use is autogeneration, and the emissions produced should be reported under the industry concerned. However, most National Energy Statistics (including the UK) report emissions from electricity generation as a separate category. The UK inventory attempts to report as far as possible according to the IPCC methodology. Hence autogenerators would be reported in the relevant sector where they can be identified e.g. iron and steel (combustion), refineries (combustion). In some cases the autogenerator cannot be identified from the energy statistics so it would be classified as other industry (combustion). This means that the split between iron and steel (combustion) and other industry (combustion) may be uncertain. Also, for certain sectors, data on fuel deliveries are used in preference to data on fuel consumption because deliveries will include autogeneration whereas consumption does not.

**Table A3.3.1** Emission Factors for the Combustion of Liquid Fuels for 2004<sup>14</sup> (kg/t)

Fuel	Source	C <sup>aj</sup>	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	CO	NMVOC	SO <sub>2</sub>
ATF	Aircraft Military	859 <sup>a</sup>	0.103 <sup>ad</sup>	0.1 <sup>g</sup>	8.5 <sup>ad</sup>	8.2 <sup>ad</sup>	1.1 <sup>ad</sup>	0.66 <sup>z</sup>
Burning Oil	Domestic	859 <sup>a</sup>	0.462 <sup>g</sup>	0.0277 <sup>g</sup>	3.23 <sup>l</sup>	1.85 <sup>l</sup>	0.048 <sup>f</sup>	0.54 <sup>z</sup>
Burning Oil (P)	Domestic	859 <sup>a</sup>	0.462 <sup>g</sup>	0.0277 <sup>g</sup>	3.23 <sup>l</sup>	1.85 <sup>l</sup>	0.048 <sup>f</sup>	0.01 <sup>z</sup>
Burning Oil	Other Industry	859 <sup>a</sup>	0.0924 <sup>g</sup>	0.0277 <sup>g</sup>	3.06 <sup>l</sup>	0.17 <sup>l</sup>	0.028 <sup>e</sup>	0.54 <sup>z</sup>
Burning Oil	Public Service, Railways (Stationary)	859 <sup>a</sup>	0.462 <sup>g</sup>	0.0277 <sup>g</sup>	2.05 <sup>l</sup>	0.16 <sup>l</sup>	0.048 <sup>f</sup>	0.54 <sup>z</sup>
Burning Oil	Miscellaneous	859 <sup>a</sup>	0.462 <sup>g</sup>	0.0277 <sup>g</sup>	2.70 <sup>l</sup>	0.16 <sup>l</sup>	0.048 <sup>f</sup>	0.54 <sup>z</sup>
Gas Oil	Agriculture	870 <sup>a</sup>	0.225 <sup>g</sup>	0.0273 <sup>g</sup>	NA	NA	0.048 <sup>f</sup>	2.98 <sup>z</sup>
Gas Oil	Domestic	870 <sup>a</sup>	0.455 <sup>g</sup>	0.0273 <sup>g</sup>	3.19 <sup>l</sup>	1.82 <sup>l</sup>	0.048 <sup>f</sup>	2.98 <sup>z</sup>
Gas Oil	Fishing; Coastal Shipping, Naval; International Marine	870 <sup>a</sup>	0.288 <sup>c</sup>	0.2 <sup>t</sup>	57 <sup>t</sup>	7.4 <sup>t</sup>	2.11 <sup>c</sup>	19.4 <sup>h</sup>
Gas Oil	Iron&Steel	870 <sup>a</sup>	0.0910 <sup>g</sup>	0.0273 <sup>g</sup>	17.28 <sup>l</sup>	6.72 <sup>l</sup>	0.028 <sup>f</sup>	2.98 <sup>z</sup>
Gas Oil	Refineries	870 <sup>a</sup>	0.0136 <sup>g</sup>	0.0273 <sup>g</sup>	4.56 <sup>k</sup>	0.24 <sup>i</sup>	0.028 <sup>f</sup>	2.98 <sup>z</sup>
Gas Oil	Other Industry	870 <sup>a</sup>	0.0910 <sup>g</sup>	0.0273 <sup>g</sup>	4.28 <sup>l</sup>	0.54 <sup>l</sup>	0.028 <sup>f</sup>	2.98 <sup>z</sup>
Gas Oil	Public Service	870 <sup>a</sup>	0.455 <sup>g</sup>	0.0273 <sup>g</sup>	2.44 <sup>l</sup>	0.38 <sup>l</sup>	0.048 <sup>f</sup>	2.98 <sup>z</sup>
Gas Oil	Miscellaneous	870 <sup>a</sup>	0.455 <sup>g</sup>	0.0273 <sup>g</sup>	1.47 <sup>l</sup>	0.19 <sup>l</sup>	0.048 <sup>f</sup>	2.98 <sup>z</sup>
Fuel Oil	Agriculture	879 <sup>a</sup>	0.433 <sup>g</sup>	0.026 <sup>g</sup>	7.69 <sup>l</sup>	0.31 <sup>l</sup>	0.14 <sup>f</sup>	16.46 <sup>z</sup>
Fuel Oil	Public Service	879 <sup>a</sup>	0.433 <sup>g</sup>	0.026 <sup>g</sup>	7.21 <sup>l</sup>	0.83 <sup>l</sup>	0.14 <sup>f</sup>	16.46 <sup>z</sup>
Fuel Oil	Miscellaneous	879 <sup>a</sup>	0.433 <sup>g</sup>	0.026 <sup>g</sup>	4.00 <sup>l</sup>	0.16 <sup>l</sup>	0.14 <sup>f</sup>	16.46 <sup>z</sup>
Fuel Oil	Fishing; Coastal Shipping, International Marine	879 <sup>a</sup>	0.288 <sup>c</sup>	0.2 <sup>t</sup>	57 <sup>t</sup>	7.4 <sup>t</sup>	2.11 <sup>c</sup>	56.4 <sup>h</sup>
Fuel Oil	Domestic	879 <sup>a</sup>	0.433 <sup>g</sup>	0.026 <sup>g</sup>	3.19 <sup>l</sup>	1.82 <sup>l</sup>	0.14 <sup>f</sup>	16.46 <sup>z</sup>
Fuel Oil	Iron&Steel	879 <sup>a</sup>	0.087 <sup>g</sup>	0.026 <sup>g</sup>	6.83 <sup>l</sup>	0.88 <sup>l</sup>	0.035 <sup>f</sup>	16.46 <sup>z</sup>
Fuel Oil	Railways (Stationary)	879 <sup>a</sup>	0.433 <sup>g</sup>	0.026 <sup>g</sup>	7.21 <sup>l</sup>	0.83 <sup>l</sup>	0.14 <sup>f</sup>	16.46 <sup>z</sup>
Fuel Oil	Other Industry	879 <sup>a</sup>	0.087 <sup>g</sup>	0.026 <sup>g</sup>	7.02 <sup>l</sup>	0.90 <sup>l</sup>	0.035 <sup>f</sup>	16.46 <sup>z</sup>
Fuel Oil	Refineries (Combustion)	879 <sup>a</sup>	0.130 <sup>g</sup>	0.026 <sup>g</sup>	3.89 <sup>ag</sup>	1.37 <sup>ag</sup>	0.035 <sup>f</sup>	14.48 <sup>ag</sup>
Lubricants	Other Industry	865 <sup>x</sup>	0.091 <sup>e</sup>	0.027 <sup>e</sup>	4.56 <sup>k</sup>	0.26 <sup>f</sup>	0.14 <sup>f</sup>	11.4 <sup>x</sup>

<sup>14</sup> These are the factors used the latest inventory year. The corresponding time series of emission factors and calorific values may be available electronically [on the CD accompanying this report].

Fuel	Source	C <sup>aj</sup>	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	CO	NMVOC	SO <sub>2</sub>
Naphtha	Refineries	854 <sup>a</sup>	0.130 <sup>an</sup>	0.026 <sup>g</sup>	4.62 <sup>k</sup>	0.24 <sup>e</sup>	0.028 <sup>e</sup>	0.2 <sup>af</sup>
Petrol	Refineries	855 <sup>a</sup>	0.141 <sup>an</sup>	0.028 <sup>g</sup>	4.62 <sup>k</sup>	0.24 <sup>e</sup>	0.028 <sup>e</sup>	0.07 <sup>z</sup>

**Table A3.3.2** Emission Factors for the Combustion of Coal for 2004<sup>15</sup> (kg/t)

Source	C <sup>aj</sup>	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	CO	NMVOC	SO <sub>2</sub>
Agriculture	639.1 <sup>ao</sup>	0.011 <sup>o</sup>	0.148 <sup>w</sup>	4.75 <sup>l</sup>	8.25 <sup>l</sup>	0.05 <sup>o</sup>	20.42 <sup>aa</sup>
Collieries	689.6 <sup>ao</sup>	0.011 <sup>o</sup>	0.146 <sup>w</sup>	4.75 <sup>l</sup>	8.25 <sup>l</sup>	0.05 <sup>o</sup>	24.78 <sup>aa</sup>
Domestic	692.5 <sup>ao</sup>	15.7 <sup>o</sup>	0.122 <sup>w</sup>	3.47 <sup>l</sup>	180.7 <sup>l</sup>	14 <sup>o</sup>	18.57 <sup>aa</sup>
Iron and Steel (Combustion)	693.8 <sup>a</sup>	0.011 <sup>o</sup>	0.237 <sup>w</sup>	IE	IE	0.05 <sup>o</sup>	20.42 <sup>aa</sup>
Lime Production (Combustion)	614.5 <sup>ao</sup>	0.011 <sup>o</sup>	0.215 <sup>w</sup>	68.1 <sup>v</sup>	37.14 <sup>v</sup>	0.05 <sup>o</sup>	20.42 <sup>aa</sup>
Miscellaneous	714.8 <sup>ao</sup>	0.011 <sup>o</sup>	0.147 <sup>w</sup>	4.69 <sup>l</sup>	7.95 <sup>l</sup>	0.05 <sup>o</sup>	20.42 <sup>aa</sup>
Public Service	714.8 <sup>ao</sup>	0.011 <sup>o</sup>	0.147 <sup>w</sup>	4.78 <sup>l</sup>	8.93 <sup>l</sup>	0.05 <sup>o</sup>	20.42 <sup>aa</sup>
Other Industry	614.5 <sup>ao</sup>	0.011 <sup>o</sup>	0.215 <sup>w</sup>	4.00 <sup>l</sup>	1.65 <sup>l</sup>	0.05 <sup>o</sup>	20.42 <sup>aa</sup>
Railways	714.8 <sup>ao</sup>	0.011 <sup>o</sup>	0.147 <sup>w</sup>	4.78 <sup>l</sup>	8.93 <sup>l</sup>	0.05 <sup>o</sup>	20.42 <sup>aa</sup>
Autogenerators	614.5 <sup>ao</sup>	0.02 <sup>o</sup>	0.0664 <sup>w</sup>	6.16 <sup>l</sup>	1.33 <sup>l</sup>	0.03 <sup>o</sup>	20.42 <sup>aa</sup>

<sup>15</sup> These are the factors used the latest inventory year. The corresponding time series of emission factors and calorific values may be available electronically [on the CD accompanying this report].

**Table A3.3.3** Emission Factors for the Combustion of Solid Fuels 2004<sup>16</sup> (kg/t)

Fuel	Source	C <sup>aj</sup>	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	CO	NMVOC	SO <sub>2</sub>
Anthracite	Domestic	818.2 <sup>ap</sup>	2 <sup>o</sup>	0.14 <sup>w</sup>	3.38 <sup>k</sup>	202.8 <sup>k</sup>	1.7 <sup>o</sup>	13.94 <sup>aa</sup>
Coke	Agriculture	781.4 <sup>r</sup>	0.011 <sup>p</sup>	0.149 <sup>w</sup>	19.26 <sup>l</sup>	0.059 <sup>l</sup>	0.05 <sup>p</sup>	19 <sup>ab</sup>
Coke	SSF Production	781.4 <sup>r</sup>	0.011 <sup>p</sup>	0.221 <sup>w</sup>	4.47 <sup>k</sup>	4.1 <sup>p</sup>	0.05 <sup>p</sup>	19 <sup>ab</sup>
Coke	Domestic	781.4 <sup>r</sup>	5.8 <sup>o</sup>	0.116 <sup>w</sup>	3.04 <sup>l</sup>	118.6 <sup>l</sup>	4.9 <sup>o</sup>	13.94 <sup>aa</sup>
Coke	I&S <sup>ak</sup> (Sinter Plant)	781.4 <sup>r</sup>	1.47 <sup>ae</sup>	0.228 <sup>w</sup>	10.51 <sup>ae</sup>	278.2 <sup>ae</sup>	0.28 <sup>ae</sup>	10.42 <sup>ae</sup>
Coke	I&S <sup>ak</sup> (Combustion)	781.4 <sup>r</sup>	0.011 <sup>p</sup>	0.228 <sup>w</sup>	0.87 <sup>l</sup>	226.2 <sup>l</sup>	0.05 <sup>p</sup>	19 <sup>ab</sup>
Coke	Other Industry	781.4 <sup>r</sup>	0.011 <sup>p</sup>	0.228 <sup>w</sup>	19.26 <sup>l</sup>	0.059 <sup>l</sup>	0.05 <sup>p</sup>	19 <sup>ab</sup>
Coke	Railways	781.4 <sup>r</sup>	0.011 <sup>p</sup>	0.149 <sup>w</sup>	19.26 <sup>l</sup>	0.059 <sup>l</sup>	0.05 <sup>p</sup>	19 <sup>ab</sup>
Coke	Miscellaneous; Public Service	781.4 <sup>r</sup>	0.011 <sup>p</sup>	0.149 <sup>w</sup>	19.26 <sup>l</sup>	0.059 <sup>l</sup>	0.05 <sup>p</sup>	19 <sup>ab</sup>
MSW	Miscellaneous	75 <sup>ah</sup>	2.85 <sup>g</sup>	0.038 <sup>g</sup>	1.52 <sup>v</sup>	0.12 <sup>v</sup>	0.007 <sup>v</sup>	0.061 <sup>v</sup>
Petroleum Coke	Domestic	930 <sup>a</sup>	NE	NE	3.95 <sup>k</sup>	158 <sup>k</sup>	4.9 <sup>am</sup>	19 <sup>ab</sup>
Petroleum Coke	Refineries	930 <sup>a</sup>	0.0152 <sup>ai</sup>	0.281 <sup>w</sup>	10.21 <sup>ag</sup>	1.47 <sup>ag</sup>	0.069 <sup>ai</sup>	39.5 <sup>ag</sup>
SSF	Agriculture; Miscellaneous; Public Service	766.3 <sup>n</sup>	0.011 <sup>p</sup>	0.151 <sup>w</sup>	4.67 <sup>k</sup>	46.65 <sup>k</sup>	0.05 <sup>p</sup>	19 <sup>ab</sup>
SSF	Domestic	774.2 <sup>n</sup>	5.8 <sup>o</sup>	0.118 <sup>w</sup>	3.11 <sup>k</sup>	124.4 <sup>k</sup>	4.9 <sup>o</sup>	16 <sup>ab</sup>
SSF	Other Industry	766.3 <sup>n</sup>	0.011 <sup>p</sup>	0.232 <sup>w</sup>	4.67 <sup>k</sup>	46.65 <sup>k</sup>	0.05 <sup>p</sup>	19 <sup>ab</sup>
Straw	Agriculture	418 <sup>g</sup>	4.5 <sup>g</sup>	0.06 <sup>g</sup>	1.5 <sup>g</sup>	75 <sup>g</sup>	9 <sup>g</sup>	0
Wood	Domestic	278 <sup>g</sup>	3 <sup>g</sup>	0.04 <sup>g</sup>	0.5 <sup>k</sup>	50 <sup>g</sup>	17 <sup>k</sup>	0.108 <sup>f</sup>

<sup>16</sup> These are the factors used the latest inventory year. The corresponding time series of emission factors and calorific values may be available electronically [on the CD accompanying this report].



**Table A3.3.4** Emission Factors for the Combustion of Gaseous Fuels 2004<sup>17</sup> (g/GJ gross)

Fuel	Source	C <sup>aj</sup>	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	CO	NMVOC	SO <sub>2</sub>
Blast Furnace Gas	Coke Production	72964 <sup>r</sup>	112 <sup>k</sup>	2.0 <sup>k</sup>	79 <sup>k</sup>	39.5 <sup>k</sup>	5.6 <sup>k</sup>	0
Blast Furnace Gas	I&S <sup>ak</sup> (Combustion), I&S <sup>ak</sup> (Flaring)	72964 <sup>r</sup>	112 <sup>k</sup>	2.0 <sup>k</sup>	79 <sup>k</sup>	39.5 <sup>k</sup>	5.6 <sup>k</sup>	0
Blast Furnace Gas	Blast Furnaces	72964 <sup>r</sup>	112 <sup>k</sup>	2.0 <sup>k</sup>	19.6 <sup>v</sup>	39.5 <sup>k</sup>	5.6 <sup>k</sup>	0
Coke Oven Gas	Other Sources	11072 <sup>r</sup>	57.25 <sup>k</sup>	2.0 <sup>k</sup>	80.5 <sup>k</sup>	40.0 <sup>k</sup>	4.35 <sup>k</sup>	241 <sup>v</sup>
Coke Oven Gas	I&S <sup>ak</sup> Blast Furnaces	11072 <sup>r</sup>	57.25 <sup>k</sup>	2.0 <sup>k</sup>	19.6 <sup>v</sup>	40.0 <sup>k</sup>	4.35 <sup>k</sup>	241 <sup>v</sup>
Coke Oven Gas	Coke Production	11072 <sup>r</sup>	57.25 <sup>k</sup>	2.0 <sup>k</sup>	352 <sup>v</sup>	40.0 <sup>k</sup>	4.35 <sup>k</sup>	241 <sup>v</sup>
LPG	Domestic	16227 <sup>a</sup>	0.896 <sup>f</sup>	0.10 <sup>g</sup>	64.8 <sup>f</sup>	8.9 <sup>f</sup>	1.55 <sup>f</sup>	0
LPG	I&S <sup>ak</sup> , Other Industry, Refineries, Gas Production	16227 <sup>a</sup>	0.896 <sup>f</sup>	0.10 <sup>g</sup>	89.3 <sup>f</sup>	15.2 <sup>f</sup>	1.55 <sup>f</sup>	0
Natural Gas	Agriculture	13986 <sup>r</sup>	5.0 <sup>g</sup>	0.10 <sup>g</sup>	39.2 <sup>l</sup>	2.13 <sup>l</sup>	2.21 <sup>f</sup>	0
Natural Gas	Miscellaneous	13986 <sup>r</sup>	5.0 <sup>g</sup>	0.10 <sup>g</sup>	30.0 <sup>l</sup>	9.85 <sup>l</sup>	2.21 <sup>f</sup>	0
Natural Gas	Public Service	13986 <sup>r</sup>	5.0 <sup>g</sup>	0.10 <sup>g</sup>	54.3 <sup>l</sup>	12.2 <sup>l</sup>	2.21 <sup>f</sup>	0
Natural Gas	Coke Production, SSF Prodn <sup>al</sup> ,	13986 <sup>r</sup>	1.0 <sup>g</sup>	0.10 <sup>g</sup>	175.0 <sup>k</sup>	2.37 <sup>l</sup>	2.21 <sup>f</sup>	0
Natural Gas	Refineries	13986 <sup>r</sup>	1.0 <sup>g</sup>	0.10 <sup>g</sup>	70.0 <sup>k</sup>	2.37 <sup>l</sup>	2.21 <sup>f</sup>	0
Natural Gas	Blast Furnaces	13986 <sup>r</sup>	5.0 <sup>g</sup>	0.10 <sup>g</sup>	19.6 <sup>v</sup>	2.37 <sup>l</sup>	2.21 <sup>f</sup>	0
Natural Gas	Domestic	13986 <sup>r</sup>	5.0 <sup>g</sup>	0.10 <sup>g</sup>	69.2 <sup>l</sup>	30.8 <sup>l</sup>	2.21 <sup>f</sup>	0
Natural Gas	Gas Prodn <sup>al</sup> ,	13986 <sup>r</sup>	1.0 <sup>g</sup>	0.10 <sup>g</sup>	84.1 <sup>l</sup>	17.4 <sup>l</sup>	2.21 <sup>f</sup>	0
Natural Gas	I&S <sup>ak</sup>	13986 <sup>r</sup>	1.0 <sup>g</sup>	0.10 <sup>g</sup>	181.5 <sup>l</sup>	181.6 <sup>l</sup>	2.21 <sup>f</sup>	0

<sup>17</sup> These are the factors used the latest inventory year. The corresponding time series of emission factors and calorific values may be available electronically [on the CD accompanying this report]. Note that all carbon emission factors used for Natural Gas include the CO<sub>2</sub> already present in the gas prior to combustion.

<b>Fuel</b>	<b>Source</b>	<b>C<sup>aj</sup></b>	<b>CH<sub>4</sub></b>	<b>N<sub>2</sub>O</b>	<b>NO<sub>x</sub></b>	<b>CO</b>	<b>NMVOC</b>	<b>SO<sub>2</sub></b>
Natural Gas	Railways	13986 <sup>r</sup>	5.0 <sup>g</sup>	0.10 <sup>g</sup>	84.1 <sup>l</sup>	33.8 <sup>l</sup>	2.21 <sup>f</sup>	0
Natural Gas	Other Industry, Nuclear Fuel Prodn <sup>al</sup> , Collieries	13986 <sup>r</sup>	5.0 <sup>g</sup>	0.10 <sup>g</sup>	95.2 <sup>l</sup>	24.3 <sup>l</sup>	2.21 <sup>f</sup>	0
Natural Gas	Autogenerators	13986 <sup>r</sup>	5.0 <sup>g</sup>	0.10 <sup>g</sup>	90.9 <sup>l</sup>	23.7 <sup>l</sup>	2.21 <sup>f</sup>	0
Natural Gas	Ammonia (Combustion)	13986 <sup>r</sup>	5.0 <sup>g</sup>	0.10 <sup>g</sup>	141.9 <sup>d</sup>	NE	2.21 <sup>f</sup>	0
OPG	Gas production, Other Industry	15582 <sup>a</sup>	1.0 <sup>g</sup>	NE	70.0 <sup>k</sup>	2.37 <sup>i</sup>	1.55 <sup>f</sup>	0
OPG	Refineries (Combustion)	15582 <sup>a</sup>	1.0 <sup>g</sup>	NE	82.2 <sup>ag</sup>	6.47 <sup>z</sup>	1.55 <sup>f</sup>	0
Colliery Methane	All Sources	13914 <sup>a</sup>	3.6 <sup>s</sup>	0.10 <sup>g</sup>	70.0 <sup>k</sup>	2.37 <sup>i</sup>	2.21 <sup>f</sup>	0
Sewage Gas	Public Services	27404 <sup>g</sup>	1.0 <sup>g</sup>	0.10 <sup>g</sup>	39.8 <sup>f</sup>	4.2 <sup>f</sup>	1.44 <sup>f</sup>	0
Landfill Gas	Miscellaneous	27404 <sup>g</sup>	5.0 <sup>g</sup>	0.10 <sup>g</sup>	23.2 <sup>f</sup>	73.0 <sup>f</sup>	2.16 <sup>f</sup>	0

## Footnotes to **Tables A3.3.1 to A3.3.4**

a	Carbon Factor Review (2004), Review of Carbon Emission Factors in the UK Greenhouse Gas Inventory. Report to UK Defra. Baggott, SL, Lelland, A, Passant and Watterson, JW (UKPIA (2004)-Liquid Fuels, Transco (2004) – Natural Gas, Quick (2004) and AEP(2004) – Power Station Coal) Note that all carbon emission factors used for Natural Gas include the CO <sub>2</sub> already present in the gas prior to combustion.
b	CORINAIR (1992)
b+	Derived from CORINAIR(1992) assuming 30% of total VOC is methane
c	Methane factor estimated as 12% of total hydrocarbon emission factor taken from EMEP/CORINAIR(1996) based on speciation in IPCC (1997c)
d	Based on operator data: Terra Nitrogen (2005), Invista (2005), BP Chemicals (2005)
e	As for gas oil
f	USEPA (2005)
g	IPCC (1997c)
h	EMEP (1990)
i	Walker <i>et al</i> (1985)
j	As for fuel oil.
k	EMEP/CORINAIR (2003)
l	Netcen estimate based on application of literature emission factors at a greater level of detail than the sector listed (see Section A.3.3.1).
m	USEPA (1997)
n	British Coal (1989)
o	Brain <i>et al</i> , (1994)
p	As for coal
q	EMEP/CORINAIR (2004)
r	Netcen estimate based on carbon balance
s	As for natural gas
t	EMEP/CORINAIR (1996)
u	IPCC (2000)
v	Emission factor derived from emissions reported in the Pollution Inventory (Environment Agency, 2005)
w	Fynes <i>et al</i> (1994)
x	Passant (2005)
y	UKPIA (1989)
z	Emission factor derived from data supplied by UKPIA (2005)
aa	Emission factor for 2004 based on data provided by UK Coal (2005), Scottish Coal (2005), Celtic Energy (2000), Tower (2001), Betwys (2000)
ab	Munday (1990)
ac	Estimated from THC data in CRI (Environment Agency, 1997) assuming 3.% methane split given in EMEP/CORINAIR (1996)
ad	EMEP/CORINAIR (1999)
ae	Netcen estimate based on data from Environment Agency (2005) and Corus (2005)
af	UKPIA (2002)
ag	Netcen estimate based on data from Environment Agency (2005), UKPIA, DUKES, and other sources
ah	Royal Commission on Environmental Pollution (1993)
ai	DTI (1994)
aj	Emission factor as mass carbon per unit fuel consumption
ak	I&S = Iron and Steel
al	Prod'n = Production
am	As for SSF
an	As for burning oil
ao	Netcen estimate based on carbon factors review
NE	Not estimated
NA	Not available
IE	Included elsewhere

### A3.3.2 Conversion of energy activity data and emission factors

The NAEI databases store activity data in Mtonnes for solid and liquid fuels and Mtherms (gross) for gaseous fuels. Emission factors are in consistent units namely: ktonnes/Mtonne for solid and liquid fuels and ktonnes/Mtherm (gross) for gaseous fuels. For some sources emission factors are taken from IPCC and CORINAIR sources and it is necessary to convert them from a net energy basis to a gross energy basis. For solid and liquid fuels:

$$H_n = m h_g f$$

and for gaseous fuels:

$$H_n = H_g f$$

where:

$H_n$	Equivalent energy consumption on net basis(kJ)
$m$	Fuel consumption(kg)
$h_g$	Gross calorific value of fuel(kJ/kg)
$f$	Conversion factor from gross to net energy consumption(-)
$H_g$	Energy Consumption on gross basis(kJ)

In terms of emission factors:

$$e_m = e_n h_g f$$

or

$$e_g = e_n f$$

where:

$e_m$	Emission factor on mass basis(kg/kg)
$e_n$	Emission factor on net energy basis(kg/kJ net)
$e_g$	Emission factor on gross energy basis(kg/kJ gross)

The gross calorific values of fuels used in the UK are tabulated in DTI, (2004). The values of the conversion factors used in the calculations are given in **Table A3.3.5**.

**Table A3.3.5** Conversion Factors for Gross to Net Energy Consumption

Fuel	Conversion Factor
Other Gaseous Fuels	0.9
Solid and Liquid Fuels	0.95
LPG and OPG	0.92
Blast Furnace Gas	1.0

The values given for solid, liquid and other gaseous fuels are taken from IPCC Guidelines (IPCC, 1997c). The value used for LPG is based on the calorific value for butane, the major constituent of LPG (Perry *et al*, 1973). Blast furnace gas consists mainly of carbon monoxide and carbon dioxide. Since little hydrogen is present, the gross calorific value and the net calorific values will be the same.

### **A3.3.3 Energy Industries (1A1)**

#### **A3.3.3.1 Electricity generation**

The NAEI category Power Stations is mapped onto 1A1 Electricity and Heat Production, and this category reports emissions from electricity generation by companies whose main business is producing electricity (Major Power Producers) and hence excludes autogenerators. Activity data for this category are taken from fuel consumption data in the annual publication *The Digest of UK Energy Statistics* (DTI, 2005) in conjunction with site-specific fuel use data obtained directly from plant operators. Coal and natural gas data from DUKES are very close to the category definition (i.e. exclude autogenerators) but fuel oil data does contain a small contribution from transport undertakings and groups of factories. From 1999 onwards, the fuel oil consumption reported within DUKES has been significantly lower than that estimated from returns from the power generators. In the inventory, the fuel oil use data from the power station operators are used; if the DUKES data was to be used, the emission factors implied by the data reported to UK environmental regulators (EA, SEPA, NIDoE) would be impossibly high. A correction is applied to the Other Industry (Combustion) category in the NAEI to ensure that total UK fuel oil consumption corresponds to that reported in DUKES<sup>18</sup>.

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<sup>18</sup> Making use, from 2000 onwards, of supplementary data from DTI because of a revision to the DUKES reporting format.

**Table A3.3.6** Emission Factors for Power Stations in 2004 [A time series of carbon emission factors can be found in the background energy tables on the accompanying CD]

Source	Unit	CO <sub>2</sub> <sup>1</sup>	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	CO	NMVOC	SO <sub>2</sub>
Coal	Kt/Mt	627.2 <sup>a</sup>	0.02 <sup>e</sup>	0.063 <sup>l</sup>	6.023 <sup>n</sup>	1.024 <sup>n</sup>	0.0235 <sup>n</sup>	10.02 <sup>n</sup>
Fuel Oil	Kt/Mt	879 <sup>a</sup>	0.130 <sup>h</sup>	0.0260 <sup>h</sup>	10.37 <sup>n</sup>	1.382 <sup>n</sup>	0.0250 <sup>n</sup>	12.64 <sup>n</sup>
Gas Oil	Kt/Mt	870 <sup>a</sup>	0.136 <sup>h</sup>	0.0273 <sup>h</sup>	210.13 <sup>n</sup>	30.06 <sup>n</sup>	1.01 <sup>n</sup>	67.9 <sup>n</sup>
Natural gas	Kt/Mth	1.476 <sup>a</sup>	0.00011 <sup>h</sup>	1.055E-05 <sup>h</sup>	0.004 <sup>n</sup>	0.0011 <sup>n</sup>	0.00029 <sup>n</sup>	9.904E-05 <sup>n</sup>
MSW	Kt/Mt	75 <sup>d</sup>	0.285 <sup>h</sup>	0.038 <sup>h</sup>	1.517 <sup>o</sup>	0.121 <sup>o</sup>	0.00664 <sup>o</sup>	0.0618 <sup>o</sup>
Sour gas	Kt/Mth	1.916 <sup>c</sup>	0.00011 <sup>h</sup>	1.055E-05 <sup>h</sup>	0.0031 <sup>n</sup>	0.012 <sup>o</sup>	0.0005 <sup>n</sup>	0.00305 <sup>n</sup>
Poultry Litter	Kt/Mt	NE	0.411 <sup>h</sup>	0.0584 <sup>j</sup>	1.217 <sup>n</sup>	0.623 <sup>o</sup>	0.00533 <sup>o</sup>	0.928 <sup>n</sup>
Sewage Gas	Kt/Mth	NE	0.00011 <sup>h</sup>	1.055E-05 <sup>h</sup>	0.0042 <sup>k</sup>	0.00045 <sup>k</sup>	0.00015 <sup>k</sup>	NE
Waste Oils	Kt/Mt	864.84 <sup>b</sup>	NE	NE	10.37 <sup>n</sup>	1.4 <sup>n</sup>	0.025 <sup>n</sup>	12.639 <sup>n</sup>
Landfill gas	Kt/Mth	NE	0.00011 <sup>h</sup>	1.055E-05 <sup>h</sup>	0.0024 <sup>k</sup>	0.0077 <sup>k</sup>	0.00023 <sup>k</sup>	NE

## Footnotes to **A3.3.6** (Emission Factors for Power Stations)

- l Emission factor as mass carbon/ unit fuel consumption
- a Baggott *et al* (2004) - Review of Carbon Emission Factors in the UK Greenhouse Gas Inventory. Report to UK Defra. Baggott, SL, Lelland, A, Passant and Watterson, JW  
(UKPIA (2004)-Liquid Fuels, Transco (2004) – Natural Gas, Quick (2004) and AEP(2004) – Power Station Coal). Note that all carbon emission factors used for Natural Gas include the CO<sub>2</sub> already present in the gas prior to combustion.
- b Passant, N.R., Emission factors programme Task 1 – Summary of simple desk studies (2003/4), AEA Technology Plc, Report No AEAT/ENV/R/1715/Issue 1, March 2004
- c Stewart *et al* (1996a) Emissions to Atmosphere from Fossil Fuel Power Generation in the UK, AEAT-0746, ISBN 0-7058-1753-3
- d RCEP (Royal Commission on Environmental Protection) 17th Report - Incineration of Waste, 1993
- e Brain (1994)
- f Stewart *et al* (1996) estimated from total VOC factor assuming 27.2% is methane after USEPA(1997)
- g CORINAIR (1992)
- h IPCC (1997c)
- i EMEP/CORINAIR (1996)
- j IPCC (1997)
- k USEPA (2004)
- l Fynes *et al* (1994)
- m Stewart (1997)
- n Based on reported emissions data from the EA Pollution Inventory (Environment Agency, 2005), SEPA's EPER inventory (SEPA, 2005), NI DoE's ISR list (NI DoE, 2005) and direct communications with plant operators (Pers. Comms., 2005)
- o Environment Agency (2005)
- p USEPA (1997)
- NE Not Estimated

The emission factors used for Power Stations are shown in **Table A3.3.6**. The NO<sub>x</sub> and SO<sub>2</sub> emissions from coal and oil stations are based on emission estimates for individual power stations reported by plant operators to the UK environmental regulatory agencies (EA, SEPA, NIDoE, all 2005). These emission estimates are reported on a power station basis, so those from coal fired plant will include emissions from the fuel oil used to light up the boilers. A correction has been applied to the data so that the coal emissions reported in the NAEI pertain only to the coal burnt, and the oil emissions apply only to the oil burnt. This is necessary to fulfill IPCC and UNECE reporting requirements. The CO and NMVOC emissions are reported to the UK environmental regulatory agencies on the same basis, hence a similar correction is made.

National emission estimates for SO<sub>2</sub>, NO<sub>x</sub> and CO are based on estimates for each power station provided by the process operators to UK regulators. These data relate to total emissions from each power station and comprise emissions from more than one fuel in many cases (e.g. coal and fuel oil at coal-fired stations where fuel oil is used during start-up periods). The process operators do not provide emission estimates broken down by fuel. Estimates of emissions by fuel are made by the Inventory Agency using reported plant-specific fuel use data (obtained directly from operators) and using calculated factors for the secondary fuels. Consumption of each fuel type is either known or can be estimated for each station, from operator-supplied information and plant capacity. Emission factors for each fuel type are calculated from the overall emission estimates by assuming that the calculated factors will be proportional to each other by the same ratio as that derived for each combination of fuel types from a set of 'default', literature-based emission factors.

From 1991 to 1997 some UK power stations burnt orimulsion, an emulsion of bitumen and water. DTI (1998) gives the UK consumption of orimulsion. This fuel was only used by the electricity supply industry so these data were used in the category power stations. The carbon content of the fuel was taken from the manufacturers specification (BITOR, 1995). The emissions of NO<sub>x</sub>, SO<sub>2</sub>, NMVOC and CO were taken from Environment Agency (1998) but emission factors for methane and N<sub>2</sub>O were derived from those of heavy fuel oil but adjusted on the basis of the gross calorific value. The CO emission factor is based on measured data. This fuel is no longer used.

Electricity has been generated from the incineration of municipal solid waste (MSW) for some years now, though generation capacity has recently increased markedly owing to construction and upgrading of incinerators to meet new regulations which came into force at the end of 1996. Data are available (DTI, 2005) on the amount of waste used in heat and electricity generation and the emissions from the incinerators (Environment Agency, 2005). Since 1997, all MSW incinerators have generated electricity so emissions are no longer reported under the waste incineration category.

In addition to MSW combustion, the inventory reports emissions from the combustion of scrap tyres. The carbon emissions are based on estimates compiled by DTI (2000) and a carbon emission factor based on the carbon content of tyres (Ogilvie, 1995). IPCC default factors based on oil are used. In 2000, the tyre-burning plant closed down.



Also included are emissions from four plants that burnt poultry litter and wood chips. In 2000 one of these was converted to burn meat and bone meal. The carbon emissions are not included in the UK total since these derive from biomass, but emissions are reported for information in the CRF. Emission factors are based on Environment Agency (2005) data and IPCC (1997) defaults for biomass. Fuel use data is provided directly by the operators of three plant and has been estimated for the fourth plant based on information published on the internet by the process operator at [www.eprl.co.uk/assets/westfield/overview.html](http://www.eprl.co.uk/assets/westfield/overview.html). There is considerable variation in emission factors for different sites due to the variability of fuel composition.

Emission estimates are made from the generation of electricity from landfill gas and sewage gas (DTI, 2005). It is assumed that the electricity from this source is fed into the public supply or sold into non-waste sectors and hence classified as public power generation. The gases are normally used to power reciprocating gas (or dual-fuel engines), which may be part of combined heat and power schemes. Emission factors for landfill gas and sewage gas burnt in reciprocating engines have not been found so those for these gases burnt in gas turbines have been used instead (USEPA, 2004). DTI (2005) reports the energy for electricity production and for heat production separately. The emissions for electricity generation are allocated to 'Public Power' whilst those for heat production are reported under 'Miscellaneous' for landfill gas and 'Public Services' for sewage gas. The carbon emissions are not included in the UK total as they are derived from biomass, but emissions are reported for information in the CRF.

### **A3.3.3.2 Petroleum refining**

The NAEI category refinery (combustion) is mapped onto the IPCC category 1A1b Petroleum Refining. The emission factors used are shown in **Table A3.3.1**. Included in this category is an emission from the combustion of petroleum coke. This emission arises from the operation of fluidized bed catalytic crackers. During the cracking processes coke is deposited on the catalyst degrading its performance. The catalyst must be continuously regenerated by burning off the coke. The hot flue gases from the regeneration stage are used as a source of heat for the process. Since the combustion provides useful energy and the estimated amount of coke consumed is reported (DTI, 2005), the emissions are reported under 1A1b Petroleum Refining rather than as a fugitive emission under 1B2. Emission factors are either based on operators' data (UKPIA, 2005) or IPCC (1997) defaults for oil. The NAEI definition of Refinery (Combustion) includes all combustion sources: refinery fuels, electricity generation in refineries and fuel oils burnt in the petroleum industry. In previous inventories the consumption of LPG and OPG by gas separation plants was classified under refinery (combustion) refineries. It has become clear that these processes occur in oil terminals, reported under offshore oil and gas (see **Section A3.3.8**). However, as OPG and LPG are already reported under offshore own gas use this was a double count and was removed in the 1999 Inventory.

### **A3.3.3.3 Manufacture of solid fuels**

The mappings used for these categories are given in **Sections A3.1-3.2** and emission factors for energy consumption in these industries are given in **Tables A3.3.1-3.3.4**. The fuel consumption for these categories are taken from DTI (2005). The emissions from these sources (where it is clear that the fuel is being burnt for energy production) are calculated as in the base combustion module and reported in IPCC Table 1A Energy. Where the fuel is used

as a feedstock resulting in it being transformed into another fuel, which may be burnt elsewhere, a more complex treatment is needed. The approach used by the NAEI is to perform a carbon balance over solid smokeless fuel (SSF) production and a separate carbon balance over coke production, sinter production, blast furnaces and basic oxygen furnaces. This procedure ensures that there is no double counting of carbon and is consistent with IPCC guidelines. No town gas was manufactured in the UK over the period covered by these estimates so this is not considered.

The transformation processes involved are:

### *Solid Smokeless Fuel Production*

coal → SSF + carbon emission

### *Coke Production/Sinter production/Blast furnaces/Basic oxygen furnaces (simplified)*

coal → coke + coke oven gas + benzoles & tars + fugitive carbon emission

coke + limestone + iron ore → sinter + carbon emission

sinter + coke + other reducing agents → pig iron + blast furnace gas

pig iron + oxygen → steel + basic oxygen furnace gas

Carbon emissions from each process can be estimated by comparing the carbon inputs and outputs of each stage of the transformation. The carbon content of the primary fuels are fixed based on the findings of the 2004 UK carbon factor review, as is the carbon content of coke oven gas, blast furnace gas, pig iron, and steel. The carbon contents of coke, coke breeze, and basic oxygen furnace gas are allowed to vary in order to enable the carbon inputs and outputs to be balanced. The calculations are so arranged that the total carbon emission corresponds to the carbon content of the input fuels in accordance with IPCC Guidelines. In the case of SSF production, the carbon content of both input (coal) and output (SSF) are held constant with the difference being treated as an emission of carbon from the process (since the carbon content of the input is always greater than the output). This procedure has been adopted because it has been assumed that some carbon would be emitted in the form of gases, evolved during the production process.

In reporting emissions from coke ovens and SSF manufacturing processes, emissions arising from fuel combustion for energy are reported under 1A1ci Manufacture of Solid Fuels, whilst emissions arising from the transformation process are reported under 1B1b Solid Fuel Transformation. In the case of blast furnaces, energy emissions are reported under 1A2a Iron and Steel and process emissions under 2C1 Iron and Steel Production.

### **A3.3.3.4 Other energy industries**

**Section A3.2** shows the NAEI source categories mapped onto 1A1cii Other Energy Industries. All these emissions are treated according to the base combustion module using emission factors given in **Tables A3.3.1 to A3.3.4**. However, the treatment of gas oil use on offshore installations is anomalous: this is accounted for within the NAEI category Coastal Shipping and is mapped to 1A3dii National Navigation, based on the reporting of gas oil use in DUKES and the absence of any detailed data to split gas oil used in coastal vessels and that used to service offshore installations. There are no double counts in these emissions.

The estimation of emissions from natural gas, LPG and OPG used as a fuel in offshore installations and onshore terminals is discussed in **Section A3.3.8**. These emissions are reported in category 1A1cii, but the methodology used in their estimation is closely linked to the estimation of offshore fugitive emissions.

### **A3.3.4 Manufacturing Industries and Construction (1A2)**

#### **A3.3.4.1 Other Industry**

In the NAEI, the autogenerators category reports emissions from electricity generation by companies primarily for their own consumption. The Inventory makes no distinction between electricity generation and combined heat and power or heat plants. Hence CHP systems where the electricity is fed into the public supply are classified as power stations and CHP systems where the electricity is used by the generator are classified as autogeneration. The autogenerators category is mapped onto the IPCC category 1A2f Other Industry. The IPCC 1A1 category also refers to CHP plant and heat plant.

### **A3.3.5 Transport (1A3)**

#### **A3.3.5.1 Aviation**

##### ***Overview of method to estimate emissions from civil aviation***

In accordance with the agreed guidelines, the UK inventory contains estimates for both domestic and international civil aviation. Emissions from international aviation are recorded as a memo item, and are not included in national totals. Emissions from both the Landing and Take Off (LTO) phase and the Cruise phase are estimated. The method used to estimate emissions from military aviation can be found towards the end of this section on aviation.

In 2004, the simple method previously been used to estimate emissions from aviation overestimated fuel use and emissions from domestic aircraft because only two aircraft types were considered and the default emission factors used applied to older aircraft. It is clear that more smaller modern aircraft are used on domestic and international routes. Emissions from international aviation were correspondingly underestimated. A summary of the more detailed approach now used is given below, and a full description is given in Watterson *et al.* (2004).

The current method estimates emissions from the number of aircraft movements broken down by aircraft type at each UK airport, and so complies with the IPCC Tier 3 specification. Emissions of a range of pollutants are estimated in addition to the reported greenhouse gases. In comparison with earlier methods used to estimate emissions from aviation, the current approach is much more detailed and reflects differences between airports and the aircraft that use them. Emissions from additional sources (such as aircraft auxiliary power units) are also now included.

This method utilises data from a range of airport emission inventories compiled in the last few years by Netcen. This work includes the RASCO study (23 regional airports, with a 1999 case calculated from CAA movement data) carried out for the Department for Transport (DfT), and the published inventories for Heathrow, Gatwick and Stansted airports, commissioned by BAA and representative of the fleets at those airports. Emissions of NO<sub>x</sub> and fuel use from the Heathrow inventory have been used to verify the results of this study.

Separate estimates have been made for emissions from the LTO cycle and the cruise phase for both domestic and international aviation. For the LTO phase, fuel consumed and emissions per LTO cycle are based on detailed airport studies and engine-specific emission factors (from the ICAO database). For the cruise phase, fuel use and emissions are estimated using distances (based on great circles) travelled from each airport for a set of representative aircraft.

## *Emission reporting categories for civil aviation*

**Table A3.3.7** below shows the emissions included in the emission totals for the domestic and international civil aviation categories currently reported to the FCCC and the UN/ECE. Note the reporting requirements to the UN/ECE have altered recently – the table contains the most recent reporting requirements.

**Table A3.3.7** Components of Emissions Included in Reported Emissions from Civil Aviation

Organisation receiving emissions data	Category of emissions	LTO	Cruise
FCCC	Domestic	✓	✓
	International	m	m
UN/ECE	Domestic	✓	m
	International	m	m

### Notes

✓ emissions included in national totals

m memo items - emissions are estimated and reported, but are **not included in national totals**

Emissions from the LTO cycle include emissions within a 1000 m ceiling of landing.

## *Aircraft movement data (activity data)*

The methods used to estimate emissions from aviation require the following activity data:

- **Aircraft movements and distances travelled**

Detailed activity data has been provided by the UK Civil Aviation Authority (CAA). These data include aircraft movements broken down by: airport; aircraft type; whether the flight is international or domestic; and, the next/last POC (port of call) from which sector lengths (great circle) have been calculated. A summary of aircraft movement data is given in **Table A3.3.8**.

- **Inland deliveries of aviation spirit and aviation turbine fuel**

Total inland deliveries of aviation spirit and aviation turbine fuel to air transport are given in DTI (2004). This is the best approximation of aviation bunker fuel consumption available and is assumed to cover international, domestic and military use.

- **Consumption of aviation turbine fuel by the military**

Total consumption by military aviation is given in ONS (1995) and MOD (2005a) and is assumed to be aviation turbine fuel.

**Table A3.3.8** Aircraft Movement Data

	<b>International LTOs (000s)</b>	<b>Domestic LTOs (000s)</b>	<b>International Aircraft, Gm flown</b>	<b>Domestic Aircraft, Gm flown</b>
1990	410.1	311.4	635.4	97.9
1991	397.4	307.1	623.9	96.3
1992	432.8	325.1	705.8	102.0
1993	443.6	332.7	717.3	105.8
1994	461.8	312.6	792.5	101.8
1995	480.7	325.5	831.9	106.9
1996	507.1	337.5	871.4	112.6
1997	537.4	342.2	948.9	117.7
1998	575.6	355.6	1034.4	123.7
1999	609.6	363.8	1101.4	128.3
2000	646.3	367.4	1171.2	130.4
2001	653.2	376.5	1186.4	137.0
2002	650.0	374.8	1178.6	136.2
2003	669.3	375.0	1230.7	136.4
2004	700.3	397.9	1335.1	144.0

**Notes**

Gm Giga metres, or 10<sup>9</sup> metres

Estimated emissions from aviation are based on data provided by the CAA / International aircraft, Gm flown, calculated from total flight distances for departures from UK airports

**Emission factors used**

The following emission factors were used to estimate emissions from aviation. The emissions of CO<sub>2</sub>, SO<sub>2</sub> and metals depend on the carbon, sulphur and metal contents of the aviation fuels'. Emissions factors for CO<sub>2</sub>, SO<sub>2</sub> and metals have been derived from the contents of carbon, sulphur and metals in aviation fuels. These contents are reviewed, and revised as necessary, each year. Full details of the emission factors used are given in Watterson *et al.* (2004).

**Table A3.3.9a** Carbon Dioxide and Sulphur Dioxide Emission Factors for Civil and Military Aviation for 2004 (kg/t)

<b>Fuel</b>	<b>CO<sub>2</sub></b>	<b>SO<sub>2</sub></b>
Aviation Turbine Fuel	859	0.82
Aviation Spirit	853	0.82

**Notes**

Carbon and sulphur contents of fuels provided by UKPIA (2005)

Carbon emission factor as kg carbon/tonne

Military aviation only uses ATF

For the LTO-cycle calculations, emissions per LTO cycle are required for each of a number of representative aircraft types. Emission factors for the LTO cycle of aircraft operation have been taken from the International Civil Aviation Organization (ICAO) database. The cruise

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emissions have been taken from CORINAIR data (which are themselves developed from the same original ICAO dataset).

**Table A3.3.9b** Non-CO<sub>2</sub> Emission Factors for Civil and Military Aviation

	<b>Fuel</b>	<b>Units</b>	<b>CH<sub>4</sub></b>	<b>N<sub>2</sub>O</b>	<b>NO<sub>x</sub></b>	<b>CO</b>	<b>NMVOC</b>
<b>Civil aviation</b>							
Domestic LTO	AS	kt/Mt	1.65	0.1	4.55	992.7	15.1
Domestic LTO	ATF	kt/Mt	0.22	0.1	9.80	12.9	2.33
Domestic Cruise	ATF	kt/Mt	0.0	0.1	13.1	2.88	0.71
International LTO	AS	kt/Mt	-	-	-	-	-
International LTO	ATF	kt/Mt	0.12	0.1	12.8	8.84	1.23
International Cruise	ATF	kt/Mt	0.0	0.1	14.3	1.12	0.51
<b>Military aviation</b>	ATF	kt/Mt	0.1	0.1	8.50	8.20	1.1

**Notes**

AS – Aviation Spirit

ATF – Aviation Turbine Fuel

Use of all aviation spirit assigned to the LTO cycle

***Method used to estimate emissions from the LTO cycle – civil aviation – domestic and international***

The basic approach to estimating emissions from the LTO cycle is as follows. The contribution to aircraft exhaust emissions (in kg) arising from a given mode of aircraft operation (see list below) is given by the product of the duration (seconds) of the operation, the engine fuel flow rate at the appropriate thrust setting (kg fuel per second) and the emission factor for the pollutant of interest (kg pollutant per kg fuel). The annual emissions total for the mode (kg per year) is obtained by summing contributions over all engines for all aircraft movements in the year.

The time in each mode of operation for each type of airport and aircraft has been taken from individual airport studies. The time in mode is multiplied by an emission rate (the product of fuel flow rate and emission factor) at the appropriate engine thrust setting in order to estimate emissions for phase of the aircraft flight. The sum of the emissions from all the modes provides the total emissions for a particular aircraft journey. The modes considered are:

- Taxi-out
- Hold
- Take-off Roll (start of roll to wheels-off)
- Initial-climb (wheels-off to 450 m altitude)
- Climb-out (450 m to 1000 m altitude)
- Approach (from 1000 m altitude)
- Landing-roll
- Taxi-in
- APU use after arrival
- Auxiliary Power Unit (APU) use prior to departure

Departure movements comprise the following LTO modes: taxi-out, hold, take-off roll, initial-climb, climb-out and APU use prior to departure.

Arrivals comprise: approach, landing-roll, taxi-in and APU use after arrival.

### ***Method used to estimate emissions in the cruise – civil aviation - domestic and international***

The approaches to estimating emissions in the cruise are summarised below. Cruise emissions are only calculated for aircraft departures from UK airports (emissions therefore associated with the departure airport), which gives a total fuel consumption compatible with recorded deliveries of aviation fuel to the UK. This procedure prevents double counting of emissions allocated to international aviation.

*Estimating emissions of the indirect and non-greenhouse gases.* The EMEP/CORINAIR Emission Inventory Guidebook (EMEP/CORINAIR, 1996) provides fuel consumption and emissions of non-GHGs (NO<sub>x</sub>, HC and CO) for a number of aircraft modes in the cruise. The data are given for a selection of generic aircraft type and for a number of standard flight distances.

The breakdown of the CAA movement by aircraft type contains a more detailed list of aircraft types than in the EMEP/CORINAIR Emission Inventory Guidebook. Therefore, each specific aircraft type in the CAA data has been assigned to a generic type in the Guidebook. Details of this mapping are given in Watterson *et al.* (2004).

A linear regression has been applied to these data to give emissions (and fuel consumption) as a function of distance:

$$E_{Cruise_{d,g,p}} = m_{g,p} \times d + c_{g,p}$$

Where:

$E_{Cruise_{d,g,p}}$	is the emissions in cruise of pollutant $p$ for generic aircraft type $g$ and flight distance $d$ (kg)
$d$	is the flight distance
$g$	is the generic aircraft type
$p$	is the pollutant (or fuel consumption)
$m_{g,p}$	is the slope of regression for generic aircraft type $g$ and pollutant $p$ (kg / km)
$c_{g,p}$	is the intercept of regression for generic aircraft type $g$ and pollutant $p$ (kg)

Emissions of SO<sub>2</sub> and metals are derived from estimates of fuels consumed in the cruise (see equation above) multiplied by the sulphur and metals contents of the aviation fuels for a given year.

*Estimating emissions of the direct greenhouse gases.* Estimates of CO<sub>2</sub> were derived from estimates of fuel consumed in the cruise (see equation above) and the carbon contents of the aviation fuels.

Methane emissions are believed to be negligible at cruise altitudes, and the emission factors listed in EMEP/CORINAIR guidance are zero (EMEP/CORINAIR, 1996); we have also

assumed them to be zero. This was the assumption in the previous aviation calculation method also.

Estimates of N<sub>2</sub>O have been derived from an emission factor recommended by the IPCC (IPCC, 1997c) and the estimates of fuel consumed in the cruise (see equation above).

### ***Classification of domestic and international flights***

The UK CAA has provided the aircraft movement data used to estimate emissions from civil aviation. The definitions the CAA use to categorise whether a movement is international or domestic are (CAA, *per. comm.*)

- **Domestic**                      a flight is domestic if the initial point on the service is a domestic and the final point is a domestic airport
- **International**                a flight is international if either the initial point or the final point on the service is an international airport

Take, for example, a flight (service) that travels the following route: **Glasgow** (within the UK) – **Birmingham** (within the UK) – **Paris** (outside the UK). The airport reporting the aircraft movement in this example is Glasgow, and the final airport on the service is Paris. The CAA categorises this flight as international, as the final point on the service is outside the UK.

Flights to the Channel Islands and the Isle of Man are considered to be within the UK in the CAA aircraft movement data.

By following the IPCC Good Practice guidance (IPCC, 2000), it is necessary to know whether passengers or freight are put down before deciding whether the whole journey is considered as an international flight or consisting of a (or several) domestic flight(s) and an international flight. We feel the consequence of the difference between CAA and IPCC definitions will have a small impact on total emissions.

The CAA definitions above are also used by the CAA to generate national statistics of international and domestic aircraft movements. Therefore, the aircraft movement data used in this updated aviation methodology are consistent with national statistical datasets on aircraft movements.

### ***Overview of method to estimate emission from military aviation***

LTO data are not available for military aircraft movements, so a simple approach is used to estimate emissions from military aviation. A first estimate of military emissions is made using military fuel consumption data and IPCC (1997) and EMEP/CORINAIR (1999) cruise defaults shown in Table 1 of EMEP/CORINAIR (1999) (see **Table A3.3.9b**). The EMEP/CORINAIR (1999) factors used are appropriate for military aircraft. The military fuel data include fuel consumption by all military services in the UK. It also includes fuel shipped to overseas garrisons, casual uplift at civilian airports, but not fuel uplifted at foreign military airfields or *ad hoc* uplift from civilian airfields.

Emissions from military aircraft are reported under IPCC category 1A5 Other.



***Fuel reconciliation***

The estimates of aviation fuels consumed in the commodity balance table in the DTI publication DUKES are the national statistics on fuel consumption, and IPCC guidance states that national total emissions must be on the basis of fuel sales. Therefore, the estimates of emissions have been re-normalised based on the results of the comparison between the fuel consumption data in DUKES and the estimate of fuel consumed produced from the civil aviation emissions model. The ATF fuel consumptions presented in DTI DUKES include the use of both civil and military ATF, and the military ATF use must be subtracted from the DUKES total to provide an estimate of the civil aviation consumption. This estimate of civil ATF consumption has been used in the fuel reconciliation. Emissions will be re-normalised each time the aircraft movement data is modified or data for another year added.

***Geographical coverage of aviation emission estimates***

According to the IPCC Guidelines, *"inventories should include greenhouse gas emissions and removals taking place within national (including administered) territories and offshore areas over which the country has jurisdiction."* IPCC, (1997c); (IPCC Reference Manual, Overview, Page 5).

The national estimates of aviation fuels consumed in the UK are taken from DTI DUKES. The current (and future) methods used to estimate emissions from aviation rely on these data, and so the geographical coverage of the estimates of emissions will be determined by the geographical coverage of DUKES.

The UK DTI has confirmed that the coverage of the energy statistics in DUKES is England, Wales, Scotland and Northern Ireland plus any oil supplied from the UK to the Channel Islands and the Isle of Man. This clarification was necessary since this information cannot be gained from UK trade statistics. The DTI have confirmed estimates in DUKES exclude Gibraltar and the other UK overseas territories. The DTI definition accords with that of the "economic territory of the United Kingdom" used by the UK Office for National Statistics (ONS), which in turn accords with the definition required to be used under the European System of Accounts (ESA95).

**A3.3.5.2 Railways**

The UK GHGI reports emissions from both stationary and mobile sources. The inventory source "*railways (stationary)*" comprises emissions from the combustion of burning oil, fuel oil and natural gas by the railway sector. The natural gas emission derives from generation plant used for the London Underground. These stationary emissions are reported under 1A4a Commercial/Institutional in the IPCC reporting system. Most of the electricity used by the railways for electric traction is supplied from the public distribution system, so the emissions arising from its generation are reported under 1A1a Public Electricity. These emissions are based on fuel consumption data from DTI (2005). Emission factors are reported in **Tables A3.3.1 to A3.3.3**.

The UK GHGI reports emissions from diesel trains in three categories: freight, intercity and regional. Emission estimates are based on train kilometres travelled and gas oil consumption by the railway sector. Gas oil consumption is estimated from data provided by the Association of Train Operating Companies (ATOC) and from other research (Netcen, 2004). Emissions from diesel trains are reported under the IPCC category 1A3c Railways.

Carbon dioxide, sulphur dioxide and nitrous oxide emissions are calculated using fuel-based emission factors and fuel consumption data. The fuel consumption is distributed according to:

- Train km data taken from SRA Operator returns and Transport Statistics of Great Britain (DfT, 2005) for the three categories;
- Assumed mix of locomotives for each category; and
- Fuel consumption factors for different types of locomotive (LRC (1998), BR (1994) and Hawkins & Coad (2004)).

Emissions of CO, NMVOC, NO<sub>x</sub> and methane are based on the train km estimates and emission factors for different train types. The emission factors shown in **Table A3.3.10** are aggregate factors so that all factors are reported on the common basis of fuel consumption.

**Table A3.3.10** Railway Emission Factors (kt/Mt)

	C <sup>1</sup>	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	CO	NMVOC	SO <sub>2</sub>
Freight	870	0.16	1.2	23.6	7.3	3.8	3.0
Intercity	870	0.09	1.2	18.0	5.7	2.3	3.0
Regional	870	0.04	1.2	33.7	3.5	1.2	3.0

<sup>1</sup> Emission factors expressed as ktonnes carbon per Mtonne fuel

### A3.3.5.3 Road Transport

Emissions from road transport are calculated either from a combination of total fuel consumption data and fuel properties or from a combination of drive related emission factors and road traffic data.

#### A3.3.5.3.1 Improvements in the 2004 inventory

Several changes have been made to the methodologies and data used for compiling the 2004 inventory for the road transport sector as shown below.

There are three main improvements in the 2004 inventory which may cause differences in the 2003 figures for this and last years' inventory versions:

- Revisions to the estimates of consumption of lubricating oil combustion allocated to road transport. This affects only carbon and SO<sub>2</sub>.
- The treatment of cold start emissions has been improved. These changes mainly affect CO and NMVOCs and have no effect on the greenhouse gases, NH<sub>3</sub> or SO<sub>2</sub>.
- Some revision to the vehicle kilometre time-series data for Northern Ireland. This was a re-allocation of the vehicle kilometres between cars and LGVs and an amendment to the vehicle kilometres for HGVs, following a prolonged period of discussions with the DoENI and DRDNI in 2005. Although Northern Ireland makes a small contribution to the UK total vehicle kilometres, the changes in the allocation were sufficiently big to have an impact on the UK emissions, especially for those pollutants which are

sensitive to the vehicle kilometres for LGVs, which is mainly PM<sub>10</sub>. The changes affect all pollutants, except carbon and SO<sub>2</sub>.

### *A3.3.5.3.2 Fuel-based emissions*

Emissions of carbon dioxide and sulphur dioxide from road transport are calculated from the consumption of petrol and diesel fuels and the sulphur content of the fuels consumed. Data on petrol and diesel fuels consumed by road transport in the UK are taken from the Digest of UK Energy Statistics published by the DTI and corrected for consumption by off-road vehicles.

In 2004, 19.48 Mtonnes of petrol and 18.51 Mtonnes of diesel fuel (DERV) were consumed in the UK. It was estimated that of this, around 1.0% of petrol was consumed by off-road vehicles and machinery, leaving 19.29 Mtonnes of petrol consumed by road vehicles in 2004. According to figures in DUKES (DTI, 2005), 0.112 Mtonnes of LPG were used for transport in 2004, up from 0.104 Mtonnes the previous year.

Emissions of CO<sub>2</sub>, expressed as kg carbon per tonne of fuel, are based on the H/C ratio of the fuel; emissions of SO<sub>2</sub> are based on the sulphur content of the fuel. Values of the fuel-based emission factors for CO<sub>2</sub> and SO<sub>2</sub> from consumption of petrol and diesel fuels are shown in **Table A3.3.11**. Values for SO<sub>2</sub> vary annually as the sulphur-content of fuels change, and are shown in **Table A3.3.11** for 2004 fuels based on data from UKPIA (2005).

**Table A3.3.11** Fuel-Based Emission Factors for Road Transport (kg/tonne fuel)

Fuel	C <sup>a</sup>	SO <sub>2</sub> <sup>b</sup>
Petrol	855	0.07
Diesel	863	0.07

a Emission factor in kg carbon/tonne, based on UKPIA (2005)

b 2004 emission factor calculated from UKPIA (2005) – figures on the weighted average sulphur-content of fuels delivered in the UK in 2004

Emissions of CO<sub>2</sub> and SO<sub>2</sub> can be broken down by vehicle type based on estimated fuel consumption factors and traffic data in a manner similar to the traffic-based emissions described below for other pollutants. The important equations relating fuel consumption to average speed based on the set of tailpipe CO<sub>2</sub>, CO and total hydrocarbon (THC) emission-speed equations were developed by TRL (Barlow *et al*, 2001). The TRL equations were derived from their large database of emission measurements compiled from different sources covering different vehicle types and drive cycles. A substantial part of the emission measurements for Euro I and II standard vehicles come from test programmes funded by DfT and Defra and carried out in UK test laboratories between 1999 and 2001. The measurements were made on dynamometer test facilities under simulated real-world drive cycles.

For cars, average fuel consumption factors were calculated from UK fleet-averaged CO<sub>2</sub> emission factors for different car vintages (years of production) provided by DfT (2004a) following consultation with the Society of Motor Manufacturers and Traders (SMMT). Their dependence on speed used the TRL-based speed relations for vehicles categorised into each Euro standard. For LGVs, buses and motorcycles, the inventory used fuel consumption factors expressed as g fuel per kilometre for each vehicle type and road type calculated

directly from the TRL equations. Data on the average fuel efficiency of HGVs in the fleet since 1990 were taken from DfT (2004b) who, through the Continuous Survey of Road Goods Transport (CSRGT), obtain data each year on the fuel efficiency of HGVs of different weights from surveys among goods hauliers. These relate to fuel consumption (e.g. in litre/100km or in miles per gallon) that are averaged over all operational drive cycles, so their dependence on speed were estimated using the TRL-based speed relations for HGVs categorised into each Euro standard.

Average fuel consumption factors are shown in **Table A3.3.12** for each vehicle type, emission regulation and road type in the UK. The different emission standards are described in a later section. A normalisation procedure was used to ensure that the breakdown of petrol and diesel consumption by each vehicle type calculated on the basis of the fuel consumption factors added up to the DTI figures for total fuel consumption in the UK (adjusted for off-road consumption).

Total CO<sub>2</sub> emissions from vehicles running on LPG are estimated on the basis of national figures (from DTI) on the consumption of this fuel by road transport. The CO<sub>2</sub> emissions from LPG consumption cannot be broken down by vehicle type because there are no figures available on the total number of vehicles or types of vehicles running on this fuel. This is unlike vehicles running on petrol and diesel where the DfT has statistics on the numbers and types of vehicles registered as running on these fuels. It is believed that many vehicles running on LPG are cars and vans converted by their owners and that these conversions are not necessarily reported to vehicle licensing agencies. It is for this same reason that LPG vehicle emission estimates are not possible for other pollutant types, because these would need to be based on traffic data and emission factors for different vehicle types rather than on fuel consumption.

Emissions from vehicles running on natural gas are not estimated at present, although the number of such vehicles in the UK is very small. Estimates are not made as there are no separate figures from DTI on the amount of natural gas used by road transport, nor are there useable data on the total numbers and types of vehicles equipped to run on natural gas.

### *A3.3.5.3.3 Traffic-based emissions*

Emissions of the pollutants NMVOCs, NO<sub>x</sub>, CO, CH<sub>4</sub> and N<sub>2</sub>O are calculated from measured emission factors expressed in grammes per kilometre and road traffic statistics from the Department for Transport (DfT, 2004c). The emission factors are based on experimental measurements of emissions from in-service vehicles of different types driven under test cycles with different average speeds. The road traffic data used are vehicle kilometre estimates for the different vehicle types and different road classifications in the UK road network. These data have to be further broken down by composition of each vehicle fleet in terms of the fraction of diesel- and petrol-fuelled vehicles on the road and in terms of the fraction of vehicles on the road made to the different emission regulations which applied when the vehicle was first registered. These are related to the age profile of the vehicle parc.

Emissions from motor vehicles fall into three different types, which are each calculated in a different manner. These are hot exhaust emissions, cold-start emissions and, for NMVOCs, evaporative emissions.

### A3.3.5.3.3.1 Hot exhaust emissions

Hot exhaust emissions are emissions from the vehicle exhaust when the engine has warmed up to its normal operating temperature. Emissions depend on the type of vehicle, the type of fuel its engine runs on, the driving profile of the vehicle on a journey and the emission regulations which applied when the vehicle was first registered as this defines the type of technology the vehicle is equipped with affecting emissions.

**Table A3.3.12** Fuel Consumption Factors for Road Transport (in g fuel/km)

g/km	Standard	Urban	Rural	Motorway
Petrol cars	ECE 15.01	77.9	65.1	76.8
	ECE 15.02	73.1	61.0	72.0
	ECE 15.03	73.1	61.0	72.0
	ECE 15.04	66.7	55.7	65.7
	Euro I	65.4	58.2	68.2
	Euro II	63.0	59.7	72.2
	Euro III	59.2	56.1	67.8
	Euro IV	52.8	50.0	60.5
Diesel cars	Pre-Euro I	64.5	51.0	60.5
	Euro I	63.4	55.8	71.6
	Euro II	61.1	56.0	74.3
	Euro III	54.5	49.9	66.3
Petrol LGVs	Pre-Euro I	73.9	61.5	99.8
	Euro I	93.3	83.2	109.6
	Euro II	95.3	85.5	112.6
	Euro III	90.9	81.5	107.4
Diesel LGV	Pre-Euro I	95.1	95.1	138.4
	Euro I	94.9	81.9	132.6
	Euro II	95.1	82.1	132.9
	Euro III	87.4	75.5	122.1
Rigid HGVs	Pre-1988	241	225	263
	88/77/EEC	241	225	263
	Euro I	241	225	263
	Euro II	241	225	263
	Euro III	241	225	263
Artic HGVs	Pre-1988	393	317	362
	88/77/EEC	393	317	362
	Euro I	348	330	360
	Euro II	321	304	332
	Euro III	321	304	332
Buses	Pre-1988	399	178	229
	88/77/EEC	386	174	224
	Euro I	319	195	213
	Euro II	288	191	208
	Euro III	288	191	208
Mopeds, <50cc, 2st	Pre-2000	25.0	25.0	25.0
	Euro I	25.0	25.0	25.0
Motorcycles, >50cc, 2st	Pre-2000	30.1	33.1	38.2
	Euro I	30.1	33.1	38.2
Motorcycles, >50cc, 4st	Pre-2000	28.5	30.7	38.8
	Euro I	28.5	30.7	38.8

For a particular vehicle, the drive cycle over a journey is the key factor that determines the amount of pollutant emitted. Key parameters affecting emissions are the acceleration,

deceleration, steady speed and idling characteristics of the journey, as well as other factors affecting load on the engine such as road gradient and vehicle weight. However, work has shown that for modelling vehicle emissions for an inventory covering a road network on a national scale, it is sufficient to calculate emissions from emission factors in g/km related to the average speed of the vehicle in the drive cycle (Zachariadis and Samaras, 1997). Emission factors for average speeds on the road network are then combined with the national road traffic data.

### Vehicle and fuel type

Emissions are calculated for vehicles of the following types:

- Petrol cars
- Diesel cars
- Petrol Light Goods Vehicles (Gross Vehicle Weight (GVW)  $\leq$  3.5 tonnes)
- Diesel Light Goods Vehicles (Gross Vehicle Weight (GVW)  $\leq$  3.5 tonnes)
- Rigid-axle Heavy Goods Vehicles (GVW  $>$  3.5 tonnes)
- Articulated Heavy Goods Vehicles (GVW  $>$  3.5 tonnes)
- Buses and coaches
- Motorcycles

Total emission rates are calculated by multiplying emission factors in g/km with annual vehicle kilometre figures for each of these vehicle types on different types of roads.

### Vehicle kilometres by road type

Hot exhaust emission factors are dependent on average vehicle speed and therefore the type of road the vehicle is travelling on. Average emission factors are combined with the number of vehicle kilometres travelled by each type of vehicle on many different types of urban roads with different average speeds and the emission results combined to yield emissions on each of these main road types:

- Urban
- Rural single carriageway
- Motorway/dual carriageway

DfT estimates annual vehicle kilometres for the road network in Great Britain by vehicle type on roads classified as trunk, principal and minor roads in built-up areas (urban) and non-built-up areas (rural) and motorways (DfT, 2005c). The DfT Report “Transport Statistics Great Britain” (DfT, 2005c) provides vehicle kilometres data up to 2004. No changes were made to the vehicle kilometres data from 1994 to 2003 in the 2005 publication.

Vehicle kilometre data for Northern Ireland became available for 1999 and 2001 onwards from survey reports provided by Department for Regional Development (DRD), Northern Ireland, Road Services Headquarters (DRDNI, 2002, 2003a, 2003b, 2004, 2005). Data for 2000 were not available, but were estimated from the 1999 and 2001 figures.

Revisions were made to the vehicle kilometres data for 2002 and 2003 due to a revision of total vehicle kilometres provided by DRDNI in 2005. In addition, there were revisions to the

vehicle kilometres time-series data for Northern Ireland. This was a reallocation of the vehicle kilometres between cars and LGVs and an amendment to the vehicle kilometres for HGVs, following discussions with the DOENI and DRDNI in 2005. The Northern Ireland data have been combined with the DfT data for Great Britain to produce a time-series of total UK vehicle kilometres by vehicle and road type from 1970 to 2004.

The vehicle kilometre data were grouped into the three road types mentioned above for combination with the associated hot exhaust emission factors.

### Vehicle speeds by road type

Average speed data for traffic in a number of different urban areas have been published in a series of DETR reports based on measured traffic speed surveys (DETR (1998a, 1998b, 1998c, 1998d), DfT (2004c)). These data were rationalised with speed data from other DETR sources, including the 1997 National Road Traffic Forecasts (DETR, 1997), which give average speeds for different urban area sizes, and consolidated with average speed data for unconstrained rural roads and motorways published in Transport Statistics Great Britain (DfT, 2004c). They are shown in **Table A3.3.13**. The speeds are averages of speeds at different times of day and week, weighted by the level of traffic at each of these time periods where this information is known.

Weighting by the number of vehicle kilometres on each of the urban road types gives an overall average speed for urban roads of 43 kph.

### Vehicle fleet composition: by age, technology and fuel type

The vehicle kilometres data based on traffic surveys do not distinguish between the type of fuels the vehicles are being run on (petrol and diesel) nor on their age. The latter determines the type of emission regulation that applied when the vehicle was first registered. These have successively entailed the introduction of tighter emission control technologies, for example three-way catalysts and better fuel injection and engine management systems.

**Table A3.3.14** shows the regulations that have come into force up to 2004 for each vehicle type.

The average age profile and the fraction of petrol and diesel cars and LGVs in the traffic flow each year are based on the composition of the UK vehicle fleet using DfT Vehicle Licensing Statistics. The Transport Statistics Bulletin “Vehicle Licensing Statistics: 2004” (DfT, 2005d) either gives historic trends in the composition of the UK fleet directly or provides sufficient information for this to be calculated from new vehicle registrations and average vehicle survival rates. The vehicle licensing data are combined with data on the change in annual vehicle mileage with age to take account of the fact that newer vehicles on average travel a greater number of kilometres in a year than older vehicles. For cars and LGVs, such mileage data are from the National Travel Survey (DETR, 1998e); data for HGVs of different weights are taken from the Continuous Survey of Road Goods Transport (DETR, 1996a).

The fraction of diesel cars and LGVs in the fleet was taken from data in “Vehicle Licensing Statistics: 2004” (DfT, 2005d). Year-of-first registration data for vehicles licensed in each



year from 1990 to 2004 have been taken from DfT's Vehicle Licensing Statistics reflect the age distribution of the fleet in these years.

**Table A3.3.13** Average Traffic Speeds in Great Britain

<b>URBAN ROADS</b>		kph
Central London	Major/trunk A roads	18
	Other A roads	14
	Minor roads	16
Inner London	Major/trunk A roads	28
	Other A roads	20
	Minor roads	20
Outer London	Major/trunk A roads	45
	Other A roads	26
	Minor roads	29
Urban motorways		95
Large conurbations	Central	34
	Outer trunk/A roads	45
	Outer minor roads	34
Urban, pop >200,000	Central	37
	Outer trunk/A roads	50
	Outer minor roads	37
Urban, pop >100,000	Central	40
	Outer trunk/A roads	54
	Outer minor roads	40
Urban >25 sq km	Major roads	46
	Minor roads	42
Urban 15-25 sq km	Major roads	49
	Minor roads	46
Urban 5-15 sq km	Major roads	51
	Minor roads	48
Urban < 5sq km	Major roads	52
	Minor roads	48

**Table A3.3.13** Average Traffic Speeds in Great Britain (continued)

<b>RURAL ROADS</b>		Lights kph	Heavies kph
Rural single carriageway	Major roads	80	75
	Minor roads	67	63
Rural dual carriageway		113	89
Rural motorway		113	92

**Table A3.3.14a** Vehicles types and regulation classes

Vehicle Type	Fuel	Regulation	Approx. date into service in UK
Cars	Petrol	Pre ECE-15.00 ECE-15.00 ECE-15.01 ECE-15.02 ECE-15.03 ECE-15.04 91/441/EEC (Euro I) 94/12/EC (Euro II) 98/69/EC (Euro III) 98/69/EC (Euro IV)	1/1/1971 1/7/1975 1/7/1976 1/7/1979 1/7/1983 1/7/1992 1/1/1997 1/1/2001 1/1/2006
	Diesel	Pre-Euro I 91/441/EEC (Euro I) 94/12/EC (Euro II) 98/69/EC (Euro III)	1/1/1993 1/1/1997 1/1/2001
LGVs	Petrol	Pre-Euro I 93/59/EEC (Euro I) 96/69/EEC (Euro II) 98/69/EC (Euro III)	1/7/1994 1/7/1997 1/1/2001 (<1.3t) 1/1/2002 (>1.3t)
	Diesel	Pre-Euro I 93/59/EEC (Euro I) 96/69/EEC (Euro II) 98/69/EC (Euro III)	1/7/1994 1/7/1997 1/1/2001 (<1.3t) 1/1/2002 (>1.3t)
HGVs and buses	Diesel (All types)	Old 88/77/EEC (Pre-Euro I) 91/542/EEC (Euro I) 91/542/EEC (Euro II) 99/96/EC (Euro III)	1/10/1988 1/10/1993 1/10/1996 1/10/2001
Motorcycles	Petrol	Pre-2000: < 50cc, >50cc (2 st, 4st) 97/24/EC: all sizes	1/1/2000

Note: Euro IV standards for petrol cars are shown because some new cars models sold from 2001 already meet Euro IV standards even they are not required to until 2006.

Statistics are also available on the number of new registrations in each year up to 2004, reflecting the number of new vehicles entering into service in previous years. The two sets of data combined allow an average survival rate to be determined for each type of vehicle. Particularly detailed information is available on the composition of the HGV stock by age and size.

Assumptions are made about the proportion of failing catalysts in the petrol car fleet. For first-generation catalyst cars (Euro I), it is assumed that the catalysts fail in 5% of cars fitted

with them each year (for example due to mechanical damage of the catalyst unit) and that 95% of failed catalysts are repaired each year, but only for cars more than three years in age, when they first reach the age for MOT testing. Following discussions with DfT, a review of information from the Vehicle Inspectorate, TRL, the Cleaner Vehicles Task Force, industry experts and other considerations concerning durability and emission conformity requirements in in-service tests, lower failure rates are assigned to Euro II, III and IV cars manufactured since 1996. The following failure rates are assumed in the inventory:

- Euro I                      5%
- Euro II                     1.5%
- Euro III, IV                0.5%

The inventory takes account of the early introduction of certain emission and fuel quality standards and additional voluntary measures to reduce emissions from road vehicles in the UK fleet. The Euro III emission standards for passenger cars (98/69/EC) came into effect from January 2001 (new registrations). However, some makes of cars sold in the UK already met the Euro III standards prior to this (DfT, 2001). Figures from the Society of Motor Manufacturers and Traders suggested that 3.7% of new cars sold in 1998 met Euro III standards (SMMT, 1999). Figures were not available for 1999 and 2000, but it was assumed that 5% of new car sales met Euro III standards in 1999 increasing to 10% in 2000. In 2001, an assumption was made that 15% of all new petrol cars sold in the UK met Euro IV standards, increasing to 81% in 2004 even though the mandatory date of introduction of this standard is not until 2006 (DfT, 2004e). The remaining new petrol car registrations in 2001 - 2004 would meet Euro III standards.

In January 2000, European Council Directive 98/70/EC came into effect relating to the quality of petrol and diesel fuels. This introduced tighter standards on a number of fuel properties affecting emissions. The principle changes in UK market fuels were the sulphur content and density of diesel and the sulphur and benzene content of petrol. The volatility of summer blends of petrol was also reduced, affecting evaporative losses. During 2000-2004, virtually all the diesel sold in the UK was of ultra-low sulphur grade (<50 ppmS), even though this low level of sulphur content is not required by the Directive until 2005. Similarly, ultra-low sulphur petrol (ULSP) became on-line in filling stations in 2000, with around one-third of sales being of ULSP quality during 2000, the remainder being of the quality specified by the Directive. In 2001-2003, virtually all unleaded petrol sold was of ULSP grade (UKPIA, 2004). These factors and their effect on emissions were taken into account in the inventory. It is assumed that prior to 2000, only buses had made a significant switch to ULSD, as this fuel was not widely available in UK filling stations.

Freight haulage operators are now looking at incentives to upgrade the engines in their HGVs or retrofit them with particle traps. DETR estimated that around 4,000 HGVs and buses were retrofitted with particulate traps in 2000, rising to 10,000 vehicles by the end of 2003 (DETR, 2000). This was accounted for in the 2003 inventory.

Detailed information from DVLA was used on the composition of the motorcycle fleet in terms of engine capacity (DfT, 2004d). The information was used to calculate the proportion of motorcycles on the road less than 50cc (i.e. mopeds), >50cc, 2-stroke and >50cc, 4-stroke.

## A3.3.5.3.3.2 Hot emission factors

The emission factors for NO<sub>x</sub>, CO and NMVOCs used for pre-Euro I vehicles in the 2001 inventory are based on data from TRL (Hickman, 1998) and COPERT II, “*Computer Programme to Calculate Emissions from Road Transport*” produced by the European Topic Centre on Air Emissions for the European Environment Agency (1997). Both these sources provide emission functions and coefficients relating emission factor (in g/km) to average speed for each vehicle type and Euro emission standard derived by fitting experimental measurements to some polynomial functional form.

Emission factors for Euro I and Euro II vehicles are based on speed-emission factor relationships derived by TRL from emission test programmes carried out in the UK (Barlow *et al*, 2001). The tests were carried out on in-service vehicles on dynamometer facilities under simulated real-world drive cycles. These provided a more robust source of emission factors for these vehicle classes than had hitherto been available. The factors for NMVOCs are actually based on emission equations for total hydrocarbons (THC), the group of species that are measured in the emission tests. To derive factors for non-methane VOCs, the calculated g/km factors for methane were subtracted from the corresponding THC emission factors.

Due to lack of measured data, emission factors for Euro III vehicles (and Euro IV petrol cars) were estimated by applying scaling factors to the Euro II factors. The scale factors for light duty vehicles take into consideration the requirement for new vehicles to meet certain durability standards set in the Directives. Scaling factors were first estimated by considering how much emissions from Euro II vehicles would need to be reduced to meet the Euro III and IV limit values taking account of the characteristics and average speed of the regulatory test cycles used for type-approval of the vehicle’s engine. It was then assumed that emissions from new vehicles would be a certain percentage lower than the limit value-derived figure when new so that the vehicle would not have emissions that degrade to levels higher than the limit value over the durability period of the vehicle set in the Directives. The emission degradation rates permitted for Euro III and IV light duty vehicles by Directive 98/69/EC are as follows:

**Table A3.3.14b** Emission Degradation rates permitted for Euro III and IV Light-Duty Vehicles by Directive 98/69/EC

			Degradation rate
Petrol vehicles	NO <sub>x</sub> , HC and CO	Euro III	x1.2 over 80,000km
		Euro IV	x1.2 over 100,000km
Diesel vehicles	PM	Euro III	x1.2 over 80,000km
		Euro IV	x1.2 over 100,000km
	CO	Euro III	x1.1 over 80,000km
		Euro IV	x1.1 over 100,000km

For heavy-duty vehicles, the emission scaling factors were taken from COPERT III (European Environment Agency, 2000).

The speed-emission factor equations were used to calculate emission factor values for each vehicle type and Euro emission standard at each of the average speeds of the road and area

types shown in **Table A3.3.13**. The calculated values were averaged to produce single emission factors for the three main road classes described earlier (urban, rural single carriageway and motorway/dual carriageway), weighted by the estimated vehicle kilometres on each of the detailed road types taken from the 1997 NRTF (DETR, 1997).

For each type of vehicle, both TRL and COPERT II provide equations for different ranges of vehicle engine capacity or vehicle weight. Emission factors calculated from these equations were therefore averaged, weighted according to the proportion of the different vehicle sizes in the UK fleet, to produce a single average emission factor for each vehicle type and road type. These average emission factors are given in **Tables A3.3.17 to 21** for each of the different vehicle types and emission regulations.

Speed-dependent functions provided by TRL (Hickman, 1998) for different sizes of motorcycles were used. Prior to 2000, all motorcycles are assumed to be uncontrolled. It was also assumed that mopeds (<50cc) operate only in urban areas, while the only motorcycles on motorways are the type more than 50cc, 4-stroke. Otherwise, the number of vehicle kilometres driven on each road type was disaggregated by motorcycle type according to the proportions in the fleet. Motorcycles sold since the beginning of 2000 were assumed to meet the Directive 97/24/EC and their emission factors were reduced according to the factors given in the latest version of COPERT III (European Environment Agency, 2000).

Emissions from buses were scaled down according to the proportion running on ultra-low sulphur diesel fuel in each year, the proportion fitted with oxidation catalysts or particulate traps (CRTs) and the effectiveness of these measures in reducing emissions from the vehicles. The effectiveness of these measures in reducing emissions from a Euro II bus varies for each pollutant and is shown in **Table A3.3.15**. It is assumed that a bus fitted with an oxidation catalyst or CRT is also running on ULS diesel.

**Table A3.3.15** Scale Factors for Emissions from a Euro II Bus Running on Ultra-Low Sulphur Diesel and Fitted with an Oxidation Catalyst or CRT

		<b>NO<sub>x</sub></b>	<b>CO</b>	<b>NMVOCs</b>
ULS diesel only	Urban	1.01	0.91	0.72
	Rural	0.99	1.01	1.02
ULS diesel + Oxy catalyst	Urban	0.97	0.20	0.39
	Rural	0.95	0.22	0.55
ULS diesel + CRT	Urban	0.90	0.17	0.19
	Rural	0.88	0.19	0.27

These scale factors are relative to emissions from a bus running on 500ppm S diesel and are based on analysis of fuel quality effects by Murrells (2000) and data on the effectiveness of oxidation catalysts on bus emissions by LT Buses (1998).

Similarly, the small numbers of HGVs equipped with CRTs have their emissions reduced by the amounts shown in **Table A3.3.16**. Again these vehicles will also be running on ULS diesel.

**Table A3.3.16** Scale Factors for Emissions from a Euro II HGV Running on Ultra-Low Sulphur Diesel and Fitted with an Oxidation Catalyst or CRT

		<b>NO<sub>x</sub></b>	<b>CO</b>	<b>NMVOCs</b>
ULS diesel only	Urban	0.94	0.96	0.97
	Rural	0.99	1.01	1.02
ULS diesel + CRT	Urban	0.81	0.10	0.12
	Rural	0.85	0.10	0.12

The older in-service vehicles in the test surveys that were manufactured to a particular emission standard would have covered a range of different ages. Therefore, an emission factor calculated for a particular emission standard (e.g. ECE 15.04) from the emission functions and coefficients from TRL and COPERT II is effectively an average value for vehicles of different ages which inherently takes account of possible degradation in emissions with vehicle age. However, for the more recent emission standards (Euro I and II), the vehicles would have been fairly new when the emissions were measured. Therefore, based on data from the European Auto-Oil study, the deterioration in emissions with age or mileage was taken into account for catalyst cars. It was assumed that emissions of CO and NO<sub>x</sub> increase by 60% over 80,000 km, while emissions of NMVOCs increase by 30% over the same mileage (DETR, 1996b). Based on the average annual mileage of cars, 80,000 km corresponds to a time period of 6.15 years. Emissions from Euro III and IV light duty vehicles were assumed to degrade at rates described earlier, consideration given to the durability requirements of the Directive 98/69/EC.

For methane, factors for pre-Euro I and/or Euro I standards for each vehicle type were taken from COPERT III which provided either full speed-emission factor equations or single average factors for urban, rural and highway roads. Methane emission factors for other Euro standards were scaled according to the ratio in the THC emission factors between the corresponding Euro standards. This assumes that methane emissions are changed between each standard to the same extent as total hydrocarbons so that the methane fraction remains constant.

Emission factors for nitrous oxide (N<sub>2</sub>O) are the road-type factors taken from COPERT III. Due to lack of available data, no distinction between different Euro standards can be discerned, except for the higher N<sub>2</sub>O emissions arising from petrol vehicles fitted with a three-way catalyst (Euro I and on).

The uncertainties in the CH<sub>4</sub> and N<sub>2</sub>O factors can be expected to be quite large. However, the emission factors used reflect the fact that three-way catalysts are less efficient in removing

methane from the exhausts than other hydrocarbons and also lead to higher N<sub>2</sub>O emissions than non-catalyst vehicles.

### A3.3.5.3.3.3 Cold-Start Emissions

When a vehicle's engine is cold it emits at a higher rate than when it has warmed up to its designed operating temperature. This is particularly true for petrol engines and the effect is even more severe for cars fitted with three-way catalysts, as the catalyst does not function properly until the catalyst is also warmed up. Emission factors have been derived for cars and LGVs from tests performed with the engine starting cold and warmed up. The difference between the two measurements can be regarded as an additional cold-start penalty, paid on each trip a vehicle is started with the engine (and catalyst) cold.

The procedure for estimating cold-start emissions is taken from COPERT II (European Environment Agency, 1997), taking account of the effects of ambient temperature on emission factors for different vehicle technologies and its effect on the distance travelled with the engine cold. A factor, the ratio of cold to hot emissions, is used and applied to the fraction of kilometres driven with cold engines to estimate the cold start emissions from a particular vehicle type using the following formula:

$$E_{\text{cold}} = \beta \cdot E_{\text{hot}} \cdot (e^{\text{cold}}/e^{\text{hot}} - 1)$$

where

$E_{\text{hot}}$  = hot exhaust emissions from the vehicle type  
 $\beta$  = fraction of kilometres driven with cold engines  
 $e^{\text{cold}}/e^{\text{hot}}$  = ratio of cold to hot emissions for the particular pollutant and vehicle type

The parameters  $\beta$  and  $e^{\text{cold}}/e^{\text{hot}}$  are both dependent on ambient temperature and  $\beta$  is also dependent on driving behaviour in, particular the average trip length, as this determines the time available for the engine and catalyst to warm up. The equations relating  $e^{\text{cold}}/e^{\text{hot}}$  to ambient temperature for each pollutant and vehicle type were taken from COPERT II and were used with an annual mean temperature for the UK of 11°C. This is based on historic trends in Met Office data for ambient temperatures over different parts of the UK.

The factor  $\beta$  is related to ambient temperature and average trip length by the following equation taken from COPERT II:

$$\beta = 0.698 - 0.051 \cdot l_{\text{trip}} - (0.01051 - 0.000770 \cdot l_{\text{trip}}) \cdot t_a$$

where

$l_{\text{trip}}$  = average trip length  
 $t_a$  = average temperature

An average trip length for the UK of 8.4 km was used, taken from Andre *et al* (1993). This gives a value for  $\beta$  of 0.23.



This methodology was used to estimate annual UK cold start emissions of NO<sub>x</sub>, CO and NMVOCs from petrol and diesel cars and LGVs. Emissions were calculated separately for catalyst and non-catalyst petrol vehicles. Cold start emissions data are not available for heavy-duty vehicles, but these are thought to be negligible (Boulter, 1996).

All the cold start emissions are assumed to apply to urban driving.

Cold-start emissions data are not available for the pollutants methane and nitrous oxide.

### A3.3.5.3.3.4 Evaporative Emissions

Evaporative emissions of petrol fuel vapour from the tank and fuel delivery system in vehicles constitute a significant fraction of total NMVOC emissions from road transport. The procedure for estimating evaporative emissions of NMVOCs takes account of changes in ambient temperature and fuel volatility.

There are three different mechanisms by which gasoline fuel evaporates from vehicles:

#### ***i) Diurnal loss***

This arises from the increase in the volatility of the fuel and expansion of the vapour in the fuel tank due to the diurnal rise in ambient temperature. Evaporation through “tank breathing” will occur each day for all vehicles with gasoline fuel in the tank, even when stationary.

#### ***ii) Hot soak loss***

This represents evaporation from the fuel delivery system when a hot engine is turned off and the vehicle is stationary. It arises from transfer of heat from the engine and hot exhaust to the fuel system where fuel is no longer flowing. Carburettor float bowls contribute significantly to hot soak losses.

#### ***iii) Running loss***

These are evaporative losses that occur while the vehicle is in motion.

Evaporative emissions are dependent on ambient temperature and the volatility of the fuel and, in the case of diurnal losses, on the daily *rise* in ambient temperature. Fuel volatility is usually expressed by the empirical fuel parameter known as Reid vapour pressure (RVP). For each of these mechanisms, equations relating evaporative emissions to ambient temperature and RVP were developed by analysis of empirically based formulae derived in a series of CONCAWE research studies in combination with UK measurements data reported by TRL. Separate equations were developed for vehicles with and without evaporative control systems fitted such as carbon canister devices. The overall methodology is similar to that reported by COPERT II (European Environment Agency, 1997), but the data are considered to be more UK-biased.

Evaporative emissions are calculated using monthly average temperature and RVP data. Using this information, evaporative emissions are calculated from the car fleet for each month of the year and the values summed to derive the annual emission rates. Calculating emissions on a monthly basis enables subtle differences in the seasonal fuel volatility trends and differences in monthly temperatures to be better accounted for. Monthly mean temperatures from 1970-2003 were used for the calculations based on Met Office for Central England (CET

data). The monthly average, monthly average daily maximum and monthly average diurnal rise in temperatures were required. The monthly average RVP of petrol sold in the UK used historic trends data on RVP and information from UKPIA on the RVP of summer and winter blends of fuels supplied in recent years and their turnover patterns at filling stations (Watson, 2001, 2003). The average RVP of summer blends of petrol in the UK in 2003 was 68 kPa, 2kPa below the limit set by European Council Directive 98/70/EC for Member States with “arctic” summer conditions (UKPIA, 2004).

All the equations for diurnal, hot soak and running loss evaporative emissions from vehicles with and without control systems fitted developed for the inventory are shown in **Table A3.3.22**. The inventory uses equations for Euro I cars with “first generation” canister technology, based on early measurements, but equations taken from COPERT III leading to lower emissions were used for Euro II-IV cars as these better reflected the fact that modern cars must meet the 2g per test limit on evaporative emissions by the diurnal loss and hot soak cycles under Directive 98/69/EC.

For **diurnal losses**, the equations for pre-Euro I (non-canister) and Euro I cars were developed from data and formulae reported by CONCAWE (1987), TRL (1993) and ACEA (1995). Equations for Euro II-IV cars were taken from COPERT III. The equations specified in **Table A3.3.22** give diurnal loss emissions in g/vehicle.day for uncontrolled ( $DL_{uncontrolled}$ ) and Euro I and Euro II-IV canister controlled vehicles ( $DL_{EU1}$ ,  $DL_{EUII-IV}$ ). Total annual diurnal losses were calculated from the equation:

$$E_{diurnal} = 365 \cdot N \cdot (DL_{uncontrolled} \cdot F_{uncontrolled} + DL_{EU1} \cdot F_{EU1} + DL_{EUII-IV} \cdot F_{EUII-IV})$$

where:

- N = number of petrol vehicles (cars and LGVs) in the UK parc
- $F_{uncontrolled}$  = fraction of vehicles not fitted with carbon canisters, assumed to be the same as the fraction of pre-Euro I vehicles
- $F_{EU1}$  = fraction of Euro I vehicles in the fleet
- $F_{EUII-IV}$  = fraction of Euro II-IV vehicles in the fleet

For **hot soak losses**, the equations were developed from data and formulae reported by CONCAWE (1990), TRL (1993) and COPERT II. The equations specified in **Table A3.3.22** give hot soak loss emissions in g/vehicle.trip for uncontrolled ( $HS_{uncontrolled}$ ) and Euro I and Euro II-IV canister controlled ( $HS_{EU1}$ ,  $HS_{EUII-IV}$ ) vehicles. Total annual hot soak losses were calculated from the equation:

$$E_{hot\ soak} = (VKM / l_{trip}) \cdot (HS_{uncontrolled} \cdot F_{uncontrolled} + HS_{EU1} \cdot F_{EU1} + HS_{EUII-IV} \cdot F_{EUII-IV})$$

where

- VKM = total number of vehicle kilometres driven in the UK by the petrol vehicles (cars and LGVs)
- $l_{trip}$  = average trip length (8.4 km in the UK)

For **running losses**, the equations were developed from data and formulae reported by CONCAWE (1990) and COPERT II.

The equations specified in **Table A3.3.22** give running loss emissions in g/vehicle.km for uncontrolled ( $RL_{uncontrolled}$ ) and canister controlled ( $RL_{controlled}$ ) vehicles with no distinction made between Euro I and Euro II-IV canister cars. Total annual running losses were calculated from the equation:

$$E_{\text{running loss}} = VKM. (RL_{uncontrolled} \cdot F_{uncontrolled} + RL_{controlled} \cdot F_{controlled})$$

where

$$F_{controlled} = F_{EUI} + F_{EUII-IV}$$

**Table A3.3.17** NMVOC Emission Factors for Road Transport (in g/km)

g/km	Standard	Urban	Rural	Motorway
Petrol cars	ECE 15.01	1.748	1.116	0.936
	ECE 15.02	1.764	1.126	0.945
	ECE 15.03	1.764	1.126	0.945
	ECE 15.04	1.416	0.904	0.758
	Euro I	0.033	0.030	0.082
	Euro II	0.024	0.021	0.024
	Euro III	0.018	0.016	0.019
	Euro IV	0.018	0.015	0.018
Diesel cars	Pre-Euro I	0.139	0.074	0.041
	Euro I	0.070	0.039	0.026
	Euro II	0.057	0.026	0.017
	Euro III	0.042	0.019	0.013
Petrol LGVs	Pre-Euro I	1.356	0.735	0.812
	Euro I	0.036	0.038	0.029
	Euro II	0.022	0.025	0.019
	Euro III	0.017	0.019	0.015
Diesel LGV	Pre-Euro I	0.270	0.137	0.146
	Euro I	0.121	0.095	0.086
	Euro II	0.121	0.095	0.086
	Euro III	0.099	0.078	0.070
Rigid HGVs	Pre-1988	3.350	2.872	2.779
	88/77/EEC	1.667	1.429	1.383
	Euro I	0.609	0.487	0.435
	Euro II	0.481	0.414	0.401
	Euro III	0.329	0.283	0.274
Artic HGVs	Pre-1988	3.563	2.494	1.960
	88/77/EEC	1.415	0.990	0.778
	Euro I	1.509	1.205	1.063
	Euro II	1.244	1.067	1.021
	Euro III	0.850	0.729	0.698
Buses	Pre-1988	5.252	1.915	1.806
	88/77/EEC	1.272	0.464	0.438
	Euro I	0.945	0.402	0.362
	Euro II	0.681	0.341	0.332
	Euro III	0.465	0.233	0.227
Mopeds, <50cc, 2st	Pre-2000	12.085	18.283	25.312
	Euro I	2.659	4.022	5.569
Motorcycles, >50cc, 2st	Pre-2000	9.370	8.129	8.140
	Euro I	6.484	5.796	4.958
Motorcycles, >50cc, 4st	Pre-2000	1.627	1.068	1.055
	Euro I	0.686	0.424	0.313

**Table A3.3.18** NO<sub>x</sub> Emission Factors for Road Transport (in g/km)

g/km	Standard	Urban	Rural	Motorway
Petrol cars	ECE 15.01	2.104	2.528	2.822
	ECE 15.02	1.794	2.376	3.494
	ECE 15.03	1.921	2.606	3.859
	ECE 15.04	1.644	2.211	3.164
	Euro I	0.219	0.314	0.566
	Euro II	0.195	0.209	0.316
	Euro III	0.085	0.092	0.138
	Euro IV	0.061	0.065	0.099
Diesel cars	Pre-Euro I	0.623	0.570	0.718
	Euro I	0.537	0.465	0.693
	Euro II	0.547	0.505	0.815
	Euro III	0.547	0.505	0.815
Petrol LGVs	Pre-Euro I	1.543	1.783	2.351
	Euro I	0.308	0.304	0.454
	Euro II	0.273	0.329	0.484
	Euro III	0.119	0.144	0.212
Diesel LGV	Pre-Euro I	1.332	1.254	1.549
	Euro I	1.035	0.892	1.384
	Euro II	0.983	0.848	1.315
	Euro III	0.737	0.636	0.986
Rigid HGVs	Pre-1988	12.735	13.439	13.439
	88/77/EEC	5.663	4.929	5.864
	Euro I	7.176	6.818	7.178
	Euro II	6.129	5.743	5.977
	Euro III	4.247	3.979	4.141
Artic HGVs	Pre-1988	19.479	20.555	20.555
	88/77/EEC	15.931	12.840	11.436
	Euro I	19.058	18.122	19.089
	Euro II	13.140	12.312	12.815
	Euro III	9.104	8.530	8.879
Buses	Pre-1988	16.973	13.734	13.263
	88/77/EEC	13.814	5.407	6.089
	Euro I	11.085	6.134	6.461
	Euro II	9.917	5.484	5.709
	Euro III	6.871	3.800	3.955
Mopeds, <50cc, 2st	Pre-2000	0.030	0.030	0.030
	Euro I	0.010	0.010	0.010
Motorcycles, >50cc, 2st	Pre-2000	0.032	0.066	0.126
	Euro I	0.025	0.029	0.051
Motorcycles, >50cc, 4st	Pre-2000	0.156	0.229	0.385
	Euro I	0.210	0.279	0.448

**Table A3.3.19** CO Emission Factors for Road Transport (in g/km)

g/km	Standard	Urban	Rural	Motorway
Petrol cars	ECE 15.01	18.85	11.84	14.26
	ECE 15.02	15.63	9.82	11.82
	ECE 15.03	16.40	10.30	12.41
	ECE 15.04	10.10	6.34	7.64
	Euro I	1.02	0.98	2.84
	Euro II	0.684	0.493	0.411
	Euro III	0.637	0.459	0.383
	Euro IV	0.506	0.364	0.304
Diesel cars	Pre-Euro I	0.647	0.430	0.399
	Euro I	0.282	0.147	0.196
	Euro II	0.233	0.072	0.072
	Euro III	0.148	0.046	0.046
Petrol LGVs	Pre-Euro I	13.70	10.62	31.87
	Euro I	2.064	1.245	1.401
	Euro II	0.477	0.418	0.394
	Euro III	0.444	0.389	0.367
Diesel LGV	Pre-Euro I	0.980	0.763	1.171
	Euro I	0.453	0.510	0.909
	Euro II	0.453	0.510	0.909
	Euro III	0.288	0.324	0.578
Rigid HGVs	Pre-1988	3.286	2.780	2.589
	88/77/EEC	2.526	2.137	1.990
	Euro I	1.427	1.216	1.178
	Euro II	1.156	0.977	0.910
	Euro III	0.802	0.678	0.631
Artic HGVs	Pre-1988	3.830	3.278	3.269
	88/77/EEC	2.923	2.502	2.495
	Euro I	4.001	3.409	3.303
	Euro II	3.106	2.628	2.447
	Euro III	2.155	1.823	1.698
Buses	Pre-1988	18.37	7.47	9.24
	88/77/EEC	8.159	3.319	4.102
	Euro I	2.541	1.135	1.100
	Euro II	2.106	0.916	0.853
	Euro III	1.461	0.636	0.592
Mopeds, <50cc, 2st	Pre-2000	23.81	36.46	50.80
	Euro I	2.38	3.65	5.08
Motorcycles, >50cc, 2st	Pre-2000	23.37	25.80	28.43
	Euro I	12.04	21.54	31.93
Motorcycles, >50cc, 4st	Pre-2000	20.81	22.20	30.83
	Euro I	6.97	10.01	18.38

**Table A3.3.20** Methane Emission Factors for Road Transport (in g/km)

g/km	Standard	Urban	Rural	Motorway
Petrol cars	ECE 15.01	0.105	0.033	0.048
	ECE 15.02	0.106	0.033	0.049
	ECE 15.03	0.106	0.033	0.049
	ECE 15.04	0.085	0.026	0.039
	Euro I	0.037	0.017	0.023
	Euro II	0.026	0.011	0.007
	Euro III	0.015	0.007	0.004
	Euro IV	0.012	0.005	0.003
Diesel cars	Pre-Euro I	0.008	0.010	0.018
	Euro I	0.004	0.005	0.011
	Euro II	0.003	0.004	0.007
	Euro III	0.002	0.002	0.005
Petrol LGVs	Pre-Euro I	0.150	0.040	0.025
	Euro I	0.036	0.017	0.027
	Euro II	0.022	0.011	0.018
	Euro III	0.013	0.006	0.011
Diesel LGV	Pre-Euro I	0.005	0.005	0.005
	Euro I	0.002	0.003	0.003
	Euro II	0.002	0.003	0.003
	Euro III	0.002	0.003	0.002
Rigid HGVs	Pre-1988	0.241	0.091	0.079
	88/77/EEC	0.120	0.045	0.039
	Euro I	0.044	0.015	0.012
	Euro II	0.035	0.013	0.011
	Euro III	0.024	0.009	0.008
Artic HGVs	Pre-1988	0.441	0.201	0.176
	88/77/EEC	0.175	0.080	0.070
	Euro I	0.187	0.097	0.096
	Euro II	0.154	0.086	0.092
	Euro III	0.108	0.060	0.064
Buses	Pre-1988	0.722	0.330	0.289
	88/77/EEC	0.175	0.080	0.070
	Euro I	0.130	0.069	0.058
	Euro II	0.094	0.059	0.053
	Euro III	0.066	0.041	0.037
Mopeds, <50cc, 2st	Pre-2000	0.219	0.219	0.219
	Euro I	0.048	0.048	0.048
Motorcycles, >50cc, 2st	Pre-2000	0.150	0.150	0.150
	Euro I	0.104	0.107	0.091
Motorcycles, >50cc, 4st	Pre-2000	0.200	0.200	0.200
	Euro I	0.084	0.079	0.059

**Table A3.3.21** N<sub>2</sub>O Emission Factors for Road Transport (in g/km)

g/km	Standard	Urban	Rural	Motorway
Petrol cars	ECE 15.01	0.005	0.005	0.005
	ECE 15.02	0.005	0.005	0.005
	ECE 15.03	0.005	0.005	0.005
	ECE 15.04	0.005	0.005	0.005
	Euro I	0.053	0.016	0.035
	Euro II	0.053	0.016	0.035
	Euro III	0.053	0.016	0.035
	Euro IV	0.053	0.016	0.035
Diesel cars	Pre-Euro I	0.027	0.027	0.027
	Euro I	0.027	0.027	0.027
	Euro II	0.027	0.027	0.027
	Euro III	0.027	0.027	0.027
Petrol LGVs	Pre-Euro I	0.006	0.006	0.006
	Euro I	0.053	0.016	0.035
	Euro II	0.053	0.016	0.035
	Euro III	0.053	0.016	0.035
Diesel LGV	Pre-Euro I	0.017	0.017	0.017
	Euro I	0.017	0.017	0.017
	Euro II	0.017	0.017	0.017
	Euro III	0.017	0.017	0.017
Rigid HGVs	Pre-1988	0.03	0.03	0.03
	88/77/EEC	0.03	0.03	0.03
	Euro I	0.03	0.03	0.03
	Euro II	0.03	0.03	0.03
	Euro III	0.03	0.03	0.03
Artic HGVs	Pre-1988	0.03	0.03	0.03
	88/77/EEC	0.03	0.03	0.03
	Euro I	0.03	0.03	0.03
	Euro II	0.03	0.03	0.03
	Euro III	0.03	0.03	0.03
Buses	Pre-1988	0.03	0.03	0.03
	88/77/EEC	0.03	0.03	0.03
	Euro I	0.03	0.03	0.03
	Euro II	0.03	0.03	0.03
	Euro III	0.03	0.03	0.03
Mopeds, <50cc, 2st	Pre-2000	0.001	0.001	0.001
	Euro I	0.001	0.001	0.001
Motorcycles, >50cc, 2st	Pre-2000	0.002	0.002	0.002
	Euro I	0.002	0.002	0.002
Motorcycles, >50cc, 4st	Pre-2000	0.002	0.002	0.002
	Euro I	0.002	0.002	0.002



**Table A3.3.22** Equations for diurnal, hot soak and running loss evaporative emissions from vehicles with and without control systems fitted

Emission factor	Units	Uncontrolled vehicle (pre-Euro I)
Diurnal loss (DL <sub>uncontrolled</sub> )	g/vehicle.day	$1.54 * (0.51 * T_{\text{rise}} + 0.62 * T_{\text{max}} + 0.22 * \text{RVP} - 24.89)$
Hot soak (HS <sub>uncontrolled</sub> )	g/vehicle.trip	$\exp(-1.644 + 0.02 * \text{RVP} + 0.0752 * T_{\text{mean}})$
Running loss (RL <sub>uncontrolled</sub> )	g/vehicle.km	$0.022 * \exp(-5.967 + 0.04259 * \text{RVP} + 0.1773 * T_{\text{mean}})$

Emission factor	Units	Carbon canister controlled vehicle (Euro I)
Diurnal loss (DL <sub>EUI</sub> )	g/vehicle.day	$0.3 * (\text{DL}_{\text{uncontrolled}})$
Hot soak (HS <sub>EUI</sub> )	g/vehicle.trip	$0.3 * \exp(-2.41 + 0.02302 * \text{RVP} + 0.09408 * T_{\text{mean}})$
Running loss (RL <sub>controlled</sub> )	g/vehicle.km	$0.1 * (\text{RL}_{\text{uncontrolled}})$

Emission factor	Units	Carbon canister controlled vehicle (Euro II-IV)
Diurnal loss (DL <sub>EUII-IV</sub> )	g/vehicle.day	$0.2 * 9.1 * \exp(0.0158 * (\text{RVP} - 61.2) + 0.0574 * (T_{\text{max}} - T_{\text{rise}} - 22.5) + 0.0614 * (T_{\text{rise}} - 11.7))$
Hot soak (HS <sub>EUII-IV</sub> )	g/vehicle.trip	0
Running loss (RL <sub>controlled</sub> )	g/vehicle.km	$0.1 * (\text{RL}_{\text{uncontrolled}})$

where

$T_{\text{rise}}$  = diurnal rise in temperature in °C  
 $T_{\text{max}}$  = maximum daily temperature in °C  
 $T_{\text{mean}}$  = annual mean temperature in °C  
 $\text{RVP}$  = Reid Vapour Pressure of petrol in kPa

### **A3.3.5.4 Navigation**

The UK GHGI provides emission estimates for coastal shipping, fishing, naval shipping and international marine. Coastal shipping is reported within IPCC category 1A3dii National Navigation and includes emissions from diesel use at offshore oil & gas installations. A proportion of this diesel use will be for marine transport associated with the offshore industry but some will be for use in turbines, motors and heaters on offshore installations. Detailed fuel use data is no longer available to determine emissions from diesel use in fishing vessels, as the DTI gas oil dataset has been revised in the latest inventory cycle. All emissions from fishing are now included within the coastal shipping sector, 1A3dii National Navigation.

The emissions reported under coastal shipping, naval shipping and fishing are estimated according to the base combustion module using the emission factors given in **Table A3.3.1**.

The NAEI category International Marine is the same as the IPCC category 1A3i International Marine. The estimate used is based on the following information and assumptions:

- (i) Total deliveries of fuel oil, gas oil and marine diesel oil to marine bunkers are given in DTI (2005).
- (ii) Naval fuel consumption is assumed to be marine diesel oil (MOD, 2004). Emissions from this source are not included here but are reported under 1A5 Other.
- (iii) The fuel consumption associated with international marine is the marine bunkers total minus the naval consumption. The emissions were estimated using the emission factors shown in **Table A3.3.1**.

Emissions from 1A3i International Marine are reported for information only and are not included in national totals. Bunker fuels data for shipping are provided to the DTI by UKPIA, and are based on sale of fuels to UK operators going abroad and overseas operators (assumed to be heading abroad) (DTI 2004, per. comm.<sup>19</sup>).

### **A3.3.6 Other Sectors (1A4)**

The mapping of NAEI categories to 1A4 Other Sectors is shown in **Section A3.2**. For most sources, the estimation procedure follows that of the base combustion module using DTI reported fuel use data and emission factors from **Table A3.3.1**. The NAEI category public service is mapped onto 1A4a Commercial and Institutional. This contains emissions from stationary combustion at military installations, which should be reported under 1A5a Stationary. Also included are stationary combustion emissions from the railway sector, including generating plant dedicated to railways. Also included in 1A4 are emissions from the 'miscellaneous' sector, which includes emissions from the commercial sector and some service industries.

Emissions from 1A4b Residential and 1A4c Agriculture/Forestry/Fishing are disaggregated into those arising from stationary combustion and those from off-road vehicles and other machinery. The estimation of emissions from off-road sources is discussed in **Section A3.3.7.1** below. Emissions from fishing vessels are now included within the coastal shipping

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<sup>19</sup> DTI (2004) Personal communication from Martin Young, DTI.

sector, due to the withdrawal of more detailed fuel use datasets that have historically been provided by DTI but are now determined to be of questionable accuracy.

### **A3.3.7 Other (1A5)**

Emissions from military aircraft and naval vessels are reported under 1A5b Mobile. The method of estimation is discussed in **Sections A3.3.5.1 and A3.3.5.4** with emission factors given **Table A3.3.1**. Note that military stationary combustion is included under 1A4a Commercial and Institutional due to a lack of more detailed data. Emissions from off-road sources are estimated and are reported under the relevant sectors, i.e. Other Industry, Residential, Agriculture and Other Transport. The methodology of these estimates is discussed in **Section A3.3.7.1**.

#### **A3.3.7.1 Estimation of other Off-road sources**

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

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

The mapping of these categories to the appropriate IPCC classes is shown in **Section 3.2**. Aircraft support is mapped to Other Transport and the other categories map to the off-road vehicle subcategories of Residential, Agriculture and Manufacturing Industries and Construction.

The estimates are calculated using a modification of the methodology given in EMEP/CORINAIR (1996). This involves the estimation of emissions from around seventy classes of off-road source using the following equation for each class:

$$E_j = N_j \cdot H_j \cdot P_j \cdot L_j \cdot W_j \cdot (1 + Y_j \cdot a_j / 2) \cdot e_j$$

where

$E_j$	=	Emission of pollutant from class j (kg/y)
$N_j$	=	Population of class j.
$H_j$	=	Annual usage of class j (hours/year)
$P_j$	=	Average power rating of class j (kW)
$L_j$	=	Load factor of class j (-)
$Y_j$	=	Lifetime of class j (years)
$W_j$	=	Engine design factor of class j (-)
$a_j$	=	Age factor of class j ( $y^{-1}$ )
$e_j$	=	Emission factor of class j (kg/kWh)

For petrol-engined sources, evaporative NMVOC emissions are also estimated as:

$$E_{vj} = N_j \cdot H_j \cdot e_{vj}$$

where

$$\begin{aligned} E_{vj} &= \text{Evaporative emission from class } j \text{ kg} \\ e_{vj} &= \text{Evaporative emission factor for class } j \text{ kg/h} \end{aligned}$$

The population, usage and lifetime of different types of off-road machinery were updated following a study carried out recently by NETCEN on behalf of the Department for Transport (NETCEN, 2004a). This study researched the current UK population, annual usage rates, lifetime and average engine power for a range of different types of diesel-powered non-road mobile machinery. Additional information including data for earlier years were based on research by Off Highway Research (2000) and market research polls amongst equipment suppliers and trade associations by Precision Research International on behalf of the former DoE (Department of the Environment) (PRI, 1995, 1998). Usage rates from data published by Samaras *et al* (1993, 1994) were also used.

The emission factors used came mostly from EMEP/CORINAIR (1996) though a few of the more obscure classes were taken from Samaras & Zierock (1993). The load factors were taken from Samaras (1996). Emission factors for garden machinery, such as lawnmowers and chainsaws were updated following a recent review by NETCEN (2004b), considering the impact of Directive 2002/88/EC on emissions from these types of machinery.

It was possible to calculate fuel consumptions for each class of machinery based on fuel consumption factors given in EMEP/CORINAIR (1996). Comparison with known fuel consumption for certain groups of classes (e.g. agriculture and construction) suggested that the population method over estimated fuel consumption by factors of 5-12. Hence the methodology was modified in the following way:

- 1) Aggregate emission factors were calculated for each of the four main categories listed above as:

$$e_p = \frac{E}{F}$$

where

$$\begin{aligned} e_p &= \text{Aggregate emission factor for main NAEI category (kg/t fuel)} \\ E &= \text{Sum of emissions of pollutant from classes within main NAEI category calculated from the population approach (kg)} \\ F &= \text{Sum of fuel consumption from classes within main NAEI category calculated from the population approach (tonnes)} \end{aligned}$$

- 2) Estimates were derived for the fuel consumptions for the years 1990-2004 for each of the four main categories:

- A. *Agricultural power units:* Data on gas oil consumption were taken from DTI (2005). The consumption of petrol was estimated using the population method for 1995 without correction. The same estimate was used for 1990 to 2004.

- B. *Aircraft support*: Data on diesel oil consumption at Heathrow Airport were extrapolated on the basis of the number of takeoffs and landings (DfT, 2004c; Leech, 1994)
- C. *Industrial off-road*: The construction component of the gas oil consumption was calculated from DUKES data (DTI, 2005) on building and contracting; mines and quarrying and water giving a time series for 1990-2004. Gas oil consumption by other types of industrial machinery was estimated from the population approach. This gave an estimate for 1995, which was used for all years. The petrol consumption was estimated from the population approach for 1995 and used for the period 1990-2004. Earlier years were extrapolated based on the building, contracting, mines, quarrying and water diesel consumption.
- D. *Domestic house & garden*: Petrol and diesel oil consumption were estimated from the EMEP/CORINAIR population approach for 1995 and the same value used for all years.

3) The emission for each of the four main NAEI categories was estimated as:

$$E_p = e_p \cdot A_p$$

where

$$A_p = \text{Fuel consumption of NAEI main category } p \text{ (tonnes)}$$

Emissions from off-road sources are particularly uncertain. The population and usage data found by a recent study (NETCEN 2004a) produced higher gas-oil fuel consumption estimates than the DTI data for sector groups by between 5 and 12 times. The DTI gas-oil fuel data are currently mainly used in estimation of off-road emissions. This is under review. Note that the petrol consumed by off-road machinery is still only a tiny proportion of total petrol sales.

**Table A3.3.23** Aggregate Emission Factors for Off-Road Source Categories<sup>1</sup> in 2004 (t/kt fuel)

Source	Fuel	C <sup>2</sup>	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	CO	NM VOC	SO <sub>2</sub> <sup>3</sup>
Domestic House&Garden	DERV	863	0.165	1.36	50.14	5.57	3.12	0.07
Domestic House&Garden	Petrol	855	5.46	0.045	5.95	1027	206	0.07
Agricultural Power Units	Gas Oil	870	0.158	1.28	48.83	16.1	6.59	2.98
Agricultural Power Units	Petrol	855	7.53	0.02	1.98	1367	753	0.07
Industrial Off-road	Gas Oil	870	0.163	1.36	41.39	17.5	6.71	2.98
Industrial Off-road	Petrol	855	6.03	0.067	8.15	2388	125	0.07
Aircraft Support	Gas Oil	870	0.167	1.34	42.8	12.5	5.27	2.98

1 Emission factors reported are for 2004

2 Emission factor as kg carbon/t, UKPIA (2004)

3 UKPIA (2004), Factor for 2004

The emission factors used for carbon dioxide were the standard emission factors for DERV, gas oil and petrol given in **Table A3.3.1**.

### A3.3.8 Fugitive Emissions From fuels (1B)

#### A3.3.8.1 Solid fuels (1B1)

##### A3.3.8.1.1 Coal Mining

Emissions for IPCC categories 1B1ai Underground Mines-mining, 1B1ai Underground Mines-post-mining and 1B1aia Surface Mines are calculated from saleable coal production statistics reported by DTI (2005). Licensed mines referred to privately owned mines and were generally smaller and shallower than previously nationalised mines. The distinction was sufficiently marked to allow the use of a separate emission factor. Data on the shallower licensed mines are supplied by Barty (1995) up to 1994. Following privatisation, the distinction between licensed mines and deep mines no longer exists and all domestically produced coal that is not open-cast is assumed to be deep mined. For 1995, data from 1994 were used but in subsequent years the distinction has been abandoned. The emission factors used are shown in **Table A3.3.24**.

**Table A3.3.24** Methane Emission Factors for Coal Mining (kg/t coal)

Year	Deep Mined	Coal Storage & Transport <sup>a</sup>	Licensed Mine <sup>d</sup>	Open Cast <sup>c</sup>
1990	10.0 <sup>a</sup>	1.16	1.36	0.34
1991	10.2 <sup>a</sup>	1.16	1.36	0.34
1992	11.0 <sup>a</sup>	1.16	1.36	0.34
1993	13.1 <sup>a</sup>	1.16	1.36	0.34
1994	13.0 <sup>a</sup>	1.16	1.36	0.34
1995	13.0 <sup>a</sup>	1.16	1.36	0.34
1996	13.4 <sup>a</sup>	1.16	1.36	0.34
1997	13.4 <sup>a</sup>	1.16	1.36	0.34
1998	13.4 <sup>a</sup>	1.16	-	0.34
1999	13.5	1.16	-	0.34
2000	14.0 <sup>b</sup>	1.16	-	0.34
2001	12.6 <sup>b</sup>	1.16	-	0.34
2002	13.5 <sup>b</sup>	1.16	-	0.34
2003	11.7 <sup>b</sup>	1.16	-	0.34
2004	13.7 <sup>b</sup>	1.16	-	0.34

a Bennet *et al* (1995)

b Factor based on UK Coal Mining Ltd data

c Williams (1993)

The licensed and open cast factors are taken from Williams (1993). The deep mined factors for 1990 -1992 and the coal storage factor are taken from Bennet *et al* (1995). This was a study on deep mines which produced estimates of emissions for the period 1990-93. This was a period over which significant numbers of mines were being closed, hence the variation in emission factors. The emission factors for 1998-2004 are based on operator's measurements of the methane extracted by the mine ventilation systems. The mines surveyed cover around 90% of deep mined production. No time series data are available for 1993-97, so the 1998

factor was used. Methane extracted is either emitted to atmosphere or utilised for energy production. Methane is not flared for safety reasons. The factors reported in **Table A3.3.24** refer to emissions and exclude the methane utilised. The coal storage and transport factor is only applied to deep mined coal production.

The activity data for the coal mining emissions are reported in the CRF tables attached as a CD ROM to this report. Note that the number of active deep mines reported is defined as the number of mines producing at any one time during the period (Coal Authority, 2005). Hence, this would include large mines as well as small ones or those that only produced for part of the year. The colliery methane utilisation data are taken from DTI (2005).

Methane from closed coal mines is included in sector 1B1a of the UK inventory following publication of the findings of a recent study funded by Defra (Kershaw, 2005).

Methane emissions from abandoned mines arise at the surface through many possible flow paths: vents into the workings to relieve pressure, old mine entries, diffuse emission through fractured and permeable strata. Direct measurement of the total quantity of gas released from abandoned mines is not practical. Emission estimates for 1990 to 2004 have been calculated using a relationship between emission and the quantity of the underlying methane gas within the abandoned mine workings.

Methane reserves have been calculated for all UK coalfields that are not totally flooded between 1990 and 2005. The gas reserves are calculated by totalling all the gas quantities in individual seams likely to have been disturbed by mining activity. To enable calculation of the reserves over time, it has been necessary to calculate the rises in water levels in the abandoned mines due to water inflow. As workings become flooded they cease to release significant amounts of methane to the surface.

Monitoring has been carried out to measure methane emission from vents and more diffuse sources. Monitoring of vents involved measurement of the flows and concentrations of the gas flowing out of the mine. Monitoring of more diffuse sources required collection of long-term gas samples to measure any increases in background atmospheric methane level in the locality.

Methane flows measured by both methods showed a general increase with the size of the underlying gas reserve. The data indicated an emission of 0.74% of the reserve per year as a suitable factor to apply to the methane reserve data in order to derive methane emission estimates for abandoned UK coalfields for 1990 to 2004.

### *A3.3.8.1.2 Solid Fuel Transformation*

Fugitive emissions from solid fuel transformation processes are reported in IPCC category 1B1b. The IPCC Revised 1996 Guidelines do not provide any methodology for such estimates, hence emissions are largely based on default emission factors. Combustion emissions from these processes have already been discussed in **Section A3.3.3**.

In a coke oven, coal is transformed into coke and coke oven gas. The coke oven gas is used as a fuel to heat the coke oven or elsewhere on the site. The coke may be used elsewhere as a

fuel or as a reducing agent in metallurgical processes. A carbon balance is performed over the coke oven on the fuels input and the fuels produced as described in **Section A.3.3.1**.

Process emissions of other pollutants from coke ovens are estimated either on the basis of total production of coke or the coal consumed. Emission factors are given in **Table A3.3.25**.

Emissions of carbon from solid smokeless fuel production are calculated using a mass balance approach, described previously in Section A.3.3.1. A similar mass balance is carried out for SO<sub>2</sub>. For emissions of other pollutants, a mass balance approach is not used. It is likely that emissions will arise from the combustion of the gases produced by some SSF retorts but this combustion is not identified in the energy statistics. Process emissions from SSF plant are estimated on the basis of total production of SSF. The emission factors used are given in **Table A3.3.25** and are based on USEPA (2004) factors for coke ovens. There are a number of processes used in the UK ranging from processes similar to coking to briquetting of anthracite dust and other smokeless fuels. Given the number of processes in use these estimates will be very uncertain.

Data are available on the production of SSF and the fuels used (DTI, 2005), however it is clear that in recent years both coke and imported petroleum coke have been used in the production of smokeless fuels. Data on the total UK imports and exports of petroleum coke are available but little information is available on its consumption. In the GHGI, it is assumed that 245 kt *per annum* of petroleum coke were used in SSF production from 1990 to 1998 based on data provided within DUKES (DTI, 1999). For 1999-2004 approximate estimates by DTI (2005) are used. The carbon content of the petroleum coke consumed is not included in the SSF carbon balance – instead it is allocated to the domestic sector as a separate fuel. Coke used by SSF manufacturers is assumed to be burnt as a fuel and is also not included in the carbon balance. The model used is not entirely satisfactory but further information would be required before a more accurate carbon balance could be developed.

Emissions from the combustion of fuels to heat the smokeless fuel retorts are reported under 1A1ci Manufacture of Solid Fuels, however process emissions and the residual carbon emission discussed above are considered to be fugitives and are reported under 1B1b Solid Fuel Transformation.

**Table A3.3.25** Emission Factors Used for Coke and Solid Smokeless Fuel Production

	Units	CH <sub>4</sub>	CO	NO <sub>x</sub>	SO <sub>2</sub>	NMVOC
<b>Coke</b>	kt/Mt coke made	0.08 <sup>a</sup>	1.49 <sup>c</sup>	-	1.61 <sup>c</sup>	0.018 <sup>e</sup>
<b>Coke</b>	kt/Mt coal consumed	-	-	0.02 <sup>b</sup>		-
<b>SSF</b>	kt/Mt SSF made	0.08 <sup>a</sup>	0.12 <sup>c</sup>	0.09 <sup>c</sup>	-	0.018 <sup>a</sup>
<b>SSF</b>	kt/Mt coal consumed	-	-	0.005 <sup>b</sup>	3.46 <sup>d</sup>	-

a EIPPCB, (2000)

b USEPA (2004)

c Factor for 2004 based on Environment Agency (2005)

d Based on mass balance but zero for 2002 (because calculated sulphur content of SSF produced was higher than the sulphur content of coal used to make the SSF).

e Derived from benzene emission factor assuming a VOC/benzene ratio of 3.9:2.195, which is based on emission factors suggested by Corus, 2000



### **A3.3.8.2 Oil and Natural Gas (1B2)**

The emissions reported in this sector pertain to the offshore platforms and onshore terminals on the UK Continental Shelf Area and represented by the United Kingdom Offshore Operators Association (UKOOA). Emissions estimates for the offshore industry are based on data provided by the trade organisation, UKOOA, through their annual emissions reporting mechanism to UK regulators, the Environmental Emissions Monitoring System (EEMS). This system provides a detailed inventory of point source emissions estimates, based on operator returns for the years 1995-2004. Additional, more detailed data on CO<sub>2</sub> emissions from some offshore combustion processes has become available as a result of the development of the industry's National Allocation Plan pertaining to the EU Emission Trading Scheme. Therefore, for the main combustion sources in the offshore oil & gas sector, the UKOOA data from 1998 onwards is sourced via NAP estimates, replacing historic estimates previously reported via EEMS.

For years prior to 1995 (i.e. pre-EEMS), emission totals are based on an internal UKOOA summary report produced in 1998. These data were revised and reported with the 1995-2004 datasets in the UKOOA 2005 submission to the inventory. The 1998 UKOOA report presents data from detailed industry studies in 1991 and 1995 to derive emission estimates for 1990 from available operator estimates. Emission estimates for 1991-1994 were then calculated using production-weighted interpolations. Only limited data were available from operators in 1990-1994, and emission totals could only be estimated in broadly aggregated sectors of: drilling (offshore), production (offshore), loading (offshore) and total emissions onshore. Estimates of the more detailed oil & gas processing source sectors for 1990-1994 are therefore based on applying the fraction of total emissions derived from the 1997 data from EEMS.

UKOOA has periodically produced operator guidance for estimating and reporting emissions from offshore oil & gas processes, with recent guidance covering CO<sub>2</sub> emissions from combustion processes (Russell, 2004) and other guidance for emissions of other pollutants such as CH<sub>4</sub>, VOCs, NO<sub>x</sub> and SO<sub>2</sub> (UKOOA, 2001). A spreadsheet-based tool has also been developed to improve quality and consistency of operator reports. The operators are required to report flaring and venting masses and compositions. Methodologies have been developed to estimate combustion emissions from turbines, boilers and heaters and fugitive emissions. These are calculated on a plant item-by-item basis.

For some sections of the EEMS data prior to 1999 where detailed data were not provided, estimates have been made on the basis of oil and gas throughput. However, since improvements in the reporting system have minimised the need for such assumptions, since 1999 the majority of emission estimates are based on detailed data. For example, prior to 1999, N<sub>2</sub>O emissions were not monitored by the plant operators and hence the 1990-1998 N<sub>2</sub>O emissions data are based on emission factors (derived from the 1999 data) and estimated production throughput data.

The data reported in the EEMS database must be reconciled with the UK Energy Statistics and integrated into the NAEI without double-counting emissions. The diesel oil consumption by offshore installations is not reported separately in the UK Energy Statistics but is included under coastal shipping. In order to avoid double counts the UKOOA estimates have been corrected to remove diesel oil emissions.

In the NAEI, offshore emissions are estimated in the following categories each with its own methodology:

- Offshore flaring
- Offshore Oil & Gas (well testing)
- Offshore Oil & Gas (venting)
- Offshore Oil & Gas process emissions
- Offshore Loading
- Onshore loading
- Oil Terminal Storage
- Offshore own gas use (reported under 1A1c Other Energy Industries)
- Gas Separation Plant (Combustion) (reported under 1A1c Other Energy Industries)

The mapping of these sources to IPCC categories is described in **Section A3.2**. Activity data are reported in the CRF Background Table 1B2, however in most cases these data are not used to calculate the emissions, but are provided for comparison with other inventories.

### *A3.3.8.2.1 Offshore flaring*

This includes flaring from offshore platforms and onshore terminals. Flaring emission data for CO<sub>2</sub>, SO<sub>2</sub>, NO<sub>x</sub>, CO, NMVOC, and CH<sub>4</sub> are taken from the UKOOA (2005) dataset. Data from 1995-2004 are based on detailed operator returns, whilst 1990-1994 data are calculated from extrapolation of total emissions data and the use of 1997 data splits between sources. N<sub>2</sub>O emissions are based on operator information from 1999-2003, and on emission factors and production throughput data for 1990-1998.

The aggregate emission factors are given in **Table A3.3.26** and the activity data in **Table A3.3.27**. The aggregate emission factors for 1990-2004 are reported as kg pollutant/kg gas flared and are calculated from emissions and activity data reported by UKOOA in 2005.

**Table A3.3.26** Aggregate Emission Factors for Offshore Gas Flaring

	CO <sub>2</sub>	CH <sub>4</sub>	NO <sub>x</sub>	CO	NMVOC	SO <sub>2</sub>	N <sub>2</sub> O	Units
<b>2004</b>	2.58	0.0097	0.0015	0.00740	0.00677	0.00020	0.00008	kg/kg
<b>2003</b>	2.64	0.0102	0.0015	0.00751	0.00672	0.00016	0.00008	kg/kg
<b>2002</b>	2.64	0.0097	0.0018	0.00755	0.00698	0.00015	0.00008	kg/kg
<b>2001</b>	2.47	0.0099	0.0014	0.00730	0.00700	0.00022	0.00008	kg/kg
<b>2000</b>	2.38	0.0109	0.0013	0.00717	0.00642	0.00018	0.00008	kg/kg
<b>1999</b>	2.49	0.0103	0.0014	0.00760	0.00819	0.00025	0.00008	kg/kg
<b>1998</b>	2.51	0.0107	0.0014	0.00716	0.00901	0.00014	0.00008	kg/kg
<b>1997</b>	2.52	0.0107	0.0015	0.00741	0.00969	0.00014	0.00008	kg/kg
<b>1996</b>	2.43	0.0104	0.0014	0.00744	0.00961	0.00013	0.00008	kg/kg
<b>1995</b>	2.45	0.0102	0.0014	0.00745	0.00979	0.00014	0.00008	kg/kg
<b>1994</b>	2.58	0.0097	0.0015	0.00740	0.00677	0.00020	0.00008	kg/kg
<b>1993</b>	2.18	0.0106	0.0012	0.00842	0.01219	0.00006	0.00007	kg/kg
<b>1992</b>	2.18	0.0124	0.0013	0.00864	0.01279	0.00006	0.00007	kg/kg
<b>1991</b>	2.18	0.0133	0.0014	0.00888	0.01348	0.00006	0.00007	kg/kg
<b>1990</b>	2.18	0.0139	0.0014	0.00888	0.01289	0.00006	0.00007	kg/kg

The UKOOA data from the EEMS database do not include flaring on onshore oil production fields. These emissions are estimated by extrapolation using flaring volume data collected by

DTI (2005a) and the offshore flaring factors. The onshore flaring data are shown in **Table A3.3.27** though the contribution is very small.

Flaring is reported under 1B2ciii Flaring – Combined, since many of the platforms produce both oil and gas. An estimate of NMVOC emissions from refinery flares is reported in 1B2ci Venting and Flaring: Oil. This is based on estimates supplied by UKPIA (2005).

**Table A3.3.27** Activity Data for Offshore Gas Flaring

Year	Gas Flared (kt) <sup>1</sup>	Gas Flared, Offshore Fields & Terminals (Mm <sup>3</sup> ) <sup>2</sup>	Gas Flared, Onshore Fields (Mm <sup>3</sup> ) <sup>2</sup>
2004	1,551	1896	16.7
2003	1,487	1697	21.4
2002	1,710	1665	19.1
2001	1,869	1808	11.6
2000	1,987	1814	15.0
1999	2,113	2206	4.6
1998	2,056	2110	0
1997	2,042	2122	7
1996	2,308	2539	15
1995	2,272	2388	11
1994	2,164	3282	10
1993	2,034	2461	16
1992	1,905	2468	12
1991	1,775	2531	7
1990	1,796	2793	7

1 EEMS data, UKOOA (2005)

2 DTI (2005)

3 A correction has been applied for non-reporting operators

## *A3.3.8.2.2 Offshore gas use*

This refers to the use of unrefined natural gas on offshore platforms and onshore terminals as a fuel in heaters, boilers, turbines and reciprocating engines. Gas combustion emission data for CO<sub>2</sub>, SO<sub>2</sub>, NO<sub>x</sub>, CO, NMVOC, and CH<sub>4</sub> are taken from the UKOOA (2005) dataset. Data from 1995-2004 are based on detailed operator returns, whilst 1990-1994 data are calculated from extrapolation of total emissions data and the use of 1995 data splits between sources. N<sub>2</sub>O emissions are based on operator information from 1999-2004, and on emission factors and production throughput data for 1990-1998.

The aggregate emission factors are given in **Table A3.3.28**. The aggregate emission factors for 1990-2004 are reported as kg pollutant/ kg gas used and are calculated from the emissions and activity data reported within the UKOOA 2005 dataset.

**Table A3.3.28** Aggregate Emission Factors for Offshore Own Gas Use

	CO <sub>2</sub>	CH <sub>4</sub>	NO <sub>x</sub>	CO	NMVOC	SO <sub>2</sub>	N <sub>2</sub> O	Units
2004	2.67	0.0004	0.0093	0.0017	0.00017	0.00007	0.00007	kg/kg
2003	2.66	0.0004	0.0089	0.0017	0.00013	0.00009	0.00007	kg/kg
2002	2.63	0.0004	0.0090	0.0016	0.00013	0.00009	0.00008	kg/kg
2001	2.62	0.0005	0.0071	0.0017	0.00016	0.00009	0.00008	kg/kg
2000	2.55	0.0005	0.0072	0.0017	0.00014	0.00010	0.00008	kg/kg
1999	2.70	0.0005	0.0076	0.0017	0.00014	0.00011	0.00008	kg/kg
1998	2.74	0.0002	0.0066	0.0017	0.00006	0.00008	0.00008	kg/kg
1997	2.70	0.0003	0.0069	0.0017	0.00008	0.00008	0.00008	kg/kg
1996	2.63	0.0002	0.0067	0.0017	0.00005	0.00008	0.00008	kg/kg
1995	2.62	0.0002	0.0066	0.0018	0.00005	0.00010	0.00008	kg/kg
1994	2.77	0.0004	0.0062	0.0023	0.00013	0.00004	0.00008	kg/kg
1993	2.77	0.0004	0.0067	0.0023	0.00013	0.00005	0.00008	kg/kg
1992	2.77	0.0004	0.0071	0.0024	0.00014	0.00005	0.00008	kg/kg
1991	2.77	0.0005	0.0077	0.0025	0.00015	0.00005	0.00008	kg/kg
1990	2.77	0.0005	0.0077	0.0025	0.00014	0.00005	0.00008	kg/kg

These emissions apply to the mixture of methane, ethane, propane and butane used. In the NAEI database they are reported in the categories:

- Offshore own gas use: natural gas
- Gas separation plant: LPG
- Gas separation plant: OPG

Emissions are reported under 1A1cii Other Energy Industries.

### A3.3.8.2.3 *Well testing*

This activity involves the combustion of crude oil and crude gas during well testing, and is an activity that is not included in UK Energy Statistics from the DTI. Combustion emission data for CO<sub>2</sub>, SO<sub>2</sub>, NO<sub>x</sub>, CO, NMVOC, and CH<sub>4</sub> are taken from the UKOOA (2005) dataset. Data from 1995-2004 are based on detailed operator returns, whilst 1990-1994 data are calculated from extrapolation of total emissions data and the use of 1997 data splits between sources. N<sub>2</sub>O emissions are based on operator information from 1999-2004, and on emission factors and production throughput data for 1990-1998.

The estimates of the amounts of crude oil and gas burnt are of unknown quality. Data is provided by the DTI regarding the number of wells tested annually, but the number of wells tested is only a small proportion of the number of wells explored and that proportion may vary from year to year. Also the number of wells explored varies considerably from year to year.

The aggregate emission factors are given in **Table A3.3.29**. Well testing is reported under 1B2a Oil Production since many of the wells produce oil and gas.

**Table A3.3.29** Aggregate Emission Factors for Offshore Well Testing (kt/well explored)

	C	SO <sub>2</sub>	NO <sub>x</sub>	CO	NMVOC	CH <sub>4</sub>	N <sub>2</sub> O	Units
2004	1.20	0	0.0031	0.0159	0.0179	0.0567	0.0001	Kt/well
2003	1.40	0	0.0038	0.0192	0.0222	0.0646	0.0001	Kt/well
2002	2.51	0	0.0083	0.0412	0.0522	0.0988	0.0002	Kt/well
2001	1.23	0	0.0043	0.0212	0.0274	0.0462	0.0001	Kt/well
2000	1.45	0	0.0052	0.0256	0.0335	0.0524	0.0001	Kt/well
1999	3.61	0.0001	0.0111	0.0558	0.0685	0.1513	0.0004	Kt/well
1998	3.73	0.1309	0.0120	0.0619	0.0656	0.1599	0.0004	Kt/well
1997	2.78	0.1039	0.0090	0.0461	0.0519	0.1206	0.0003	Kt/well
1996	2.34	0.0923	0.0080	0.0411	0.0462	0.1077	0.0002	Kt/well
1995	2.69	0.1000	0.0087	0.0445	0.0500	0.1167	0.0003	Kt/well
1994	7.17	0.1266	0.1601	0.0926	0.0544	0.1005	0.0003	Kt/well
1993	8.19	0.1498	0.1951	0.1083	0.0650	0.1220	0.0003	Kt/well
1992	5.29	0.1005	0.1348	0.0716	0.0440	0.0921	0.0002	Kt/well
1991	3.41	0.0675	0.0934	0.2879	0.0299	0.0635	0.0001	Kt/well
1990	2.32	0.0460	0.0636	0.0323	0.0195	0.0453	0.0001	Kt/well

#### A3.3.8.2.4 Other emissions from platforms and terminals

These include emissions of CH<sub>4</sub> and NMVOC from platforms and terminals arising from cold venting, other fugitive emissions and also from storage of crude oil at terminals. Emissions data are taken from the UKOOA (2005) dataset. Data from 1995-2004 are based on detailed operator returns, whilst 1990-1994 data are calculated from extrapolation of total emissions data and the use of 1997 data splits between sources.

These other emissions from platforms and terminals are reported in the following NAEI categories, all mapped to 1B2a Oil ii Production: offshore oil & gas (fugitive and process emissions), offshore venting and oil terminal storage. It is not possible to split oil and gas production emissions since oil and gas are frequently produced on the same platform.

**Table A3.3.30** Aggregate Emission Factors used for Emissions from Platforms and Terminals

	Period	Units	CH <sub>4</sub>	NMVOC
Gas Platforms	1970-92	kt/installation	0.589	0.0754
Oil Platforms	1970-92	kt/installation	0.327	0.393
Oil/Gas Platforms	1970-92	kt/installation	0.763	0.686
Gas Terminals	1970-92	kt/installation	3.0	0.425
Oil Terminals	1970-92	kt/installation	0.076	0.315

#### A3.3.8.2.5 Loading emissions

This sector includes emissions of CH<sub>4</sub> and NMVOCs from tanker loading and unloading based on data from the UKOOA (2005) dataset. Data from 1995-2004 are based on detailed operator returns, whilst 1990-1994 data are calculated from extrapolation of total emissions data and the use of 1997 data splits between sources.

These data are derived from operator information on the tonnage of oil shipped and site-specific emission factors, taking account for the application of abatement measures. A

correction is made regarding emissions from the Seal Sands Refinery to take account of discrepancies across the time series between data provided by the operator and the Pollution Inventory (Environment Agency, 2005).

Emissions data are reported using oil shipment data taken from DTI (2005), covering the amount of crude oil shipped by tanker from:

- production sites to UK users and export
- onshore terminals to UK users and export

It is assumed that no emission occurs from the amounts of crude oil transported by pipeline. **Table A3.3.31** shows aggregate factors calculated from the amounts of oil loaded. Oil shipment data are reported in the CRF tables.

**Table A3.3.31** Aggregate Emission Factors for Crude Oil Loading and Unloading

	Onshore CH <sub>4</sub>	Onshore NMVOC	Offshore CH <sub>4</sub>	Offshore NMVOC	Units
<b>2004</b>	0.014	0.12	0.084	1.12	t/kt oil
<b>2003</b>	0.012	0.21	0.080	1.38	t/kt oil
<b>2002</b>	0.015	0.22	0.124	1.60	t/kt oil
<b>2001</b>	0.017	0.23	0.113	1.54	t/kt oil
<b>2000</b>	0.017	0.32	0.110	1.69	t/kt oil
<b>1999</b>	0.017	0.23	0.071	1.38	t/kt oil
<b>1998</b>	0.017	0.22	0.043	1.44	t/kt oil
<b>1997</b>	0.017	0.22	0.036	1.98	t/kt oil
<b>1996</b>	0.017	0.24	0.035	1.96	t/kt oil
<b>1995</b>	0.018	0.24	0.036	2.00	t/kt oil
<b>1994</b>	0.035	0.30	0.033	2.14	t/kt oil
<b>1993</b>	0.038	0.30	0.036	2.24	t/kt oil
<b>1992</b>	0.044	0.30	0.042	2.35	t/kt oil
<b>1991</b>	0.047	0.32	0.045	2.48	t/kt oil
<b>1990</b>	0.049	0.33	0.047	2.37	t/kt oil

## A3.3.8.2.6 Leakage from the gas transmission system

The NAEI category Gas Leakage covers emissions of CH<sub>4</sub> and NMVOC from the UK gas transmission and distribution system. This is accounted for within the IPCC category 1B2b Natural Gas ii Transmission/Distribution. Data on gas leakage and the methane & NMVOC content of natural gas are provided by UK Transco and four companies (newly formed in 2005) that operate the low-pressure gas distribution networks. The leakage estimates are determined in three parts:

- Losses from High Pressure Mains (UK Transco)
- Losses from Low Pressure Distribution Network (UKD, Scotia Gas, Northern Gas Networks, Wales & West)
- Other losses, from Above Ground Installations and other sources (UK Transco)

Estimates are derived from specific leakage rates measured on the various types of gas mains and installations, together with data on the infrastructure of the UK supply system (such as length and type of pipelines and other units). Historic data for the leakage from the low-pressure distribution network and “other losses” (AGIs etc.) is based on studies from British Gas in the early 1990s (British Gas, 1993; Williams, 1993). Emission estimates for 1997 to 2004 are derived from an industry leakage model (data provided by the four network operator companies independently due to commercial confidentiality concerns), whilst emission estimates from 1990-96 are based on an older British Gas model that provided historical data for 1991-94 but projected estimates for 1995-96. The methane and NMVOC content of natural gas is shown in **Table A3.3.32**, and was provided by contacts within British Gas Research for 1990-1996 and from UK Transco from 1997 onwards (Malin, 2005). Data on NMVOC content for 2001-2003 has been estimated by interpolation due to a lack of data.

The full time-series of emissions from the high-pressure mains has been revised by UK Transco in the latest inventory cycle (Williams, 2005). Revisions to these and the “other losses” emission estimates have lowered the previous estimates across the time-series by around 30%.

**Table A3.3.32** Methane and NMVOC Composition of Natural Gas

Period	CH <sub>4</sub> weight %	NMVOC weight %
1990-96 <sup>1</sup>	84.3	8.9
1997-99 <sup>2</sup>	77.1	14.7
2000 <sup>2</sup>	77.6	14.7
2001 <sup>2</sup>	77.1	14.8 <sup>3</sup>
2002 <sup>2</sup>	77.3	15.0 <sup>3</sup>
2003 <sup>2</sup>	77.4	15.2 <sup>3</sup>
2004 <sup>2</sup>	77.4	15.3

1 British Gas (1994)

2 UK Transco (2005)

3 Netcen estimate (2005), based on data provided for other years

### *A3.3.8.2.7 Petrol distribution*

The NAEI reports emissions from the storage, distribution and sale of petrol in the following categories each of which is further divided into emissions of leaded and unleaded petrol:

- Refineries (Road/Rail Loading). Emissions during loading of petrol on to road and rail tankers at refineries
- Petrol Terminals (Storage). Emissions from storage tanks at petrol distribution terminals.
- Petrol Terminals (Tanker Loading). Emissions during loading of petrol on to road and rail tankers at petrol terminals.
- Petrol Stations (Petrol Delivery). Emissions during loading of petrol from road tankers into storage tanks at petrol stations.
- Petrol Stations (Storage Tanks). Emissions from storage tanks at petrol stations.
- Petrol Stations (Vehicle Refuelling). Emissions due to displacement of vapour during the refuelling of motor vehicle at petrol stations.

- Petrol Stations (Spillages). Emissions due to spillages during refuelling of motor vehicles at petrol stations.

Emissions would also occur from storage tanks at refineries. This source is included together with emissions from the storage of crude oil and other volatile materials in the NAEI source category, refineries (tankage).

The estimate for road and rail tanker loading at refineries are supplied by UKPIA (2005). The remaining estimates are based on methodologies published by the Institute of Petroleum (2000) or, in the case of petrol terminal storage, based on methods given by CONCAWE (1986). The calculations require information on petrol density, given in DTI (2005), and petrol Reid Vapour Pressure (RVP), data for which have been obtained from a series of surveys carried out by Associated Octel between 1970 and 1994. More recent, detailed RVP data are not available, but UKPIA have suggested values for 1999 onwards. Central England Temperature (CET) data (Met Office, 2005) are used for ambient UK temperatures. The methodology also includes assumptions regarding the level of vapour recovery in place at terminals and petrol stations. These assumptions draw upon annual account surveys carried out by the Petroleum Review (2000 onwards) that include questions on petrol station controls, and the timescales recommended in Secretary of State's Guidance for petrol terminals (PG 1/13 (97)). The activity data are the sales of leaded and unleaded petrol from DTI (2005).

### *A3.3.8.2.8 Refineries and petroleum processes*

The IPCC category 1B2aiv Refining and Storage reports estimates of NMVOC emissions from oil refineries. In the NAEI these are split into:

- Refineries (drainage)
- Refineries (tankage)
- Refineries (Process)

All are based on UKPIA (2005) estimates for 1994-2004. The UKPIA data refer to the following installations:

- Texaco, Milford Haven
- Elf, Milford Haven
- BP, Coryton
- Shell, Shell Haven (closed during 1999)
- Conoco, South Killingholme
- Lindsey, Killingholme
- Shell, Stanlow
- PIP, North Tees
- Esso, Fawley
- BP, Grangemouth
- Gulf, Milford Haven (closed during 1997)

UKPIA also supply estimates for loading of petrol into road and rail tankers at refineries – see **Section A3.3.8.2.7**



Prior to 1994, process emissions are estimated by extrapolation from the 1994 figure on the basis of refinery throughput, whereas emissions from tankage, flares and drainage systems are assumed to be constant.

Also included under 1B2aiv Refining and Storage are NMVOC emissions from the NAEI category petroleum processes. This reports NMVOC emissions from specialist refineries (Llandarcy, Eastham, Dundee, & Harwich), onshore oil production facilities, and miscellaneous petroleum processes not covered elsewhere in the inventory (most significant of which are the Tetney Lock and Tranmere oil terminals). Emissions are taken from the Pollution Inventory (Environment Agency, 2005). No emissions data have been found for the Dundee refinery.

### *A3.3.8.2.9 Gasification processes*

The NAEI also reports NMVOC emissions from on shore gas production facilities, refining and odourisation of natural gas, natural gas storage facilities, and processes involving reforming of natural gas and other feedstocks to produce carbon monoxide and hydrogen gases. Emissions are taken from the Pollution Inventory (Environment Agency, 2005). For the years prior to 1994, they are extrapolated based on gas throughput. Care is taken to avoid double counting with the offshore emissions.

### **A3.3.9 Stored carbon**

In 2005, the treatment of the non-energy uses of fuels and stored carbon in the UK GHG inventory was reviewed. In previous UK GHG inventories, the UK did not use the IPCC default methodology for stored carbon in products because it was not clear what processes it represented or if it was applicable to the UK. The procedure adopted was to report emissions from the combustion of fuels only with emissions from the non-energy use of fuels assumed to be zero (i.e. the carbon is assumed to be sequestered as products). The only exceptions to this approach were those instances where an emission could be identified. This is true in the following cases, for which emissions are included in the inventory:

- Catalytic crackers – regeneration of catalysts
- Ammonia production
- Aluminium production – consumption of anodes
- Benzoles and tars – produced in coke ovens and emissions assigned to the waste sector
- Combustion of waste lubricants and waste solvents
- Incineration of fossil carbon in products disposed of as waste.

Netcen estimates of the quantities of lubricants burnt are based on data from Recycling Advisory Unit, 1999; Oakdene Hollins Ltd, 2001 & BLF/UKPIA/CORA, 1994. Separate estimates are produced for the following sources:

- Power stations
- Cement kilns
- Other industry

In addition, an estimate is made of lubricants burnt in vehicle engines. Carbon emissions from these sources are calculated using a carbon factor derived from analysis of eight samples of

waste oil (Passant, 2004). In 2005, the combustion of lubricating oils within engines was reviewed. Analysis by UK experts in transport emissions and oil combustion have lead to a revision to the assumptions regarding re-use or combustion of lubricating oils from vehicle and industrial machinery.

Changes have been made to the estimation method and sector allocations within the 1990-2003 inventory, leading to reductions in the estimated emissions and a re-allocation to other IPCC sectors from combustion within the 1A3d (Road Transport) sector. The fate of the unrecovered oil has now been allocated across several NAEI categories including road, rail, marine, off-road and air transport. Some of the unrecovered oil is now allocated to non-oxidising fates such as coating on products, leaks and disposal to landfill.

Fossil carbon destroyed in MSW incinerators and clinical waste incinerators is included in the GHG inventory, as is carbon emitted by chemical waste incinerators.

As part of our review of the base year GHG inventory estimates, the UK has reviewed the treatment of stored carbon in the UK GHG inventory and the fate of carbon from the NEU of products and the breakdown of those products. This appraisal included a review of the National Inventory Reports (NIRs) of other countries. The US NIR contained a detailed methodology of the approach used in the US inventory to estimate emissions of stored carbon, and the US NIR presents 'storage factors' for a range of products. Some of these factors have been used in the new UK method.

The UK Inventory Agency has conducted a series of calculations to estimate the fate of carbon contained in those petroleum products shown in the 'non-energy use' line of the UK commodity balance tables. The analysis indicates that most of the carbon is 'stored', although a significant quantity does appear to be emitted. Some of the emitted carbon has been included in previous versions of the GHG inventory, e.g. carbon from chemical waste incinerators; most has not. A summary of the estimates of emitted/stored carbon has been produced and this will be presented in a separate technical report. The study also provides subjective, qualitative commentary regarding the quality of the estimates.

The analysis also includes an assessment of the fate of carbon from the use of coal tars and benzoles. Benzoles and coal tars are shown as an energy use in the DTI DUKES and up until the 2002 version of the GHG inventory, the carbon was included in the coke ovens carbon balance as an emission of carbon from the coke ovens.

When the carbon balance methodology was improved for the 2003 GHG inventory, the UK inventory treated it as a non-emissive output from the coke ovens. However, we were not sure what the ultimate fate of the carbon was but were unable to research this in time for the 2003 GHG inventory. It was therefore treated as an emission from the waste disposal sector - thus ensuring that total UK carbon emissions were not altered until we had sufficient new information to judge what the fate of the carbon was.

New information from Corus UK Ltd (the sole UK operator of coke ovens) indicates that the benzoles & coal tars are recovered and sold on for other industrial uses, the emissions from which are already covered elsewhere within the inventory. Hence the carbon content from

these coke oven by-products is now considered as stored and the carbon emissions included in previous inventories has been removed from the new version of the GHG inventory.

The analysis estimates emissions from:

- the 'energy' uses of coal tars and benzoles;
- the 'non-energy' uses of petroleum products

Since emissions of carbon are estimated, carbon which is not emitted (i.e. 'stored') can be calculated from the DTI DUKES consumption data by difference. The analysis divides the various fossil fuels into six categories:

1. coal tars & benzoles
2. lubricants
3. petroleum coke
4. petroleum waxes
5. bitumen
6. chemical feedstocks (ethane, propane, butane, other gases, naphtha, industrial spirit, white spirit, middle distillate feedstock)

After considering the magnitude of the source in relation to the national totals, the uncertainty associated with emissions, and the likely forthcoming IPCC reporting requirements in the 2006 Guidelines, emissions of carbon from the following additional sources have been included in the 2004 GHG inventory (2006 NIR):

- ▶ Petroleum waxes
- ▶ Carbon emitted during energy recovery - chemical industry
- ▶ Carbon in products - soaps, shampoos, detergents etc.
- ▶ Carbon in products - pesticides

A full time series of emissions has been included. For transparency, these emissions are reported in Sector 7 in the CRF and IPCC Sectoral tables rather than aggregating emissions with other sectors.

**A3.4 INDUSTRIAL PROCESSES (CRF SECTOR 2)****A3.4.1 Mineral Processes (2A)****A3.4.1.1 Cement Production (2A1)**

Emission factors for the production of cement, as described in **Chapter 4**, are as follows:

**Table A3.4.1a** Emission Factors for Cement Kilns based on Fuel Consumption, 2004

Fuel	C <sup>a</sup>	CH <sub>4</sub>	N <sub>2</sub> O	Units
Coal	744.3 <sup>b</sup>	0.3 <sup>e</sup>	0.109 <sup>h</sup>	Kt / Mt fuel
Fuel Oil	879 <sup>b</sup>	0.00865 <sup>f</sup>	0.0260 <sup>f</sup>	Kt / Mt fuel
Natural Gas	1.48 <sup>b</sup>	0.0005 <sup>f</sup>	NE	Kt / Mtherm
Petroleum Coke	829.6 <sup>b</sup>	0.415 <sup>g</sup>	0.143 <sup>h</sup>	Kt / Mt fuel
Scrap Tyres	757 <sup>c</sup>	0.96 <sup>f</sup>	NE	Kt / Mt fuel
Waste Oils	864.8 <sup>d</sup>	0.0909 <sup>i</sup>	NE	Kt / Mt fuel

a Emission factor as mass carbon per unit fuel consumed

b Baggott *et al* (2004)

c Emission factor derived from emissions reported in the PI

d Passant, N.R., 2004

e Brain, SA et al. British Coal Corp, CRE (1994)

f IPCC 1997c

g DTI (1994)

h Fynes *et al* (1994)

i As for gas oil

**Table A3.4.1b** Emission Factors for Cement Kilns based on Clinker Production, 1990-2004

Year	CO	NO <sub>x</sub>	NMVOC	SO <sub>2</sub>	Units
1990-94	2.96	5.65	0.135	3.05	kt/Mt Clinker
1995	2.86	5.13	0.135	3.33	kt/Mt Clinker
1996	4.39	3.43	0.135	2.11	kt/Mt Clinker
1997	1.91	3.72	0.135	2.37	kt/Mt Clinker
1998	1.45	3.86	0.135	2.26	kt/Mt Clinker
1999	2.58	3.61	0.121	2.26	kt/Mt Clinker
2000	2.49	3.42	0.124	1.88	kt/Mt Clinker
2001	2.31	3.06	0.156	1.93	kt/Mt Clinker
2002	2.40	2.89	0.111	2.07	kt/Mt Clinker
2003	NR	NR	NR	NR	kt/Mt Clinker
2004	NR	NR	NR	NR	kt/Mt Clinker

NR – 2003 and 2004 emission factor data are not reported due to issues of commercial confidentiality raised by the BCA.

## **A3.4.1.2 Lime Production (2A2)**

Emission factors for the production of lime, as discussed in **Chapter 4, Section 4.3**:

**Table A3.4.1c** Emission Factors for Lime Kilns based on Fuel Consumption, 2004

Fuel	C <sup>a</sup>	CH <sub>4</sub>	N <sub>2</sub> O	Units
Coal	614.5 <sup>b</sup>	0.011 <sup>c</sup>	0.215 <sup>e</sup>	Kt / Mt fuel
Natural Gas	1.48 <sup>b</sup>	0.00053 <sup>f</sup>	1.055E-05 <sup>f</sup>	Kt / Mtherm
Coke	781.4 <sup>d</sup>	0.011 <sup>c</sup>	0.228 <sup>e</sup>	Kt / Mt fuel

a Emission factor as mass carbon per unit fuel consumed

b Baggott *et al* (2004)

c Brain, SA et al. British Coal Corp, CRE (1994)

d netcen estimate based on carbon balance

e Fynes *et al* (1994)

f IPCC(1997) IPCC Revised 1996 Guidelines

**Table A3.4.1d** 2004 Emission Factors for Lime Kilns: Indirect GHGs

Fuel	CO	NO <sub>x</sub>	NMVOC	Units
Coal	37.14	68.08	0.05	Kt / Mt fuel
Natural Gas	0.1192	0.0202	0.00023	Kt / Mtherm
Coke	17.73	0.1244	0.05	Kt / Mt fuel

## **A3.4.2 Chemical Industry (2B)**

### **A3.4.2.1 Nitric Acid Production (2B2)**

**Table A3.4.2** Summary of Nitric Acid Production in the UK, 1990-2004

	1990	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
No of Sites	8	6	6	6	6	6	6	6	5	4	4	4
Production (Mt 100% Nitric Acid)	2.41	2.43	2.45	2.47	2.49	2.40	2.44	2.35	2.61	2.44	2.03	1.65
Aggregate EF (kt N <sub>2</sub> O / Mt Acid)	5.54	5.55	5.60	5.58	4.20	4.14	4.19	4.12	4.27	6.56	7.33	7.04
Aggregate EF (kt NO <sub>x</sub> / Mt Acid)	3.36	3.00	2.64	2.28	1.93	0.81	0.74	0.90	0.73	0.91	0.99	0.66

### **A3.4.2.2 Adipic Acid Production (2B3)**

There is only one company manufacturing adipic acid in the UK. Production data are not provided in the NIR because it may be commercially confidential.

The Inventory Agency has estimated plant production and emissions data based on information from the process operator (Invista, 2005) and from the Pollution Inventory (PI) of the Environment Agency. The emission estimates in the PI are based on extrapolation of on-line measurement of the concentration of nitrous oxide in the flue gases, conducted for regulatory compliance monitoring purposes since 1998. Prior to 1998, the operators have provided emission estimates based on emission factors.

In 1998 an N<sub>2</sub>O abatement system was fitted to the plant. The abatement system is a thermal oxidation unit and is reported by the operators to be 99.99% efficient at N<sub>2</sub>O destruction. The abatement unit is not available 100% of the time, and typically achieves 90-95% availability during AA production. The abatement plant availability has a very significant impact upon the annual emissions of N<sub>2</sub>O, and leads to somewhat variable trends in IEFs over the time-series.

A small nitric acid plant is associated with the adipic acid plant. This NA plant also emits nitrous oxide but has no abatement fitted. Operator emission estimates from the NA plant are based on emission factors; there is no online measurement of N<sub>2</sub>O in the stack from the NA plant. From 1994 onwards this emission is reported as nitric acid production but prior to 1994 it is included under adipic acid production. This will cause a variation in reported effective emission factor for these years. This allocation reflects the availability of data.

The level of uncertainty associated with reported emissions of N<sub>2</sub>O is not known, but the data are considered to be reliable as they are subject to QA/QC checks by the operator, by the Environment Agency (before being reported in the Pollution Inventory) and by the regulators of the UK Emission Trading Scheme (DEFRA NCCP).

### **A3.4.3 Metal Production (2C)**

#### **A3.4.3.1 Iron and Steel (2C1)**

The following emissions are reported under 2C1 Iron and Steel Production.

- Blast furnaces: process emissions of CO, NO<sub>x</sub>, and SO<sub>2</sub>
- Flaring of blast furnace gas/basic oxygen furnace gas
- Electric arc furnace emissions
- Basic oxygen furnaces: process emissions of CO and NO<sub>x</sub>.
- Rolling mill process emissions of VOC
- Slag processing: process emissions of SO<sub>2</sub>

Emissions arising from the combustion of blast furnace gas and other fuels used for heating the blast furnace are reported under 1A2a Iron and Steel. Emissions of CO, NO<sub>x</sub>, and SO<sub>2</sub> from integrated steelworks, and the flaring of blast furnace gas and basic oxygen furnace gas are reported under 2C1 Iron & Steel Production. CO<sub>2</sub> emissions from limestone and dolomite use in iron and steel production are reported under 2A3 Limestone and Dolomite use.

## *A3.4.3.1.1 Carbon Dioxide Emissions*

Carbon emissions from flaring of blast furnace gas (BFG) and basic oxygen furnace gas (BOFG) are calculated using an emission factor of 72,970 g C/GJ, a figure which is calculated as part of the carbon balance used to estimate emissions from CRF category 1A2a. Emissions from electric arc furnaces are 2 kt C/Mt steel (Briggs, 2005).

## *A3.4.3.1.2 Other Pollutants*

Emissions from blast furnaces of other pollutants are partly based on the methodology described in IPCC (1997) for blast furnace charging and pig iron tapping and partly on emissions data reported by the process operators. The emission factors are expressed in terms of the emission per Mt of pig iron produced and are given in **Table A3.4.3a**. Data on iron production are reported in ISSB (2005).

**Table A3.4.3a** Emission Factors for Blast Furnaces (BF), Electric Arc Furnaces (EAF) and Basic Oxygen Furnaces (BOF), 2004

	<b>C<sup>a</sup></b>	<b>CH<sub>4</sub></b>	<b>N<sub>2</sub>O</b>	<b>NO<sub>x</sub></b>	<b>SO<sub>2</sub></b>	<b>NMVOC</b>	<b>CO</b>	<b>Units</b>
Blast furnaces	IE	NE	NE	NE	0.055 <sup>b</sup>	0.12 <sup>c</sup>	1.44 <sup>c</sup>	kt/Mt pig iron
Electric arc furnaces	2 <sup>d</sup>	0.01 <sup>e</sup>	0.005 <sup>e</sup>	0.02 <sup>e</sup>	0.14 <sup>b</sup>	0.09 <sup>e</sup>	0.85 <sup>b</sup>	kt/Mt Steel
Basic oxygen furnaces	IE	NE	NE	0.012 <sup>f</sup>	IE	NE	5.04 <sup>b</sup>	kt/Mt Steel
Losses of BFG/BOFG	7.7 <sup>g</sup>	NE	NE	NE	NE	NE	NE	kt/Mtherm gas
Slag processing	NE	NE	NE	NE	0 <sup>b</sup>	NE	NE	kt/Mt Pig iron

a Emission factor as kt carbon/unit activity

b Emission factor for 2004 based on data from Corus (2005)

c IPCC (1997)

d Briggs (2005)

e EMEP/CORINAIR(1999)

f EIPPCB(2000), Corus (2001, 2000)

g Netcen estimate based on carbon balance

NE Not estimated

IE Emission included elsewhere.

Emissions from electric arc furnaces are calculated mainly using default emission factors taken from EMEP/CORINAIR (1999). The CO<sub>2</sub> emission arises from the consumption of a graphite anode and the emission factor has been suggested by Briggs (2005). Emissions of CO from basic oxygen furnaces are based on data supplied by Corus (2005) while the NO<sub>x</sub> emission is based on an EIPPCB default.

Emissions of NMVOC are estimated from the hot rolling and cold rolling of steel using emission factors of 1 g/tonne product and 25 g/tonne product respectively (EMEP/CORINAIR, 1996). Activity data were taken from ISSB (2005).

There is insufficient activity or emission factor data to make an estimate for emissions from ferroalloys. Emissions of CO<sub>2</sub> will be included in 1A2a, since the fuels used as reducing agents are included in the energy statistics.

### A3.4.3.2 Aluminium production (2C3)

Details of the method used to estimate emissions of F-gases from this source are given in AEAT (2004). Emission factors for aluminium production, as discussed in **Chapter 4, Section 4.16**, are shown in **Table A3.4.3b**.

**Table A3.4.3b** Emission Factors for Aluminium Production, 2004

	C <sup>a</sup>	SO <sub>2</sub> <sup>b</sup>	NO <sub>x</sub> <sup>b</sup>	CO <sup>b</sup>	Units
Prebake	420	14.3	0.79	77.1	Kt / Mt Al
Anode Baking	IE	1.34	0.39	2.74	Kt / Mt anode

a Emission factor as kt carbon per unit activity, Walker, 1997.

b Environment Agency Pollution Inventory (2005) and SEPA (2005)

IE Emission included elsewhere.

### A3.4.3.3 SF<sub>6</sub> used in Aluminium and Magnesium Foundries (2C4)

The method used to estimate emissions of SF<sub>6</sub> from this source is described in AEAT (2004).

### A3.4.3.4 Food and Drink (2D2)

NMVOC emission factors for food and drink, as discussed in **Chapter 4, Section 4.20**.

**Table A3.4.3c** NMVOC Emission Factors for Food and Drink Processing, 2003

Food/Drink	Process	Emission Factor	Units
Beer	Barley Malting Wort Boiling Fermentation	0.6 <sup>c</sup> 0.0048 <sup>c</sup> 0.02 <sup>c</sup>	g/L beer
Cider	Fermentation	0.02 <sup>c</sup>	g/L cider
Wine	Fermentation	0.2 <sup>c</sup>	kg/m <sup>3</sup>
Spirits	Fermentation Distillation Casking Spent grain drying Barley Malting Maturation	1.58 <sup>d</sup> 0.79 <sup>g</sup> 0.40 <sup>h</sup> 1.31 <sup>i</sup> 4.8 <sup>c</sup> 15.78 <sup>d</sup>	g/ L alcohol g/ L alcohol g/ L whiskey kg/ t grain kg/ t grain g/ L alcohol
Bread Baking		1 <sup>a</sup>	kg/tonne
Meat, Fish & Poultry		0.3 <sup>f</sup>	kg/tonne
Sugar		0.020 <sup>b</sup>	kg/tonne
Margarine and solid cooking fat		10 <sup>f</sup>	kg/tonne
Cakes, biscuits, breakfast cereal, animal feed		1 <sup>f</sup>	kg/tonne
Malt production (exports)		4.8 <sup>c</sup>	kg/ t grain
Coffee Roasting		0.55 <sup>f</sup>	kg/tonne

a Federation of Bakers (2000)

b Environment Agency Pollution Inventory (2004)

c Gibson *et al* (1995)

d Passant *et al* (1993)



- e Assumes 0.1% loss of alcohol based on advice from distiller
- f EMEP/CORINAIR, 2003
- g Unpublished figure provided by industry
- h Based on loss rate allowed by HMCE during casking operations
- i US EPA, 2004

### **A3.4.4 Production of Halocarbons and SF<sub>6</sub> (2E)**

Details of the method used to estimate emissions of F-gases from this source are given in AEAT (2004).

### **A3.4.5 Consumption of Halocarbons and SF<sub>6</sub> (2F)**

#### **A3.4.5.1 Refrigeration and Air Conditioning Equipment (2F1)**

Details of the method used to estimate emissions of F-gases from this source are given in AEAT (2004).

#### **A3.4.5.2 Foam Blowing (2F2)**

Details of the method used to estimate emissions of F-gases from this source are given in AEAT (2004).

#### **A3.4.5.3 Fire Extinguishers (2F3)**

Details of the method used to estimate emissions of F-gases from this source are given in AEAT (2004).

#### **A3.4.5.4 Aerosols/ Metered Dose Inhalers (2F4)**

Details of the method used to estimate emissions of F-gases from this source are given in AEAT (2004).

#### **A3.4.5.5 Solvents (2F5)**

Details of the method used to estimate emissions of F-gases from this source are given in AEAT (2004).

#### **A3.4.5.6 Semiconductor Manufacture (2F6)**

Details of the method used to estimate emissions of F-gases from this source are given in AEAT (2004).

#### **A3.4.5.7 Electrical Equipment (2F7)**

Details of the method used to estimate emissions of F-gases from this source are given in AEAT (2004).

#### **A3.4.5.8 One Component Foams (2F8A)**

Details of the method used to estimate emissions of F-gases from this source are given in AEAT (2004).

#### **A3.4.5.9 Semiconductors, Electrical and Production of Trainers (2F8B)**

Details of the method used to estimate emissions of F-gases from this source are given in AEAT (2004).

**A3.5 SOLVENT AND OTHER PRODUCT USE (CRF SECTOR 3)**

There is currently no additional information for this sector in this Annex.

**A3.6 AGRICULTURE (CRF SECTOR 4)****A3.6.1 Enteric Fermentation (4A)**

Methane is produced in herbivores as a by-product of enteric fermentation, a digestive process by which carbohydrates are broken down by microorganisms. Emissions are calculated from animal population data (**Table A3.6.1**) collected in the June Agricultural Census and published in Defra (2005a) and the appropriate emission factors. Data for earlier years are often revised so information was taken from the Defra agricultural statistics database.

**Table A3.6.2** shows the emission factors used.

Apart from cattle, lambs and deer, the methane emission factors are IPCC Tier 1 defaults (IPCC, 1997) and do not change from year to year. The dairy cattle emission factors are estimated following the IPCC Tier 2 procedure (IPCC, 1997) and vary from year to year. For dairy cattle, the calculations are based on the population of the ‘dairy breeding herd’ rather than ‘dairy cattle in milk’. The former definition includes ‘cows in calf but not in milk’. The emission factors for beef and other cattle were also calculated using the IPCC Tier 2 procedure (**Table A3.6.4**), but do not vary from year to year. The enteric emission factors for beef cattle were almost identical to the IPCC Tier 1 default so the default was used in the estimates.

The base data and emission factors for 1990-2004 are given in **Table A3.6.3** and **Table A3.6.4**. The emission factor for lambs is assumed to be 40% of that for adult sheep (Sneath *et al.* 1997). In using the animal population data, it is assumed that the reported numbers of animals are alive for that whole year. The exception is the treatment of sheep where it is normal practice to slaughter lambs and other non-breeding sheep after 6 to 9 months. Hence it is assumed that breeding sheep are alive the whole year but that lambs and other non-breeding sheep are only alive 6 months of a given year (based on Smith and Frost 2000). The sheep emission factors in **Table A3.6.2** are reported on the basis that the animals are alive the whole year.

**Table A3.6.1** Livestock Population Data for 2004 by Animal Type

Animal Type	Number
<b>Cattle:</b>	
Dairy Breeding Herd	2,131,353
Dairy Heifers	459,996
Beef Herd	1,737,980
Other cattle >2 years	675,068
Other cattle 1-2 years	2,523,330
Other cattle < 1 year	2,840,338
<b>Pigs:</b>	
All breeding pigs	600,482
Other pigs > 50 kg	1,794,754
Other pigs 20-50 kg	1,318,939
Pigs <20 kg	1,446,200
<b>Sheep:</b>	
Breeding sheep	17,658,709
Other sheep	951,639
Lambs < 1 year	17,270,610
<b>Goats</b>	91,515
<b>Horses</b>	329,319
<b>Deer:</b>	28,858
<b>Poultry (000 head):</b>	
Broilers	116,792
Breeders	5,918
Layers	29,663
Growing Pullets	8,155
Ducks, geese and guinea fowl	3,068
Turkeys	6,868

**Table A3.6.2** Methane Emission Factors for Livestock Emissions

Animal Type	Enteric methane <sup>a</sup> kg CH <sub>4</sub> /head/year	Methane from manures <sup>a</sup> kg CH <sub>4</sub> /head/year
Dairy Breeding Herd	101.7 <sup>b</sup>	24.98 <sup>b</sup>
Beef Herd	48	2.74
Other Cattle >1 year, Dairy Heifers	48	6
Other Cattle <1 year	32.8	2.96
Pigs	1.5	3
Breeding Sheep	8	0.19
Other Sheep	8 <sup>c</sup>	0.19 <sup>c</sup>
Lambs < 1 year	3.2 <sup>ce</sup>	0.076 <sup>ce</sup>
Goats	5	0.12
Horses	18	1.4
Deer: Stags & Hinds	10.4 <sup>c</sup>	0.26 <sup>c</sup>
Deer: Calves	5.2 <sup>c</sup>	0.13 <sup>c</sup>
Poultry <sup>d</sup>	NE	0.078

a IPCC (1997)

b Emission factor for year 2004

c Sneath *et al.* (1997)

d Chickens, turkeys, geese, ducks and guinea fowl

e Factor quoted assumes animal lives for a year; emission calculation assumes animal lives for 6 months

**Table A3.6.3** Dairy Cattle Methane Emission Factors<sup>a</sup>

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Average Weight of cow (kg) <sup>b</sup>	550	549	564	564	559	559	563	566	558	555	563	575	579	576	579
Average Rate of Milk Production (litre/d)	14.3	14.2	14.5	14.7	14.7	15.0	15.1	15.9	16.1	16.4	16.6	16.7	17.9	18.3	18.1
Average Fat Content (%)	4.01	4.04	4.06	4.07	4.05	4.05	4.08	4.07	4.07	4.03	4.03	4.01	3.97	3.96	4.00
Enteric Emission Factor (kg CH <sub>4</sub> /head/y)	88.1	88.4	90.1	90.8	90.9	92.3	93.2	96.0	96.8	97.8	98.7	99.4	102.7	103.8	101.8
Manure Emission Factor (kg CH <sub>4</sub> /head/y)	21.6	21.7	22.1	22.3	22.3	22.7	22.8	23.6	23.8	24.0	24.2	24.4	25.2	25.5	24.9

a In 2003, 46% of animals graze on good quality pasture, rest confined

Gestation period 281 days

Digestible energy 74% (Bruce Cottrill, ADAS, *pers. comm.*)

Methane conversion rate 6%

Ash content of manure 8%

Methane producing capacity of manure 0.24 m<sup>3</sup>/kg VS

b Weights according to Steve Walton, Defra, *pers. comm.*, from 1990 to 2004

**Table A3.6.4** Beef and Other Cattle Methane Emission Factors<sup>a</sup>

	<b>Beef Cattle</b>	<b>Other Cattle</b>
Average Weight of Animal (kg)	500	180
Time Spent Grazing	50%	46%
GE (MJ/d)	123.3	83.4
Enteric Emission Factor (kg CH <sub>4</sub> /head/y)	48.5 <sup>b</sup>	32.8
Manure Emission Factor (kg CH <sub>4</sub> /head/y)	2.74	2.96

- a Digestible Energy 65%, Ash content of manure 8%  
Methane producing capacity of manure 0.24 m<sup>3</sup>/kg VS
- b IPCC (1997) default (48 kg/head/y) used since calculated factor is very close to default and the difference under the Tier 2 method will not affect the accuracy of the emission factor at the required level of precision

## **A3.6.2 Manure Management (4B)**

### **A3.6.2.1 Methane emissions from animal manures**

Methane is produced from the decomposition of manure under anaerobic conditions. When manure is stored or treated as a liquid in a lagoon, pond or tank it tends to decompose anaerobically and produce a significant quantity of methane. When manure is handled as a solid or when it is deposited on pastures, it tends to decompose aerobically and little or no methane is produced. Hence the system of manure management used affects emission rates. Emissions of methane from animal manures are calculated from animal population data (Defra, 2005a) in the same way as the enteric emissions. The emission factors are listed in **Table A3.6.2**. Apart from cattle, lambs and deer, these are all IPCC Tier 1 defaults (IPCC, 1997) and do not change from year to year. The emission factors for lambs are assumed to be 40% of that for adult sheep. Emission factors for dairy cattle were calculated from the IPCC Tier 2 procedure using data shown in **Table A3.6.3** and **Table A3.6.5** (Defra, 2002). There was a revision (in 2002) of the allocation of manure to the different management systems based on new data. This is detailed in **Section 6.3.2.2**. For dairy cattle, the calculations are based on the population of the 'dairy breeding herd' rather than 'dairy cattle in milk' used in earlier inventories. The former definition includes 'cows in calf but not in milk'. The waste factors used for beef and other cattle are now calculated from the IPCC Tier 2 procedure but do not vary from year to year. Emission factors and base data for beef and other cattle are given in **Table A3.6.4**.

**Table A3.6.5** Cattle Manure Management Systems in the UK

<b>Manure Handling System</b>	<b>Methane Conversion Factor %<sup>a</sup></b>	<b>Fraction of manure handled using manure system %</b>	<b>Fraction of manure handled using manure system %</b>
		<i>Dairy</i>	<i>Beef and Other</i>
Pasture Range	1	45.5	50.5
Liquid System	39	30.6	6
Solid Storage	1	9.8	20.7
Daily Spread	0.1	14.1	23

- a IPCC (2000)

## **A3.6.2.2 Nitrous Oxide emissions from Animal Waste Management Systems**

Animals are assumed not to give rise to nitrous oxide emissions directly, but emissions from their manures during storage are calculated for a number of animal waste management systems (AWMS) defined by IPCC. Emissions from the following AWMS are reported under the Manure Management IPCC category:

- Flushing anaerobic lagoons. These are assumed not to be in use in the UK.
- Liquid systems
- Solid storage and dry lot (including farm-yard manure)
- Other systems (including poultry litter, stables)

According to IPCC (1997) guidelines, the following AWMS are reported in the Agricultural Soils category:

- All applied animal manures and slurries
- Pasture range and paddock

Emissions from the combustion of poultry litter for electricity generation are reported under power stations.

The IPCC (1997) method for calculating emissions of N<sub>2</sub>O from animal waste management systems can be expressed as:

$$N_2O_{(AWMS)} = 44/28 \cdot \sum N_{(T)} \cdot Nex_{(T)} \cdot AWMS_{(W)} \cdot EF_{(AWMS)}$$

where

$N_2O_{(AWMS)}$	=	N <sub>2</sub> O emissions from animal waste management systems (kg N <sub>2</sub> O/yr)
$N_{(T)}$	=	Number of animals of type T
$Nex_{(T)}$	=	N excretion of animals of type T (kg N/animal/yr)
$AWMS_{(W)}$	=	Fraction of Nex that is managed in one of the different waste management systems of type W
$EF_{(AWMS)}$	=	N <sub>2</sub> O emission factor for an AWMS (kg N <sub>2</sub> O-N/kg of Nex in AWMS)

The summation takes place over all animal types and the AWMS of interest. Animal population data are taken from Agricultural Statistics (Defra, 2005a). **Table A3.6.6** shows emission factors for nitrogen excretion per head for domestic livestock in the UK (Nex). These are based on N balance figures of Smith and Frost (2000) and Smith *et al.* (2000), using linear regression to interpolate between animal weights reported in their paper.

The UK methodology assumes that 20% of the total N emitted by livestock volatilises as NO<sub>x</sub> and NH<sub>3</sub> and therefore does not contribute to N<sub>2</sub>O emissions from AWMS. This is because in the absence of a more detailed split of NH<sub>3</sub> losses at the different stages of the manure handling process it has been assumed that NH<sub>3</sub> loss occurs prior to major N<sub>2</sub>O losses. Thus, the Nex factors used in the AWMS estimates (and those reported in **Table A3.6.6** and **Table A3.6.7**) exclude the fraction of N volatilising and are 20% less than if they were reported on the same basis as the 'total' Nex factors reported in the IPCC Guidelines. Values of total N

excreted shown in the Common Reporting Format are not corrected in this way and are estimates of total N excreted from livestock. Next factors for dairy cattle take account of the data of cow weight provided by Defra (S. Walton, *pers. comm.*, 1990–2004) and are shown in **Table A3.6.7**.

The conversion of excreted N into N<sub>2</sub>O emissions is determined by the type of manure management system used. The distribution of waste management systems for each animal type (AWMS<sub>(T)</sub>) is given in **Table A3.6.8**. The distributions used were revised for cattle and poultry in the 2000 Inventory. The change related to the way that data on ‘no significant storage capacity’ of farmyard manure (FYM) were allocated. This could have a large effect on emissions because it amounted to around 50% of manure and the ‘Daily spread (DS)’ category has an emission factor of zero, compared to 0.02 for the ‘Solid storage and dry lot (SSD)’ category. However, we are advised (Smith, 2002) that:

*In terms of slurry, it seems likely that where a proportion of the estimated slurry production is attributed with “nil” or little storage (<1 month capacity), as above, it can be assumed that such units will rely on a significant amount of daily – weekly spreading activity, according to land availability and trafficability, throughout. With FYM and poultry manure, however, significant storage capacity exists within the house and so, “no storage” generally implies that manure is cleared from the house/straw littered yard and spread direct on land. Storage capacity within the house or yard might comprise between 7 weeks – 12 months (poultry) or several months (cattle) and is unlikely to require “daily” spreading activity.*

Therefore, assigning this ‘stored in house’ manure to ‘daily spread’ is acceptable only if emissions from the housing phase are thought to be very small. Calculations were performed with the N<sub>2</sub>O Inventory of Farmed Livestock to compare housing and storage phases (Sneath *et al.* 1997). For pigs and poultry, the emission factor for housing is the same as or greater than that of storage. It would therefore lead to significant underestimation to use the daily spread emission factor. All of the FYM in this case has therefore been re-allocated to SSD.

For dairy and non-dairy cattle, the emission factor for the housing phase is around 10% of the storage phase, so the non-stored FYM has been split between SSD and DS to account for this.

**Table A3.6.9** gives the N<sub>2</sub>O emission factor for each animal waste management system (EF<sub>(AWMS)</sub>). These are expressed as the emission of N<sub>2</sub>O-N per mass of excreted N processed by the waste management system.

Emissions from grazing animals (pasture range and paddock) and daily spread are calculated in the same way as the other AWMS. However, emissions from land spreading of manure that has previously been stored in a) liquid systems, b) solid storage and dry lot and c) other systems, are treated differently. These are discussed in **Section A3.6.3**.

**Table A3.6.6** Nitrogen Excretion Factors for Animals in the UK<sup>a</sup>

Animal Type	Emission Factor kg N/animal/year <sup>b</sup>
Dairy Cows	84.6 <sup>c</sup>
Other Cattle > 2 year	60
Other Cattle 1-2 year	47
Other Cattle <1 year	11.8
Pigs < 20kg	3.0
Other Pigs 20-50 kg	7.1
Fattening & Other Pigs > 50 kg	10.7
Breeding Pigs > 50 kg	14.3
Breeding Sheep	9.2
Other Sheep <1 year	9.2 <sup>e</sup>
Lambs	3.36 <sup>e</sup>
Goats	7.2
Broilers	0.495
Broiler Breeders	0.899
Layers	0.589
Ducks,	0.984
Turkeys	1.052
Growing Pullets	0.106
Horses	32
Deer: Stags <sup>d</sup>	17.5
Deer: Hinds <sup>d</sup>	11.7
Deer: Calves <sup>d</sup>	8.64

a Smith and Frost (2000), Smith *et al.* (2000)

b Nex factors exclude 20% N volatilising as NO<sub>x</sub> and NH<sub>3</sub>

c Weighted average of dairy breeding herd (based on liveweight) and dairy heifers, 2004

d Sneath *et al.* (1997)

e Factor quoted assumes animal lives for a year. Emission calculation assumes animal lives for 6 months (Smith and Frost, 2000)

**Table A3.6.7** Nitrogen Excretion Factors for Dairy Cattle<sup>a</sup>

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Emission Factor kg N/animal/year	80.9	80.6	82.7	82.5	81.9	81.7	81.9	82.3	81.2	81.0	82.0	83.9	84.6	84.5	84.6

a Nex factors exclude 20% N volatilising as NO<sub>x</sub> and NH<sub>3</sub>. Weighted average of dairy breeding herd and dairy heifers in first calf.



**Table A3.6.8** Distribution of Animal Waste Management Systems used for Different Animal types<sup>c</sup>

Animal Type	Liquid System	Daily Spread	Solid Storage and Dry Lot <sup>a</sup>	Pasture Range and Paddock	Other <sup>b</sup>	Fuel
Dairy Cows	30.6	14.1	9.8	45.5		
Other Cattle >1 year	6.0	23.0	20.4	50.5		
Other Cattle <1 year		22.9	22.3	54.8		
Fattening & Other Pigs > 20 kg,	29.2	5.8	64.0	1.0		
Breeding sows	35.5	7.1	28	29.3		
Pigs <20 kg	38.3	7.7	46.0	8.0		
Sheep			2.0	98.0		
Goats				96.0	4.0	
Broilers & Table Fowl (2003)				1.0	63.0	36.0
Breeders				1.0	99.0	
Layers <sup>e</sup>				10.0	90.0	
Pullets <sup>e</sup>				10.0	90.0	
Ducks, Geese & Guinea Fowl <sup>c</sup>				50.0	50.0	
Turkeys <sup>e</sup>				8.0	92.0	
Horses				96.0	4.0	
Deer: Stags <sup>d</sup>				100		
Deer: Hinds & Calves <sup>d</sup>				75.0	25.0	

- a Farmyard manure
- b Poultry litter, Stables
- c ADAS (1995a), Smith (2002)
- d Sneath *et al.* (1997)
- e Tucker and Canning (1997)

**Table A3.6.9** Nitrous Oxide Emission Factors for Animal Waste Handling Systems<sup>a</sup>

Waste Handling System	Emission Factor kg N <sub>2</sub> O-N per kg N excreted
Liquid System	0.001
Daily Spread <sup>b</sup>	0
Solid Storage and Dry Lot	0.02
Pasture, Range and Paddock <sup>b</sup>	0.02
Fuel	-
Other	0.005

- a IPCC (1997)
- b Reported under Agricultural Soils

## **A3.6.3 Agricultural Soils (4D)**

### **A3.6.3.1 Source category description**

Direct emissions of nitrous oxide from agricultural soils are estimated using the IPCC recommended methodology (IPCC, 1997) but incorporating some UK specific parameters. The IPCC method involves estimating contributions from:

- (i) The use of inorganic fertilizer
- (ii) Biological fixation of nitrogen by crops
- (iii) Ploughing in crop residues
- (iv) Cultivation of Histosols (organic soils)
- (v) Spreading animal manures on land
- (vi) Manures dropped by animals grazing in the field

In addition to these, the following indirect emission sources are estimated:

- (vii) Emission of N<sub>2</sub>O from atmospheric deposition of agricultural NO<sub>x</sub> and NH<sub>3</sub>
- (viii) Emission of N<sub>2</sub>O from leaching of agricultural nitrate and runoff

Descriptions of the methods used are described in **Section 6.5.2**.

### **A3.6.3.2 Inorganic Fertiliser**

Emissions from the application of inorganic fertilizer are calculated using the IPCC (1997) methodology and IPCC default emission factors. They are given by:

$$N_2O_{(SN)} = 44/28 \cdot N_{(FERT)} \cdot (1 - \text{Frac}_{(GASF)}) \cdot EF_1$$

where

$N_2O_{(SN)}$	=	Emission of N <sub>2</sub> O from synthetic fertiliser application (kg N <sub>2</sub> O/yr)
$N_{(FERT)}$	=	Total use of synthetic fertiliser (kg N/yr)
$\text{Frac}_{(GASF)}$	=	Fraction of synthetic fertiliser emitted as NO <sub>x</sub> + NH <sub>3</sub>
	=	0.1 kg NH <sub>3</sub> -N+NO <sub>x</sub> -N / kg synthetic N applied
$EF_1$	=	Emission Factor for direct soil emissions
	=	0.0125 kg N <sub>2</sub> O-N/kg N input

annual consumption of synthetic fertilizer is estimated based on crop areas (Defra, 2005a) and fertilizer application rates (BSFP, 2005).

### **A3.6.3.3 Biological Fixation of Nitrogen by crops**

Emissions of nitrous oxide from the biological fixation of nitrogen by crops are calculated using the IPCC (2000) Tier 1a methodology and IPCC default emission factors. They are given by:

$$N_2O_{(BF)} = 44/28 \cdot 2 \cdot \text{Crop}_{(BF)} \cdot \text{Frac}_{DM} \cdot \text{Frac}_{(NCRBF)} \cdot EF_1$$

where

$N_2O_{(BF)}$	=	Emission of $N_2O$ from biological fixation (kg $N_2O$ /yr)
$Crop_{(BF)}$	=	Production of legumes (kg /yr)
$Frac_{DM}$	=	Dry matter fraction of crop
$Frac_{(NCRBF)}$	=	Fraction of nitrogen in N fixing crop
	=	0.03 kg N/ kg dry mass
$EF_1$	=	Emission Factor for direct soil emissions
	=	0.0125 kg $N_2O$ -N/kg N input

The factor of 2 converts the edible portion of the crop reported in agricultural statistics to the total biomass. The fraction of dry mass for the crops considered is given in **Table A3.6.10**.

**Table A3.6.10** Dry Mass Content and Residue Fraction of UK Crops

Crop Type	Fraction dry mass <sup>b</sup>	Residue/Crop
Broad Beans, Green Peas	0.08	1.1
Field Bean <sup>d</sup> , Peas(harvest dry)	0.86	1.1
Rye, Mixed corn, Triticale	0.855 <sup>a</sup>	1.6
Wheat, Oats	0.855 <sup>a</sup>	1.3
Barley	0.855 <sup>a</sup>	1.2
Oilseed Rape, Linseed	0.91 <sup>a</sup>	1.2
Maize	0.50	1
Hops <sup>c</sup>	0.20	1.2
Potatoes	0.20	0.4
Roots, Onions	0.07	1.2
Brassicas	0.06	1.2
Sugar Beet	0.1	0.2
Other	0.05	1.2
Phaseolus beans	0.08	1.2

a Defra (2002)

b Burton (1982), Nix (1997) or Defra estimates

c Hops dry mass from Brewers Licensed Retail Association (1998)

d Field beans dry mass from PGRE (1998)

The data for the ratio residue/crop are default values found under Agricultural Soils or derived from Table 4.17 in Field Burning of Agricultural Residues (IPCC, 1997). Crop production data are taken from Defra (2005a, 2005b). The total nitrous oxide emission reported also includes a contribution from improved grass calculated using a fixation rate of 4 kg N/ha/year (Lord, 1997).

### A3.6.3.4 Crop Residues

Emissions of nitrous oxide from the ploughing in of crop residues are calculated using a combination of the IPCC (2000) Tier 1b and 1a methodology, for non-N fixing and N-fixing crops, respectively, and IPCC default emission factors. They are given by:

$$N_2O_{(CR)} = \sum_i (Crop_{O_i} \cdot Res_{oi}/Crop_{oi} \cdot FracDM_i \cdot Frac_{(NCRO)} \cdot (1-Frac_B) + \sum_j (2 \cdot Crop_{(BFj)} \cdot FracDM_j \cdot Frac_{(NCRBFj)}) \cdot (1-Frac_{Rj}) \cdot (1-Frac_{Bj})) \cdot EF_1 \cdot 44/28$$

where

$N_2O_{(CR)}$	=	Emission of $N_2O$ from crop residues (kg $N_2O$ /yr)
$Crop_{Oi}$	=	Production of non-N fixing crop i (kg /yr)
$Frac_{(NCRO)}$	=	Fraction of nitrogen in non-N fixing crops
	=	0.015 kg N/ kg dry mass
$FracDM_{i,j}$	=	dry matter fraction of crop i, j.
$Frac_R$	=	Fraction of crop that is remove from field as crop
$Frac_B$	=	Fraction of crop residue that is burnt rather than left on field
$EF_1$	=	Emission Factor for direct soil emissions
	=	0.0125 kg $N_2O$ -N/kg N input
$Crop_{(BFj)}$	=	Production of legume crop j (kg /year)
$Frac_{(NCRBF)}$	=	Fraction of nitrogen in N fixing crop
	=	0.03 kg N/ kg dry mass

Production data of crops are taken from Defra (2005a, 2005b). The dry mass fraction of crops and residue fraction are given in **Table A3.6.10**. Field burning has largely ceased in the UK since 1993. For years prior to 1993, field-burning data were taken from the annual MAFF Straw Disposal Survey (MAFF, 1995).

### A3.6.3.5 Histosols

Emissions from Histosols were estimated using the IPCC (2000) default factor of 8 kg  $N_2O$ -N/ha/yr. The area of cultivated Histosols is assumed to be equal to that of eutric organic soils in the UK and is based on a FAO soil map figure supplied by SSLRC (now NSRI).

### A3.6.3.6 Grazing Animals

Emissions from manure deposited by grazing animals are reported under agricultural soils by IPCC. The method of calculation is the same as that for AWMS (see **Section A3.6.2.2**), using factors for pasture range and paddock.

### A3.6.3.7 Organic Fertilizers

Emissions from animal manures and slurries used as organic fertilizers are reported under agricultural soils by IPCC. The calculation involves estimating the amount of nitrogen applied to the land and applying IPCC emission factors. For daily spreading of manure, the emission is given by:

$$N_2O_{(DS)} = 44/28 \cdot \sum_T (N_T \cdot Nex_{(T)} \cdot AWMS_{(DS)}) \cdot EF_1$$

where

$N_2O_{(DS)}$	=	$N_2O$ emissions from daily spreading of wastes (kg $N_2O$ /yr)
$N_T$	=	Number of animals of type T
$Nex_{(T)}$	=	N excretion of animals of type T (kg N/animal/yr), net of N volatilising as $NO_x$ and $NH_3$ (values in <b>Table A3.6.6</b> )
$AWMS_{(DS)}$	=	Fraction of $Nex$ that is daily spread
$EF_1$	=	Emission Factor for direct soil emissions
	=	0.0125 kg $N_2O$ -N/kg N input

For the application of previously stored manures to land, a correction is applied to account for previous N<sub>2</sub>O losses during storage.

$$N_2O_{(FAW)} = 44/28 \cdot \sum_T (N_T \cdot Nex_{(T)} \cdot AWMS_{(W)} - N_{(AWMS)}) \cdot EF_1$$

where

$N_2O_{(FAW)}$	=	N <sub>2</sub> O emission from organic fertiliser application
$N_T$	=	Number of animals of type T
$Nex_{(T)}$	=	N excretion of animals of type T (kg N/animal/yr) net of N volatilising as NO <sub>x</sub> and NH <sub>3</sub> (values in <b>Table A3.6.6</b> )
$AWMS_{(W)}$	=	Fraction of Nex that is managed in one of the different waste management systems of type W
$N_{(AWMS)}$	=	N <sub>2</sub> O emissions from animal waste management systems as nitrogen (kg N <sub>2</sub> O-N/yr)

The summation is for all animal types and manure previously stored in categories defined as a) liquid, b) solid storage and dry lot and c) other.

### **A3.6.3.8 Atmospheric deposition of NO<sub>x</sub> and NH<sub>3</sub>**

Indirect emissions of N<sub>2</sub>O from the atmospheric deposition of ammonia and NO<sub>x</sub> are estimated according to the IPCC (1997) methodology but with corrections to avoid double counting N. The sources of ammonia and NO<sub>x</sub> considered are synthetic fertiliser application and animal manures applied as fertiliser.

The contribution from synthetic fertilisers is given by:

$$N_2O_{(DSN)} = 44/28 \cdot N_{(FERT)} \cdot Frac_{(GASF)} \cdot EF_4$$

where

$N_2O_{(DSN)}$	=	Atmospheric deposition emission of N <sub>2</sub> O arising from synthetic fertiliser application (kg N <sub>2</sub> O/yr)
$N_{(FERT)}$	=	Total mass of nitrogen applied as synthetic fertiliser (kg N/yr)
$Frac_{(GASF)}$	=	Fraction of total synthetic fertiliser nitrogen that is emitted as NO <sub>x</sub> + NH <sub>3</sub>
	=	0.1 kg N/ kg N
$EF_4$	=	N deposition emission factor
	=	0.01 kg N <sub>2</sub> O-N/kg NH <sub>3</sub> -N and NO <sub>x</sub> -N emitted

The indirect contribution from waste management systems is given by:

$$N_2O_{(DWS)} = 44/28 \cdot (N_{(EX)} / (1 - \text{Frac}_{(GASM)}) - N_{(F)}) \cdot \text{Frac}_{(GASM)} \cdot EF_4$$

where

$N_2O_{(DWS)}$	=	Atmospheric deposition emission of $N_2O$ arising from animal wastes (kg $N_2O$ /yr)
$N_{(EX)}$	=	Total N excreted by animals (kg N/yr), net of N volatilising as $NO_x$ and $NH_3$ (values in <b>Table A3.6.6</b> )
$\text{Frac}_{(GASM)}$	=	Fraction of livestock nitrogen excretion that volatilises as $NH_3$ and $NO_x$
	=	0.2 kg N/kg N
$N_{(F)}$	=	Total N content of wastes used as fuel (kg N/yr)

The equation corrects for the N content of manures used as fuel but no longer for the N lost in the direct emission of  $N_2O$  from animal manures as previously. The nitrogen excretion data in **Table A.3.6.6** already exclude volatilisation losses, and hence a correction is included for this.

### A3.6.3.9 Leaching and runoff

Indirect emissions of  $N_2O$  from leaching and runoff are estimated according the IPCC methodology but with corrections to avoid double counting N. The sources of nitrogen considered, are synthetic fertiliser application and animal manures applied as fertiliser.

The contribution from synthetic fertilisers is given by:

$$N_2O_{(LSN)} = 44/28 \cdot (N_{(FERT)} \cdot (1 - \text{Frac}_{(GASF)}) - N_{(SN)}) \cdot \text{Frac}_{(LEACH)} \cdot EF_5$$

where

$N_2O_{(LSN)}$	=	Leaching and runoff emission of $N_2O$ arising from synthetic fertiliser application (kg $N_2O$ /yr)
$N_{(FERT)}$	=	Total mass of nitrogen applied as synthetic fertiliser (kg N/yr)
$N_{(SN)}$	=	Direct emission of $N_2O_{(SN)}$ as nitrogen (kg $N_2O$ -N/yr)
$\text{Frac}_{(GASF)}$	=	Fraction of total synthetic fertiliser nitrogen emitted as $NO_x + NH_3$
	=	0.1 kg N/ kg N
$\text{Frac}_{(LEACH)}$	=	Fraction of nitrogen input to soils lost through leaching and runoff
	=	0.3 kg N/ kg fertiliser or manure N
$EF_5$	=	Nitrogen leaching/runoff factor
	=	0.025 kg $N_2O$ -N /kg N leaching/runoff

The estimate includes a correction to avoid double counting  $N_2O$  emitted from synthetic fertiliser use.

The indirect contribution from waste management systems is given by:

$$N_2O_{(LWS)} = 44/28. ((N_{(EX)} - N_{(F)} - N_{(AWMS)}) \cdot \text{Frac}_{(LEACH)} \cdot EF_5$$

where

$N_2O_{(LWS)}$	=	Leaching and runoff emission of $N_2O$ from animal wastes (kg $N_2O$ /yr)
$N_{(EX)}$	=	Total N excreted by animals (kg N/yr), net of N volatilising as $NO_x$ and $NH_3$ (values in <b>Table A3.6.6</b> )
$N_{(F)}$	=	Total N content of wastes used as fuel (kg N/yr)
$N_{(AWMS)}$	=	Total N content of $N_2O$ emissions from waste management systems including daily spread and pasture range and paddock (kg $N_2O$ -N/yr)
$\text{Frac}_{(LEACH)}$	=	Fraction of nitrogen input to soils that is lost through leaching and runoff
	=	0.3 kg N/ kg fertiliser or manure N
$EF_5$	=	Nitrogen leaching/runoff factor
	=	0.025 kg $N_2O$ -N /kg N leaching/runoff

The equation corrects both for the N lost in the direct emission of  $N_2O$  from animal wastes and the N content of wastes used as fuel.

## **A3.6.4 Field Burning of Agricultural Residues (4F)**

The National Atmospheric Emissions Inventory reports emissions from field burning under the category agricultural incineration. The estimates are derived from emission factors calculated according to IPCC (1997) and from USEPA (1997) shown in **Table A3.6.11**.

**Table A3.6.11** Emission Factors for Field Burning (kg/t)

	<b>CH<sub>4</sub></b>	<b>CO</b>	<b>NO<sub>x</sub></b>	<b>N<sub>2</sub>O</b>	<b>NMVOC</b>
Barley	3.05 <sup>a</sup>	63.9 <sup>a</sup>	2.18 <sup>a</sup>	0.060 <sup>a</sup>	7.5 <sup>b</sup>
Other	3.24 <sup>a</sup>	67.9 <sup>a</sup>	2.32 <sup>a</sup>	0.064 <sup>a</sup>	9.0 <sup>b</sup>

a IPCC (1997)

b USEPA (1997)

The estimates of the masses of residue burnt of barley, oats, wheat and linseed are based on crop production data (Defra, 2005b) and data on the fraction of crop residues burnt (MAFF, 1995; ADAS, 1995b). Field burning ceased in 1993 in England and Wales. Burning in Scotland and Northern Ireland is considered negligible, as is grouse moor burning, so no estimates are reported from 1993 onwards. The carbon dioxide emissions are not estimated because under the IPCC Guidelines they are considered to be part of the annual carbon cycle.

**A3.7 LAND USE CHANGE AND FORESTRY (CRF SECTOR 5)**

The following section describes in detail the methodology used in the Land-Use Change and Forestry Sector. Further information regarding this Sector can be found in **Chapter 7**.

**A3.7.1 Land converted to Forest Land (5A2)**

The carbon uptake by the forests planted since 1920 is calculated by a carbon accounting model (Dewar & Cannell, Cannell & Dewar 1995, Milne *et al.* 1998) as the net change in pools of carbon in standing trees, litter, soil in conifer and broadleaf forests and in products. Restocking is assumed in all forests. The method can be described as Tier 3, as defined in the GPG LULUCF (IPCC 2003). Two types of input data and two parameter sets were required for the model (Cannell & Dewar 1995). The input data are a) areas of new forest planted in each year in the past and b) the stemwood growth rate and harvesting pattern. Parameter values were required to estimate i) stemwood, foliage, branch and root masses from the stemwood volume and ii) the decomposition rates of litter, soil carbon and wood products.

For the estimates described here we used the combined area of new private and state planting from 1920 to 2004 for England, Scotland, Wales and Northern Ireland sub-divided into conifers and broadleaves. Restocking was dealt with in the model through the second and subsequent rotations, which occur after clearfelling at the time of Maximum Area Increment (MAI). Hence areas restocked in each year did not need to be considered separately. The basic assumption is that the forests are felled according to standard management tables. However, a comparison of forest census data over time has indicated that there are variations in the felling/replanting date during the 20<sup>th</sup> century, i.e. non-standard management. These variations in management have been incorporated into the forest model, and the methodology will be kept under review in future reporting.

The carbon flow model uses Forestry Commission Yield Tables (Edwards & Christie 1981) to describe forest growth after thinning and an expo-linear curve for growth before thinning. It was assumed that all new conifer plantations have the same growth characteristics as Sitka spruce (*Picea sitchensis* (Bong.) Carr.) under an intermediate thinning management regime. Sitka spruce is the commonest species in UK forests being about 50% by area of conifer forests. Milne *et al.* (1998) have shown that mean Yield Class for Sitka spruce varied across Great Britain from 10-16 m<sup>3</sup> ha<sup>-1</sup> a<sup>-1</sup>, but with no obvious geographical pattern, and that this variation had an effect of less than 10% on estimated carbon uptake for the country as a whole. The Inventory data has therefore been estimated by assuming all conifers in Great Britain followed the growth pattern of Yield Class 12 m<sup>3</sup> ha<sup>-1</sup> a<sup>-1</sup>, but in Northern Ireland Yield Class 14 m<sup>3</sup> ha<sup>-1</sup> a<sup>-1</sup> was used. Milne *et al.* (1998) also showed that different assumptions for broadleaf species had little effect on carbon uptake. It is assumed that broadleaf forests have the characteristics of beech (*Fagus sylvatica* L.) of Yield Class 6 m<sup>3</sup> ha<sup>-1</sup> a<sup>-1</sup>. The most recent inventory of British woodlands (Forestry Commission 2002) shows that beech occupies about 8% of broadleaf forest area (all ages) and no single species occupies greater than 25%. Beech was selected to represent all broadleaves as it has characteristics intermediate between fast growing species e.g. birch, and very slow growing species e.g. oak. However, using oak or birch Yield Class data instead of beech data has been shown to have an effect of less than 10% on the overall removal of carbon to UK forests (Milne *et al.* 1998). The use of beech as the representative species will be kept under review.



Irrespective of species assumptions, the variation in removals from 1990 to the present is determined by the afforestation rate in earlier decades and the effect this has on the age structure in the present forest estate, and hence the average growth rate. It can be shown that if forest expansion continues at the present rate, removals of atmospheric carbon will continue to increase until about 2005 and then will begin to decrease, reflecting the reduction in afforestation rate after the 1970s. This afforestation is all on ground that has not been wooded for many decades. **Table A3.7.1** shows the afforestation rate since 1922 and the present age structure of these forests.

A comparison of historical forest census data and the historical annual planting rates has been undertaken. Forest censuses were taken in 1924, 1947, 1965, 1980 and the late 1990s. The comparison of data sources showed that discrepancies in annual planting rates and inferred planting date (from woodland age in the forest census) are mainly due to variations in the harvesting rotations. However, there is also evidence of shortened conifer rotations in some decades and transfer of woodland between broadleaved categories (e.g. between coppice and high forest). As a result, the afforestation series for conifers in England and Wales were subdivided into the standard 59 year rotation (1921-2004), a 49 year rotation (1921-1950) and a 39 year rotation (1931-1940, England only). It is difficult to incorporate non-standard management in older conifer forests and broadleaved forests into the Inventory because it is not known whether these forests are on their first rotation or subsequent rotations. Further work is planned for this area.

In addition to these planted forests, there are about 822,000 ha of woodland planted prior to 1922 or not of commercial importance. These forests are assumed to fall in Category 5.A.1 (Forest Land remaining Forest Land). It is evident from the comparison of historical forest censuses that some of this forest area is still actively managed, but overall this category is assumed to be carbon-neutral. The possible contribution of this category to carbon emissions and removals will be considered in more detail in future reporting.

**Table A3.7.1** Afforestation rate and age distribution of conifers and broadleaves in the United Kingdom since 1922

Period	Planting rate (000 ha a <sup>-1</sup> )		Age distribution	
	Conifers	Broadleaves	Conifers	Broadleaves
1922-1929	4.9	2.4	2.9%	6.7%
1930-1939	7.2	2.2	5.3%	7.8%
1940-1949	6.3	1.9	4.6%	6.7%
1950-1959	20.0	3.0	14.8%	10.7%
1960-1969	28.4	2.9	21.0%	10.4%
1970-1979	33.2	1.5	24.6%	5.3%
1980-1989	22.5	1.4	16.7%	4.9%
1990	26.8	3.1	2.0%	1.1%
1991	15.4	5.8	1.1%	2.0%
1992	13.4	6.8	1.0%	2.4%
1993	11.6	6.5	0.9%	2.3%
1994	10.1	8.9	0.7%	3.1%

Period	Planting rate (000 ha a <sup>-1</sup> )		Age distribution	
	Conifers	Broadleaves	Conifers	Broadleaves
1995	7.4	11.2	0.5%	4.0%
1996	9.5	10.5	0.7%	3.7%
1997	7.4	8.9	0.5%	3.2%
1998	7.0	9.7	0.5%	3.4%
1999	6.6	10.1	0.5%	3.6%
2000	6.5	10.9	0.5%	3.9%
2001	4.9	13.4	0.4%	4.8%
2002	3.9	10.0	0.3%	3.5%
2003	3.7	9.3	0.3%	3.3%
2004	2.9	8.9	0.2%	3.1%

Increases in stemwood volume were based on standard Yield Tables, as in Dewar & Cannell (1992) and Cannell & Dewar (1995). These Tables do not provide information for years prior to first thinning so a curve was developed to bridge the gap (Hargreaves *et al.* 2003). The pattern fitted to the stemwood volume between planting and first thinning from the Yield Tables follows a smooth curve from planting to first thinning. The formulation begins with an exponential pattern but progresses to a linear trend that merges with the pattern in forest management tables after first thinning.

The mass of carbon in a forest was calculated from volume by multiplying by species-specific wood density, stem to branch and root mass ratios and the fraction of carbon in wood (0.5 assumed). The values used for these parameters for conifers and broadleaves are given in **Table A3.7.2**.

**Table A3.7.2** Main parameters for forest carbon flow model for species used to estimates carbon uptake by planting of forests of Sitka spruce (*P. sitchensis*) and beech (*F. sylvatica*) in the United Kingdom (Dewar & Cannell 1992)

	<i>P. sitchensis</i>	<i>P. sitchensis</i>	<i>F. sylvatica</i>
	YC12	YC14	YC6
Rotation (years)	59	57	92
Initial spacing (m)	2	2	1.2
Year of first thinning	25	23	30
Stemwood density (t m <sup>-3</sup> )	0.36	0.35	0.55
Maximum carbon in foliage (t ha <sup>-1</sup> )	5.4	6.3	1.8
Maximum carbon in fine roots (t ha <sup>-1</sup> )	2.7	2.7	2.7
Fraction of wood in branches	0.09	0.09	0.18
Fraction of wood in woody roots	0.19	0.19	0.16
Maximum foliage litterfall (t ha <sup>-1</sup> a <sup>-1</sup> )	1.1	1.3	2
Maximum fine root litter loss (t ha <sup>-1</sup> a <sup>-1</sup> )	2.7	2.7	2.7
Dead foliage decay rate (a <sup>-1</sup> )	1	1	3
Dead wood decay rate (a <sup>-1</sup> )	0.06	0.06	0.04
Dead fine root decay rate (a <sup>-1</sup> )	1.5	1.5	1.5
Soil organic carbon decay rate (a <sup>-1</sup> )	0.03	0.03	0.03

Fraction of litter lost to soil organic matter	0.5	0.5	0.5
Lifetime of wood products	57	59	92

The parameters controlling the transfer of carbon into the litter pools and its subsequent decay are given in **Table A3.7.2**. Litter transfer rate from foliage and fine roots increased to a maximum at canopy closure. A fraction of the litter was assumed to decay each year, half of which added to the soil organic matter pool, which then decayed at a slower rate. Tree species and Yield Class, but not other factors which varied with location, were assumed to control the decay of litter and soil matter. Additional litter was generated at times of thinning and felling.

Estimates of carbon losses from the soils afforested are based on measurements taken at deep peat moorland locations covering afforestation of peat from 1 to 9 years previously and at a 26 year old conifer forest (Hargreaves *et al.* 2003). These measurements suggest that long term losses from afforested peatlands are not as great as had been previously thought, settling to about 0.3 tC ha<sup>-1</sup> a<sup>-1</sup> thirty years after afforestation. In addition, a short burst of regrowth of moorland plant species occurs before forest canopy closure.

Carbon incorporated into the soil under all new forests is included, and losses from pre-existing soil layers are described by the general pattern measured for afforestation of deep peat with conifers. Account is taken of the relative amounts of afforestation on deep peat and other soils in the decades since 1920. For planting on organo-mineral and mineral soils, it is assumed that the pattern of emissions after planting will follow that measured for peat, but the emissions from the pre-existing soil layers will broadly be in proportion to the soil carbon density of the top 30 cm relative to that same depth of deep peat. A simplified approach was taken to deciding on the proportionality factors, and it is assumed that emissions from pre-existing soil layers will be equal to that from the field measurements for all planting in Scotland and Northern Ireland and for conifer planting on peat in England and Wales. Losses from broadleaf planting in England and Wales are however assumed to proceed at half the rate of the field measurements. These assumptions are based on consideration of mean soil carbon densities for non-forest in the fully revised UK soil carbon database. The temporary re-growth of grasses is however assumed to occur for all planting at the same rate as in afforested peat moorland. This assumption agrees with qualitative field observations at plantings on agricultural land in England.

It is assumed in the carbon accounting model that harvested material from thinning and felling is made into wood products. The net change in the carbon in this pool of wood products is reported in Category 5G.

### **A3.7.2 Harvested Wood Products (5G)**

The CFlow model adopts a simple approach to the decay of HWP. A carbon stock loss of 5% is assumed to be lost immediately at harvest. Subsequently, the decay time (time to 95% loss of carbon stock) of products is set equal to the rotation time for that species. This approach was taken to capture the fact that fast growing softwoods tend to be used for shorter lived products than slower growing hardwoods. Calculated in this way, that part of the total wood products pool from UK forests is presently increasing due to continuing expansion in forest area. Dewar & Cannell (1992) and Cannell & Dewar (1995) provided a detailed description of all the assumptions in the model. Only products from UK forests planted since 1920 (i.e. those

for which biomass and soil carbon stock changes are reported) are considered at present. It is not considered to be of high priority to consider decay of imported products etc. as there is no international agreement on a single methodology to be used for reporting

Exponential single decay constants are used for conifers and broadleaves. Products from thinnings are assumed to have a lifetime (time to 95% loss) of 5 years (half life~0.9 years). Main harvest products have lifetime (time to 95% loss) equal to rotation length. For conifers this equates to a half life of 14 years and for broadleaves a half life of 21 years. These values fall mid range between those tabled in the LULUCF GPG (IPCC 2003) for paper and sawn products. Limited data were available for the decay of products in the UK when the model was originally developed. The mix of products may be changing in the UK and this could affect the 'true' mean value of product lifetime but there is very limited accurate data on either decay rates or volume statistics for different products. The method used in the UK takes a top-down approach by assuming that the decay of all conifer products and all broadleaf products can be approximated by separate single decay constants. Given the uncertainty on decay of products it is difficult to decide if this is worse than a bottom-up approach where each product is given an (uncertain) decay and combined with (uncertain) decay of other products using harvest statistics which are in themselves uncertain. It is likely that this HWP calculation method for the UK will be replaced in the next few years by one which uses information on the volume and decay characteristics of different products.

The time pattern of HWP stock changes is due to the historical pattern of new planting and by the resulting history of production harvesting (and thinning). The stock of carbon in HWP (from UK forests planted since 1920) has been increasing since 1990 but this rate of rise has recently reversed, reflecting a severe dip in new planting in the 1940s. The stock of carbon in HWP will fall for a few more years but will then begin to rise steeply due to harvesting of the extensive conifer forests planted from 1950 until late 1980s.

### **A3.7.3 Biomass Burning due to deforestation (5C2, 5E2)**

Levy & Milne (2004) discuss methods for estimating deforestation using a number of data sources. Here we use their approach of combining Forestry Commission felling licence data for rural areas with Ordnance Survey data for non-rural areas.

In Great Britain, some activities that involve tree felling require permission from the Forestry Commission, in the form of a felling licence, or a felling application within the Woodland Grant Scheme. Under the Forestry Act 1967, there is a presumption that the felled areas will be restocked, usually by replanting. Thus, in the 1990s, around 14,000 ha a<sup>-1</sup> were felled and restocked. However, some licences are granted without the requirement to restock, where there is good reason – so-called unconditional felling licences. Most of these areas are small (1-20 ha), but their summation gives some indication of areas deforested. These areas are not published, but recent figures from the Forestry Commission have been collated. These provide estimates of rural deforestation rates in England for 1990 to 2002 and for GB in 1999 to 2001. The most recent deforestation rate available for rural areas is for 2002 so rates for 2003 and 2004 were estimated by extrapolating forwards from the rates for 1999 to 2002

Only local planning authorities hold documentation for allowed felling for urban development, and the need for collation makes estimating the national total difficult. However, in England, the Ordnance Survey (national mapping agency) makes an annual assessment of land use change (Office of The Deputy Prime Minister 2004) from the data it collects for map updating. Eleven broad land-use categories are defined, with a number of sub-categories. The data for England (1990 to 2004) were available to produce a land-use change matrix, quantifying the transitions between land-use classes. Deforestation rate was calculated as the sum of transitions from all forest classes to all non-forest classes providing estimates on non-rural deforestation.

The rural and non-rural values for England were each scaled up to GB scale, assuming that England accounted for 72 per cent of deforestation, based on the distribution of licensed felling between England and the rest of GB in 1999 to 2001. However, the Ordnance Survey data come from a continuous rolling survey programme, both on the ground and from aerial photography. The changes reported each year may have actually occurred in any of the preceding 1-5 years (the survey frequency varies among areas, and can be up to 10 years for moorland/mountain areas). Consequently, a three-year moving average was applied to the data to smooth out the between-year variation appropriately, to give a suitable estimate with annual resolution.. Deforestation is not currently estimated for Northern Ireland. Rural deforestation is assumed to convert the land to Grassland use (reported in Category 5C2) and non-rural deforestation causes conversion to the Settlement land type (reported in 5E2). Information from land use change matrices (Section 3.7.4) shows that conversion of forest to cropland is negligible.

On deforestation it is assumed that 60% of the standing biomass is removed as timber products and the remainder is burnt. The annual area loss rates were used in the method described in the IPCC 1996 guidelines (IPCC 1997c, 1997a, 1997b) to estimate immediate emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O from this biomass burning. Only immediate losses are considered because sites are normally completely cleared for development, leaving no debris to decay. Changes in stocks of soil carbon after deforestation are included with those due to other land use transitions as described in Section 3.7.4.

### **A3.7.4 Land Use Change and Soils (5B2, 5C2, 5E2)**

The basic method for assessing changes in soil carbon due to land use change is to use a matrix of change from surveys of land linked to a dynamic model of gain or loss of carbon. For Great Britain (England, Scotland and Wales), matrices from the Monitoring Landscape Change (MLC) data from 1947 & 1980 (MLC 1986) and the Countryside Surveys (CS) of 1984, 1990 and 1998 (Haines-Young *et al.* 2000) are used. In Northern Ireland, less data is available to build matrices of land use change, but for 1990 to 1998 a matrix for the whole of Northern Ireland was available from the Northern Ireland Countryside Survey (Cooper & McCann 2002). The only data available for Northern Ireland pre-1990 is land use areas from The Agricultural Census and The Forest Service, processed by Cruickshank & Tomlinson (2000). Matrices of land use change had then to be estimated for 1970-79 and 1980-89 using area data. The basis of the method devised was to assume that the relationship between the matrix of land use transitions for 1990 to 1998 and the area data for 1990 is the same as the relationship between the matrix and area data for each of two earlier periods – 1970-79 and

1980-89. The matrices developed by this approach were used to extrapolate areas of land use transition back to 1950 to match the start year in the rest of the UK.

The Good Practice Guidance for Land Use, Land Use Change and Forestry (IPCC 2003) recommends use of six classes of land for descriptive purposes: Forest, Grassland, Cropland, Settlements, Wetlands and Other Land. The data presently available for the UK does not distinguish wetlands from other types, so land in the UK has been placed into the five other types. The more detailed categories for the two surveys in Great Britain were combined as shown in **Tables A3.7.3a** for MLC and **A3.7.3b** for CS.

**Table A3.7.3a** Grouping of MLC land cover types for soil carbon change modelling

CROPLAND	GRASSLAND	FORESTLAND	SETTLEMENTS (URBAN)	OTHER
Crops	Upland heath	Broadleaved wood	Built up	Bare rock
Market garden	Upland smooth grass	Conifer wood	Urban open	Sand/shingle
	Upland coarse grass	Mixed wood	Transport	Inland water
	Blanket bog	Orchards	Mineral workings	Coastal water
	Bracken		Derelict	
	Lowland rough grass			
	Lowland heather			
	Gorse			
	Neglected grassland			
	Marsh			
	Improved grassland			
	Rough pasture			
	Peat bog			
	Fresh Marsh			
	Salt Marsh			

**Table A3.7.3b** Grouping of Countryside Survey Broad Habitat types for soil carbon change modelling

CROPLAND	GRASSLAND	FORESTLAND	SETTLEMENTS (URBAN)	OTHER
Arable	Improved grassland	Broadleaved/mixed	Built up areas	Inland rock
Horticulture	Neutral grassland	Coniferous	Gardens	Supra littoral rock
	Calcareous grassland			Littoral rock
	Acid grassland			Standing waters
	Bracken			Rivers
	Dwarf shrub heath			Sea
	Fen, marsh, swamp			
	Bogs			
	Montane			
	Supra littoral sediment			
	Littoral sediment			

The database of soil carbon density for the UK (Milne & Brown 1997, Cruickshank *et al.* 1998) used prior to the 2003 GHG Inventory has been extensively revised (Bradley *et al.* 2005) and were incorporated into the 2003 Inventory. There are three soil survey groups covering the UK and the field data, soil classifications and laboratory methods were

harmonized to reduce uncertainty in the final data. The depth of soil considered was also restricted to 1 m at maximum as part of this process. Values of carbon content and bulk densities for organic soils in Scotland have also been more recently revised and have been incorporated into this 2004 Inventory. **Table A3.7.4** shows total stock of soil carbon (1990) for different land types in the four devolved areas of the UK.

**Table A3.7.4** Soil carbon stock (TgC = MtC) for depths to 1 m in different land types in the UK

<b>Region Type</b>	England	Scotland	Wales	N. Ireland	UK
Forestland	108	295	45	20	467
Grassland	995	2,349	283	242	3,870
Cropland	583	114	8	33	738
Settlements	54	10	3	1	69
Other	0	0	0	0	–
<b>TOTAL</b>	<b>1,740</b>	<b>2,768</b>	<b>340</b>	<b>296</b>	<b>5,144</b>

The effect of land use change from 1950 to the present on stocks of soil carbon is taken into account. Area data exist for various periods between 1947 and 1998 and how these are used is shown in **Table A3.7.5**. The land use change data over the different periods were used to estimate annual changes by assuming that these were uniform across the measurement period. Examples of these annual changes (for the period 1990 to 1999) are given in **Tables 3.7.6a-d**. The data for afforestation and deforestation shown in the Tables are adjusted before use for estimating carbon changes to harmonise the values with those used in the calculations described in **Sections A3.7.1, A3.7.2 and A3.7.3**.

**Table A3.7.5a** Sources of land use change data in Great Britain for different periods in estimation of changes in soil carbon

<b>Year or Period</b>	<b>Method</b>	<b>Change matrix data</b>
1950-1979	Measured LUC matrix	MLC 1947->MLC1980
1980 - 1984	<i>Interpolated</i>	<i>CS1984-&gt;CS1990</i>
1984 - 1989	Measured LUC matrix	CS1984->CS1990
1990 - 1998	Measured LUC matrix	CS1990->CS1998
1999-2003	<i>Extrapolated</i>	<i>CS1990-&gt;CS1998</i>

**Table A3.7.5b** Sources of land use change data in Northern Ireland for different periods in estimation of changes in soil carbon

<b>Year or Period</b>	<b>Method</b>	<b>Change matrix data</b>
1950 - 1969	<i>Extrapolation and ratio method</i>	<i>NICS1990-&gt;NICS1998</i>
1970 - 1989	<i>Land use areas and ratio method</i>	<i>NICS1990-&gt;NICS1998</i>
1990 - 1998	Measured LUC matrix	NICS1990->NICS1998

1999-2003	Extrapolated	NICS1990->NICS1998
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Footnote: NICS = Northern Ireland Countryside Survey

The core equation describing changes in soil carbon with time for any land use transition is:

$$C_t = C_f - (C_f - C_0)e^{-kt}$$

where

$C_t$  is carbon density at time  $t$

$C_0$  is carbon density initially

$C_f$  is carbon density after change to new land use

$k$  is time constant of change

By differentiating we obtain the equation for flux  $f_t$  (emission or removal) per unit area:

$$f_t = k(C_f - C_0)e^{-kt}$$

From this equation we obtain, for any inventory year, the land use change effects from any specific year in the past. If  $A_T$  is area in a particular land use transition in year  $T$  considered from 1950 onwards then total carbon lost or gained in an inventory year, e.g. 1990, is given by:

$$F_{1990} = \sum_{T=1950}^{t=1990} kA_T(C_f - C_0)(e^{-k(1990-T)})$$

This equation is used with  $k$ ,  $A_T$  and  $(C_f - C_0)$  chosen by Monte Carlo methods within ranges set by prior knowledge e.g. literature, soil carbon database, agricultural census, LUC matrices.

The land use transitions considered are each of those between the Forestland, Grassland, Cropland and Settlements. It is assumed there are no conversions between these and Other Land. Scotland, England, Northern Ireland and Wales are treated separately.

**Table A3.7.6a** Annual changes (000 ha) in land use in England in matrix form for 1990 to 1999. Based on land use change between 1990 and 1998 from Countryside Surveys (Haines-Young *et al.* 2000). Data have been rounded to 100 ha.

From \ To	Forestland	Grassland	Cropland	Settlements
Forestland		8.9	3.4	2.1
Grassland	8.7		55.3	3.4



<b>Cropland</b>	0.5	62.9		0.6
<b>Settlements</b>	1.2	8.5	2.1	

**Table A3.7.6b** Annual changes (000 ha) in land use in Scotland in matrix form for 1990 to 1999. Based on land use change between 1990 and 1998 from Countryside Surveys (Haines-Young *et al.* 2000). Data have been rounded to 100 ha.

<b>From</b> <b>To</b>	<b>Forestland</b>	<b>Grassland</b>	<b>Cropland</b>	<b>Settlements</b>
<b>Forestland</b>		11.1	0.6	0.2
<b>Grassland</b>	5.0		16.8	0.7
<b>Cropland</b>	0.1	21.4		0.3
<b>Settlements</b>	0.3	2.2	0.1	

**Table A3.7.6c** Annual changes (000 ha) in land use in Wales in matrix form for 1990 to 1999. Based on land use change between 1990 and 1998 from Countryside Surveys (Haines-Young *et al.* 2000). Data have been rounded to 100 ha.

<b>From</b> <b>To</b>	<b>Forestland</b>	<b>Grassland</b>	<b>Cropland</b>	<b>Settlements</b>
<b>Forestland</b>		2.4	0.2	0.2
<b>Grassland</b>	1.5		5.5	0.6
<b>Cropland</b>	0.0	8.0		0.0
<b>Settlements</b>	0.1	1.8	0.2	

**Table A3.7.6d** Annual changes (000 ha) in land use in Northern Ireland in matrix form for 1990 to 1999. Based on land use change between 1990 and 1998 from Northern Ireland Countryside Surveys (Cooper & McCann 2002). Data have been rounded to 100 ha.

<b>From</b> <b>To</b>	<b>Forestland</b>	<b>Grassland</b>	<b>Cropland</b>	<b>Settlements</b>
<b>Forestland</b>		1.6	0.0	0.0
<b>Grassland</b>	0.3		5.9	0.0
<b>Cropland</b>	0.0	3.7		0.0
<b>Settlements</b>	0.1	1.0	0.0	

In the model, the change is required in equilibrium carbon density from the initial to the final land use during a transition. Here, these are calculated for each land use category as averages for Scotland, England, Wales and Northern Ireland. These averages are weighted by the area of Land Use Change occurring in four broad soil groups (organic, organo-mineral, mineral, unclassified) in order to account for the actual carbon density where change has occurred.

Hence mean soil carbon density change is calculated as:

$$\bar{C}_{ijc} = \frac{\sum_{s=1}^6 (C_{sijc} L_{sijc})}{\sum_{s=1}^6 L_{sijc}}$$

which is the weighted mean, for each country, of change in equilibrium soil carbon when land use changes, where:

$i$  = initial land use (Forestland, Grassland, Cropland, Settlements)

$j$  = new land use (Forestland, Grassland, Cropland, Settlements)

$c$  = country (Scotland, England, N. Ireland & Wales)

$s$  = soil group (organic, organo-mineral, mineral, unclassified)

$C_{sijc}$  is change in equilibrium soil carbon for a specific land use transition

The most recent land use data (1990 to 1998) is used in the weighting. The averages calculated are presented in **Tables A3.7.7a-d**.

The rate of loss or gain of carbon is dependent on the type of land use transition (**Table A3.7.8**). For transitions where carbon is lost e.g. transition from Grassland to Cropland, a ‘fast’ rate is applied whilst a transition that gains carbon occurs much more slowly. A literature search for information on measured rates of changes of soil carbon due to land use was carried out and, in combination with expert judgement, ranges of possible times for completion of different transitions were selected. These are shown in **Table A3.7.9**.

**Table A3.7.7a** Weighted average change in equilibrium soil carbon density ( $\text{kg m}^{-2}$ ) to 1 m deep for changes between different land types in England

<b>From</b> <b>To</b>	<b>Forestland</b>	<b>Grassland</b>	<b>Cropland</b>	<b>Settlements</b>
<b>Forestland</b>	0	25	32	83
<b>Grassland</b>	-21	0	23	79
<b>Cropland</b>	-31	-23	0	52
<b>Settlements</b>	-87	-76	-54	0

## Other Detailed Methodological Descriptions **A3**

**Table A3.7.7b** Weighted average change in equilibrium soil carbon density ( $\text{kg m}^{-2}$ ) to 1 m deep for changes between different land types in Scotland

<b>From</b> <b>To</b>	<b>Forestland</b>	<b>Grassland</b>	<b>Cropland</b>	<b>Settlements</b>
<b>Forestland</b>	0	47	158	246
<b>Grassland</b>	-52	0	88	189
<b>Cropland</b>	-165	-90	0	96
<b>Settlements</b>	-253	-187	-67	0

**Table A3.7.7c** Weighted average change in equilibrium soil carbon density ( $\text{kg m}^{-2}$ ) to 1 m deep for changes between different land types in Wales

<b>From</b> <b>To</b>	<b>Forestland</b>	<b>Grassland</b>	<b>Cropland</b>	<b>Settlements</b>
<b>Forestland</b>	0	23	57	114
<b>Grassland</b>	-18	0	36	101
<b>Cropland</b>	-53	-38	0	48
<b>Settlements</b>	-110	-95	-73	0

**Table A3.7.7d** Weighted average change in equilibrium soil carbon density ( $\text{kg m}^{-2}$ ) to 1 m deep for changes between different land types in Northern Ireland

<b>From</b> <b>To</b>	<b>Forestland</b>	<b>Grassland</b>	<b>Cropland</b>	<b>Settlements</b>
<b>Forestland</b>	0	94	168	244
<b>Grassland</b>	-94	0	74	150
<b>Cropland</b>	-168	-74	0	76
<b>Settlements</b>	-244	-150	-76	0

**Table A3.7.8** Rates of change of soil carbon for land use change transitions. (“Fast” & “Slow” refer to 99% of change occurring in times shown in **Table A3.7.9**)

		<b>Initial</b>			
		<b>Cropland</b>	<b>Grassland</b>	<b>Settlement</b>	<b>Forestland</b>
<b>Final</b>	<b>Cropland</b>		<i>slow</i>	<i>slow</i>	<i>slow</i>
	<b>Grassland</b>	<i>fast</i>		<i>slow</i>	<i>slow</i>
	<b>Settlement</b>	<i>fast</i>	<i>fast</i>		<i>slow</i>
	<b>Forestland</b>	<i>fast</i>	<i>fast</i>	<i>fast</i>	

**Table A3.7.9** Range of times for soil carbon to reach 99% of a new value after a change in land use in England (E), Scotland (S) and Wales (W)

	<b>Low (years)</b>	<b>High (years)</b>
Carbon loss (“fast”) E, S, W	50	150

Carbon gain (“slow”) E, W	100	300
Carbon gain (“slow”) S	300	750

Changes in soil carbon from equilibrium to equilibrium ( $C_f - C_o$ ) were assumed to fall within ranges based on 2004 database values for each transition and the uncertainty indicated by this source (up to  $\pm 11\%$  of mean). The areas of land use change for each transition were assumed to fall a range of uncertainty of  $\pm 30\%$  of mean.

The model of change was run 1000 times with the time constant for change in soil carbon, land use change areas and equilibrium carbon change being selected separately using a Monte Carlo approach for England, Scotland N. Ireland and Wales from within the ranges described above. The mean carbon flux for each region resulting from this imposed random variation is reported as the estimate for the Inventory. An adjustment was made to these calculations for each country to remove increases in soil carbon due to afforestation, as the C-Flow model (See **Section A3.7.1**) provides a better estimate of these fluxes.

Variations from year to year in the reported net emissions reflect the trend in land use change as described by the matrices of change.

### **A3.7.5 Liming of Agricultural Soils (5B1, 5C1)**

The method for estimating CO<sub>2</sub> emissions due to the application of lime and related compounds is that described in the IPCC 1996 Guidelines. For limestone and chalk, an emission factor of 120 tC/kt applied is used, and for dolomite application, 130 tC/kt. These factors are based on the stoichiometry of the reaction and assume pure limestone/chalk and dolomite.

Only dolomite is subjected to calcination. However, some of this calcinated dolomite is not suitable for steel making and is returned for addition to agricultural dolomite – this fraction is reported in PA1007 as ‘material for calcination’ under agricultural end use. Calcinated dolomite, having already had its CO<sub>2</sub> removed, will therefore not cause the emissions of CO<sub>2</sub> and hence is not included here. Lime (calcinated limestone) is also used for carbonation in the refining of sugar but this is not specifically dealt with in the UK LUCF GHG Inventory.

Lime is applied to both grassland and cropland. The annual percentages of arable and grassland areas receiving lime in Great Britain for 1994–2004 were obtained from the Fertiliser Statistics Report 2005 (Agricultural Industries Confederation 2005) Percentages for 1990–1993 were assumed to be equal to those for 1994.

### **A3.7.6 Lowland Drainage (5B1)**

Lowland wetlands in England were drained many years ago for agricultural purposes and continue to emit carbon from the soil. Bradley (1997) described the methods used to estimate these emissions. The baseline (1990) for the area of drained lowland wetland for the UK was taken as 150,000 ha. This represents all of the East Anglian Fen and Skirtland and limited areas in the rest of England. This total consists of 24,000 ha of land with thick peat (more than 1 m deep) and the rest with thinner peat. Different loss rates were assumed for these two thicknesses as shown in **Table A3.7.10**. The large difference between the Implied Emission

Factors is due to the observation that those peats described as ‘thick’ lose volume (thickness) more rapidly than those peats described as ‘thin’. The ‘thick’ peats are deeper than 1m and have 21% carbon by mass and in general have different texture and less humose topsoil than the ‘thin’ peats that have depths in the range up to 1m (many areas ~0.45 m deep) with carbon content of 12% by mass.

**Table A3.7.10** Area and carbon loss rates of UK fen wetland in 1990

	Area	Organic carbon content	Bulk density kg m <sup>-3</sup>	Volume loss rate m <sup>3</sup> m <sup>-2</sup> a <sup>-1</sup>	Carbon mass loss GgC a <sup>-1</sup>	Implied emission factor gC m <sup>-2</sup> a <sup>-1</sup>
<b>‘Thick’ peat</b>	24x10 <sup>7</sup> m <sup>2</sup> (24,000 ha)	21%	480	0.0127	307	1280
<b>‘Thin’ peat</b>	126x10 <sup>7</sup> m <sup>2</sup> (126,000 ha)	12%	480	0.0019	138	109
<b>Total</b>	<b>150x10<sup>7</sup> m<sup>2</sup> (150 kha)</b>				<b>445</b>	<b>297</b>

The trend in emissions after 1990 was estimated on the assumption that no more area has been drained since then but the existing areas have continued to lose carbon. The annual loss decreases for a specific location in proportion to the amount of carbon remaining. But, in addition to this, as the peat loses carbon it will become more mineral in structure. Burton (1995) provides data on how these soil structure changes proceed with time. The Century model of plant and soil carbon was used to average the carbon losses for the areas of component soils as they thinned to lose peat, become humose and possibly even mineral (Bradley 1997).

### **A3.7.7 Changes in stocks of carbon in non-forest biomass (5B1, 5B2, 5C2, 5E2)**

New approaches to estimating changes in the stock of carbon in biomass other than in forests have been introduced this year. Under category 5B1 (Cropland remaining Cropland) an annual value is reported for changes in carbon stock on the assumption that the annual average standing biomass of cereals has increased linearly with increase in yield between 1980 and 2000 (Sylvester-Bradley et al. 2002).

Changes in stocks of carbon in biomass due to land use change are now based on the same area matrices used for estimating changes in stock of carbon in soils (**Section A3.7.4**). The biomass carbon density for each land type is assigned by expert judgement based on the work of Milne & Brown (1997) and these are shown in **Table A3.7.11**. Five basic land uses were initially assigned biomass carbon densities then the relative proportions of the occurrence of these uses in the four countries of the UK were used to calculate mean densities for each of the IPCC types, Cropland, Grassland and Settlements. Biomass carbon stock changes due to conversions to and from Forest Land are dealt with elsewhere. The mean biomass carbon densities for each land type were further weighted by the relative proportions of change occurring between land types (**Tables A3.7.12a-d**), similarly to the calculations for changes in soil carbon densities (**Section A3.7.4**). Changes between these equilibrium biomass carbon densities were assumed to happen in one year.

**Table A3.7.11** Equilibrium biomass carbon density ( $\text{kg m}^{-2}$ ) for different land types

Density ( $\text{kg m}^{-2}$ )	Scotland	England	Wales	N. Ireland
Arable	<b>0.15</b>	<b>0.15</b>	<b>0.15</b>	<b>0.15</b>
Gardens	<b>0.35</b>	<b>0.35</b>	<b>0.35</b>	<b>0.35</b>
Natural	<b>0.20</b>	<b>0.20</b>	<b>0.20</b>	<b>0.20</b>
Pasture	<b>0.10</b>	<b>0.10</b>	<b>0.10</b>	<b>0.10</b>
Urban	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>
IPPC types weighted by occurrence				
Cropland	<b>0.15</b>	<b>0.15</b>	<b>0.15</b>	<b>0.15</b>
Grassland	<b>0.18</b>	<b>0.12</b>	<b>0.13</b>	<b>0.12</b>
Settlements	<b>0.29</b>	<b>0.28</b>	<b>0.28</b>	<b>0.26</b>

**Table A3.7.12a** Weighted average change in equilibrium biomass carbon density ( $\text{kg m}^{-2}$ ) to 1 m deep for changes between different land types in England (Transitions to and from Forestland are considered elsewhere)

<b>From</b> <b>To</b>	<b>Forestland</b>	<b>Grassland</b>	<b>Cropland</b>	<b>Settlements</b>
<b>Forestland</b>				
<b>Grassland</b>		0	-0.08	-0.13
<b>Cropland</b>		0.08	0	-0.08
<b>Settlements</b>		0.13	0.08	0

**Table A3.7.12b** Weighted average change in equilibrium biomass carbon density ( $\text{kg m}^{-2}$ ) to 1 m deep for changes between different land types in Scotland. (Transitions to and from Forestland are considered elsewhere)

<b>From</b> <b>To</b>	<b>Forestland</b>	<b>Grassland</b>	<b>Cropland</b>	<b>Settlements</b>
<b>Forestland</b>				
<b>Grassland</b>		0	-0.02	-0.14
<b>Cropland</b>		0.02	0	-0.09
<b>Settlements</b>		0.14	0.09	0

**Table A3.7.12c** Weighted average change in equilibrium biomass carbon density ( $\text{kg m}^{-2}$ ) to 1 m deep for changes between different land types in Wales. (Transitions to and from Forestland are considered elsewhere)

<b>From</b> <b>To</b>	<b>Forestland</b>	<b>Grassland</b>	<b>Cropland</b>	<b>Settlements</b>
<b>Forestland</b>				
<b>Grassland</b>		0	-0.07	-0.13
<b>Cropland</b>		0.07	0	-0.08
<b>Settlements</b>		0.13	0.08	0

**Table A3.7.12d** Weighted average change in equilibrium biomass carbon density ( $\text{kg m}^{-2}$ ) to 1 m deep for changes between different land types in Northern Ireland.  
(Transitions to and from Forestland are considered elsewhere)

<b>From To</b>	<b>Forestland</b>	<b>Grassland</b>	<b>Cropland</b>	<b>Settlements</b>
<b>Forestland</b>				
<b>Grassland</b>		0	-0.08	-0.11
<b>Cropland</b>		0.08	0	-0.06
<b>Settlements</b>		0.11	0.06	0

### **A3.7.8 Peat extraction (5C1)**

Cruickshank & Tomlinson (1997) provide initial estimates of Emissions due to peat extraction. Since their work, trends in peat extraction in Scotland and England over the period 1990 to 2004 have been estimated from activity data taken from the UK Minerals Handbook (BGS 2005). In Northern Ireland, no new data on use of peat for horticultural use has been available but a recent survey of extraction for fuel use suggested that there is no significant trend for this purpose. The contribution of emissions due to peat extraction in Northern Ireland is therefore incorporated as constant from 1990 to 2004. Peat extraction is negligible in Wales. For 2004, emissions due to peat used as a fuel are reported in the Energy Sector while peat for horticulture use remains in Sector 5; the Sector 5 figures are therefore lower than in previous inventory reports.

Emissions factors are from Cruickshank & Tomlinson (1997) and are shown in **Table A3.7.13**.

**Table A3.7.13** Emission Factors for Peat Extraction

	<b>Emission Factor</b> $\text{kg C m}^{-3}$
Great Britain Horticultural Peat	55.7
Northern Ireland Horticultural Peat	44.1



**A3.8 WASTE (CRF SECTOR 6)****A3.8.1 Solid Waste Disposal on Land (6A)*****Degradable Organic Carbon (DOC) and Fraction Dissimilated (DOCF)***

UK values for DOC and  $DOCF$  are based on an emissions model maintained by LQM (2003) that uses updated degradable carbon input parameters with values based on well-documented US research for the USEPA's life-cycle programme. This has been adapted to UK conditions and incorporated into (1) the Environment Agency's WISARD life cycle assessment model (WS Atkins, 2000); (2) the HELGA framework model (Gregory et al., 1999) and (3) GasSim (Environment Agency, 2002).

Cellulose and hemi-cellulose are known to make up approximately 91% of the degradable fraction, whilst other potential degradable fractions which *may* have a small contribution (such as proteins and lipids) are ignored. The amount of degradable carbon that produces landfill gas is determined using the mass (expressed on a percentage dry weight basis) and degradability (expressed as a percentage decomposition) of cellulose and hemi-cellulose using data provided by Barlaz et al. (1997). The input values for these parameters are provided in Tables A3.8.1a and A3.8.1b below for each of the waste fractions for both municipal (MSW) and commercial and industrial (C&I) waste categories, respectively. Also included are the proportions of individual waste streams that are considered to be rapidly, moderately or slowly degradable.

These data are used within the model to determine the amount of degradable carbon that decays at the relevant decay rate. This process requires complete disaggregation of the waste streams into their component parts, allocation of degradability and rate of decomposition to each component and application of the IPCC model approach at this disaggregated level.

## Other Detailed Methodological Descriptions **A3**

**Table A3.8.1a** Waste degradable carbon model parameters for MSW waste

Waste category	Fraction				Moisture content	Cellulose	Hemi-cellulose	DOC	DOC	Decomposition (DOC <sub>f</sub> )
	Readily Degradable	Moderately Degradable	Slowly Degradable	Inert	(%)	(% Dry waste)	(% Dry waste)	(% Dry waste)	(% Wet waste)	(%)
Paper and card	0	25	75	0	30	61.2	9.1	70.3	54.08	61.8
Dense plastics	0	0	0	100	5	0	0	0	0.00	0
Film plastics (until 1995)	0	0	0	100	30	0	0	0	0.00	0
Textiles	0	0	100	0	25	20	20	40	32.00	50
Misc. combustible (plus non-inert fines from 1995)	0	100	0	0	20	25	25	50	41.67	50
Misc. non-combustible (plus inert fines from 1995)	0	0	0	100	5	0	0	0	0.00	0
Putrescible	100	0	0	0	65	25.7	13	38.7	23.45	62
Composted putrescibles	0	50	50	0	30	0.7	0.7	1.4	1.08	57
Glass	0	0	0	100	5	0	0	0	0.00	0
Ferrous metal	0	0	0	100	5	0	0	0	0.00	0
Non-ferrous metal and Al cans	0	0	0	100	10	0	0	0	0.00	0
Non-inert fines	100	0	0	0	40	25	25	50	35.71	50
Inert fines	0	0	0	100	5	0	0	0	0.00	0

Notes:

1. DOC is Degradable Organic Carbon.
2. DOC<sub>f</sub> is the portion of DOC that is converted to landfill gas.

## Other Detailed Methodological Descriptions **A3**

**Table A3.8.1b** Waste degradable carbon model parameters for C & I waste

Waste category	Fraction				Moisture content	Cellulose	Hemi-cellulose	DOC	DOC	Decomposition (DOC <sub>d</sub> )
	Readily Degradable	Moderately Degradable	Slowly Degradable	Inert	(%)	(% Dry waste)	(% Dry waste)		Readily Degradable	Moderately Degradable
Commercial	15	57	15	13	37	76	8	Commercial	15	57
Paper and card	0	25	75	0	30	87.4	8.4	Paper and card	0	25
General industrial waste	15	43	20	22	37	76	8	General industrial waste	15	43
Food solids	79	10	0	11	65	55.4	7.2	Food solids	79	10
Food effluent	50	5	0	45	65	55.4	7.2	Food effluent	50	5
Abattoir waste	78	10	0	12	65	55.4	7.2	Abattoir waste	78	10
Misc processes	0	5	5	90	20	10	10	Misc processes	0	5
Other waste	15	35	35	15	20	25	25	Other waste	15	35
Power station ash	0	0	0	100	20	0	0	Power station ash	0	0
Blast furnace and steel slag	0	0	0	100	20	0	0	Blast furnace and steel slag	0	0
Construction/demolition	0	5	5	90	30	8.5	8.5	Construction/demolition	0	5
Sewage sludge	100	0	0	0	70	14	14	Sewage sludge	100	0

Notes:

1. DOC is Degradable Organic Carbon.
2. DOC<sub>d</sub> is the portion of DOC that is converted to landfill gas.

Notes:

1. DOC is Degradable Organic Carbon.

**A3.8.2 Flaring and Energy Recovery**

Flaring and energy recovery constitutes the method likely to reduce methane emissions from landfills by the largest amount, and was surveyed was carried out in 2002, as described below. It is estimated that in 2004 69% of the total landfill gas generated in the UK was flared or utilised (**Table 3.8.2**).

**A3.8.2.1 Gas Utilisation**

The gas utilisation data are based on comparison of information from the trade association, the Renewables Energy Association, formerly Biogas Association (Gaynor Hartnell, Pers. Comm. 2002) and current DTI figures. In addition, LQM (2003) included data on utilisation prior to the first round of the Non Fossil Fuel Obligation (NFFO) contracts (Richards and Aitchison, 1990). The first four NFFO rounds (NFFO 1-4) and the Scottish Renewables Order (SRO) round are all taken to be completed and operational schemes, since there are relatively few outstanding schemes still to be implemented. It is known that not all of the proposed early schemes were found to be economic, and no NI-NFFO (Northern Ireland-NFFO) schemes have progressed, so those known schemes have not been included in the total (Gaynor Hartnell, Pers. Comm. 2002).

This approach, comparing the trade association and Government data sources, provides a reasonable correlation, and so LQM is confident in the accuracy of its estimates of current installed capacity. The latest round of NFFO (NFFO 5) has been implemented in the forecasting model over the period 2000 – 2005, to give a reasonable lead in time for these new projects. Various industry sources have indicated in confidence that some of the proposed NFFO 5 projects are now also considered uneconomic under NFFO. Some of these have definitely been abandoned, some have been surrendered and re-started under the new renewables order, and others are likely to follow this route. These figures are likely to have only a small uncertainty, as they are directly derived from power generation figures supplied by the industry and the Department of Trade and Industry.

**A3.8.2.2 Flaring**

Information on flaring capacity was obtained through consultation with flare manufacturers. LQM (2003) collected information from all but one of the UK flare companies contacted. The data collected was divided into flares supplied for routine flaring and flares supplied as back-up to generation sets. The data produced demonstrates total flare capacity as opposed to the actual volumes of gas being flared in each year. There are difficulties in ascertaining the actual volumes of LFG burnt, as detailed records, if they exist at all, are held by individual site operators. It is rare to find a flare stack with a flow measurement.

The operational capacity is derived by subtracting the back-up capacity from the total. LQM's total for generation back-up capacity remains at a fairly constant percentage of the installed generation capacity (around 60%), indicating that these figures are realistic. In the model, there is a further correction factor used in arriving at the final volume of gas flared each year, to take account of maintenance downtime (15%). In addition, it is assumed that since 1984 (i.e. three years after the first flare was commissioned) 7% of capacity in any given year is treated as replacement. This effectively gives the flare an expected 15-year operational lifetime. In 1990, the methane captured equates to 11% of the total generated, rising to 69%

in 2004 (**Table 3.8.2**). The downtime and replacement figures are LQM assessments following inquiries made as part of the 2002 survey

The last input of gas utilisation data in the model is year 2005 and the last input of flare data is year 2002. Gas utilisation and flaring is assumed constant thereafter.

**Table 3.8.2** Amount of methane generated, captured, oxidised and emitted.

Year	Mass of waste landfilled (Mt)			Methane generated (kt)	Methane captured (kt)	Methane captured (%)	Residual methane oxidised (kt)	Residual methane oxidised (%)	Methane emitted (kt) MSW
	MSW	C&I	Combined waste streams						
<b>1990</b>	18.19	81.83	100.02	2947	322	10.91	263	8.91	2363
<b>1991</b>	18.84	81.77	100.61	3024	436	14.43	259	8.56	2329
<b>1992</b>	19.47	81.72	101.19	3098	576	18.58	252	8.14	2270
<b>1993</b>	20.09	81.66	101.76	3170	712	22.47	246	7.75	2212
<b>1994</b>	20.71	81.61	102.32	3240	832	25.67	241	7.43	2167
<b>1995</b>	23.83	81.56	105.39	3294	962	29.20	233	7.08	2099
<b>1996</b>	24.76	78.17	102.93	3330	1077	32.36	225	6.76	2027
<b>1997</b>	26.14	72.86	99.00	3352	1279	38.15	207	6.19	1866
<b>1998</b>	25.94	65.63	91.57	3361	1433	42.65	193	5.74	1735
<b>1999</b>	27.03	63.84	90.87	3371	1620	48.04	175	5.20	1577
<b>2000</b>	27.54	62.05	89.59	3384	1749	51.68	164	4.83	1472
<b>2001</b>	26.85	60.27	87.11	3394	1975	58.19	142	4.18	1277
<b>2002</b>	27.17	58.48	85.64	3405	2114	62.09	129	3.79	1162
<b>2003</b>	26.39	58.48	84.87	3415	2287	66.96	113	3.30	1016
<b>2004</b>	25.47	58.48	83.94	3425	2377	69.40	105	3.06	943

**A3.8.3 Wastewater Handling (6B)*****Notes on the use of the 1996 Hobson Model within the UK GHG Inventory***

The NAEI estimate is based on the work of Hobson *et al* (1996) who estimated emissions of methane for the years 1990-95. Subsequent years are extrapolated on the basis of population. Sewage disposed to landfill is included in landfill emissions.

The basic activity data are the throughput of sewage sludge through the public system. The estimates are based on the UK population connected to the public sewers and estimates of the amount of sewage per head generated. From 1995 onwards the per capita production is a projection (Hobson *et al*, 1996). The main source of sewage activity data is the UK Sewage Survey (DOE, 1993). Emissions are calculated by disaggregating the throughput of sewage into 14 different routes. The routes consist of different treatment processes each with specific emission factors. The treatment routes and emission factors are shown in **Table A3.8.3a**.

***Industrial Wastewater Treatment Plants***

There is no separate estimate made of emissions from private wastewater treatment plants operated by companies prior to discharge to the public sewage system or rivers, as there is no available activity data for this source and it has historically been assumed to be a minor source.

Where an IPC/IPPC-regulated industrial process includes an on-site water treatment works, any significant emission sources (point-source or fugitive) are required to be reported within their annual submission to UK environmental regulatory agencies, including emissions from their water treatment plant. Therefore, methane emissions from industrial wastewater treatment should be included within operator returns to the pollution inventories of the EA, SEPA and NIDoE, and therefore accounted for within the Industrial Process sector of the GHG Inventory.

However, it is not straightforward to ascertain the extent to which this is the case across different industry sectors. Within sector-specific guidance to plant operators on pollution inventory data preparation, emissions of methane from wastewater treatment are not highlighted as a common source to be considered (whereas in some guidance, wastewater treatment is singled out as a potentially significant source of NH<sub>3</sub> and N<sub>2</sub>O emissions).

***Sludge Applications to Agricultural Land***

The Hobson model includes emissions of methane from sewage sludge applications to agricultural land, and these emissions are therefore included within sector 6B2, rather than within the agricultural sector as recommended in IPCC guidance. There is no double-counting of these emissions, however; methane emissions from sludge application to land are excluded from the agricultural inventory compiled by IGER.

***Sewage Treatment Systems Outside of the National Network***

The model does not take account for sewage treatment systems that are not connected to the national network of treatment works. The emissions are all determined on a population basis, using factors that pertain to “mainstream” treatment systems. Differences in emissions from

alternative systems such as septic tanks are not considered, as it is assumed that the vast majority of the UK population is connected to the public wastewater treatment system.

### ***Design of Wastewater Treatment Systems in the UK***

Most UK wastewater treatment works comprise the following components as a minimum:

- Initial screening / grit removal
- Primary settlement tanks, using simple sedimentation
- Secondary treatment (usually a biological process such as activated sludge systems & sedimentation or percolating filters)

Many also have a tertiary treatment unit to complete waste-water filtration, remove target nutrients (such as nitrogen or phosphorus) or specific industrial pollutants, to “polish” the water as required prior to outputting treated water to watercourses.

In each of the treatment phases, sewage sludge is produced and may be treated in a variety of ways, each with different methane emission characteristics, and these options are accounted for within the model.

### ***Emissions from Anaerobic Digestion***

The model includes calculations to account for different designs of anaerobic digesters, primary and secondary digestion phases, the utilisation of digester gas flaring, CHP and venting systems, and uses emission factors derived for each design type, which include consideration of fugitive losses of methane in each case. The dataset is, however, limited to plant survey data and emission factor research from the early 1990s, and hence the data may not be representative of current emissions research, plant design and practice.

**Table 3.8.3a** Specific Methane Emission Factors for Sludge Handling (kg CH<sub>4</sub>/Mg dry solids, Hobson *et al* (1996))

Sludge Handling System	Gravity Thickening <sup>1</sup>	Long term storage	Anaerobic Digestion <sup>2</sup>	Agricultural Land	Landfill
Anaerobic digestion to agriculture	0.72		143	5	
Digestion, drying, agriculture	0.72		143	5	
Raw sludge, dried to agriculture	0.72			20	
Raw sludge, long term storage (3m), agriculture	0.72	36		20	
Raw sludge, dewatered to cake, to agriculture	0.72			20	
Digestion, to incinerator	0.72		143		
Raw sludge, to incinerator	0.72				
Digestion, to landfill	0.72		143		0
Compost, to agriculture	0.72			5	
Lime raw sludge, to agriculture	0.72			20	
Raw Sludge, to landfill	0.72				0
Digestion, to sea disposal	0.72		143		
Raw sludge to sea disposal	0.72				
Digestion to beneficial use (e.g. land reclamation)	0.72		143	5	

2 An emission factor of 1 kg/tonne is used for gravity thickening. Around 72% of sludge is gravity thickened hence an aggregate factor of 0.72 kg CH<sub>4</sub>/Mg is used.

- 3 The factor refers to methane production, however it is assumed that 121.5 kg CH<sub>4</sub>/Mg is recovered or flared

**Table 3.8.3b** Time-Series of Methane Emission Factors for Emissions from Wastewater Handling, based on Population (kt CH<sub>4</sub> / million people)

Year	CH <sub>4</sub> Emission (kt)	CH <sub>4</sub> EF (kt CH <sub>4</sub> / million people)
1990	33.80	0.588
1991	31.68	0.551
1992	35.17	0.611
1993	34.87	0.604
1994	36.38	0.629
1995	34.75	0.599
1996	35.69	0.614
1997	36.63	0.629
1998	37.58	0.644
1999	36.44	0.623
2000	37.32	0.636
2001	37.56	0.635
2002	37.79	0.636
2003	38.19	0.641
2004	38.06	0.636

Nitrous oxide emissions from the treatment of human sewage are based on the IPCC (1997c) default methodology. The most recent average protein consumption per person is based on the National Food Survey (Defra, 2004); see **Table 3.8.3c**. The food survey is based on household consumption of food and so may give a low estimate.

**Table 3.8.3c** Time-series of per capita protein consumptions (kg/person/yr)

Year	Protein consumption (kg/person/yr)
1990	23.0
1991	22.7
1992	22.9
1993	22.7
1994	22.8
1995	23.0
1996	23.7
1997	26.3
1998	26.0
1999	25.8
2000	25.7
2001	26.3
2002	26.0
2003	26.0



Year	Protein consumption (kg/person/yr)
2004	25.9

# **A4. ANNEX 4: Comparison of CO<sub>2</sub> Reference and Sectoral Approaches**

This annex presents information about the Reference Approach calculations, and its comparison with the Sectoral Approach.

## **A4.1 ESTIMATION OF CO<sub>2</sub> FROM THE REFERENCE APPROACH**

The UK greenhouse gas inventory uses the bottom-up (sectoral) approach based on the combustion of fuels in different economic sectors and estimates of non-combustion emissions from other known sectors to produce detailed sectoral inventories of the 10 pollutants. In addition, estimates are also provided of carbon dioxide emissions using the IPCC Reference Approach. This is a top down inventory calculated from national statistics on production, imports, exports and stock changes of crude oil, natural gas and solid fuels. It is based on a different set of statistics and methodology and produces estimates around between 1% lower to 3 % higher than the bottom-up approach when categories not included in the reference approach are removed from the sectoral approach estimate.

## **A4.2 DISCREPANCIES BETWEEN THE IPCC REFERENCE AND SECTORAL APPROACH**

The UK GHGI contains a number of sources not accounted for in the IPCC Reference Approach and so gives a higher estimate of CO<sub>2</sub> emissions. The sources not included in the reference approach are:

- Land use change and forestry
- Offshore flaring and well testing
- Waste incineration
- Non-Fuel industrial processes

In principle the IPCC Reference Total can be compared with the IPCC Table 1A Total plus the emissions arising from fuel consumption in 1B1 Solid Fuel Transformation and Table 2 Industrial Processes (Iron and Steel and Ammonia Production). The IPCC Reference totals range between 1% lower to 3 % higher than the comparable bottom up totals.

1. The IPCC Reference Approach is based on statistics of production, imports, exports and stock changes of fuels whilst the sectoral approach uses fuel consumption data. The two sets of statistics can be related using mass balances (see the publication 'Digest of UK Energy Statistics' DTI, 2005), but these show that some fuel is unaccounted for. This fuel is reported in DUKES as statistical differences – these differences consist of measurement

## Comparison of CO<sub>2</sub> Reference and Sectoral Approaches **A4**

errors and losses. The system of energy statistics operated by the DTI aims to keep UK statistical differences (without normalisation) at less than 0.5% of energy supply, and generally manages to meet this target, not only for total supply but by fuel. Time series of UK statistical differences can be found in Table 1.1.2 at:

[www.dti.gov.uk/energy/inform/energy\\_stats/total\\_energy/index.shtml](http://www.dti.gov.uk/energy/inform/energy_stats/total_energy/index.shtml)

Nevertheless a proportion of the difference between the Reference Approach and the sectoral totals will be accounted for by statistical differences, particularly for liquid fuels.

2. The sectoral approach only includes emissions from the non-energy use of fuel where they can be specifically identified and estimated such as with fertilizer production and iron and steel production. The IPCC Reference approach implicitly treats the non-energy use of fuel as if it were combustion. A correction is then applied by deducting an estimate of carbon stored from non-energy fuel use. The carbon stored is estimated from an approximate procedure that does not identify specific processes. The result is that the IPCC Reference approach is based on a higher estimate of non-energy use emissions.
3. The IPCC Reference Approach uses data on primary fuels such as crude oil and natural gas liquids, which are then corrected for imports, exports and stock changes of secondary fuels. Thus the estimates obtained will be highly dependent on the default carbon contents used for the primary fuels. The sectoral approach is based wholly on the consumption of secondary fuels where the carbon contents are known with greater certainty. In particular the carbon contents of the primary liquid fuels are likely to vary more than those of secondary fuels.

### **A4.3 TIME SERIES OF DIFFERENCES IN THE IPCC REFERENCE AND SECTORAL INVENTORIES**

**Table A4.1** shows the percentage differences between the IPCC Reference Approach and the National Approach. These percentages include a correction for the fact that a significant proportion of fuel consumption emissions occur in the 2C Metal Production and 2B1 Ammonia Production sectors.

**Table A4.1** Modified comparison of the IPCC Reference Approach and the National Approach

Year	1990	1991	1992	1993	1994	1995
Percentage difference	-1.4	0.0	0.9	0.3	0.8	2.3

Year	1996	1997	1998	1999	2000	2001
Percentage difference	0.6	0.4	1.3	1.9	2.5	1.3

Year	2002	2003	2004
Percentage difference	0.7	-0.1	0.3

## A5. ANNEX 5: Assessment of Completeness

**Table A5.1** shows sources of GHGs that are not estimated in the UK GHG inventory, and the reasons for those sources being omitted. This table is taken from the CRF; Table “Table9s1”.

**Table A5.1** GHGs and sources not considered in the UK GHG inventory

GHG	CRF sector	Source/sink category	Reason
CO <sub>2</sub>	2. Industrial Processes	2A5/6 Asphalt Roofing/Paving	No methodology available but considered negligible
CO <sub>2</sub>	3. Solvent and Other Product Use		Carbon equivalent of solvent use not included in total - provided for information
CO <sub>2</sub>	5. Land-Use Change and Forestry	5C1 Grassland remaining Grassland - Carbon stock change in living biomass	Emissions believed small
CO <sub>2</sub>	5. Land-Use Change and Forestry	5A1/5A2/5B2/5C1/5C2/5E Biomass burning by Wildfires	Methodology being developed - believed small
N <sub>2</sub> O	3. Solvent and Other Product Use	3D Other –Anaesthesia	Activity not readily available – believed small
N <sub>2</sub> O	5. Land-Use Change and Forestry	5A1/5A2 Direct N <sub>2</sub> O emissions from N fertilisation	Methodology being developed (emissions small)
N <sub>2</sub> O	5. Land-Use Change and Forestry	5A N <sub>2</sub> O emissions from drainage of soils	Methodology being developed (emissions small)
N <sub>2</sub> O	5. Land-Use Change and Forestry	5B2 N <sub>2</sub> O emissions from disturbance associated with LUC to Cropland	Methodology being developed (emissions small)
N <sub>2</sub> O	5. Land-Use Change and Forestry	5A1/5A2/5B2/5C1/5C2/5E Biomass burning by Wildfires	Methodology being developed - believed small
CH <sub>4</sub>	2. Industrial Processes	2B1 Ammonia Production	Manufacturers do not report emission - believed negligible
CH <sub>4</sub>	2. Industrial Processes	2C1 Iron and Steel	EAF emission and flaring only estimated - methodology not available for other sources
CH <sub>4</sub>	2. Industrial Processes	2C2 Ferroalloys	Methodology not available but considered negligible
CH <sub>4</sub>	2. Industrial Processes	2C3 Aluminium	Methodology not available but considered negligible
CH <sub>4</sub>	5. Land-Use Change and Forestry	5A1/5A2/5B2/5C1/5C2/5E Biomass burning by Wildfires	Methodology being developed - believed small
CH <sub>4</sub>	6. Waste	6B1 Industrial Waste Water	Activity data unavailable - most waste water treated in public system- believed small
CH <sub>4</sub>	6. Waste	6B1 Industrial Waste Water	Activity data unavailable - most waste water treated in public system- believed small

## **A6. ANNEX 6: Additional Information - Quantitative Discussion of 2004 Inventory**

This Annex discusses the emission estimates made in the 1990-2004 Greenhouse Gas Inventory. Each IPCC sector is described in detail with significant points noted for each pollutant where appropriate. It should be noted that tables show rounded percentages only. All calculations are based on IPCC categorisation, which in all cases apart from Land-use Change and Forestry (LULUCF) is the same as CRF format. For LULUCF, emissions for IPCC and CRF are categorised slightly differently and so figures shown in this annex can only be derived from IPCC tables.

### **A6.1 ENERGY SECTOR (1)**

**Figure A6.1** and **A6.2** show both emissions of direct and indirect Greenhouse Gases for the Energy sector (category 1) in the UK for the years 1990-2004. Emissions from direct greenhouse gases in this sector have declined 7% since 1990, although an increase of 0.5% was seen between 2003 and 2004.

**Tables A6.1** to **A6.4** summarise the changes observed through the time series for each pollutant, as well as the contribution the emissions make to both sector 1 and the overall emissions in the UK during 2004.

#### **A6.1.1 Carbon Dioxide**

Analysing emissions by pollutant shows that 98% of total net CO<sub>2</sub> emissions in 2004 came from the Energy sector (**Table A6.4**), making this sector by far the most important source of CO<sub>2</sub> emissions in the UK. Overall, CO<sub>2</sub> emissions from sector 1 have declined by 4% since 1990 (**Table A6.1**).

Energy industries (category 1A1) were responsible for 38% of the sector's CO<sub>2</sub> emissions in 2004 (**Table A6.3**). There has been an overall decline in emissions from this sector of 12% since 1990 (**Table A6.1**). Since the privatisation of the power industry in 1990, there has been a move away from coal and oil generation towards combined cycle gas turbines (CCGT) and nuclear power, the latter through greater availability. During this time there has been an increase of around 18% in the amount of electricity generated<sup>\*20</sup>, but a decrease in CO<sub>2</sub> emissions from Power stations (1A1a) of 16%. This can be attributed to several reasons. Firstly, the greater efficiency of the CCGT stations compared with conventional stations – around 46% as opposed to 36%<sup>•21</sup>. Secondly, the calorific value of natural gas per unit mass

<sup>20</sup> \* Electricity generated by Major Power Producers, Table 5.1.3, DTI (2005)

<sup>21</sup> • Plant loads, demand and efficiency, Table 5.10, DTI (2005)

carbon being higher than that of coal and oil and thirdly, the proportion of nuclear generated electricity supplied increasing from 21% to 24%.

Emissions of from category 1A2 – Manufacturing Industries and Construction contributed 16% (**Table A6.4**) to overall net CO<sub>2</sub> emissions in the UK in 2004. Since 1990, these emissions have declined by 11%, (**Table A6.1**) mostly as a result of a decline in the emissions from the Iron and steel industry. This sector has seen a significant decrease in coke, coal and fuel oil usage, with an increase occurring in the emissions of natural gas from combustion.

Emissions of CO<sub>2</sub> from 1A3 (Transport) have increased by 10% since 1990 (**Table A6.1**). In 2004, this sector contributed 23% (**Table A6.4**) to overall CO<sub>2</sub> emissions within the UK. Emissions from transport are dominated by the contribution from road transport (1A3b), which in 2004 contributed 93% to the emissions from transport. Since 1990, emissions from road transport have increased by 9%. In recent years (since around 1998), although the vehicle kilometres driven have continued to increase, the rate of increase in emissions of CO<sub>2</sub> from road transport has slowed. In part this is due to the increasing fuel efficiency of new cars.

Emissions of CO<sub>2</sub> from 1A4 (Other) have increased by 6% since 1990 (**Table A6.1**). During this period, residential emissions have increased by over 12% and emissions from the commercial/institutional subsector have decreased by 10%. Fuel consumption data shows a trend away from coal, coke, fuel oil and gas oil towards burning oil and natural gas usage.

Emissions of CO<sub>2</sub> from 1A5 (Fuel Combustion; Other), 1B1 (Fugitive Emissions from Fuels; Solid fuels) and 1B2 (Fugitive Emissions from Fuels; Oil and Natural Gas) show large decreases between 1990-2004, although they only contribute a small percentage towards emissions from the energy sector.

### **A6.1.2 Methane**

In 2004, 24% (see **Table A6.4**) of total methane emissions came from the energy sector, the majority (49%, **Table A6.3**) from fugitive emissions from oil and natural gas (1B2). Emissions from this category have decreased by 42% since 1990 (**Table A6.1**). Sources include leakage from the gas transmission and distribution system and offshore emissions. Estimates of leakage from the gas distribution system are based on leakage measurements made by Transco together with data on their gas main replacement programme, and have declined since 1990 as old mains are replaced. The major sources of emissions from the offshore oil and gas industry are venting, fugitive emissions and loading and flaring from offshore platforms.

### **A6.1.3 Nitrous Oxide**

The energy sector accounted for 22% of total N<sub>2</sub>O emissions in the UK during 2004. Of this, a majority (61%, **Table A6.3**) arose from the transport sector (1A3). Between 1990 and 2004, emissions increased by over 298% (**Table A6.1**). This is because of the increasing numbers

of petrol driven cars fitted with three-way catalytic converters. Catalytic converters are used to reduce emissions of nitrogen oxides, carbon monoxide and non-methane volatile organic compounds. However, nitrous oxide is produced as a by-product and hence emissions from this sector have increased.

The other major contribution towards N<sub>2</sub>O emissions within the energy sector comes from the energy industries (1A1). Within this category, emissions from both the public electricity and petroleum refining industries have remained fairly constant and so no particular trend is apparent. Emissions from 1A1c (Manufacture of Solid Fuels and Other Energy Industries), however, have steadily increased between 1990 and 2004 - N<sub>2</sub>O emissions have increased overall by 28% since 1990. Over this period the use of coal has decreased and the use of natural gas increased.

### **A6.1.4 Nitrogen Oxides**

In 2004, over 99% of NO<sub>x</sub> emissions in the UK came from the energy sector. Since 1990 emissions from this sector have decreased by 44% (**Table A6.1**), mostly as a result of abatement measures on power stations, three-way catalytic converters fitted to cars and stricter emission regulations on trucks. The main source of NO<sub>x</sub> emissions is transport: in 2004, emissions from transport contributed 43% (**Table 6.4**) to the total emissions of NO<sub>x</sub> in the UK, with 37% arising from road transport (1A3b). From 1970, emissions from transport increased (especially during the 1980s) and reached a peak in 1989 before falling by 51% (**Table A6.1**) since 1990. This reduction in emissions is due to the requirement since the early 1990s for new petrol cars to be fitted with catalytic converters and the further tightening up of emission standards on these and all types of new diesel vehicles over the last decade.

Emissions from the energy industries (1A1) contributed 27% (**Table A6.4**) to total NO<sub>x</sub> emissions in the UK during 2004. Between 1990 and 2004, emissions from this sector decreased by 48% (**Table A6.1**). The main reason for this was a decrease in emissions from public electricity and heat (1A1a) of 58%. Since 1998 the electricity generators adopted a programme of progressively fitting low NO<sub>x</sub> burners to their 500 Mwe coal fired units. Since 1990, further changes in the electricity supply industry such as the increased use of nuclear generation and the introduction of CCGT plant have resulted in additional reduction in NO<sub>x</sub> emissions.

Emissions from Manufacturing, Industry and Construction (1A2) have fallen by 29% (**Table A6.1**) since 1990. In 2004, emissions from this sector contributed 16% (**Table A6.4**) to overall emissions of NO<sub>x</sub>. Over this period, the iron and steel sector has seen a move away from the use of coal, coke and fuel oil towards natural gas and gas oil usage.

### **A6.1.5 Carbon Monoxide**

Emissions of carbon monoxide from the energy sector contributed 94% (**Table A6.4**) to overall UK CO emissions in 2004. Of this, 52% of emissions (**Table A6.4**) occur from the transport sector. Since 1990, emissions from 1A3 have declined by almost 75% (**Table A6.1**), which is mainly because of the increased use of catalytic converters, although a proportion is a consequence of fuel switching in moving from petrol to diesel cars.

Emissions from sector 1A2 contributed 23% (**Table A6.4**) to overall emissions of CO in 2004. Emissions from within this category mostly come from the Iron and Steel industry and from petrol use in off-road vehicles within the Manufacturing, industry and combustion sector.

### **A6.1.6 Non Methane Volatile Organic Compounds**

In 2004, 46% (**Table A6.4**) of non-methane volatile organic compound emissions came from the energy sector. Of these, the largest contribution arises from the fugitive emissions of oil and natural gas (1B2), which contributed 20% (**Table A6.4**) towards the overall UK emissions of NMVOCs in 2004. This includes emissions from gas leakage, which comprise around 10% of the total for the energy sector. Remaining emissions arise from oil transportation, refining, storage and offshore.

Emissions from transport (1A3) contribute 15% (**Table A6.4**) to overall emissions of NMVOC in the UK in 2004. Since 1990, emissions from this sector have decreased by 83% (**Table A6.1**) due to the increased use of catalytic converters on cars.

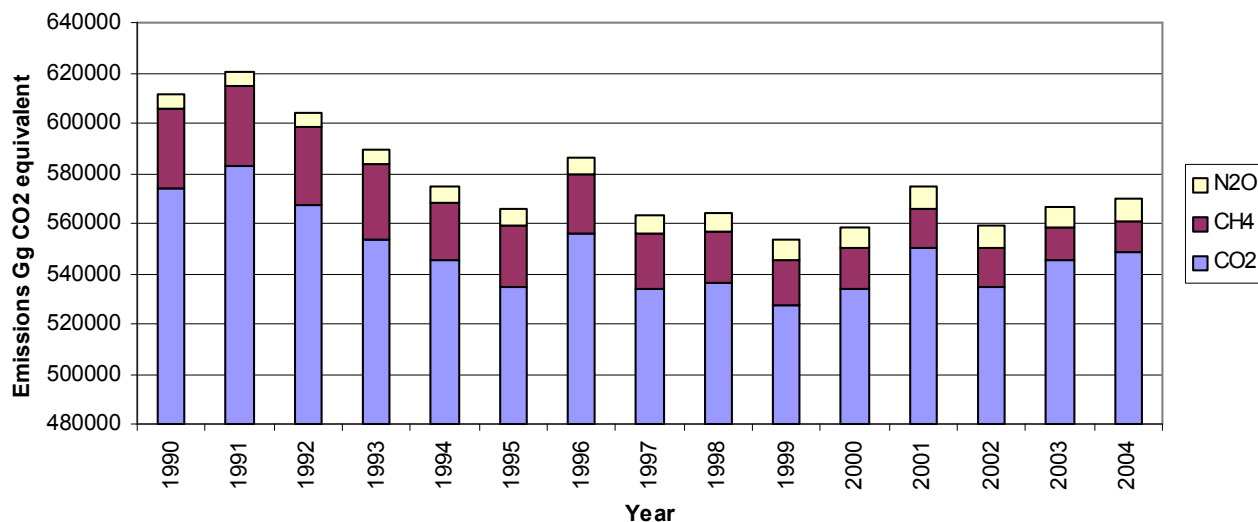
### **A6.1.7 Sulphur Dioxide**

96% (**Table A6.4**) of emissions of sulphur dioxide came from the energy sector in 2004. 71% (**Table A6.4**) of these emissions arose from the energy industries sector (1A1). A majority of these emissions are from the public electricity and heat production category (1A1a). Since 1990, emissions from the power stations have declined by 82%. This decline has been due to the increase in the proportion of electricity generated in nuclear plant and the use of CCGT stations and other gas fired plant. CCGTs run on natural gas and are more efficient (see **Section A6.1.1**) than conventional coal and oil stations and have negligible SO<sub>2</sub> emissions.

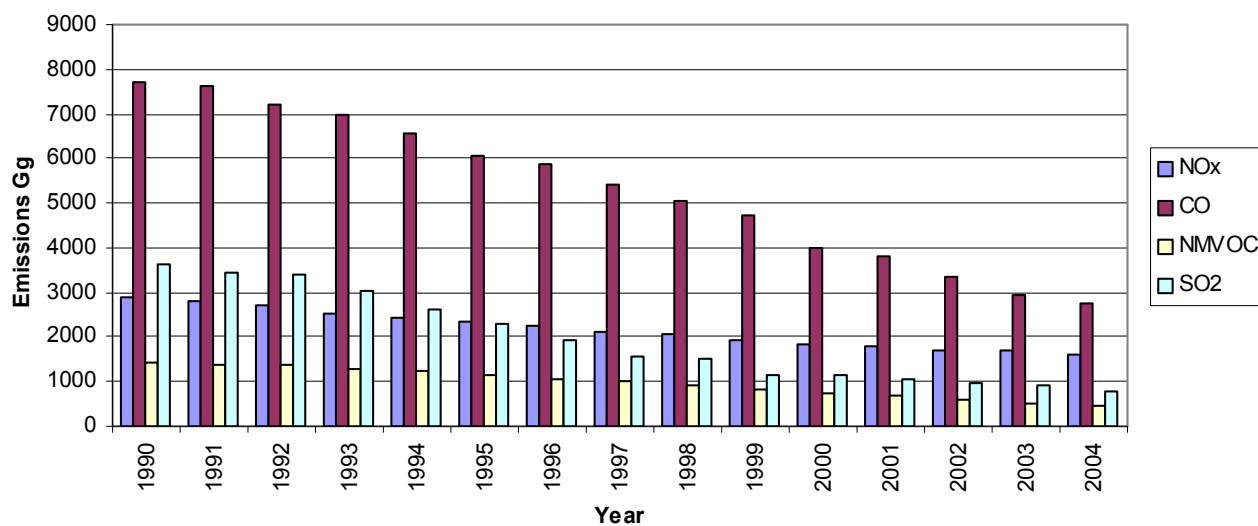
Emissions from Manufacturing, Industry and Construction were responsible for 17% (**Table A6.4**) of UK emissions of SO<sub>2</sub> in 2004. Since 1990, emissions from this sector have declined by 66% (**Table A6.1**). This decline is due to the reduction in the use of coal and oil in favour of natural gas, and also some improvement in energy efficiency.



**Figure A6.1: UK emissions of Direct Greenhouse Gases from IPCC sector 1, 1990-2004**



**Figure A6.2: UK emissions of Indirect Greenhouse Gases from IPCC sector 1, 1990-2004**



**Table A6.1**

% changes 1990-2004 within sector 1

	CO2	CH4	N2O	NOx	CO	NMVOC	SO2
1A1	-12%	10%	-32%	-48%	-36%	-27%	-80%
1A2	-11%	-11%	-14%	-29%	-10%	-3%	-66%
1A3	10%	-68%	298%	-51%	-74%	-83%	-60%
1A4	6%	-56%	-28%	-10%	-56%	-44%	-80%
1A5	-45%	-44%	-44%	-43%	-45%	-44%	-42%
1B1	-80%	-73%	-16%	-37%	-83%	-71%	-58%
1B2	-11%	-42%	-7%	-79%	-44%	-45%	-83%
<b>Overall</b>	<b>-4%</b>	<b>-61%</b>	<b>50%</b>	<b>-44%</b>	<b>-64%</b>	<b>-67%</b>	<b>-78%</b>

**Table A6.2**

% changes 2003-2004 within sector 1

	CO2	CH4	N2O	NOx	CO	NMVOC	SO2
1A1	-0.2%	4%	-2%	-3%	0.3%	6%	-23%
1A2	2%	-2%	3%	-2%	6%	-2%	15%
1A3	1%	-11%	4%	-5%	-13%	-17%	22%
1A4	0.1%	8%	-3%	-7%	3%	1%	-5%
1A5	3%	16%	11%	30%	2%	11%	47%
1B1	50%	-10%	71%	30%	-38%	-18%	21%
1B2	-3%	4%	2%	-3%	2%	-9%	10%
<b>Overall</b>	<b>1%</b>	<b>-2%</b>	<b>2%</b>	<b>-4%</b>	<b>-6%</b>	<b>-10%</b>	<b>-15%</b>

**Table A6.3**

% contribution to sector 1

	CO2	CH4	N2O	NOx	CO	NMVOC	SO2
1A1	38%	1%	14%	28%	3%	1%	71%
1A2	16%	2%	16%	16%	24%	8%	18%
1A3	23%	2%	61%	43%	52%	32%	5%
1A4	21%	6%	8%	12%	20%	14%	5%
1A5	1%	0.02%	0.4%	1%	0.3%	0.3%	1%
1B1	0.03%	40%	0.02%	0.02%	0.2%	0.02%	1%
1B2	1%	49%	0.4%	0.2%	0.4%	45%	0.2%

**Table A6.4**

% contribution to overall pollutant emissions

	CO2	CH4	N2O	NOx	CO	NMVOC	SO2
1A1	37%	0%	3%	27%	3%	1%	68%
1A2	16%	1%	3%	16%	23%	3%	17%
1A3	23%	0%	13%	43%	49%	15%	5%
1A4	21%	1%	2%	12%	19%	6%	5%
1A5	1%	0%	0%	1%	0%	0%	1%
1B1	0%	10%	0%	0%	0%	0%	1%
1B2	1%	12%	0%	0%	0%	20%	0%
<b>Overall</b>	<b>98%</b>	<b>24%</b>	<b>22%</b>	<b>99.7%</b>	<b>94%</b>	<b>46%</b>	<b>96%</b>

**A6.2 INDUSTRIAL PROCESSES SECTOR (2)**

**Figure A6.3** and **A6.4** show both emissions of direct and indirect Greenhouse Gases for the UK industrial processes sector in 1990-2004. Emissions from direct Greenhouse gases within this sector have decreased by 54% since 1990. **Tables A6.5** to **A6.8** summarise the changes observed through the time series for each pollutant as well as the contribution the emissions make to Sector 2 and total UK emissions during 2004.

**A6.2.1 Carbon Dioxide**

The industrial sector is not a major source of emissions in the UK for carbon dioxide. In 2004, just 2% (**Table A6.8**) of UK emissions originated from this sector.

**A6.2.2 Methane**

Emissions of methane from the industrial sector are very small and have a negligible effect on overall methane emissions in the UK.

**A6.2.3 Nitrous Oxide**

In 2004, 10% (**Table A6.8**) of N<sub>2</sub>O emissions in the UK came from the industrial sector. Between 1990 and 2004, emissions from this sector declined by 86% (**Table A6.5**) due to reductions in emissions from adipic acid manufacture (a feedstock for nylon) and nitric acid production. N<sub>2</sub>O emissions from nitric acid manufacture show a fall in 1995 due to the installation of an abatement system at one of the plants. Emissions from adipic acid manufacture were reduced significantly from 1998 onwards due to the retrofitting of an emissions abatement system to the only adipic acid plant in the UK.

**A6.2.4 Hydrofluorocarbons**

**Table A6.8** shows that the industrial processes sector was responsible for 100% of emissions of HFCs in the UK in 2004. Since 1990, emissions of HFCs have decreased by 22% (**Table A6.5**). The largest contribution to this sector in 2004 arises from category 2F1 – refrigeration and air conditioning equipment. In 2004, these contributed 57% (**Table A6.8**) to the overall emissions of HFCs. Emissions from this category arise due to leakage from refrigeration and air conditioning equipment during its manufacture and lifetime. Emissions from aerosols contribute the next largest percentage (29%, **Table A6.8**) to overall HFC emissions. In this category, it is assumed that all the fluid is emitted in the year of manufacture. This category contains mainly industrial aerosols and also the medical use in metered dose inhalers (MDI).

The remaining emissions arise from foam blowing (6%, **Table A6.8**), by-product emissions (3%, **Table A6.8**) and fire extinguishers (3%, **Table A6.8**).

**A6.2.5 Perfluorocarbons**

In 2004, 100% (**Table A6.8**) of PFC emissions came from the industrial processes sector. Since 1990, emissions from this sector have declined by 75% (**Table A6.5**), although a 19% increase has occurred (**Table A6.6**) since 2003. Within this sector, the main contribution to emissions comes from aluminium production (43%, **Table A6.8**). During the process of

aluminium smelting, PFC is formed as a by-product. 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 then reacts with the carbon anode to create CF<sub>4</sub> and C<sub>2</sub>F<sub>6</sub>. Since 1990, emissions arising from aluminium production have shown an 89% decrease (**Table A6.5**) due to significant improvements in process control and an increase in the rate of aluminium recycling.

The next largest emissions occur from fugitives. In 2004, this contributed 30% (**Table A6.8**) to overall PFC totals in the UK. The remaining contribution arises from 2F8, which includes a range of sources including the semiconductor and electronics industries. In 2004, this sector contributed 27% (**Table A6.8**) to overall PFC emissions in the UK.

### **A6.2.6 Sulphur Hexafluoride**

In 2004, the industrial sectors category contributed 100% (**Table A6.8**) towards the emissions of SF<sub>6</sub> in the UK. Emissions arise from two main sectors. The use of SF<sub>6</sub> in aluminium and magnesium foundries contributed 34% (**Table A6.8**) towards total emissions in 2004. Emissions from 2F6 – Other contributed 66% (**Table A6.8**) towards emissions, which includes emissions from electrical insulation. Emissions arise during the manufacture and filling of circuit breakers and from leakage and maintenance during the equipment lifetime. It also includes emissions from applications in the electronics industry and sports shoes. Since 1990, emissions from SF<sub>6</sub> have increased by 9% (**Table A6.5**).

### **A6.2.7 Nitrogen Oxides**

Although emissions of NO<sub>x</sub> from this sector do occur, overall they have little impact on emissions of NO<sub>x</sub> in the UK (see **Table A6.8**).

### **A6.2.8 Carbon Monoxide**

During 2004, emissions from the industrial sector contributed 5% (**Table A6.8**) to overall CO emissions in the UK. Contributions within this sector arise mainly from the chemical industry, iron and steel production, and aluminium production. For details see **Table A6.7**. Since 1990, emissions from this sector have decreased by 51% (**Table A6.5**).

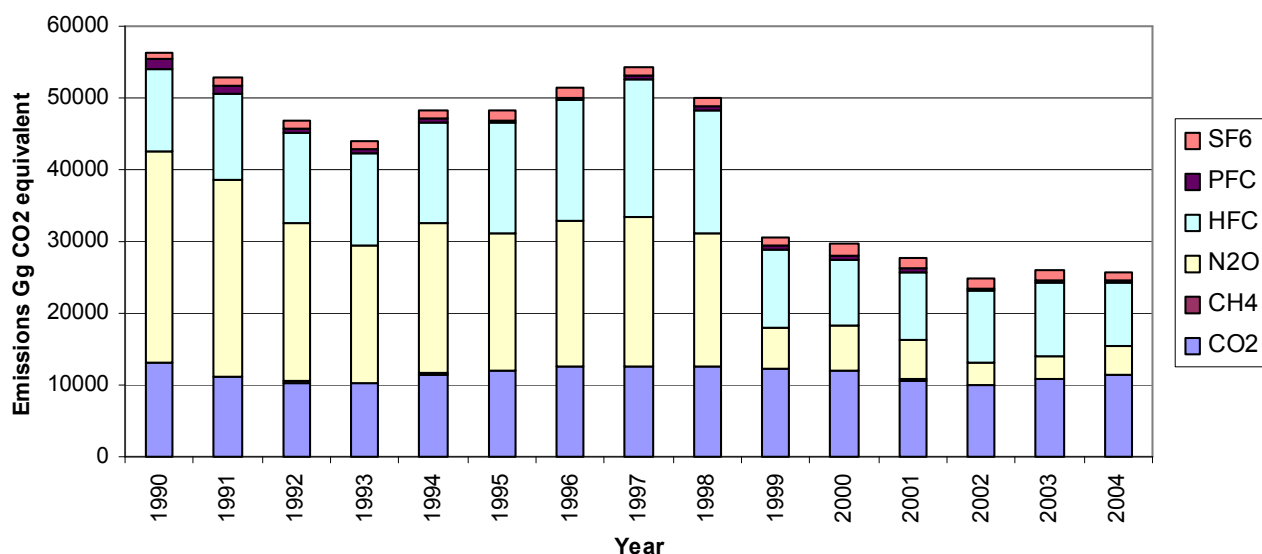
### **A6.2.9 Non Methane Volatile Organic Compounds**

In 2004, emissions from the industrial sector contributed 14% (**Table A6.8**) to overall UK emissions of NMVOCs. The majority of emissions within this category come from the pulp and paper sector. Emissions also arise from the chemical industry.

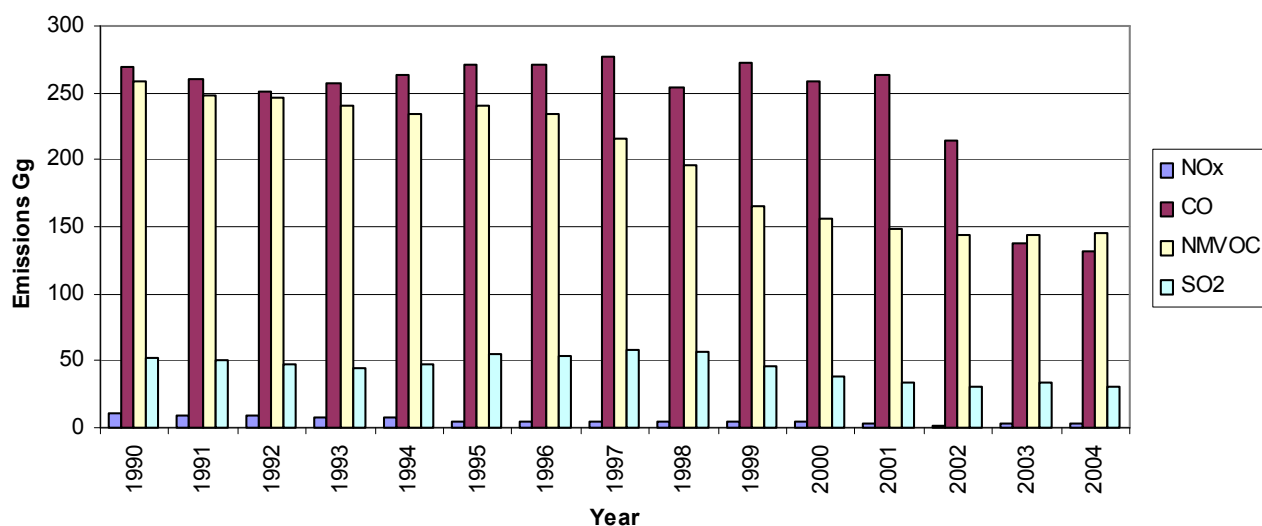
### **A6.2.10 Sulphur Dioxide**

In 2004, SO<sub>2</sub> emissions from the industrial sector contributed just 4% (**Table A6.8**) to overall emissions in the UK. Emissions arise from a variety of sources including the chemical industry, metal production and mineral products (Fletton brick production). Since 1990, SO<sub>2</sub> emissions from this sector have declined by over 40% (**Table A6.5**), showing a 6% reduction on 2003 emissions.

**Figure A6.3: UK emissions of Direct Greenhouse Gases from IPCC sector 2, 1990-2004**



**Figure A6.4: UK emissions of Indirect Greenhouse Gases from IPCC sector 2, 1990-2004**



# Quantitative Discussion of 2004 Inventory **A6**

**Table A6.5**

% changes 1990-2004 within sector 2

	CO2	CH4	N2O	HFC	PFC	SF6	NOx	CO	NMVOC	SO2
2A1	-18%									
2A2	-32%									
2A3	7%									
2A4	7%									
2A5										
2A6									-20%	
2A7	-23%	-43%						-48%	-46%	284%
2B1	1%									
2B2			-29%				-91%			
2B3			-96%							
2B4										
2B5		-76%					-7%	-65%	-68%	-81%
2C1	-17%	-15%	-25%				-25%	-38%	-21%	-67%
2C2										
2C3	23%				-89%		-58%	30%		33%
2C4						-9%				
2C5								-99%		-46%
2D1									-94%	
2D2									10%	
2E1				-98%						
2E2					875%					
2E3										
2F1					-100%					
2F2										
2F3										
2F4				155394%						
2F5										
2F8					62%	22%				
2G										
<b>Overall</b>	<b>-13%</b>	<b>-66%</b>	<b>-86%</b>	<b>-22%</b>	<b>-75%</b>	<b>9%</b>	<b>-76%</b>	<b>-51%</b>	<b>-44%</b>	<b>-40.2%</b>

**Table A6.6**

% changes 2003-2004 within sector 2

	CO2	CH4	N2O	HFC	PFC	SF6	NOx	CO	NMVOC	SO2
2A1	2%									
2A2	-10%									
2A3	5%									
2A4	18%									
2A5										
2A6									2%	
2A7	-3%	-2%						-2%	12%	1%
2B1	14%									
2B2			12%				1%			
2B3			90%							
2B4										
2B5		-4%					-20%	-22%	3%	-22%
2C1	16%	12%	17%				15%	3%	3%	-25%
2C2										
2C3	5%				21%		2%	1%		14%
2C4						-42%				
2C5								-56%		-34%
2D1									2%	
2D2									0.4%	
2E1				-85%						
2E2					61%					
2E3										
2F1				2%						
2F2				25%						
2F3				-4%						
2F4				1%						
2F5				58%						
2F8				3%	-11%	14%				
2G										
<b>Overall</b>	<b>5%</b>	<b>-0.2%</b>	<b>26%</b>	<b>-13%</b>	<b>19%</b>	<b>-15%</b>	<b>3%</b>	<b>-5%</b>	<b>2%</b>	<b>-6%</b>

**Table A6.7**

% contribution to sector 2

	CO2	CH4	N2O	HFC	PFC	SF6	NOx	CO	NMVOC	SO2
2A1	48%									
2A2	7%									
2A3	12%									
2A4	2%									
2A5										
2A6									5%	
2A7	1%	21%						2%	1%	53%
2B1	12%									
2B2			72%				28%			
2B3			27%							
2B4										
2B5		55%					14%	22%	37%	24%
2C1	14%	23%	0.2%				45%	54%	1%	3%
2C2										
2C3	5%				43%		14%	22%		17%
2C4				0.01%		34%				
2C5								0.4%		3%
2D1									0.2%	
2D2									55%	
2E1				3%						
2E2					30%					
2E3										
2F1				57%		0.02%				
2F2				6%						
2F3				3%						
2F4				29%						
2F5				0%						
2F8				1%	27%	66%				
2G										



**Table A6.8**

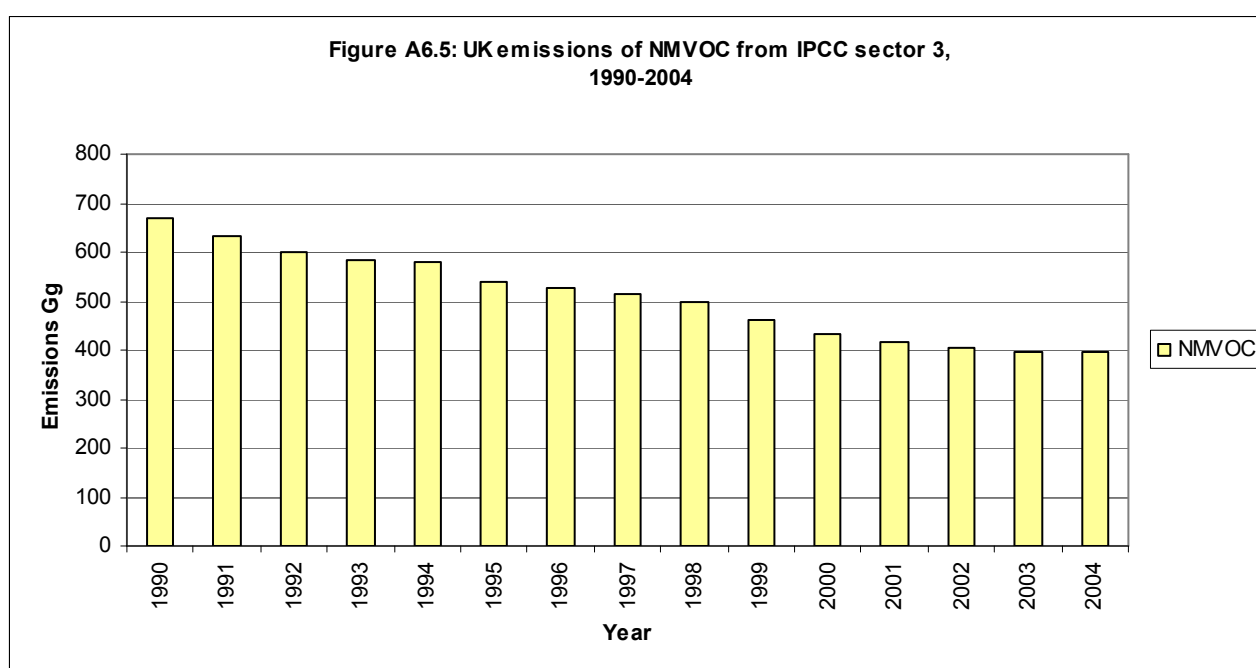
% contribution to overall pollutant emissions

	CO2	CH4	N2O	HFC	PFC	SF6	NOx	CO	NMVOC	SO2
2A1	1%									
2A2	0.1%									
2A3	0.2%									
2A4	0.03%									
2A5										
2A6									1%	
2A7	0.02%	0.02%						0.1%	0.2%	2%
2B1	0.2%									
2B2			7%				0.05%			
2B3			3%							
2B4										
2B5		0.06%					0.02%	1%	5%	1%
2C1	0.3%	0.03%	0.02%				0.07%	2%	0.2%	0.1%
2C2										
2C3	0.1%				43%		0.02%	1%		1%
2C4				0.01%		34%				
2C5								0.02%		0.1%
2D1									0.02%	
2D2									8%	
2E1				3%						
2E2					30%					
2E3										
2F1				57%		0.02%				
2F2				6%						
2F3				3%						
2F4				29%						
2F5				0%						
2F8				1%	27%	66%				
2G										
<b>Overall</b>	<b>2%</b>	<b>0.11%</b>	<b>10%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>0.16%</b>	<b>5%</b>	<b>14%</b>	<b>4%</b>

**A6.3 SOLVENTS AND OTHER PRODUCT USE SECTOR (3)**

Only emissions of NMVOCs occur from the solvents category. **Figure A6.5** displays total NMVOC emissions for 1990-2004. **Tables A6.9-6.12** summarise the changes observed through the time series as well as the contribution the emissions make to both sector 3 and the overall emissions in the UK during 2004. Emissions from this sector contribute 39% to overall emissions of NMVOC in the UK (**Table A6.12**), and since 1990 emissions have declined by 41% (**Table A6.9**).

The largest source of emissions within the solvents sector is category 3D (solvent and other product use: other), contributing 57% of NMVOC emissions in this sector (**Table A6.11**).



**Table A6.9**

**% changes 1990-2004 within sector 3**

	NMVOC
3A	-42%
3B	-63%
3C	-68%
3D	-30%
<b>Overall</b>	<b>-41%</b>

**Table A6.10**

**% changes 2003-2004 within sector 3**

	NMVOC
3A	0.1%
3B	-5%
3C	-0.4%
3D	1%
<b>Overall</b>	<b>0.1%</b>

**Table A6.11**

**% contribution to sector 3**

	NMVOC
3A	31%
3B	8%
3C	4%
3D	57%

**Table A6.12**

**% contribution to overall pollutant emissions**

	NMVOC
3A	12%
3B	3%
3C	1%
3D	22%
<b>Overall</b>	<b>39%</b>

**A6.4 AGRICULTURE SECTOR (4)**

**Figures A6.6** and **A6.7** show both emissions of direct and indirect greenhouse gases for the agricultural sector (category 4) in the UK for the years 1990-2004. Emissions of direct greenhouse gases from this sector have decreased by 15% since 1990.

**Tables A6.13-A6.16** summarise the changes observed through the time series for each pollutant emitted from the agricultural sector, as well as the contribution emissions make to both the sector and the overall UK estimates during 2004.

**A6.4.1 Methane**

Agriculture is the second largest source of methane in the UK, and in 2004 emissions from this sector totalled 36% (**Table A6.16**) of the UK total. Since 1990, methane emissions from agriculture have declined by 13% (**Table A6.13**). The largest single source within the agricultural sector is 4A1 – enteric fermentation from cattle. This accounts for 65% of methane emissions from this sector (**Table A6.15**), and 24% of total methane emissions in 2004 (**Table A6.16**). Since 1990, emissions from cattle have declined by 10% (**Table A6.13**) and this is due to a decline in cattle numbers over this period.

**A6.4.2 Nitrous Oxide**

In 2004, nitrous oxide emissions from agriculture contributed 65% (**Table A6.16**) to the UK total emission. Of this, 95% (**Table A6.16**) came from the agricultural soils sector, 4D. Since 1990, emissions of N<sub>2</sub>O from the agricultural sector have declined by 17% (**Table A6.13**), driven by a fall in synthetic fertiliser application and a decline in animal population over this period.

**A6.4.3 Nitrogen Oxides**

Emissions from the agricultural sector occur for NO<sub>x</sub> until 1993 only. During 1993, agricultural stubble burning was stopped and therefore emissions of NO<sub>x</sub> became zero after this time.

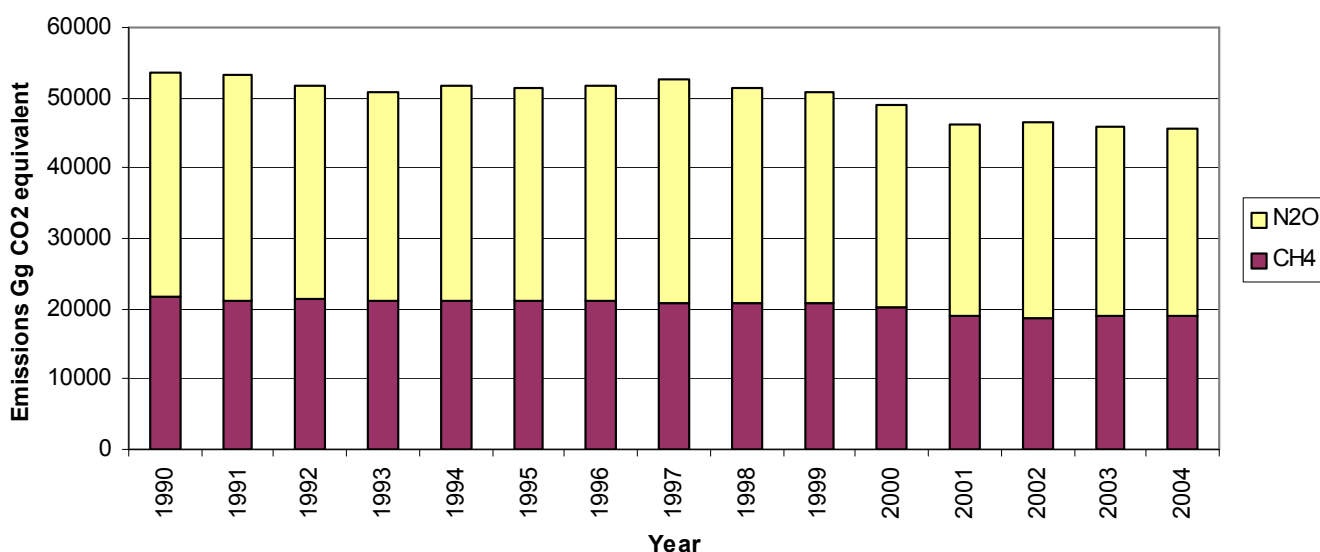
**A6.4.4 Carbon Monoxide**

Emissions from the agricultural sector occur for CO until 1993 only. During 1993, agricultural stubble burning was stopped and therefore emissions of CO became zero after this time.

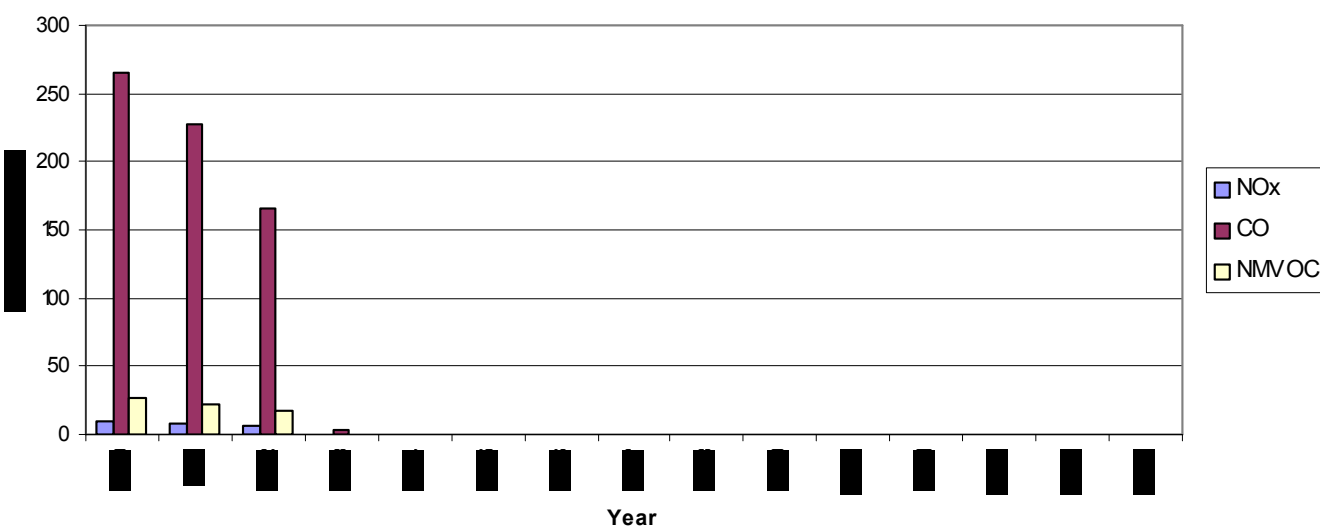
**A6.4.5 Non-Methane Volatile Organic Compounds**

Emissions from the agricultural sector occur for NMVOC until 1993 only. During 1993, agricultural stubble burning was stopped and therefore emissions of NMVOC became zero after this time.

**Figure A6.6: UK emissions of Direct Greenhouse Gases from IPCC sector 4, 1990-2004**



**Figure A6.7: UK emissions of Indirect Greenhouse Gases from IPCC sector 4, 1990-2004**



**Table A6.13**

**% changes 1990-2004 within sector 4**

	CH4	N2O	NOx	CO	NMVOC
4A1	-10%				
4A2					
4A3	-17%				
4A4	-19%				
4A5					
4A6	63%				
4A7					
4A8	-32%				
4A9					
4A10	-22%				
4B1	-12%				
4B2					
4B3	-17%				
4B4	-19%				
4B5					
4B6	63%				
4B7					
4B8	-32%				
4B9	25%				
4B10					
4B11		-19%			
4B12		-15%			
4B13		-29%			
4B14					
4C					
4D		-17%			
4E					
4F1	-100%	-100%	-100%	-100%	-100%
4F2					
4F3					
4F4					
4F5	-100%	-100%	-100%	-100%	-100%
4G					
<b>Overall</b>	<b>-13%</b>	<b>-17%</b>	<b>-100%</b>	<b>-100%</b>	<b>-100%</b>

**Table A6.14**

**% changes 2003-2004 within sector 4**

	CH4	N2O	NOx	CO	NMVOC
4A1	0.2%				
4A2					
4A3	0.3%				
4A4	3%				
4A5					
4A6	10%				
4A7					
4A8	2%				
4A9					
4A10	0%				
4B1	-1%				
4B2					
4B3	0.3%				
4B4	3%				
4B5					
4B6	10%				
4B7					
4B8	2%				
4B9	-3%				
4B10					
4B11		-1%			
4B12		1%			
4B13		-26%			
4B14					
4C					
4D		-1%			
4E					
4F1					
4F2					
4F3					
4F4					
4F5					
4G					
<b>Overall</b>	<b>0.2%</b>	<b>-1%</b>			

Table A6.15

% contribution to sector 4

	CH4	N2O	NOx	CO	NMVOC
4A1	65%				
4A2					
4A3	19%				
4A4	0.1%				
4A5					
4A6	1%				
4A7					
4A8	1%				
4A9					
4A10	1%				
4B1	10%				
4B2					
4B3	0.5%				
4B4	0%				
4B5					
4B6	0.1%				
4B7					
4B8	2%				
4B9	1%				
4B10					
4B11		0.2%			
4B12		4%			
4B13		1%			
4B14					
4C					
4D		95%			
4E					
4F1					
4F2					
4F3					
4F4					
4F5					



**Table A6.16**

	CH4	N2O	NOx	CO	NMVOC
4A1	24%				
4A2					
4A3	7%				
4A4	0.02%				
4A5					
4A6	0.2%				
4A7					
4A8	0.3%				
4A9					
4A10	0.4%				
4B1	4%				
4B2					
4B3	0.2%				
4B4	0%				
4B5					
4B6	0.02%				
4B7					
4B8	1%				
4B9	1%				
4B10					
4B11		0.1%			
4B12		3%			
4B13		0.4%			
4B14					
4D		62%			
4E					
4F1					
4F2					
4F3					
4F4					
4F5					
<b>Overall</b>	<b>36%</b>	<b>65%</b>	<b>0%</b>	<b>0%</b>	<b>0%</b>

**A6.5 LAND USE CHANGE AND FORESTRY (5)**

**Figures A6.8** and **A6.9** show both net emissions of direct Greenhouse gases, and emissions of indirect Greenhouse gases for the Land-use change and forestry sector (sector 5) in the UK for the years 1990-2004.

**Tables A6.17** to **A6.18** summarise the changes observed through the time series for each pollutant.

**A6.5.1 Carbon Dioxide**

**Figure 6.8** shows net emissions/removals of carbon dioxide. Since 1990, there has been a change in net emissions of carbon dioxide of -167%. In 2004, the total removals from this sector are greater than the emissions, so that the net value is negative. Most emissions from land-use change and forestry arise from the emissions of CO<sub>2</sub> from cropland (5B), whilst the majority of CO<sub>2</sub> removals occur in sector 5A (forestry).

**A6.5.2 Methane**

Emissions of methane from Land Use Change and Forestry are emitted from the grassland and settlements categories (5C and 5E). Emissions from this sector have declined by 9% since 2003 (**Table A6.18**), but have increased overall by 21% since 1990 (**Table A6.17**).

**A6.5.3 Nitrous Oxide**

Emissions of nitrous oxide from Land Use Change and Forestry are emitted from the grassland and settlements categories (5C and 5E). Emissions of nitrous oxide from this sector have increased by 21% since 1990 (**Table A6.17**), and shown a decline of 9% since 2003 (**Table A6.18**).

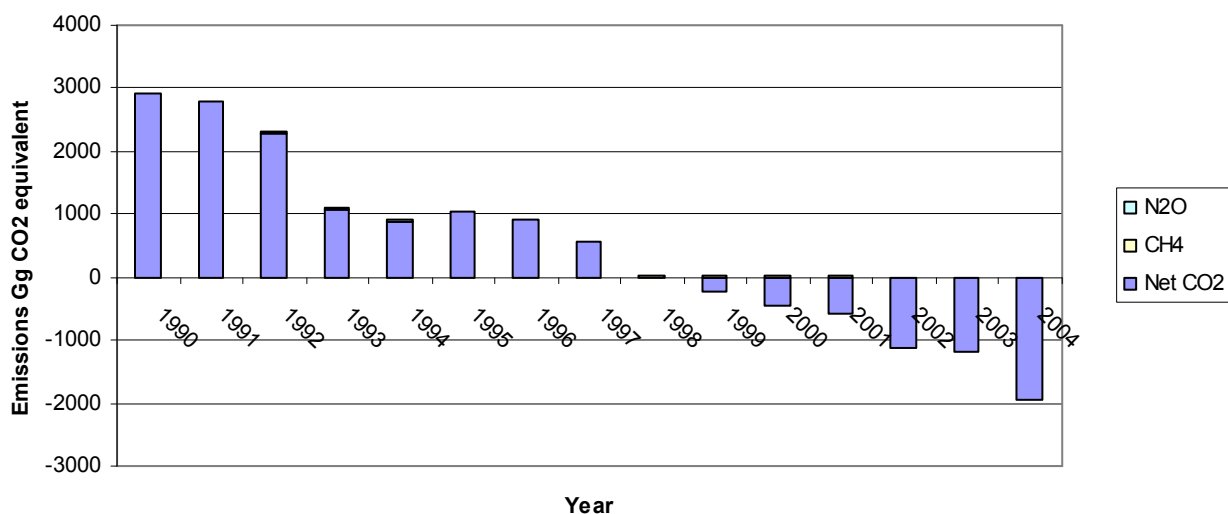
**A6.5.4 Nitrogen Oxides**

Emissions of nitrogen oxides from Land Use Change and Forestry are emitted from the grassland and settlements categories (5C and 5E). Emissions from this sector have declined by 9% since 2003 (**Table A6.18**), but have increased overall by 21% since 1990 (**Table A6.17**).

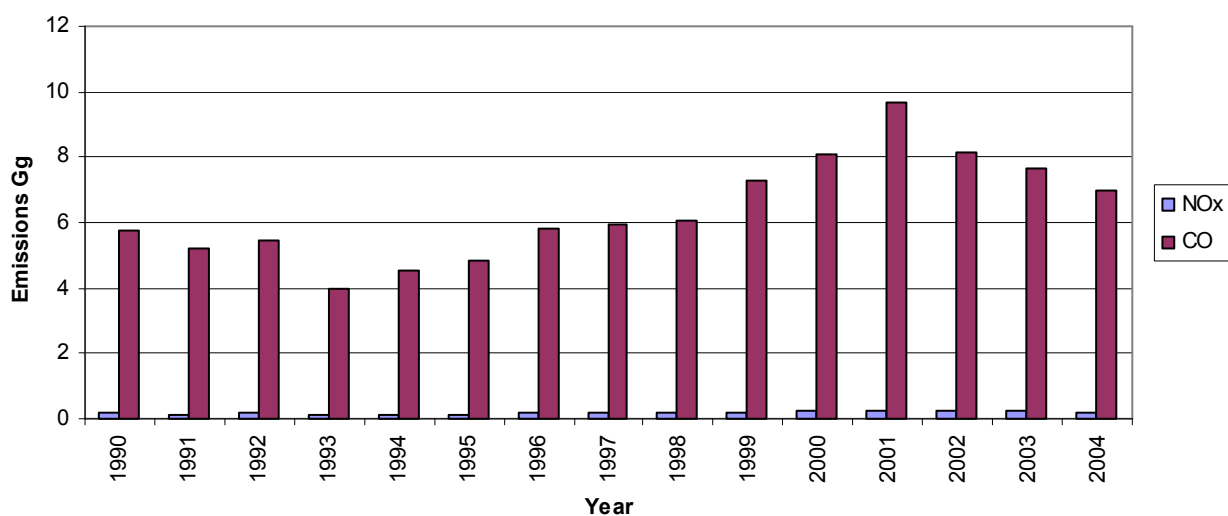
**A6.5.5 Carbon Monoxide**

Emissions of carbon monoxide from Land Use Change and Forestry are emitted from the grassland and settlements categories (5C and 5E). Emissions of nitrous oxide from this sector have increased by 21% since 1990 (**Table A6.17**), and shown a decline of 9% since 2003 (**Table A6.18**).

**Figure A6.8: UK net emissions/removals of Direct Greenhouse Gases from IPCC sector 5, 1990-2004**



**Figure A6.9: UK emissions of Indirect Greenhouse Gases from IPCC sector 5, 1990-2004**



**Table A6.17**

**% changes 1990-2004 within sector 5**

	CO2	CH4	N2O	NOx	CO
5A	34%				
5B	-3%				
5C	27%	286%	286%	286%	286%
5D					
5E	-10%	-55%	-55%	-55%	-55%
5F					
5G	-143%				
<b>Overall</b>	<b>-167%</b>	<b>21%</b>	<b>21%</b>	<b>21%</b>	<b>21%</b>

**Table A6.18**

**% changes 2003-2004 within sector 5**

	CO2	CH4	N2O	NOx	CO
5A	4%				
5B	0%				
5C	4%	-11%	-11%	-11%	-11%
5D					
5E	0%	-4%	-4%	-4%	-4%
5F					
5G	83%				
<b>Overall</b>	<b>65%</b>	<b>-9%</b>	<b>-9%</b>	<b>-9%</b>	<b>-9%</b>

**A6.6 WASTE (6)**

**Figures A6.10** and **A6.11** show emissions of both direct and indirect greenhouse gases from the waste category (sector 6) in the UK for the years 1990-2004. Emissions from direct greenhouse gases in this sector have declined by 58% since 1990. This is mostly as a result of a decline in methane emissions, although emissions of nitrous oxide have shown an increase.

**Tables A6.19** to **A6.22** summarise the changes observed through the time series for each pollutant, as well as the contribution the emissions make to both sector 6 and the overall emissions in the UK during 2004.

**A6.6.1 Carbon Dioxide**

Emissions of carbon dioxide from the waste sector occur from waste incineration only. These emissions are small in comparison to CO<sub>2</sub> emissions from other sectors and have a negligible effect on overall net CO<sub>2</sub> emissions in the UK (see **Table A6.22**). Since 1990, CO<sub>2</sub> emissions arising from the waste sector have decreased by 63% (**Table A6.19**), but have shown only a small decrease since 2003 (2%, **Table A6.20**).

**A6.6.2 Methane**

Emissions of methane from the waste sector accounted for around 40% (**Table A6.22**) of total CH<sub>4</sub> emissions in the UK during 2004. Emissions from methane occur from landfills, waste water treatment and waste incineration. The largest single source is landfill (6A1), with emissions from wastewater treatment and incineration being small in comparison (see **Table A6.21**). Emissions estimates from landfill are derived from the amount of putrescible waste disposed of to landfill and are based on a model of the kinetics of anaerobic digestion involving four classifications of landfill site. The model accounts for the effects of methane recovery, utilisation and flaring. Since 1990, methane emissions from landfill have declined by 60% (**Table 6.19**) due to the implementation of methane recovery systems. This trend is likely to continue as all new landfill sites are required to have these systems and many existing sites may have systems retrofitted.

**A6.6.3 Nitrous Oxide**

Nearly all nitrous oxide waste emissions in the UK occur from the wastewater handling sector (see **Table A6.21**). Since 1990, N<sub>2</sub>O emissions from this sector have increased by 16% (**Table A6.19**). Overall, this sector contributes just 3% (**Table A6.22**) to overall nitrous oxide emissions.

**A6.6.4 Nitrogen Oxides**

Emissions of NO<sub>x</sub> from the waste category have a negligible effect on overall UK emissions.

**A6.6.5 Carbon Monoxide**

Emissions of CO from the waste category have a negligible effect on overall UK emissions, contributing less than 1% during 2004 (**Table A6.22**).

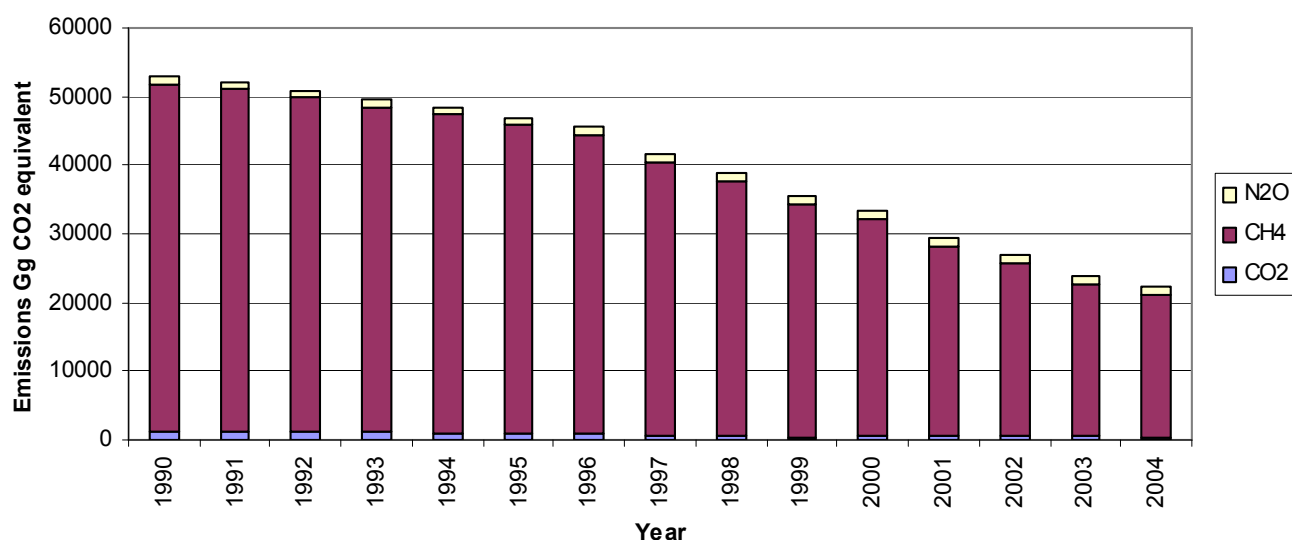
### **A6.6.6 Non-Methane Volatile Organic Compounds**

Emissions of NMVOC from the waste category have a very small influence (1%, **Table A6.22**) on overall UK emissions.

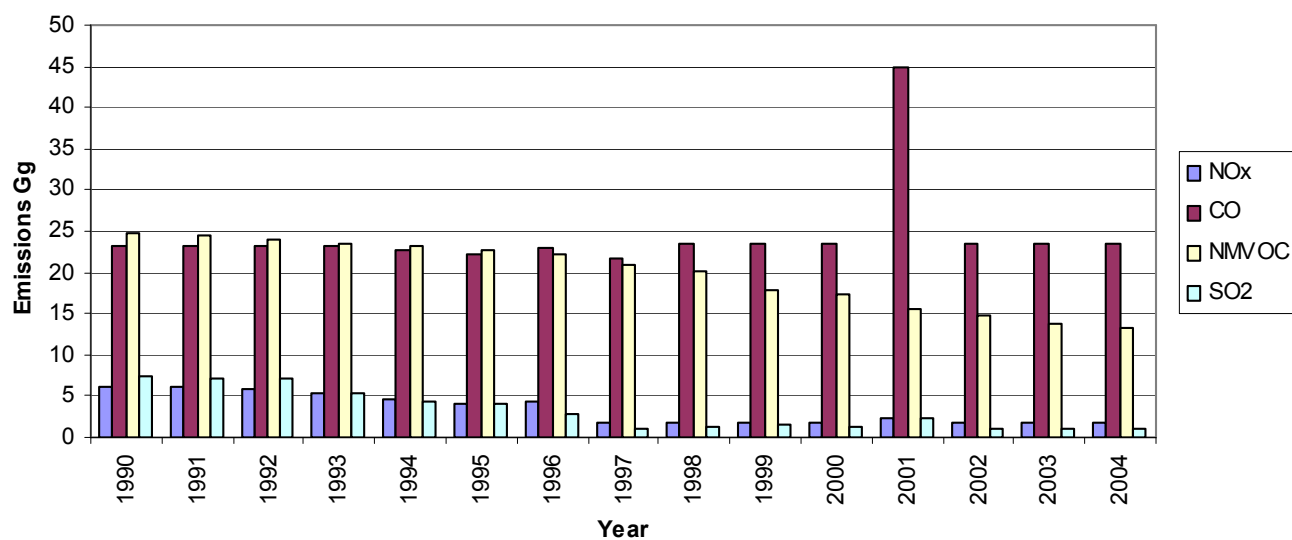
### **A6.6.7 Sulphur Dioxide**

Emissions of SO<sub>2</sub> from the waste category have a negligible effect on overall UK emissions.

**Figure A6.10: UK emissions of Direct Greenhouse Gases from IPCC sector 6, 1990-2004**



**Figure A6.11: UK Emissions of Indirect Greenhouse Gases from IPCC sector 6, 1990-2004**



**Table A6.19**

% changes 1990-2004 within sector 6

	CO2	CH4	N2O	NOx	CO	NMVOC	SO2
6A1		-60%				-63%	
6B2		13%	17%				
6C	-63%	-98%	1%	-71%	1%	2%	-88%
<b>Overall</b>	<b>-63%</b>	<b>-59%</b>	<b>16%</b>	<b>-71%</b>	<b>1%</b>	<b>-46%</b>	<b>-88%</b>

**Table A6.20**

% changes 2003-2004 within sector 6

	CO2	CH4	N2O	NOx	CO	NMVOC	SO2
6A1		-7%				-7%	
6B2		-0.3%	-1%				
6C	-2%	0%	0%	-1%	-0.02%	2%	-3%
<b>Overall</b>	<b>-2%</b>	<b>-7%</b>	<b>-1%</b>	<b>-1%</b>	<b>-0.02%</b>	<b>-3%</b>	<b>-3%</b>

**Table A6.21**

% contribution to sector 6

	CO2	CH4	N2O	NOx	CO	NMVOC	SO2
6A1		96%				50%	
6B2		4%	96%				
6C	100%	0.02%	4%	100%	100%	50%	100%

**Table A6.22**

% contribution to overall pollutant emissions

	CO2	CH4	N2O	NOx	CO	NMVOC	SO2
6A1		38%				0.7%	
6B2		2%	3%				
6C	0.1%	0.01%	0.1%	0.1%	1%	0.7%	0.1%
<b>Overall</b>	<b>0.1%</b>	<b>39.79%</b>	<b>3.1%</b>	<b>0.1%</b>	<b>0.8%</b>	<b>1.3%</b>	<b>0.1%</b>



## A7. ANNEX 7: Uncertainties

Uncertainty estimates are provided using both the Tier 1 and Tier 2 methods described by the IPCC and this submission introduces a number of improvements, including presenting estimates of uncertainties according to IPCC sector in addition to presenting estimates by direct greenhouse gas.

A range of refinements are introduced in this submission, including revisions of selected uncertainties allocated to the activity data and emission factors.

### A7.1 ESTIMATION OF UNCERTAINTY BY SIMULATION

Quantitative estimates of the uncertainties in the emissions were calculated using Monte Carlo simulation. This corresponds to the IPCC Tier 2 approach discussed in the Good Practice Guidance (IPCC, 2000). This work is described in detail by Eggleston *et al* (1998) with the estimates reported here revised to reflect changes in the 2004 inventory. This section gives a brief summary of the methodology, assumptions and results of the simulation.

The computational procedure was:

- A probability distribution function (PDF) was allocated to each emission factor and piece of activity data. The PDFs were mostly normal, log-normal or uniform. The parameters of the PDFs were set by analysing the available data on emission factors and activity data or by expert judgement.
- A calculation was set up to estimate the emission of each gas, carbon dioxide sink, and the global warming potential for the years 1990 and 2004. This analysis includes both 1990 and the 'base year' emissions. In this section, the 'base year' comprises the emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O for 1990, and the emissions of HFC, PFC and SF<sub>6</sub> for 1995. These 'base year' emissions **are not** those calculated as part of the assessment towards the Kyoto target.
- Using the software tool @RISK™, each PDF was sampled 20,000 times and the emission calculations performed to produce a converged output distribution.
- It was assumed that the distribution of errors in the parameter values was normal. The quoted range of possible error of uncertainty is taken as 2s, where s is the standard deviation. If the expected value of a parameter is E and the standard deviation is s, then the uncertainty is quoted as 2s/E expressed as a percentage. For a normal distribution the probability of the parameter being less than E-2s is 0.025 and the probability of the emission being less than E+2s is 0.975.
- For methane and nitrous oxide, it was assumed that there was no correlation between emission factors for the same fuels applied to different sources. For CO<sub>2</sub> emission factors for LPG, orimulsion and MSW and were correlated with those for the same fuel used in different sources.

- The uncertainties used for the fuel activity data were estimated from the statistical difference between supply and demand for each fuel. This means that the quoted uncertainty in **Table A7.1** refers to the total fuel consumption rather than the consumption by a particular sector, e.g. residential coal. Hence, to avoid underestimating uncertainties, it was necessary to correlate the uncertainties used for the same fuel in different sectors. A further refinement was to correlate the data used for the same fuels to calculate emissions of carbon dioxide, methane and nitrous oxide. These modifications to the methodology were introduced in the 2000 inventory. The approach to estimating uncertainties between supply and demand were refined in the 2004 inventory and details of the approach used are given in **Section A7.2 Estimation Of Uncertainties Using A Tier 1 Approach**.
- The uncertainty in the trend between 1990 and 2004 according to gas was also estimated. This will be influenced by the degree of correlation of activity data and emission factors between 1990 and 2004. Generally it was assumed that activity data from different years were not correlated, but certain emission factors were. These correlations are discussed in subsequent sections.
- The uncertainties for total halocarbon and SF<sub>6</sub> emissions were taken from the recent study on emissions and projections of HFCs, PFCs and SF<sub>6</sub> for the UK and constituent countries (AEAT, 2004).

## **A7.1.1 Carbon Dioxide Emission Uncertainties**

It was necessary to estimate the uncertainties in the activity data and the emission factors for the main sources and then combine them.

The uncertainties in the fuel activity data for major fuels were estimated from the statistical differences data in the UK energy statistics. This is explained further in section A7.2. These are effectively the residuals when a mass balance is performed on the production, imports, exports and consumption of fuels. For solid and liquid fuels both positive and negative results are obtained indicating that these are uncertainties rather than losses. For gaseous fuels these figures include losses and tended to be negative. For natural gas, a correction was made to take account of leakage from the gas transmission system but for other gases this was not possible. The uncertainties in activity data for minor fuels (colliery methane, orimulsion, SSF, petroleum coke) and non-fuels (limestone, dolomite and clinker) were estimated based on judgement comparing their relative uncertainty with that of the known fuels. The high uncertainty in the aviation fuel consumption reflects the uncertainty in the split between domestic and international aviation fuel consumption. This uncertainty was reviewed in 2005. Additional error for this source is also introduced by the use of a model (see A7.2).

The uncertainties in the emission factors were based largely on expert judgement. It was possible to compare the coal emission factors used in the inventory with measurements (Fynes, 1994). Also, Transco (1998) data allowed an estimate of the uncertainty in the carbon content of natural gas. The time series data of the gross calorific value of fuels used in the UK (DTI, 2005) would also give *some indication* of the relative variability in the carbon contents. Thus the uncertainties in the fuel emission factors were based on judgements on whether they were likely to be similar or less than those of coal or natural gas.

In the case of non-fuel sources, the uncertainty depended on the purity of limestone or the lime content of clinker so the uncertainties estimated were speculative.

The uncertainties in certain sources were estimated directly. Offshore flaring uncertainties were estimated by comparing the UKOOA (2005) flaring time series data with the flaring volumes reported by DTI (2001). The uncertainty in the activity data was found to be around 16%. This uncertainty will be an over estimate since it was assumed that the flaring volume data reported by DTI should be in a fixed proportion to the mass data reported by UKOOA. The uncertainty in the carbon emission factor was estimated by the variation in the time series to be around 6%. Again this will be an over estimate since it was assumed that the carbon emission factor is constant. Uncertainties for fuel gas combustion were estimated in a similar way. Uncertainties in the land use change sources were recalculated (Milne, 1999) for the revised source categories in the IPCC 1996 Guidelines using data from Eggleston *et al* (1998). A new carbon source – Fletton bricks – has been added, and the uncertainty based on expert assessment of the data used to make the estimate. There has been a very slight revision to the uncertainty used for cement production, based on the estimates reported in IPCC (2000). Clinical waste incineration was assumed to have the same uncertainty as MSW incineration.

The overall uncertainty was estimated as around 2% in both 1990 and 2004.

The uncertainty in the trend between 1990 and 2004 was also estimated. In running this simulation it was necessary to make assumptions about the degree of correlation between sources in 1990 and 2004. If source emission factors are correlated this will have the effect of reducing the trend uncertainty. The assumptions were:

- Activity data are uncorrelated
- Emission factors of similar fuels are correlated (i.e. gas oil with gas oil, coke with coke etc)
- Land Use Change and forestry emissions are correlated (i.e. 5A with 5A etc)
- Offshore emissions are not correlated since they are based on separate studies using emission factors appropriate for the time.
- Emission factors covered by the Carbon Factors Review (Baggott et al, 2004) are not correlated
- Process emissions from blast furnaces, coke ovens and ammonia plant were not correlated.

The trend was found to range between –3% and –8% - that is to say this analysis indicated 95% probability that CO<sub>2</sub> emissions in 2004 were between 3% and 8% below the level in 1990.

**Table A7.1a** Estimated Uncertainties in Carbon Dioxide Emissions for 1990 (only major sources are listed)

Fuel/IPCC Sector	Activity Uncertainty %	Emission Factor Uncertainty %	Uncertainty in Emission %
Coal	1.5	1	±
Coke	3	3	±
Petroleum coke	7.8	3	±
SSF	3.3	3	±
Burning oil	6	2	±
Fuel oil	5.5	1.7	±
Gas oil	1.8	1.4	±
DERV	1.8	2.1	±
Petrol	1	4.8	±
Orimulsion	1	2	±
Aviation turbine fuel	20	3.3	±
Natural gas	2.8	1.5	±
Colliery methane	5	5	±
LPG	25.7	3	±
OPG	1.4	3	±
MSW	7	20	±
Sour gas	2.8	1	±
Naphtha	7.3	3	±
Refinery miscellaneous	11.9	3	±
Blast furnace gas	1.5	6	±
Coke oven gas	1.5	6	±
Town gas	0	0	±
Lubricants	20	5	±
Waste oils	20	5	±
Scrap tyres	15	10	±
Aviation spirit	20	3.3	±
Anthracite	1.5	6	±
Burning oil (premium)	6	2	±
Vaporising oil	0	0	±
Limestone	1	5	±
Dolomite	1	5	±
Clinical waste	7	20	±
Chemical waste	7	15	±
Waste solvent	1	10	±
1A1c	7	4	±
1A5b	10	2	±
1B2a	1	28	±
1B2c	1	14	±

Fuel/IPCC Sector	Activity Uncertainty %	Emission Factor Uncertainty %	Uncertainty in Emission %
1B2c Flaring	16	6	‡
1B2c Venting	16	6	‡
2A1	1	2.2	‡
2A2	1	5	‡
2A3	1	5	‡
2A4	15	2	‡
2A7	20	70	‡
2B1	10	1	‡
2C1	1	20	‡
2C3	1	5	‡
5A Forest Land	1	25	‡
5B Cropland	1	50	‡
5C Grassland	1	70	‡
5E Settlements	1	50	‡
5G Other Activities	1	30	‡
7	50	20	‡

‡ Input parameters were uncertainties of activity data and emission factors.

**Table A7.1b** Estimated Uncertainties in Carbon Dioxide Emissions for 2004 (only major sources are listed)

Fuel/IPCC Sector	Activity Uncertainty %	Emission Factor Uncertainty %	Uncertainty in Emission %
Coal	0.4	1	‡
Coke	1.3	3	‡
Petroleum coke	4.2	3	‡
SSF	8.1	3	‡
Burning oil	9.3	2	‡
Fuel oil	19.7	1.7	‡
Gas oil	1.7	1.4	‡
DERV	1.7	2.1	‡
Petrol	2.8	4.8	‡
Orimulsion	1	2	‡
Aviation turbine fuel	20	3.3	‡
Natural gas	0.2	1.5	‡
Colliery methane	5	5	‡
LPG	12.9	3	‡
OPG	22.8	3	‡
MSW	7	20	‡
Sour gas	0.2	1	‡
Naphtha	23.1	3	‡
Refinery miscellaneous	87.3	3	‡

Fuel/IPCC Sector	Activity Uncertainty %	Emission Factor Uncertainty %	Uncertainty in Emission %
Blast furnace gas	0.4	6	‡
Coke oven gas	0.4	6	‡
Town gas	0	0	‡
Lubricants	20	5	‡
Waste oils	20	5	‡
Scrap tyres	15	10	‡
Aviation spirit	20	3.3	‡
Anthracite	0.4	6	‡
Burning oil (premium)	9.3	2	‡
Vaporising oil	0	0	‡
Limestone	1	5	‡
Dolomite	1	5	‡
Clinical waste	7	20	‡
Chemical waste	7	15	‡
Waste solvent	1	10	‡
1A1c	7	4	‡
1A5b	10	2	‡
1B2a	1	28	‡
1B2c	1	14	‡
1B2c Flaring	16	6	‡
1B2c Venting	16	6	‡
2A1	1	2.2	‡
2A2	1	5	‡
2A3	1	5	‡
2A4	15	2	‡
2A7	20	70	‡
2B1	10	1	‡
2C1	1	20	‡
2C3	1	5	‡
5A Forest Land	1	25	‡
5B Cropland	1	50	‡
5C Grassland	1	70	‡
5E Settlements	1	50	‡
5G Other Activities	1	30	‡
7	50	20	‡

‡ Input parameters were uncertainties of activity data and emission factors.

## A7.1.2 Methane Emission Uncertainties

In the methane inventory, combustion sources are a minor source of emissions. The review of the activity data uncertainty has been used to estimate the over all uncertainty associated with the methane emissions from these sources, although the effect of the large uncertainty associated with the emission factors in most cases outweighs this. The errors in the major sources are listed in **Tables A7.2a and A7.2b**. The non fuel combustion sources are mainly derived from the source documents for the estimates or from the Watt Committee Report (Williams, 1993). The uncertainty in offshore emissions was revised for the 2000 inventory using improved estimates of the activity data. The methane factors were assumed to have an uncertainty of 20% since the flaring factors are based on test measurements.

**Table A7.2a** Estimated Uncertainties in Methane Emissions for 1990 (only major sources are listed)

Source	Reference	Activity %	Emission Factor %	Source Uncertainty %
Coal		1.5	50	
Coke		3	50	
Petroleum coke		7.8	50	
SSF		3.3	50	
Burning oil		6	50	
Fuel oil		5.5	50	
Gas oil		1.8	50	
DERV		1.8	50	
Petrol		1	50	
Orimulsion		1	50	
Aviation turbine fuel		20	50	
Natural gas		2.8	50	
Colliery methane		5	50	
LPG		25.7	50	
OPG		1.4	50	
MSW		7	50	
Sour gas		2.8	50	
Naphtha		7.3	50	
Refinery miscellaneous		11.9	50	
Blast furnace gas		1.5	50	
Coke oven gas		1.5	50	
Town gas		0	50	
Lubricants		20	50	
Waste oils		20	50	
Scrap tyres		15	50	
Aviation spirit		20	50	
Anthracite		1.5	50	
Burning oil (premium)		6	50	
Vaporising oil		0	50	

Source	Reference	Activity %	Emission Factor %	Source Uncertainty %
Clinical waste		7	50	
Poultry litter		7	50	
Landfill gas		5	50	
Sewage gas		5	50	
Wood		30	50	
Straw		50	50	
Sewage sludge combustion		7	50	
Field Burning	‡	-	-	50
Landfill	Brown <i>et al</i> 1999	-	-	~48 <sup>1</sup>
Livestock: enteric	Williams, 1993	0.1	20	*
Livestock: wastes	Williams, 1993	0.1	30	*
Coal Mining	Bennett <i>et al</i> , 1995	1.2	13	*
Offshore	‡	16	20	*
Gas Leakage	Williams, 1993	-	-	17-75 <sup>2</sup>
Chemical Industry	‡	20	20	*
Fletton Bricks	‡	20	100	*
Sewage Sludge	Hobson <i>et al</i> , 1996	-	-	50

1 Skewed distribution

2 Various uncertainties for different types of main and service

‡ See text

\* Input parameters were uncertainties of activity data and emission factors

**Table A7.2b** Estimated Uncertainties in Methane Emissions for 2004(only major sources are listed)

Source	Reference	Activity %	Emission Factor %	Source Uncertainty %
Coal		0.4	50	
Coke		1.3	50	
Petroleum coke		4.2	50	
SSF		8.1	50	
Burning oil		9.3	50	
Fuel oil		19.7	50	
Gas oil		1.7	50	
DERV		1.7	50	
Petrol		2.8	50	
Orimulsion		1	50	
Aviation turbine fuel		20	50	
Natural gas		0.2	50	
Colliery methane		5	50	
LPG		12.9	50	



Source	Reference	Activity %	Emission Factor %	Source Uncertainty %
OPG		22.8	50	
MSW		7	50	
Sour gas		0.2	50	
Naphtha		23.1	50	
Refinery miscellaneous		87.3	50	
Blast furnace gas		0.4	50	
Coke oven gas		0.4	50	
Town gas		0	50	
Lubricants		20	50	
Waste oils		20	50	
Scrap tyres		15	50	
Aviation spirit		20	50	
Anthracite		0.4	50	
Burning oil (premium)		9.3	50	
Vaporising oil		0	50	
Clinical waste		7	50	
Poultry litter		7	50	
Landfill gas		5	50	
Sewage gas		5	50	
Wood		30	50	
Straw		50	50	
Sewage sludge combustion		7	50	
Field Burning	‡	-	-	50
Landfill	Brown <i>et al</i> 1999	-	-	~48 <sup>1</sup>
Livestock: enteric	Williams, 1993	0.1	20	*
Livestock: wastes	Williams, 1993	0.1	30	*
Coal Mining	Bennett <i>et al</i> , 1995	1.2	13	*
Offshore	‡	16	20	*
Gas Leakage	Williams, 1993	-	-	17-75 <sup>2</sup>
Chemical Industry	‡	20	20	*
Fletton Bricks	‡	20	100	*
Sewage Sludge	Hobson <i>et al</i> , 1996	-	-	50

1 Skewed distribution

2 Various uncertainties for different types of main and service

‡ See text

\* Input parameters were uncertainties of activity data and emission factors

The sources quoted in **Tables A7.2a and A7.2b** are assumed to have normal distributions of uncertainties with the exception of landfills. Brown *et al.* (1999) estimated the uncertainty distribution for landfill emissions using Monte Carlo analysis and found it to be skewed. For normal distributions there is always a probability of negative values of the emission factors arising. For narrow distributions this probability is negligible; however with wide distributions the probability may be significant. In the original work (Eggleston *et al*, 1998)

this problem was avoided by using truncated distributions. However, it was found that this refinement made very little difference to the final estimates, so in these estimates normal distributions were used rather than truncated normal.

The total emission of methane in 2004 was estimated as 2,191 Gg. The Monte Carlo analysis suggested that 95% of trials were between 1,869 Gg and 2,761 Gg. The total uncertainty was around 19%. The emission of methane in 1990 was estimated as 4,387 Gg. The Monte Carlo analysis suggested that 95% of trials were between 3,588 Gg and 5,955 Gg. The uncertainty was around 25%.

The uncertainty in the trend between 1990 and 2004 was also estimated. In running this simulation it was necessary to make assumptions about the degree of correlation between sources in 1990 and 2004. If source emission factors are correlated this will have the effect of reducing the emissions. The assumptions were:

- Activity data are uncorrelated between years, but activity data for major fuels were correlated in the same year in a similar manner to that described above for carbon.
- Emission factors for animals are correlated across years for a given species.
- Landfill emissions were partly correlated across years in the simulation. It is likely that the emission factors used in the model will be correlated, and also the historical estimates of waste arisings will be correlated since they are estimated by extrapolation from the year of the study. However, the reduction in emissions is due to flaring and utilisation systems installed since 1990 and this is unlikely to be correlated. As a crude estimate it was assumed that the degree of correlation should reflect the reduction. Emissions have reduced by 63% hence the degree of correlation was 37%.
- Offshore emissions are not correlated across years since they are based on separate studies using emission factors that reflected the processes in use at the time.
- Gas leakage emissions were fully correlated across years.
- Emissions from deep mines were not correlated across years as they were based on different studies, and a different selection of mines. Open cast and coal storage and transport were correlated since they are based on default emission factors.

On the basis of this analysis there is 95% probability that methane emissions in 2004 were between 35% and 63% below the level in 1990.

## **A7.1.3 Nitrous Oxide Emission Uncertainties**

The analysis of the uncertainties in the nitrous oxide emissions is particularly difficult because emissions sources are diverse, and few data are available to form an assessment of the uncertainties in each source. Emission factor data for the combustion sources are scarce and for some fuels are not available. The parameter uncertainties are shown in **Tables A7.3a and A7.3b**. The uncertainty assumed for agricultural soils uses a lognormal distribution since the range of possible values is so high. Here it is assumed that the 97.5 percentile is greater by a factor of 100 than the 2.5 percentile based on advice from the Land Management Improvement Division of DEFRA (per. comm.). The uncertainty distribution of the calculated emission was heavily skewed with a mean emission of 132 Gg in 2004 with 95% of the values found to lie between 33 Gg and 472 Gg N<sub>2</sub>O.

The uncertainty in the trend between 1990 and 2004 was also estimated. In running this simulation it was necessary to make assumptions about the degree of correlation between sources in 1990 and 2004. If sources are correlated this will have the effect of reducing the emissions. The assumptions were:

- Activity data are uncorrelated between years, but similar fuels are correlated in the same year.
- Emissions from agricultural soils were correlated
- The emission factor used for sewage treatment was assumed to be correlated, though the protein consumption data used as activity data were assumed not to be correlated.
- Nitric acid production emission factors were assumed not to be correlated, for reasons explained in the 2000 National Inventory Report.
- Adipic acid emissions were assumed not to be correlated because of the large reduction in emissions due to the installation of abatement plant in 1998.

95% of the values for the trend were found to lie between -20% and -75%, that is to say the analysis indicates a 95% probability that emissions in 2004 were between 20 and 75% below the level in 1990.

**Table A7.3a** Estimated Uncertainties in the Nitrous Oxide Emissions for 1990<sup>1</sup> (only major sources are listed)

	Emission Factor Uncertainty %	Activity Rate Uncertainty %
Coke	195	1.5
Petroleum coke	118	3
SSF	118	7.8
Burning oil	118	3.3
Fuel oil	140	6
Gas oil	140	5.5
DERV	140	1.8
Petrol	170	1.8
Orimulsion	170	1
Aviation turbine fuel	140	1
Natural gas	170	20
Colliery methane	110	2.8
LPG	110	5
OPG	110	25.7
MSW	110	1.4
Sour gas	230	7
Naphtha	110	2.8
Refinery miscellaneous	140	7.3
Blast furnace gas	140	11.9
Coke oven gas	118	1.5
Town gas	118	1.5

	Emission Factor Uncertainty %	Activity Rate Uncertainty %
Lubricants	118	0
Waste oils	140	20
Scrap tyres	140	20
Aviation spirit	140	15
Anthracite	170	20
Burning oil (premium)	387	1.5
Vaporising oil	140	6
Limestone	140	0
Dolomite	0	1
Clinical waste	0	1
Poultry litter	230	7
Landfill gas	230	7
Sewage gas	110	5
Wood	110	5
Straw	230	30
Sewage sludge combustion	230	50
Agricultural Soils	Log-normal <sup>2</sup>	0
Wastewater Treatment	Log-normal <sup>2</sup>	10
Adipic Acid	15	0.5
Nitric Acid	230	10

4 Expressed as 2s/E

5 With 97.5 percentile 100 times the 2.5 percentile

**Table A7.3b** Estimated Uncertainties in the Nitrous Oxide Emissions for 2004<sup>1</sup> (only major sources are listed)

	Emission Factor Uncertainty %	Activity Rate Uncertainty %
Coke	195	0.4
Petroleum coke	118	1.3
SSF	118	4.2
Burning oil	118	8.1
Fuel oil	140	9.3
Gas oil	140	19.7
DERV	140	1.7
Petrol	170	1.7
Orimulsion	170	2.8
Aviation turbine fuel	140	1
Natural gas	170	20
Colliery methane	110	0.2
LPG	110	5
OPG	110	12.9

	Emission Factor Uncertainty %	Activity Rate Uncertainty %
MSW	110	22.8
Sour gas	230	7
Naphtha	110	0.2
Refinery miscellaneous	140	23.1
Blast furnace gas	140	87.3
Coke oven gas	118	0.4
Town gas	118	0.4
Lubricants	118	0
Waste oils	140	20
Scrap tyres	140	20
Aviation spirit	140	15
Anthracite	170	20
Burning oil (premium)	387	0.4
Vaporising oil	140	9.3
Limestone	140	0
Dolomite	0	1
Clinical waste	0	1
Poultry litter	230	7
Landfill gas	230	7
Sewage gas	110	5
Wood	110	5
Straw	230	30
Sewage sludge combustion	230	50
Agricultural Soils	Log-normal <sup>2</sup>	0
Wastewater Treatment	Log-normal <sup>2</sup>	10
Adipic Acid	15	0.5
Nitric Acid	230	10

1 Expressed as 2s/E

2 With 97.5 percentile 100 times the 2.5 percentile

## **A7.1.4 Halocarbons and SF<sub>6</sub>**

The uncertainties in the emissions of HFCs, PFCs and SF<sub>6</sub> were taken from a recent publication on (AEAT, 2004). The uncertainties were estimated as 21% for HFCs, 13% for PFCs and 16% for SF<sub>6</sub>, and were assumed uncorrelated between 1990 and 2004. Trend uncertainties are reported in **Table A7.4a**.

## **A7.1.5 GWP Weighted emissions**

The uncertainty in the combined GWP weighted emission of all the greenhouse gases in both 2004 and in 1990 was estimated as 14%. The trend in the total GWP is -15%, with 95% of the values found to lie within the range -11% and -19%. The uncertainty estimates for all gases are summarised in **Table A7.4a**. The source which makes the major contribution to the overall uncertainty is 4D Agricultural Soils. This source shows little change over the years, but other sources have fallen since 1990.

In previous years, trend uncertainties from the base year to the current inventory year have also been reported here. This table has not been included this year, to avoid confusion regarding differences in the totals due to the treatment of LULUCF emissions and removals. **Base year emissions can be found in Table ES5.**

**Table A7.4a** Summary of Tier 2 Uncertainty Estimates 1990 - 2004

A	B	C	D	E	F	G	H	I	J
IPCC Source Category	Gas	1990 Emissions	2004 Emissions	Uncertainty in 2004 emissions as % of emissions in category		Uncertainty Introduced on national total in 2004	% change in emissions between 2004 and 1990	Range of likely % change between 2004 and 1990	
				2.5 percentile	97.5 percentile			2.5 percentile	97.5 percentile
		Gg CO2 equivalent	Gg CO2 equivalent	Gg CO2 equivalent	Gg CO2 equivalent	%	%	%	%
TOTAL	CO2 (net)	593235	560418	547467	573144	2%	-6%	-8%	-3%
	CH4	103654	51840	42742	68758	23%	-50%	-63%	-35%
	N2O	68379	40797	10499	145942	224%	-40%	-75%	-20%
	HFC	11375	8873	7066	10679	21%	-22%	-40%	-1%
	PFC	1401	352	308.0	396.4	13%	-75%	-78%	-71%
	SF6	1030.0	1128.1	947.7	1308.4	16%	10%	-17%	49%
	All	779074	663408	625798	769757	14%	-15%	-19%	-11%

a Calculated as  $2s/E$  where  $s$  is the standard deviation and  $E$  is the mean, calculated in the simulation.

b Quoted but distribution is highly skewed.

Emissions of CO<sub>2</sub> are net emissions (i.e. sum of emissions and removals)

**A7.1.6 Sectoral Uncertainties**

The emissions from all sectors were calculated by summing the GWP weighted emissions of carbon, N<sub>2</sub>O, methane, the halocarbons and SF<sub>6</sub>. It was then possible to estimate uncertainties for most of the sectors for which we have emissions. In some cases, such as refrigeration and air conditioning, data were not available for the base year emissions hence some uncertainties could not be calculated. Where the Monte Carlo simulation returned equal values for the mean and the 95% confidence intervals, the uncertainty introduced on the national total cannot be calculated. The emissions and uncertainties per sector are presented in **Table A7.4b**.



**Table A7.4b** Sectoral Uncertainty Estimates

A IPCC Source Category	C 1990 Emissions	D 2004 Emissions	E Uncertainty in 2004 emissions as % of emissions in category		G Uncertainty Introduced on national total in 2004
			2.5 percentile	97.5 percentile	
	Gg CO2 equivalent	Gg CO2 equivalent	Gg CO2 equivalent	Gg CO2 equivalent	%
1A1a	206330	172546	170172	174963	1.4%
1A1b	18388	17672	15675	19648	11.5%
1A1c	13737	19157	18882	19425	1.4%
1A2a	24446	19290	19096	19487	1.0%
1A2f	76555	70271	68519	72054	2.6%
1A3a	1325	2357	2028	2687	14.3%
1A3b	111542	125057	118386	131905	5.5%
1A3c	2160	2794	2554	3034	8.7%
1A3d	4207	3749	3560	3938	5.1%
1A3e	303	474	399	549	16.2%
1A4a	25624	23018	22682	23350	1.5%
1A4b	80356	88851	87504	90164	1.5%
1A4c	5768	5185	4481	5883	13.8%
1A5b	5356	2943	2525	3361	14.5%
1B1a	18271	4922	4436	5410	10.1%
1B1b	877	181	176	186	2.6%
1B2a	2785	1285	1024	1543	20.6%
1B2b	7955	4849	4818	4879	0.6%
1B2c Flaring	4482	4398	3717	5101	15.9%
1B2c Venting	885	615	469	772	25.3%
2A1	6659	5456	5326	5585	2.4%
2A2	1192	815	804	827	1.4%
2A3	1285	1371	1352	1391	1.5%
2A4	167	180	153	206	15.1%
2A5	0	0	0	0	λ
2A6	0	0	0	0	λ
2A7	189	141	51	237	67.3%
2B1	1322	1329	1316	1343	1.0%
2B2	4134	2923	-3707	9502	230.8%
2B3	25136	1103	941	1266	15.0%
2B5	136	33	27	40	20.2%
2C1	1887	1557	1538	1576	1.2%
2C3	1783	706	679	734	4.0%
2C4	426	389	389	389	0.0%
2C5	0	0	0	0	λ
2D1	0	0	0	0	λ
2D2	0	0	0	0	λ
2E1	11374	283	283	283	λ
2E2	11	106	106	106	0.0%
2F1	0	5062	5062	5062	0.0%
2F2	0	509	509	509	0.0%
2F3	0	291	291	291	0.0%
2F4	2	2586	2586	2586	0.0%
2F5	0	34	34	34	0.0%
2F8	662	940	940	940	0.0%
3	0	0	0	0	λ
3A	0	0	0	0	λ
3B	0	0	0	0	λ
3C	0	0	0	0	λ
3D	0	0	0	0	λ
4A1	13484	12185	10400	13931	14.8%
4A10	257	201	173	228	14.0%
4A3	4354	3627	2916	4339	20.0%
4A4	12	10	8	11	20.0%
4A6	76	124	100	149	20.0%
4A8	238	163	131	194	20.0%
4B1	2114	1867	1467	2265	21.9%
4B11	0	0	0	0	λ
4B12	0	0	0	0	λ
4B13	70	62	62	62	0.0%
4B3	103	86	60	112	30.5%
4B4	0	0	0	0	30.5%
4B6	6	10	7	13	30.5%
4B8	476	325	228	422	30.5%
4B9	224	279	218	340	22.7%
4B9a	0	0	0	0	30.5%
4D	31921	26535	1344	132458	344.0%
4F1	342	0	0	0	λ
4F5	2	0	0	0	λ
6A1	49772	19823	*	*	λ
6B2	1743	2009	680	6865	206.1%
6C	1388	503	399	609	21.4%
7	1844	2093	1307	2906	39.3%
Aviation_Bunkers	0	0	0	0	λ
LULUCF_5A	-13658	-16302	-20179	-12428	-28.9%
LULUCF_5B	151	15329	8049	22600	57.7%
LULUCF_5C	0	-7836	-13045	-2625	λ
LULUCF_5D	15029	0	0	0	λ
LULUCF_5E	1394	6248	3178	9311	50.0%

λ Value could not be calculated or was equal to 0 (see text)

## **A7.2 ESTIMATION OF UNCERTAINTIES USING A TIER 1 APPROACH**

The IPCC Good Practice Guidance (IPCC, 2000) defines Tier 1 and Tier 2 approaches to estimating uncertainties in national greenhouse gas inventories. The Monte Carlo approach described above corresponds to Tier 2 whilst Tier 1 provides for a simplified calculation method based on the error propagation equations. The results of the Tier 1 approach are shown in **Tables A7.5a, A7.5 b and Tables A7.6a, A7.6 b**. In the Tier 1 approach the emission sources are aggregated up to a level broadly similar to the IPCC Summary Table 7A. Uncertainties are then estimated for these categories. The uncertainties used in the Tier 1 approach are not exactly the same as those used in the Monte Carlo Simulation since the Tier 1 source categorisation is far less detailed. However, the values used were chosen to agree approximately with those used in the Monte Carlo Simulation. The Tier 1 approach is only able to model normal distributions. This presented a problem in how to estimate a normal distribution approximation of the lognormal distribution used for agricultural soils and wastewater treatment. The approach adopted was to use a normal distribution with the same mean as the lognormal distribution.

There have been a number of major improvements to the key source analysis this year. In part, these improvements have been made following comments made in the Fourth Centralised Review and have been made to improve the transparency of the uncertainty analysis. The improvements are summarised below.

- ▶ The ERT commented that the key source analysis was not consistent with the IPCC GPG. The comment was in reference to the guidance where it says "*The (key source) analysis should be performed at the level of IPCC source categories*". Our analysis included disaggregation of 1B1 and 1B2 in the case of CH<sub>4</sub>, rather than treating each of these as a single source category. This has been revised by summing these categories.
- ▶ The uncertainties associated with some of the fuel consumptions in the 2005 NIR were derived from an analysis of the statistical differences between supply and demand for one year, presented in the 1996 UK energy statistics. This analysis has been updated and we have now revised the uncertainty associated the consumptions of the fuels listed below this bullet point. The uncertainties were calculated from the differences between supply and demand<sup>22</sup> as presented in the 1996 DTI DUKES. We have now chosen to use a 5-year rolling average since this is a time period short enough to allow a satisfactory estimate of the change in the variability in the supply and demand, but avoids the sometimes large year-to-year variability that can be a feature of the UK energy statistics. This large year-to-year variability is in part controlled by the historical revisions to the energy statistics that the DTI perform each year, and in some years, revisions to historic estimates of supply and demand will alter the uncertainty calculated from previous data.

<sup>22</sup> We have assumed that the distribution of errors in the parameter values was normal. The quoted range of possible error of uncertainty is taken as 2s, where s is the standard deviation. If the expected value of a parameter is E and the standard deviation is s, then the uncertainty is quoted as 2s/E expressed as a percentage. For a normal distribution the probability of the parameter being less than E-2s is 0.025 and the probability of the emission being less than E+2s is 0.975.

The uncertainty between supply and demand has been estimated for the following UK fuels:

- Coal
- Coke
- Petroleum coke
- Solid smokeless fuel
- Burning oil
- Fuel oil
- Gas oil
- Petrol
- Natural gas
- LPG
- OPG
- Naphtha
- Miscellaneous
- Blast furnace gas
- Coke oven gas

In a few cases in this uncertainty analysis, types of fuels are grouped into one class: for example, oil in IPCC sector 1A used in stationary combustion; this oil is a combination of burning oil (minimal quantities used), fuel oil, and gas oil. In this case, and in other instances like it, we have used expert judgement to assign an uncertainty to a fuel class from the estimated uncertainties associated with individual fuels of that class. The uncertainties in the consumption of Aviation Turbine Fuel and Aviation Spirit has been reviewed and this is discussed below.

- ▶ We have reviewed the uncertainties associated with the emissions of HFC, PFC and SF<sub>6</sub> from industrial processes. The uncertainties associated with the total F-gas emissions has been assigned to the EF in the Tier 1 analysis since uncertainties are not known individually for the ADs and EFs as the emissions are produced from a model. The uncertainties used are weighted values, and reflect the individual uncertainties and the magnitude of emissions in each of the respective sectors.
- ▶ The LULUCF sectoral experts, CEH, have revised the uncertainties associated with emissions associated with Land Use Change and Forestry. The uncertainties associated with the emissions in each LULUCF category have been assigned to the EF in the Tier 1 analysis, since uncertainties are not known individually for the ADs and EFs as emissions are produced from a complicated model.
- ▶ We have reviewed the uncertainties associated with the consumptions of Aviation Turbine Fuel and Aviation Spirit. For this review we contacted the UK DTI for their view about the 95% CI that could be applied to the demand of Aviation Spirit and Aviation Turbine Fuel in the UK energy statistics. We then considered the additional uncertainty that would be introduced by the Tier 3 aviation model, which is used to estimate emissions. The overall uncertainty in the AD has been assigned by expert

judgement considering the uncertainty in the DTI fuel consumption data and the additional uncertainty introduced by the model.

- ▶ We have reviewed the uncertainties associated with selected carbon emission factors (CEFs) for natural gas, coal used in power stations, and selected liquid fuels. The CEF uncertainty for natural gas was taken from analytical data of determinations of the carbon contents presented in a TRANSCO report. This report was produced for the Carbon Factor Review. The CEF uncertainty for the coal used in power stations has been derived from expert judgement following a consultation with representatives from the UK electricity supply industry, and takes into account analytical data of determinations of the carbon contents of power station coal. Analytical data of determinations of the carbon contents of liquid fuels from UKPIA have been used to determine the CEF uncertainties associated with the following fuels: motor spirit, kerosene, diesel, gas oil, and fuel oil. Analytical data were available for naphtha and aviation spirit, but these were not used to modify the existing uncertainties, as the sample sizes were too small. The existing CEF uncertainties were retained for these fuels.
- ▶ Uncertainties for the ADs and EFs for peat combustion have been assigned using expert judgement
- ▶ Expert judgement has been used to assign uncertainties to the AD and EF of the carbon emissions in Sector 7. These carbon emissions are the sum of four new sources.

**Table A7.7** shows the revisions that have been made to the uncertainty parameters associated with activity data and emission factors. The table contains brief notes of the reason behind the change.

The Tier 1 analysis, **including** LULUCF emissions, suggests an uncertainty of 17% in the combined GWP total emission in 2004 (GWP emission uncertainty of 17% in the 2003 inventory - 2005 NIR). The analysis also estimates an uncertainty of 3% in the trend between 1990 and 2004 (trend uncertainty of 2% in the 2003 inventory - 2005 NIR).

The Tier 1 analysis, **excluding** LULUCF emissions, suggests an uncertainty of 17% in the combined GWP total emission in 2004 (no comparable analysis was completed last year). The analysis also estimates an uncertainty of 3% in the trend between 1990 and 2004 (no comparable analysis was completed last year).

In the UK inventory, certain source categories are particularly significant in terms of their contribution to the overall uncertainty of the inventory. These key source categories have been identified so that the resources available for inventory preparation may be prioritised, and the best possible estimates prepared for the most significant source categories. We have used the method set out in Section 7.2 of the IPCC Good Practice Guidance (2000) (*Determining national key source categories*) to determine the key source categories. The results of this key source analysis can be found in **Annex 1**.

**Table A7.5a** Summary of Tier 1 Uncertainty Estimates Including LULUCF

	Source Category (Analysis with LULUCF)	Gas	Base year emissions 1990	Year Y emissions 2004	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty range as % of national total in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced trend in total emissions by source category
			Gg CO2 equiv	Gg CO2 equiv	%	%	%	%	%	%	%	%	%
	A	B	C	D	E	F	G	H	I	J	K	L	M
1A	Coal	CO2	248420	144359	0.4	1	1.077	0.234366	-0.085955	0.185297	-0.085955	0.104820	0.135556
1A(stationary)	Oil	CO2	91436	61226	15	2	15.133	1.396606	-0.021327	0.078588	-0.042654	1.667111	1.667657
1A	Natural Gas	CO2	108857	206459	0.2	1.5	1.513	0.470945	0.145820	0.265006	0.218730	0.074955	0.231217
1A	Other (waste)	CO2	813	1921	7	20	21.190	0.061363	0.001578	0.002466	0.031554	0.024412	0.039895
1A	Lubricant	CO2	387	356	30	2	30.067	0.016146	0.000034	0.0000457	0.000069	0.019400	0.019400
1A3a	Aviation Fuel	CO2	1309	2332	20	3.3	20.270	0.071241	0.001561	0.002993	0.005153	0.084648	0.084804
1A3b	Auto Fuel	CO2	109638	119614	2.8	3.5	4.482	0.808150	0.033651	0.153534	0.117778	0.607963	0.619267
1A3d	Marine Fuel	CO2	4014	3550	1.7	1.4	2.202	0.011784	0.000169	0.004556	0.000236	0.010954	0.010957
1A3	Other Diesel	CO2	2201	2920	1.7	1.4	2.202	0.009692	0.001342	0.003748	0.001878	0.009010	0.009204
1A4	Peat	CO2	477	442	30	10	31.623	0.021065	0.000046	0.000567	0.000459	0.024065	0.024070
1B	Solid Fuel Transformation	CO2	856	168	0.4	6	6.013	0.001524	-0.000720	0.000216	-0.004322	0.000122	0.004324
1B	Oil & Natural Gas	CO2	5760	5100	16	6	17.088	0.131364	0.000250	0.006546	0.001501	0.148123	0.148131
2A1	Cement Production	CO2	6659	5456	1	2.2	2.417	0.019873	-0.000276	0.007003	-0.000607	0.009903	0.009922
2A2	Lime Production	CO2	1192	815	1	5	5.099	0.006268	-0.000256	0.001047	-0.001278	0.001480	0.001956
2A3	Limestone & Dolomite use	CO2	1285	1371	1	5	5.099	0.010539	0.000355	0.001760	0.001776	0.002489	0.003058
2A4	Soda Ash Use	CO2	167	180	15	2	15.133	0.004097	0.000048	0.000231	0.000095	0.004890	0.004891
2A7	Fletton Bricks	CO2	167	128	20	70	72.801	0.014045	-0.000018	0.000164	-0.001255	0.004646	0.004813
2B	Ammonia Production	CO2	1322	1329	10	1.5	10.112	0.020260	0.000262	0.001706	0.000392	0.024128	0.024132
2C1	Iron&Steel Production	CO2	2310	2089	1.2	6	6.119	0.019266	0.000157	0.002681	0.000939	0.004550	0.004646
5A	SA LUCF	CO2	-12203	-16302	1	25	25.020	-0.614820	-0.007589	-0.020925	-0.189713	-0.029592	0.192007
5B	SB LUCF	CO2	15842	15329	1	50	50.010	1.155564	0.002361	0.019676	0.118026	0.027826	0.121262
5C	SC LUCF	CO2	-6193	-7836	1	70	70.007	-0.826856	-0.003289	-0.010057	-0.230227	-0.014223	0.230666
5E	SE LUCF	CO2	6925	6248	1	50	50.010	0.470998	0.000451	0.008020	0.022533	0.011342	0.025226
5G	SG LUCF	CO2	-1456	619	1	30	30.017	0.027999	0.002386	0.000794	0.071569	0.001123	0.071578
6C	Waste Incineration	CO2	1205	452	7	20	21.190	0.014431	-0.000737	0.000580	-0.014749	0.005741	0.015827
7C	Other	CO2	1844	2093	50	20	53.852	0.169875	0.000671	0.002686	0.013419	0.189941	0.190414
		CO2	593,234.75	560,417.53									
1A	All Fuel	CH4	2017.5342	1123.10487	0.4	50	50.002	0.084649	-0.000764	0.001442	-0.038179	0.000815	0.038187
1A3a	Aviation Fuel	CH4	2.65613032	2.767746	20	50	53.852	0.000225	0.000001	0.000004	0.000032	0.000100	0.000106
1A3b	Auto Fuel	CH4	614.371252	186.351209	2.8	50	50.078	0.014067	-0.000432	0.000239	-0.021616	0.000947	0.021636
1A3d	Marine Fuel	CH4	7.62048	6.71347296	1.7	50	50.029	0.000506	0.000000	0.000009	0.000014	0.000021	0.000025
1A3	Other Diesel	CH4	1.66785302	2.20572004	1.7	50	50.029	0.000166	0.000001	0.000003	0.000050	0.000007	0.000051
1B1	Coal Mining	CH4	18285.666	4929.740	0.4	13	13.006	0.096648	-0.013656	0.006328	-0.177522	0.003579	0.177558
	Solid Fuel Transformation	CH4	4.043	3.389	0.4	50	50.002	0.000255	0.000000	0.000004	-0.000003	0.000002	0.000004
1B2	Natural Gas Transmission	CH4	7954.835	4848.541	1	15	15.033	0.109872	-0.002471	0.006223	-0.037065	0.008801	0.038095
	Offshore Oil& Gas	CH4	2349.856	1158.501	16	20	25.612	0.044727	-0.001081	0.001487	-0.021627	0.033648	0.039999
2A7	Fletton Bricks	CH4	22.426	12.798	20	100	101.980	0.001967	-0.000008	0.000016	-0.000809	0.000465	0.000933
2B	Chemical Industry	CH4	136.172	32.969	20	20	28.284	0.001406	-0.000107	0.000042	-0.002130	0.001197	0.002444
2C	Iron & Steel Production	CH4	16.357	13.834	0.4	50	50.002	0.001043	0.000000	0.000018	-0.000006	0.000010	0.000012
4A	Enteric Fermentation	CH4	18421.026	16309.153	0.1	20	20.000	0.491685	0.000799	0.020934	0.015990	0.002961	0.016262
4B	Manure Management	CH4	2923.202	2567.513	0.1	30	30.000	0.116106	0.000101	0.003296	0.003015	0.000466	0.003051
4F	Field Burning	CH4	266.045	0.000	25	50	55.902	0.000000	-0.000291	0.000000	-0.014539	0.000000	0.014539
5C2	SC2 LUCF	CH4	3.077	11.875	1	20	20.025	0.000358	0.000012	0.000015	0.000238	0.000022	0.000239
5E2	SE2 LUCF	CH4	10.763	4.884	1	20	20.025	0.000147	-0.000005	0.000006	-0.000110	0.000009	0.000110
6A	Solid Waste Disposal	CH4	49772.458	19822.975	15	46	48.384	1.445737	-0.028939	0.025444	-1.331195	0.539756	1.436459
6B	Wastewater Handling	CH4	709.705	799.298	1	50	50.010	0.060254	0.000250	0.001026	0.012512	0.001451	0.012596
6C	Waste Incineration	CH4	134.434	3.299	7	50	50.488	0.000251	-0.000143	0.000004	-0.007135	0.000042	0.007135
		CH4	103,653.91	51,839.91									

**Table A7.5b** Summary of Tier 1 Uncertainty Estimates Including LULUCF

	Source Category	Gas	Base year emissions 1990	Year Y emissions 2004	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty range as % of national total in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced trend in total emissions by source category
			Gg CO2 equiv	Gg CO2 equiv	%	%	%	%	%	%	%	%	%
	A	B	C	D	E	F	G	H	I	J	K	L	M
1A1&1A2&1A4	Other Combustion	N2O	4522.787	3388.914	0.4	195	195.000	0.996130	-0.000593	0.004350	-0.115730	0.002461	0.115756
1A3a	Aviation Fuel	N2O	12.960	23.029	20	170	171.172	0.005942	0.000015	0.000030	0.002617	0.000836	0.002747
1A3b	Auto Fuel	N2O	1025.188	5037.740	2.8	170	170.023	1.291111	0.005346	0.006466	0.908772	0.025605	0.909133
1A3d	Marine Fuel	N2O	78.120	68.822	1.7	170	170.008	0.017637	0.000003	0.000088	0.000502	0.000212	0.000545
1A3	Other Diesel	N2O	260.581	346.061	1.7	140	140.010	0.073035	0.000159	0.000444	0.022313	0.001068	0.022338
1B1	Coke Oven Gas	N2O	2.085	1.748	0.4	118	118.001	0.000311	0.000000	0.000002	-0.000004	0.000001	0.000004
1B2	Oil & Natural Gas	N2O	42.396	39.237	16	110	111.158	0.006574	0.000004	0.000050	0.000443	0.001140	0.001223
2B	Adipic Acid Production	N2O	25136.350	1103.290	0.5	15	15.008	0.024960	-0.026050	0.001416	-0.390746	0.001001	0.390747
2B	Nitric Acid Production	N2O	4133.694	2922.680	10	230	230.217	1.014236	-0.000767	0.003751	-0.176328	0.053054	0.184137
2C	Iron & Steel	N2O	11.107	8.278	0.4	118	118.001	0.001472	-0.000002	0.000011	-0.000179	0.000006	0.000179
4B	Manure Management	N2O	1583.857	1316.301	1	414	414.001	0.821442	-0.000042	0.001690	-0.017221	0.002389	0.017386
4D	Agricultural Soils	N2O	30407.121	25281.338	1	424	424.001	16.157978	-0.000784	0.032451	-0.332604	0.045892	0.335755
4F	Field Burning	N2O	77.762	0.000	25	230	231.355	0.000000	-0.000085	0.000000	-0.019549	0.000000	0.019549
5C2	5C2 LUCF	N2O	0.312	1.205	1	20	20.025	0.000036	0.000001	0.000002	0.000024	0.000002	0.000024
5E2	5E2 LUCF	N2O	1.092	0.496	1	20	20.025	0.000015	-0.000001	0.000001	-0.000011	0.000001	0.000011
6B	Wastewater Handling	N2O	1033.645	1209.295	10	401	401.125	0.731192	0.000422	0.001552	0.169396	0.021952	0.170812
6C	Waste Incineration	N2O	47.899	48.298	7	230	230.106	0.016753	0.000010	0.000062	0.002217	0.000614	0.002301
		N2O	68,376.96	40,796.73									
2	Industrial Processes	HFC	11375	8873	1	19	19.026	0.254479	-0.001044	0.011389	-0.019834	0.016107	0.025551
2	Industrial Processes	PFC	1401	352	1	10	10.050	0.005336	-0.001080	0.000452	-0.010797	0.000639	0.010816
2	Industrial Processes	SF6	1030	1128	1	20	20.025	0.034035	0.000322	0.001447	0.006431	0.002047	0.006749
		Halocarbon	13,806.83	10,352.92									
	TOTALS	GWP	779,072.44	663,407.09				16.6					2.59
	Total Uncertainties%												

**Table A7.6a** Summary of Tier 1 Uncertainty Estimates Excluding LULUCF

	Source Category (Analysis with LULUCF)	Gas	Base year emissions 1990	Year Y emissions 2004	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty range as % of national total in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced trend in total emissions by source category
			Gg CO2 equiv	Gg CO2 equiv	%	%	%	%	%	%	%	%	%
	A	B	C	D	E	F	G	H	I	J	K	L	M
1A	Coal	CO2	248420	144359	0.4	1	1.077	0.233688	-0.088095	0.185996	-0.088095	0.105215	0.137226
1A(stationary)	Oil	CO2	91436	61226	15	2	15.133	1.392569	-0.022077	0.078885	-0.044155	1.673406	1.673989
1A	Natural Gas	CO2	108857	206459	0.2	1.5	1.513	0.469584	0.145573	0.266006	0.218359	0.075238	0.230958
1A	Other (waste)	CO2	813	1921	7	20	21.190	0.061185	0.001578	0.002475	0.031554	0.024504	0.039951
1A	Lubricant	CO2	387	356	30	2	30.067	0.016099	0.000032	0.000459	0.000063	0.019474	0.019474
1A3a	Aviation Fuel	CO2	1309	2332	20	3.3	20.270	0.071035	0.001558	0.003004	0.005140	0.084967	0.085123
1A3b	Auto Fuel	CO2	109638	119614	2.8	3.5	4.482	0.805814	0.032975	0.154114	0.115412	0.610259	0.621076
1A3d	Marine Fuel	CO2	4014	3550	1.7	1.4	2.202	0.011750	0.000140	0.004574	0.000196	0.010996	0.010998
1A3	Other Diesel	CO2	2201	2920	1.7	1.4	2.202	0.009664	0.001330	0.003762	0.001863	0.009044	0.009234
1A4	Peat	CO2	477	442	30	10	31.623	0.021004	0.000043	0.000569	0.000425	0.024156	0.024160
1B	Solid Fuel Transformation	CO2	856	168	0.4	6	6.013	0.001519	-0.000729	0.000217	-0.004376	0.000123	0.004378
1B	Oil & Natural Gas	CO2	5760	5100	16	6	17.088	0.130985	0.000209	0.006571	0.001254	0.148683	0.148688
2A1	Cement Production	CO2	6659	5456	1	2.2	2.417	0.019816	-0.000326	0.007029	-0.000717	0.009941	0.009967
2A2	Lime Production	CO2	1192	815	1	5	5.099	0.006250	-0.000265	0.001051	-0.001327	0.001486	0.001992
2A3	Limestone & Dolomite use	CO2	1285	1371	1	5	5.099	0.010509	0.000347	0.001767	0.001735	0.002499	0.003042
2A4	Soda Ash Use	CO2	167	180	15	2	15.133	0.004085	0.000047	0.000231	0.000093	0.004909	0.004909
2A7	Fletton Bricks	CO2	167	128	20	70	72.801	0.014004	-0.000019	0.000165	-0.001345	0.004664	0.004854
2B	Ammonia Production	CO2	1322	1329	10	1.5	10.112	0.020202	0.000253	0.001713	0.000379	0.024219	0.024222
2C1	Iron&Steel Production	CO2	2310	2089	1.2	6	6.119	0.019211	0.000140	0.002691	0.000841	0.004567	0.004644
5A	5A LUCF	CO2	0	0	1	25	25.020	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5B	5B LUCF	CO2	0	0	1	50	50.010	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5C	5C LUCF	CO2	0	0	1	70	70.007	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5E	5E LUCF	CO2	0	0	1	50	50.010	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5G	5G LUCF	CO2	0	0	1	30	30.017	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6C	Waste Incineration	CO2	1205	452	7	20	21.190	0.014389	-0.000749	0.000582	-0.014981	0.005763	0.016051
7C	Other	CO2	1844	2093	50	20	53.852	0.169384	0.000660	0.002696	0.013200	0.190658	0.191114
		CO2	590,319.32	562,359.08									
1A	All Fuel	CH4	2017.534204	1123.10487	0.4	50	50.002	0.084405	-0.000781	0.001447	-0.039063	0.000819	0.039071
1A3a	Aviation Fuel	CH4	2.656130323	2.767746	20	50	53.852	0.000224	0.000001	0.000004	0.000032	0.000101	0.000106
1A3b	Auto Fuel	CH4	614.3712517	186.351209	2.8	50	50.078	0.014026	-0.000438	0.000240	-0.021923	0.000951	0.021943
1A3d	Marine Fuel	CH4	7.62048	6.71347296	1.7	50	50.029	0.000505	0.000000	0.000009	0.000012	0.000021	0.000024
1A3	Other Diesel	CH4	1.667853023	2.20572004	1.7	50	50.029	0.000166	0.000001	0.000003	0.000050	0.000007	0.000050
1B1	Coal Mining	CH4	18285.666	4929.740	0.4	13	13.006	0.096369	-0.013841	0.006352	-0.179935	0.003593	0.179971
	Solid Fuel Transformation	CH4	4.043	3.389	0.4	50	50.002	0.000255	0.000000	0.000004	-0.000005	0.000002	0.000006
1B2	Natural Gas Transmission	CH4	7954.835	4848.541	1	15	15.033	0.109554	-0.002539	0.006247	-0.038080	0.008835	0.039091
	Offshore Oil& Gas	CH4	2349.856	1158.501	16	20	25.612	0.044598	-0.001103	0.001493	-0.022054	0.033775	0.040337
2A7	Fletton Bricks	CH4	22.426	12.798	20	100	101.980	0.001962	-0.000008	0.000016	-0.000828	0.000466	0.000950
2B	Chemical Industry	CH4	136.172	32.969	20	20	28.284	0.001402	-0.000108	0.000042	-0.002158	0.001201	0.002470
2C	Iron & Steel Production	CH4	16.357	13.834	0.4	50	50.002	0.001040	0.000000	0.000018	-0.000012	0.000010	0.000016
4A	Enteric Fermentation	CH4	18421.026	16309.153	0.1	20	20.000	0.490264	0.000667	0.021013	0.013349	0.002972	0.013675
4B	Manure Management	CH4	2923.202	2567.513	0.1	30	30.000	0.115771	0.000079	0.003308	0.002383	0.000468	0.002429
4F	Field Burning	CH4	266.045	0.000	25	50	55.902	0.000000	-0.000294	0.000000	-0.014692	0.000000	0.014692
5C2	5C2 LUCF	CH4	0.000	0.000	1	20	20.025	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5E2	5E2 LUCF	CH4	0.000	0.000	1	20	20.025	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6A	Solid Waste Disposal	CH4	49772.458	19822.975	15	46	48.384	1.441559	-0.029413	0.025540	-1.353001	0.541794	1.457447
6B	Wastewater Handling	CH4	709.705	799.298	1	50	50.010	0.060080	0.000246	0.001030	0.012299	0.001456	0.012385
6C	Waste Incineration	CH4	134.434	3.299	7	50	50.488	0.000250	-0.000144	0.000004	-0.007211	0.000042	0.007212
		CH4	103,640.07	51,823.15									

**Table A7.6b** Summary of Tier 1 Uncertainty Estimates Excluding LULUCF

	Source Category	Gas	Base year emissions 1990	Year Y emissions 2004	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty range as % of national total in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced trend in total emissions by source category
			Gg CO2 equiv	Gg CO2 equiv	%	%	%	%	%	%	%	%	%
	A	B	C	D	E	F	G	H	I	J	K	L	M
1A1&1A2&1A4	Other Combustion	N2O	4522.787	3388.914	0.4	195	195.000	0.993251	-0.000629	0.004366	-0.122636	0.002470	0.122661
1A5	Aviation Fuel	N2O	12.960	23.029	20	170	171.172	0.005925	0.000015	0.000030	0.002611	0.000839	0.002742
1A3b	Auto Fuel	N2O	1025.188	5037.740	2.8	170	170.023	1.283739	0.005358	0.006491	0.910925	0.025702	0.911288
1A3d	Marine Fuel	N2O	78.120	68.822	1.7	170	170.008	0.017586	0.000002	0.000089	0.000406	0.000213	0.000459
1A3	Other Diesel	N2O	260.581	346.061	1.7	140	140.010	0.072824	0.000158	0.000446	0.022130	0.001072	0.022155
1B1	Coke Oven Gas	N2O	2.085	1.748	0.4	118	118.001	0.000310	0.000000	0.000002	-0.000006	0.000001	0.000006
1B2	Oil & Natural Gas	N2O	42.396	39.237	16	110	111.158	0.006555	0.000004	0.000051	0.000410	0.001144	0.001215
2B	Adipic Acid Production	N2O	25136.350	1103.290	0.5	15	15.008	0.024888	-0.026332	0.001422	-0.394986	0.001005	0.394987
2B	Nitric Acid Production	N2O	4133.694	2922.680	10	230	230.217	1.011305	-0.000800	0.003766	-0.183967	0.053254	0.191520
2C	Iron & Steel	N2O	11.107	8.278	0.4	118	118.001	0.001468	-0.000002	0.000011	-0.000189	0.000006	0.000189
4B	Manure Management	N2O	1583.857	1316.301	1	414	414.001	0.819067	-0.000053	0.001696	-0.022096	0.002398	0.022226
4D	Agricultural Soils	N2O	30407.121	25281.338	1	424	424.001	16.111274	-0.001010	0.032573	-0.428391	0.046065	0.430861
4F	Field Burning	N2O	77.762	0.000	25	230	231.355	0.000000	-0.000086	0.000000	-0.019754	0.000000	0.019754
5C2	5C2 LUCF	N2O	0.000	0.000	1	20	20.025	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5E2	5E2 LUCF	N2O	0.000	0.000	1	20	20.025	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6B	Wastewater Handling	N2O	1033.645	1209.295	10	401	401.125	0.729079	0.000416	0.001558	0.166995	0.022035	0.168443
6C	Waste Incineration	N2O	47.899	48.298	7	230	230.106	0.016704	0.000009	0.000062	0.002145	0.000616	0.002232
		N2O	68,375.55	40,795.03									
2	Industrial Processes	HFC	11375	8873	1	19	19.026	0.253743	-0.001131	0.0011432	-0.021494	0.016168	0.026896
2	Industrial Processes	PF6	1401	352	1	10	10.050	0.005320	-0.001094	0.000454	-0.010941	0.000642	0.010959
2	Industrial Processes	SF6	1030	1128	1	20	20.025	0.033937	0.000315	0.001453	0.006304	0.002055	0.006631
		Halocarbon	13,806.83	10,352.92									
	TOTALS	GWP	776,141.77	665,330.19				16.4					2.60



**Table A7.7** Revisions to Activity Data and Emission Factor Uncertainty Parameters

IPPC Sector	Fuel	GHG	AD Uncertainty		Reason	EF Uncertainty		Reason
			2003	2004		2003	2004	
1A	Coal	CO <sub>2</sub>	1.2	0.4	Review of DTI energy data	6	1	Review of ESI CEF data
1A (Stationary)	Oil	CO <sub>2</sub>	2	15	Review of DTI energy data	(b)	(b)	
1A	Natural Gas	CO <sub>2</sub>	2.4	0.2	Review of DTI energy data	1	1.5	Review of TRANSCO CEF data
1A	Lubricants	CO <sub>2</sub>	(c)	30	New fuel in this category for 2004	(c)	2	New fuel in this category for 2004
1A3a	Aviation Fuel	CO <sub>2</sub>	50	20	Review of DTI energy data	2	3.3	Review of UKPIA CEF data
1A3b	Auto Fuel	CO <sub>2</sub>	0.8	2.8	Review of DTI energy data	2	3.5	Review of UKPIA CEF data
1A3d	Marine Fuel	CO <sub>2</sub>	1.4	1.7	Review of DTI energy data	2	1.4	Review of UKPIA CEF data
1A3	Other diesel	CO <sub>2</sub>	1.4	1.7	Review of DTI energy data	2	1.4	Review of UKPIA CEF data
1A4	Peat	CO <sub>2</sub>	(c)	30	New source for 2004	(c)	10	New source for 2004
1B	Solid Fuel Transformation	CO <sub>2</sub>	1.2	0.4	Review of DTI energy data	(b)	(b)	
2B	Ammonia Production	CO <sub>2</sub>	(b)	(b)		1	1.5	
5A	Land Use Change & Forestry	CO <sub>2</sub>	(a)	1	New estimate of uncertainty for the new reporting category	(a)	25	New estimate of uncertainty for the new reporting category
5B	Land Use Change & Forestry	CO <sub>2</sub>	(a)	1	New estimate of uncertainty for the new reporting category	(a)	50	New estimate of uncertainty for the new reporting category
5C	Land Use Change & Forestry	CO <sub>2</sub>	(a)	1	New estimate of uncertainty for the new reporting category	(a)	70	New estimate of uncertainty for the new reporting category
5D	Land Use Change & Forestry	CO <sub>2</sub>	(a)	No emissions in this category		(a)	No emissions in this category	
5E	Land Use Change & Forestry	CO <sub>2</sub>	(a)	1	New estimate of uncertainty for the new reporting category	(a)	50	New estimate of uncertainty for the new reporting category
5F	Land Use Change & Forestry	CO <sub>2</sub>	(a)	No emissions in this category		(a)	No emissions in this Category	
5G	Land Use Change & Forestry	CO <sub>2</sub>	(a)	1	New estimate of uncertainty for the new reporting category	(a)	30	New estimate of uncertainty for the new reporting category
7C	Other	CO <sub>2</sub>	(d)	50	New sources for 2004 assigned to Sector 7	(d)	20	New sources for 2004 assigned to Sector 7
1A (Stationary)	All Fuel	CH <sub>4</sub>	1.2	0.4	Review of DTI energy data	(b)	(b)	
1A3a	Aviation Fuel	CH <sub>4</sub>	50	20	Review of DTI energy data	(b)	(b)	
1A3b	Auto Fuel	CH <sub>4</sub>	0.8	2.8	Review of DTI energy data	(b)	(b)	
1A3d	Marine Fuel	CH <sub>4</sub>	1.4	1.7	Review of DTI energy data	(b)	(b)	
1A3	Other diesel	CH <sub>4</sub>	1.4	1.7	Review of DTI energy data	(b)	(b)	
1B1	Coal Mining	CH <sub>4</sub>	1.2	0.4	Review of DTI energy data	(b)	(b)	

IPPC Sector	Fuel	GHG	AD Uncertainty		Reason	EF Uncertainty		Reason
			2003	2004		2003	2004	
Solid Fuel Transformation	Solid Fuel Transformation	CH <sub>4</sub>	1.2	0.4	Review of DTI energy data	(b)	(b)	
2C	Iron & Steel Production	CH <sub>4</sub>	1.2	0.4	Review of DTI energy data	(b)	(b)	
5C2	Land Use Change & Forestry	CH <sub>4</sub>	(a)	1	New estimate of uncertainty for the new reporting category	(a)	20	New estimate of uncertainty for the new reporting category
5E2	Land Use Change & Forestry	CH <sub>4</sub>	(a)	1	New estimate of uncertainty for the new reporting category	(a)	20	New estimate of uncertainty for the new reporting category
1A1&1A2&1A4&1A5	Other Combustion	N <sub>2</sub> O	1.2	0.4	Review of DTI energy data	(b)	(b)	
1A3a	Aviation Fuel	N <sub>2</sub> O	50	20	Review of DTI energy data	(b)	(b)	
1A3b	Auto Fuel	N <sub>2</sub> O	0.8	2.8	Review of DTI energy data	(b)	(b)	
1A3d	Marine Fuel	N <sub>2</sub> O	0.8	1.7	Review of DTI energy data	(b)	(b)	
1A3	Other diesel	N <sub>2</sub> O	1.4	1.7	Review of DTI energy data	(b)	(b)	
1B1	Coke Oven Gas	N <sub>2</sub> O	1.2	0.4	Review of DTI energy data	(b)	(b)	
2C	Iron & Steel	N <sub>2</sub> O	1.2	0.4	Review of DTI energy data	(b)	(b)	
5C2	Land Use Change & Forestry	N <sub>2</sub> O	(a)	1	New sources for 2004 assigned to Sector 7	(a)	20	New estimate of uncertainty for the new reporting category
5E2	Land Use Change & Forestry	N <sub>2</sub> O	(a)	1	New sources for 2004 assigned to Sector 7	(a)	20	New estimate of uncertainty for the new reporting category
2	Industrial Processes	HFC	(b)	(b)		25	19	Review of uncertainties associated with F-gas model
2	Industrial Processes	PFC	(b)	(b)		19	10	Review of uncertainties associated with F-gas model
2	Industrial Processes	SF <sub>6</sub>	(b)	(b)		13	20	Review of uncertainties associated with F-gas model

## Notes

- CEF Carbon Emission Factor
- AD Activity Data
- EF Emission Factor
- ESI Electricity Supply Industry
- (a) Reporting nomenclature changed in the 2004 GHG inventory to correspond to the IPPC LULUCF GPG categories.
- (b) No change in the values of uncertainties assigned.
- (c) New category, no data for 2003
- (d) No data for 2003

## **A8. ANNEX 8: Verification**

This Annex describes research on inventory verification using atmospheric measurements of greenhouse gas concentrations and inverse modelling.

*Note: The verification work was carried out before the update to the landfill methane emissions and this is therefore not considered in the work below.*

### **A8.1 MODELLING APPROACH USED FOR THE VERIFICATION OF THE UK GHGI**

Defra supports continuous high-frequency observations of the greenhouse gas concentrations at the Mace Head Atmospheric Research Station on the Atlantic Ocean coastline of Ireland. This work is under contract to University of Bristol (Simmonds *et al.* 1996). Also under contract to Defra, the Met Office employs the Lagrangian dispersion model NAME (Numerical Atmospheric dispersion Modelling Environment) (Ryall *et al.* 1998) (Jones *et al.* 2004) driven by 3D synoptic meteorology from the Unified Model (Cullen, 1993) to sort the observations made at Mace Head into those that represent Northern Hemisphere baseline air masses and those that represent regionally-polluted air masses arriving from Europe. The Mace Head observations and the hourly air origin maps are applied in an inversion algorithm to estimate the magnitude and spatial distribution of the European emissions that best support the observations (Manning *et al.* 2003). The technique has been applied to each year of the available data.

The inversion (best-fit) technique (simulated annealing) is used to fit the model emissions to the observations. It assumes that the emissions from each grid box are uniform in both time and space over the duration of the data. This implies that the release is independent of meteorological factors such as temperature and diurnal or seasonal cycles, and that in its industrial production and use there is no definite cycle or intermittency. The geographical area defined as UK within the NAME estimates includes the coastal waters around the UK.

In the past year (2005) considerable effort has been focussed on improving the NAME model, most notably in its use of meteorology. The improvements to the model have had a noticeable impact (+20 to +30%) on the emission estimates compared to estimates from previous years, though the trends have largely been unaffected.

### **A8.2 RESULTS**

**Table A8.1** shows long run averages over the period since 1995 as estimated by the inventory and the NAME model for the greenhouse gases presently covered. Results are rounded to two significant figures.

**Table A8.1** Verification of the UK emission inventory estimates in Gg yr<sup>-1</sup> for 1995 to 2004

	<b>Inventory average (Gg/yr)</b>	<b>NAME average (Gg/yr)</b>
<b>Methane</b>	3,369	2,780
<b>Nitrous Oxide</b>	157	150
<b>HFC-134a</b>	2.35	1.83
<b>HFC-152a</b>	0.13	0.094

**Notes**

The emissions in the table exclude the very small contributions from the UK's overseas territories of Bermuda, Cayman Islands, Falkland Islands and Montserrat. These emissions have been omitted from the average emissions because these territories are remote from the UK and are excluded from the NAME model domain.

The NAME estimates are subject to an uncertainty of order  $\pm 50\%$  and the inventory estimates for these gases are uncertain, in 2003, to around:

- CO<sub>2</sub>            2.4%
- CH<sub>4</sub>            13%
- N<sub>2</sub>O            230%

(see **Annex 7**). The uncertainty ranges therefore overlap.

When applied to the trend in emissions the NAME estimates presently show agreement to within the band of uncertainties and have similar slope at the European level. Country estimates including those of the UK, France and Germany can have opposite slope with the present analysis, although this is still likely to be within the uncertainty range.

Details of this work can be found in Manning *et al.* (2005). The UK believes that techniques of this kind are promising for verification purposes and plans to continue working on their development.

## **A9. ANNEX 9: IPCC Sectoral Tables of GHG Emissions**

The tables in this Annex present summary data for UK greenhouse gas emissions for the years 1990-2004, inclusive. The data are given in IPCC reporting format. These data are updated annually to reflect revisions in the methodology and the availability of new information. These adjustments are applied retrospectively to earlier years, which accounts for any differences in data published in previous reports, to ensure a consistent time series.

Emissions from the UK overseas territories have been included in the totals for the relevant IPCC sectors in these tables. In the CRF tables, direct emissions are included in the relevant IPCC sector where possible, whereas indirect emissions are reported in Sector 7 (see **Chapter 9** for details). Due to these differences, although the totals are the same, the individual sector totals may differ slightly to those reported in the CRF.

**Tables A9.1.1 to Tables A9.1.13** present UK GHG emissions as **summary reports** for national greenhouse gas inventories (**IPCC Table 7A**).

TABLE A9.1.1 SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (IPCC TABLE 7A) – 1990

Submission 2006

1990

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		CO2 net	CH4	N2O	HFCs		PFCs		SF6		NOx	CO	NMVOC	SO2	
					P	A	P	A	P	A					
															CO2 equivalent (Gg)
		(Gg)	(Gg)												
Total National Emissions and Removals		593235	4936	221	12	11375	74	1401	0.08	0.04	2932	8280	2394	3699	
1. Energy		574169	1488	19							2906	7714	1415	3640	
A. Fuel Combustion		Reference Approach	564095												
		Sectoral Approach	567552	126	19						2892	7655	1034	3611	
1. Energy Industries			236429	7	6						852.5	131.3	8.1	2888.0	
2. Manufacturing Industries and Construction			99064	15	5						369.3	734.3	36.3	416.1	
3. Transport			117533	30	4						1420.3	5525.3	873.1	94.8	
4. Other Sectors			109241	74	3						214.4	1250.3	114.0	203.0	
5. Other		a	5285	0	0						35.5	13.4	2.3	9.2	
B. Fugitive Emissions from Fuels			6617	1362	0						14	60	381	28	
1. Solid Fuels			856	871	0						0.6	38.3	0.3	20.7	
2. Oil and Natural Gas			5760	491	0						13.3	21.5	380.7	7.8	
2. Industrial Processes			13102	8	94	12	11375	74	1401	0.08	0.04	10.94	270.08	258.44	52.22
A. Mineral Products			9470	1	0		0.00		0.00		0.00	0.0	5.0	12.9	4.3
B. Chemical Industry			1322	6	94		0.00		0.00		0.00	8.5	81.9	165.7	39.0
C. Metal Production			2310	1	0	0.00	0.00	0.00	1332.75	0.00	0.02	2.5	183.2	2.1	8.9
D. Other Production			0	0	0		0.00		0.00		0.00	0.0	0.0	77.7	0.0
E. Production of Halocarbons and SF6			0	0	0	0.00	11374	0.00	10.90		0.00	0.0	0.0	0.0	0.0
F. Consumption of Halocarbons and SF6		b	0	0	0	12	2	73.65	57.84	0.08	0.03	0.0	0.0	0.0	0.0
G. Other			0	0	0		0.00		0.00		0.00	0.0	0.0	0.0	0.0
3. Solvent and Other Product Use			0	0	0	0	0	0	0	0	0	0	0	669.6	0.0
4. Agriculture			0	1029	103						9	266	26	0	0
A. Enteric Fermentation			0	877	0						0.0	0.0	0.0	0.0	
B. Manure Management			0	139	5						0.0	0.0	0.0	0.0	
C. Rice Cultivation			0	0	0						0.0	0.0	0.0	0.0	
D. Agricultural Soils			0	0	98						0.0	0.0	0.0	0.0	
E. Prescribed Burning of Savannas			0	0	0						0.0	0.0	0.0	0.0	
F. Field Burning of Agricultural Residues		c	0	13	0						9.1	266.0	26.1		
G. Other			0	0	0						0.0	0.0	0.0	0.0	
5. Land-Use Change and Forestry			2915	0.66	0.005	0	0	0	0	0	0	0.2	5.8	0	0
5A Forest Land			-12203	0	0						0.0	0.0			
5B Cropland			15842	0	0						0.0	0.0			
5C Grassland			-6193	0.15	0.001						0.04	1.3			
5D Wetland			0	0	0						0.0	0.0			
5E Settlements			6925	0.51	0.004						0.1	4.5			
5F Other Land			0	0	0						0.0	0.0			
5G Other Activities			-1456	0	0						0.0	0.0			
6. Waste			1205	2410	3	0	0	0	0	0	0	6	23	25	7
A. Solid Waste Disposal on Land			0	2370	0						0.0	0.0	0.0	18.2	0.0
B. Wastewater Handling		d	0	34	3						0.0	0.0	0.0	0.0	0.0
C. Waste Incineration			1205	6	0						6.1	23.3	6.5	7.3	
D. Other			0	0	0						0.0	0.0	0.0	0.0	0.0
7. Other (please specify)			1844	0	0	0	0	0	0	0	0	0	0	0	0
Memo Items: (?)															
International Bunkers		e	22345	1	1	0	0	0	0	0	0	195	28	9	95
Aviation		e	15668	0	0						75.6	12.8	5.1	3.0	
Marine		e	6677	1	0						119.6	15.5	4.4	92.5	
Multilateral Operations															
CO2 Emissions from Biomass		ef	2979												

TABLE A9.1.2 SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (IPCC TABLE 7A) - 1991

Submission 2006

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		CO2 net	CH4	N2O	HFCs		PFCs		SF6		NOx	CO	NMVOC	SO2	
					P	A	P	A	P	A					
		(Gg)	CO2 equivalent (Gg)				(Gg)								
Total National Emissions and Removals		600034	4895	214	12	11854	83	1171	0.08	0.05	2803	8128	2313	3522	
1. Energy		583089	1504	19							2779	7611	1385	3464	
A. Fuel Combustion		Reference Approach	580707												
		Sectoral Approach	576874	128	19						2765	7528	1004	3439	
1. Energy Industries			235949	6	6						754.6	130.4	8.0	2702.8	
2. Manufacturing Industries and Construction			99133	15	5						353.3	685.9	34.4	429.8	
3. Transport			116853	29	5						1395.2	5342.3	842.9	92.0	
4. Other Sectors			120646	77	3						228.5	1358.6	116.8	205.8	
5. Other		a	4292	0	0						33.7	10.8	2.0	9.6	
B. Fugitive Emissions from Fuels			6215	1376	0						14	83	381	25	
1. Solid Fuels			519	895	0						0.4	35.6	0.3	17.5	
2. Oil and Natural Gas			5696	481	0						13.2	47.0	380.9	7.7	
2. Industrial Processes			11086	8	89	12	11854	83	1171	0.08	0.05	9.82	260.95	247.58	50.43
A. Mineral Products			8078	1	0		0.00		0.00		0.00	0.0	4.1	12.5	3.5
B. Chemical Industry			1324	6	88		0.00		0.00		0.00	7.7	80.1	155.6	38.3
C. Metal Production			1684	1	0	0.00	0.00	0.00	1095.57	0.00	0.02	2.1	176.8	1.9	8.6
D. Other Production			0	0	0		0.00		0.00		0.00	0.0	0.0	77.6	0.0
E. Production of Halocarbons and SF6			0	0	0	0.00	11842	0.00	10.91		0.00	0.0	0.0	0.0	0.0
F. Consumption of Halocarbons and SF6		b	0	0	0	12	12	83.00	64.33	0.08	0.03	0.0	0.0	0.0	0.0
G. Other			0	0	0		0.00		0.00		0.00	0.0	0.0	0.0	0.0
3. Solvent and Other Product Use			0	0	0	0	0	0	0	0	0.0	0.0	632.8	0.0	0.0
4. Agriculture			0	1012	103						8	228	23	0	0
A. Enteric Fermentation			0	864	0						0.0	0.0	0.0		
B. Manure Management			0	137	5						0.0	0.0	0.0		
C. Rice Cultivation			0	0	0						0.0	0.0	0.0		
D. Agricultural Soils			0	0	98						0.0	0.0	0.0		
E. Prescribed Burning of Savannas			0	0	0						0.0	0.0	0.0		
F. Field Burning of Agricultural Residues		c	0	11	0						7.8	227.8	22.5		
G. Other			0	0	0						0.0	0.0	0.0		
5. Land-Use Change and Forestry			2782	1	0.004	0	0	0	0	0	0.1	5.2	0	0	0
5A Forest Land			-12715	0	0						0.0	0.0			
5B Cropland			16001	0	0						0.0	0.0			
5C Grassland			-6146	0.16	0.001						0.04	1.4			
5D Wetland			0	0	0						0.0	0.0			
5E Settlements			6851	0.44	0.003						0.1	3.9			
5F Other Land			0	0	0						0.0	0.0			
5G Other Activities			-1210	0	0						0.0	0.0			
6. Waste			1199	2370	3	0	0	0	0	0	6	23	24	7	0
A. Solid Waste Disposal on Land			0	2332	0						0.0	0.0	17.8	0.0	0.0
B. Wastewater Handling		d	0	32	3						0.0	0.0	0.0	0.0	0.0
C. Waste Incineration			1199	6	0						6.1	23.3	6.6	7.2	0.0
D. Other			0	0	0						0.0	0.0	0.0	0.0	0.0
7. Other (please specify)			1878	0	0	0	0	0	0	0	0	0	0	0	0
Memo Items: (7)															
International Bunkers		e	21898	1	1	0	0	0	0	0	189	27	9	91	0
Aviation		e	15441	0	0						73.2	11.9	4.4	3.9	0
Marine		e	6457	1	0						115.6	15.0	4.3	87.1	0
Multilateral Operations															
CO2 Emissions from Biomass		ef	3138												

TABLE A9.1.3 SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (IPCC TABLE 7A) - 1992

Submission 2006

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		CO2 net	CH4	N2O	1992										
					HFCs		PFCs		SF6		NOx	CO	NMVOC	SO2	
					P	A	P	A	P	A					
(Gg)				CO2 equivalent (Gg)				(Gg)							
Total National Emissions and Removals		583087	4823	192	13	12324	95	574	0.08	0.05	2719	7668	2247	3430	
1. Energy		567392	1484	19							2698	7222	1361	3376	
A. Fuel Combustion		Reference Approach	569402												
		Sectoral Approach	560822	120	19						2685	7167	976	3352	
1. Energy Industries			224837	6	6						738.2	127.6	7.7	2584.7	
2. Manufacturing Industries and Construction			96154	14	5						344.2	694.0	34.2	464.8	
3. Transport			118173	28	5						1346.0	5111.4	818.5	95.2	
4. Other Sectors			117571	71	3						224.9	1224.1	113.5	197.8	
5. Other		a	4087	0	0						31.5	10.3	1.8	9.1	
B. Fugitive Emissions from Fuels			6570	1363	0						14	55	385	24	
1. Solid Fuels			450	887	0						0.3	32.4	0.3	16.0	
2. Oil and Natural Gas			6120	476	0						13.2	22.2	384.7	7.9	
2. Industrial Processes			10335	8	72	13	12324	95	574	0.08	0.05	8.86	251.75	246.00	46.93
A. Mineral Products			7538	1	0		0.00		0.00		0.00	0.0	3.7	12.4	3.1
B. Chemical Industry			1346	7	72		0.00		0.00		0.00	6.9	79.4	154.0	35.7
C. Metal Production			1451	0	0	0.00	0.00	0.00	490	0.00	0.02	2.0	168.7	1.9	8.1
D. Other Production			0	0	0		0.00		0.00		0.00	0.0	0.0	77.7	0.0
E. Production of Halocarbons and SF6			0	0	0	0.00	12310	0.00	10.96		0.00	0.0	0.0	0.0	0.0
F. Consumption of Halocarbons and SF6		b	0	0	0	13	13	94.74	72	0.08	0.03	0.0	0.0	0.0	0.0
G. Other			0	0	0		0.00		0.00		0.00	0.0	0.0	0.0	0.0
3. Solvent and Other Product Use			0	0	0	0	0	0	0	0	0	0.0	0.0	600.1	0.0
4. Agriculture			0	1015	98							6	165	17	0
A. Enteric Fermentation			0	870	0							0.0	0.0	0.0	
B. Manure Management			0	137	5							0.0	0.0	0.0	
C. Rice Cultivation			0	0	0							0.0	0.0	0.0	
D. Agricultural Soils			0	0	93							0.0	0.0	0.0	
E. Prescribed Burning of Savannas			0	0	0							0.0	0.0	0.0	
F. Field Burning of Agricultural Residues		c	0	8	0							5.6	165.2	16.7	
G. Other			0	0	0							0.0	0.0	0.0	
5. Land-Use Change and Forestry			2290	1	0.004	0	0	0	0	0	0	0.2	5.4	0	0
5A Forest Land			-13340	0	0							0.0	0.0		
5B Cropland			16004	0	0							0.0	0.0		
5C Grassland			-6254	0.17	0.001							0.04	1.5		
5D Wetland			0	0	0							0.0	0.0		
5E Settlements			6799	0.45	0.003							0.1	3.9		
5F Other Land			0	0	0							0.0	0.0		
5G Other Activities			-920	0	0							0.0	0.0		
6. Waste			1158	2315	3	0	0	0	0	0	0	6	23	24	7
A. Solid Waste Disposal on Land			0	2274	0							0.0	0.0	17.4	0.0
B. Wastewater Handling		d	0	35	3							0.0	0.0	0.0	0.0
C. Waste Incineration			1158	6	0							5.9	23.3	6.6	7.0
D. Other			0	0	0							0.0	0.0	0.0	0.0
7. Other (please specify)			1913	0	0	0	0	0	0	0	0	0	0	0	0
Memo Items: (?)															
International Bunkers		e	23829	1	1	0	0	0	0	0	0	201	28	9	95
Aviation		e	17081	0	1							80.1	12.7	4.4	5.4
Marine		e	6748	1	0							121.1	15.7	4.5	89.6
Multilateral Operations															
CO2 Emissions from Biomass		ef	3553												



TABLE A9.1.4 SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (IPCC TABLE 7A) - 1993

Submission 2006

1993

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		CO2 net	CH4	N2O	HFCs		PFCs		SF6		NOx	CO	NMVOC	SO2	
					P	A	P	A	P	A					
					CO2 equivalent (Gg)										(Gg)
Total National Emissions and Removals		568176	4676	180	752	13000	112	491	0.08	0.05	2545	7261	2138	3085	
1. Energy		553788	1406	19							2532	6973	1290	3035	
A. Fuel Combustion		Reference Approach	552161												
		Sectoral Approach	546900	118	19						2518	6919	909	3012	
1. Energy Industries			207078	6	5						629.6	117.5	7.5	2234.7	
2. Manufacturing Industries and Construction			95286	14	5						345.3	693.2	34.7	462.7	
3. Transport			119378	27	6						1285.2	4770.2	752.4	92.9	
4. Other Sectors			121017	70	3						228.7	1328.0	112.9	213.3	
5. Other		a	4141	0	0						29.3	10.4	1.8	8.0	
B. Fugitive Emissions from Fuels			6888	1288	0						14	54	381	24	
1. Solid Fuels			345	826	0						0.4	30.4	0.3	15.4	
2. Oil and Natural Gas			6543	462	0						13.1	23.2	381.0	8.1	
2. Industrial Processes			10278	7	61	752	13000	112	491	0.08	0.05	8.05	257.55	240.32	44.66
A. Mineral Products			7564	1	0		0.00		0.00		0.00	0.0	3.1	12.0	2.6
B. Chemical Industry			1348	6	61		0.00		0.00		0.00	6.1	81.6	148.2	33.9
C. Metal Production			1365	0	0	0.00	0.00	0.00	381.33	0.00	0.02	2.0	172.9	1.9	8.2
D. Other Production			0	0	0		0.00		0.00		0.00	0.0	0.0	78.2	0.0
E. Production of Halocarbons and SF6			0	0	0	0.00	12780	0.00	27.23		0.00	0.0	0.0	0.0	0.0
F. Consumption of Halocarbons and SF6		b	0	0	0	752	220	111.88	82.08	0.08	0.03	0.0	0.0	0.0	0.0
G. Other			0	0	0		0.00		0.00		0.00	0.0	0.0	0.0	0.0
3. Solvent and Other Product Use			0	0	0	0	0	0	0	0	0	0	583.4	0.0	0.0
4. Agriculture			0	1007	96							0	4	0	0
A. Enteric Fermentation			0	869	0							0.0	0.0	0.0	
B. Manure Management			0	138	5							0.0	0.0	0.0	
C. Rice Cultivation			0	0	0							0.0	0.0	0.0	
D. Agricultural Soils			0	0	91							0.0	0.0	0.0	
E. Prescribed Burning of Savannas			0	0	0							0.0	0.0	0.0	
F. Field Burning of Agricultural Residues		c	0	0	0							0.1	3.5	0.5	
G. Other			0	0	0							0.0	0.0	0.0	
5. Land-Use Change and Forestry			1082	0	0.003	0	0	0	0	0	0	0.1	4.0	0	0
5A Forest Land			-13714	0	0							0.0	0.0		
5B Cropland			15579	0	0							0.0	0.0		
5C Grassland			-6660	0.13	0.001							0.03	1.1		
5D Wetland			0	0	0							0.0	0.0		
5E Settlements			6719	0.32	0.002							0.1	2.8		
5F Other Land			0	0	0							0.0	0.0		
5G Other Activities			-842	0	0							0.0	0.0		
6. Waste			1075	2256	3	0	0	0	0	0	0	5	23	24	5
A. Solid Waste Disposal on Land			0	2215	0							0.0	0.0	16.9	0.0
B. Wastewater Handling		d	0	35	3							0.0	0.0	0.0	0.0
C. Waste Incineration			1075	5	0							5.5	23.3	6.6	5.3
D. Other			0	0	0							0.0	0.0	0.0	0.0
7. Other (please specify)			1954	0	0	0	0	0	0	0	0	0	0	0	0
Memo Items: (?)															
International Bunkers		e	24864	1	1	0	0	0	0	0	0	205	29	9	94
Aviation		e	18184	0	1							85.2	13.6	4.6	4.6
Marine		e	6680	1	0							119.9	15.6	4.4	89.7
Multilateral Operations															
CO2 Emissions from Biomass		ef	3705												

TABLE A9.1.5 SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (IPCC TABLE 7A) - 1994

Submission 2006

1994

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		CO2	CH4	N2O	HFCs		PFCs		SF6		NOx	CO	NM VOC	SO2
		net			P	A	P	A	P	A				
		(Gg)												
		CO2 equivalent (Gg)												
Total National Emissions and Removals		560329	4342	189	2458	14011	142	491	0.07	0.05	2455	6856	2076	2649
1. Energy		545074	1109	20							2443	6565	1240	2597
A. Fuel Combustion		545945												
	Reference Approach	537968	103	20							2430	6510	855	2574
	Sectoral Approach	202432	6	5							590.3	126.0	8.2	1901.5
2. Manufacturing Industries and Construction		95949	15	5							357.6	707.9	36.6	390.7
3. Transport		119530	25	7							1231.9	4500.6	706.5	96.3
4. Other Sectors		116097	56	3							222.5	1165.7	101.7	177.8
5. Other		a 3960	0	0							27.5	10.0	1.7	7.7
B. Fugitive Emissions from Fuels		7106	1006	0							14	55	385	23
1. Solid Fuels		163	548	0							0.4	30.8	0.3	14.3
2. Oil and Natural Gas		6943	458	0							13.1	24.0	385.1	8.4
2. Industrial Processes		11456	9	68	2458	14011	142	491	0.07	0.05	7.33	263.54	233.62	47.59
A. Mineral Products		8466	1	0		0.00		0.00		0.00	0.0	3.5	12.5	5.5
B. Chemical Industry		1350	7	68		0.00		0.00		0.00	5.3	86.2	139.9	34.0
C. Metal Production		1640	1	0	0.00	0.00	0.00	345.16	0.00	0.02	2.1	173.9	2.0	8.1
D. Other Production		0	0	0		0.00		0.00		0.00	0.0	0.0	79.2	0.0
E. Production of Halocarbons and SF6		0	0	0	0.00	13265	0.00	49.01		0.00	0.0	0.0	0.0	0.0
F. Consumption of Halocarbons and SF6		b 0	0	0	2458	746	142.19	96.38	0.07	0.03	0.0	0.0	0.0	0.0
G. Other		0	0	0		0.00		0.00		0.00	0.0	0.0	0.0	0.0
3. Solvent and Other Product Use		0	0	0	0	0	0	0	0	0	0.0	0.0	578.5	0.0
4. Agriculture		0	1013	98							0	0	0	0
A. Enteric Fermentation		0	873	0							0.0	0.0	0.0	
B. Manure Management		0	139	5							0.0	0.0	0.0	
C. Rice Cultivation		0	0	0							0.0	0.0	0.0	
D. Agricultural Soils		0	0	93							0.0	0.0	0.0	
E. Prescribed Burning of Savannas		0	0	0							0.0	0.0	0.0	
F. Field Burning of Agricultural Residues		c 0	0	0							0.0	0.0	0.0	
G. Other		0	0	0							0.0	0.0	0.0	
5. Land-Use Change and Forestry		889	1	0.004	0	0	0	0	0	0	0.1	4.5	0	0
5A Forest Land		-14193	0	0							0.0	0.0		
5B Cropland		15632	0	0							0.0	0.0		
5C Grassland		-6605	0.14	0.001							0.03	1.2		
5D Wetland		0	0	0							0.0	0.0		
5E Settlements		6688	0.38	0.003							0.1	3.3		
5F Other Land		0	0	0							0.0	0.0		
5G Other Activities		-633	0	0							0.0	0.0		
6. Waste		920	2211	3	0	0	0	0	0	0	5	23	23	4
A. Solid Waste Disposal on Land		0	2171	0							0.0	0.0	16.7	0.0
B. Wastewater Handling		d 0	36	3							0.0	0.0	0.0	0.0
C. Waste Incineration		920	4	0							4.6	22.6	6.6	4.3
D. Other		0	0	0							0.0	0.0	0.0	0.0
7. Other (please specify)		1990	0	0	0	0	0	0	0	0	0	0	0	0
Memo Items: (7)														
International Bunkers		e 25177	1	1	0	0	0	0	0	0	201	28	9	85
Aviation		e 18929	0	1							88.6	13.3	4.5	6.0
Marine		e 6249	1	0							112.1	14.6	4.2	79.4
Multilateral Operations														
CO2 Emissions from Biomass		ef 4327												

TABLE A9.1.6 SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (IPCC TABLE 7A) - 1995

Submission 2006

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		CO2 net	CH4	N2O	HFCs		PFCs		SF6		NOx	CO	NMVOC	SO2	
					P	A	P	A	P	A					
(Gg)				CO2 equivalent (Gg)				(Gg)							
Total National Emissions and Removals		550900	4298	184	4170	15494	182	471	0.08	0.05	2355	6338	1936	2343	
1. Energy		535066	1150	21							2346	6040	1135	2284	
A. Fuel Combustion		Reference Approach	543501												
		Sectoral Approach	526427	88	21						2331	5985	778	2266	
1. Energy Industries			199429	6	5						556.8	122.5	8.2	1737.6	
2. Manufacturing Industries and Construction			92710	15	5						343.9	720.8	37.3	305.6	
3. Transport			118537	23	8						1187.4	4224.4	640.2	83.9	
4. Other Sectors			111866	44	3						215.7	907.0	90.3	131.5	
5. Other		a	3886	0	0						27.6	9.8	1.7	7.6	
B. Fugitive Emissions from Fuels			8639	1062	0						14	55	357	17	
1. Solid Fuels			226	600	0						0.5	30.9	0.3	10.8	
2. Oil and Natural Gas			8413	462	0						13.9	24.2	356.8	6.6	
2. Industrial Processes			11890	7	61	4170	15494	182	471	0.08	0.05	4.62	271.14	240.73	54.47
A. Mineral Products			8599	1	0		0.00		0.00		0.00	0.0	3.5	11.8	9.7
B. Chemical Industry			1353	5	61		0.00		0.00		0.00	2.4	88.4	147.7	36.7
C. Metal Production			1939	1	0	0.00	0.00	0.00	286.29	0.00	0.02	2.2	179.3	2.0	8.1
D. Other Production			0	0	0		0.00		0.00		0.00	0.0	0.0	79.2	0.0
E. Production of Halocarbons and SF6			0	0	0	0.00	13981	0.00	70.79		0.00	0.0	0.0	0.0	0.0
F. Consumption of Halocarbons and SF6		b	0	0	0	4170	1513	181.91	113.64	0.08	0.03	0.0	0.0	0.0	0.0
G. Other			0	0	0		0.00		0.00		0.00	0.0	0.0	0.0	0.0
3. Solvent and Other Product Use			0	0	0	0	0	0	0	0	0	0.0	0.0	538.3	0.0
4. Agriculture			0	1000	98							0	0	0	0
A. Enteric Fermentation			0	864	0							0.0	0.0	0.0	
B. Manure Management			0	136	5							0.0	0.0	0.0	
C. Rice Cultivation			0	0	0							0.0	0.0	0.0	
D. Agricultural Soils			0	0	93							0.0	0.0	0.0	
E. Prescribed Burning of Savannas			0	0	0							0.0	0.0	0.0	
F. Field Burning of Agricultural Residues		c	0	0	0							0.0	0.0	0.0	
G. Other			0	0	0							0.0	0.0	0.0	
5. Land-Use Change and Forestry			1034	1	0.004	0	0	0	0	0	0	0.1	4.8	0	0
5A Forest Land			-13948	0	0							0.0	0.0		
5B Cropland			15771	0	0							0.0	0.0		
5C Grassland			-6536	0.16	0.001							0.04	1.4		
5D Wetland			0	0	0							0.0	0.0		
5E Settlements			6647	0.39	0.003							0.1	3.4		
5F Other Land			0	0	0							0.0	0.0		
5G Other Activities			-900	0	0							0.0	0.0		
6. Waste			920	2141	3	0	0	0	0	0	0	4	22	23	4
A. Solid Waste Disposal on Land			0	2102	0							0.0	0.0	16.1	0.0
B. Wastewater Handling		d	0	35	3							0.0	0.0	0.0	0.0
C. Waste Incineration			920	4	0							4.1	22.3	6.6	4.2
D. Other			0	0	0							0.0	0.0	0.0	0.0
7. Other (please specify)			1990	0	0	0	0	0	0	0	0	0	0	0	0
Memo Items: (7)															
International Bunkers		e	26836	1	1	0	0	0	0	0	0	214	29	9	96
Aviation		e	20129	0	1							93.9	13.8	4.5	5.1
Marine		e	6707	1	0							120.3	15.6	4.5	91.1
Multilateral Operations															
CO2 Emissions from Biomass		ef	4644												

TABLE A9.1.7 SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (IPCC TABLE 7A) - 1996

Submission 2006

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		CO2 net	CH4	N2O	HFCs		PFCs		SF6		NOx	CO	NMVOC	SO2
					P	A	P	A	P	A				
(Gg)				CO2 equivalent (Gg)				(Gg)						
Total National Emissions and Removals		572563	4183	190	5236	16724	227	493	0.05	0.05	2277	6189	1830	1999
1. Energy		556320	1096	22							2268	5890	1046	1942
A. Fuel Combustion	Reference Approach	555768												
	Sectoral Approach	547057	90	22							2257	5836	705	1923
1. Energy Industries		200887	6	4							511.7	121.4	8.8	1468.5
2. Manufacturing Industries and Construction		93883	16	5							320.0	729.6	37.5	242.8
3. Transport		123359	22	10							1164.7	4048.4	566.4	70.8
4. Other Sectors		125122	47	3							232.8	926.9	91.0	133.6
5. Other	a	3805	0	0							27.6	9.6	1.7	7.6
B. Fugitive Emissions from Fuels		9263	1005	0							11	54	341	19
1. Solid Fuels		367	556	0							0.4	30.9	0.3	11.5
2. Oil and Natural Gas		8897	449	0							11.0	23.2	340.7	7.1
2. Industrial Processes		12456	8	65	5236	16724	227	493	0.05	0.05	4.49	270.40	234.53	54.19
A. Mineral Products		8875	1	0		0.00		0.00		0.00	0.0	3.2	10.6	10.2
B. Chemical Industry		1355	6	65		0.00		0.00		0.00	2.2	85.5	140.5	35.7
C. Metal Production		2226	1	0	0.00	0.00	0.00	282.17	0.00	0.02	2.2	181.7	2.1	8.3
D. Other Production		0	0	0		0.00		0.00		0.00	0.0	0.0	81.3	0.0
E. Production of Halocarbons and SF6		0	0	0	0.00	14321	0.00	77.14		0.00	0.0	0.0	0.0	0.0
F. Consumption of Halocarbons and SF6	b	0	0	0	5236	2404	227.38	133.96	0.05	0.04	0.0	0.0	0.0	0.0
G. Other		0	0	0		0.00		0.00		0.00	0.0	0.0	0.0	0.0
3. Solvent and Other Product Use		0	0	0	0	0	0	0	0	0	0.0	0.0	527.1	0.0
4. Agriculture		0	1008	99							0	0	0	0
A. Enteric Fermentation		0	871	0							0.0	0.0	0.0	
B. Manure Management		0	137	5							0.0	0.0	0.0	
C. Rice Cultivation		0	0	0							0.0	0.0	0.0	
D. Agricultural Soils		0	0	94							0.0	0.0	0.0	
E. Prescribed Burning of Savannas		0	0	0							0.0	0.0	0.0	
F. Field Burning of Agricultural Residues	c	0	0	0							0.0	0.0	0.0	
G. Other		0	0	0							0.0	0.0	0.0	
5. Land-Use Change and Forestry		902	1	0.005	0	0	0	0	0	0	0.2	5.8	0	0
5A Forest Land		-13720	0	0							0.0	0.0		
5B Cropland		15802	0	0							0.0	0.0		
5C Grassland		-6786	0.18	0.001							0.05	1.6		
5D Wetland		0	0	0							0.0	0.0		
5E Settlements		6627	0.48	0.003							0.1	4.2		
5F Other Land		0	0	0							0.0	0.0		
5G Other Activities		-1021	0	0							0.0	0.0		
6. Waste		885	2070	4	0	0	0	0	0	0	4	23	22	3
A. Solid Waste Disposal on Land		0	2031	0							0.0	0.0	15.6	0.0
B. Wastewater Handling	d	0	36	3							0.0	0.0	0.0	0.0
C. Waste Incineration		885	4	0							4.4	22.9	6.6	2.8
D. Other		0	0	0							0.0	0.0	0.0	0.0
7. Other (please specify)		2000	0	0	0	0	0	0	0	0	0	0	0	0
Memo Items: (7)														
International Bunkers		e	28672	1	1	0	0	0	0	0	232	32	10	104
Aviation		e	21342	0	1						100.1	14.5	4.7	5.4
Marine		e	7330	1	0						131.5	17.1	4.9	98.8
Multilateral Operations														
CO2 Emissions from Biomass	ef	4884												

TABLE A9.1.8 SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (IPCC TABLE 7A) - 1997

Submission 2006

1997

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		CO2 net	CH4	N2O	HFCs		PFCs		SF6		NOx	CO	NMVOC	SO2
					P	A	P	A	P	A				
		(Gg)				CO2 equivalent (Gg)				(Gg)				
Total National Emissions and Removals		549624	3952	195	7095	19187	279	417	0.03	0.05	2121	5723	1764	1635
1. Energy		534021	1042	22							2114	5418	1014	1576
A. Fuel Combustion	Reference Approach	532119												
	Sectoral Approach	527030	86	22						2109	5369	645	1557	
1. Energy Industries		188060	6	4						431.7	69.8	7.0	1144.2	
2. Manufacturing Industries and Construction		94713	16	5						318.8	716.0	37.8	231.3	
3. Transport		124825	20	11						1109.0	3717.4	512.1	58.6	
4. Other Sectors		115801	43	3						221.0	856.3	86.9	115.0	
5. Other		3631	0	0						28.2	9.1	1.6	8.2	
B. Fugitive Emissions from Fuels		6991	956	0						5	49	369	19	
1. Solid Fuels		460	533	0						0.4	30.9	0.3	11.4	
2. Oil and Natural Gas		6532	424	0						4.4	18.4	368.4	7.4	
2. Industrial Processes		12547	6	67	7095	19187	279	417	0.03	0.05	4.85	277.35	216.18	58.11
A. Mineral Products		9696	1	0		0.00		0.00		0.00	0.0	3.2	10.0	13.4
B. Chemical Industry		888	5	67		0.00		0.00		0.00	2.6	86.3	124.1	34.0
C. Metal Production		1962	1	0	0.00	0.00	0.00	220.26	0.00	0.02	2.2	187.8	2.1	10.7
D. Other Production		0	0	0		0.00		0.00		0.00	0.0	0.0	79.9	0.0
E. Production of Halocarbons and SF6		0	0	0	0.00	15622	0.00	38.34		0.00	0.0	0.0	0.0	0.0
F. Consumption of Halocarbons and SF6		0	0	0	7095	3564	279.38	158.24	0.03	0.03	0.0	0.0	0.0	0.0
G. Other		0	0	0		0.00		0.00		0.00	0.0	0.0	0.0	0.0
3. Solvent and Other Product Use		0	0	0	0	0	0	0	0	0	0.0	0.0	512.9	0.0
4. Agriculture		0	997	102							0	0	0	0
A. Enteric Fermentation		0	860	0							0.0	0.0	0.0	
B. Manure Management		0	137	5							0.0	0.0	0.0	
C. Rice Cultivation		0	0	0							0.0	0.0	0.0	
D. Agricultural Soils		0	0	97							0.0	0.0	0.0	
E. Prescribed Burning of Savannas		0	0	0							0.0	0.0	0.0	
F. Field Burning of Agricultural Residues		0	0	0							0.0	0.0	0.0	
G. Other		0	0	0							0.0	0.0	0.0	
5. Land-Use Change and Forestry		552	1	0.005	0	0	0	0	0	0	0.2	6.0	0	0
5A Forest Land		-13512	0	0							0.0	0.0		
5B Cropland		15542	0	0							0.0	0.0		
5C Grassland		-6889	0.15	0.001							0.04	1.3		
5D Wetland		0	0	0							0.0	0.0		
5E Settlements		6607	0.53	0.004							0.1	4.6		
5F Other Land		0	0	0							0.0	0.0		
5G Other Activities		-1197	0	0							0.0	0.0		
6. Waste		500	1906	4	0	0	0	0	0	0	2	22	21	1
A. Solid Waste Disposal on Land		0	1869	0							0.0	0.0	14.4	0.0
B. Wastewater Handling		0	37	4							0.0	0.0	0.0	0.0
C. Waste Incineration		500	0	0							1.9	21.8	6.5	1.1
D. Other		0	0	0							0.0	0.0	0.0	0.0
7. Other (please specify)		2005	0	0	0	0	0	0	0	0	0	0	0	0
Memo Items: (7)														
International Bunkers		e	30914	1	1	0	0	0	0	0	253	34	10	124
Aviation		e	22694	0	1						106.4	15.0	4.9	7.2
Marine		e	8221	1	1						147.1	19.1	5.5	116.9
Multilateral Operations														
CO2 Emissions from Biomass		ef	5167											

TABLE A9.1.9 SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (IPCC TABLE 7A) - 1998

Submission 2006

1998

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		CO2 net	CH4	N2O	HFCs		PFCs		SF6		NOx	CO	NMVOC	SO2
					P	A	P	A	P	A				
		(Gg)					CO2 equivalent (Gg)					(Gg)		
Total National Emissions and Removals		551368	3730	186	8804	17275	293	421	0.03	0.05	2052	5328	1615	1591
1. Energy		536357	954	24							2046	5044	902	1533
A. Fuel Combustion	Reference Approach	539183												
	Sectoral Approach	529767	85	23							2042	4996	572	1516
1. Energy Industries		191626	6	4							427.8	81.1	4.7	1160.0
2. Manufacturing Industries and Construction		93236	16	5							318.6	706.2	38.1	206.1
3. Transport		124080	19	12							1052.7	3391.0	442.7	51.4
4. Other Sectors		117631	45	3							220.7	809.5	85.3	92.1
5. Other		a 3194	0	0							21.7	8.1	1.4	6.0
B. Fugitive Emissions from Fuels		6590	869	0							4	48	330	17
1. Solid Fuels		158	454	0							0.4	30.7	0.3	9.5
2. Oil and Natural Gas		6431	415	0							3.8	17.7	329.7	7.5
2. Industrial Processes		12524	5	59	8804	17275	293	421	0.03	0.05	4.15	254.19	196.44	56.87
A. Mineral Products		9626	1	0		0.00		0.00		0.00	0.0	3.3	9.9	13.1
B. Chemical Industry		1111	3	59		0.00		0.00		0.00	2.5	68.8	104.7	34.4
C. Metal Production		1787	1	0	0.00	0.00	0.00	217.11	0.00	0.02	1.7	182.0	2.0	9.4
D. Other Production		0	0	0		0.00		0.00		0.00	0.0	0.0	79.8	0.0
E. Production of Halocarbons and SF6		0	0	0	0.00	12357	0.00	42.51		0.00	0.0	0.0	0.0	0.0
F. Consumption of Halocarbons and SF6		b 0	0	0	8804	4917	293.05	161.30	0.03	0.03	0.0	0.0	0.0	0.0
G. Other		0	0	0		0.00		0.00		0.00	0.0	0.0	0.0	0.0
3. Solvent and Other Product Use		0	0	0	0	0	0	0	0	0	0.0	0.0	496.3	0.0
4. Agriculture		0	995	99							0	0	0	0
A. Enteric Fermentation		0	858	0							0.0	0.0	0.0	
B. Manure Management		0	137	5							0.0	0.0	0.0	
C. Rice Cultivation		0	0	0							0.0	0.0	0.0	
D. Agricultural Soils		0	0	94							0.0	0.0	0.0	
E. Prescribed Burning of Savannas		0	0	0							0.0	0.0	0.0	
F. Field Burning of Agricultural Residues		c 0	0	0							0.0	0.0	0.0	
G. Other		0	0	0							0.0	0.0	0.0	
5. Land-Use Change and Forestry		0	1	0.005	0	0	0	0	0	0	0.2	6.0	0	0
5A Forest Land		-13406	0	0							0.0	0.0		
5B Cropland		15427	0	0							0.0	0.0		
5C Grassland		-7288	0.16	0.001							0.04	1.4		
5D Wetland		0	0	0							0.0	0.0		
5E Settlements		6573	0.53	0.004							0.1	4.7		
5F Other Land		0	0	0							0.0	0.0		
5G Other Activities		-1306	0	0							0.0	0.0		
6. Waste		504	1776	4	0	0	0	0	0	0	2	23	20	1
A. Solid Waste Disposal on Land		0	1738	0							0.0	0.0	13.5	0.0
B. Wastewater Handling		d 0	38	4							0.0	0.0	0.0	0.0
C. Waste Incineration		504	0	0							1.9	23.4	6.6	1.2
D. Other		0	0	0							0.0	0.0	0.0	0.0
7. Other (please specify)		1983	0	0	0	0	0	0	0	0	0	0	0	0
Memo Items: (7)														
International Bunkers		e 34226	1	1	0	0	0	0	0	0	278	37	11	125
Aviation		e 25254	0	1							117.9	16.3	5.3	8.0
Marine		e 8971	1	1							160.2	20.8	5.9	116.8
Multilateral Operations														
CO2 Emissions from Biomass		ef 5823												

TABLE A9.1.10 SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (IPCC TABLE 7A) - 1999

Submission 2006

GREENHOUSE GAS SOURCE AND SINK CATEGORIES															CO2 net		CH4	N2O	HFCs		PFCs		SF6		NOx	CO	NMVOC	SO2
															(Gg)		CO2 equivalent (Gg)						(Gg)					
Total National Emissions and Removals															542055	3479	143	9756	10838	330	399	0.03	0.06	1936	5010	1461	1202	
1. Energy															527477	866	24								1930	4707	814	1154
A. Fuel Combustion															533682													
Reference Approach															521212	87	24								1925	4666	512	1144
Sectoral Approach															181232	7	4								384.9	72.8	4.6	848.6
1. Energy Industries															94527	16	5								309.2	710.6	37.6	169.1
2. Manufacturing Industries and Construction															124942	17	13								989.3	3064.6	382.4	39.2
3. Transport															117361	47	3								219.0	809.7	85.5	81.1
4. Other Sectors																												
5. Other															a	3150	0	0							22.9	7.9	1.4	6.3
B. Fugitive Emissions from Fuels															6264	779	0								5	41	303	10
1. Solid Fuels															112	381	0								0.3	23.9	0.3	8.0
2. Oil and Natural Gas															6152	398	0								4.3	17.1	302.5	1.7
2. Industrial Processes															12342	4	18	9756	10838	330	399	0.03	0.06	4.41	272.16	165.97	46.22	
A. Mineral Products															9137	1	0		0.00		0.00	0.00	0.00	0.0	1.6	8.6	8.9	
B. Chemical Industry															1113	2	18		0.00		0.00	0.00	0.00	2.7	65.6	74.2	29.0	
C. Metal Production															2091	1	0	0.00	0.00	0.00	190.59	0.00	0.03	1.7	205.0	1.9	8.3	
D. Other Production															0	0	0		0.00		0.00		0.00	0.0	0.0	81.3	0.0	
E. Production of Halocarbons and SF6															0	0	0	0.00	5381	0.00	19.50		0.00	0.0	0.0	0.0	0.0	
F. Consumption of Halocarbons and SF6															b	0	0	9756	5457	330.47	188.56	0.03	0.03	0.0	0.0	0.0	0.0	
G. Other															0	0	0		0.00		0.00		0.00	0.0	0.0	0.0	0.0	
3. Solvent and Other Product Use															0	0	0	0	0	0	0	0	0	0.0	0.0	462.6	0.0	
4. Agriculture															0	992	97							0	0	0	0	
A. Enteric Fermentation															0	857	0							0.0	0.0	0.0		
B. Manure Management															0	135	5							0.0	0.0	0.0		
C. Rice Cultivation															0	0	0							0.0	0.0	0.0		
D. Agricultural Soils															0	0	92							0.0	0.0	0.0		
E. Prescribed Burning of Savannas															0	0	0							0.0	0.0	0.0		
F. Field Burning of Agricultural Residues															c	0	0	0						0.0	0.0	0.0		
G. Other															0	0	0							0.0	0.0	0.0		
5. Land-Use Change and Forestry															-234	1	0.006	0	0	0	0	0	0	0.2	7.3	0	0	
5A Forest Land															-13504	0	0							0.0	0.0			
5B Cropland															15328	0	0							0.0	0.0			
5C Grassland															-7275	0.39	0.003							0.10	3.4			
5D Wetland															0	0	0							0.0	0.0			
5E Settlements															6485	0.44	0.003							0.1	3.9			
5F Other Land															0	0	0							0.0	0.0			
5G Other Activities															-1268	0	0							0.0	0.0			
6. Waste															457	1616	4	0	0	0	0	0	0	2	24	18	1	
A. Solid Waste Disposal on Land															0	1579	0							0.0	0.0	11.1	0.0	
B. Wastewater Handling															d	0	36	4						0.0	0.0	0.0	0.0	
C. Waste Incineration															457	0	0							1.8	23.5	6.7	1.4	
D. Other															0	0	0							0.0	0.0	0.0	0.0	
7. Other (please specify)															2014	0	0	0	0	0	0	0	0	0	0	0	0	
Memo Items: (7)																												
International Bunkers															e	33941	1	1	0	0	0	0	0	242	32	10	89	
Aviation															e	27440	0	1						126.6	17.2	5.5	6.1	
Marine															e	6501	1	0						115.9	15.0	4.3	83.1	
Multilateral Operations																												
CO2 Emissions from Biomass															ef	6411												

TABLE A9.1.11 SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (IPCC TABLE 7A) - 2000

Submission 2006

2000

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		CO2	CH4	N2O	HFCs		PFCs		SF6		NOx	CO	NM VOC	SO2
		net			P	A	P	A	P	A				
		(Gg)												
		CO2 equivalent (Gg)												
Total National Emissions and Removals		547605	3263	143	11442	9092	370	498	0.03	0.08	1856	4283	1346	1173
1. Energy		533635	788	25							1850	3992	739	1133
A. Fuel Combustion		543913												
	Reference Approach	527961	76	25							1847	3953	429	1125
	Sectoral Approach	191835	8	4							413.4	82.5	6.6	888.2
1. Energy Industries		92127	15	4							291.1	598.8	37.2	135.3
2. Manufacturing Industries and Construction		124257	15	14							906.0	2568.2	309.5	29.6
3. Transport		116826	37	2							214.3	695.8	74.6	65.4
4. Other Sectors		a	2916	0	0						22.0	7.3	1.3	6.1
5. Other		5674	712	0							4	39	310	9
B. Fugitive Emissions from Fuels		102	333	0							0.3	24.4	0.2	7.3
1. Solid Fuels		5571	379	0							3.3	15.0	310.0	1.6
2. Oil and Natural Gas		11938	3	20	11442	9092	370	498	0.03	0.08	4.06	258.87	156.66	37.95
2. Industrial Processes		8655	1	0		0.00		0.00		0.00	0.0	2.8	9.8	10.5
A. Mineral Products		1301	2	20		0.00		0.00		0.00	2.4	82.6	65.8	20.1
B. Chemical Industry		1983	1	0	0.00	0.00	0.00	257.88	0.00	0.05	1.6	173.5	1.8	7.3
C. Metal Production		0	0	0		0.00		0.00		0.00	0.0	0.0	79.3	0.0
D. Other Production		0	0	0	0.00	2677	0.00	23.08		0.00	0.0	0.0	0.0	0.0
E. Production of Halocarbons and SF6		b	0	0	11442	6415	370.47	217.28	0.03	0.03	0.0	0.0	0.0	0.0
F. Consumption of Halocarbons and SF6		0	0	0		0.00		0.00		0.00	0.0	0.0	0.0	0.0
G. Other		0	0	0							0.0	0.0	0.0	0.0
3. Solvent and Other Product Use		0	0	0	0	0	0	0	0	0	0.0	0.0	432.7	0.0
4. Agriculture		0	959	93							0	0	0	0
A. Enteric Fermentation		0	829	0							0.0	0.0	0.0	
B. Manure Management		0	130	5							0.0	0.0	0.0	
C. Rice Cultivation		0	0	0							0.0	0.0	0.0	
D. Agricultural Soils		0	0	88							0.0	0.0	0.0	
E. Prescribed Burning of Savannas		0	0	0							0.0	0.0	0.0	
F. Field Burning of Agricultural Residues		c	0	0							0.0	0.0	0.0	
G. Other		0	0	0							0.0	0.0	0.0	
5. Land-Use Change and Forestry		-440	1	0.006	0	0	0	0	0	0	0.2	8.1	0	0
5A Forest Land		-13805	0	0							0.0	0.0		
5B Cropland		15339	0	0							0.0	0.0		
5C Grassland		-7427	0.59	0.004							0.15	5.1		
5D Wetland		0	0	0							0.0	0.0		
5E Settlements		6402	0.34	0.002							0.1	2.9		
5F Other Land		0	0	0							0.0	0.0		
5G Other Activities		-950	0	0							0.0	0.0		
6. Waste		463	1512	4	0	0	0	0	0	0	2	24	17	1
A. Solid Waste Disposal on Land		0	1474	0							0.0	0.0	10.7	0.0
B. Wastewater Handling		d	0	37							0.0	0.0	0.0	0.0
C. Waste Incineration		463	0	0							1.8	23.5	6.7	1.2
D. Other		0	0	0							0.0	0.0	0.0	0.0
7. Other (please specify)		2009	0	0	0	0	0	0	0	0	0	0	0	0
Memo Items: (7)														
International Bunkers		e	35955	1	0	0	0	0	0	0	240	32	10	76
Aviation		e	30243	0	1						138.2	18.3	5.8	6.9
Marine		e	5712	1	0						101.8	13.2	3.8	69.4
Multilateral Operations														
CO2 Emissions from Biomass		ef	6873											



**TABLE A9.1.12 SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (IPCC TABLE 7A) - 2001**  
**SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (IPCC TABLE 7A)**

Submission 2006

2001

GREENHOUSE GAS SOURCE AND SINK CATEGORIES			CO2	CH4	N2O	HFCs		PFCs		SF6		NOx	CO	NM VOC	SO2
			net			P	A	P	A	P	A				
			(Gg)										(Gg)		
Total National Emissions and Removals			562774	2985	136	11952	9686	263	425	0.04	0.06	1799	4108	1250	1111
1. Energy			550150	760	27							1793	3790	671	1075
A. Fuel Combustion		Reference Approach	553819												
		Sectoral Approach	544569	77	27							1789	3762	376	1066
1. Energy Industries			201743	8	4							432.8	79.9	5.5	796.0
2. Manufacturing Industries and Construction			95299	14	5							294.8	713.6	37.2	172.3
3. Transport			123601	13	15							823.3	2199.3	255.3	21.7
4. Other Sectors			121004	42	2							217.5	762.4	76.7	69.8
5. Other			a 2922	0	0							20.8	7.4	1.3	5.7
B. Fugitive Emissions from Fuels			5581	683	0							4	28	295	10
1. Solid Fuels			102	302	0							0.3	13.7	0.2	8.2
2. Oil and Natural Gas			5479	381	0							3.4	14.2	295.3	1.6
2. Industrial Processes			10706	3	17	11952	9686	263	425	0.04	0.06	3.03	263.29	148.75	33.07
A. Mineral Products			7849	1	0		0.00		0.00		0.00	0.0	2.5	9.2	9.0
B. Chemical Industry			1373	2	17		0.00		0.00		0.00	1.6	81.7	57.3	16.3
C. Metal Production			1485	0	0	0.00	0.00	0.00	223.22	0.00	0.03	1.4	179.1	1.6	7.8
D. Other Production			0	0	0		0.00		0.00		0.00	0.0	0.0	80.7	0.0
E. Production of Halocarbons and SF6			0	0	0	0.00	2451.94	0.00	54.05		0.00	0.0	0.0	0.0	0.0
F. Consumption of Halocarbons and SF6			b 0	0	0	11952.23	7234.30	262.60	148.07	0.04	0.03	0.0	0.0	0.0	0.0
G. Other			0	0	0		0.00		0.00		0.00	0.0	0.0	0.0	0.0
3. Solvent and Other Product Use			0	0	0	0	0	0	0	0	0	0.0	0.0	414.6	0.0
4. Agriculture			0	904	87							0	0	0	0
A. Enteric Fermentation			0	779	0							0.0	0.0	0.0	0.0
B. Manure Management			0	125	5							0.0	0.0	0.0	0.0
C. Rice Cultivation			0	0	0							0.0	0.0	0.0	0.0
D. Agricultural Soils			0	0	83							0.0	0.0	0.0	0.0
E. Prescribed Burning of Savannas			0	0	0							0.0	0.0	0.0	0.0
F. Field Burning of Agricultural Residues			c 0	0	0							0.0	0.0	0.0	0.0
G. Other			0	0	0							0.0	0.0	0.0	0.0
5. Land-Use Change and Forestry			-596	1	0.008	0	0	0	0	0	0	0.3	9.7	0	0
5A Forest Land			-14348	0	0							0.0	0.0		
5B Cropland			15287	0	0							0.0	0.0		
5C Grassland			-7449	0.77	0.005							0.19	6.8		
5D Wetland			0	0	0							0.0	0.0		
5E Settlements			6358	0.33	0.002							0.1	2.9		
5F Other Land			0	0	0							0.0	0.0		
5G Other Activities			-445	0	0							0.0	0.0		
6. Waste			490	1317	4	0	0	0	0	0	0	2	45	15	2
A. Solid Waste Disposal on Land			0	1279	0							0.0	0.0	8.9	0.0
B. Wastewater Handling			d 0	38	4							0.0	0.0	0.0	0.0
C. Waste Incineration			490	0	0							2.4	44.8	6.6	2.3
D. Other			0	0	0							0.0	0.0	0.0	0.0
7. Other (please specify)			2025	0	0	0	0	0	0	0	0	0	0	0	0
Memo Items: (7)															
International Bunkers			e 35901	1	1	0	0	0	0	0	0	248	32	10	78
Aviation			e 29484	0	1							133.9	17.3	5.4	7.5
Marine			e 6417	1	0							114.4	14.9	4.2	70.0
Multilateral Operations															
CO2 Emissions from Biomass			ef 7223												

TABLE A9.1.13 SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (IPCC TABLE 7A) - 2002

Submission 2006

2002

GREENHOUSE GAS SOURCE AND SINK CATEGORIES			CO2 net	CH4	N2O	HFCs		PFCs		SF6		NOx	CO	NMVOC	SO2
						P	A	P	A	P	A				
			(Gg)						CO2 equivalent (Gg)						(Gg)
Total National Emissions and Removals			546221	2843	131	12466	9907	154	323	0.03	0.06	1693	3614	1173	994
1. Energy			534732	743	27							1688	3369	612	962
A. Fuel Combustion		Reference Approach	534338												
		Sectoral Approach	529102	70	27							1684	3348	332	955
1. Energy Industries			200029	7	4							430.9	76.8	7.4	733.1
2. Manufacturing Industries and Construction			84742	13	4							264.2	681.9	36.3	141.2
3. Transport			125902	12	16							761.3	1918.1	215.6	21.1
4. Other Sectors			115372	37	2							207.7	663.2	71.6	54.6
5. Other			a 3057	0	0							20.0	7.7	1.3	5.2
B. Fugitive Emissions from Fuels			5630	674	0							4	21	280	7
1. Solid Fuels			111	302	0							0.3	7.1	0.1	5.8
2. Oil and Natural Gas			5519	372	0							3.8	13.7	279.7	1.2
2. Industrial Processes			10061	3	10	12466	9907	154	323	0.03	0.06	2.29	213.99	144.37	30.79
A. Mineral Products			7655	1	0		0.00		0.00		0.00	0.0	2.5	9.6	11.9
B. Chemical Industry			1233	2	10		0.00		0.00		0.00	1.1	39.2	53.1	12.7
C. Metal Production			1172	0	0	0.00	0.00	0.00	158.48	0.00	0.04	1.2	172.3	1.4	6.2
D. Other Production			0	0	0		0.00		0.00		0.00	0.0	0.0	80.3	0.0
E. Production of Halocarbons and SF6			0	0	0	0.00	1990	0.00	57.35		0.00	0.0	0.0	0.0	0.0
F. Consumption of Halocarbons and SF6			b 0	0	0	12466	7917	154.38	106.88	0.03	0.03	0.0	0.0	0.0	0.0
G. Other			0	0	0		0.00		0.00		0.00	0.0	0.0	0.0	0.0
3. Solvent and Other Product Use			0	0	0	0	0	0	0	0	0	0.0	0.0	402.2	0.0
4. Agriculture			0	895	89							0	0	0	0
A. Enteric Fermentation			0	771	0							0.0	0.0	0.0	
B. Manure Management			0	124	5							0.0	0.0	0.0	
C. Rice Cultivation			0	0	0							0.0	0.0	0.0	
D. Agricultural Soils			0	0	85							0.0	0.0	0.0	
E. Prescribed Burning of Savannas			0	0	0							0.0	0.0	0.0	
F. Field Burning of Agricultural Residues			c 0	0	0							0.0	0.0	0.0	
G. Other			0	0	0							0.0	0.0	0.0	
5. Land-Use Change and Forestry			-1120	1	0.006	0	0	0	0	0	0	0.2	8.1	0	0
5A Forest Land			-15045	0	0							0.0	0.0		
5B Cropland			15314	0	0							0.0	0.0		
5C Grassland			-7742	0.67	0.005							0.17	5.9		
5D Wetland			0	0	0							0.0	0.0		
5E Settlements			6306	0.25	0.002							0.1	2.2		
5F Other Land			0	0	0							0.0	0.0		
5G Other Activities			47	0	0							0.0	0.0		
6. Waste			481	1202	4	0	0	0	0	0	0	2	24	15	1
A. Solid Waste Disposal on Land			0	1164	0							0.0	0.0	8.1	0.0
B. Wastewater Handling			d 0	38	4							0.0	0.0	0.0	0.0
C. Waste Incineration			481	0	0							1.8	23.5	6.6	0.9
D. Other			0	0	0							0.0	0.0	0.0	0.0
7. Other (please specify)			2067	0	0	0	0	0	0	0	0	0	0	0	0
Memo Items: (?)															
International Bunkers			e 34279	1	1	0	0	0	0	0	0	226	29	9	67
Aviation			e 28934	0	1							130.5	17.0	5.5	6.1
Marine			e 5345	0	0							95.2	12.4	3.5	60.8
Multilateral Operations															
CO2 Emissions from Biomass			ef 7531												

TABLE A9.1.14 SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (IPCC TABLE 7A) - 2003

Submission 2006

2003

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		CO2 net	CH4	N2O	HFCs		PFCs		SF6		NOx	CO	NMVOC	SO2
					P	A	P	A	P	A				
CO2 equivalent (Gg)										(Gg)				
Total National Emissions and Removals		557759	2553	129	11915	10201	151	297	0.03	0.06	1685	3099	1071	973
1. Energy		545526	597	28							1680	2929	517	939
A. Fuel Combustion		542207												
Sectoral Approach		540164	62	28							1677	2907	288	930
1. Energy Industries		208320	7	4							457.0	83.7	5.6	729.6
2. Manufacturing Industries and Construction		86186	14	4							267.4	623.4	35.9	122.6
3. Transport		127290	11	17							729.7	1657.5	181.2	31.3
4. Other Sectors		115553	30	2							207.1	534.9	63.9	43.4
5. Other		a 2815	0	0							15.5	7.2	1.1	3.7
B. Fugitive Emissions from Fuels		5362	535	0							3	23	230	9
1. Solid Fuels		112	260	0							0.3	10.7	0.1	7.3
2. Oil and Natural Gas		5251	275	0							2.9	11.8	229.5	1.2
2. Industrial Processes		10865	3	10	11915	10201	151	297	0.03	0.06	2.58	138.43	143.50	33.30
A. Mineral Products		7852	1	0		0.00		0.00		0.00	0.0	2.7	9.2	16.2
B. Chemical Industry		1164	2	10		0.00		0.00		0.00	1.2	37.1	52.1	9.5
C. Metal Production		1848	1	0	0.00	0.00	0.00	126.00	0.00	0.03	1.4	98.7	1.6	7.6
D. Other Production		0	0	0		0.00		0.00		0.00	0.0	0.0	80.6	0.0
E. Production of Halocarbons and SF6		0	0	0	0.00	1852	0.00	66.00		0.00	0.0	0.0	0.0	0.0
F. Consumption of Halocarbons and SF6		b 0	0	0	11915	8350	151.42	104.81	0.03	0.03	0.0	0.0	0.0	0.0
G. Other		0	0	0		0.00		0.00		0.00	0.0	0.0	0.0	0.0
3. Solvent and Other Product Use		0	0	0	0	0	0	0	0	0	0.0	0.0	397.0	0.0
4. Agriculture		0	898	87							0	0	0	0
A. Enteric Fermentation		0	774	0							0.0	0.0	0.0	
B. Manure Management		0	123	4							0.0	0.0	0.0	
C. Rice Cultivation		0	0	0							0.0	0.0	0.0	
D. Agricultural Soils		0	0	82							0.0	0.0	0.0	
E. Prescribed Burning of Savannas		0	0	0							0.0	0.0	0.0	
F. Field Burning of Agricultural Residues		c 0	0	0							0.0	0.0	0.0	
G. Other		0	0	0							0.0	0.0	0.0	
5. Land-Use Change and Forestry		-1180	1	0.006	0	0	0	0	0	0	0.2	7.7	0	0
5A Forest Land		-15646	0	0							0.0	0.0		
5B Cropland		15380	0	0							0.0	0.0		
5C Grassland		-7526	0.63	0.004							0.16	5.5		
5D Wetland		0	0	0							0.0	0.0		
5E Settlements		6274	0.24	0.002							0.1	2.1		
5F Other Land		0	0	0							0.0	0.0		
5G Other Activities		337	0	0							0.0	0.0		
6. Waste		460	1056	4	0	0	0	0	0	0	2	24	14	1
A. Solid Waste Disposal on Land		0	1017	0							0.0	0.0	7.2	0.0
B. Wastewater Handling		d 0	38	4							0.0	0.0	0.0	0.0
C. Waste Incineration		460	0	0							1.8	23.5	6.6	0.9
D. Other		0	0	0							0.0	0.0	0.0	0.0
7. Other (please specify)		2088	0	0	0	0	0	0	0	0	0	0	0	0
Memo Items: (7)														
International Bunkers		e 34776	1	1	0	0	0	0	0	0	225	29	9	70
Aviation		e 29643	0	1							133.7	17.1	5.5	7.2
Marine		e 5133	0	0							91.2	11.8	3.4	63.1
Multilateral Operations														
CO2 Emissions from Biomass		ef 8283												

TABLE A9.1.15 SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (IPCC TABLE 7A) – 2004

Submission 2006 2004													
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO2 net	CH4	N2O	HFCs		PFCs		SF6		NOx	CO	NM VOC	SO2
				P	A	P	A	P	A				
	(Gg)			CO2 equivalent (Gg)				(Gg)					
<b>Total National Emissions and Removals</b>	<b>560418</b>	<b>2469</b>	<b>132</b>	<b>9799</b>	<b>8873</b>	<b>149</b>	<b>352</b>	<b>0.03</b>	<b>0.05</b>	<b>1621</b>	<b>2919</b>	<b>1022</b>	<b>833</b>
<b>1. Energy</b>	<b>548447</b>	<b>584</b>	<b>29</b>							<b>1616</b>	<b>2757</b>	<b>465</b>	<b>801</b>
A. Fuel Combustion													
Reference Approach	547547												
Sectoral Approach	543179	63	29							1613	2738	257	791
1. Energy Industries	207940	7	4							444.7	84.0	5.9	565.1
2. Manufacturing Industries and Construction	87890	14	4							263.0	660.3	35.1	140.7
3. Transport	128758	9	18							691.7	1435.1	150.8	38.7
4. Other Sectors	115687	32	2							193.1	551.5	64.3	41.0
5. Other	a 2903	0	0							20.2	7.3	1.3	5.4
B. Fugitive Emissions from Fuels	5268	521	0							3	19	208	10
1. Solid Fuels	168	235	0							0.4	6.6	0.1	8.8
2. Oil and Natural Gas	5100	286	0							2.8	12.0	207.9	1.3
<b>2. Industrial Processes</b>	<b>11368</b>	<b>3</b>	<b>13</b>	<b>9799</b>	<b>8873</b>	<b>149</b>	<b>352</b>	<b>0.03</b>	<b>0.05</b>	<b>2.66</b>	<b>131.67</b>	<b>145.74</b>	<b>31.20</b>
A. Mineral Products	7950	1	0		0.00		0.00		0.00	0.0	2.6	9.5	16.4
B. Chemical Industry	1329	2	13		0.00		0.00		0.00	1.1	28.9	53.7	7.4
C. Metal Production	2089	1	0	0.00	1.18	0.00	152.36	0.00	0.02	1.6	100.1	1.6	7.4
D. Other Production	0	0	0		0.00		0.00		0.00	0.0	0.0	80.9	0.0
E. Production of Halocarbons and SF6	0	0	0	0.00	283	0.00	106.34		0.00	0.0	0.0	0.0	0.0
F. Consumption of Halocarbons and SF6	b 0	0	0	9799	8589	148.52	93.53	0.03	0.03	0.0	0.0	0.0	0.0
G. Other	0	0	0		0.00		0.00		0.00	0.0	0.0	0.0	0.0
<b>3. Solvent and Other Product Use</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0.0</b>	<b>0.0</b>	<b>397.3</b>	<b>0.0</b>
<b>4. Agriculture</b>	<b>0</b>	<b>899</b>	<b>86</b>							<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>
A. Enteric Fermentation	0	777	0							0.0	0.0	0.0	
B. Manure Management	0	122	4							0.0	0.0	0.0	
C. Rice Cultivation	0	0	0							0.0	0.0	0.0	
D. Agricultural Soils	0	0	82							0.0	0.0	0.0	
E. Prescribed Burning of Savannas	0	0	0							0.0	0.0	0.0	
F. Field Burning of Agricultural Residues	c 0	0	0							0.0	0.0	0.0	
G. Other	0	0	0							0.0	0.0	0.0	
<b>5. Land-Use Change and Forestry</b>	<b>-1942</b>	<b>1</b>	<b>0.005</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0.2</b>	<b>7.0</b>	<b>0</b>	<b>0</b>
5A Forest Land	-16302	0	0							0.0	0.0		
5B Cropland	15329	0	0							0.0	0.0		
5C Grassland	-7836	0.57	0.004							0.14	4.9		
5D Wetland	0	0	0							0.0	0.0		
5E Settlements	6248	0.23	0.002							0.1	2.0		
5F Other Land	0	0	0							0.0	0.0		
5G Other Activities	619	0	0							0.0	0.0		
<b>6. Waste</b>	<b>452</b>	<b>982</b>	<b>4</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>2</b>	<b>24</b>	<b>13</b>	<b>1</b>
A. Solid Waste Disposal on Land	0	944	0							0.0	0.0	6.7	0.0
B. Wastewater Handling	d 0	38	4							0.0	0.0	0.0	0.0
C. Waste Incineration	452	0	0							1.8	23.5	6.7	0.9
D. Other	0	0	0							0.0	0.0	0.0	0.0
<b>7. Other (please specify)</b>	<b>2093</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>
Memo Items: (7)													
International Bunkers	e 38997	1	1	0	0	0	0	0	0	254	32	10	82
Aviation	e 33125	0	1							149.4	18.5	6.0	8.6
Marine	e 5872	1	0							104.3	13.5	3.9	73.0
Multilateral Operations													
CO2 Emissions from Biomass	ef 9372												

