UK Greenhouse Gas Inventory, 1990 to 2006

Annual Report for submission under the Framework Convention on Climate Change

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Preface

This is the United Kingdom's National Inventory Report (NIR) submitted in April 2008 to the United Nations Framework Convention on Climate Change (UNFCCC). It contains national greenhouse gas emission estimates for the period 1990-2006, 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. This submission constitutes the UK's voluntary submission under the Kyoto Protocol. 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.

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) Climate and Energy: Science and Analysis Division, by AEA. 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.

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	μ

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 covert 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_2 equivalent

Gg (of GHG) * GWP = Gg CO_2 equivalent

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

Abbreviations for Greenhouse Gases and Chemical Compounds

Type of greenhouse gas	Formula or abbreviation	Name
Direct	CH_4	Methane
Direct	CO_2	Carbon dioxide
Direct	N_2O	Nitrous oxide
Direct	HFCs	Hydrofluorocarbons
Direct	PFCs	Perfluorocarbons
Direct	SF_6	Sulphur hexafluoride
Indirect	CO	Carbon monoxide
Indirect	NMVOC	Non-methane volatile organic compound
Indirect	NO_X	Nitrogen oxides (reported as nitrogen dioxide)
Indirect	SO_2	Sulphur oxides (reported as sulphur dioxide)

HFCs, PFCs and SF_6 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 UK's National Inventory Report (NIR) submitted in April 2008. It contains GHG gas emissions estimates for the period 1990 to 2006, 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/CP8 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 AEA of AEA Technology. AEA also compiles the UK's National Atmospheric Emissions Inventory, used for reporting emissions to other international agreements. Most of the underlying information is held in 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 via 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_6)

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_2)
- Carbon monoxide
- Non-Methane Volatile Organic Compounds (NMVOC)
- Sulphur oxides (reported as SO_2)

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 indicated, 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 domestic goals to reduce CO_2 emissions. Geographical coverage[1] of these two targets differs to some extent, because:

1. Domestic goals for CO_2 have 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 (the Cayman Islands, the Falkland Islands, Bermuda, Monserrat and Gibraltar), and to non-CO_2 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_2 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 for geographical coverage 2. **Table ES6** shows total CO_2 emissions by sources minus removals by sinks for geographical coverage 1, which is the time series used relevant to the UK's domestic goals to reduce CO_2.

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[1] The geographical coverage of the UK GHG inventory is explained in Section 1.9 with further details given in Chapter 9.

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, 1990-2006

Table ES1a	Mt CO$_2$ Equivalent								
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
CO$_2$ (Including net LULUCF)	593.53	600.25	583.12	568.23	560.46	551.03	572.24	549.31	551.07
CO$_2$ (Excluding net LULUCF)	590.63	597.44	580.94	567.16	559.61	549.86	571.33	548.73	551.08
CH$_4$ (Including net LULUCF)	103.69	102.91	101.38	98.29	91.28	90.31	87.89	83.05	78.38
CH$_4$ (Excluding net LULUCF)	103.67	102.89	101.37	98.28	91.27	90.28	87.87	83.02	78.36
N$_2$O (Including net LULUCF)	63.88	63.85	57.51	53.03	54.31	53.05	53.44	54.88	54.57
N$_2$O (Excluding net LULUCF)	63.87	63.84	57.51	53.03	54.30	53.05	53.44	54.87	54.56
HFCs	11.38	11.85	12.32	13.00	14.02	15.50	16.74	19.21	17.30
PFCs	1.40	1.17	0.57	0.49	0.49	0.47	0.49	0.42	0.43
SF$_6$	1.03	1.08	1.12	1.17	1.18	1.24	1.27	1.23	1.26
Total (Emissions including net GHG from LULUCF)	774.90	781.12	756.03	734.21	721.73	711.60	732.07	708.09	703.01
Total (Emissions excluding net GHG from LULUCF)	771.98	778.28	753.83	733.13	720.86	710.40	731.13	707.47	703.00

Table ES1a	Mt CO$_2$ Equivalent								% change
	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**1990 - 2006**
CO$_2$ (Including net LULUCF)	541.53	549.82	560.69	544.01	556.04	556.39	556.56	555.86	-6.3%
CO$_2$ (Excluding net LULUCF)	541.82	550.25	561.26	545.13	557.18	558.29	558.62	557.86	-5.5%
CH$_4$ (Including net LULUCF)	73.11	68.54	62.56	59.54	53.57	51.71	49.75	49.25	-52.5%
CH$_4$ (Excluding net LULUCF)	73.09	68.51	62.53	59.51	53.54	51.68	49.73	49.22	-52.5%
N$_2$O (Including net LULUCF)	44.21	43.61	41.56	40.11	39.83	40.62	39.82	38.34	-40.0%
N$_2$O (Excluding net LULUCF)	44.20	43.60	41.55	40.10	39.83	40.62	39.82	38.34	-40.0%
HFCs	10.86	9.12	9.72	9.95	10.26	8.95	9.22	9.20	-19.1%
PFCs	0.36	0.49	0.42	0.31	0.26	0.33	0.25	0.30	-78.9%
SF$_6$	1.43	1.80	1.42	1.51	1.32	1.13	1.10	0.88	-14.7%
Total (Emissions including net GHG from LULUCF)	671.50	673.37	676.37	655.42	661.29	659.13	656.70	653.83	-15.6%
Total (Emissions excluding net GHG from LULUCF)	671.77	673.77	676.90	656.52	662.40	661.00	658.73	655.79	-15.1%

1. One Mt equals one Tg, which is 10^{12} 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 <u>excluding</u> all estimated GHG emissions from relevant Overseas Territories, 1990-2006

Table ES1b	Mt CO_2 Equivalent								
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
CO_2 (Including net LULUCF)	592.42	599.12	581.97	567.09	559.29	549.83	571.04	548.11	549.87
CO_2 (Excluding net LULUCF)	589.54	596.32	579.80	566.03	558.45	548.67	570.14	547.54	549.89
CH_4 (Including net LULUCF)	103.49	102.71	101.18	98.09	91.08	90.17	87.76	82.91	78.25
CH_4 (Excluding net LULUCF)	103.47	102.69	101.17	98.08	91.07	90.14	87.74	82.89	78.23
N_2O (Including net LULUCF)	63.83	63.81	57.47	52.99	54.26	53.00	53.39	54.83	54.52
N_2O (Excluding net LULUCF)	63.82	63.80	57.46	52.98	54.26	53.00	53.39	54.82	54.52
HFCs	11.38	11.85	12.32	13.00	14.01	15.50	16.73	19.20	17.29
PFCs	1.40	1.17	0.57	0.49	0.49	0.47	0.49	0.42	0.43
SF_6	1.03	1.08	1.12	1.17	1.18	1.24	1.27	1.23	1.26
Total (Emissions including net GHG from LULUCF)	773.55	779.74	754.64	732.83	720.31	710.22	730.69	706.69	701.61
Total (Emissions excluding net GHG from LULUCF)	770.64	776.91	752.45	731.75	719.46	709.02	729.76	706.09	701.62

Table ES1b	Mt CO_2 Equivalent								% change
	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**1990 - 2006**
CO_2 (Including net LULUCF)	540.29	548.55	559.41	542.71	554.70	555.08	555.22	554.52	-6.4%
CO_2 (Excluding net LULUCF)	540.59	549.00	559.99	543.85	555.87	556.99	557.31	556.54	-5.6%
CH_4 (Including net LULUCF)	72.98	68.40	62.43	59.41	53.45	51.59	49.64	49.14	-52.5%
CH_4 (Excluding net LULUCF)	72.96	68.38	62.40	59.39	53.42	51.56	49.61	49.11	-52.5%
N_2O (Including net LULUCF)	44.16	43.56	41.50	40.05	39.78	40.57	39.77	38.29	-40.0%
N_2O (Excluding net LULUCF)	44.16	43.55	41.50	40.05	39.78	40.56	39.77	38.29	-40.0%
HFCs	10.85	9.11	9.70	9.93	10.24	8.93	9.21	9.18	-19.3%
PFCs	0.36	0.48	0.42	0.31	0.26	0.33	0.25	0.30	-78.9%
SF_6	1.43	1.80	1.42	1.51	1.32	1.13	1.10	0.88	-14.7%
Total (Emissions including net GHG from LULUCF)	670.06	671.90	674.88	653.93	659.76	657.63	655.18	652.30	-15.7%
Total (Emissions excluding net GHG from LULUCF)	670.35	672.32	675.42	655.03	660.90	659.51	657.24	654.29	-15.1%

1. One Mt equals one Tg, which is 10^{12} 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, 1990-2006

Table ES2a	Mt Carbon Equivalent								
	1990	1991	1992	1993	1994	1995	1996	1997	1998
CO$_2$ (Including net LULUCF)	161.87	163.71	159.03	154.97	152.85	150.28	156.07	149.81	150.29
CO$_2$ (Excluding net LULUCF)	161.08	162.94	158.44	154.68	152.62	149.96	155.82	149.65	150.30
CH$_4$ (Including net LULUCF)	28.28	28.07	27.65	26.81	24.89	24.63	23.97	22.65	21.38
CH$_4$ (Excluding net LULUCF)	28.27	28.06	27.65	26.80	24.89	24.62	23.96	22.64	21.37
N$_2$O (Including net LULUCF)	17.42	17.41	15.69	14.46	14.81	14.47	14.58	14.97	14.88
N$_2$O (Excluding net LULUCF)	17.42	17.41	15.68	14.46	14.81	14.47	14.57	14.97	14.88
HFCs	3.10	3.23	3.36	3.55	3.82	4.23	4.56	5.24	4.72
PFCs	0.38	0.32	0.16	0.13	0.13	0.13	0.13	0.11	0.12
SF$_6$	0.28	0.29	0.31	0.32	0.32	0.34	0.35	0.33	0.34
Total (Emissions including net GHG from LULUCF)	211.34	213.03	206.19	200.24	196.84	194.07	199.66	193.11	191.73
Total (Emissions excluding net GHG from LULUCF)	210.54	212.26	205.59	199.94	196.60	193.74	199.40	192.95	191.73

Table ES2a	Mt Carbon Equivalent								% change
	1999	2000	2001	2002	2003	2004	2005	2006	1990 - 2006
CO$_2$ (Including net LULUCF)	147.69	149.95	152.92	148.37	151.65	151.74	151.79	151.60	-6.3%
CO$_2$ (Excluding net LULUCF)	147.77	150.07	153.07	148.67	151.96	152.26	152.35	152.14	-5.5%
CH$_4$ (Including net LULUCF)	19.94	18.69	17.06	16.24	14.61	14.10	13.57	13.43	-52.5%
CH$_4$ (Excluding net LULUCF)	19.93	18.69	17.05	16.23	14.60	14.10	13.56	13.42	-52.5%
N$_2$O (Including net LULUCF)	12.06	11.89	11.33	10.94	10.86	11.08	10.86	10.46	-40.0%
N$_2$O (Excluding net LULUCF)	12.06	11.89	11.33	10.94	10.86	11.08	10.86	10.46	-40.0%
HFCs	2.96	2.49	2.65	2.71	2.80	2.44	2.52	2.51	-19.1%
PFCs	0.10	0.13	0.11	0.08	0.07	0.09	0.07	0.08	-78.9%
SF$_6$	0.39	0.49	0.39	0.41	0.36	0.31	0.30	0.24	-14.7%
Total (Emissions including net GHG from LULUCF)	183.14	183.65	184.46	178.75	180.35	179.76	179.10	178.32	-15.6%
Total (Emissions excluding net GHG from LULUCF)	183.21	183.76	184.61	179.05	180.66	180.27	179.65	178.85	-15.1%

1. One Mt equals one Tg, which is 10^{12} 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, 1990-2006

Table ES2b	Mt Carbon Equivalent								
	1990	1991	1992	1993	1994	1995	1996	1997	1998
CO_2 (Including net LULUCF)	161.57	163.40	158.72	154.66	152.53	149.95	155.74	149.48	149.96
CO_2 (Excluding net LULUCF)	160.78	162.63	158.13	154.37	152.30	149.64	155.49	149.33	149.97
CH_4 (Including net LULUCF)	28.22	28.01	27.60	26.75	24.84	24.59	23.93	22.61	21.34
CH_4 (Excluding net LULUCF)	28.22	28.01	27.59	26.75	24.84	24.58	23.93	22.61	21.33
N_2O (Including net LULUCF)	17.41	17.40	15.67	14.45	14.80	14.46	14.56	14.95	14.87
N_2O (Excluding net LULUCF)	17.41	17.40	15.67	14.45	14.80	14.45	14.56	14.95	14.87
HFCs	3.10	3.23	3.36	3.55	3.82	4.23	4.56	5.24	4.71
PFCs	0.38	0.32	0.16	0.13	0.13	0.13	0.13	0.11	0.12
SF_6	0.28	0.29	0.31	0.32	0.34	0.32	0.34	0.35	0.34
Total (Emissions including net GHG from LULUCF)	210.97	212.66	205.81	199.86	196.45	193.70	199.28	192.73	191.35
Total (Emissions excluding net GHG from LULUCF)	210.17	211.89	205.21	199.57	196.22	193.37	199.03	192.57	191.35

Table ES2b	Mt Carbon Equivalent								% change
	1999	2000	2001	2002	2003	2004	2005	2006	1990 - 2006
CO_2 (Including net LULUCF)	147.35	149.61	152.57	148.01	151.28	151.38	151.42	151.23	-6.4%
CO_2 (Excluding net LULUCF)	147.43	149.73	152.72	148.32	151.60	151.91	151.99	151.78	-5.6%
CH_4 (Including net LULUCF)	19.90	18.66	17.03	16.20	14.58	14.07	13.54	13.40	-52.5%
CH_4 (Excluding net LULUCF)	19.90	18.65	17.02	16.20	14.57	14.06	13.53	13.39	-52.5%
N_2O (Including net LULUCF)	12.04	11.88	11.32	10.92	10.85	11.06	10.85	10.44	-40.0%
N_2O (Excluding net LULUCF)	12.04	11.88	11.32	10.92	10.85	11.06	10.85	10.44	-40.0%
HFCs	2.96	2.48	2.65	2.71	2.79	2.44	2.51	2.50	-19.3%
PFCs	0.10	0.13	0.11	0.08	0.07	0.09	0.07	0.08	-78.9%
SF_6	0.39	0.49	0.39	0.41	0.36	0.31	0.30	0.24	-14.7%
Total (Emissions including net GHG from LULUCF)	182.74	183.25	184.06	178.34	179.93	179.35	178.69	177.90	-15.7%
Total (Emissions excluding net GHG from LULUCF)	182.82	183.36	184.21	178.65	180.25	179.87	179.25	178.44	-15.1%

1. One Mt equals one Tg, which is 10^{12} 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 1990-2006 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_2 equivalent)

Table ES3a	Aggregated emission trends per source category (Mt CO_2 equivalent)								
Source Category	1990	1991	1992	1993	1994	1995	1996	1997	1998
1. Energy	611.19	620.46	604.31	589.00	574.36	565.31	585.34	562.08	562.98
2. Industrial Processes	53.95	52.29	46.82	43.51	46.05	46.39	48.19	50.82	49.16
3. Solvents and Other Product	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Agriculture	53.89	53.36	51.73	50.99	51.84	51.72	52.05	52.75	51.75
5. LULUCF	2.92	2.84	2.20	1.08	0.87	1.21	0.94	0.61	0.01
6. Waste	52.95	52.16	50.97	49.62	48.62	46.97	45.55	41.83	39.11
Total (net emissions)	**774.90**	**781.12**	**756.03**	**734.21**	**721.73**	**711.60**	**732.07**	**708.09**	**703.01**

Table ES3a	Aggregated emission trends per source category (Mt CO_2 equivalent)							
Source Category	1999	2000	2001	2002	2003	2004	2005	2006
1. Energy	552.32	559.87	571.71	556.02	564.57	565.05	564.38	562.86
2. Industrial Processes	32.74	31.25	29.45	26.88	27.91	27.65	27.22	26.80
3. Solvents and Other Product Use[a]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Agriculture	51.03	49.17	46.27	46.61	46.00	45.92	45.08	44.12
5. LULUCF	-0.27	-0.40	-0.53	-1.10	-1.12	-1.87	-2.03	-1.96
6. Waste	35.68	33.49	29.47	27.01	23.93	22.38	22.05	22.01
Total (net emissions)	**671.50**	**673.37**	**676.37**	**655.42**	**661.29**	**659.13**	**656.70**	**653.83**

Footnotes:

[a] 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 <u>excluding</u> all estimated GHG emissions from relevant Overseas Territories

Table ES3b	Aggregated emission trends per source category (Mt CO$_2$ equivalent)								
Source Category	1990	1991	1992	1993	1994	1995	1996	1997	1998
1. Energy	610.09	619.34	603.17	587.87	573.20	564.14	584.17	560.90	561.80
2. Industrial Processes	53.95	52.29	46.82	43.51	46.04	46.38	48.18	50.81	49.15
3. Solvents and Other Product	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Agriculture	53.72	53.19	51.57	50.83	51.67	51.55	51.89	52.59	51.59
5. LULUCF	2.91	2.83	2.19	1.07	0.86	1.19	0.93	0.60	0.00
6. Waste	52.87	52.09	50.89	49.55	48.55	46.94	45.52	41.80	39.07
Total (net emissions)	**773.55**	**779.74**	**754.64**	**732.83**	**720.31**	**710.22**	**730.69**	**706.69**	**701.61**

Table ES3b	Aggregated emission trends per source category (Mt CO$_2$ equivalent)							
Source Category	1999	2000	2001	2002	2003	2004	2005	2006
1. Energy	551.10	558.62	570.44	554.74	563.26	563.76	563.07	561.55
2. Industrial Processes	32.73	31.23	29.43	26.86	27.90	27.63	27.20	26.78
3. Solvents and Other Product Use[a]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Agriculture	50.87	49.01	46.11	46.45	45.84	45.77	44.94	43.98
5. LULUCF	-0.28	-0.41	-0.54	-1.11	-1.14	-1.89	-2.06	-1.99
6. Waste	35.65	33.46	29.45	26.99	23.90	22.35	22.02	21.98
Total (net emissions)	**670.06**	**671.90**	**674.88**	**653.93**	**659.76**	**657.63**	**655.18**	**652.30**

Footnotes:

[a] 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 2006 this contributed 86% to the total emissions including relevant OTs. Emissions of CO_2, CH_4 and N_2O all arise from this sector. Since 1990, emissions from the energy sector have declined by about 8%.

The second largest source of greenhouse gases is the agricultural sector. Emissions from this sector arise for both CH_4 and N_2O. Since 1990, emissions from this sector have declined by 18%, 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 2006. Emissions of all six direct greenhouse gases occur from this sector.

Land Use, Land-use Change and Forestry contains sinks as well as sources of CO_2 emissions. LULUCF is a net sink in 2006. Emissions from this source occur for CO_2, N_2O and CH_4.

The remaining source that contributes to direct greenhouse gas totals is waste. In 2006 this contributed 3.4% to the national total. Emissions arise for CO_2, CH_4 and N_2O, with emissions occurring from waste incineration, solid waste disposal on land and wastewater handling. Emissions from this sector have steadily declined and in 2006 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, 1990-2006 (in kt)

Gas	1990	1991	1992	1993	1994	1995	1996	1997
NO_x	2,967.34	2,838.05	2,756.73	2,582.08	2,491.00	2,389.73	2,314.68	2,162.60
CO	8,224.86	8,075.09	7,615.56	7,209.71	6,808.10	6,297.15	6,144.31	5,673.45
NMVOC	2,385.71	2,305.27	2,238.82	2,128.97	2,065.88	1,926.82	1,821.65	1,755.90
SO_2	3,717.35	3,530.54	3,442.19	3,096.17	2,663.95	2,351.82	2,003.45	1,661.36

Gas	1998	1999	2000	2001	2002	2003	2004	2005	2006
NO_x	2,088.30	1,975.37	1,899.13	1,827.97	1,714.53	1,720.65	1,659.11	1,619.53	1,594.65
CO	5,266.29	4,916.01	4,221.10	3,871.36	3,329.06	2,922.71	2,680.89	2,379.30	2,263.21
NMVOC	1,608.73	1,457.10	1,336.78	1,235.69	1,155.73	1,061.16	1,000.07	959.35	908.52
SO_2	1,632.77	1,208.77	1,198.50	1,095.20	978.20	967.19	812.47	688.02	675.63

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_x, CO and SO_2, over 90% of emissions for each gas arise from activities within this sector. For NMVOC, 41% 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).

The Base Year for emissions of carbon dioxide, methane and nitrous oxide is 1990. The Base Year for emissions of fluorinated gases (f-gases) is 1995.

This year, the table includes two Base Year totals. The first (in the Kyoto Protocol Total row) is the 'Base Year' calculated from the 2006 inventory, based on the totals calculated for each sector this year, together with Article 3.7, and including any recalculations made since the previous inventory. The 'Fixed Base Year' is the base year total calculated from the 2004 Inventory, which has been used to calculate the UK's Assigned Amount. This has been reviewed during an In Country Review of the UK inventory in March 2007 and agreed by the UNFCCC. This is the total that the UK's progress towards its Kyoto Protocol target will be judged against.

Table ES5a   Kyoto basket of emissions, and emissions associated with Articles 3.3, 3.4 and 3.7, 1990-2006 (in Mt CO_2 equivalent)

Table ES5a	Mt CO_2 Equivalent									
	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998
CO_2	590.63	590.63	597.44	580.94	567.16	559.61	549.86	571.33	548.73	551.08
CH_4	103.67	103.67	102.89	101.37	98.28	91.27	90.28	87.87	83.02	78.36
N_2O	63.87	63.87	63.84	57.51	53.03	54.30	53.05	53.44	54.87	54.56
HFCs	15.50	11.38	11.85	12.32	13.00	14.02	15.50	16.74	19.21	17.30
PFCs	0.47	1.40	1.17	0.57	0.49	0.49	0.47	0.49	0.42	0.43
SF_6	1.24	1.03	1.08	1.12	1.17	1.18	1.24	1.27	1.23	1.26
Grand Total	**775.38**	**771.98**	**778.28**	**753.83**	**733.13**	**720.86**	**710.40**	**731.13**	**707.47**	**703.00**
Article 3.3		0.20	0.35	0.39	0.31	0.16	-0.06	-0.28	-0.52	-0.74
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
Article 3.7	0.33									
Kyoto Protocol Total	**775.72**	**770.82**	**777.27**	**752.87**	**732.08**	**719.67**	**708.98**	**729.50**	**705.60**	**700.90**
Fixed Base Year[1]	**779.90**									

Table ES5a	Mt CO_2 Equivalent								% Changes	
	1999	2000	2001	2002	2003	2004	2005	2006	1990-2006	Base Year - 2006
CO_2	541.82	550.25	561.26	545.13	557.18	558.29	558.62	557.86	-5.5%	-5.5%
CH_4	73.09	68.51	62.53	59.51	53.54	51.68	49.73	49.22	-52.5%	-52.5%
N_2O	44.20	43.60	41.55	40.10	39.83	40.62	39.82	38.34	-40.0%	-40.0%
HFCs	10.86	9.12	9.72	9.95	10.26	8.95	9.22	9.20	-19.1%	-40.7%
PFCs	0.36	0.49	0.42	0.31	0.26	0.33	0.25	0.30	-78.9%	-37.1%
SF_6	1.43	1.80	1.42	1.51	1.32	1.13	1.10	0.88	-14.7%	-29.1%
Grand Total	**671.77**	**673.77**	**676.90**	**656.52**	**662.40**	**661.00**	**658.73**	**655.79**	**-15.1%**	**-15.4%**
Article 3.3	-0.89	-1.02	-1.12	-1.32	-1.52	-1.73	-1.91	-2.09		
Article 3.4 (capped at -0.37 MtC)	-1.36	-1.36	-1.36	-1.36	-1.36	-1.36	-1.36	-1.36		
Article 3.7										
Kyoto Protocol Total	**669.52**	**671.40**	**674.42**	**653.84**	**659.53**	**657.92**	**655.46**	**652.34**	**-15.4%**	
Fixed Base Year[1]										**-16.4%**

Footnotes:

[1] The Fixed Base Year is taken from the UK's Assigned Amount report. This report was submitted in 2006, based on emissions reported in the 1990-2004 Greenhouse Gas Inventory, and was subject to an official review in 2007, which concluded that this figure was correct. This base year is now fixed, and is the value that the UK will be assessed against for its Kyoto Protocol target.

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, 1990-2006 (in Mt C equivalent)

Table ES5b	Mt Carbon Equivalent									
	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998
CO_2	161.08	161.08	162.94	158.44	154.68	152.62	149.96	155.82	149.65	150.30
CH_4	28.27	28.27	28.06	27.65	26.80	24.89	24.62	23.96	22.64	21.37
N_2O	17.42	17.42	17.41	15.68	14.46	14.81	14.47	14.57	14.97	14.88
HFCs	4.23	3.10	3.23	3.36	3.55	3.82	4.23	4.56	5.24	4.72
PFCs	0.13	0.38	0.32	0.16	0.13	0.13	0.13	0.13	0.11	0.12
SF_6	0.34	0.28	0.29	0.31	0.32	0.32	0.34	0.35	0.33	0.34
Grand Total	**211.47**	**210.54**	**212.26**	**205.59**	**199.94**	**196.60**	**193.74**	**199.40**	**192.95**	**191.73**
Article 3.3		0.05	0.10	0.11	0.08	0.04	-0.02	-0.08	-0.14	-0.20
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
Article 3.7	0.09									
Kyoto Protocol Total	**211.56**	**210.22**	**211.98**	**205.33**	**199.66**	**196.27**	**193.36**	**198.95**	**192.44**	**191.15**
Fixed Base Year[1]	**212.70**									

Table ES5b	Mt Carbon Equivalent								% Changes	
	1999	2000	2001	2002	2003	2004	2005	2006	1990-2006	Base Year - 2006
CO_2	147.77	150.07	153.07	148.67	151.96	152.26	152.35	152.14	-5.5%	-5.5%
CH_4	19.93	18.69	17.05	16.23	14.60	14.10	13.56	13.42	-52.5%	-52.5%
N_2O	12.06	11.89	11.33	10.94	10.86	11.08	10.86	10.46	-40.0%	-40.0%
HFCs	2.96	2.49	2.65	2.71	2.80	2.44	2.52	2.51	-19.1%	-40.7%
PFCs	0.10	0.13	0.11	0.08	0.07	0.09	0.07	0.08	-78.9%	-37.1%
SF_6	0.39	0.49	0.39	0.41	0.36	0.31	0.30	0.24	-14.7%	-29.1%
Grand Total	**183.21**	**183.76**	**184.61**	**179.05**	**180.66**	**180.27**	**179.65**	**178.85**	**-15.1%**	**-15.4%**
Article 3.3	-0.24	-0.28	-0.31	-0.36	-0.41	-0.47	-0.52	-0.57		
Article 3.4 (capped at -0.37 MtC)	-0.37	-0.37	-0.37	-0.37	-0.37	-0.37	-0.37	-0.37		
Article 3.7										
Kyoto Protocol Total	**182.60**	**183.11**	**183.93**	**178.32**	**179.87**	**179.43**	**178.76**	**177.91**	**-15.4%**	
Fixed Base Year[1]										**-16.4%**

Footnotes:

[1] The Fixed Base Year is taken from the UK's Assigned Amount report. This report was submitted in 2006, based on emissions reported in the 1990-2004 Greenhouse Gas Inventory, and was subject to an official review in 2007, which concluded that this figure was correct. This base year is now fixed, and is the value that the UK will be assessed against for its Kyoto Protocol target.

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 ES6a   Net emissions of carbon including all estimated carbon emissions from the Crown Dependencies but excluding emissions from relevant Overseas Territories (Mt CO_2 eq)

Table ES6a	Mt CO_2 equivalent							
	1990	1991	1992	1993	1994	1995	1996	1997
Net CO_2 Emissions	592.42	599.12	581.97	567.09	559.29	549.83	571.04	548.11
% change relative to 1990		1.13%	-1.76%	-4.28%	-5.59%	-7.19%	-3.61%	-7.48%

Table ES6a									
	1998	1999	2000	2001	2002	2003	2004	2005	2006
Net CO_2 Emissions	549.87	540.29	548.55	559.41	542.71	554.70	555.08	555.22	554.52
% change relative to 1990	-7.18%	-8.80%	-7.41%	-5.57%	-8.39%	-6.37%	-6.30%	-6.28%	-6.40%

Footnotes:

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

Table ES6b   Net emissions of carbon including all estimated carbon emissions from the Crown Dependencies but excluding emissions from relevant Overseas Territories (Mt C eq)

Table ES6b	Mt C equivalent							
	1990	1991	1992	1993	1994	1995	1996	1997
Net CO_2 Emissions	161.57	163.40	158.72	154.66	152.53	149.95	155.74	149.48
% change relative to 1990		1.13%	-1.76%	-4.28%	-5.59%	-7.19%	-3.61%	-7.48%

Table ES6b	Mt C equivalent							
	1998	1999	2000	2001	2002	2003	2004	2005	2006
Net CO_2 Emissions	149.96	147.35	149.61	152.57	148.01	151.28	151.38	151.42	151.23
% change relative to 1990	-7.18%	-8.80%	-7.41%	-5.57%	-8.39%	-6.37%	-6.30%	-6.28%	-6.40%

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

Contacts

This work is part of the Climate, Energy and Ozone: Science and Analysis (CEOSA) Research Programme of the Department for Environment, Food and Rural Affairs (Contract RMP/2106). The Land Use Change and Forestry estimates were provided by the Centre for Ecology and Hydrology (CEH) Edinburgh (Contract CPEG 1). The Institute of Grassland and Environmental Research (IGER) provide the estimates of agricultural emissions.

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A copy of this report and related data may be found on the website maintained by AEA for Defra: http://www.naei.org.uk/

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Document revision history

Issue	Revision history
Issue - Draft	• Reviewed by Defra, IGER and CEH • Revision following these comments
1.0	• Submission to the UNFCCC Secretariat on 13.04.2007 • Ammendment to footnote of Table A 7.1.7 on 14.05.2007

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 2006. 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/CP8[2] 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 AEA. 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. The differences occur in the reporting of emissions from UK Overseas Territories[3] (OTs), and Crown Dependencies[4] (CDs). In the CRF, emissions of indirect GHGs

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[2] FCCC Decision 18/CP.8. Guidelines for the preparation of national communications by Parties included in Annex I to the Convention, part I:UNFCCC reporting guidelines on annual inventories. Report of the Conference of the Parties on its Eighth Session, held at New Delhi from 23 October to 1 November 2002. FCCC/CP/2002/7/Add.2 28 March 2003.
[3] The Overseas Territories are: the Cayman Islands, Falkland Islands, Bermuda, Montserrat and Gibraltar.
[4] The Crown Dependencies are: the Baliwick of Jersey, the Baliwick of Guernsey and the Isle of Man.

from these OTs and CDs are reported in sub-categories under IPCC Sector 7 ("other emissions"), whereas these emissions are allocated to the appropriate IPCC sectors in this NIR. This has been done as the CRF cannot accommodate indirect emissions in the appropriate source categories.

1.1.2   Nomenclature of the inventory period reported

This report is the UK National Inventory Report of 2008. It contains revised emissions estimates for the years 1990 to 2006 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 1990-2006, 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 2006. 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_2 emissions from Land Use Change and Forestry

The reporting of CO_2 emissions from Land Use Change and Forestry 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_2)
- Methane   (CH_4)
- Nitrous oxide   (N_2O)
- Hydrofluorocarbons   (HFCs)
- Perfluorocarbons   (PFCs)
- Sulphur hexafluoride   (SF_6)

Indirect Greenhouse Gases
- Nitrogen oxides   (NO_x, as NO_2)
- Carbon monoxide   (CO)
- Non-Methane Volatile Organic Compounds   (NMVOC)
- Sulphur dioxide   (SO_2)

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_2. 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/CP3.

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

Gas	GWP
Carbon Dioxide	1

Gas	GWP
Methane	21
Nitrous Oxide	310
HFCs	140-11,700
PFCs	6,500-9,200
SF_6	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 and Fourth Assessment Reports (IPCC, 2001; IPCC, 2007). 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_2 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

1.2   INSTITUTIONAL ARRANGEMENTS FOR INVENTORY PREPARATION

The UK Greenhouse Gas Inventory is compiled and maintained by AEA of AEA Technology plc – the **Inventory Agency** - under contract with the Climate, Energy and Ozone, Science and Analysis (CEOSA) Division in the UK Department for Environment, Food & Rural Affairs (Defra). AEA 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). AEA 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 (SAS) Division 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 CEOSA.

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 31st December 2005. The development of more formal agreements between Defra and Key Data Providers (KDPs) within the NIS 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. AEA 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
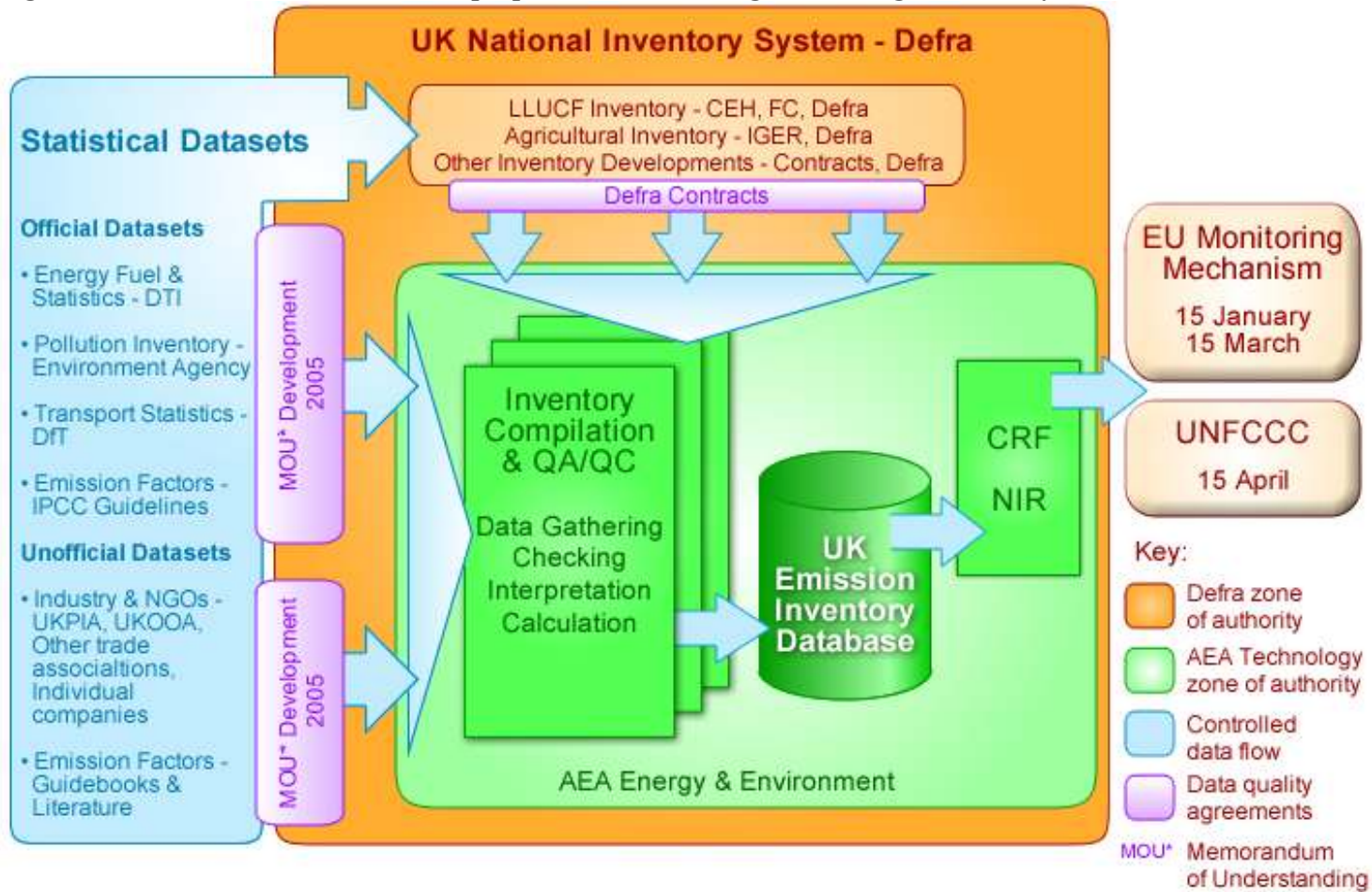
1.2.2   UK NIS - Organisational Structure

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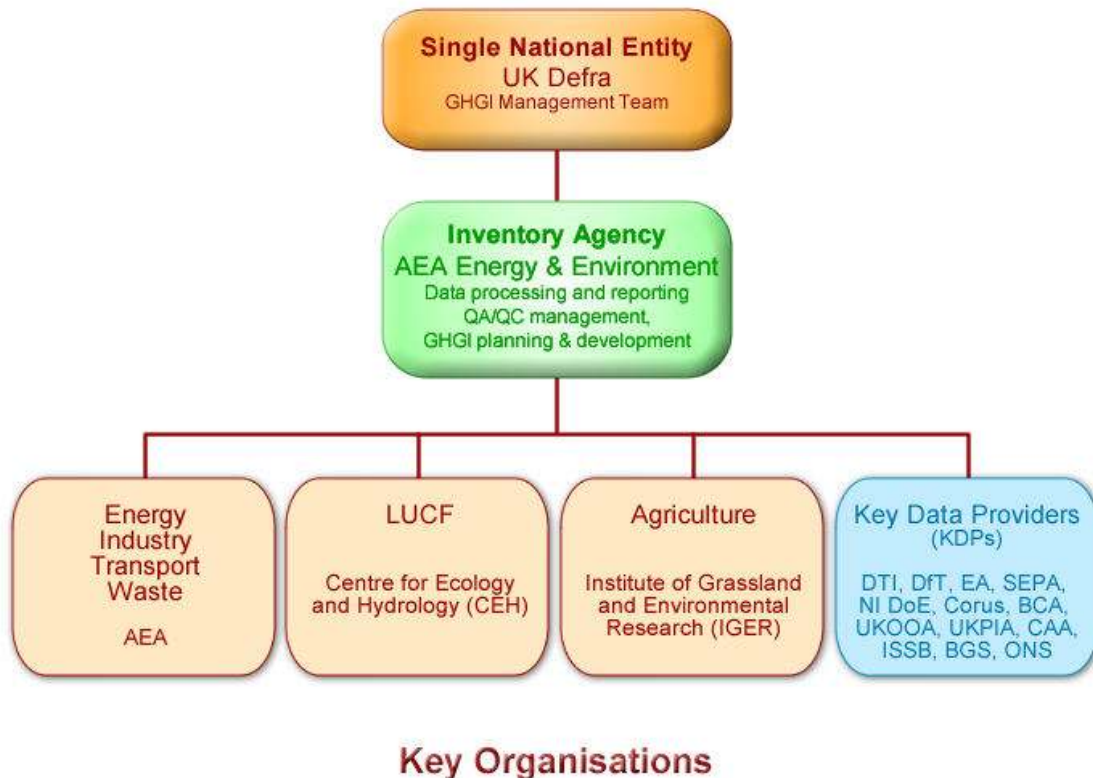
The following sections summarises the roles and responsibilities of key stakeholders in the UK NIS.

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 Climate, Energy and Ozone, Science Analysis (CEOSA) Division administers this responsibility. CEOSA 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 AEA, CEH and IGER.

1.2.2.2   Inventory Agency - AEA

AEA under contract to Defra to performs the role of Inventory Agency and is responsible for all aspects of national inventory preparation, reporting and quality management. AEA 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, AEA 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 under contract to Defra is 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 AEA for inclusion within the UK GHG inventory dataset.

IGER, also under contract to Defra, is responsible for the preparation and development of the agriculture inventory. IGER conducts specific research in the agriculture sector and provide finalised GHG emissions data to AEA 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, AEA 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 AEA 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 AEA.

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, in consultation with industry, provides improved emission estimates of HFCs, PFCs and SF_6 (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.

1.2.2.4   Changes to the National System

No changes were made to the UK National Inventory System in 2007.

1.2.3   Legal Framework

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

The legislation relied upon has been 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[5]. This legislation makes

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

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. The UK values voluntary participation and 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 2008, 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 was established in 2006 to provide an independent review group to assist in the review & improvement of the UK inventory. The role of the committee is to 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 AEA, 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 is not yet 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 Marrakesh Accords and to address some of the identified gaps in best practice, Defra has established a formal cross-Government Steering Committee tasked with the official consideration and approval of the national inventory prior to submission to the UNFCCC. The role of the Committee is to 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 include the Inventory Agency team at AEA, other contractors, plus appropriate sector, legal and economic experts. These experts are responsible for reviewing methodologies, activity data, emission factors and emission estimates at a sectoral level and 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 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

Organisation	Key Roles for the UK GHG inventory	General Responsibilities
Defra, Climate Energy Science and Analysis	• Administer functions of Single National Entity for the UK National Inventory System • Overall responsibility for inventory development, compilation and reporting • Manage GHG inventory research contracts • Provide Secretariat to Steering Committee	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	• Manage the agricultural inventory research contract	Management and administration of the sub-contracted agriculture inventory, to ensure that it conforms to international standards and is submitted on time to AEA each year.
Defra, Environmental Statistics and Indicators	• Provide a statistical check of emissions data used to derive climate change indicators	Publication of Defra climate change indicators each year.
Defra, Climate and Energy : Business and Transport	• Provide fuel use and fuel characterisation datasets from the EU-ETS for use by both DBERRand the GHGI in the determination of industrial fuel use statistics and the resultant emissions of GHGs from combustion sources.	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.
Department for Business, Enterprise and Regulatory Reform (DBERR), EA Regulator	• 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.	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)
DBERR – Offshore Regulator	• Ensure that the offshore oil & gas industry (via the trade association, UKOOA) produces annual activity and emissions data in the required format and timescale for inventory estimation and reporting.	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
DBERR, Energy	• Provide energy statistics in the required format and timescale for inventory estimation and reporting.	Publication of the Digest of UK Energy Statistics each year, to meet DTI and National Statistics requirements.
Department for Communities and Local Government (DCLG)	• Provide housing statistics in the required format and timescale for inventory estimation and reporting	Responsible for publication of housing statistics each year.
DfT	• Provide transport statistics in the required format and timescale for inventory estimation and reporting.	Responsible for publication of transport statistics each year.
UK environmental regulators (EA, SEPA, DoENI)	• 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	Responsible for the management, compilation, QAQC and reporting of pollutant emission inventories / registers under IPPC regulations.
Devolved Administrations	• Review aspects of the UK GHG inventory that correspond to devolved issues, ensuring the integration of local datasets and specific research where appropriate	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

Organisation	Key Roles for the UK GHGI	General Responsibilities
GHG Inventory Agency contractor (AEA)	• 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 • Participate in sectoral expert panels as required • Provide Secretariat support to Steering Committee	Contractor responsible for national GHG inventory; activity data, methods, emission factors, emissions estimation, reporting and archiving
Agricultural inventory contractor (IGER)	• Prepare and develop agricultural inventory and deliver on time for incorporation into national inventory • Participate in sectoral expert panels as required	Contractor responsible for agricultural inventory; activity data, methods, emission factors and emissions estimation
LULUCF inventory contractor (CEH)	• Prepare and develop LULUCF inventory of emissions and removals and deliver on time for incorporation into national inventory • Participate in sectoral expert panels as required	Contractor responsible for LULUCF inventory; activity data, methods, emission factors, emissions and removals estimation
Defra – Climate Change Economics	• Provide ad-hoc economic advice to the committee e.g. in developing a risk register to enable the committee to review key risks to delivery of annual inventory and develop management strategies	Ad-hoc economic advice
Defra - LEGAL	• Provide ad-hoc legal advice to the committee e.g. in developing data supply agreements with key data suppliers to specify timing, quality, security and format of data require for national inventory	Ad-hoc legal advice
External reviewers & sector experts	• Provide a review function to improve & develop the UK GHG inventory	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
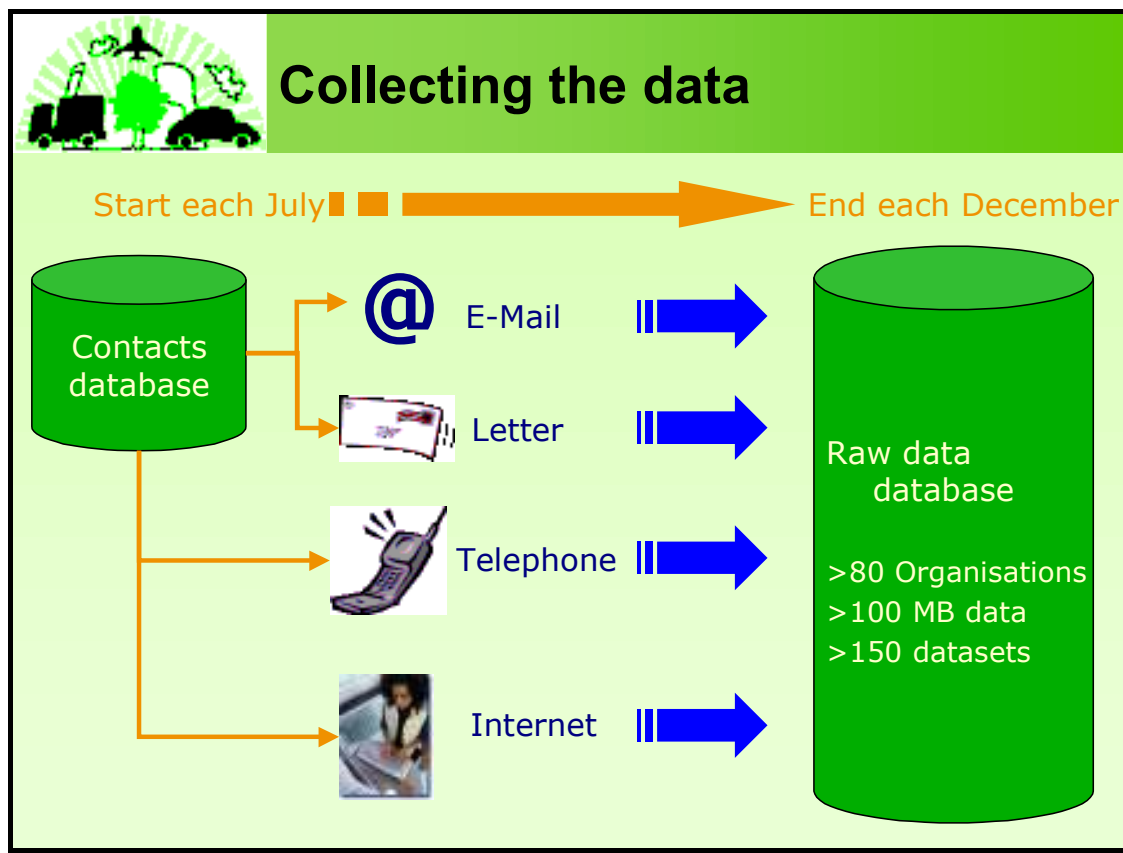
The following activities are carried out each year, in order, as the inventory is compiled:

- *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
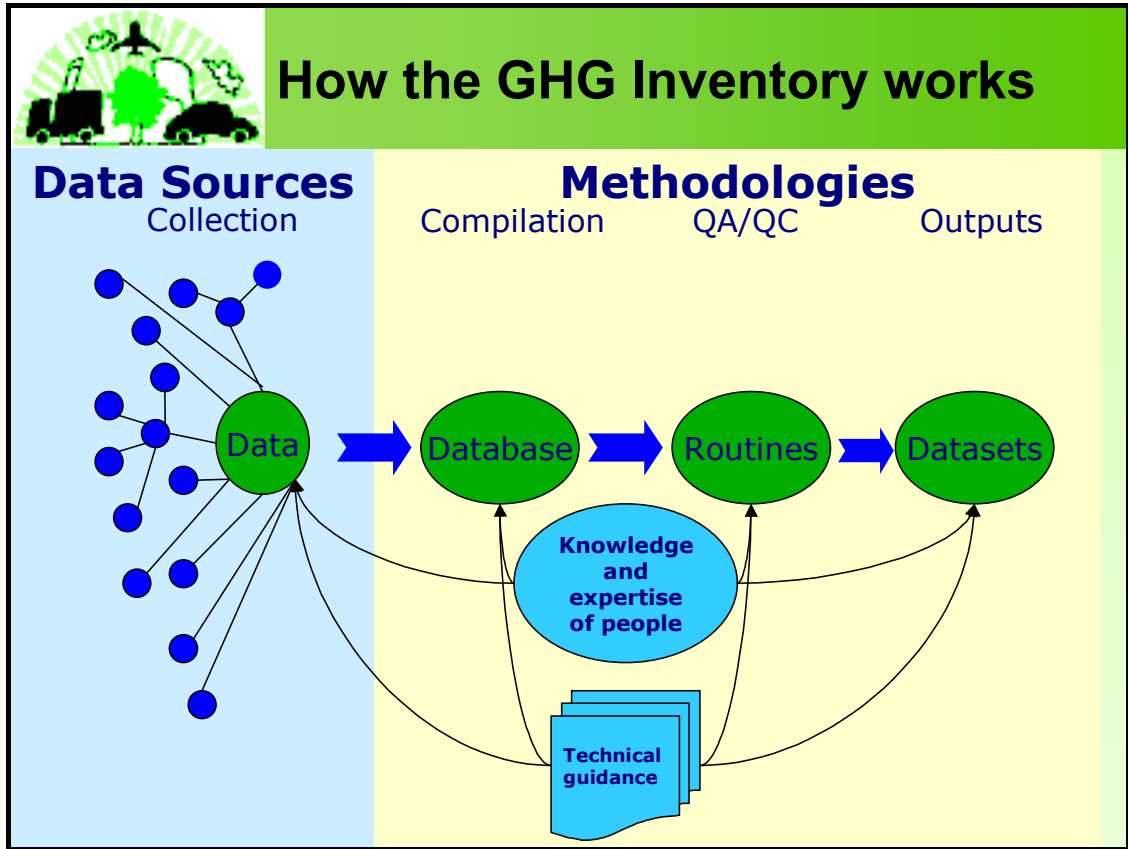
The methods used to estimate emissions are described in detail in the relevant sections of this report. The direct and indirect GHGs reported are estimated using methodologies corresponding mostly to the detailed sectoral Tier 2/3 methods in the IPCC Guidelines. **Table 1.2** provides a brief summary 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 **Annex 3**, **Section A3.3.1**)
	Transport model (see **Annex 3**, **Section A3.3.5**)
1B	Carbon Balance approach (See **Annex 3**, **Section A3.3.8.1.2**)
	UKOOA EEMS inventory (See **Annex 3**, **Section A3.3.8.2**)
	Transco gas leakage model (See **Annex 3**, **Section A3.3.8.2.6**)
2A	Cement production: IPCC Tier 2 approach (see **Chapter 4**, **Section 4.4.2**)
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 **Annex 3**, **Section A3.3.3.3** and **A3.4.3.1**)
	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 1.5**. 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
Digest of UK Energy Statistics (UK Department for Business, Enterprise and Regulatory Reform)	• Energy statistics for the UK (imports, exports, production, consumption, demand) of liquid, solid and gaseous fuels • Calorific values of fuels and conversion factors
Transport Statistics GB (UK Department for Transport)	• Vehicle km according to vehicle type and road type • Vehicle licensing statistics (split in vehicle km by fuel type) • Selected domestic and international civil aviation aircraft km flown
Northern Ireland Department of the Environment	• Traffic count and vehicle km data for Northern Ireland • Information on regulated processes in NI
Civil Aviation Authority	• Detailed domestic and international civil aviation aircraft km flown
Pollution Inventory (Environment Agency)	• Information on emissions from regulated processes in England and Wales
Scottish Environmental Protection Agency	• Information on regulated processes in Scotland
United Kingdom Petroleum Industry Association	• Refinery emissions, • Lead and sulphur contents of fuels, benzene content of petrol, RVP of petrol
United Kingdom Offshore Operators Association	• Detailed inventory of oil & gas emissions
Iron and Steel Statistics Bureau	• Energy production and consumption in the Iron and Steel industry • Other statistics regarding the Iron and Steel industry
United Kingdom Minerals Yearbook (British Geological Society)	• Statistical data on minerals production, consumption and trade
Annual Abstract of Statistics (Office for National Statistics)	• Population data

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 1.6** and **1.7** summarise the key source categories, for 2006, derived from the IPCC Approach 1 uncertainty analysis. Details of the key source category analysis are given in **Annex 1**, including an anlysis of key soruce categories in the base year.

Table 1.6   Key Source Categories (including LULUCF)

IPCC source category	Fuel/Activity	GHG	Reason (s)
1A	Coal	CO_2	Level
1A(stationary)	Oil	CO_2	Level
1A	Natural Gas	CO_2	Level
1A3b	Auto Fuel	CO_2	Level
5A	5A LULUCF	CO_2	Level
5B	5B LULUCF	CO_2	Level, Trend
5C	5C LULUCF	CO_2	Level
5E	5E LULUCF	CO_2	Level
4A	Enteric Fermentation	CH_4	Level
6A	Solid Waste Disposal	CH_4	Level, Trend
1A1&1A2&1A4&1A5	Other Combustion	N_2O	Level, Trend
1A3b	Auto Fuel	N_2O	Level, Trend
2B	Nitric Acid Production	N_2O	Level, Trend
4B	Manure Management	N_2O	Level, Trend
4D	Agricultural Soils	N_2O	Level, Trend
6B	Wastewater Handling	N_2O	Level, Trend
2	Industrial Processes	HFC	Level

Table 1.7   Key Source Categories (excluding LULUCF)

IPCC source category	Fuel/Activity	GHG	Reason (s)
1A	Coal	CO_2	Level
1A(stationary)	Oil	CO_2	Level
1A	Natural Gas	CO_2	Level
1A3b	Auto Fuel	CO_2	Level
4A	Enteric Fermentation	CH_4	Level
6A	Solid Waste Disposal	CH_4	Level, Trend
1A1&1A2&1A4&1A5	Other Combustion	N_2O	Level, Trend
1A3b	Auto Fuel	N_2O	Level, Trend
2B	Nitric Acid Production	N_2O	Level, Trend
4B	Manure Management	N_2O	Level, Trend
4D	Agricultural Soils	N_2O	Level, Trend
6B	Wastewater Handling	N_2O	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 AEA, 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 AEA 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 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.* AEA is currently accredited to BS EN ISO 9001:2000, and was last audited in January 2008 by Lloyds.

Figure 1.4   System of referencing and documentation used within UK greenhouse gas inventory
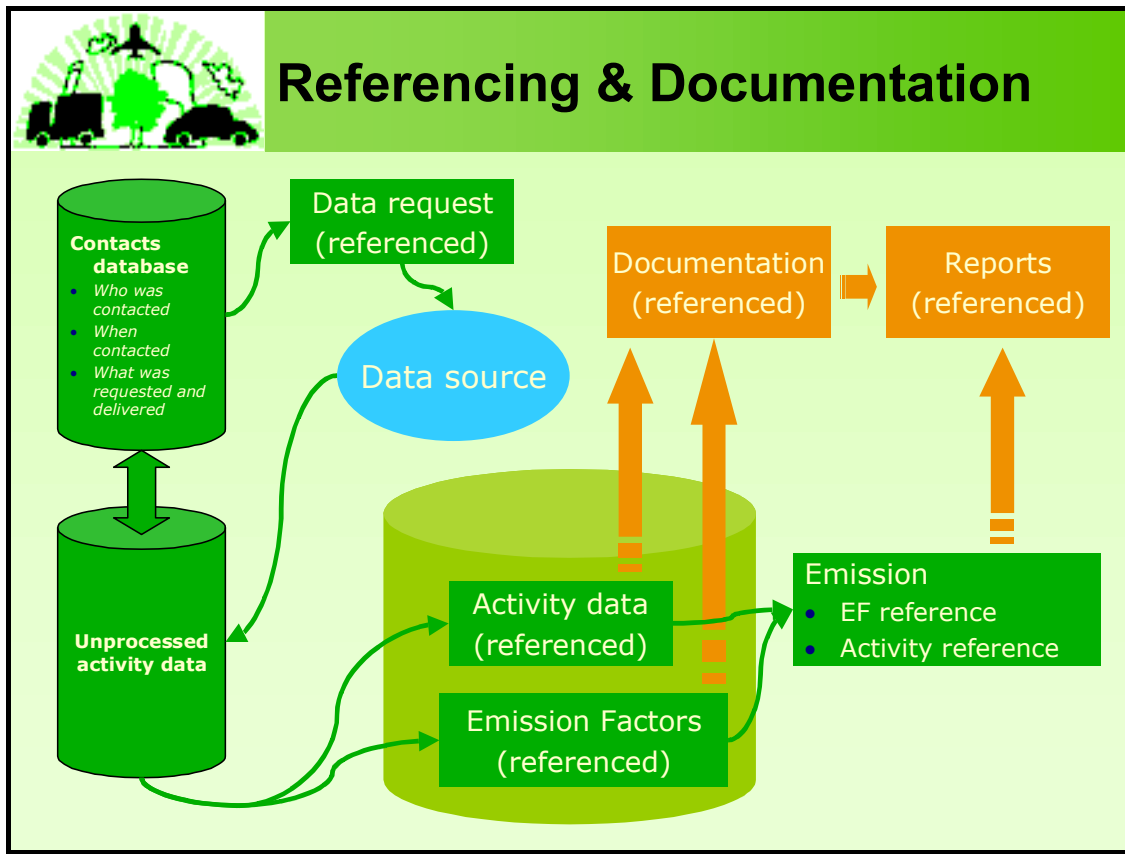
The system incorporates the following activities (see **Figure 1.4**), which are carried out each year as the inventory is compiled:

1.   ***Documentation***
▸ Source data received by AEA 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 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***

▶ AEA'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 DBERR.

▶ 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 Approach 1 (error propagation) and Tier 2 procedures set out in the IPCC GPG.
  ▶ A ranking exercise is performed according to Approach 1 (error propagation) 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 Approach 1 (error propagation) 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)
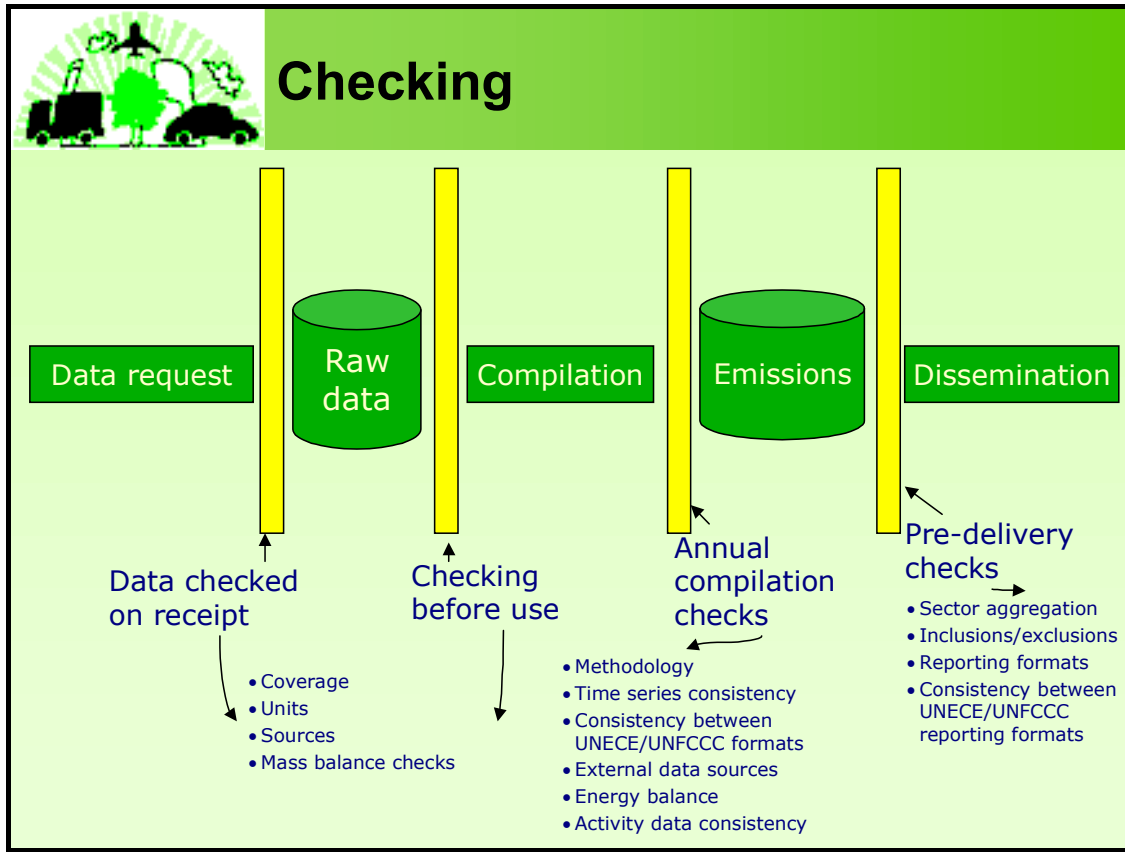
1.6.2   Special QA/QC activities undertaken in 2007-2008

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

Review of EU-ETS activity data
See Annex 12

Detailed discussions with Key Data Providers
We have continued to have one-to-one meetings or engage in detailed discussions with Key Data Providers to help ensure that the inventory is using the best available data.

1.6.3   Future development of the QA/QC system

The programme of UK inventory improvement was reviewed by the UK GHG Inventory Steering Group Committee in 2007. This programme will again be reviewed in 2008 and inventory QA/QC priorities and improvements will be updated/derived.

1.6.4 Compliance of National Statistical Agencies

Many of the data received by AEA 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 complied 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_2 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 Daemmgenm 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 AEA (representing the Inventory Agency). The review covered: the methods used to estimate agricultural emissions, including emissions from agricultural soils (N_2O), manure management (N_2O) and enteric fermentation (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.

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**. Verification of this year's Inventory was unavailable and hence results presented in **Annex 8** are based on the 1990-2005 inventory submission.

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 Approach 1 (error propagation) and Approach 2 (Monte Carlo simulation) described by the IPCC. Approach 1 provides estimates of uncertainty by GHG according to IPCC sector. Approach 2 considers the correlations between sources and provides estimates of uncertainty according to GHG in 1990 and the latest reporting year, and has now been extended to provide emissions by IPCC sector.

Approach 2 (Monte Carlo simulation) suggests that the uncertainty in the combined GWP weighted emissions of all the greenhouse gases is 15% in 1990 and 14% in 2006. The trend in the total GWP weighted emissions expressed as the fall between 1990 and 2006 is -16%, with 95% of the values found to lie within the range -18% to -13%. The source making the major contribution to the overall uncertainty is 4D – Agricultural soils.

A full description of the uncertainty analysis is presented in **Annex 7**. The uncertainty estimates for all gases are summarised in **Table A7.3.1**.

1.8   GENERAL ASSESSMENT OF COMPLETENESS

The UK GHG inventory aims to include all anthropogenic sources of GHGs. **Annex 5** shows sources of GHGs that are not estimated in the UK GHG inventory, and the reasons for those sources being omitted.

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 DBERR through their publication the Digest of UK Environmental Statistics (DUKES) (see **Table 1.5**), and the geographical coverage of DUKES helps define the geographical coverage of the inventory.

The DBERR advises that the geographical coverage of the statistics is the United Kingdom (DBERR, 2007). 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 DBERR 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)[6] who have joined, or are likely to join, the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol.
The UK has two 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 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. The Crown Depedencies are not members of the European Union.

▶ 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. The OTs include the Sovereign Bases (SBs) as a subset.

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[6] These OTs are the Cayman Islands, Falkland Islands, Bermuda, Montserrat and Gibraltar

The UK currently submits the same GHG inventory to the European Monitoring Mechanism and the UNFCCC. However, from 2009 the UK will submit a separate inventory to the EUMM, including emissions only from the UK and Gibraltar, and excluding all other OTs and CDs that do not form part of the EU.

1.10 UK GREENHOUSE GAS REGISTRY

The UK Greenhouse Gas Registry is operated and mainted by the Environment Agency on the behalf of Defra. Information on legal entities authorised to participate in mechanisms under Articles 6, 12 and 17 of the Kyoto Protocol can be found on the Emissions registry website at http://emissionsregistry.gov.uk/

A full description of the UK Registry system is presented in the UK's Initial Report under the Kyoto Protocol.[7]

1.10.1 Units held in 2007

The UK will report annually on acquisition, holding, transfer, cancellation, withdrawal and carryover of assigned amount units, removal units, emission reduction units and certified emission reductions during the previous year.

In the UK no units of the kind listed above were issued, acquired, held, transferred, cancelled, withdrawn or carried over in 2007.

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[7] http://unfccc.int/national_reports/initial_reports_under_the_kyoto_protocol/items/3765.php

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 2006, the total direct greenhouse gas net emissions (including LULUCF emissions) in the UK were estimated to be 653.8 Mt CO_2 equivalent. This was some 15.6% below the 1990 level. There was a reduction of about 16.4% relative to the fixed base year under the Kyoto Protocol, which includes F gas emissions for 1995 rather than 1990 and only includes LULUCF emissions and removals under Article 3.7 (base year) and Articles 3.3, 3.4 for the rest of the timeseries.

The following sections summarise the emission trends between 1990-2006 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%. 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 15.6% since 1990 (16.4% relative to the fixed base year under the Kyoto Protocol), with emissions of all gases declining.

In 2006, CO_2 emissions were 555.9 Mt CO_2 equivalent, 6.3% below the 1990 level. Emissions have risen about 2.6% since 1999 due to higher coal burn relative to gas and in some years reduced nuclear output and lower outside temperatures.

Methane is the second most significant greenhouse gas in the UK after CO_2. In 2006, methane emissions were 49.3 Mt CO_2 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 53%.

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 2006, emissions of nitrous oxide were 38.3 Mt CO_2 equivalent. Emissions have declined 40% since 1990. This decline is due to decreases in emissions from both the agricultural and industrial sectors. Emissions of nitrous oxide from transportation have increased due to greater use of catalytic converters.

Emissions of the F-gases (HFCs, PFCs, and SF_6) totalled 10.4 Mt CO_2 equivalent in 2006. Since 1990 the overall decrease in their emissions has been 25%, due mainly to the fall in industrial process F-gas emissions.

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 some 86% to the total emissions. Within this category the largest contributions arise from the energy industries (33%) and transport (24%). 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 8% 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 18% 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 50%, mostly due to a change in the emissions from the chemical industry

Land Use, Land-use Change and Forestry contains sinks as well as sources of CO_2 emissions. LULUCF has been a net sink since 1999. Emissions from this source occur for CO_2, N_2O and CH_4.

Emissions from the waste sector contributed 3.4% to greenhouse gas emission in 2006. Emissions consist of CO_2, N_2O and CH_4 from waste incineration, and CH_4 and N_2O 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_2

The indirect greenhouse gases in the UK consist of Nitrogen Oxides (NO_X), Carbon Monoxide (CO), Non-Methane Volatile Organic Compounds (NMVOC) and Sulphur dioxide (SO_2). Of these, NO_x, 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_X 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 2006, the total emissions were 1595 Gg, with 99.7% of these emissions arising from the energy sector. Since 1990, emissions have decreased by 46%, 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 2006, the total emissions were 2263Gg, of which 91% were from the energy sector. Since 1990, emissions of CO have decreased by 72%. 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 2006, total emissions of NMVOCs were 909 Gg, of which 41% 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 62%. 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. Further reductions have occurred due to control of emissions from most industrial sources of NMVOCs.

Total SO_2 emissions in 2006 were 676 Gg. Of this, 95% 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_2 from the energy sector have decreased by 82%. 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
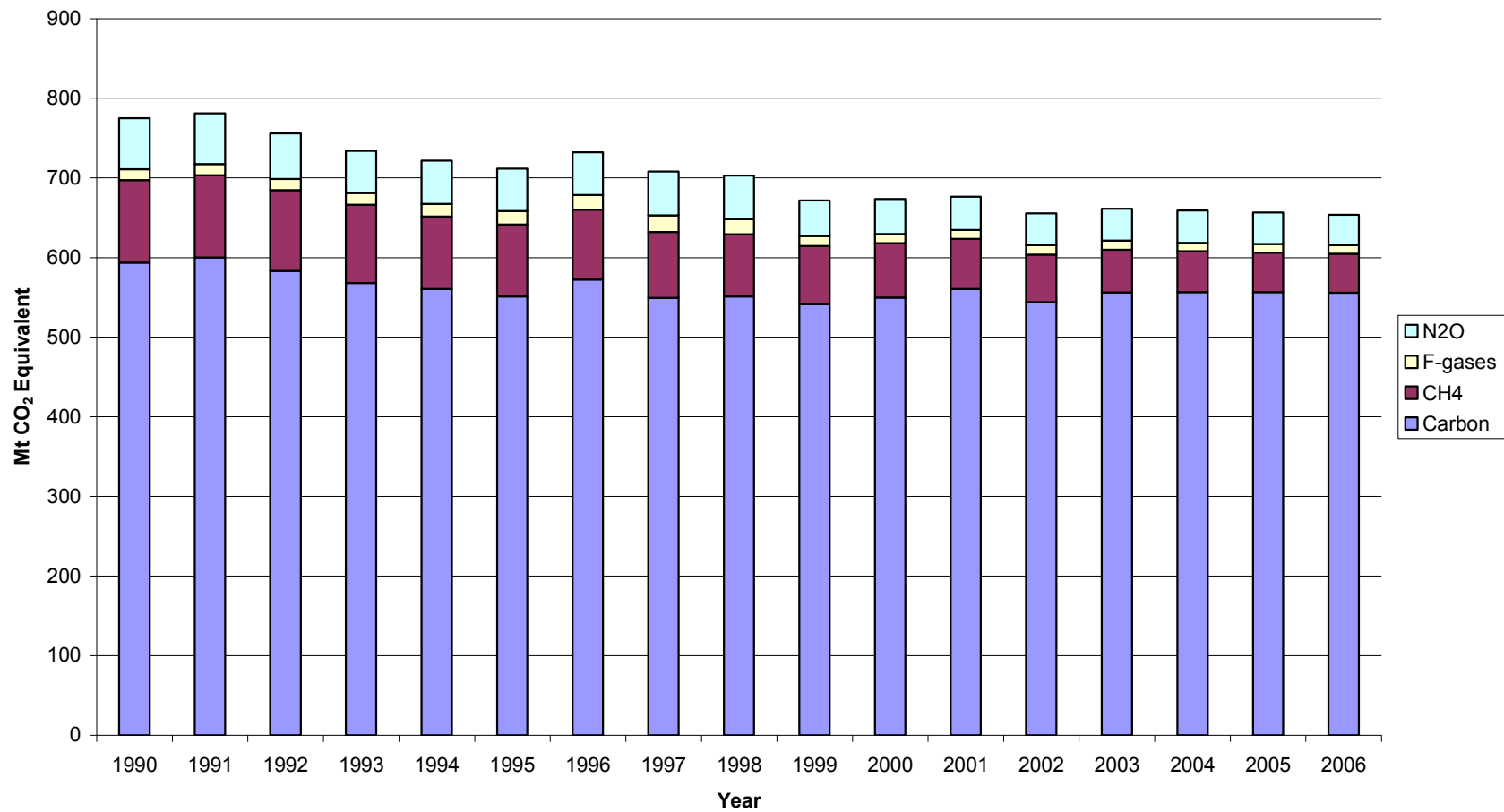
Figure 2.2: UK Net Emissions of Greenhouse Gases by Source
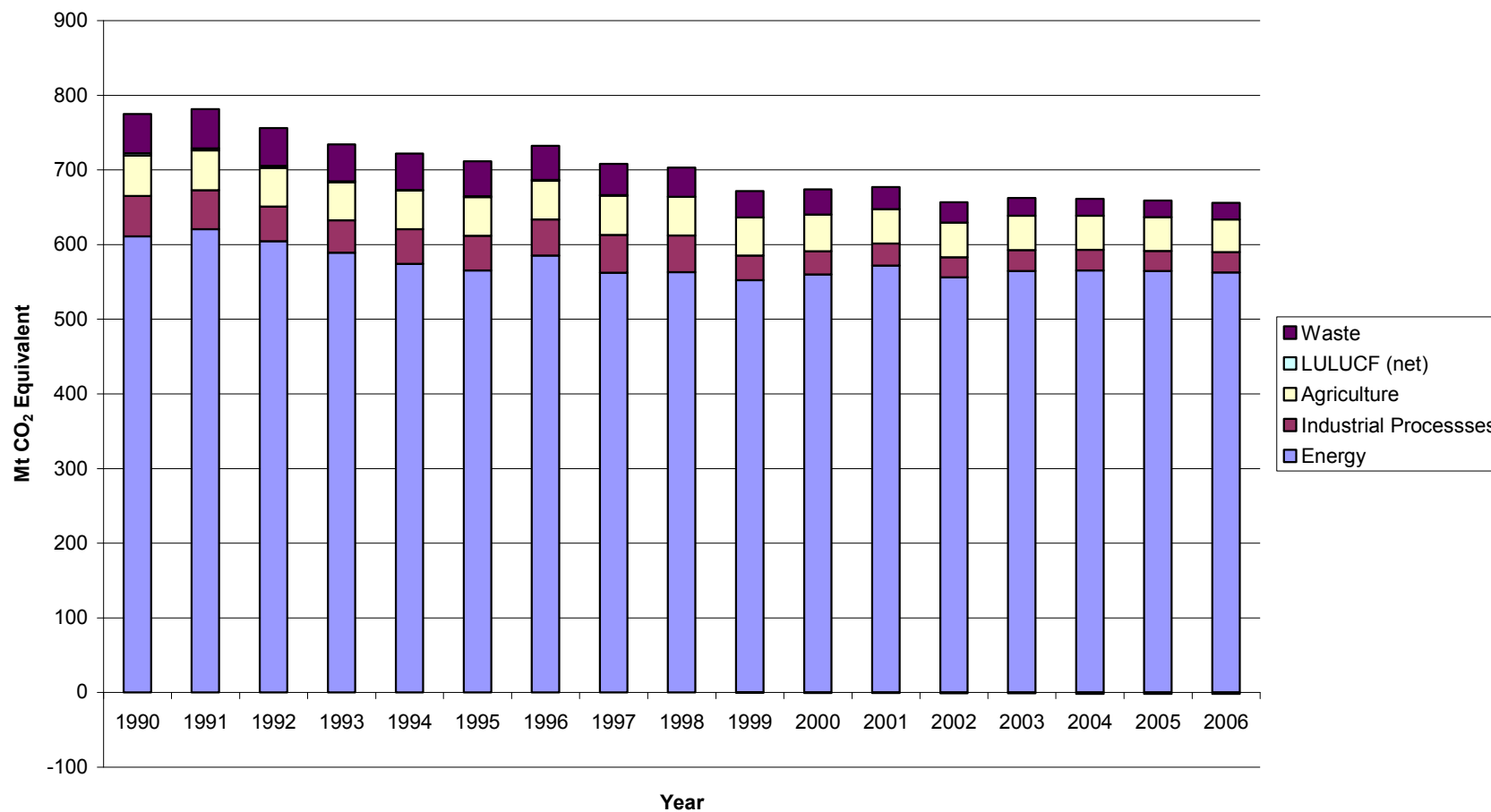
'Solvent and Other Product Use' is not shown in Figure 2.2 as it has zero emissions for all years.

Figure 2.3: UK Net Emissions of Indirect Greenhouse Gases
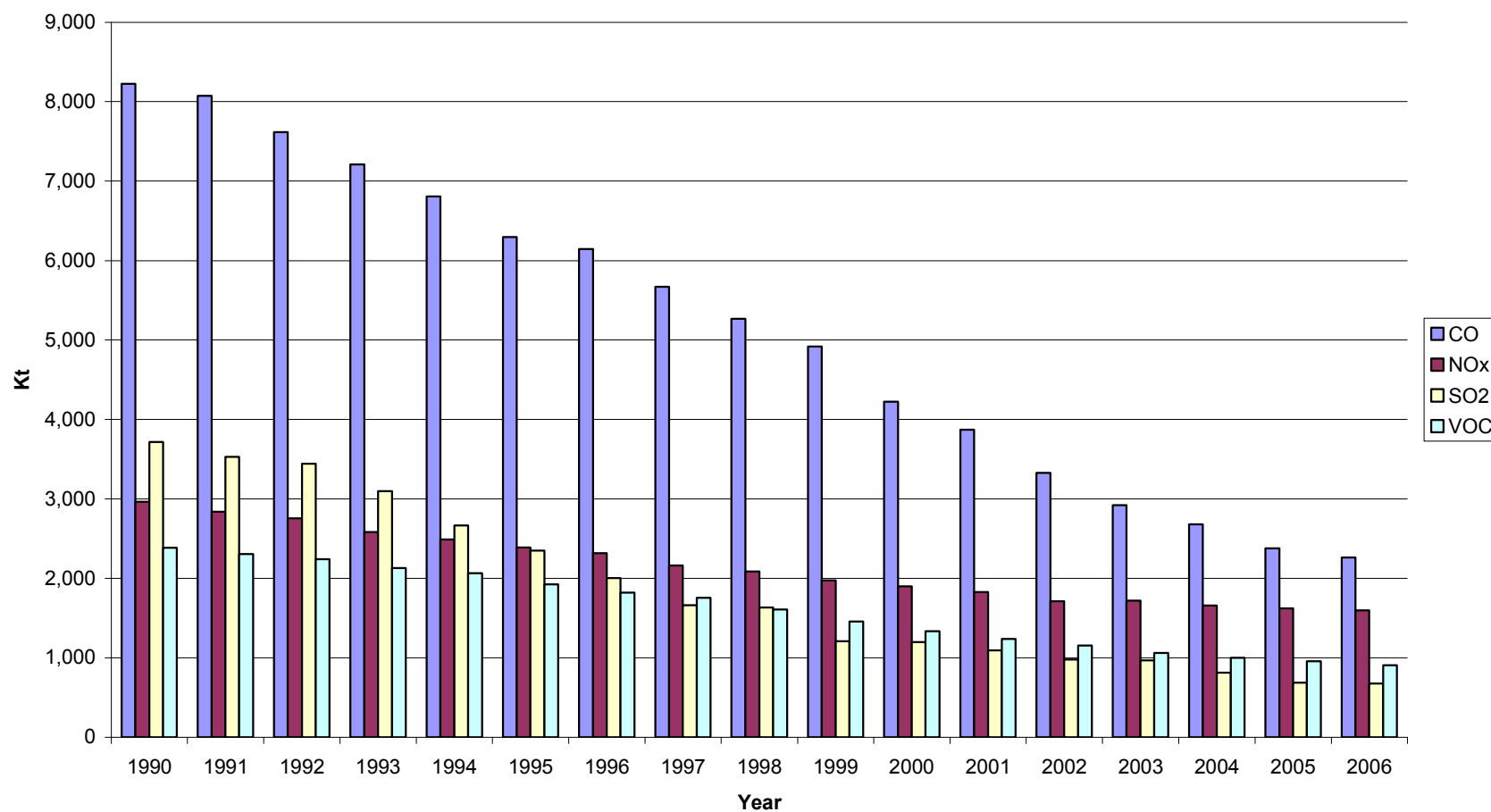
3   Energy (CRF sector 1)

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 2006, 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 56 mtonnes of coal was burnt at 17 power stations during 2006, while approximately 9,500 Mtherms of natural gas was consumed at 38 large power stations and 10 small (50MWth) regional stations (mostly Combined-Cycle Gas Turbines, CCGTs). Heavy fuel oil was the main fuel at 4 facilities, one being a small regional station, and gas oil or burning oil was used by 12 small power stations.

Bio-fuels are burnt at an increasing number of power generation sites to help electricity generators 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. CO_2 emissions associated with biofuel combustion are estimated and reported as memo items, but not included in national totals. Emissions of other greenhouse gases are estimated and included. This is in accordance with IPCC advice in the treatment of biofuels.

Electricity is also generated at 21 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.

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 2006, there were five coke ovens at steelworks and one independent coke oven. A further three coke ovens have closed in the last four 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 two 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 (BERR, 2007) 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 reallocation concerns oils consumed in power stations. DUKES reports less fuel burnt by power producers than is reported by operators either directly to AEA or via the EU Emissions Trading Scheme (EUETS). Therefore fuel oil, gas oil, and burning oil are reallocated from industry to power stations to ensure consistency with operator data. The reallocation for fuel oil was introduced to the inventory in previous versions but has been revised for this version, and corrections for gas oil and burning oil have become necessary for the first time in this version of the inventory. As well as incorporating data for 2006, some historical input data have been revised for this version, leading to the need for changes in the methodology for gas oil and burning oil and revisions to estimates for use of fuel oil.

Previously, a reallocation had also been made to the GHGI estimates for coal compared with DUKES. This was done because DUKES data for coal consumed by industry were insufficiently high to cover coal use reported by the cement sector and coal use estimated for other industrial sectors. On the advise of BERR, a reallocation of coal from power stations to industry, equal to reported use of coal by the cement sector, was made. Due to revisions to DUKES, this reallocation is no longer needed and has been removed for this version of the inventory.

For some sectors, emissions data are available for individual sites, either from the Environment Agency for England and Wales (EA, 2007), via the Pollution Inventory (PI); from the Scottish Environment Protection Agency (SEPA, 2007), via the Scottish Pollutant Release Inventory (SPRI); or from the Inventory of Statutory Releases (ISR) of the Department of the Environment in Northern Ireland (DOENI, 2007). 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$_2$	CH$_4$	N$_2$O	CO	NOx	SO$_2$	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 Approach 1 (error propagation) uncertainty analysis in **Annex 7** 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 DBERR 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 DBERR (formally 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 the DBERR.

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	• EFs vary somewhat across the time series based on comprehensive carbon factor review in 2004. • Key sources of carbon EF data include: UKPIA, Association of Electricity Producers, Powertech, Transco.
CH$_4$, N$_2$O	1A1	All fuels	• Nearly all EFs are constant over the entire time series, with limited use of time-varying EFs due to fuel variability or technological developments. • Increased availability of data from emissions of combustion of poultry litter has resulted in variable EFs across the time-series for both CH$_4$ and N$_2$O.

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 DBERR (formally 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

Some recalculations for indirect greenhouse gases emissions have been made due to further development and refinement of the system for calculating emissions of indirect gases from power stations. A review of this system was started for the 2004 inventory leading to the calculations being transferred from spreadsheet to database form. At the same time, the data and assumptions used in the calculations were reviewed and any errors or inconsistencies corrected.. The development of this new system has, so far, focussed on the derivation of emission factors for the year 1997 onwards, and emission factors for earlier years have not been reviewed and refined to the same extent, largely due to the complexity of that task. Future improvements should address this, and though it is not anticipated that it will result in very significant changes in emission estimates, it should improve the transparency of the methodology used in this area.

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 2005 inventory (2007 NIR). Comparisons are made

between the current inventory (1990-2006) and the previous inventory (1990-2005) for the year 2005.

3.2.4.1.1   Carbon Dioxide (CO_2)

- Overall there has been an increase in estimated emissions for 2005 of 3105 Gg CO_2 from sector 1A1. This increase 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 of 2206 Gg CO_2 from power stations due to a reallocation of coal from other industrial combustion to power stations. This was done so that fuel use in the inventory was consistent with that reported in the EU-ETS.
- A revision to energy statistics for gas oil use in power stations caused an increase in emissions of 427 Gg CO_2.
- A decrease of 148 Gg CO_2 from fuel oil use in power stations occurred due to a revision to energy statistics.
- Petroleum coke emissions from power stations have, for the first time, been included in this year's inventory. These emissions total 226 Gg CO_2.
- There has been an increase in estimated emissions of 545 Gg CO_2 from petroleum refining due to a revision in energy statistics for natural gas.

3.2.4.1.2   Methane (CH_4)

- Overall there has been an increase in estimated emissions for 2005 of 0.16 Gg CH_4 from sector 1A1.
- The major cause of this increase was a change in the emission factor used for petroleum coke from petroleum refining. This caused an increase of 0.11Gg CH_4.
- Energy statistics revisions to gas oil use in power stations caused an increase of 0.02 Gg CH_4.
- Energy statistics revisions to coal use in power stations caused an increase of 0.02 Gg CH_4.
- Energy statistics revisions to fuel oil use in power stations caused a decrease of 0.01 Gg CH_4.
- The addition of emissions from petroleum coke in power stations caused an increase of 0.01 Gg CH_4

3.2.4.1.3   Nitrous oxide (N_2O)

- There was a decrease of 0.07 Gg of N_2O from coal use in Power stations due to revisions to both the activity data and emission factor.

3.2.4.1.4   Nitrogen Oxides (NO_X)

- There has been a decrease of 3 Gg NO_x in estimated emissions from oil-fired power stations and an increase of 3 Gg NO_x for gas-fired power stations, due to revisions to energy statistics, the updating of input data, and the correction of some errors in the calculation of emission factors for power stations.

3.2.4.1.5   Carbon Monoxide (CO)

- There have been revisions to estimates of emissions from power station use of coal (-2Gg), petroleum coke (+2Gg), natural gas (+1Gg) and fuel oil (-1Gg) due to revisions to energy statistics, the updating of input data, and the correction of some errors in the calculation of emission factors for power stations.

3.2.4.1.6   Sulphur Dioxide (SO_2)

- There has been a decrease of 1 Gg SO_2 in estimated emissions from coal-fired power stations due to revisions to energy statistics, the updating of input data, and the correction of some errors in the calculation of emission factors for power stations.

3.2.4.1.7   Volatile Organic Compounds (VOC)

- There have been no significant recalculations for this version of the inventory.

3.2.5   Source-specific planned improvements

Emission factors and activity data are kept under review. Fuel characterisation data from verified Emission Trading Scheme datasets will be considered in future GHGI cycles. Further refinement of emission estimates for indirect gases will concentrate on improving the transparency of the methodology used for the years 1990-1996.

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 or melting 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 emission from 1A2

Sector/pollutant	CO$_2$	CH$_4$	N$_2$O	CO	NO$_x$	SO$_2$	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[1]	Emission factors and fuel consumption data						
Other Industry	Emission factors and fuel consumption data[2]						
Sinter Plant	Emission factors and fuel consumption data			Emissions estimates for individual sites provided by process operators			

[1] For the largest coal fired autogenerator, emissions data from the Pollution Inventory is used for CO, NO$_x$, SO$_2$
[2] Emission estimated for NO$_x$ 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 Approach 1 (error propagation) uncertainty analysis in **Annex 7** 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 DBERR 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	• 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.
CH$_4$, N$_2$O	1A2	All fuels	• Nearly all EFs are constant over the entire time series, with limited use of time-varying EFs due to fuel variability or technological developments.

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 DBERR 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 lead to amendments to fuel allocations reported by DBERR(through fuel re-allocations between sectors).

3.3.5 Source-specific recalculations

Reallocation of gas oil and DERV relative to DUKES is necessary because the GHGI divides the use of these fuels between stationary plant and mobile plant (off-road vehicles and mobile machinery), whereas DUKES does not. The reallocation method used in the 2005 inventory would have produced negative values for fuel used in industrial stationary plant in the 2006 inventory so clearly required revision. The methodology has therefore been revised so that a greater proportion of fuel is reallocated from the commercial and public sectors and less from the industrial sector. The GHGI still maintains consistency with the total UK consumption of gas oil/DERV reported in DUKES.

As already described in **Section 3.2.2**, a reallocation of coal from the power sector to the cement sector previously had beenmade, but has now been discontinued since problems reconciling UK energy statistics and coal use data provided by the British Cement Association (2007) have been resolved. 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.

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 2005 inventory (2007 NIR). Comparisons are made between the current inventory (1990-2006) and the previous inventory (1990-2005) for the year 2005.

3.3.5.1.1 Carbon Dioxide (CO_2)
- Estimated emissions of CO_2 from 1A2 have decreased by 1431 Gg CO_2. The main reasons for these changes are given below.
- Emissions from manufacturing, industry and combustion (1A2f) decreased by 2003 Gg CO_2 as a result of changes to both the activity data and emission factor for coal.
- An increase of 442 Gg CO_2 occurred as a result of changes to gas oil activity data statistics.
- There was a decrease of 875 Gg CO_2 from autogeneration due to changes in natural gas activity statistics
- There was an increase of 995 Gg CO_2 from other industrial combustion as a result of changes in natural gas activity statistics.

3.3.5.1.2   Methane (CH_4)

- There was an overall decrease in emissions of 0.09 Gg CH_4. The major cause of this decrease was a change in the emission factor used for petroleum coke from petroleum refining. This caused a decrease in emissions of 0.11 Gg CH_4. The remaining changes were caused by small fluctuations in activity data for coal, natural gas and gas oil.

3.3.5.1.3   Nitrous Oxide (N_2O)
- There has been an overall decrease of 0.2 Gg N_2O from 1A2. This was caused by changes to both the emission factor and activity statistics for coal.

3.3.5.1.4   Nitrogen Oxides (NO_x)
- There have been a series of recalculations to estimated emissions from natural gas combustion by autogenerators and industrial combustion of coal, coke, and natural gas due to revisions to emissions data available from regulators and updates to energy data. A revision to the emission factor used for medium (20 – 50 MWth) boilers, and a correction in the case of industrial coke combustion have also affected emission estimates. The overall impact of these changes is a decrease in emissions from 1A2f of 15 Gg.

3.3.5.1.5   Carbon Monoxide (CO)
- Estimated emissions from industrial combustion of coal have decreased by 2 Gg due to revisions to energy statistics.

3.3.5.1.6   Sulphur Dioxide (SO_2)
- Estimated emissions from industrial combustion of coal have decreased by 18 Gg due to revisions to energy statistics and incorporation of updated data on coal sulphur content.

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[8]. Emissions from aviation comprise emissions from the landing and take-off phases and the cruise phase of the flight. A technique following the IPCC Tier 3 method to estimate emissions and fuel use for civil aircraft in the UK has been developed and is used. 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 cycle 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 Approach 1 (error propagation) uncertainty analysis in **Annex 7** 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 DBERR 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. 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.

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[8] 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 requiremnts of other international treaties.

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	• 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
CH_4, N_2O	1A3	Fuel types used in the UK	• For road transport, time varying EFs used appropriate to emission standards in force and age profile of vehicle fleet

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 2005 inventory. Comparisons are made between the current inventory (1990-2006) and the previous inventory (1990-2005) for the year 2005.

3.4.5.1.1 Carbon Dioxide (CO_2)
- Emissions from 1A3 Transport have increased overall by 26 Gg CO_2, due to changes in estimates for rail transport and civil aviation..
- Estimated emissions from category 1A3a Aviation decreased by 62 Gg CO_2 This was due to the incorporation of revised operational data in the LTO cycle (principally thrust settings at take-off).
- Estimated emissions from Railways (1A3c) have increased by 95 Gg CO_2 due to improved rail freight emission factors being used and improvements to the methodology for passenger transport.
- Although there has been no change in total CO_2 emissions from road transport, there are revisions in the allocation between vehicle types due to revisions in fuel consumption factors used for individual vehicle categories.

3.4.5.1.2 Methane (CH_4)
- There has been a small increase in estimated methane emissions from transport of 0.02 Gg. There were very minor reductions in the estimated emissions from buses, but these were offset by the introduction of improved emission factors in the rail sector.

3.4.5.1.3 Nitrogen Oxides (NO_x)
- The decrease in emission estimates from 2005 to 2006 is due to increased penetration of cleaner vehicles. This is somewhat offset by increases to the rail sector due to new and improved emission factors being utilised.

3.4.5.1.4   Carbon Monoxide (CO)
- The decrease in emission estimates from 2005 to 2006 is due to increased penetration of cleaner vehicles. This is somewhat offset by increases to the rail sector due to new and improved emission factors being utilised.

3.4.5.1.5   Non-Methane Volatile Organic Compounds (NMVOC)
- The decrease in emission estimates from 2005 to 2006 is due to increased penetration of cleaner vehicles. Again this is offset to a small extent by the increased emissions from the rail sector due to new and improved emission factors being used.

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 to estimate consumption of petroleum coke as a fuel by the domestic sector has been revised. DUKES does not include any estimates of the use of petroleum coke as a fuel in balance tables, although some estimates of total consumption of petroleum coke for energy are given in the accompanying text. The GHGI therefore includes AEA's own estimates. The methodology has been revised this year to make better use of data available on the use of petroleum coke by power stations and cement works. The result is that estimates of domestic consumption of petroleum coke are significantly lower than previously.

The methodology by which gas oil is reallocated from the industrial, commercial and public sectors to off-road vehicles and mobile machinery has changed, resulting in smaller estimates of gas oil burnt in the commercial and public sectors relative to use of the previous method, and larger estimates of consumption by industry. However, the GHGI still maintains consistency with the total UK consumption of gas oil/DERV reported in DUKES.

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 AEA, which includes some minor modifications to fuel use allocations from DUKES. See Section A.3.3.7 for further details.

3.5.3   Uncertainties and time-series consistency

The Approach 1 (error propagation) uncertainty analysis in **Annex 7** 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 DBERR 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	• EFs vary somewhat across time series based on the UK carbon factor review in 2004.
CH_4, N_2O	1A4	All fuels	• Nearly all EFs are constant over the entire time series, with limited use of time-varying EFs due to fuel variability or technological developments.

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).

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 2005 inventory (2007 NIR). Comparisons are made between the current inventory (1990-2006) and the previous inventory (1990-2005) for the year 2005.

3.5.5.1.1   Carbon Dioxide (CO_2)
- Overall CO_2 emissions from 1A4 decreased by 922 Gg CO_2. The main reasons for this changes are highlighted below.
- 1A4a emissions from gas oil decreased by 483 Gg CO_2 due to revisions to national statistics.
- Revisions to national statistics caused an increase of 112 Gg CO_2 from natural gas in 1A4a.
- In the residential sector (1A4b), emissions from natural gas increased by 394 Gg CO_2 as a result of changes to national statistics.
- Emissions from petroleum coke in the residential sector decreased by 610 Gg CO_2 as a result of changes in national statistics.

3.5.5.1.2   Methane (CH_4)
- There was a revision to the methodology used to estimate emissions from Overseas Territoires which lead to a decrease of 0.52 Gg from 1A4cii.
- A reallocation of gas oil to reflect new rail methodology caused a decrease of 0.14 Gg from 1A4a.

3.5.5.1.3   Nitrous Oxide (N_2O)
- A reallocation of gas oil to reflect new rail methodology caused a decrease of 0.01 Gg from 1A4a

3.5.5.1.4   Carbon Monoxide (CO)
- Estimated emissions of CO from domestic combustion of petroleum coke decreased by 28Gg as a result of revisions to activity 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 Approach 1 (error propagation) uncertainty analysis in **Annex 7** 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 has 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	• EFs vary somewhat across time series based on the UK carbon factor review in 2004.
CH_4, N_2O	1A2	All fuels	• Nearly all EFs are constant over the entire time series, with limited use of time-varying EFs due to fuel variability or technological developments.

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
There were no significant recalculations for this sector.

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_2. In 2006, the shipping emission contributed 16% to total bunker emissions, with aviation contributing the remaining 84%. 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$_2$ FROM FLUE GASES

Currently in the UK, CO$_2$ 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 2006), emissions estimated by the Reference Approach have fallen by 2.3 % compared with 5.2% for the sectoral approach. A more detailed discussion of the reasons for this difference are given in **Annex 4**.

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**) 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 A3.3.27**.

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**.   For other pollutants, estimates are either made based on operators' reported emissions or on production data and emission factors as provided in **Table A3.3.27**.

Methane emissions from closed coal mines are accounted for within Sector 1B1a of the UK inventory, with estimates based on consultation with the author of a recent study funded by Defra (Kershaw, UK Coal, 2007). The original study into closed coal mine emissions was conducted during 2005. The estimation method for both historic and projected methane emissions from UK coal mines comprised two separate sets of calculations to estimate emissions from (1) coal mines that had been closed for some years, and (2) methane emissions from mines that had recently closed or were forecast to close over 2005 to 2009. The 2005 study derived emission estimates for the years 1990 to 2050 using a relationship between emissions and the quantity of the underlying methane gas within the abandoned mine workings, including site-specific considerations of the most appropriate decay model for the recently closed mines. Consultation with the author has confirmed the actual mine closure programme in the UK and has thus provided updated estimates for 2005 and 2006. 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 Approach 1 (error propagation) uncertainty analysis in **Annex 7** 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 DBERR 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**.

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

3.12.5.1.1 Methane (CH_4)

- There was an increase in emissions of 13.4 Gg from closed coal mines for the 2005 data only, due to a revision of the recent coal mine closure programme and consultation with the UK Coal Board. This resulted in a revision to the emission factor for closed coal mines.

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_2, CH_4, CO, N_2O, NO_x, SO_2, 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_4 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_4 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_4, CO, N_2O, NO_x, SO_2, 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

Emission estimates for the offshore oil & gas industry are based on data provided by the trade organisation, Oil and Gas UK (formerly UKOOA), through their annual emissions reporting mechanism to the UK regulatory agency (the Department of Business, Enterprise and Regulatory Reform), called the Environmental Emissions Monitoring System (EEMS). This system provides a detailed inventory of point source emissions estimates, based on operator returns for the years 1995-2006. Additional, more detailed data on CO_2 emissions from some offshore combustion processes has become available via the National Allocation Plan and annual operator emission estimates for sites participating in the EU Emission Trading Scheme. Therefore, for the main combustion sources in the offshore oil & gas sector, the Oil and Gas UK data from 1998 onwards is sourced from NAP estimates and reported EU-ETS data, superseding any historic estimates previously reported via EEMS. The time-series of data has been reviewed for the 1990-2006 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 Oil and Gas UK summary report produced in 1998.   The 1990-1994 detailed estimates are 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 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 are then calculated using production-weighted interpolations. Only limited data are available from operators in 1990-1994, and emission totals are only presented 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 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 are available for 2002 and 2004 onwards, whilst in England & Wales the Pollution Inventory of the EA holds emissions data from industrial plant from around 1995 onwards.

For the EEMS reporting cycle for 2006 data, a new online system of operator reporting was implemented by DBERR. However, due to teething problems of this new system the operator emissions data provided to the Inventory Agency was incomplete for several sources including

drilling and well testing (all activity data and emissions data), onshore loading (missing NMVOC emissions for several sites), onshore fugitive emission sources (missing methane data for some sites), and onshore own gas use data (CO_2 emissions for some sites).

To resolve these data gaps, the Inventory Agency agreed the following actions with DBERR (Furneaux, 2007):

- Offshore well testing: 2005 data used for 2006
- Onshore loading: NMVOC emissions reconciled with (higher) reported totals from all terminal sites within the SPRI and PI for 2006
- Onshore Fugitive sources: Methane emissions reconciled with (higher) reported totals from all terminal sites within the SPRI and PI for 2006
- Onshore Own Gas use: Carbon dioxide emissions reconciled with (higher) reported totals from all terminal sites within the SPRI and PI for 2006

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, 2007) 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 Approach 1 (error propagation) uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type.

The emission estimates for the offshore industry are based on the Oil and Gas UK EEMS dataset for 1995-2005. Emission estimates from 1990-1994 (i.e. pre-EEMS) are estimated from specific Oil and Gas UK studies of 1991 and 1998, using production data as a basis for interpolation of data between 1990 and 1995. The new dataset provided in 2007 by Oil and Gas UK now provides a more consistent time-series of data for the range of activities within this sector. **However, significant gaps identified in the 2006 data suggest that the new online reporting system does not currently provide a comprehensive dataset for some sources in this sector, which is primarily a matter for the regulatory agency, DBERR to address.** 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**. Oil and Gas UK provides emission estimation guidance for all operators to assist in the completion of EEMS and EU-ETS returns to the UK environmental regulators, including the provision of appropriate default emission factors for specific activities, where installation-specific factors are not available.

The data gaps inconsistencies evident within the latest (2006) data submission (e.g. when compared to previous submissions to the Inventory Agency through EEMS) indicate that the source data may not be subjected to significant QA/QC by either the regulatory agency (DBERR) or the trade association (Oil and Gas UK) or indeed the operators themselves.

There are inconsistencies evident from oil and gas terminal submissions to different reporting mechanisms. For example different NMVOC and methane emission totals have been reported by terminal operators under IPPC compared to those submitted under the EEMS system. It is unclear whether these reporting inconsistencies are due to a different scope of operator activities being reported via these two systems, or due to operator errors.

3.13.5   Source-specific recalculations

There have been no major recalculations.

3.13.5.1 Recalculation by gas
There have been no major recalculations for sector 1B2.

3.13.6   Source-specific planned improvements

There are some significant step-changes in emission factors 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 have not been thoroughly conducted. These issues were raised at a meeting between the Inventory Agency, Single National Entity and the offshore industry regulator (DBERR) in summer 2006, and this led to some improvements in the quality and timeliness of data delivered for the 2005 inventory cycle. However, it is evident from the 2006 dataset that this sector is now a high priority for further data and method improvements during 2008. A meeting with DBERR and UK Oil and Gas is planned for summer 2008. Access to verified ETS data may provide some useful clarifications.

3.14   GENERAL COMMENTS ON QA/QC

3.14.1   DBERR Energy Balance Data

The DBERR (formally the DTI) provides the majority of the energy statistics required for compilation of the NAEI and the GHGI. These statistics are obtained from the DBERR 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*[9] and as such is subject to regular QA audits and reviews.

The DBERR 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, DBERR 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 seasonal, comparison is also made with corresponding data for the same month or quarter in the previous year. The DBERR also uses an energy balance approach to verify that individual returns are sensible. Any queries are followed up with the reporting companies. The DBERR 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 DBERR 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. Improvements are evident in DUKES 2006 onwards.

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 has now been completed, 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 ENERGY SECTOR 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:

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[9] ONS. National Statistics Code of Practice Statement of Principles. ISBN 0 11 703077 5. TSO, London, UK. http://www.statistics.gov.uk/about_ns/cop/downloads/StatementRD.pdf

- 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 DBERR 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 ($CaCO_3$), 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 (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 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 NO_X and N_2O which are reported under 1A2f. Finally, emissions of methane, NMVOC, SO_2 and 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 current GHGI methodology for estimating emissions of these pollutants does not allow emissions from fuels and emissions from raw materials to be quantified separately and so all emissions of these four pollutants are reported under 1A2f.

The UK had 16 sites producing cement clinker during 2006.

4.2.2   Methodological issues

The methodology used for estimating CO_2 emissions from calcination is to use data provided by the British Cement Association (2007), which in turn is based on data generated by UK

cement clinker producers for the purposes of reporting to the EU Emission Trading Scheme. The data are available for 2005 and 2006 only, and so the value for 2005 has been applied to earlier years as well. Previously, estimates had been based on the IPCC Tier 2 approach (IPCC, 2000), yielding an emission factor of 137.6 t C/kt clinker. The revised emission factors are about 10% higher than this figure and the reasons for this disparity are that the previous emission factor:

- Slightly underestimated the CaO content of clinker produced;
- Failed to take account of CO_2 emitted from dolomite (i.e. the method assumed a zero MgO content, which was not correct).

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.

The activity data show a peak production of clinker in 1990, followed by a sharp decline by 1992/1993 (production in 1992 was just 75% of the figure in 1990). Following this slump, production increased again and remained fairly consistent until 2000, after which time production again decreased. Average production in the years 2001-2006 has been about 90% of the average level during the period 1994-2000. The initial large drop in clinker production can be explained by a sharp drop in construction activity and hence a decline in the need for cement (confirmed by statistics available for the construction industry). The less pronounced decline in production over the period 1994-2006 may, in part, be due to increased use of slag cement, the production of which is likely to have risen sharply over the same period.

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

The change to the methodology for estimating decarbonisation emissions leads to an increase in estimated emissions of 518 Gg CO_2 for 2005.

4.2.6   Source-specific planned improvements

Emission factors and activity data will be kept under review.

4.3   SOURCE CATEGORY 2A2 – LIME PRODUCTION

4.3.1   Source category description

Lime (CaO) is manufactured by the calcination of limestone ($CaCO_3$) and dolomite ($CaCO_3MgCO_3$) 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 16 UK sites during 2006. Two of these produce lime for use on-site in the Solvay process and six 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, 2007). 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 and 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 separately by the British Geological Survey, but included in the limestone data: the use of the limestone factor for this dolomite calcination will cause a small under-estimate of emissions. Dolomite calcination is believed to be a small proportion of the total hence the underestimate is unlikely to be significant. The limestone calcination data exclude limestone calcined in the chemical industry since a large proportion of this is use in the Solvay process, which does not release CO_2. The calcination of limestone in the sugar industry is also excluded for the same reason.

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 underestimate in emissions. The exclusion of limestone used by the chemicals industry and sugar production will also lead to a small underestimate since not all CO_2 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 2004-2006 do not include an estimate of the quantity of limestone used by the chemical industry, thus this has had to be estimated by AEA. This means that the estimates for these years are somewhat more uncertain than estimates for other years. Should BGS data continue to omit these data, then additional data sets may need to be sought in order to avoid an increasing level of uncertainty in emission estimates for this sector.

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

An error in the calculation of activity data for 2005 has been corrected which leads to an increase in estimated emissions of 55 Gg CO_2.

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 being 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 in the steel industry, 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_2 emissions from combustion processes. The limestone reacts with the SO_2 and is converted to gypsum, with CO_2 being evolved.

The UK had three operational steel-making sites during 2006 and approximately 20 large glassworks manufacturing soda-lime type glasses. FGD was operational on five UK power stations by the end of 2006.

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 (2007) and the Iron & Steel Statistics Bureau (2007), respectively and gypsum produced in FGD plant is available from the British Geological Survey (2007).

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 Approach 1 (error propagation) uncertainty analysis in **Annex 7** 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

Some updates have been made in the limestone and dolomite consumption data provided by the Iron & Steel Statistics Bureau and BGS. The revisions lead to an increase in CO2 emissions of 21 Gg in 2005.

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, Na_2CO_3) is used in the manufacture of soda-lime glasses. The soda ash decomposes in the melt to Na_2O, which is incorporated into the glass, and CO_2, which is released to atmosphere. Other uses of soda ash can also result in the emission of 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 20 large glassworks manufacturing soda-lime type glasses.

Soda ash in the UK is manufactured at two sites using the Solvay process. These processes involve the use of natural gas to calcine limestone, thereby producing lime and CO2. The CO2 resulting from combustion of the natural gas is reported under 1A2f, while the CO2 resulting from the decarbonisation of the limestone is assumed to be consumed in the subsequent production of soda ash. Some emissions of CO do occur from the process and are reported under 2A4.

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, 2007). 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.

Emissions of CO from soda ash production are estimated based on emissions data reported in the Pollution Inventory (Environment Agency, 2007).

4.5.3   Uncertainties and time-series consistency

The Approach 1 (error propagation) uncertainty analysis in **Annex 7** 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_2 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_2 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 (BERR, 2007).

4.7.3   Uncertainties and time-series consistency

The Approach 1 (error propagation) uncertainty analysis in **Annex 7** 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. Emissions occur due only to the use of specialised bitumen products containing kerosene and it is unclear whether the extrapolation using consumption of bitumen for all applications will be reliable.

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

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

4.7.6   Source-specific planned improvements

Emission factors and activity data will be kept under review.

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_2 emissions as well.

Glass fibres were manufactured at one site in the UK during 2006, and glass wool was manufactured at ten 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, 2007). 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.
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 has not provided any additional data; this necessitated extrapolation which will have 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, 2007 and an emission factor of 8.73 g/t coated roadstone, which is the average of emission factors given by US EPA, 2007 for various types of batch roadstone coating plant.

4.8.3   Uncertainties and time-series consistency

The Approach 1 (error propagation) uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type.

The estimates for all of these processes are 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

Due to some minor revisions to data used to calculate CO2 emissions from Fletton brickworks, there has been a decrease of 2 Gg CO2 from this sector.

4.8.6 Source-specific planned improvements

Emission factors and activity data will be kept under review.

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:
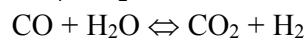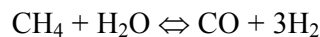
$CH_4 + H_2O \Leftrightarrow CO + 3H_2$
$CO + H_2O \Leftrightarrow CO_2 + H_2$
The hydrogen is then reacted with nitrogen from air to form ammonia

$N_2 + 3H_2 \Leftrightarrow 2NH_3$
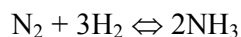
If there is no use of the by-products CO and CO_2 formed, then these are emitted to atmosphere. Ammonia plants can be integrated with methanol and/or acetic acid manufacture for greater efficiency. Thus, hydrogen formed as a by-product from acetic acid manufacture is used as the feedstock for ammonia manufacture. Some carbon monoxide and carbon dioxide from the reforming process is used to manufacture methanol:

$CO + 2H_2 \Leftrightarrow CH_3OH$
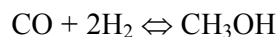
One ammonia plant sells CO_2 to the food industry and nuclear industry. Because this CO_2 is still ultimately emitted to atmosphere, it is included in the emissions reported here. This is considered more reliable than trying to identify carbon emissions at the point of final use since CO_2 will also be emitted from other processes such as fermentation.

Ammonia was being produced at four UK sites by the end of 2006, 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_2 from natural gas used as a feedstock in the ammonia and other processes.

The second category includes emissions of CO_2 and other pollutants from the combustion of natural gas to produce the heat required by the reforming process.

Emissions of CO_2 from feedstock use of natural gas are calculated by combining reported data on CO_2 produced, emitted and sold by the various ammonia processes. Where data are 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_2.

A correction has to be made for CO_2 produced at one site where some of this CO_2 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. Methanol is used as a chemical feedstock and also as a solvent and emissions of volatile organic compounds resulting from these uses are reported predominantly under 2B5 and 3D.

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

1. natural gas equivalent to carbon sequestrated in methanol (see above)
2. natural gas equivalent to the CO_2 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 is used to convert between carbon and natural gas. The total feedstock use of natural gas is estimated as the sum of items 1-3 and a CO_2 emission factor can be calculated from the CO_2 emission estimate already generated.

Emissions of CO_2 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_x are back-calculated from reported NO_x emissions data, while emission factors for carbon, methane, CO, N_2O and NMVOC are default emission factors for industrial gas combustion.

4.9.3   Uncertainties and time-series consistency

The Approach 1 (error propagation) uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type.

A consistent time series of activity data has been reported from the manufacturers of ammonia, and this results in good time series consistency of emissions. For 2001 to 2006, 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 2001-2006.

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**. and the source emissions data from plant operators is subject to the QA/QC procedures of the Environment Agency's Pollution Inventory.

4.9.5   Source-specific recalculations

No recalculations have been made for emission estimates in this category.

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:

$4NH_3 + 5O_2 \Rightarrow 4NO + 6H_2O$
$2NO + O_2 \Leftrightarrow 2NO_2$
$3NO_2 + H_2O \Leftrightarrow 2HNO_3 + NO$
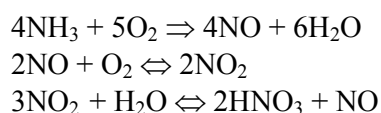
Nitrous oxide is also formed by oxidation of ammonia:

$4NH_3 + 3O_2 \Rightarrow 2N_2O + 6H_2O$
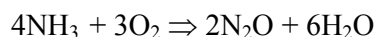
Nitrous oxide is emitted from the process as well as a small percentage of the NO_x. Nitric acid was being manufactured at 4 UK sites at the end of 2006. One of the sites has NOx/nitrous oxide abatement fitted to all nitric acid process plant since commissioning (all pre-1990). The three other sites have no nitrous oxide abatement fitted to any units.

4.10.2   Methodological issues

Across the 1990-2005 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 from plant operators are available for all sites from 1998 onwards from the EA's Pollution Inventory. For the plant (now closed) in Northern Ireland, emissions data from plant operators 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 N_2O 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 N_2O /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 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 NO_x emission factor of 3.98 tonne 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 is 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**) but 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 Approach 1 (error propagation) uncertainty analysis in **Annex 7** 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_2O for this sector does vary through the time-series depending upon the availability of data. The calculated N_2O 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_2O 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_2O abatement.

For all plants in England, emissions of N_2O 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_2O 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_2O /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_2O monitoring methodologies at the one UK plant with N_2O 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

No recalculations have been made for emission estimates in this category

### 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, 2007). The emission estimates are based on the use of plant-specific emission factors for unabated flue gases, which were determined through a series of measurements on the plant, combined with plant production data and data on the proportion of flue gases that are unabated. In 1998 an N_2O 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_2O destruction. In 2004 it was operational 92.6 % of the time (when compared to plant operation). Variation in the extent to which this abatement plant is operational, account for the large variations in emission factors for the adipic acid plant since 1999.

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.

4.11.3   Uncertainties and time-series consistency

The Approach 1 (error propagation) uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type.

Emissions of N_2O 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_2O is not fully understood. 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_2O 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, AEA, plant operators and the UK Meteorological 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_2O 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 made for emission estimates in this category

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_X, SO_2, 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. Since the 2004 inventory, emission estimates for CO_2 have also been included.

CO_2 emissions can occur direct from chemical processes, and estimates are made in the case of production of ammonia (see section 4.9). It is possible that other chemical processes also result in direct CO_2 emissions but none have been identified. Chemical processes can result indirectly in emissions if wastes from the process are subsequently used as fuels and emission estimates for this type of source have been included in the inventory since the 2004 version. 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 2006 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_2, NMVOC
- Chemical industry (carbon black) - CO, SO_2
- Chemical industry (nitric acid use) - NO_x
- Chemical industry (pigment manufacture) - SO_2
- Chemical industry (reforming) - CO
- Chemical industry (soda ash) - CO
- Chemical industry (sulphuric acid use) - SO_2
- Chemical industry (titanium dioxide) - CO
- Coal, tar and bitumen processes - NMVOC
- Solvent and oil recovery - NMVOC
- Ship purging - NMVOC
- Sulphuric acid production - SO_2

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_X and SO_2 respectively. Manufacture of nitric acid (see **Section 4.10**) and sulphuric acid are treated separately from use. Sulphuric acid was being produced at three sites at the end of 2006. 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

Estimates of CO_2 from the combustion of waste chemicals as a fuel were estimated for the first time in the 2004 version of the inventory. The quantity of waste recovered for use as a fuel was estimated based on analysis of data reported to the Environment Agency for the years 1998-2002 and contained in the Pollution Inventory data supplied in 2005. The average mass of waste recovered for use as a fuel over these five years was 183 ktonnes. This figure was assumed applicable for all years. The wastes were characterised only as either 'special' or 'non-special' so no details were available which would allow the carbon content to be calculated. Previously, the carbon content was assumed to be the same as for waste oils used as a fuel but this is likely to have overestimated the carbon emissions. For this version of the inventory, a carbon emission factor for waste solvents used in the cement industry has been applied instead and results in significantly lower estimates of emissions.

In the case of other pollutants, emissions data for chemical processes located in England and Wales are available in the Pollution Inventory (Environment Agency, 2007). 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, 2007). 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. Additional data on Northern Ireland's only major chemical works is provided by DoE NI (2007). 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 (2007). In a few cases, such as the figures for methane from ethylene production and SO_2 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 Approach 1 (error propagation) uncertainty analysis in **Annex 7** 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 some other year 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 and other regulator's inventories, with the *de minimis* limits for reporting of emissions of some pollutants being raised. This will lead to a slightly increased need for extrapolation of data from one year to another.

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

The revision to the emission factor used for CO_2 emissions leads to a significant decrease in emissions from 2B5.

Some recalculation of emissions of other pollutants has also 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 2006, 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 2005 might previously been filled using emissions reported for 2004, whereas now the mean of the 2004 and 2006 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. One significant change has been made in the VOC inventory where, for the 2006 inventory, the assumptions made when interpreting VOC emissions data reported in the Pollution Inventory were reviewed for consistency across years and also in terms of their reasonableness. This review identified a number of instances in the period 2003-2005 where assumptions made about data from individual chemical processes were probably not justified and these assumptions were changed, resulting in a significant decrease in emission estimates for these years.

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 2005 inventory (2007 NIR). Comparisons are made between the current inventory (1990-2006) and the previous inventory (1990-2005) for the year 2005.

4.13.5.1.1 CO_2

- Emission estimates for CO_2 have decreased by 281 Gg due to the change in emission factor mentioned in section 4.13.2.

4.13.5.1.2 NMVOC

- Estimated emissions from 2B5 have decreased by 15 Gg, largely due to changes in the interpretation of data reported in the Pollution Inventory.

4.13.6   Source-specific planned improvements

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 with the resources available.

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_2, CH_4, CO, NO_x SO_2, 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_2. 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_x 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 Corus (2005). 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_2 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 Approach 1 (error propagation) uncertainty analysis in **Annex 7** 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 DBERR 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 recalculations have been made as a result of updates to the energy data provided by BERR, the Environment Agency, and Corus UK Ltd, but the overall change is trivial.

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_2, CO, NMVOC and SO_2. The high temperatures necessary in the process mean that NO_x is also emitted.   Finally, the PFC species tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6) 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. These emissions are reported in the Environment Agency's Pollution Inventory, and are incorporated into the Greenhouse Gas Inventory from here.

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).

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).

Activity data are taken from BGS data sets for all years except 2005, where production data available directly from the operators of each site did not agree with the BGS figure, the sum of

the site-specific data being slightly higher. The BGS data was therefore replaced by the site-specific data for this year.

4.16.3   Uncertainties and time-series consistency

The Approach 1 (error propagation) uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type.

The source of activity data is almost always 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. The alternative data used for 2005 is only slightly higher (0.4%) than the BGS nuber and supports the view that the BGS data are reliable.

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

An increase in emissions of 2 Gg CO_2 results from an update to the estimate of aluminium production. Emissions of PFCs have been recalculated to be consistent with emissions reported in the Pollution Inventory.

4.16.6   Source-specific planned improvements

Defra are currently funding a project to review the current inventory estimates of f-gas emissions, and to revise projections data. The findings of this research will be included in the 1990-2007 inventory.

4.17   SOURCE CATEGORY 2C4 – SF$_6$ USED IN ALUMINIUM AND MAGNESIUM FOUNDRIES

4.17.1   Source category description

SF_6 is used in the magnesium alloy and casting industry as a cover gas, to prevent molten magnesium oxidising when exposed to air. All SF_6 used in this way is released to the atmosphere unless capture/recycle technologies are employed. SF_6 is non-flammable and non-toxic, and is therefore a safe gas to use. In the UK, SF_6 has been used as an alternative cover gas to SO_2 in magnesium alloy production and sand and die-casting since the early 1990s. Magnesium alloy production and casting are therefore significant emitters of SF_6 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, SF6 is used for casting specific magnesium alloys where other cover gases, such as argon, are not suitable.

4.17.2   Methodological issues

For magnesium alloy production, emissions from 1998-2006 were estimated based on the emission data reported by the company to the UK's Pollution Inventory. These data are 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_6 (and thus reducing emissions on a CO_2 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_6 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_6 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.

4.17.3   Uncertainties and time-series consistency

The Approach 1 (error propagation) uncertainty analysis in **Annex 7** 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 SF6 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 1998-2006, the uncertainty of the time-series emissions is estimated to be significantly lower (+/- 10%). Data received from the main magnesium alloy producer are considered to be reasonably robust and accurate.

4.17.4   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**.

4.17.5   Source-specific recalculations

Emissions of SF_6 from the magnesium alloy producer in 2005 were revised based on data from the Pollution Inventory. HFC use is estimated as a fraction of the total cover gas used, and so this revision has affected the HFC emissions from this source also.

4.17.6   Source-specific planned improvements

Defra are currently funding a project to review the current inventory estimates of f-gas emissions, and to revise projections data. The findings of this research will be included in the 1990-2007 inventory.

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_2 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_6 used in Aluminium and Magnesium Foundries') actual emissions of SF_6 and HFC134a for this sector are reported under 2C5 'Other metal production' for practical reasons, 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, 2007). 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 Approach 1 (error propagation) uncertainty analysis in **Annex 7** 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 significant recalculations have been made.

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, 2007). Production of the wood products is estimated from data published by the Office of National Statistics (2007). 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 Approach 1 (error propagation) uncertainty analysis in **Annex 7** 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 and England also produce other distilled spirits such as gin and vodka, with production being concentrated in Scotland.

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 (2007), 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 Approach 1 (error propagation) uncertainty analysis in **Annex 7** 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

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

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$_6$

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$_6$.

In terms of their global warming impact (expressed as kt CO$_2$ eq.), HFC 23 emissions are responsible for the substantial majority of emissions from this manufacturing sector. 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

A full description of the emission model and associated methodology used for this sector 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 were members of the UK greenhouse gas Emissions Trading Schemes. All three now report their emissions to the Environment Agency's Pollution Inventory and these reported emissions have been used to calculate total emissions in later years. 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 Approach 1 (error propagation) uncertainty analysis in Annex 7, shown in **section A7.6**, 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 oxider 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 oxider at the second of the UK's HCFC22 manufacturing sites. This was installed in late 2003, and became fully operational 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 and 2005, emissions reported by the company increased compared with the preceding 3 years of fairly stable emission levels 2001-2003. 2006 emissions have shown a decrease.

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 had their emissions externally validated as part of the requirements of the UK Emissions Trading Scheme.

4.21.5   Source-specific recalculations

Emissions of PFCs in 1996-1998 have been recalculated, as an error in the calculation had been identified. This did not lead to a significant change in the emissions.

4.21.6   Source-specific planned improvements

Defra are currently funding a project to review the current inventory estimates of f-gas emissions, and to revise projections data. The findings of this research will be included in the 1990-2007 inventory.

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

A full description of the emissions and associated methodology used for this sector 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

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. Uncertainty data from this study have been used in the uncertainty analysis presented in **Annex 7**.

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

Defra are currently funding a project to review the current inventory estimates of f-gas emissions, and to revise projections data. The findings of this research will be included in the 1990-2007 inventory.

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_2. 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 now banned 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

A full description of the emissions and associated methodology used for this sector 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 Approach 1 (error propagation) uncertainty analysis in **Annex 7**, provides estimates of uncertainty according to IPCC source category and fuel type.

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. Uncertainty data from this study have been used in the uncertainty analysis presented in **Annex 7**.

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

Defra are currently funding a project to review the current inventory estimates of f-gas emissions, and to revise projections data. The findings of this research will be included in the 1990-2007 inventory.

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 11-12 years. Fluorocarbons currently take up a significant proportion 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

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%. Uncertainty data from this study have been used in the uncertainty analysis presented in **Annex 7**.

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

Defra are currently funding a project to review the current inventory estimates of f-gas emissions, and to revise projections data. The findings of this research will be included in the 1990-2007 inventory.

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 will be banned from July 2009, under the EC Regulation on fluorinated greenhouse gases (EC 842/2006).

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_2 equivalent).

4.25.2   Methodological issues

A full description of the emissions and associated methodology used for this sector 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 Approach 1 (error propagation) uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type.

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. Uncertainty data from this study have been used in the uncertainty analysis presented in **Annex 7**.

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

There have been no recalculations to emissions in this sector compared with the previous inventory submission.

4.25.6 Source-specific planned improvements

Defra are currently funding a project to review the current inventory estimates of f-gas emissions, and to revise projections data. The findings of this research will be included in the 1990-2007 inventory.

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

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 Approach 1 (error propagation) uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type.

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%). Uncertainty data from this study have been used in the uncertainty analysis presented in **Annex 7**.

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

Defra are currently funding a project to review the current inventory estimates of f-gas emissions, and to revise projections data. The findings of this research will be included in the 1990-2007 inventory.

4.27 SOURCE CATEGORY 2F6 – SEMICONDUCTOR MANUFACTURE

4.27.1 Source category description

PFCs and SF_6 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_6 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_6 is released from activities in this source sector.

Emissions of SF_6 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_2 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

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 Approach 1 (error propagation) uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type.

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%.   Uncertainty data from this study have been used in the uncertainty analysis presented in **Annex 7**.

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

Defra are currently funding a project to review the current inventory estimates of f-gas emissions, and to revise projections data.   The findings of this research will be included in the 1990-2007 inventory.

4.30   SOURCE CATEGORY 2F8B – SEMICONDUCTORS, ELECTRICAL AND PRODUCTION OF TRAINERS

4.30.1   Source category description

SF_6 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_6 has also been used for filling tennis balls, but this practice has now ceased.

SF_6 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 48% of emissions in 2006.

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_6 is used in etching processes for polysilicon and nitrite surfaces, and there is some usage of CHF_3 and NF_3. 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. 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_6 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 methodology, 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_6 consumption data to extrapolate backwards to 1990 from the 1995 estimates.

Emissions of PFC and SF_6 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 Approach 1 (error propagation) uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type.

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%. Uncertainty data from this study have been used in the uncertainty analysis presented in **Annex 7**.

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

Defra are currently funding a project to review the current inventory estimates of f-gas emissions, and to revise projections data. The findings of this research will be included in the 1990-2007 inventory.

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	'DIY' decorative coatings mainly sold directly to the public
Trade decorative	'Professional' decorative coatings mainly sold to decorating contractors
Industrial coatings:	
ACE	Coatings for agricultural, construction and earthmoving equipment
Aircraft	Coatings for aircraft & aircraft components
Coil	Coatings for steel and aluminium coil
Commercial vehicles	Coatings for new, non-mass produced vehicles
Drum	Coatings for new and reclaimed metal drums
High performance	Coatings for large structures such as bridges, offshore installations etc.
Marine	Coatings for the exteriors and interiors of ships and yachts including both new and old vessels
Metal and plastic	Coatings for metal and plastic substrates not covered elsewhere
Metal packaging	Coatings for food and beverage cans and other small metal packaging
OEM	Coatings for new mass-produced road vehicles
Vehicle refinishing	Coatings for the refinishing of road vehicles
Wood	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; BCF, 2006; BCF, 2007). 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 Approach 1 (error propagation) 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 are 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 thought unlikely 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

Some minor recalculations have been made to the estimates for solvent emitted from use of automotive coatings, to take account of changes in capacity/production at various plants. updated activity data provided by the British Coatings Federation (2007). These recalculations lead to a decrease in estimated emissions of NMVOC of 1 Gg in 2005.

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

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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, 2007), 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 Approach 1 (error propagation) 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 can use large quantities 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, 2001), 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 Approach 1 (error propagation) 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 Approach 1 (error propagation) 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

No significant recalculations were necessary for this sector.

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

In accordance with IPCC guidance, Sector 4 includes all anthropogenic emissions from agriculture, except for emissions from fuel combustion, sewage and liming of land. These emissions are included in Energy 1A, Waste 6B, and LULUCF 5 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 also included here, although 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

CH_4 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_4, 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.

It is therefore assumed that breeding sheep are alive for the whole year but that lambs and other non-breeding sheep are only alive for 6 months of a given year (based on Smith and Frost, 2000). These assumptions for lambs cannot currently be improved, as there are no direct measurements of CH_4 emissions from lambs in the UK.

6.2.3   Uncertainties and time-series consistency

The Approach 1 (error propagation) uncertainty analysis in **Annex 7**, 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 UK Government publication, and is required to maintain specified levels of quality assurance and control to be accredited as National Statistics. The compilers of the activity data strive to use consistent methods to produce the data. Consequently the time-series consistency of these 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%. This is based on the expert opinion of Bruce Cottrill (ADAS), and subsequent acceptance by the research community in the UK.

6.2.6   Source-specific planned improvements

There is an on-going national level research programme which periodically provides new country specific data on emissions from this source. As a result, new data can be incorporated into the annual review of emission factors.

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 (CH_4) emissions from animal manures
A more detailed description of the method used and emission factors can be found in **Annex 3**, **Section A3.6**.

CH_4 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 CH_4. 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, 2006a) in the same way as the enteric emissions.

Apart from cattle, lambs and deer, calculations use IPCC Tier 1 defaults (IPCC, 1997) and do not change from year to year.

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.

The emission factors for lambs are assumed to be 40% of that for adult sheep (Sneath *et al.* 1997).

6.3.2.2   Nitrous Oxide (N_2O) emissions from Animal Waste Management Systems

Animals are assumed not to give rise to N_2O 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_2O 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_x and NH_3 and therefore does not contribute to N_2O emissions from AWMS. This is because in the absence of a more detailed split of NH_3 losses at the different stages of the manure handling process it has been assumed that NH_3 loss occurs prior to major N_2O 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 CRF are not corrected in this way and are estimates of total N excreted from livestock. The UK is currently looking into improving the link between NH_3, NO_x and N_2O emissions from agriculture, and is incorporating NO_x into a study (desk/experimental), which will review the current assumption of 20% of N lost as NH_3 and NO_x.

The conversion of excreted N into N_2O 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. More details are provided in **A3.6.3.6.**

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 Approach 1 (error propagation) uncertainty analysis in **Annex 7**, 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 UK Government publication, and is required to maintain specified levels of quality assurance and control to be accredited as National Statistics. The compilers of the activity data strive to use consistent methods to produce the data. Consequently the time-series consistency of these 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).

The nitrogen excretion (Nex) values assigned to the different livestock types across the timeseries have been substantially revised. This is because the existing country specific Nex level data from the literature was reviewed for the purpose of updating the UK NH_3 emissions inventory. A number of changes were made to the Nex values used in the NH_3 emissions inventory, and the N_2O emissions inventory was similarly updated to ensure consistency.

6.3.6   Source-specific planned improvements

There is an on-going national level research programme (associated with both N_2O and NH_3 emissions) which periodically provides new country specific data on emissions and mitigation policies from this source. As a result, new data can be incorporated into the annual review of emission factors.

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_2O from atmospheric deposition of agricultural NOx and NH3
(viii) Emission of N_2O from leaching of agricultural nitrate and runoff

Descriptions of the methods used are described in **Section 6.5.2**. A nitrogen cycle is included to describe the sources of N_2O from agriculture (Figure 6.1).
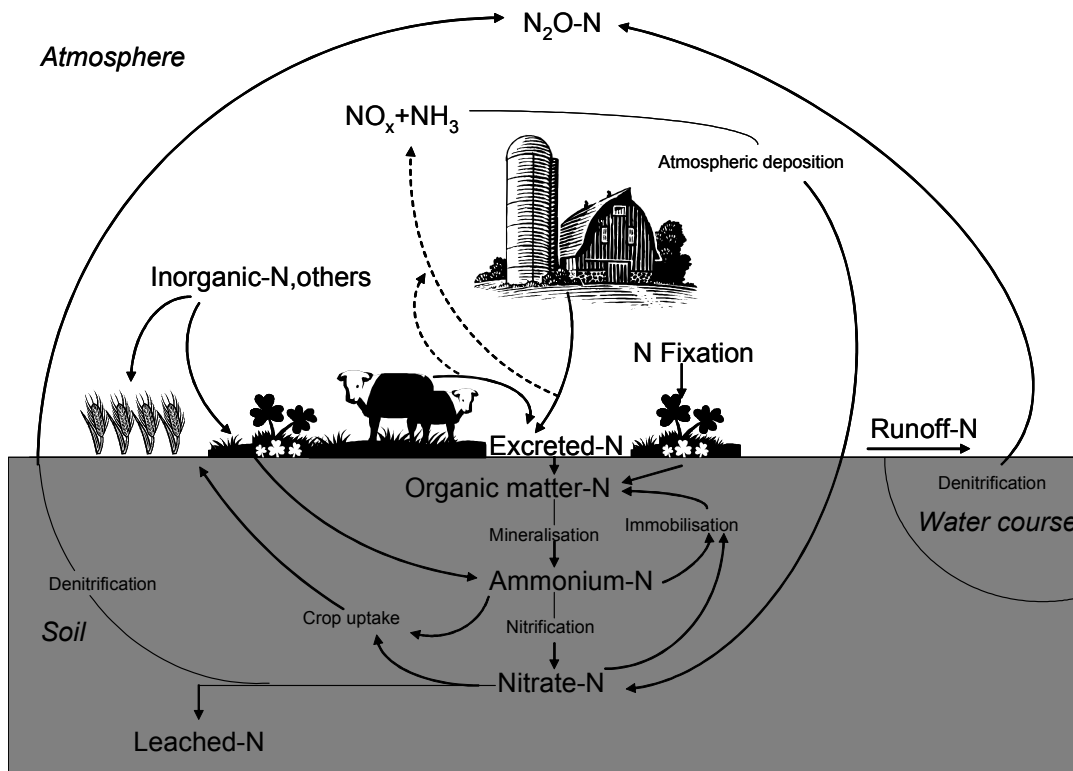
Figure 6.1   **Simplified Nitrogen cycle highlighting the steps affecting the production of N_2O from agriculture. Others refer to crop residues**

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, 2006a) and fertilizer application rates (BSFP, 2006).

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 of 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 (2006a, 2006b).

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). This calculation requires

estimating the amount of N that is fixed, and then applying the emission factor. Previously the IEF was calculated from the ratio of N_2O emission: dry matter, which was different to the IPCC default value (0.013). This has now been modified so that the IEF coincides with the IPCC default value.

6.5.2.3   Crop Residues

Emissions of N_2O 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 (2006a, 2006b). Field burning has ceased to be legal in the UK since 1993, and none is assume to occur after this date. 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_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 the Soil Survey and Land Research Centre (SSLRC) (now National Soil Resources Institute (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), based on country specific data.

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 N 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_X and NH_3

according to the IPCC (1997) methodology but with corrections to avoid double counting N. The sources of NH_3 and NO_x 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_2O from animal manures as in previous submissions. This is because the nitrogen excretion data in **Table A3.6.6** already exclude volatilisation losses and hence a correction is already included.

6.5.2.8   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 N considered are synthetic fertiliser application and animal manures applied as fertiliser.

6.5.3   Uncertainties and time-series consistency

The Approach 1 (error propagation) uncertainty analysis in **Annex 7** 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_2O 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, although Figure 1 in A3.7.2 highlights the uncertainty associated with the absolute values.

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

The N excretion factors have been revised according to values provided by Ken Smith and Bruce Cottrill (ADAS). These were corrected for all years 1990-2006. The new values are based on estimation of the total N consumption minus the N content of livestock products, for all the major categories of farm livestock and were developed and published in a DEFRA report (Defra, 2006). These data were incorporated to ensure consistency with the UK NH_3 emissions inventory.

6.5.6   Source-specific planned improvements

There is an on-going national level research programme (associated with both N_2O and NH_3 emissions) which periodically provides new country specific data on emissions and mitigation policies from this source. As a result, new data can be incorporated into the annual review of emission factors.

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_2 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, 2006a) and data on the fraction of crop residues burnt (MAFF, 1995; ADAS, 1995b). Field burning ceased being legal in 1993 in England and Wales. Burning in Scotland and Northern Ireland is considered negligible, 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 Approach 1 (error propagation) uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category.

Field burning ceased being legal in 1993, 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

6.8.1   Source category description

Emissions of manure management from the UK's Overseas Territories are reported under 4G.

6.8.2   Methodological issues

This is discussed in **Annex 3.9**.

6.8.3 Uncertainties and time-series consistency

This is discussed in **Annex 3.9**.

6.8.4 Source-specific QA/QC and verification

This is discussed in **Annex 3.9**.

6.8.5 Source-specific recalculations

The livestock numbers of the Overseas Territories have been reviewed and updated. In the 1990-2005 GHG inventory, the livestock numbers for 2005 were assumed equal to those for 2004 as more recent data could not be identified.

6.8.6 Source-specific planned improvements

Emission factors and activity data will be kept under review.

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 follow 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) and incorporated into inventory spreadsheets without the need for manual data entry.

The emission factors and other coefficients that are used checked 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.

Furthermore, the data provided by IGER is then subjected to a range of checks by the emissions inventory team at AEA.

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. LULUCF is estimated to have been a net sink since 1999, amounting in 2006 to some 1.95 Mt CO_2 equivalent.

New fluxes have been included and there have been minor revisions of the data used for this Sector for the 2008 NIR, starting from the approaches described by Cannell et al. (1999) and Milne and Brown (1999), taking account of the requirements of IPCC (1997a,b,c; 2003). Estimates of LULUCF net emissions from the UK's Overseas Territories and Crown Dependencies (**Annex 3.9**) are included for the first time (Ruddock, 2007). **Annex 3.7** contains more detailed descriptions of the methods used to estimate emissions in this Sector. A full uncertainty analysis of the sector is planned under the current three-year inventory work programme (2006-2009) and will be reported once it is complete.

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 9th 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 2006 have been submitted using the CRF Reporter. The relationship of this reporting format to that used in pre-2004 NIRs for the UK is discussed in the 2004 National Inventory Report

Net emissions in 1990 are estimated here to be 2928 Gg CO_2 compared to 2882 Gg CO_2 in the 2005 National Inventory Report. For 2005 a net removal of -2037 Gg CO_2 is estimated here compared to a net removal of -2056 Gg CO_2 in the 2005 Inventory. These differences are due to the inclusion of a new flux (forest wildfires) and minor revisions of the data on conversion of Forest Land to Settlement, which affected the land use transition matrix.

Following comments from the UN Expert Review Team in 2007 we have included annual land use transition matrices for the UK in 1990 and 2006 (Table7.1 and Table 7.2). The initial areas in 1990 were estimated from the Countryside Survey data, translated into IPCC land use categories and adjusted to take account of other data sources. The Other Land category is used to take account of the discrepancy between the different data sources and the total land area of the UK. Land use change up to 2006 is calculated by rolling forward from the 1990 areas using land use change data from the Countryside Survey and data on forest planting and deforestation. The off-diagonal items (land use change data from the Countryside Survey, forest planting and deforestation datasets)in the matrix are used to estimate the fluxes in the LULUCF inventory: the diagonal items (land remaining in the same use, in italics) are included for information only.

Table 7.1: Land use transition matrix, ha, for the UK in 1990-1991

From / To	Forest	Cropland	Grassland	Wet-lands	Settlements	Other Land	Total (final)
Forest	*2 167 286*	1 633	18 748	-	759	-	2 188 427
Cropland	0	*5 380 616*	95 948	-	942	-	5 477 506
Grassland	212	83 447	*13 091 440*	-	4 663	-	13 179 762
Wetlands	-	-	-	-	-	-	-
Settlements	644	2 475	13 462	-	*1 937 096*	-	1 953 678
Other Land	-	-	-	-	-	*1 633 621*	1 633 621
Total (initial)	2 168 142	5 468 171	13 219 599		1 943 461	1 633 621	*24 432 994*

Table 7.2: Land use transition matrix, ha, for the UK in 2005-2006

From / To	Forest	Cropland	Grassland	Wet-lands	Settlements	Other Land	Total (final)
Forest	*2 420 004*	961	6 658	-	534	-	2 428 157
Cropland	0	*5 529 899*	95 948	-	942	-	5 626 790
Grassland	741	83 447	*12 541 792*	-	4 662	-	12 630 643
Wetlands	-	-	-	-	-	-	-
Settlements	417	2 475	13 462	-	*2 097 428*	-	2 113 782
Other Land	-	-	-	-	-	1633621	1 633 621
Total (initial)	2 421 163	5 616 782	12 657 861		2 103 567	1633621	*24 432 994*

7.2   CATEGORY 5A – FOREST LAND

7.2.1   Source/sink category description

All UK forests are classified as temperate and about 67% of these have been planted since 1921 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. 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.

The forests in existence since before 1921 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**)

Emissions of nitrous oxide from direct nitrogen fertilisation of forests are included in the inventory this year. It is assumed that fertiliser is only applied to newly planted forests with 'poor' soils, so emissions from this activity are reported in category 5.A.2/5(I).

7.2.2   Methodological issues

The carbon uptake by the forests planted since 1920 is calculated by a carbon accounting model, C-Flow (Dewar and Cannell, 1992, Cannell and Dewar, 1995, Milne *et al*. 1998) 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 Good Practice Guidance for 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. This year the C-Flow model was adapted so that it

produced separate gains and losses for Carbon stock change in living biomass, rather than net change as previously.

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 a separate section **in Annex 3.**

Estimates of emissions from wildfires on forest land are included in the inventory for the first time this year. These fires only affect a small area in the UK and do not result in land use conversion. The approach (described in **Annex 3.7**) is Tier 2, using country-specific activity data and default emission factors. There is no information as to the age and type of forest that is burnt in wildfires, so all wildfire emissions are recorded under 5.A.2, which includes all land converted to forest since 1921.

Direct N_2O emissions from N fertilization of forests are included in the inventory this year. Information on forest fertilisation was gathered from a search of the relevant literature and discussion with private chartered foresters and the Forestry Commission (Skiba 2007). In the UK the general recommendation is not to apply fertiliser to forests unless it is absolutely necessary: it is not applied to native woodlands, mature forest stands or replanted forests. The instances where N fertiliser is applied to forests are first rotation (afforestation) forests on 'poor' soil, e.g. reclaimed slag heaps, impoverished brown field sites, upland organic soils. In the context of the inventory land use categories, N fertilisation was assumed for Settlement converted to Forest Land and Grassland converted to Forest Land on organic soils only. A Tier 1 approach is used with the amount of N fertiliser calculated using a fixed application rate and the areas of relevant forest planting. Further details are given in **Annex 3.7**.

N_2O emissions from drainage of soils on Forest Land have previously been assessed as small in the UK and are therefore not reported (Skiba et al. 2005). This assessment is discussed in **Annex 3.7**.

7.2.3   Uncertainties and time-series consistency

The Approach 1 (error propagation) uncertainty analysis in **Annex 7** provides estimates of uncertainty according to GPG source category and gas.

Activity data for afforestation and N fertilisation of forests are obtained consistently from the same national forestry sources, which helps ensure time series consistency of estimated removals.

Activity data for wildfires have been collated for 1990-2004 from several published sources, but all originate from either the Forestry Commission or Forest Service of Northern Ireland, so there is good time series consistency in the dataset. The uncertainty for this activity is estimated to be 50% for the activity data 1990-2004, but 100% for the 2005 and 2006 values, as these have been extrapolated from previous years. The IPCC default of 70% uncertainty is used for the emission factors.

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.**

A National Inventory of Woodland and Trees is in development, which should produce estimates of carbon stocks in above-ground living biomass, dead material and soils, allowing the verification of carbon stock estimates from the C-Flow model. In the mean time, alternative sources of verification information are being sought.

The activity data on wildfires has been collated from several sources but there are no discrepancies in the data where the sources overlap. The area estimated to be affected by wildfires each year is consistent with that reported to the FAO (FAO 2005).

7.2.5   Source-specific recalculations

The estimates of emissions and removals due to afforestation were updated with planting statistics for 2005.

Emissions estimates for wildfires and N fertilisation of forests are included in the inventory for the first time this year.

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 and 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. An investigation of the impact of forest management (species planting mix, thinning, harvest age) on forest carbon stocks and fluxes is also underway, enabled by access to more detailed forest datasets. This will contribute to the reporting of removals due to forest management under Article 3.4.

Work is also planned to investigate further the affect of afforestation on soil carbon, specifically the effect of planting broadleaved trees on ex-agricultural mineral soils. This research will get underway in the summer of 2008, and the results of this research will be included in the inventory in due course.

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.

Three activities are considered for 5.B.1: the effect on non-forest biomass due to crop yield improvements, 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 ($CaCO_3$) and Dolomite ($CaMg(CO_3)_2$)).

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, 1950 – 1990 and 1991 onwards.

N_2O emissions from disturbance associated with land use conversion to Cropland are not reported (Skiba et al. 2005). This assessment is discussed in **Annex 3.7**.

The data reported for the UK in Sectoral Table 5 in the Information item "Grassland converted to other Land-Use Categories" are changes in carbon stock in soils after change to another land use category.

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 CO2, 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 the Business Monitor of Mineral Extraction in the UK (Office of National Statistics 2007). They also include 'material for calcination'. In agriculture all three minerals are applied to the soil, and CO_2 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 are provided by the British Geological Survey each year as only their total is published because of commercial confidentiality rules for small quantities (Office of National Statistics 2007). 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 2006. A fourth CEH Countryside Survey took place during 2007 which should allow the matrices to be updated in 2009.

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 and McCann 2002). The only data available pre-1990 for Northern Ireland is land use areas from the Agricultural Census and the Forest Service which were processed by Cruickshank and Tomlinson (2000). Matrices of land use change were then 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 third Northern Ireland Countryside Survey was undertaken in 2007 which should allow the matrices to be updated in 2009.

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.

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**. An adjustment is 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.

Changes in stocks of carbon in biomass due to land use change are estimated using the Countryside Survey Land Use Change matrix approach, with biomass densities weighted by expert judgement. Detailed descriptions of the methods and emission factors used for this and the other activities of fenland drainage, application of lime and changes in non-forest biomass due to yield improvements can be found in **Annex 3.7**.

7.3.3   Uncertainties and time-series consistency

The Approach 1 (error propagation) uncertainty analysis in **Annex 7** 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**.

Experimental work to detect the effect of cultivation (i.e. Grassland converted to Cropland) on CO_2 and N_2O fluxes and on soil carbon stocks is currently in progress. The results from this

work will be used to verify assumptions in the land use change model and to modify the model if necessary.

7.3.5   Source-specific recalculations

7.3.5.1   Changes in non-forest biomass due to yield improvements in Cropland
No recalculations were undertaken for this category.

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 2006 data (ONS 2007 and BGS personal communication). Revisions in the agricultural census dataset resulted in changes in the allocation of lime to either Cropland or Grassland at the UK scale. However, total emissions from the application of lime remain the same, only the allocation to land use has changed. Estimated emissions from Cropland have fallen by 25.3 Gg CO_2 in 2005 compared with the numbers for 2005 in the previous submission (2007 NIR).

7.3.5.4   Changes in non-forest biomass due to land use change to Cropland
No recalculations were undertaken for this category.

7.3.5.5   Changes in soil carbon stocks due to land use change to Cropland
No recalculations were undertaken for this category.

7.3.6   Source-specific planned improvements

Sampling of the National Soil Inventory between 1978 and 2003 (Bellamy *et al.* 2005) has found large losses of carbon from soils across England and Wales. Work is now underway to assess the relative contributions of land use and management and climate change (and their interaction) to these soil carbon losses. This should produce an estimate of the likely magnitude of past changes in soil organic carbon under different management scenarios and the relative importance of the various drivers of those changes (by 2009). There will then be an assessment as to whether the inventory methodology needs to be adapted in the light of these results. A soil carbon inventory project is underway for Northern Ireland, the results of which will be incorporated into the inventory methodology. Other 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, 1950 – 1989 and 1990 onwards. Biomass burning emissions due to conversion of Forest Land to Grassland is reported for all of the UK from 1990 onwards (emissions occur in the same year as the land use conversion).

Carbon dioxide emissions from agricultural lime application to Grassland is disaggregated into application of Limestone ($CaCO_3$) and Dolomite ($CaMg(CO_3)_2$).

The data reported for the UK in Sectoral Table 5 in 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_2 emissions/removals".

7.4.1.1   Emissions from biomass burning (5C)

These are emissions of CO_2, CH_4 and N_2O resulting from the burning of forest biomass when Forest Land is converted to Grassland. The interpretation of the available data (described in **Annex 3, Section 3.7.4**) 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. Only peat extraction for horticulture is reported in this sector: 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 (2006). They also include 'material for calcination'. In agriculture all three minerals are applied to the soil, and CO2 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 are provided by the British Geological Survey 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

Detailed descriptions of the methods and emission factors used for the activities in this Category can be found in **Annex 3.7**.

7.4.3 Uncertainties and time-series consistency

The uncertainty analysis in **Annex 7** 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

Data on rural deforestation (Forest Land converted to Grassland) is only available up to 2002; therefore areas for 2003-2006 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. The estimates of emissions have been updated with 2006 data (Office for National Statistics 2007).

7.4.5.3   Application of lime to Grassland

The estimates of emissions due to liming have been updated with 2006 data (Office for National Statistics 2007). Revisions in the agricultural census dataset resulted in changes in the allocation of lime to either Cropland or Grassland. However, total emissions from the application of lime remain the same, only the allocation to land use has changed. Estimated emissions from Grassland have risen by 25.3 Gg CO_2 in 2005 compared with the numbers for 2005 in the previous submission (2007 NIR).

7.4.5.4   Changes in non-forest biomass due to land use change to Grassland

No recalculations were undertaken for this category.

7.4.5.5   Changes in soil carbon stocks due to land use change to Grassland

The revision of the deforestation dataset resulted in a re-allocation of areas in the land use change matrix, producing changes in emission/removal estimates from those in the 2005 National Inventory Report. There was a change of 2.2 Gg CO_2 in 2005 (compared with the estimate for 2005 in the 2007 NIR).

7.4.6   Source-specific planned improvements

All emission factors and activity data will be kept under review. Input data for the deforestation activity remain a problem and work to assimilate relevant data sources for each of the four UK countries is under discussion. A repeat survey of peat extraction (for fuel and horticultural use) in Northern Ireland is underway and due to be completed by 2009.

7.5   CATEGORY 5D – WELANDS

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, 1950 - 1989 and 1990 onwards. Biomass burning emissions

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due to conversion of Forest Land to Settlements are reported for all of UK from 1990 onwards (emissions occur in the same year as the land use conversion).

The data reported for the UK in Sectoral Table 5 in 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_2 emissions/removals".

The data reported for the UK in Sectoral Table 5 in the Information item "Grassland converted to other Land-Use Categories" are changes in carbon stock in soils after change to another land use category.

7.6.1.1   Emissions from biomass burning after conversion of Forest Land to Settlements (5E)

These are emissions of CO_2, CH_4 and N_2O resulting from the burning of forest biomass when Forest Land is converted to Settlements. The interpretation of the available data (described in **Annex 3.7**) 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, to Settlements.

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

Detailed descriptions of the methods and emission factors used for the activities in this Category can be found in **Annex 3.7**.

7.6.3   Uncertainties and time-series consistency

The uncertainty analysis in **Annex 7** 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 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

The data on the area of deforestation in non-rural areas have been revised for 2000-2004. A five-year moving average has been applied on the recommendation of the data suppliers (Department of Communities and Local Government). The area of deforestation in 2005 and 2006 has been estimated by extrapolation from earlier years. These revisions have resulted in a change of -4 Gg CO_2 for 2005 compared with the 2005 estimate submitted in the 2007 NIR.

7.6.5.2 Changes in non-forest biomass due to land use change to Settlements

No recalculations were undertaken for this category.

7.6.5.3 Changes in soil carbon stocks due to land use change to Settlements

The revision of the deforestation dataset (2000-2004) resulted in a re-allocation of areas in the land use change matrix, producing a change of -2 Gg CO_2 in emission/removal estimates in 2005 from those in the 2007 NIR.

7.6.6   Source-specific planned improvements

All emission factors and activity data will be kept under review. Input data for the deforestation activity remain a problem and work to assimilate relevant data sources for each of the four UK countries is under discussion.

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 accounting model (C-Flow) is used to calculate the net changes in carbon stocks of harvested wood products, in the same way as it is used to estimate carbon stock changes in 5.A. The C-Flow model method can be described as Tier 3, as defined in the GPG LULUCF (IPCC 2003). It calculates the amount of carbon in the different stock pools of new even-aged plantations (i.e. forest planted on land that previously under a non-forest land use) of conifers and broadleaves. These are assumed to be under an intermediate thinning management regime with clear-felling and replanting at the time of Maximum Area Increment (57 or 59 years for conifers and 92 years for broadleaves). Both thinnings and harvested materials are assumed to enter the HWP stock pool, where they decay at different rates. Only harvested wood products from UK forests planted since 1921 (i.e. those reported in 5.A.2) are included: the decay of imported products is not considered at present, pending international agreement on a single methodology to be used for reporting. The C-Flow method of estimating carbon stocks in harvested wood products is closest to the Production Approach described in Appendix 3a.1 in the LULUCF GPG (see Thomson in Milne and Mobbs (2005) for a comparison).

A detailed description of the method used and emission factors can be found in **Annex 3**.**7.**

7.8.3   Uncertainties and time-series consistency

The uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and gas.

Activity data (areas planted and consequently harvested) 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.** Work is currently being undertaken to verify the modelled Harvested Wood Products by comparison with the Forestry Commission Production Forecast.

7.8.5   Source-specific recalculations

The afforestation activity data (which is also the activity data for the HWP activity) has been updated with new values for 2006.

This year, CEH have developed a time series of LULUCF emissions for the UK's Overseas Territories and the Crown Dependencies. The total LULUCF emissions from the OTs and CDs are currently included in sector 5G because the CRF Reporter does not easily allow these emissions to have their own sub-category in source sector 5. Including these emissions results in an apparent decline in emissions in 2005. However, the emissions estimated from

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Harvested Wood Products in 2005 are unchanged. Further details of the method used to estimate LULUCF emissions from the OTs and CDs is discussed in **Annex 3.9**.

7.8.6   Source-specific planned improvements

This category will be kept under review.

7.9   SEPARATE REPORTING OF EMISSIONS AND REMOVALS

The UK is now reporting using the categories of the LULUCF GPG (FCCC/SBSTA/2004/8). Tables showing the relationship between the previous NIR categories and the GPG categories can be found in the 2004 National Inventory Report.

The latest version of the CRF Reporter (3.2) asks for soil emissions to be reported separately for mineral and organic soils, and for the area of organic soil to be reported where possible. At present this is only possible for Sector 5A; in other sectors soil emissions are reported under mineral soils, with a note in the documentation box to indicate that these emissions include those from organic soils. Methods for estimating emissions in other sectors do not currently allow emissions from mineral and organic soils to be separated.

7.10   GENERAL COMMENTS ON QA/QC

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 with 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.

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 encouraged to publish non-confidential scientific information in the peer reviewed scientific literature, with the prior approval of the customer and customer acknowledgement. Inventory results and reports are archived within CEH and are also available on the project website at
http://www.edinburgh.ceh.ac.uk/ukcarbon/index.html.

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_2 and NMVOCs. The primary source of CO_2 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_2 emissions are not treated as emissions from waste. Emissions of CO_2 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_2O. 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_4) 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.

UK Waste Management Disposal to Land Legislation and Guidance
Since the introduction of the Landfill Directive (1999/31/EC), implemented within the England and Wales in July 2001 and brought about the Landfill (England and Wales) Regulations 2002; all landfills have been classified as Hazardous, Non-Hazardous or Inert. This reclassification has meant that landfills can only accept one of the three kinds of waste. Methane emissions typically are emitted from Non-Hazardous landfills.

Functioning alongside the Landfill Regulations 2002 are the Pollution Prevention and Control Regulations 2000 which is itself an implementation of the European directive 96/61/EC Integrated Pollution Prevention and Control (IPPC). The Pollution Prevention and Control (England and Wales) Regulations 2002 define pollution as:

"Emissions as a result of human activity which may be harmful to human health or the quality of the environment, cause offence to any human senses, result in damage to material property, or impair or interfere with amenities and other legitimate uses of the environment."

Landfills come under section 5.2 of the Act, which states that any landfill that receives more than 10 tonnes of waste per day and/or has a capacity of more than 25,000 tonnes per annum will require a PPC permit. Landfills

The Landfill Directive states that all landfills receiving biodegradable waste must collect their landfill gas and this must be treated by utilisation if possible and if not it must be flared.

This means that landfill operators must demonstrate "best practice", and the regulator (Environment Agency in England and Wales, Scottish Environmental Protection Agency in Scotland and the Northern Ireland Environment & Heritage Service in Northern Ireland) must also define what "best practice" is. This has lead to the replacement of the previous landfill gas guidance (Waste Management Paper 27, non-statutory), with one overarching guidance document and a series of six underpinning guidance documents on specific aspects of gas management; the full set being:

- ♦ Guidance on the management of landfill gas;
- ♦ Guidance for monitoring trace components;
- ♦ Guidance on landfill gas flaring;
- ♦ Guidance for monitoring enclosed landfill gas flares;
- ♦ Guidance for monitoring landfill engine emissions;
- ♦ Guidance for monitoring surface emissions; and
- ♦ Guidance on treatment technologies for engines.

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 the 2006 and 2007 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 are still used. They 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.

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 MSW waste disposal and composition data are based on various data sources, described fully in Brown et al. (1999), LQM (2003) and Golder (2005). Between 1945 and 1994 the waste arisings data are the same as that used for the AEA model (Brown et al., 1999) and are based on waste surveys in the UK using actual data combined with landfilled volume estimates, household waste composition surveys and population data to interpolate where necessary. From 1995 to 2000, data are based on a new study carried out by a UK consultancy ERM for input to the LQM model, using England and Wales arisings derived from Defra's Municipal Waste Management Survey for the year 1999/00. Years between 1995 and 1998 inclusive are calculated by linear interpolation between 1994 and 1999. From 2001 the model uses a scenario of waste disposal from the Local Authority Waste Recycling and Disposal (LAWRRD) model (AEA Technology, 2005; Brown et al., 2006). The LAWRRD model provides arisings for England and so the data have 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 from 1945 to 1998 were determined by Brown et al. (1999), primarily based on the Aitchison et al. (1996) model and on national estimates from a 1995 survey. Commercial waste arisings for 1993 were derived from the Department of Environment Digest of Environmental Statistics for 1994. They estimated that this value (15Mt) was subject to an uncertainty of +/- 5Mt. Industrial waste arisings for 1993 were from two sources (Pearce et al., 1993 and Bellingham et al., 1994). Industrial arisings amounted to 68Mt in 1993, of which the methane producing fractions included 10Mt of general industrial wastes, believed to be similar in nature to commercial wastes, and 20Mt of food production wastes. Historical data were scaled using employment rates in the industries concerned. In the Golder (2005) model, commercial and industrial arisings have been scaled up to the UK, based on an England and Wales total from Environment Agency data; for 2002 and assumed constant thereafter, years 1999, 2000 and 2001 are scaled values between 1998 and 2002. The breakdown of commercial and

industrial waste streams, based on the Strategic Waste Management Assessment, has been assumed to be constant from 1999.

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). Moisture content is derived from the National Household Waste Analysis Project (1994).

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; the inert fraction was discarded. For example, paper was taken to be 25% moderately degrading and 75% slowly degrading. The DOC value, applied to 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% (i.e. 15% downtime), and 7% of flares are assumed to be replaced every year, so that the flare lifetime is 15 years. This approach was taken because suitable metering data were not available. In 2005 the estimates were that 32% of generated methane was utilised and 38% was flared. Further details are provided in section A3.8 of the NIR.

The oxidation factor was based on a model developed by LQM (2003) (which distinguishes between passage of methane through fissures and through the intact cap) until the 2005 inventory; since 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^3 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 Approach 1 (error propagation) uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and gas. There are many uncertainties 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), prior to 2000 they are based on the LQM (2003) study and from 2000 they are based on modelled data from the Golder (2005) study. This has resulted in a relatively stable background trend of an annual increase of around 1 million tonnes per year. Similarly, due to the difference sources, estimates of industrial and commercial waste arisings increase rapidly from 108 million tonnes in 1995 to 169 million tonnes by 1999 (assuming a linear increase over this period). Arisings are roughly constant in the years before 1995 and after 1999; the values for 2002 are based on Environment Agency data and are assumed constant thereafter.

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$_F$ 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$_F$ 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)			Mass of waste landfilled (Mt) as reported in CRF*	Golder model (oxidation factor 0.1) Methane emitted (kt)	IPCC Methane emitted (kt)
	MSW	C&I	Combined waste streams	Excluding inorganic industrial waste		
1990	18.19	81.83	100.02	75.65	2363	2432
1991	18.84	81.77	100.61	76.57	2329	2364
1992	19.47	81.72	101.19	77.49	2270	2275
1993	20.09	81.66	101.76	78.39	2212	2190
1994	20.71	81.61	102.32	79.28	2167	2121
1995	23.83	81.56	105.39	82.69	2099	2044
1996	24.76	78.17	102.93	74.00	2027	1979
1997	26.14	72.86	99.00	67.19	1866	1795
1998	25.94	65.63	91.57	60.24	1735	1628
1999	27.03	63.84	90.87	60.25	1577	1413
2000	27.54	62.05	89.59	59.68	1472	1262
2001	26.85	60.27	87.11	57.91	1277	1032
2002	27.17	58.48	85.64	57.15	1162	884
2003	26.39	58.48	84.87	56.38	1016	710
2004	25.47	58.48	83.94	55.45	943	615
2005	24.17	58.47	82.65	54.15	927	686
2006	21.67	858.47	80.14	51.65	924	682
Total	-	-	-		**28366**	**26112**

* Total does not include inorganic industrial waste such as power station ash, construction or demolition materials, as defined in the CRF.

8.2.5   Source-specific recalculations

Methane emissions from this source were revised down by 1.4 Gg CH4 as a result of a change to the methodology used to estimate emissions from Guernsey.

8.2.6   Source-specific planned improvements

Emission factors, model parameters, and activity data will be kept under review including the possible use of weighbridge returns to improve activity data. Defra is also considering commissioning further work on measured methane emissions at landfill sites.

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_4/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.

For more details on methodology and coverage of the Hobson model, see **Section A.3.8.3**.

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 Expenditure and Food Survey (Defra, 2007). 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 Approach 1 (error propagation) uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and gas.

The same methodology has been used to estimate emissions for all years. The population data needed to estimate emissions are provided by the Office of National Statistics (ONS). The time-series consistency of these activity data is very good due to the continuity in data provided by the ONS.

The most recent average protein consumption per person is based on the Expenditure and Food Survey (Defra, 2007); see **TableA 3.8.6**. Between 1996 and 1997 there is a step change in the reported protein consumption data. This is because Defra revised their publication (formally National Food Survey) and in doing so revised the method used to calculate protein consumption. The new method only provides data back to 1997 and so a step change occurs.

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

Methane emissions have decreased by 0.02 Gg CH4 as a result of revisions made to estimates from Overseas Territories.

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 may 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 are not yet publicly available and the NIC spent time in the last two inventory compilation cycles trying to gain access to these data. Access to this new dataset has been 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 again to the 2008 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_x, SO_2, 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 but the need for extrapolation of data may contribute to significant variations in the quality of the estimates.

Emissions of CH_4, CO, N_2O, NO_x, SO_2 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_x 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_2O 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_4, CO, N_2O, NO_x, SO_2, 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_2O 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$_x$, SO$_2$ and VOC from crematoria are based on literature-based emission factors, expressed as emissions per corpse, and taken from US EPA (2007). Data on the annual number of cremations is available from the Cremation Society of Great Britain (2007).

Electricity is also generated at 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.

8.4.3   Uncertainties and time-series consistency

The Approach 1 (error propagation) uncertainty analysis in **Annex 7** 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

The overall decline in this sector is -2.43 Gg CO$_2$. This was caused by a decrease in CO$_2$ emissions of 19 Gg CO$_2$ due to updates to Pollution Inventory data for chemical waste incinerators and modifications to the assumptions needed to deal with gaps in reported data. In addition, the inclusion of an estimate for emissions from waste incineration in Bermuda increased emission estimates by 17 Gg CO$_2$..

8.4.6   Source-specific planned improvements

Emission estimates for chemical waste incineration currently do not include the burning of chemical wastes in flares and it is unclear whether these emissions might be included in the estimates reported in 2B5.. The estimates also do not include any allowance for chemical waste incineration carried out in Scotland or Northern Ireland, and the need to deal with significant gaps in the reported data means that estimates are quite uncertain. Further development of the methodology should be a priority. Other possible areas for improvement include better activity data for clinical waste, animal carcass and sewage sludge incineration.

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

The UK does not report any emissions of direct greenhouse gases in Sector 7.

10 Recalculations and Improvements

This section of the report summarises the recalculations and improvements made to the UK GHG inventory since the 2007 NIR (2005 inventory) was issued, including responses to reviews of the inventory. 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 2006 GHG inventory, please see **Annex 6**.

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. 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 2005; this report gives emission estimates for 2005, and includes estimates for the year 2006 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 and **Table 10.2** summarise the recalculations that have occurred in estimates of the direct GHGs since the 2007 NIR (2005 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 2005 (**Table 10.1**) and the base year (**Table 10.2**).

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 same level of sectoral detail in **Table 10.1 or Table 10.2**.

The percentage change, due to recalculation with respect to the previous submission, is calculated as

Percentage change = 100% x [(LS-PS)/PS]

Where
LS = Latest Submission (2006 inventory; 2008 NIR)
PS = Previous Submission (2005 inventory, 2007 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 2005 in the UK 2008 NIR (2006 inventory)

Source category and GHG	Change in emissions (GgCO$_2$eq.) (Emissions in 2006 inventory minus emissions in 2005 inventory)	Change in emissions (%) (Percentage change relative to the 2005 inventory)	Brief description of reasons for recalculation
1A1			
CO$_2$	+3,104.55	+1.48	• Increase in emissions has been caused by a combination of revisions to energy statistics and changes made to emission factors. Most revisions affect the power generation sector and the correction to power station coal use dominates the revision. • Increase in emissions from power stations due to a reallocation of coal from other industrial combustion to power stations. This was done so that fuel use in the inventory was consistent with that reported in the EU-ETS. • Revision to energy statistics of gas oil and fuel oil use in power stations has increased emissions from the use of gas oil, and decreased emissions from use of fuel oil. • Estimates of emissions of pet coke from power stations are included for the first time in the 2006 GHG inventory. • Revision to energy statistics of natural gas has increased emissions from petroleum refining.
CH$_4$	+3.36	+1.32	• The major cause of this increase was a change in the emission factor used for petroleum coke from petroleum refining. • Other minor revisions to emissions following revisions made to the energy statistics for gas oil, fuel oil and coal in power stations.
N$_2$O	+21.98	+1.40	• Revision due to minor changes in emission factors and fuel consumption statistics.
1A2			
CO$_2$	-1,430.92	-1.68	• Dominant factor is the decrease in emissions from 1A2f due to changes in the emission factor and consumptions of coal. • Increase in emissions from gas oil consumption following revisions in energy statistics. • Decline in emissions from natural gas consumed in autogeneration following revisions in energy statistics. • Increase in emissions from natural gas from other industrial combustion following revisions in energy statistics.

Source category and GHG	Change in emissions (GgCO$_2$eq.) (Emissions in 2006 inventory minus emissions in 2005 inventory)	Change in emissions (%) (Percentage change relative to the 2005 inventory)	Brief description of reasons for recalculation
CH$_4$	-1.98	-0.72	• The major cause of this decrease was a change in the emission factor used for petroleum coke from petroleum refining. • The remaining changes were caused by small fluctuations in activity data for coal, natural gas and gas oil.
N$_2$O	-62.39	-4.45	• Decline caused by changes to both the emission factor and activity statistics for coal.
1A3			
CO$_2$	+25.63	+0.02	• Increase in emissions due to revisions in estimates for rail and civil aviation. • Emissions from aviation have decreased due to the incorporation of revised operational data in the LTO cycle. • Estimated emissions from Railways (1A3c) have increased due to improved rail freight emission factors being used, and using a new model to estimate emissions from passenger transport. • No change in total emissions from road transport, but there are revisions in the allocation between vehicle types due to revisions in fuel consumption factors used for individual vehicle categories.
CH$_4$	+0.43	+0.25	• There has been a small increase in estimated methane emissions from transport of 0.02 Gg. There were very minor reductions in the estimated emissions from buses, but these were offset by the introduction of improved emission factors in the rail sector.
N$_2$O	+10.90	+0.20	• The decrease in emission estimates from 2005 to 2006 is due to increased penetration of cleaner vehicles. This is somewhat offset by increases to the rail sector due to new and improved emission factors being utilised.
1A4			
CO$_2$	-942.69	-0.85	• In the residential sector (1A4b), emissions from natural gas increased as a result of changes to national energy statistics. • Emissions in commercial/institutional sector 1A4a from gas oil declined, and increased from natural gas as a result of changes to national energy statistics. • Emissions from petroleum coke decreased by following changes in national energy statistics.
CH$_4$	-13.02	-2.67	• Revision to the methodology used to estimate emissions from Overseas Territories which lead to a decrease in emissions from 1A4cii. • Reallocation of gas oil to reflect new rail methodology caused a decrease in emissions from 1A4a.
N$_2$O	-2.14	-0.33	• A reallocation of gas oil to reflect new rail methodology caused a decrease in emissions in 1A4a.

Source category and GHG	Change in emissions (GgCO$_2$eq.) (Emissions in 2006 inventory minus emissions in 2005 inventory)	Change in emissions (%) (Percentage change relative to the 2005 inventory)	Brief description of reasons for recalculation
1A5			*No change to emissions in this sector*
CO$_2$	-	-	
CH$_4$	-	-	
N$_2$O	-	-	
1B1			
CO$_2$	-	-	
CH$_4$	+282.14	+7.41	• Emissions of CH4 from closed coal mines now include emissions from mines which closed in 2005. These emissions were omitted from the previous inventory.
N$_2$O	-	-	
1B2			*No change to emissions in this sector*
CO$_2$	-	-	
CH$_4$	-	-	
N$_2$O	-	-	
2A			
CO$_2$	+592.40	+7.64	• Increase in emissions dominated by change to the methodology for estimating decarbonisation emissions. Methodology now using data generated by UK cement clinker producers for the purposes of reporting to the EU Emission Trading Scheme. • Small error in the calculation of quantities of lime produced corrected slightly increasing emissions. • Some updates have been made in the limestone and dolomite consumption data provided by the Iron & Steel Statistics Bureau and British Geological Survey.
CH$_4$	-	-	
2B			
CO$_2$	-276.98	-8.51	• Significant decrease in CO$_2$ emissions from energy recovery from waste fuels due to use of revised emission factor. This has led to a revision across the time series.
CH$_4$	+2.37	+5.62	• Recalculations have occurred where changes have been made to data in the Pollution Inventory, and where new data were supplied for 2006 that were used to fill gaps in data for 2005 (for example if these had previously been filled with data from 2004)..
N$_2$O	-	-	• No recalculations have been made to N$_2$O emissions in this sector.

Source category and GHG	Change in emissions (GgCO₂eq.) (Emissions in 2006 inventory minus emissions in 2005 inventory)	Change in emissions (%) (Percentage change relative to the 2005 inventory)	Brief description of reasons for recalculation
2C			
CO₂	+2.61	+0.11	• Increase in emissions from an update to the estimate of aluminium production (category 2C3).
CH₄	-	-	• Trivial change in emissions.
N₂O	-	-	• Trivial change in emissions.
2C3			
PFCs	-99.91	-64.64	• Emissions of PFCs have been recalculated to be consistent with emissions reported in the Pollution Inventory.
2E			*No change to emissions in this sector*
HFC	-	-	
PFC	-	-	
2F			
HFC	+2.68	+0.03	• Minor improvements to emission estimates from the Overseas Territories in all sectors.
SF₆	+0.59	+0.07	• Minor improvements to emission estimates from the Overseas Territories in all sectors.
4A			
CH₄	-8.42	-0.05	• Minor change made to the calculation of CH₄ emissions from enteric fermentation.
4B			
CH₄	-0.01	0.00	• Minor change made to the calculation of CH₄ emissions from manure management.
N₂O	+111.07	+8.74	• Revision to nitrogen excretion rates used based on new research.
4D			
N₂O	+95.74	+0.38	• Revision to nitrogen excretion rates used based on new research.
4G			
N₂O	-2.34	-3.76	• Review of manure management activity data from UK Crown Dependencies.
5A			
CO₂	+23.62	-0.15	• The estimates of emissions and removals due to afforestation were updated with planting statistics for 2005
CH₄	+2.16	+100.00	• Emissions estimates for wildfires
N₂O	+1.80	+100.00	• Emissions estimates for wildfires and N fertilisation

Source category and GHG	Change in emissions (GgCO$_2$eq.) (Emissions in 2006 inventory minus emissions in 2005 inventory)	Change in emissions (%) (Percentage change relative to the 2005 inventory)	Brief description of reasons for recalculation
5B			
CO$_2$	-25.30	-0.17	• Estimates of emissions due to liming have been updated with 2006 data. Revisions in the agricultural census dataset resulted in changes in the allocation of lime to either Cropland or Grassland at the UK scale. However, total emissions from the application of lime remain the same, only the allocation to land use has changed. Estimated emissions from Cropland have fallen
5C			
CO$_2$	+27.53	-0.35	• The estimates of emissions due to liming have been updated with 2006 data. Revisions in the agricultural census dataset resulted in changes in the allocation of lime to either Cropland or Grassland at the UK scale. However, total emissions from the application of lime remain the same, only the allocation to land use has changed. Emissions from Grassland have risen. • The revision of the deforestation dataset resulted in a re-allocation of areas in the land use change matrix, producing changes in emission/removal estimates from those in the 2005 National Inventory Report. There was a small net increase in emissions.
5E			
CO$_2$	-6.28	-0.10	• The data on the area of deforestation in non-rural areas have been revised for 2000-2004. A five-year moving average has been applied on the recommendation of the data suppliers (Department of Communities and Local Government). The area of deforestation in 2005 and 2006 has been estimated by extrapolation from earlier years. There has been a decline in emissions due to biomass burning after conversion of Forest Land to Settlements. • The revision of the deforestation dataset (2000-2004) resulted in a re-allocation of areas in the land use change matrix, producing a change of decline in emission/removal estimates in 2005 from those in the 2007 NIR; affecting emissions from soil carbon stocks due to land use change to settlements.
CH$_4$	-0.37	-4.97	• The data on the area of deforestation in non-rural areas have been revised for 2000-2004. A five-year moving average has been applied on the recommendation of the data suppliers (Department of Communities and Local Government). The area of deforestation in 2005 and 2006 has been estimated by extrapolation from earlier years. There has been a decline in emissions due to biomass burning after conversion of Forest Land to Settlements.

Source category and GHG	Change in emissions (GgCO$_2$eq.) (Emissions in 2006 inventory minus emissions in 2005 inventory)	Change in emissions (%) (Percentage change relative to the 2005 inventory)	Brief description of reasons for recalculation
N$_2$O	-0.04	-4.98	• The data on the area of deforestation in non-rural areas have been revised for 2000-2004. A five-year moving average has been applied on the recommendation of the data suppliers (Department of Communities and Local Government). The area of deforestation in 2005 and 2006 has been estimated by extrapolation from earlier years. There has been a decline in emissions due to biomass burning after conversion of Forest Land to Settlements.
5G			
CO$_2$	-17.49	-18.16	• This year, CEH have developed a time series of LULUCF emissions for the UK's Overseas Territories and the Crown Dependencies. The total LULUCF emissions from the OTs and CDs are currently included in sector 5G because the CRF Reporter does not easily allow these emissions to have their own sub category in source sector 5. Including these emissions results in an apparent decline in emissions in 2005. However, the emissions estimated from Harvested Wood Products in 2005 are unchanged.
6A			
CH$_4$	-28.91	-0.15	• A major improvement has been made to the calculation of emissions from landfill in Guernsey (see Annex 3.9). Estimates of emissions from waste disposal in Bermuda have also been improved. These were previously assumed to be from landfill, this has now been amended as waste is now incinerated.
6B			
CH$_4$	-0.37	-0.05	• Small revisions to estimates from OTs and CDs. These are scaled from UK statistics using population data. Recalculations reflect small revisions to population data used.
N$_2$O	+0.02	+0.00	• Small revisions to estimates from OTs and CDs. These are scaled from UK statistics using population data. Recalculations reflect small revisions to population data used.
6C			
CO$_2$	-2.43	-0.53	• Decrease in emissions due to updates to Pollution Inventory data for chemical waste incinerators and modifications to the assumptions needed to deal with gaps in reported data. • Inclusion of estimate for waste incineration in Bermuda.
CH$_4$	-0.11	-3.49	• Decrease in emissions due to updates to Pollution Inventory data for chemical waste incinerators and modifications to the assumptions needed to deal with gaps in reported data. • Inclusion of estimate for waste incineration in Bermuda.

Source category and GHG	Change in emissions (GgCO$_2$eq.) (Emissions in 2006 inventory minus emissions in 2005 inventory)	Change in emissions (%) (Percentage change relative to the 2005 inventory)	Brief description of reasons for recalculation
N$_2$O	+0.57	+1.17	• Decrease in emissions due to updates to Pollution Inventory data for chemical waste incinerators and modifications to the assumptions needed to deal with gaps in reported data. • Inclusion of estimate for waste incineration in Bermuda.

Table 10.2   Recalculations of direct GHG emissions for the base year in the UK 2008 NIR (2006 inventory)

Source category and GHG	Change in emissions (GgCO₂eq.) (Emissions in 2006 inventory minus emissions in 2005 inventory)	Change in emissions (%) (Percentage change relative to the 2005 inventory)	Brief description of reasons for recalculation
1A1			
CO_2	-5.53	0.00	• Revision to emission factor used for waste incineration for power generation in the CDs, and revised fuel classifications used for the OTs.. • Revision to emission factor for colliery methane (based on the average emission factor for natural gas).
CH_4	2.12	1.50	• The majority of this change was due to a revision to the emission factor used for petroleum coke use in refineries. • Small changes from revisions to emission factors and fuel classifications for the OTs and CDs.
N_2O	3.44	0.18	• Emission factors for N_2O were reviewed and revised across the time series for various fuels. This has led to a significant increase to emissions from coal use in power stations, and smaller changes for other fuels. • Small changes from revisions to emission factors and fuel classifications for the OTs and CDs.
1A2			
CO_2	-131.43	-0.13	• This change was mostly caused by a revision to the emission factors used across the time series for the combustion of scrap tyres and petroleum coke, based on data provided by BCA. • Other small changes result from reclassification of some fuels in the OTs, and from a change to the emission factor for colliery methane across the time series.
CH_4	-0.28	-0.09	• Revision to the emission factor used for petroleum coke across the time series. • Other small changes result from reclassification of some fuels in the OTs.
N_2O	-1.42	-0.09	• Emission factors for N_2O were reviewed and revised across the time series for various fuels. • Other small changes result from reclassification of some fuels in the OTs.

Source category and GHG	Change in emissions (GgCO₂eq.) (Emissions in 2006 inventory minus emissions in 2005 inventory)	Change in emissions (%) (Percentage change relative to the 2005 inventory)	Brief description of reasons for recalculation
1A3			
CO₂	126.02	0.11	• The majority of this change was caused by the improvement to the methodology used to estimate emissions from rail, including using the new Dft rail model for passenger trains, and revised emission factors for freight trains. • Emissions from domestic aviation have decreased due to the incorporation of new operational data for LTO cycles. • Emissions from road transport in the OTs have been recalculated because the emission factors used in the UK inventory have been updated since the last time the OT data were updated. • Total emissions from UK road transport have not changed, but there have been changes to the allocation between vehicle types due to revisions to fuel consumption factors used for individual vehicle categories.
CH₄	2.32	0.37	• Emissions from rail have increased due to improved activity data from the new rail model, and revised emission factors. • Emissions from domestic aviation have changed due to improvements to the methodology.
N₂O	21.67	1.70	• The majority of this change was caused by the improvement to the methodology used to estimate emissions from rail, using the new Dft rail model. • Emissions from domestic aviation have changed due to improvements to the methodology
1A4			
CO₂	-53.67	-0.05	• This decrease has been caused by a reallocation of gas oil from the public sector, and from the commercial category to account for the increase in the rail category.
CH₄	-11.12	-0.72	• This decrease has been caused by a reallocation of gas oil from the public sector, and from the commercial category to account for the increase in the rail category.
N₂O	0.83	0.09	• Emissions in the commercial and public sector categories decreased due to the reallocation of gas oil for the rail sector. • This decrease has been offset by the increases caused by revisions to emission factors.
1A5			*No change to emissions in this sector*
CO₂			
CH₄			
N₂O			

Source category and GHG	Change in emissions (GgCO$_2$eq.) (Emissions in 2006 inventory minus emissions in 2005 inventory)	Change in emissions (%) (Percentage change relative to the 2005 inventory)	Brief description of reasons for recalculation
2A			
CO$_2$	635.93	6.71	• There has been a change to the emission factor used for clinker production across the time series. Methodology now using data generated by UK cement clinker producers for the purposes of reporting to the EU Emission Trading Scheme.
2B			
CO$_2$	-280.77	-8.87	• Revision to the emission factor for energy recovery from waste fuels. This effects emissions across the time series.
CH$_4$	0.42	0.31	• Updated data in the pollution inventories have led to revised implied emission factors being used across the time series, causing a small increase in emissions in this sector.
2C			
CO$_2$	-	-	
CH$_4$	-	-	
N$_2$O	-	-	
2C3			*No change to emissions in this sector*
PFC	-	-	
2E			*No change to emissions in this sector*
HFC	-	-	
PFC	-	-	
2F			
HFC	2.20	0.14	• Emissions from the OTs and CDs have been reviewed, and in some cases more appropriate proxy data for scaling emissions have been used.
PFC	-	-	
SF$_6$	-	-	
4A			
CH$_4$	-0.40	0.00	• Small revision to emissions calculation for livestock emissions from the CDs.
4B			
CH$_4$	-	-	•

Source category and GHG	Change in emissions (GgCO$_2$eq.) (Emissions in 2006 inventory minus emissions in 2005 inventory)	Change in emissions (%) (Percentage change relative to the 2005 inventory)	Brief description of reasons for recalculation
N$_2$O	206.57	13.65	• Change to nitrogen excretion factors used, to bring the GHG Inventory up to date with the ammonia inventory.
4D			
N$_2$O	4.82	0.02	• This has been affected by the change to nitrogen excretion rates, as explained above.
4G			*No change to emissions in this sector*
N$_2$O	-	-	
5A			
CO$_2$	46.90	-0.38	• Emissions estimates for wildfires
CH$_4$	4.30	100.00	• Emissions estimates for wildfires
N$_2$O	6.84	100.00	• Emissions estimates for wildfires and N fertilisation
5B			
CO$_2$	-13.94	-0.09	• Estimates of emissions due to liming have been updated with 2006 data. Revisions in the agricultural census dataset resulted in changes in the allocation of lime to either Cropland or Grassland at the UK scale. However, total emissions from the application of lime remain the same, only the allocation to land use has changed. Estimated emissions from Cropland have fallen
5C			
CO$_2$	13.94	-0.22	• The estimates of emissions due to liming have been updated with 2006 data. Revisions in the agricultural census dataset resulted in changes in the allocation of lime to either Cropland or Grassland at the UK scale. However, total emissions from the application of lime remain the same, only the allocation to land use has changed. Emissions from Grassland have risen.
5E			*No change to emissions in this sector*
CO$_2$	-	-	
CH$_4$	-	-	
N$_2$O	-	-	
5G			
CO$_2$	-29.10	2.00	• This is emissions from the OTs and CDs, included for the first time in the 2006 inventory.

Source category and GHG	Change in emissions (GgCO$_2$eq.) (Emissions in 2006 inventory minus emissions in 2005 inventory)	Change in emissions (%) (Percentage change relative to the 2005 inventory)	Brief description of reasons for recalculation
6A			
CH$_4$	44.13	0.09	• This change is due to the improvement in methodology for estimating emissions from landfill in Guernsey.
6B			*No change to emissions in this sector*
CH$_4$			
N$_2$O			
6C			*No change to emissions in this sector*
CO$_2$	-	-	
CH$_4$	-	-	
N$_2$O	-	-	

10.2 IMPLICATIONS FOR EMISSION LEVELS

The implications for emission levels in the year 2005 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 2006 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 2005 inventory.

Figure 10.1 summarises the effect of the recalculations in the 2008 NIR (2006 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 2005 and 2006, according to IPCC source sector. A negative difference indicates a decline in GWP emission between the inventory presented in the 2008 NIR (2006 inventory), and the inventory presented in the 2007 NIR (2005 inventory). The LULUCF totals are presented as net emissions.

Figure 10.2 summarises the effect of the recalculations in the 2008 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 2005 and 2006.

The percentage change, due to recalculation with respect to the previous submission, has been calculated as

Percentage change = 100% x [(LS-PS)/PS]

Where
LS = Latest Submission (2006 inventory; 2008 NIR)
PS = Previous Submission (2005 inventory, 2007 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 is affected by a number of time series changes, including a new methodology for calculating emissions from rail, improvements to the model for estimating aviation emissions, and changes to the emission factor for clinker production. For later years, totals have also been affected by significant revisions to national fuel use statistics (BERR, 2007). 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 the base year
- Recalculations in the base year have led to a net increase in emissions of 595Gg CO_2 eq.
- The largest single change to emissions in the base year was an increase of 636Gg CO_2 in IPCC sector 2A1. This is because of a revision to the emission factor used for clinker production, based on data reported by industry under the EU ETS.
- This was partially offset by a significant decrease in emissions from energy recovery from waste fuels of 280 Gg CO_2. The emission factor for this source was revised down to reflect a more realistic carbon content for this fuel.
- Total net emissions in sector 1A have changed slightly (a small increase of 2.21Gg CO_2eq) although there have been significant increases and decreases in individual sectors, mostly to accommodate the reallocation of gas oil due to the new methodology for emissions from rail.
- Emissions of N_2O from agriculture have increased by 211Gg CO_2 eq due to the revision to nitrogen excretion rates used in this inventory.

Reasons for changes in GWP emissions in 2005
- Recalculations in 2005 have led to an increase in emissions of 1,343Gg CO_2 eq.
- Total emissions from fuel combustion (1A) have increased by 714Gg CO_2 eq mostly because of changes to national statistics.
- The most significant changes to the inventory in 2005 occurred in the energy sector. Emissions in sector 1A1 increased by 3130 Gg CO_2eq. This increase was a result of a number of changes, the most significant being changes to national energy statistics, and a reallocation of coal from industrial combustion to power stations to be consistent with data reported under EU ETS. The reallocation of coal accounted for 2206Gg of the total increase, although this was offset in the over all total by a commensurate decrease in the industrial combustion sector (1A2).
- Emissions from 1A2 and 1A4 were mostly affected by the reallocation of coal to power stations, and gas oil to rail, in addition to revisions to national statistics and emission factors.
- Emissions in sector 1B1 have increased by 282Gg CO_2 eq to include emissions from mines closed during 2005.
- The other most significant changes were a change to the emission factor for clinker production, which is now based on EU ETS data and has led to a increase in emissions in sector 2A, and a decrease to the emission factor used for energy recovery from waste fuels in sector 2B.

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

Change in GWP emissions (2006 minus 2005 inventory estimates) according to IPCC source sector
(Basket of 6 Kyoto GHGs)
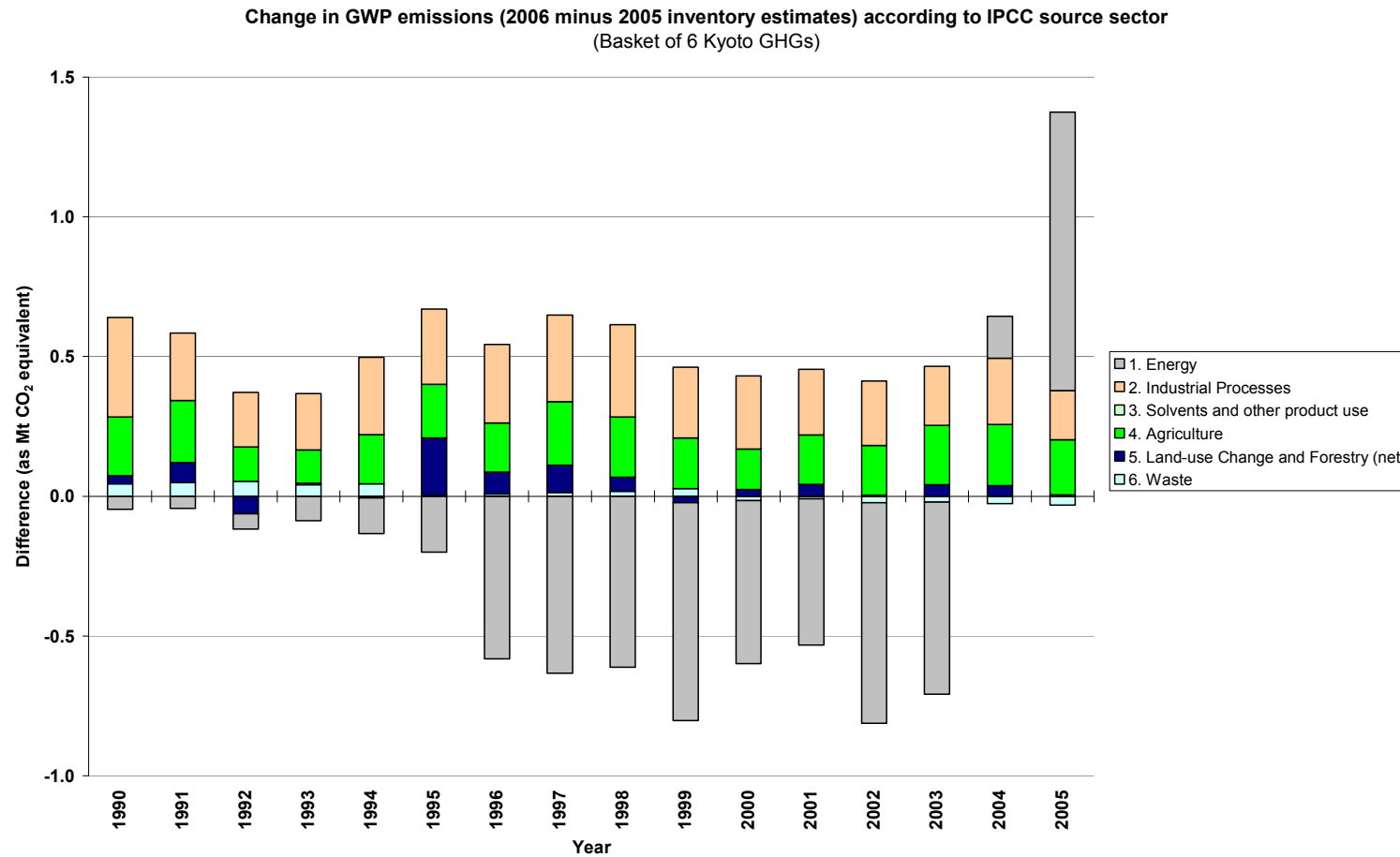
Figure 10.2   Time series of changes in total net GWP emissions, and percentage changes in total net GWP emissions, between the inventory presented in the current and the previous NIR

Difference and percentage change (2006 relative to 2005 inventory estimates) in total GWP net emissions
(Basket of 6 Kyoto GHGs)
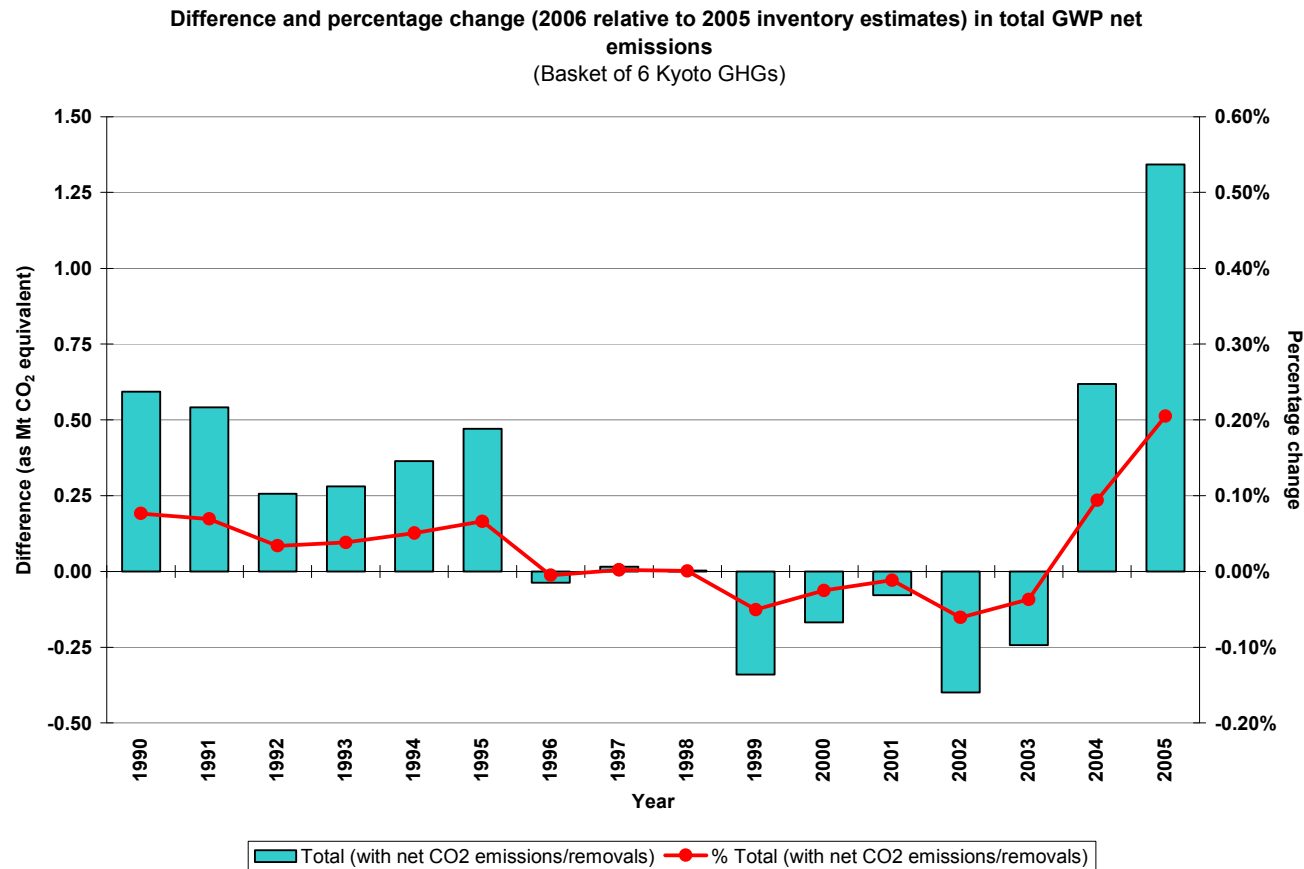
10.3.1 Response to the review process

There have been three reviews of the UKs GHG inventory since the publication of the 2007 NIR.

The UNFCCC Secretariat conducted a In-Country Review of the 2006 greenhouse gas inventory submission (2006 NIR) of the United Kingdom of Great Britain and Northern Ireland in accordance with decision 19/CP.8 of the Conference of the Parties. The review took place from 12 to 17 March 2007 in London. This review follows on from the fourth Centralised Review of the UK greenhouse gas inventory (3 to 8 October 2005, Bonn, Germany). During their visit to the UK, the UNFCCC Expert Review Team (ERT) also completed a review of the initial report of the United Kingdom of Great Britain and Northern Ireland in accordance with the guidelines for review under Article 8 of the Kyoto Protocol (decision 22/CMP.1). The 2007 NIR was produced before the formal ERT comments on the 2006 NIR became available.

A few of the tasks suggested by the ERT in the third and fourth Centralised Reviews are still ongoing.

The European Union Monitoring Mechanism (EUMM, 2007) reviewed the uncertainty estimates presented in the EC NIR for 2007, and made a series of country specific requests for clarification. The EC 2007 NIR incorporated the UK's 2007 NIR. The document included overviews of the uncertainty estimates by source category for the EU 15 Member States. The review concentrated on the Tier 1 (Approach 1) estimates for activity data, emission factors and combined uncertainties from IPCC Good Practice Guidance Table 6.1. The UK's responses to the EUMM's queries are included in **Table 10.3**.

Table 10.3 provides an overview of the actions taken to improve the NIR and the inventory in response to the comments made by UNFCCC Expert Review Teams. 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.

Table 10.3 **Brief details of improvements to the NIR and the inventory in response to FCCC reviews**

ERT comment	Actions
Third Centralised Review	
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. There is potential for the EU ETS to provide the data in the near future when the lime producers, who are not currently part of the ETS, will soon be required to be. Should the EU ETS returns not provide the necessary data, then we will contact the lime producers again directly.
Fourth Centralised Review	
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.
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. This task is still ongoing.
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_2O emissions from AWMS	The UK is looking into improving the link between the NH_3 and GHG inventories, and incorporating NO_x in a study (desk/experimental) will review the current assumption of 20% of N lost as NH_3 and NO_x.
In Country Review *March 2007*	
Cross cutting - Add a commentary about the reasons for the changes in the base year emissions	A new table, Table 10.2 *Recalculations of direct GHG emissions for the base year* , has been added to Chapter 10.
Cross cutting - Alter the pagination of the UK NIR, so that the cover page was page 1 and other pages followed on sequentially from this.	The pagination has been amended.
Cross cutting - Improve the transparency of the nomenclature used to identify the type of uncertainty analysis used	We now use the nomenclature in the 2006 IPPC guidelines to identify the type of uncertainty analysis performed – Approach 1 (error propagation analysis) and Approach 2 (Monte Carlo model).
Cross cutting - Key Category analysis includes only categories that add up to a cumulative total of more than 94 per cent.	The Key Categories presented are summed together in descending order of magnitude, and add up to over 95 per cent of the "level" or "trend" parameter.
Cross cutting - The ERT recommended adding a Key Category analysis for the base year.	This NIR contains a Key Category analysis for the base year.

ERT comment	Actions
Cross cutting - Consistency: Reporting in the NIR and CRF table Summary 3 do not always correspond.	We have tried to improve the consistency between the NIR and the CRF.
Cross cutting - Recalculations: Provide in CRF table 8(a)	The reasons for recalculations are now provided in the CRF tables for all years. They were omitted because of problems with the installation of the CRF Reproter software. Reasons for recalculations for 2005, and the base year, are also provides in Chapter 10 of the NIR.
Cross cutting - General comments on consistency within the NIR and between the NIR and the CRF	We have asked sector experts to review their sections in the NIR and to review the consistency of the NIR with the CRF.
Cross cutting - Transparency of reporting of emissions from the Crown Dependencies and the Overseas Territories.	Additional information has been provided in this NIR including information on improvements to methodologies used for emission estimates.
Energy - Large inter-annual changes in IEFs, caused by changes in annual derived CEFs. Consider applying regression analysis to avoid these inter-annual changes	We have considered this and discussed with UK Defra. For the moment, the UK continues to update CEFs on an annual basis because it considers that this approach provides the most accurate estimates of carbon emissions in a given year.
Energy - Fugitive emissions: Activity data incorrectly reported in CRF	The time series of activity data is now correctly reported in the CRF submission, and was corrected in the 2007 CRF submission also.
Industrial Processes - Cement (CO_2) – 25% decrease between 90-92 due to downturn in construction activity	An enhanced explanation has been included in the chapter on Industrial Processes.
Industrial Processes - Nitric Acid production (N_2O): Recommendation that the Party tries to reduce the uncertainty in this source by reviewing the assumptions used and investigating if other industrial data could be used as the basis for more accurate estimates of emissions.	The emissions of N_2O from nitric acid production, particularly between 1990 and 1994, are associated with a higher level of uncertainty than in later years of the time series. The higher uncertainty arises because some production data between 1990 and 1994 is unknown and has to estimated from surrogate parameters. We are trying to reduce the uncertainty in this source by reviewing the assumptions used and investigating if other industrial data could be used as the basis for more accurate estimates of emissions. No changes have been made to the estimates of emissions reported in this NIR.
Agriculture - The methodologies applied tend to utilize highly aggregated activity data. Given the range of quality data that are available, the United Kingdom is encouraged to develop methodologies that use more disaggregated data for its inventory in future.	Noted. The current methodology is based on the most disaggregated data we can obtain. However, we are starting a new project to improve the inventory methodology and this will disaggregate the input data , so as information becomes available this disaggregated data can be used
Agriculture – Suggestion of implementing a Tier 2 approach for beef cattle.	In the new project (mentioned above) Tier 2 will be implemented in all possible categories including beef cattle
Agriculture – Calculation of the Tier 2 emission factors for beef cattle – suggestion that some additional background information could have been provided in the NIR.	Noted. This information has been provided in this NIR.
LULUCF - The United Kingdom explained that LULUCF emissions were not estimated for Overseas Territories and Crown Dependencies as there was not sufficient information available.	A time series of estimates of LULUCF emissions have now been made for the Overseas Territories and Crown Dependencies and are included in this NIR.

ERT comment	Actions
LULUCF - The NIR does not provide the comprehensive information on land use and land-use change in the country in the form of a land-use matrix as described in the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry	The LULUCF chapter now contains a land use matrix.
LULUCF - Emissions of the Overseas Territories and Crown Dependencies are not included in the estimates but seem to be negligible. The ERT encourages the United Kingdom to collect data to address these gaps.	The UK inventory now contains estimates of net emissions from Overseas Territories and Crown Dependencies.
LULUCF - The LULUCF inventory does not include separate estimates of N_2O from fertilization of forests, from disturbance of soils, or from wildfires. The ERT encourages the United Kingdom to collect data to address these gaps.	The UK inventory now includes these estimates separately.
LULUCF - The United Kingdom's countryside survey does not distinguish wetland from other types of land. Wetland types are mainly included in the grassland, or in the case of open water in the category other land. Table 5.D is reported as "included elsewhere" ("IE"). Grassland converted to other land is reported in table 5 as "not occurring" ("NO"), whereas in tables 5.A, 5.B and 5.E grassland conversion is reported.	Noted.
LULUCF - The area affected by land-use change is reported under the "land converted to" subdivisions. A distinction is made between land converted before 1990 and after 1990. According to the IPCC good practice guidance for LULUCF, land converted from one land-use category to another should be kept in the conversion state for 20 years. Although after 20 years the equilibrium in soil carbon content is not reached, the management practice of the new land use may have a significant influence on the carbon stock in the soil. Hence a subdivision of land remaining in the same category would be more in accordance with the IPCC good practice guidance for LULUCF. The ERT invites the United Kingdom to consider the duration of the conversion status.	Noted.
LULUCF - The United Kingdom uses a model approach, described as a tier 3 method as defined in the IPCC good practice guidance for LULUCF, to estimate emissions and removals from forests, afforestation and deforestation. The model provides net changes of all three carbon pools – living biomass, dead organic matter, and carbon stock of soils – as well as of wood products harvested from forests in the United Kingdom. No data are provided in the columns "Increase" and "Decrease" of carbon stock changes in living biomass in table 5.A.	The UK now reports Increases and Decreases of carbon stock changes in living biomass in Table 5.A.

ERT comment	Actions
LULUCF - The United Kingdom experts further informed the ERT that they are working on the issues of afforested drained peat land, N₂O emission from drainage, and carbon stock change of organic soils, and that they intend to provide this information in the Party's next NIR.	This is still work in progress. Carbon stock changes on organic soils as a result of afforestation are now reported in table 5.A.
LULUCF - No estimates are reported for wildfires. The United Kingdom experts explained that there are almost no wildfires but that they would check whether data are available.	The UK now reports estimates for forest wildfires.
LULUCF - The United Kingdom reports a net emission of 618.82 Gg CO2 from harvested wood products in Table 5 but there is little explanation in the NIR as to how this sink is calculated. The United Kingdom is encouraged to improve the transparency of this calculation by addressing these issues in the NIR of its future submissions.	The text has been updated to improve the transparency of reporting.
Waste - Check the time series consistency of N₂O emissions from human sewage.	We have examined the time series consistency of these emissions. Between 1996 and 1997 there is a step change in the reported protein consumption data. This is because Defra revised their publication (formally National Food Survey) and in doing so revised the method used to calculate protein consumption. The new method only provides data back to 1997 and so a step change occurs.
Waste - The ERT recommended the United Kingdom to explain more clearly in the NIR how it obtained the AD for solid waste disposal on land.	The UK is currently preparing text to include in a later NIR. This will follow on from a review of the model that is used to estimate emission from the disposal of waste to landfill.
Waste - The ERT recommended the United Kingdom provide more information on how national policies and measures influence the reduction of the quantities of landfilled wastes and the CH4 emissions.	A new section has been added in the main section of the NIR "UK Waste Management Disposal to Land Legislation and Guidance" which explains the UK regulatory framework.
Waste - The ERT recommends the United Kingdom to clarify how it has obtained such high recovery rates of CH₄ in recent years (2000–2004) compared with other European countries.	This NIR contains extra information in Table 3.8.3 on the total quantities of gas flared and utilised. The UK is currently preparing text to include in a later NIR. This will follow on from a review of the model that is used to estimate emission from the disposal of waste to landfill.
Waste – N₂O and CH₄ emissions from industrial waste water are not included due to lack of activity data and of information on processes, which makes it likely that they would be underestimated. The ERT recommends the Party to include these emissions in its future inventories.	The UK has continues with its efforts to estimate emissions from this source. The UK identified has asked the UK Environment Agency to prepare a list of on-site industrial waste water treatment works. This will cover treatment plants in the England and Wales.
Waste – The United Kingdom uses country-specific EFs for estimating CO₂ emissions for waste incineration. The NIR does not provide sufficient clarity on how the biogenic portions of municipal solid waste incinerated were handled for estimating the country-specific EFs.	Additional information has been provided in the Annex 3 of the NIR. In the UK, emissions from MSW are reported under category 1A1a.

ERT comment	Actions
EUMM uncertainty review for EC 2007 NIR	
Industrial processes. 2B Chemical industry. N_2O. uncertainty estimate. Emission factor uncertainty value seems to be comparatively high (in relation to those used by other Member States).	Nitric acid and adipic acid manufacture are both key categories in the UK GHG inventory. The uncertainties assigned to the AD and EFs are: 2B2 Nitric acid production, AD 10%, EF 230%; 2B3 Adipic acid production, AD 0.5%, EF 15%. The uncertainty associated with N_2O emissions released from nitric acid production dominate the overall uncertainty in N_2O emissions in sector 2B. The uncertainty assigned to the EF of nitric acid production was taken from a study commissioned by UK Defra (Salway, 1998) and the uncertainty in the EF for nitric acid production was estimated from a range of values in the available literature - the reference in the report indicates the main source was the 1996 IPCC guidelines. The UK has not reviewed the uncertainties associated with nitric and adipic acid for some time. The UK stated that it would review the uncertainties with the manufacturers during the compilation of the 2008 NIR but has not altered the uncertainty parameters following this review. Work continues to refine the uncertainty from this source.
4B Manure management. N_2O EF uncertainty. Uncertainty value seems to be comparatively high (in relation to those used by other Member States).	Manure management is a key category in the UK GHG inventory. The emissions of N_2O from manure management are currently approximately 20 times smaller than those from agricultural soils. The uncertainties assigned to the AD and EFs are: 4B Manure management, AD 1%, EF ~400%. Emissions from this source are highly uncertain. The uncertainties ascribed were derived from the study complete by Salway et al. (1998). For the purpose of the uncertainty simulation in that study, the much smaller source manure management was included in the agricultural soil total. This was because no separate information on the uncertainty of emissions from manure management was available. In the GHG uncertainty analysis, the uncertainty associated with manure management was assigned by expert judgement. The uncertainty ascribed to the EF was reviewed during the agrcultural peer review of the 2004 and 2005 NIRs (Dämmgen and Döring, 2005). No change was recommended to the ascribed uncertainty as no better country specific data could be identifed. UK Defra continues to fund research to improve the scientific understanding of emissions from manure management.

ERT comment	Actions
4D Agricultural soils. N$_2$O EF uncertainty. Uncertainty value seems to be comparatively high (in relation to those used by other Member States).	Agricultural soils is a key category in the UK GHG inventory. The uncertainties assigned to the AD and EFs are: 4D Agricultural soils, AD 1%, EF ~400%. Emissions from this source are highly uncertain. Current research in the UK indicates that emission factors (kg per hectare per year) are likely to range over two orders of magnitude. This will be determined by a complex combination of variability (i.e. as influenced by climate, agricultural practice and soil type) and uncertainty (reflecting the difficulty in quantifying the release for any single set of conditions). As the quality of the activity information (e.g. numbers of animals, fertiliser consumption, crop areas) is generally very high compared to that which is used to quantify the emission factors, uncertainties in the activity data were ignored in the analysis (set to 1% as a mathematical device), and the uncertainties in emissions ascribed solely to those in emission factors (Salway, 1998). The distribution in emissions from agricultural soil in the UK is represented using a log-normal distribution, with the 95th percentile set to be 100 times larger than the corresponding 5th percentile (Salway et al., 1998). The uncertainties ascribed to the EF were reviewed during the agrcultural peer review of the 2004 and 2005 NIRs (Dämmgen and Döring, 2005). No change was recommended to the ascribed uncertainty as no better country specific data could be identifed. UK Defra continues to fund research to improve the scientific understanding of emissions from agricultural soils.

10.3.2 Major improvements to the current inventory

Work done to improve the current inventory is summarised below. More details can be found in the source specific recalculations sections in the appropriate chapters of this report.

- **Review of EUETS data**. Data which has been made available through the EU Emissions Trading Scheme has been reviewed for possible inclusion in the inventory. This review has not had a major impact on the inventory, since in the majority of cases the existing methodology was deemed to be more suitable. This data source will be kept under review.
- **Improvements to emissions from rail**. Emissions from passenger trains have been improved, using the new Dft rail model. Emissions from freight trains have been recalculated using revised emission factors.
- **Revision to nitrogen excretion rates**. Research carried out into appropriate nitrogen excretion rates for UK livestock have been incorporated into the agriculture sector to improve the accuracy of GHG estimates, and to maintain consistency between the ammonia inventory and the GHG inventory.

An in-country review took place in March 2007 and further work to improve the inventory may be initiated as a result of this.

11   References

References for the main chapters and the annexes are listed here and are organised by chapter and annex.

11.1   CHAPTER 1 [INTRODUCTION]

AEAT (2004) Emissions and Projections of HFCs, PFCs and SF6 for the UK and Constituent Countries. Final Report prepared for the Department for Environment, Food and Rural Affairs, 2nd Edition, June 2004, AEA Technology, Oxfordshire, UK.

Cm2427 (1994) Climate Change the UK Programme. UK's (first) report under the Framework Convention on Climate Change. HMSO, London.

Cm3558 (1997) Climate Change the UK Programme. UK's (second) report under the Framework Convention on Climate Change. HMSO, London.

Cm4913 (2000) Se 2000/209; NIA 19/00. Climate Change the UK Programme. UK's (second) report under the Framework Convention on Climate Change. HMSO, London.

Defra (2001) The UK's Third National Communication under the United Nations Framework Convention on Climate Change. Defra publications, Admail 6000, London, SW1A 2XX.

DTI (2003), Energy White Paper, London, The Stationery Office.

DTI (2005), Digest of United Kingdom Energy Statistics 2005, London, The Stationery Office.

FCCC (1992) Report of the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change on the work of the second part of its fifth session, held at New York from 30 April to 9 May 1992.

IPCC (1996) Climate Change 1995 – The science of climate change. Contribution of Working Group 1 to the Second Assessment Report of the Intergovernmental Panel on Climate Change, Ed. Houghton, JT., Cambridge University Press.

IPCC (1997a), IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories, Volume 1, Greenhouse Gas Inventory Reporting Instructions, IPCC WGI Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK.

IPCC (1997b), IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories, Volume 2, Greenhouse Gas Inventory Workbook, IPCC WGI Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK.

IPCC (1997c), IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories, Volume 3, Greenhouse Gas Inventory Reference Manual, IPCC WGI Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK.

IPCC (2000), Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, ed. Penman, J, Kruger, D, Galbally, I, et al, IPCC National Greenhouse Gas Inventories Programme, Technical Support Programme Technical Support Unit, Institute for Global Environmental Strategies, Hayama, Kanagawa, Japan.

IPCC (2001), Climate change 2001 – The scientific basis. Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press.

IPCC (2007), Climate change 2007 – The scientific basis. Contribution of Working Group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press.

Kershaw (2005), "Development of a Methodology for Estimating Methane Emissions from Abandoned Coal Mines in the UK", White Young Green report to Defra, 2005.

Salway, AG (2001), Accordance of UK Greenhouse Gas Inventory with IPCC Good Practice Guidance, Note prepared for DETR, NETCEN, AEA Technology, Culham.

Simmons, T (2002), Peer Review of the UK Greenhouse Gas Inventory CO2 from Fuel Combustion 1990 - 1999. Avonlog Ltd, 49 Headley Chase, Brentwood, Essex, CM14 5DH.

11.2   CHAPTER 3 [ENERGY (CRF SECTOR 1)]

British Cement Association (2007), UK cement clinker production, emissions, and fuel consumption data, Personal Communication (Richard Leese).

BERR (2007), Digest of United Kingdom Energy Statistics 2007, London, The Stationery Office.

DoENI (2007), Inventory of Sources and Releases, Personal Communication (David Bell)

Environment Agency (2007), Pollution Inventory, Personal Communication (Alex Hole)

Kershaw (2005) *unknown – referenced in section 3.12.2*

Rypdal *et al.* (2000), Kristin Rypdal and Ketil Flugsrud (Statistics Norway), and William Irving (USEPA). Good Practice – Methodological Choice, Good Practice – Methodological Choice – background paper.

Salway (1998) *unknown – referenced in section 3.10*

SEPA (2007), Scottish Pollutant Release Inventory, Scottish Environment Protection Agency, Personal Communication (Bob Boyce).

UKPIA (2007), Refinery production & emissions data, carbon emission factors, petroleum products data from the United Kingdom Petroleum Industry Association, Personal Communication (Ian McPherson, & Malcolm Watson)

US EPA (2007), Compilation of Air Pollutant Emission Factors, AP-42, www.epa.gov, 2007

Personal Communication, Ian Furneaux (DBERR Oil & Gas Unit, Aberdeen), October 2007

11.3   CHAPTER 4 [INDUSTRIAL PROCESSES (CRF SECTOR 2)]

BERR (2007), Digest of United Kingdom Energy Statistics 2007, London, The Stationery Office.

British Cement Association (2007), UK cement clinker production, emissions, and fuel consumption data, Personal Communication (Richard Leese).

British Geological Survey (2007), UK Minerals Yearbook 2006

British Glass (2007), UK glass production and recycling data in 2006, Personal Communication (Rebecca Cocking).

CIS (1991), Chem-Facts UK, Chemical Intelligence Services, Reed Telepublishing, Dunstable, Beds, UK.

CORINAIR (1989), CORINAIR Inventory, Commission of the European Community, Default Emission Factors Handbook, 1st edition, CITEPA, Paris.

Corus (2005), Personal Communication, Mick Briggs

Environment Agency (2007), Pollution Inventory database 2007, Personal Communication (EA PI team: Alex Wills)

Invista (2005), 2004 Plant-specific emissions and abatement details, Personal communication (Graham Hinton).

IPCC (1997), IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories, Volume 3, Greenhouse Gas Inventory Reference Manual, IPCC WGI Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK.

IPCC (2000), Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, ed. Penman, J, Kruger, D, Galbally, I, et al, IPCC National Greenhouse Gas

Inventories Programme, Technical Support Unit, Institute for Global Environmental Strategies, Hayama, Kanagawa, Japan.

Iron & Steel Statistics Bureau (2007), Iron and Steel Industry, Annual Statistics for the UK, 2007. ISSB Limited.

Munday, PK (1990) UK Emissions of Air Pollutants 1970-1988, Warren Spring Laboratory, LR 764.

NSAA (2003), Sulphuric acid plant emissions data for 2002, Personal Communication

Office of National Statistics (2007), Index of Production, Population Statistics and Prodcom data for 1990-2006, www.statistics.gov.uk

Refined Bitumen Association (1990), Personal Communication.

Rudd, HJ, Mikkelsen, M, (1996), Emissions of Volatile Organic Compounds from Ship Purging in the UK, AEA Technology Plc, Report No AEAT/20034001/REMA-208/Issue 2.

Scotch Whisky Association (2007), Statistical Report 2006.

TSO (2007), Annual Abstract of Statistics, 2007.

Transport and Road Research Laboratory (1989), Personal Communication, 1989.

US EPA (2007), United States Environmental Protection Agency, Compilation of Air Pollutant Emission Factors. Vol 1, 5th Edition, AP-42, North Carolina, Internet version, 2007.

11.4   CHAPTER 4 [INDUSTRIAL PROCESSES (CRF SECTOR 2 - F-GASES)]

AEAT (2004) Emissions and Projections of HFCs, PFCs and SF6 for the UK and Constituent Countries. Final Report prepared for the Department for Environment, Food and Rural Affairs, 2nd Edition, June 2004, AEA Technology, Oxfordshire, UK.

CSIRO (2005). Article "Metal Technologies: A Green Winner". Solve, Journal of the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO). Issue 3, May 05. http://solve.csiro.au/0505/article1.htm

Harnisch, J & Schwarz, W (2003), Costs and the impact on emissions of potential regulatory framework for reducing emissions of hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride. Prepared on behalf of EC (DG ENV).

IPCC (2000), Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Penman, J, Kruger, D, Galbally, I, Hiraishi, T, Nyenzi, B, Emmanuel, S,

Buendia, L, Hoppaus, R, Martinsen, T, Meijer, J, Miwa, K and Tanabe, K (Eds). IPCC National Greenhouse Gas Inventories Programme Published for the IPCC by the Institute for Global Environmental Strategies, Japan. ISBN 4-88788-000-6.

March (1999), UK Emissions of HFCs, PFCs and SF_6 and Potential Emission Reduction Options, March Consulting Group.

MTP (2002), UK Market Transformation Programme, Department for Environment, Food and Rural Affairs. www.mtprog.com

UNEP (1998), UNEP Halon Technical Options Committee (HTOC) report.

Verdonik D and Robin M (2004), Analysis of Emissions Data, Estimates, and Modelling of Fire Protection Agents, Hughes Associates Inc.

WS Atkins (2000), Projections of Non-CO_2 Greenhouse Gas Emissions for the UK and Constituent Countries. WS Atkins Environment.

11.5 CHAPTER 5 [SOLVENT AND OTHER PRODUCT USE (CRF SECTOR 3)]

British Coatings Federation (2005), UK production data, Personal Communication.

British Coatings Federation (2006), UK production data, Personal Communication.

British Coatings Federation (2007), UK production data, Personal Communication.

British Rubber Manufacturers Association (2001), Personal Communication, September 2001

Metal Packing Manufacturers Association (MPMA) (2000), Personal Communication.

Office of National Statistics (2007), Index of Production, Population Statistics and Prodcom data for 1990-2006, www.statistics.gov.uk

11.6 CHAPTER 6 [AGRICULTURE (CRF SECTOR 4)]

ADAS (1995a), Personal communication to A Croxford (MAFF). Distribution of animal waste management systems for cattle.

ADAS (1995b), Personal communication to A Croxford (MAFF). Linseed burning data.

Brewers Licensed Retail Association (1998), Personal communication to R Gerry (MAFF). Estimate of dry matter content of hops.

BSFP (2006). *British Survey of Fertiliser Practice: Fertiliser Use on Farm Crops for Crop Year 2005*, The BSFP Authority, Peterborough. Data for preceding years comes from earlier versions of the same publication.

Burton (1982), *Post-Harvest Physiology of Crops*, Longman, London, ISBN 0-582-46038-7.

Cottrill, B. (ADAS) Personal Communication

Defra (2002), Personal communications from M Rose, Land Management Improvement Division.

Defra (2006a), *Agriculture in the UK 2004*, The Stationery Office, London.

Defra (2004b), Basic Horticultural Statistics for the United Kingdom: Calendar and Crop Years 1991/92 – 2001/02, The Stationery Office, London.

IPCC (1997), *IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories, Volume 3, Greenhouse Gas Inventory Reference Manual*, IPCC WGI Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK.
IPCC (2000), Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories.

Lord, E (1997), Personal communication to S Gleave (MAFF). Factor for biological nitrogen fixation by improved grass.

MAFF (1995), *Straw Disposal Survey*. Data for earlier years taken from previous editions of the survey. Contact: Government Buildings, Epsom Rd., Guildford, Surrey, GU1 2LD for copies.

MAFF (1997), *Farm Incomes in the UK 1995/96*, The Stationery Office, London, ISBN 0-11-2543026-0.

Nix, J (1997), *Farm Management Pocket Book 1998*, 28th ed., Wye College Press, Ashford, UK.

PGRE (1998), Personal communication to R Gerry (MAFF). Estimate of dry matter content of field beans.

Smith, K & Frost, J (2000), Nitrogen excretion by farm livestock with respect to land spreading requirements and controlling nitrogen losses to ground and surface waters. Part 1 Cattle and sheep. *Bioresource Technology* 71, 173-181.

Smith, K, Charles, D & Moorhouse, D (2000), Nitrogen excretion by farm livestock with respect to land spreading requirements and controlling nitrogen losses to ground and surface waters. Part 2 Pigs and poultry. *Bioresource Technology* 71, 183-194.

Smith, K (2002), Personal communication from K Smith, ADAS.

Sneath, RW, Chadwick DR, Phillips VR & Pain BF (1997), A UK Inventory of Methane/Nitrous Oxide Emissions from Farmed Livestock. Contract reports (2) to MAFF, projects WA0604/5, SRI, IGER & ADAS.

Tucker, S & Canning, P (1997), Personal communication to D Wilkins (MAFF).

USEPA (1997), *Compilation of Air Pollutant Emission Factors*, volume 1, 5th ed., AP-42, United States Environmental Protection Agency, North Carolina.

11.7   CHAPTER 7 [LAND USE CHANGE AND FORESTRY (CRF SECTOR 5)]

Agricultural Industries Confederation (2006). Fertiliser Statistics 2006 Report www.agindustries.org.uk

Bellamy, P., Loveland, P.J., Bradley, R.I., Lark, R.M. and Kirk, G.J.D. (2005) Carbon losses from all soils across England and Wales. Nature 437, 245-248.

Bradley, R. I. (1997). Carbon loss from drained lowland fens. In: Carbon Sequestration in Vegetation and Soils (ed Cannell, M.G.R.). Department of Environment, London.

Bradley, R. I., Milne, R., Bell, J., et al. (2005). A soil carbon and land use database for the United Kingdom. Soil Use and Management, 21, 363-369.

BSFP (2007). The British Survey of Fertiliser Practice: Fertiliser Use on Farm Crops for Crop Year 2006, Defra. http://www.defra.gov.uk/farm/environment/land-manage/nutrient/fert/bsfp.htm.

Burton, R. (1995). Evaluating organic matter dynamics in cultivated organic topsoils – use of historical analytical data. MAFF Contract to SSLRC No. LE0203 –81/3830.

Cannell, M. G. R. and Dewar, R. C. (1995). The Carbon Sink Provided by Plantation Forests and Their Products in Britain. Forestry, 68, 35-48.

Cannell, M. G. R., Milne, R., Hargreaves, K. J., et al. (1999). National inventories of terrestrial carbon sources and sinks: The UK experience. Climatic Change, 42, 505-530.

Cooper, A. and McCann, T. (2002). Technical Report of the Northern Ireland Countryside Survey. University of Ulster.

Cruickshank, M. and Tomlinson, R. (1997). Carbon loss from UK peatlands for fuel and horticulture. In: Carbon Sequestration in Vegetation and Soils (ed Cannell, M.G.R.). Department of Environment, London.

Cruickshank, M. and Tomlinson, R. (2000). Changes in soil carbon storage in Northern Ireland: estimated by the IPCC default and matrix methods. Carbon Sequestration in Vegetation and Soils. DETR Contract EPG 1/1/39, (ed Milne, R.). Department of Environment, London.

Cruickshank, M. M., Tomlinson, R. W., Devine, P. M. and Milne, R. (1998). Carbon in the vegetation and soils of Northern Ireland. Biology and Environment-Proceedings of the Royal Irish Academy, 98B, 9-21.

Department of Communities and Local Government (2007). Land use change in England to 2006. Additional tables LUCS-21A. UK Government, London.

Dewar, R. C. and Cannell, M. G. R. (1992). Carbon Sequestration in the Trees, Products and Soils of Forest Plantations - an Analysis Using UK Examples. Tree Physiology, 11, 49-71.

Edwards, P. N. and Christie, J. M. (1981). Yield models for forest management. Forestry Commission Booklet. 48. Forestry Commission, Edinburgh.

FAO (2005). Global Forest Resources Assessment 2005. United Kingdom of Great Britain and Northern Ireland. Country report. Global Forest Resources Assessment 2005. Rome, Forestry Department, Food and Agriculture Organization of the United Nations: 64.

FAO/ECE (2002). Forest Fire Statistics 1999-2001. Timber Bulletin Volume LV(2002), No. 4. Geneva, Switzerland, Food and Agriculture Organization of the United Nations/United Nations Economic Commission for Europe.

Forestry Commission (2002). National Inventory of Woodland and Trees. Forestry Commission http://www.forestry.gov.uk/forestry/hcou-54pg4d

Forestry Commission. (2004). Forestry Statistics 2004. http://www.forestry.gov.uk/pdf/fcfs004.pdf/$FILE/fcfs004.pdf.

Haines-Young, R. H., Barr, C. J., Black, H. I. J., et al. (2000). Accounting for nature: assessing habitats in the UK countryside. DETR Countryside Survey 2000, London.

Hargreaves, K. J., Milne, R. and Cannell, M. G. R. (2003). Carbon balance of afforested peatland in Scotland. Forestry, 76, 299-317.

IPCC (1997a). Greenhouse Gas Inventory Reference Manual. IPCC WGI Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK.

IPCC (1997b). Greenhouse Gas Inventory Reporting Instructions. IPCC WGI Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK.

IPCC (1997c). Greenhouse Gas Inventory Workbook. IPCC WGI Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK.

IPCC (2003). Good Practice Guidance for Land Use, Land-Use Change and Forestry. Institute for Global Environmental strategies (IGES) for the Intergovernmental Panel on Climate Change, Kanagawa, Japan.

Levy, P. E. and Milne, R. (2004). Estimation of deforestation rates in Great Britain. Forestry, 77, 9-16.

Milne, R. and Brown, T. A. (1997). Carbon in the vegetation and soils of Great Britain. Journal of Environmental Management, 49, 413-433.

Milne, R. and Brown, T. A. W. (1999). Methods and data for Land Use Change and Forestry Sector in the 1997 IPCC Greenhouse Gas Inventory. In: Carbon Sequestration in Vegetation and Soils (ed Milne, R.).

Milne, R., Brown, T. A. W. and Murray, T. D. (1998). The effect of geographical variation in planting rate on the uptake of carbon by new forests of Great Britain. Forestry, 71, 298-309.

Milne, R. and Mobbs, D.C. (eds.) (2005). UK Emissions by Sources and Removals by Sinks due to Land Use, Land Use Change and Forestry Activities. Project report 2005. http://www.edinburgh.ceh.ac.uk/ukcarbon/reports.htm#2005.

MLC (1986). Monitoring Landscape Change. Report prepared by Hunting Surveys & Consultants Ltd for Department of the Environment and the Countryside Commission.

Office of National Statistics (2007). Mineral Extraction in Great Britain 2006. Business Monitor PA1007. www.statistics.gov.uk.

Pineiro, G., Oesterheld, M., Batista, W.B. and Paruelo, J. (2006) Opposite changes of whole-soil vs. pools C : N ratios: a case of Simpson's paradox with implications on nitrogen cycling. Global Change Biology 12 (5), 804–809.

Ruddock, K. (2007). UK Overseas Territories and Crown Dependencies: Emissions by sources and removals by sinks due to activities in the Land Use, Land Use Change and Forestry sector. MSc thesis in Environmental Sustainability, University of Edinburgh.

Skiba, U., Di Marco, C., Dragositz, U., et al. (2005). Quantification and validation of the total annual UK nitrous oxide budget. Final report to NERC - GANE. Centre for Ecology and Hydrology.

Skiba, U. (2007). N fertilisation of UK forests. Personal communication.

Sylvester-Bradley, R., Lunn, G., Foulkes, J., et al. (2002). Management strategies for high yields of cereals and oilseed rape. In HGCA R&D Conference - Agronomic Intelligence: The basis for profitable production, pp. 8.1-8.17. Home-Grown Cereals Authority.

Taylor, C. M. A. (1991). Forest fertilisation in Britain. Forestry Commission Bulletin 95.

11.8 CHAPTER 8 [WASTE (CRF SECTOR 6)]

AEA Technology (2002), Atmospheric Emissions from Small Carcass Incinerators, Report produced for the Department for Environment, Food and Rural Affairs by AEA Technology Environment, Culham Science Centre, Abingdon, Oxon. OX14 3ED, August 2002. Report AEAT/ENV/R/0920. http://www.airquality.co.uk/archive/reports/cat07/aeat-env-r-0920.pdf AEA Technology (2005), Local Authority Waste Recycling, Recovery and Disposal (LAWRRD) model user guide. Report for the UK Department of Environment, Food and Rural Affairs prepared by AEA Technology, July 2005.

Aitchison EM, Milton MJT, Wenborn MJ, Meadows MP, Marlowe IT, Mikkelsen M, Harries C and Pocock R. (1996). A methodology for updating routinely the annual estimate of methane emissions from landfill sites in the UK. ETSU report number EPG/1/1/20, Energy Technology Support Unit, Culham.

Barlaz *et al* (1997), Biodegradative analysis of municipal solid waste in laboratory scale landfills. Prepared for US Environmental Protection Agency Office of Research and Development, Washington DC 20460. Report EPA-600/R-97-071. USEPA, Washington DC.

Bellingham et al. (1994). The UK Methane Emission Inventory: a Scoping Study of the use of ambient measurements to reduce uncertainties.

Brown K, Conchie S, McHenry P, Wheeler P, van Santen A and Wood D. The LAWRRD (Local Authority Waste Recycling Recovery and Disposal) Model: A decision support tool designed to assist in waste management policy development. Waste 2006 Sustainable Waste and Resource Management Conference Proceedings, 19-21 September 2006, Stratford-upon-Avon, pp 209-218.

Brown, KA, Smith, A, Burnley, SJ, Campbell, DJV, King, K & Milton, MJT (1999), Methane Emissions from UK Landfills, AEA Technology, AEAT-5217, Culham.

The Cremation Society of Great Britain (2007), National Cremation Statistics 1960-2006, http://www.srgw.demon.co.uk/CremSoc4/Stats/

Defra (2007), Expenditure and Food Survey Report

Defra (2004), The National Food Survey 1990-03

DOE (1993), UK Sewage Sludge Survey, CES Limited, HMSO.

Environment Agency (2004), Pollution Inventory 2004

Golder Associates (2005), UK Landfill Methane Emissions: Evaluation and Apraisal of Waste Policies and Projections to 2050. Report version A.2, November 2005. Report for the UK Department of Environment, Food and Rural Affairs. Authors: Arnold, S. and Yang. Z. Report number 05529424.500

Hobson, J, Palfrey, R, Sivil, D, Palfrey, E & Day, M (1996), Control Measures to Limit Methane Emissions from Sewage and Sludge Treatment and Disposal, WRc, Report No DOE 4118.

IPCC (1997), IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories, Volume 3, Greenhouse Gas Inventory Reference Manual, IPCC WGI Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK.

IPCC (2000), Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, ed. Penman, J, Kruger, D, Galbally, I, *et al*, IPCC National Greenhouse Gas Inventories Programme, Technical Support Programme Technical Support Unit, Institute for Global Environmental Strategies, Hayama, Kanegawa, Japan.

LQM (2003), Methane emissions from landfill sites in the UK. Final report. January 2003. Report for the UK Department for Environment, Food and Rural Affairs. Authors: Gregory, RG, Gillett, AG, Bradley, D, LQM report 443/1. Defra contract EPG 1/1/145.

Milton, MJT, Partridge, RH, Goody, BA and Andrews, AS (1997),"An estimate of methane emissions from UK landfill sites based on direct flux measurements at representative sites", Final report to Department of the Environment, NPL report QM134, November 1997.

The National Household Waste Analysis Project (1994), Phase 2, Volume 3, Chemical Analysis data, Report CWM087/94.

Passant, NR (1993), Emissions of Volatile Organic Compounds from Stationery Sources in the UK: A review of Emission Factors by Species and Process (September 1993 Update), Warren Spring Laboratory, LR 990.

Pearce et al. (1993). Externalities from Landfill and Incineration, CSERGE, Warren Spring Laboratory and EFTEL

US EPA (2007), AP 42, Fifth Edition, Compilation of Air Pollutant Emission Factors, Volume I, Stationary Point and Area Sources. US EPA website, 2007: http://www.epa.gov/ttn/chief/ap42/index.html

11.9 CHAPTER 10 [RECALCULATIONS AND IMPROVEMENTS]

EUMM (2007)
http://circa.europa.eu/Members/irc/env/ccc/library?l=/working_inventories/other_documents

FCCC ERT (2005). Framework Convention on Climate Change – Expert Review Team. United Kingdom of Great Britain And Northern Ireland Report of the Individual Review Of The Greenhouse Gas Inventory Submitted in the year 2004. FCCC/WEB/IRR/2004/GBR. United Nations Framework Convention on Climate Change, Haus Carstanjen, Martin-Luther-King-Strasse 8, D-53175 Bonn, Germany:
http://unfccc.int/files/national_reports/annex_i_ghg_inventories/inventory_review_reports/application/pdf/2004_irr_centralized_review_uk.pdf

FCCC ERT (2006). Framework Convention on Climate Change – Expert Review Team. United Kingdom of Great Britain And Northern Ireland Report of the Individual Review Of The Greenhouse Gas Inventory Submitted in the year 2004. FCCC/ARR/2005/GBR. United Nations Framework Convention on Climate Change, Haus Carstanjen, Martin-Luther-King-Strasse 8, D-53175 Bonn, Germany.

11.10   ANNEX 3, SECTOR 1, 1A

AEP (2004), Joslin, A, Rodgers I, Salway G, Tabberer R, Relating fuel consumption to CO2 emissions: Review and recommendations for power station fuel and plant parameters for use in the DTI power station model.

ACEA (1995), "Evaporative Emissions Test Programme: Preliminary Report Including Diurnal Test Results", AE137/95.

Andre, M, Hassel, D, Hickman, AJ & Joumard, R (1993), The Science of the Total Environment, 134, 171.

Baggott SL, Lelland A, Passant NP, and Watterson J (2004) *Review of Carbon Emission Factors in the UK Greenhouse Gas Inventory*. AEA Energy and Environment, The Gemini Building, Fermi Avenue, Didcot, Oxfordshire, OX11 0QR, UK. November 2004. AEA report number AEAT/ENV/R/2347. Report prepared for UK Defra under contract RMP/2106.

Barlow, TJ, Hickman, AJ & Boulter, P (2001), Exhaust Emission Factors 2001: Database and Emission Factors, TRL Report PR/SE/230/00, September 2001.

BLF/UKPIA/CORA (1994), The Use and Fate of Lubricants and Used Oils.

Boulter, PG (1996), Factors Affecting Cold-Start Emissions: A Review, Transport Research Laboratory Report, PR/SE/183/96, September 1996.

Brain, SA, Carr, CE, Davies, M, Rantell, T & Stokes, BJ (1994), Emission of Volatile Organic Compounds (VOCs) from Coal-Fired Appliances, DTI, Coal R&D, Report No COAL R033. British Coal (1989), Personal Communication.

British Gas (1992,) Personal Communication from FE Shephard, Gas Research Centre, Loughborough, Leics.

British Gas (1994), Personal Communication from S Pearson, Gas Research Centre, Loughborough, Leics.

BR (1994), Research Report "Determination of Diesel Exhaust emissions on British Rail" Jan 1994.

CONCAWE (1986), Hydrocarbon Emissions from Gasoline Storage and Distribution Systems, Report No 85/54

CONCAWE (1987), "An Investigation into Evaporative Hydrocarbon Emissions from European Vehicles", Report 87/60.

CONCAWE (1990), "The Effects of Temperature and Fuel Volatility on Vehicle Evaporative Emissions", Report 90/51.

CORINAIR (1992) CORINAIR Inventory, Commission of the European Community, Default Emission Factors Handbook, 2nd ed, CITEPA, Paris.

Corus (2005), Process-specific emissions data for all UK plant, Personal Communication (Peter Quinn, Mick Briggs)

DETR (1996a), data from "Continuous Survey of Road Goods Transport" communication, June 1996.

DETR (1996b), Air and Environment Quality Division communication, May 1996.

DETR (1997), National Road Traffic Forecasts (Great Britain) 1997.

DETR (1998), Personal Communication from Dr T McMullen

DETR (1998a), Road Travel Speeds in English Urban Areas: 1996/97, Transport Statistics Report, January 1998

DETR (1998b), "Traffic Speeds in Central and Outer London: 1996-97", DETR Statistics Bulletin (98) 17, April 1998

DETR (1998c), "Vehicle Speeds in Great Britain: 1997", DETR Statistics Bulletin (98) 19, June 1998

DETR (1998d), "Traffic Speeds in Inner London: 1998", DETR Statistics Bulletin (98) 22, November 1998

DETR (1998e), Data from National Travel Survey, Transport Statistics communication, March 1998.

DETR (2000), Transport, Environment and Taxation Division communication (A Short), November 2000.

DfT (2001), New Car Fuel Consumption and Emission Figures, Vehicle Certification Agency, July 2001

DfT (2004a), Transport, Environment and Taxation Division communication (N Barter), July 2004.

DfT (2004b), Transport, Environment and Taxation Division communication (C Parkin), February 2004

DfT (2006a), Transport Statistics Great Britain: 2006 edition, The Stationery Office.

DfT (2006b), Vehicle Licensing Statistics: 2005, Transport Statistics Bulletin (SB(06)25), 2006

DfT (2007a), Transport Statistics Great Britain: 2007 edition, The Stationery Office.

DfT (2007b), Vehicle Licensing Statistics: 2006, Transport Statistics Bulletin (SB(07)19), 2007

DRDNI (2002), "Vehicle Kilometres of Travel Survey of Northern Ireland. Annual Report 1999", Report by Doran Consulting for Department for Regional Development, Northern Ireland, Road Services Headquarters (2002).

DRDNI (2003), "Vehicle Kilometres of Travel Survey of Northern Ireland. Annual Report 2001", Report by Doran Consulting for Department for Regional Development, Northern Ireland, Road Services Headquarters (2003).

DRDNI (2006), "Traffic and Travel Information Report, 2005" and communication with David Compston, Department for Regional Development, Northern Ireland, Road Services Headquarters, October 2006

DRDNI (2007), "Traffic and Travel Information Report, 2006, Incorporating Annual Traffic Census and Vehicle Kilometres of Travel" Traffic Information and Control, Department for Regional Development, Northern Ireland, October 2007

DTI (2000), Scrap Tyre Working Group, Personal Communication

DTI (2005), Digest of United Kingdom Energy Statistics 2005, London, The Stationery Office.

EMEP (1990), European Monitoring and Evaluation Programme. Proceedings of the EMEP Workshop on Emissions from Ships. State Pollution Control Authority, Norway.

EMEP/CORINAIR (1996), Atmospheric Emission Inventory Guidebook, 1st Edition, ed. G McInnes.

EMEP/CORINAIR (1999), Atmospheric Emission Inventory Guidebook, 2nd Edition, ed. S Richardson.

EMEP/CORINAIR (2003), Atmospheric Emission Inventory Guidebook, 3rd Edition. Entec (2002), Quantification of emissions from ships associated with ship movements between ports in the European Community", Report for European Commission, DG ENV. Belgium; Main Contributors Chris Whall, Karen Archer, Layla Twigger, Neil Thurston, David Ockwell, Alun McIntyre, Alistair Ritchie (Entec) and David Cooper (IVL).

Environment Agency (1997), Chemical Release Inventory 1996, Personal Communication.

Environment Agency (2005), Pollution Inventory 2004, Personal Communication.

European Environment Agency (1997), COPERT II: Computer Programme to Calculate Emissions from Road Transport - Methodology and Emission Factors, P Ahlvik et al, European Topic Centre on Air Emissions, European Environment Agency, April 1997.

European Environment Agency (2000), COPERT III: Computer Programme to Calculate Emissions from Road Transport - Methodology and Emission Factors (Version 2.1), L. Ntziachristos and Z Samaras, European Topic Centre on Air Emissions, European Environment Agency, November 2000.

Fynes, G & Sage, PW (1994), Emissions of Greenhouse Gases from Coal Fired Plant, British Coal, Coal Research Establishment, CERCHAR, DMT, Delft University of Technology, TPS Termiska Processer AB, CONTRACT NO JOUF 0047-C(SMA).

Goodwin, JWL, Salway, AG, Murrells, TP, Dore, CJ & Eggleston, HS (1999), UK Emissions of Air Pollutants 1970 to 1997, AEA Technology, AEAT/EEQC/0015, Culham.

Hawkins & Coad (2004), Personal communication. John Hawkins & Nick Coad from the Association of Train Operating Companies (ATOC).

Hickman, AJ (1998), Transport Research Laboratory, communication, February 1998.

Institute of Petroleum (2000), Protocol for the Estimation of VOC Emissions from Petroleum Refineries and Gasoline Marketing Operations

IPCC (1997a), IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories, Volume 1, Greenhouse Gas Inventory Reporting Instructions, IPCC WGI Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK.

IPCC (1997b), IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories, Volume 2, Greenhouse Gas Inventory Workbook, IPCC WGI Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK.

IPCC (1997c), IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories, Volume 3, Greenhouse Gas Inventory Reference Manual, IPCC WGI Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK.

IPCC (2000), Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, ed. Penman, J, Kruger, D, Galbally, I, *et al,* IPCC National Greenhouse Gas Inventories Programme, Technical Support Programme Technical Support Unit, Institute for Global Environmental Strategies, Hayama, Kanagawa, Japan.

Leech, P, (1994) Air Pollutant Emission Inventories for Heathrow Terminal 5 Study. Vol 2. Warren Spring Laboratory, Report LR 999.

LRC (1998), London Research Centre, UK Emission Factor Database.

LT Buses (1998), "Buses: A Cleaner Future. Bus Emissions and Air Quality in London", London Transport Buses Report, 1998.

Met Office (2005), via the internet at:
http://www.met-office.gov.uk/research/hadleycentre/obsdata/cet.html, September 2005

MOD (2005a), Defence Fuels Group, SO3 Aviation Fuel, Personal Communication (Patrick Gedge)

MOD (2005b), Defence Fuels Group, MF1b, Marine Fuels, Personal Communication (Patrick Gedge).

MOD (2007), Defence Fuels Group, MF1b, Marine Fuels, Personal Communication (Patrick Gedge)

Murrells, TP (2000), "UK Road Transport Emission Projections: The Assumptions Used and Results of the 1997 National Atmospheric Emissions Inventory Base Projections", AEA Technology Report AEAT-5953, January 2000.

Munday, PK (1990), UK Emissions of Air Pollutants 1970-1988, Warren Spring Laboratory, LR 764.

National Power (1997), Environmental Performance Review 1997.

netcen (2004a), "Non-Road Mobile Machinery Usage, Life and Correction Factors", Report to the Department for Transport, AEAT/ENV/R/1895, November 2004, www.airquality.co.uk/archive/reports/reports.php?report_id=304

netcen (2004b), "Emission factors programme Task 8c – emissions from non-road mobile machinery in the lawn and garden sector", Report to Defra, AEAT/ENV/R/1719, April 2004.

Oakdene Hollins Ltd (2001), UK Waste Oils Market 2001, Report for DETR.

Off Highway Research Ltd (2000), International Database Service, March 2000

Official Journal (1998), Official Journal of the European Communities L59/6, 59/15, February 1998.

ONS (1995), UK Defence Statistics, 1994, Office for National Statistics.

Ogilvie, SM (1995), Opportunities and Barriers to Scrap Tyre Recycling, National Environmental Technology Centre, AEA/CS R1026/C, ISBN 0 856248647.

Passant, NR (2004), 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.

Perry, RH & Chilton, C (1973), Chemical Engineer Handbook, 5th ed. McGraw-Hill, New York.
Petroleum Review (2004), UK Retail Marketing Survey

Powergen (1994), Personal communication from D Grist, Corporate Environment Unit.

Powergen (1997), Environmental Performance Report 1996.

PRI (1995), Communication from Precision Research International.

PRI (1998), Communication from Precision Research International.

Quick, W (2004) – Power Tech – Personnal correspondence

Recycling Advisory Unit (1999), Markets for Recycled Materials, 1999

Royal Commission on Environmental Pollution (1993), 17 the Report, Incineration of Waste, HMSO, London.

Samaras, Z & Zierock, KH (1993), Notes on the Assessment of the Emissions of Off-Road Mobile Machinery in the European Community.

Samaras, Z & Zierock, KH, (1994), Supplement to above.

Samaras, Z (1996), Personal Communication.

Scottish Coal (2005), Coal sales and elemental content data, Personal Communication (Louis Suffredini).

SMMT (1999), Society of Motor Manufacturers and Traders, communication, November 1999.

Stewart, R (1997), Gaseous and PM_{10} Emission Factors for Station 'W' - a Modern CCGT Power Plant, AEA Technology, AEA/20011002/002/Issue 1.

Stewart, R & Walker, D (1996), Emissions to Atmosphere from Fossil Fuel Power Generation in the United Kingdom, AEAT-0746, ISBN 0-7058-1753-3.

Terra Nitrogen (2005), Plant-specific production and emissions data, Personal Communication (Peter Rees).

Transco (2005) – Measurement and process report MPR046: Estimation of Carbon Dioxide emission factors for UK Natural Gas 1990-2004

TRL (1993), Evaporative Emissions from Petrol Fuelled UK Light Duty In-Service Vehicles, TJ Barlow, Transport Research Laboratory Report PR/ENV/022/93.

UK Coal (2005), Coal sales and methane emission estimates for 2004, Personal Communication (Chris McGlen)

UKPIA (1989), United Kingdom Petroleum Industry Association, Personal Communication.

UKPIA (2004), United Kingdom Petroleum Industry Association, Malcolm Watson communication on properties of UK fuels in 2004 (and correspondence in earlier years).

UKPIA (2005), Refinery production & emissions data, carbon emission factors, petroleum products data from the United Kingdom Petroleum Industry Association, Personal Communication (Ian McPherson, & Malcolm Watson)

UKPIA (2006), United Kingdom Petroleum Industry Association, Malcolm Watson communication on properties of UK fuels in 2005.

UKPIA (2007), United Kingdom Petroleum Industry Association, Malcolm Watson communication on properties of UK fuels in 2006.

USEPA (1997), United States Environmental Protection Agency, Compilation of Air Pollutant Emission Factors, Vol 1, 5th Edition, AP-42, North Carolina.

US EPA (2004), Compilation of Air Pollutant Emission Factors, AP-42, via the internet at: www.epa.gov, 2004

Walker, DS, Galbraith, R & Galbraith, JM (1985), Survey of Nitrogen Oxides, Carbon Monoxide and Hydrocarbon Emissions from Industrial and Commercial Boilers in Scotland, Warren Spring Laboratory, LR 524.

Watson, M (2001, 2003), UKPIA, Personal Communication.

Watson, M (2005), UKPIA, Personal Communication.

Watterson, JD, Walker, C and Eggleston, S (2004) Revision to the Method of Estimating Emissions from Aircraft in the UK Greenhouse Gas Inventory. Report to Global Atmosphere Division, UK Defra. Report number ED47052, July 2004. netcen, The Gemini Building, Harwell, Didcot, Oxfordshire, OX11 0QR, UK.

Zachariadis, Th. & Samaras, Z, (1997), Int. J. of Vehicle Design, 18, 312.

11.11   ANNEX 3, SECTOR 1, 1B

Barty, R (1995), Energy Policy and Analysis Unit, DTI, Personal Communication.

Bennet, S, Kershaw, S & Burrell, R, (1995), Control Measures for Methane Emissions from Coal Production, ETSU N/01/00006/REP.

British Gas (1993), Personal Communication from C Rose, Regional Services Engineering Dept, London.

British Gas (1994), Personal Communication from S Pearson, Gas Research Centre, Loughborough, Leics.

CIS (1991), Chem Facts UK, Chemical Intelligence Services, Reed Telepublishing, Dunstable, Beds, UK.

Coal Authority (2005), Production and Manpower Return, Personal Communication (Simon Cooke).

CONCAWE (1986), Hydrocarbon Emissions from Gasoline storage and distribution systems. Report No 85/54.

CORINAIR (1989), CORINAIR Inventory, Commission of the European Community, Default Emission Factors Handbook, 1st ed, CITEPA, Paris.

Corus (2005), Process-specific emissions data for all UK plant, Personal Communication (Peter Quinn, Mick Briggs)

DETR (1998), C McMullen, Personal Communication.

DETR (1999), Global Atmosphere Division, Personal Communication.

DTI (1997), The Energy Report 2, Oil and Gas Resources of the United Kingdom, Department of Trade and Industry, The Stationery Office.

DTI (1998), Digest of United Kingdom Energy Statistics 1998, London, The Stationery Office.

DTI (1998a), The Energy Report 2, Oil and Gas Resources of the United Kingdom, Department of Trade and Industry, The Stationery Office.

DTI (2005), Digest of United Kingdom Energy Statistics 2005, London, The Stationery Office.

DTI (2005a), Detailed fuel use data, Personal Communication (Clive Evans, Martin Young and Ian M Corrie)

DTI (2005b), Development of UK Oil and Gas Resources, 2004, Department of Trade and Industry, The Stationery Office.

E & P Forum (1994), Methods for Estimating Atmospheric Emissions from E&P Operations, The Oil Industry International Exploration & Production Forum, Report No 2.59/197.

EIPPCB (2000), European Integrated Pollution Prevention and Control Bureau, Best Available Techniques reference Document on the Production of Iron and Steel.

Environment Agency (2005), Pollution Inventory database 2004, Personal Communication (EA PI team: Charlie Corbishley, Claudia Towner and Alex Wills)

Institution of Petroleum (2000), Protocol for the Estimation of VOC Emissions from Petroleum Refineries and Gasoline Marketing Operations.

IPCC (1997), IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories, Volume 3, Greenhouse Gas Inventory Reference Manual, IPCC WGI Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK.

IPCC (2000), Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, ed. Penman, J, Kruger, D, Galbally, I, *et al*, IPCC National Greenhouse Gas Inventories Programme, Technical Support Programme Technical Support Unit, Institute for Global Environmental Strategies, Hayama, Kanagawa, Japan.

Kershaw (2005), "Development of a Methodology for Estimating Methane Emissions from Abandoned Coal Mines in the UK", White Young Green report to Defra, 2005.

Oilfield Publications (1996) North Sea Field Development Guide, 6th ed., Oilfield Publications Limited, Ledbury, Herts.

Petroleum Review (2000), 2000 UK Retail Marketing Survey. A special Supplement to Petroleum Review, Institute of Petroleum, March 2000.
Russell, P (1997), Personal Communication, Safety and Environment Directorate, BG plc.

Russell, P (2004) "UKOOA: Offshore Industry Carbon Dioxide Calculation Requirements for Emissions Trading"

Sage, PW (2001), Methane from Abandoned Coal Mines in the UK, AEA Technology, Report AEAT/ENV/R/0500, Harwell, UK.

Transco (2005), Gas leakage, regional sales and gas content data for 2004, Personal Communication (Dave Lander).

UK Coal (2005), Coal sales and methane emission estimates for 2004, Personal Communication (Chris McGlen)

UKOOA (1993), Atmospheric Emissions from UK Oil and Gas Exploration and Production Facilities in the UK Continental Shelf Area. Prepared for United Kingdom Offshore Operators Association Limited, March 1993, Ref HN08-007.REP, Brown & Root Environmental, Leatherhead, Surrey.

UKOOA (1995), Guidelines on Atmospheric Emissions Inventory, UK Offshore Operators Association Limited (Environment Committee).

UKOOA (1998), Internal UKOOA study to determine pre-EEMS emissions totals and trends, 1990-1995, via Personal Communication (Peter Russell, Granherne)

UKOOA (2001), "Environmental Emissions Monitoring System (EEMS): GUIDE FOR DATA SUBMISSION Version 7.0", UKOOA & LearnIT September 2001.

UKOOA (2005), EEMS Environmental Database for Emissions and Discharges from Offshore Installations, Atmospheric Emissions Inventory, 2003 data. Personal communication from UKOOA via Peter Russell at Granherne.

UKPIA (2005), Refinery production & emissions data, petroleum products data from the United Kingdom Petroleum Industry Association, Personal Communication (Ian McPherson, & Malcolm Watson)

USEPA (2004), United States Environmental Protection Agency, Compilation of Air Pollutant Emission Factors. Vol 1, 5th Edition, AP-42, North Carolina. www.epa.gov

Williams, A (1993), Methane Emissions, Watt Committee Report Number 28, The Watt Committee on Energy, London.

11.12   ANNEX 3, SECTORS 2 AND 3

Alcan (1997), Personal Communication from A Walker, Alcan International.

Alcan (2004), Personal Communication from J Clarkson, Alcan International.

BISPA (1997), Personel Comunication, M Funnell, British Iron and Steel Producers Association.

Blyth, WJ, Collingwood, JC, Pratten, NA, (1996), Estimation and Projection of NO_x and SO_x Emissions from UK Industrial Sectors, Phase 2. ETSU REF RYTA 18400734/Z/3

BP Chemicals (2004), Personal Communication (Dave Ingram).

Brain, SA, Carr, CE, Davies, M, Rantell, T, Stokes, BJ. (1994), Emission of Volatile Organic Compounds (VOCs) from Coal-Fired Appliances, DTI, Coal R&D, Report No COAL R033

British Cement Association (2005), UK cement clinker production & fuel use data, Personal Communication (Richard Leese, Jim Rushworth).

British Coal (1989), Personal Communication.

British Gas (1992), Personal Communication from FE Shephard, Gas Research Centre, Loughborough, Leics.

British Geological Survey (2005), UK Minerals Yearbook 2004

British Glass (2005), UK glass production and recycling data in 2004, Personal Communication (Rebecca Cocking).

CIS (1991), Chem-Facts UK, Chemical Intelligence Services, Reed Telepublishing, Dunstable, Beds, UK.

Collingwood, J (1997), ETSU, AEA Technology, Personal Communication.

CORINAIR (1989), CORINAIR Inventory, Commission of the European Community, Default Emission Factors Handbook, 1st ed, CITEPA, Paris.

CORINAIR (1992), CORINAIR Inventory, Commission of the European Community, Default Emission Factors Handbook, 2nd ed, CITEPA, Paris.

Corus (2005), Process-specific emissions data for all UK plant, Personal Communication (Peter Quinn, Mick Briggs)

DoENI (2005), ISR inventory of industrial point source emissions from the Department of the Environment of Northern Ireland, Personal Communication (David Bell).

DTI (2001b), Department of Trade and Industry. Construction Market Intelligence, Monthly Statistics of Building Materials and Components.

DTI (1992), Business Monitor PAS 4196.
DTI (2005), Digest of United Kingdom Energy Statistics 2005, London, The Stationery Office.

DTI (1994), Clean Coal Programme Report RO33

DTI (2000a), DTI Tyre Working Group, Private Communication from P Hallett

EIPPCB (2000), European Integrated Pollution Prevention and Control Bureau. Integrated Pollution Prevention and Control (IPPC): Best Available Techniques Reference Document on the Production of Iron and Steel, March 2000.

EMEP/CORINAIR (1996), Atmospheric Emission Inventory Guidebook, 1st Edition, ed. G McInnes.

EMEP/CORINAIR (1999), Atmospheric Emission Inventory Guidebook, 2nd Edition.

Environment Agency (2005), Pollution Inventory database 2004, Personal Communication (EA PI team: Charlie Corbishley, Claudia Towner and Alex Wills)

Federation of Bakers (2000), Personal Communication from J White.

Gibson, *et al* (1995), Atmospheric Environment, Vol 29, No 19, p2661-2672.

Fynes, G and Sage, PW (1994), Emissions of Greenhouse Gases from Coal Fired Plant, British Coal, Coal Research Establishment, CERCHAR, DMT, Delft University of Technology, TPS Termiska Processer AB, CONTRACT NO JOUF 0047-C(SMA).

Invista (2005), 2004 Plant-specific emissions and abatement information, Personal communication (Graham Hinton).

IPCC (1997), IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories, Volume 3, Greenhouse Gas Inventory Reference Manual, IPCC WGI Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK.

IPCC (2000), Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, ed. Penman, J, Kruger, D, Galbally, I, *et al*, IPCC National Greenhouse Gas Inventories Programme, Technical Support Unit, Institute for Global Environmental Strategies, Hayama, Kanagawa, Japan.

Iron & Steel Statistics Bureau (2005), Iron and Steel Industry, Annual Statistics for the UK, 2004. ISSB Limited.

MCG (1999), UK Emissions of HFCs, PFCs and SF$_6$ Potential Emission Reduction Options. A study for the Department of the Environment carried out by March Consulting Group. Telegraphic House, Waterfront Quay, Salford Quays, Manchester

Munday, PK (1990) UK Emissions of Air Pollutants 1970-1988, Warren Spring Laboratory, LR 764.

Netcen, (2004). Non-Road Mobile Machinery Usage, Life and Correction Factors. A report for the Department of Transport. November 2004. AEAT/ENV/R/1895.

Ogilvie, SM (1995), Opportunities and Barriers to Scrap Tyre Recycling, National Environmental Technology Centre, AEA/CS R1026/C, ISBN 0 856248647

Office of National Statistics (2005), Index of Production, Population Statistics and Prodcom data for 1990-2004, www.statistics.gov.uk

ONS (2005), Annual Abstract of Statistics 2004, Office for National Statistics, The Stationery Office.

Passant, NR (1993), Emissions of Volatile Organic Compounds from Stationery Sources in the UK, LR 990, Warren Spring Laboratory.

Passant, NR (2002), Speciation of UK Emissions of Non- Volatile Organic, AEA Technology, NETCEN, AEAT/ENV/R/0545, Culham.

Rudd, HJ (1995), Emissions of Volatile Organic Compounds from Stationery Sources in the United Kingdom: Speciation, AEA Technology, National Environmental Technology Centre, AEA/CS/16419033/REMA-029/ISSUE1.

Rudd, HJ, Mikkelsen, M (1996), Emissions of Volatile Organic Componds from Ship Purging in the UK.

SEPA (2005), 2004 EPER Inventory of industrial point source emissions, Scottish Environmental Protection Agency, Personal Communication (Bob Boyce).

SWA (2005), The Scotch Whiskey Association Statistical Report 2004, Personal Communication (Pam Peacocke)

Terra Nitrogen (2007), Plant-specific production and emissions data, Personal Communication (Peter Rees).

UKPIA (2005), Refinery production & emissions data, petroleum products data from the United Kingdom Petroleum Industry Association, Personal Communication (Ian McPherson, & Malcolm Watson)

USEPA (2004), United States Environmental Protection Agency, Compilation of Air Pollutant Emission Factors. Vol 1, 5th Edition, AP-42, North Carolina. www.epa.gov

11.13   ANNEX 3, SECTOR 4

See references under **Chapter 6**

11.14   ANNEX 3, SECTOR 5

See references under **Chapter 7**

11.15   ANNEX 3, SECTOR 6

Defra (2007), Expenditure and Food Survey Report

Environment Agency (2002). GasSim User Manual. Golder Associates (UK) Limited, Edwalton, Nottingham, UK.

Gregory RG, Revans AJ, Hill MD, Meadows MP, Paul L and Ferguson CC (1999). A Framework to Assess the Risks to Human Health and the Environment from Landfill Gas (HELGA). Environment Agency R&D Technical Report P271. Environment Agency, Bristol.

The National Household Waste Analysis Project (1994), Phase 2, Volume 3, Chemical Analysis data, Report CWM087/94.

WS Atkins (2000). Live Cycle Inventory Development for Waste Management.

11.16   ANNEX 4

DTI (2005), Digest of United Kingdom Energy Statistics 2005, London, The Stationery Office.

11.17   ANNEX 6

DTI (2005), Digest of United Kingdom Energy Statistics 2005, London, The Stationery Office.

11.18   ANNEX 7 [UNCERTAINTIES]

Bennet, S, Kershaw, S, Burrell, R (1995), Control Measures for Methane Emissions from Coal Production, ETSU N/01/00006/REP

Brown, KA, Smith, A, Burnley, SJ, Campbell, DJV, King, K, Milton, MJT, (1999) Methane Emissions from UK Landfills, AEA Technology, AEAT-5217, Culham.

DTI (1996), Digest of United Kingdom Energy Statistics 1996, London, The Stationery Office.

DTI (2005), Digest of United Kingdom Energy Statistics 2005, London, The Stationery Office.

Eggleston, HS, Salway, AG, Charles, D, Jones, BMR, Milne, R (1998), Treatment of Uncertainties for National Estimates of Greenhouse Gas Emissions, National Environmental Technology Centre, AEA Technology, Report AEAT - 2688.

Fynes, G, Sage, PW (1994), Emissions of Greenhouse Gases from Coal Fired Plant, British Coal, Coal Research Establishment, CERCHAR, DMT, Delft University of Technology, TPS Termiska Processer AB, CONTRACT NO JOUF 0047-C(SMA).

Hobson, J, Palfrey, R, Sivil, D, Palfrey, E, Day, M (1996), Control Measures to Limit Methane Emissions from Sewage and Sludge Treatment and Disposal, WRc, Report No DOE 4118.

IPCC (2000), Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, ed. Penman, J, Kruger, D, Galbally, I, *et al*, IPCC National Greenhouse Gas Inventories Programme, Technical Support Programme Technical Support Unit, Institute for Global Environmental Strategies, Hayama, Kanagawa, Japan.

Transco (1998), Personal Communication, I Jones, System Control.

Milne, R (1999), Centre for Ecology and Hydrology, (Edinburgh), Personal Communication.

UKOOA (1993), Atmospheric Emissions from UK Oil and Gas Exploration and Production Facilities in the UK Continental Shelf Area. Prepared for United Kingdom Offshore Operators Association Limited, March 1993, Ref HN08-007.REP, Brown & Root Environmental, Leatherhead, Surrey

UKOOA (2005), Environmental Database for Emissions & Discharges from Offshore Installations (EEMS), UKOOA via Peter Russell.

Williams, A (1993), Methane Emissions, Watt Committee Report Number 28, The Watt Committee on Energy, London.

11.19   ANNEX 8 [VERIFICATION]

Cullen, MJP (1993), The Unified Forecast/Climate Model, *Meteorological Magazine UK*, 1449, 81-94, 1993.

Department of the Environment, Food and Rural Affairs (Defra) (2000), Climate Change: The UK Programme, Nov 2000, www.defra.gov.uk/environment/climatechange/07.htm

Jones A.R., 'Atmospheric dispersion modelling at the Met Office', Weather 59, 311-316, 2004

Manning, AJ, Ryall, DB, Derwent, RG, Simmonds, PG, O'Doherty, S (2003), Estimating European emissions of ozone-depleting and greenhouse gases using observations and a modelling back-attribution technique, *in press J. of Geophysical Research* (atmospheres) 2003.

Manning, AJ, Derwent, RG, Ryall, DB. Interpretation of long-term measurements of radiatively active trace gases and ozone depleting substances. Defra Contract number: CPEG 11. Final Report to UK Defra, January 2004 to May 2005. Met Office, FitzRoy Road, Exeter, Devon, EX1 3PB, United Kingdom.

Manning A.J., Ryall D.B., Derwent R.G., Simmonds P.G. and O'Doherty S., 'Estimating European emissions of ozone-depleting and greenhouse gases using observations and a modelling back-attribution technique', J. Geophysical Research 108, 4405, 2003

Nilsson, M, Mikkela, C, Sundh, I, Granberg, G, Svensson, BH & Ranneby, B (2001), Methane emission from Swedish mires: Natural and regional budgets and dependence on mire vegetation, *J. of Geophys. Res.*, 106, 20847-20860, 2001.

Ryall, DB & Maryon, RH (1998), Validation of the UK Met Office's NAME model against the ETEX dataset, *Atmospheric Environment*, 32, 4265-4276, 1998.

Simmonds, PG, Derwent, RG, McCulloch, A, O'Doherty, S, Gaudry, A (1996), Long-term trends in concentrations of halocarbons and radiatively-active trace gases in Atlantic and European air masses monitored at Mace Head, Ireland from 1987-1994. *Atmospheric Environment*, 30, 4041-4063, 1996.

United Nations Framework Convention on Climate Change (UNFCCC) www.unfccc.int

11.20 ANNEX 10 [VERIFICATION]

Cannell, M.G.R. and Dewar, R.C., 1995. The Carbon Sink Provided by Plantation Forests and Their Products in Britain. Forestry, 68(1): 35-48.

Dewar, R.C. and Cannell, M.G.R., 1992. Carbon Sequestration in the Trees, Products and Soils of Forest Plantations - an Analysis Using Uk Examples. Tree Physiology, 11(1): 49-71.

FAO, 2005. Global Forest Resources Assessment 2005. United Kingdom of Great Britain and Northern Ireland. Country report., Forestry Department, Food and Agriculture Organization of the United Nations, Rome.

Forestry Commission, 2002. UK Indicators of Sustainable Forestry, Economics and Statistics Unit, Forestry Commission/Forest Service.

Forestry Commission, 2006. Forestry Statistics 2006.

Milne, R., Brown, T.A.W. and Murray, T.D., 1998. The effect of geographical variation in planting rate on the uptake of carbon by new forests of Great Britain. Forestry, 71: 298-309.

12   Acknowledgements

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Table 12.1   Contributors to this National Inventory Report and the CRF

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Main authors	
Choudrie, Sarah	Project Manager for the UK Greenhouse Gas Inventory with overall responsibility for the NIR and the CRF[10]. Contributions to most chapters, lead author of energy sector text; management of both CRF and NIR compilation and submission.
Cardenas, Laura	Sector expert for agriculture; author of all sections on agriculture. Compilation of Sector 4 of the CRF.
Leech, Andrew	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	Contributions to most chapters,Uncertainties expert & Co-author of Chapter 10, lead author of F-gas section; Final User expert, QC of data tables throughout the report. Technical support to Defra CEOSA in the development of the GHGI and CRF Reporter software. Project manager for compiling the GHG emission estimates from the Overseas Territories and Crown Dependencies.
Mobbs, Deena	Co-author of all sections on Land Use Change and Forestry; compilation of Sector 5 of the CRF.
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.
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.
Thomson, Amanda	Co-author of all sections on Land Use Change and Forestry. Compilation of Sector 5 of the CRF.
Watterson, John	Author of Chapter 10. Co-author of Uncertainties Chapter. Internal QC for consistency between the CRF, IPCC reporting formats and the UK National Atmospheric Emissions Inventory database; Tier 2 uncertainty analysis. Development of the inventory.
Contributors	
Dore, Chris	NAEI Project Director. Assistance with compiling the UK National Atmospheric Emissions Inventory database; QA checks on time series consistency and sector consistency. Cross checking consistency between NAEI and GHG agriculture estimates.
Goodwin, Justin	NAEI database development and support.

Person	Technical work area and responsibility
Tsagatakis, Ioannis	Author of Annex 6
Li, Yvonne	Contribution to Approach 1 (error propagation) uncertainty analysis. Assistance with road transport data compilation.
Manning, Alistair	Verification of the UK greenhouse gas inventory.
Milne, Ronnie	Advice about development of the LULUCF methodology
Ruddock, Kate	Assistance with compilation of LULUCF estimates for the OTs and CDs.
Thistlethwaite, Glen	Compilation of emission estimates, in particular the offshore sector and gas oil and fuel oil. Main author of chapters and annexes for 1B and adipic and nitric acid production
Wagner, Anne	Assistance with QC of the time series consistency.
Walker, Charles	Sector expert for aviation in the NAEI.
Additional assistance	
Aston, Clare	Data acquisition, compilation of summary tables in Annex 9 and Annex 11
James Davey[11]	Suggestions and improvements to draft versions of the NIR
Penman, Jim[12]	Suggestions and improvements to draft versions of the NIR
Salway, Geoff	(Formerly AEA) – for helpful comments and advice

Table 12.2   Key Data Providers to the Greenhouse Gas Inventory

Company
UKPIA
UKOOA
Environment Agency
DBERR
PowerTech
British Cement Association
Transco
Corus
DFT
UK Coal
Kemira
NIDoE
SEPA

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[11] Climate,Energy and Ozone; Science and Analysis, Department for Environment, Food & Rural Affairs
[12] Climate,Energy and Ozone; Science and Analysis, Department for Environment, Food & Rural Affairs

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