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UK Greenhouse Gas Inventory, 1990 to 2007

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 2009 to the United Nations Framework Convention on Climate Change (UNFCCC). It contains national greenhouse gas emission estimates for the period 1990-2007, 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.

The greenhouse gas inventory is compiled on behalf of the UK Department of Energy and Climate Change (DECC) Climate and Energy: Science and Analysis Division, by AEA. We acknowledge the positive support and advice from DECC 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), with reference to the new 2006 IPCC Guidelines (IPCC, 2006). 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 DECC 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 2009. It contains GHG emissions estimates for the period 1990 to 2007, 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 Energy and Climate Change (DECC) by AEA of AEA Technology. AEA also compiles the UK's National Atmospheric Emissions Inventory on behalf of the UK Department for the Environment, Food and Rural Affairs (Defra), 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 Land Management Improvement Division via a contract with North Wyke Research (NWRes), and estimates for Land-Use, Land Use Change and Forestry (LULUCF) (Sector 5) are produced on behalf of DECC by the Centre for Ecology and Hydrology (CEH). DECC and Defra also fund 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 as follows:

- Carbon dioxide;
- Methane ;
- Nitrous oxide ;
- Hydrofluorocarbons (HFCs) ;
- Perfluorocarbons (PFCs) ; and
- 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); and
- 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), based on the full coverage of UK emissions including all relevant Overseas Territories and Crown Dependencies, consistent with the UK's submission to the UNFCCC.

The UK inventory provides data to assess progress with the UK's commitments under the Kyoto Protocol, the UK's contribution to the EU's targets under the Kyoto Protocol and also progress towards domestic goals to reduce CO_2 emissions. Geographical coverage[1] for these three purposes differs to some extent, because of the following:

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); and
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.
3. The UK's commitments under the EU Monitoring Mechanism, which has been set up to enable the EU to meet its Kyoto Protocol target, only includes the parts of the UK which are also parts of the EU (the UK and Gibraltar, excluding all Crown Dependencies and other Overseas Territories).

Coverage 1 has been used for all UK inventory submissions in the past. Coverage 2 is used for the data in the CRF tables submitted to the UNFCCC because of the emerging needs of reporting under the Kyoto Protocol. Coverage 3 is only presented in Table ES5c. These emissions can be found in the CRF tables submitted under the EUMM on January 15th and March 15th. The tables in ES2 and 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.2

Table ES2a: Emissions of GHGs in terms of carbon dioxide equivalent emissions including all estimated GHG emissions from the Crown Dependencies and relevant Overseas Territories, 1990-2007. (Mt CO_2 Equivalent)

Table ES2	Mt CO_2 Equivalent									
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2 (Including net LULUCF)	594.19	601.51	584.33	569.40	563.36	554.59	576.80	553.12	555.24	544.64
CO_2 (Excluding net LULUCF)	591.24	598.64	582.02	568.26	562.42	553.33	575.78	552.41	555.14	544.82
CH_4 (Including net LULUCF)	104.49	103.72	102.20	99.13	92.14	91.16	88.75	83.94	79.56	74.32
CH_4 (Excluding net LULUCF)	104.48	103.71	102.19	99.11	92.13	91.13	88.73	83.92	79.54	74.31
N_2O (Including net LULUCF)	64.61	64.57	58.06	53.52	54.87	53.75	53.08	54.16	53.58	42.92
N_2O (Excluding net LULUCF)	64.60	64.56	58.05	53.51	54.87	53.74	53.07	54.16	53.57	42.92
HFCs	11.39	11.85	12.32	13.01	14.06	15.59	16.96	19.56	17.60	11.09
PFCs	1.40	1.17	0.57	0.49	0.49	0.47	0.49	0.42	0.41	0.40
SF_6	1.03	1.08	1.12	1.17	1.18	1.24	1.27	1.23	1.26	1.43
Total (Emissions including net GHG from LULUCF)	777.12	783.90	758.61	736.72	726.10	716.80	737.35	712.43	707.65	674.79
Total (Emissions excluding net GHG from LULUCF)	774.14	781.01	756.28	735.56	725.15	715.50	736.30	711.68	707.53	674.95

Table ES2	Mt CO_2 Equivalent								% change
	2000	2001	2002	2003	2004	2005	2006	2007	1990 - 2007
CO_2 (Including net LULUCF)	552.77	564.27	546.69	558.04	557.83	555.08	553.06	544.61	-8.3%
CO_2 (Excluding net LULUCF)	553.09	564.72	547.65	559.02	559.57	556.95	554.81	546.37	-7.6%
CH_4 (Including net LULUCF)	69.84	63.85	60.84	54.86	53.05	51.15	50.47	48.97	-53.1%
CH_4 (Excluding net LULUCF)	69.81	63.82	60.82	54.83	53.02	51.13	50.44	48.94	-53.2%
N_2O (Including net LULUCF)	41.94	39.53	37.76	37.17	37.68	36.46	34.98	34.29	-46.9%
N_2O (Excluding net LULUCF)	41.93	39.53	37.76	37.16	37.68	36.46	34.98	34.29	-46.9%
HFCs	9.99	10.73	11.05	11.40	9.99	10.18	9.98	9.61	-15.6%
PFCs	0.50	0.42	0.31	0.27	0.34	0.26	0.30	0.22	-84.6%
SF_6	1.80	1.43	1.51	1.32	1.13	1.11	0.87	0.79	-23.0%
Total (Emissions including net GHG from LULUCF)	676.83	680.23	658.17	663.05	660.01	654.23	649.66	638.49	-17.8%
Total (Emissions excluding net GHG from LULUCF)	677.12	680.63	659.10	664.01	661.73	656.08	651.39	640.21	-17.3%

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 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 dioxide equivalent emissions including all estimated GHG emissions from the Crown Dependencies and excluding all estimated GHG emissions from relevant Overseas Territories, 1990-2007. (Mt CO_2 Equivalent)

Table ES2	**Mt CO_2 Equivalent**									
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
CO_2 (Including net LULUCF)	592.90	600.17	582.96	568.02	561.93	553.13	575.33	551.60	553.62	543.00
CO_2 (Excluding net LULUCF)	589.95	597.32	580.67	566.89	561.01	551.88	574.32	550.89	553.53	543.19
CH_4 (Including net LULUCF)	104.29	103.52	102.00	98.93	91.94	91.02	88.61	83.80	79.42	74.18
CH_4 (Excluding net LULUCF)	104.27	103.50	101.99	98.91	91.92	90.99	88.59	83.77	79.40	74.16
N_2O (Including net LULUCF)	64.57	64.52	58.01	53.47	54.82	53.69	53.03	54.11	53.53	42.87
N_2O (Excluding net LULUCF)	64.56	64.51	58.01	53.47	54.82	53.69	53.02	54.11	53.53	42.87
HFCs	11.39	11.85	12.32	13.01	14.05	15.58	16.95	19.55	17.59	11.07
PFCs	1.40	1.17	0.57	0.49	0.49	0.47	0.49	0.42	0.41	0.40
SF_6	1.03	1.08	1.12	1.17	1.18	1.24	1.27	1.23	1.26	1.43
Total (Emissions including net GHG from LULUCF)	775.57	782.31	757.00	735.09	724.42	715.13	735.68	710.70	705.83	672.94
Total (Emissions excluding net GHG from LULUCF)	772.60	779.43	754.68	733.94	723.47	713.84	734.64	709.96	705.71	673.11

Table ES2	**Mt CO_2 Equivalent**								**% change**
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**1990 – 2007**
CO_2 (Including net LULUCF)	551.09	562.52	544.94	556.22	555.95	553.17	551.06	542.55	-8.5%
CO_2 (Excluding net LULUCF)	551.43	562.98	545.91	557.23	557.71	555.07	552.85	544.34	-7.7%
CH_4 (Including net LULUCF)	69.70	63.71	60.71	54.74	52.92	51.03	50.35	48.86	-53.2%
CH_4 (Excluding net LULUCF)	69.67	63.68	60.69	54.71	52.90	51.01	50.32	48.82	-53.2%
N_2O (Including net LULUCF)	41.89	39.48	37.71	37.12	37.63	36.41	34.93	34.24	-47.0%
N_2O (Excluding net LULUCF)	41.88	39.47	37.70	37.11	37.63	36.41	34.93	34.24	-47.0%
HFCs	9.96	10.70	11.03	11.37	9.96	10.15	9.95	9.58	-15.8%
PFCs	0.50	0.42	0.31	0.27	0.34	0.26	0.30	0.22	-84.6%
SF_6	1.80	1.42	1.51	1.32	1.13	1.11	0.87	0.79	-23.0%
Total (Emissions including net GHG from LULUCF)	674.94	678.26	656.21	661.04	657.93	652.12	647.48	636.24	-18.0%
Total (Emissions excluding net GHG from LULUCF)	675.24	678.68	657.15	662.02	659.66	654.00	649.23	637.99	-17.4%

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 1990-2007 for the following sectors:

- Energy;
- Industrial Processes;
- Solvents;
- Agriculture;
- Land-use Change and Forestry (LULUCF); and
- 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 ES3	Aggregated emission trends per source category (Mt CO_2 equivalent)								
Source Category	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
1. Energy	612.24	622.08	605.76	590.40	577.55	569.32	589.29	564.87	565.82
2. Industrial Processes	53.99	52.32	46.85	43.55	46.12	46.51	48.44	51.21	49.50
3. Solvents and Other Product Use[a]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Agriculture	54.96	54.44	52.70	51.99	52.86	52.70	53.01	53.77	52.82
5. LULUCF	2.98	2.89	2.33	1.17	0.96	1.30	1.05	0.75	0.13
6. Waste	52.95	52.16	50.97	49.62	48.62	46.98	45.56	41.83	39.38
Total (net emissions)	**777.12**	**783.90**	**758.61**	**736.72**	**726.10**	**716.80**	**737.35**	**712.43**	**707.65**

Table ES3	Aggregated emission trends per source category (Mt CO_2 equivalent)								
Source Category	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
1. Energy	553.65	560.74	572.86	555.87	563.46	563.14	559.14	556.86	546.00
2. Industrial Processes	33.03	32.16	30.48	28.03	29.12	28.77	28.24	26.94	27.89
3. Solvents and Other Product Use[a]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Agriculture	52.13	50.12	47.18	47.48	46.81	46.71	45.83	44.71	43.46
5. LULUCF	-0.16	-0.29	-0.41	-0.93	-0.95	-1.72	-1.85	-1.72	-1.72
6. Waste	36.14	34.10	30.12	27.72	24.62	23.10	22.87	22.87	22.86
Total (net emissions)	**674.79**	**676.83**	**680.23**	**658.17**	**663.05**	**660.01**	**654.23**	**649.66**	**638.49**

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 excluding all estimated GHG emissions from relevant Overseas Territories. (Mt CO_2 equivalent)

Table ES3	Aggregated emission trends per source category (Mt CO_2 equivalent)								
Source Category	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
1. Energy	610.95	620.75	604.40	589.02	576.12	567.87	587.84	563.37	564.22
2. Industrial Processes	53.99	52.32	46.85	43.55	46.12	46.50	48.43	51.19	49.49
3. Solvents and Other Product Use[a]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Agriculture	54.79	54.27	52.54	51.82	52.69	52.53	52.85	53.61	52.66
5. LULUCF	2.97	2.88	2.32	1.15	0.94	1.29	1.04	0.74	0.11
6. Waste	52.87	52.09	50.89	49.55	48.55	46.94	45.52	41.80	39.34
Total (net emissions)	**775.57**	**782.31**	**757.00**	**735.09**	**724.42**	**715.13**	**735.68**	**710.70**	**705.83**

Table ES3	Aggregated emission trends per source category (Mt CO_2 equivalent)								
Source Category	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
1. Energy	552.03	559.09	571.12	554.14	561.67	561.28	557.26	554.90	543.98
2. Industrial Processes	33.01	32.14	30.45	28.00	29.09	28.74	28.21	26.91	27.86
3. Solvents and Other Product Use[a]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Agriculture	51.96	49.95	47.01	47.31	46.66	46.56	45.69	44.57	43.32
5. LULUCF	-0.17	-0.30	-0.42	-0.94	-0.98	-1.73	-1.88	-1.75	-1.75
6. Waste	36.11	34.06	30.10	27.69	24.59	23.07	22.84	22.84	22.83
Total (net emissions)	**672.94**	**674.94**	**678.26**	**656.21**	**661.04**	**657.93**	**652.12**	**647.48**	**636.24**

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 2007 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 11%.

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 21%, 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 2007. 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 2007. 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 2007 this contributed 3.6% 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 2007 are 57% 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, 1990-2007 (in kt).

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998
NO_x	2,742.18	2,693.75	2,583.87	2,440.62	2,361.25	2,264.33	2,200.01	2,064.95	2,016.30
CO	8,536.78	8,361.59	7,872.07	7,423.02	7,016.90	6,473.37	6,291.18	5,785.40	5,346.38
NMVOC	2,598.96	2,505.00	2,435.12	2,302.98	2,233.86	2,041.39	1,923.44	1,847.03	1,692.20
SO_2	3,723.78	3,622.09	3,443.27	3,113.60	2,668.59	2,359.99	2,038.20	1,662.04	1,629.61

Gas	1999	2000	2001	2002	2003	2004	2005	2006	2007
NO_x	1,906.53	1,862.23	1,808.83	1,697.01	1,705.73	1,652.38	1,617.26	1,592.22	1,481.35
CO	4,955.97	4,246.33	3,884.85	3,338.28	2,928.03	2,690.61	2,365.49	2,256.92	2,101.90
NMVOC	1,515.37	1,388.13	1,294.60	1,219.00	1,110.02	1,048.42	990.91	957.53	939.32
SO_2	1,217.24	1,230.74	1,105.95	978.71	966.05	812.36	686.62	670.16	590.34

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, and SO_2, over 90% of emissions for each gas arise from activities within this sector, and 89.8% of CO emissions also arise from this sector. For NMVOC, 42.6% of emissions are energy related, with other significant contributions from both the industrial processes and solvent sectors.

ES.5

ES.5a provides the time series of the UK Kyoto basket of emissions, and ES.5b presents the equivalent values for the EU coverage of the UK inventory . The tables show the emissions making up the base year and subsequent years, and also estimated 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); and
- **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.

The tables include two Base Year totals. The first (in the Kyoto Protocol Total row) is the ‘Base Year’ calculated from the 2007 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, and in table ES.5c, the UK’s contribution to the EU’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, 1990-2007 (in Mt CO_2 equivalent).

Table ES5a	**Mt CO_2 Equivalent**										
	Base Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
CO_2	591.24	591.24	598.64	582.02	568.26	562.42	553.33	575.78	552.41	555.14	544.82
CH_4	104.48	104.48	103.71	102.19	99.11	92.13	91.13	88.73	83.92	79.54	74.31
N_2O	64.60	64.60	64.56	58.05	53.51	54.87	53.74	53.07	54.16	53.57	42.92
HFCs	15.59	11.39	11.85	12.32	13.01	14.06	15.59	16.96	19.56	17.60	11.09
PFCs	0.47	1.40	1.17	0.57	0.49	0.49	0.47	0.49	0.42	0.41	0.40
SF_6	1.24	1.03	1.08	1.12	1.17	1.18	1.24	1.27	1.23	1.26	1.43
Grand Total	**777.62**	**774.14**	**781.01**	**756.28**	**735.56**	**725.15**	**715.50**	**736.30**	**711.68**	**707.53**	**674.95**
Article 3.3		0.20	0.35	0.39	0.31	0.16	-0.06	-0.28	-0.52	-0.74	-0.89
Article 3.4 (capped at -0.37 MtC)		-1.36	-1.36	-1.36	-1.36	-1.36	-1.36	-1.36	-1.36	-1.36	-1.36
Article 3.7	0.33										
Kyoto Protocol Total	**777.95**	**772.98**	**780.01**	**755.32**	**734.51**	**723.95**	**714.09**	**734.66**	**709.81**	**705.43**	**672.70**
Fixed Base Year	**779.90**										

Table ES5a	**Mt CO_2 Equivalent**								**% Changes**	
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**1990-2007**	**Base Year - 2007**
CO_2	553.09	564.72	547.65	559.02	559.57	556.95	554.81	546.37	-7.6%	-7.6%
CH_4	69.81	63.82	60.82	54.83	53.02	51.13	50.44	48.94	-53.2%	-53.2%
N_2O	41.93	39.53	37.76	37.16	37.68	36.46	34.98	34.29	-46.9%	-46.9%
HFCs	9.99	10.73	11.05	11.40	9.99	10.18	9.98	9.61	-15.6%	-38.3%
PFCs	0.50	0.42	0.31	0.27	0.34	0.26	0.30	0.22	-84.6%	-54.2%
SF_6	1.80	1.43	1.51	1.32	1.13	1.11	0.87	0.79	-23.0%	-36.0%
Grand Total	**677.12**	**680.63**	**659.10**	**664.01**	**661.73**	**656.08**	**651.39**	**640.21**	**-17.3%**	**-17.7%**
Article 3.3	-1.02	-1.12	-1.32	-1.52	-1.72	-1.91	-2.08	-2.24		
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	**674.74**	**678.16**	**656.42**	**661.13**	**658.65**	**652.81**	**647.95**	**636.62**	**-17.6%**	**-18.2%**
Fixed Base Year										

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 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, 1990-2007 (in Mt CO_2 equivalent) – EUMM Coverage.

Table ES5b	**Mt CO_2 Equivalent**										
	Base Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
CO_2	588.77	588.77	596.07	579.36	565.59	559.67	550.48	572.81	549.35	551.91	541.65
CH_4	104.03	104.03	103.25	101.74	98.68	91.69	90.75	88.35	83.54	79.16	73.92
N_2O	64.52	64.52	64.47	57.96	53.42	54.77	53.64	52.98	54.06	53.48	42.82
HFCs	15.58	11.39	11.85	12.32	13.01	14.05	15.58	16.94	19.54	17.57	11.05
PFCs	0.47	1.40	1.17	0.57	0.49	0.49	0.47	0.49	0.42	0.41	0.40
SF_6	1.24	1.03	1.08	1.12	1.17	1.18	1.24	1.27	1.23	1.26	1.43
Grand Total	**774.59**	**771.13**	**777.89**	**753.08**	**732.36**	**721.85**	**712.15**	**732.83**	**708.12**	**703.79**	**671.26**
Article 3.3		0.20	0.35	0.39	0.31	0.16	-0.06	-0.28	-0.52	-0.74	-0.89
Article 3.4 (capped at -0.37 MtC)		-1.36	-1.36	-1.36	-1.36	-1.36	-1.36	-1.36	-1.36	-1.36	-1.36
Article 3.7	0.33										
Kyoto Protocol Total	**774.93**	**769.96**	**776.89**	**752.11**	**731.31**	**720.65**	**710.74**	**731.20**	**706.25**	**701.69**	**669.01**
Fixed Base Year	**776.34**										

Table ES5b	**Mt CO_2 Equivalent**								**% Changes**	
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**1990-2007**	**Base Year - 2007**
CO_2	550.00	561.83	544.78	556.16	556.63	554.00	551.75	543.22	-7.7%	-7.7%
CH_4	69.47	63.50	60.52	54.57	52.78	50.88	50.17	48.69	-53.2%	-53.2%
N_2O	41.84	39.42	37.65	37.07	37.59	36.37	34.89	34.20	-47.0%	-47.0%
HFCs	9.94	10.68	11.00	11.34	9.94	10.12	9.93	9.56	-16.1%	-38.6%
PFCs	0.50	0.42	0.31	0.27	0.34	0.26	0.30	0.22	-84.6%	-54.2%
SF_6	1.80	1.42	1.51	1.32	1.13	1.11	0.87	0.79	-23.1%	-36.1%
Grand Total	**673.54**	**677.27**	**655.77**	**660.74**	**658.41**	**652.74**	**647.91**	**636.68**	**-17.4%**	**-17.8%**
Article 3.3	-1.02	-1.12	-1.32	-1.52	-1.72	-1.91	-2.08	-2.24		
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	**671.17**	**674.80**	**653.10**	**657.86**	**655.33**	**649.47**	**644.48**	**633.08**	**-17.8%**	**-18.3%**
Fixed Base Year										

Footnotes:

[1] The Fixed Base Year was supplied to the EU to calculate the Assigned Amount for the EU.

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 UK and Gibraltar only.

ES.6

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	1998
Net CO_2 Emissions	592.90	600.17	582.96	568.02	561.93	553.13	575.33	551.60	553.62
% change relative to 1990		1.23%	-1.67%	-4.19%	-5.22%	-6.71%	-2.96%	-6.97%	-6.62%

Table ES6a	**Mt CO_2 equivalent**								
	1999	2000	2001	2002	2003	2004	2005	2006	2007
Net CO_2 Emissions	543.00	551.09	562.52	544.94	556.22	555.95	553.17	551.06	542.55
% change relative to 1990	-8.42%	-7.05%	-5.12%	-8.09%	-6.19%	-6.23%	-6.70%	-7.06%	-8.49%

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 and Energy: Science and Analysis (CESA) Research Programme of the Department for Energy and Climate Change. The Land Use Change and Forestry estimates were provided by the Centre for Ecology and Hydrology (CEH) Edinburgh (Contract CPEG 1). North Wyke Research (NWRes) 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 DECC: http://www.ghgi.org.uk/.

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Document Revision History

Issue	**Revision History**
Issue - Draft	Reviewed by Defra, NWRes and CEH;
Issue 1	Submission to the EUMM, incorporates comments from DECC, NWRes and CEH
Issue 2	Submission to the UNFCCC Contains an additional Annex detailing the treatment of the new reporting requirements in place for the 2010 NIR Contains CRF tables in Annex 9

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 2007. 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, under contract to Department of Energy and Climate Change (DECC) and agricultural emissions by North Wyke Research, under contract to the Department of Environment, Food and Rural Affairs (Defra). DECC 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).

To fulfil both EUMM and UNFCCC reporting requirements the UK has prepared two sets of CRF tables. This is the first year that two separate sets have been prepared and officially reported. These two sets of tables present emission estimates for different geographical coverages:

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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.

1. EUMM CRF (reported 15th January): Includes UK, and Gibraltar
2. UNFCCC CRF (reported 15th April) : Include UK, Crown Dependencies (Jersey, Guernsey, Isle of Man) and Overseas Territories (Bermuda, Cayman Islands, Montserrat, Falkland Islands, Gibraltar).

1.1.2 Nomenclature of the Inventory Period Reported

This report is the UK National Inventory Report of 2009. It contains revised emissions estimates for the years 1990 to 2007 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 1990-2007, 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 2007. 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 for each reported geographical coverage 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
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 formed the basis of the UK's Fourth National Communication to the UNFCCC.

The Climate Change Act became UK Law on the 26th November 2008. This is a legally binding target to reduce GHG emissions to 80% below base year by 2050, with legally binding five year GHG budgets. The independent Committee on Climate Change (CCC) has been set up to advise the UK Government on Budgets. The CCC published its first advice to the UK Government on the 1st December 2008. Government will set out policies and measures to meet GHG budgets in Summer 2009.

A full set of policies for the Carbon Reduction Committment shall become available in Summer 2009.

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, Science and Analysis (CESA) Division in the UK Department of Energy and Climate Change (DECC). 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 Land Management Improvement Division by means of a contract with North Wyke Research.

Land-Use Change and Forestry emissions (CRF sector 5) are calculated by the UK Centre for Ecology and Hydrology (CEH), under separate contract to CESA (DECC).

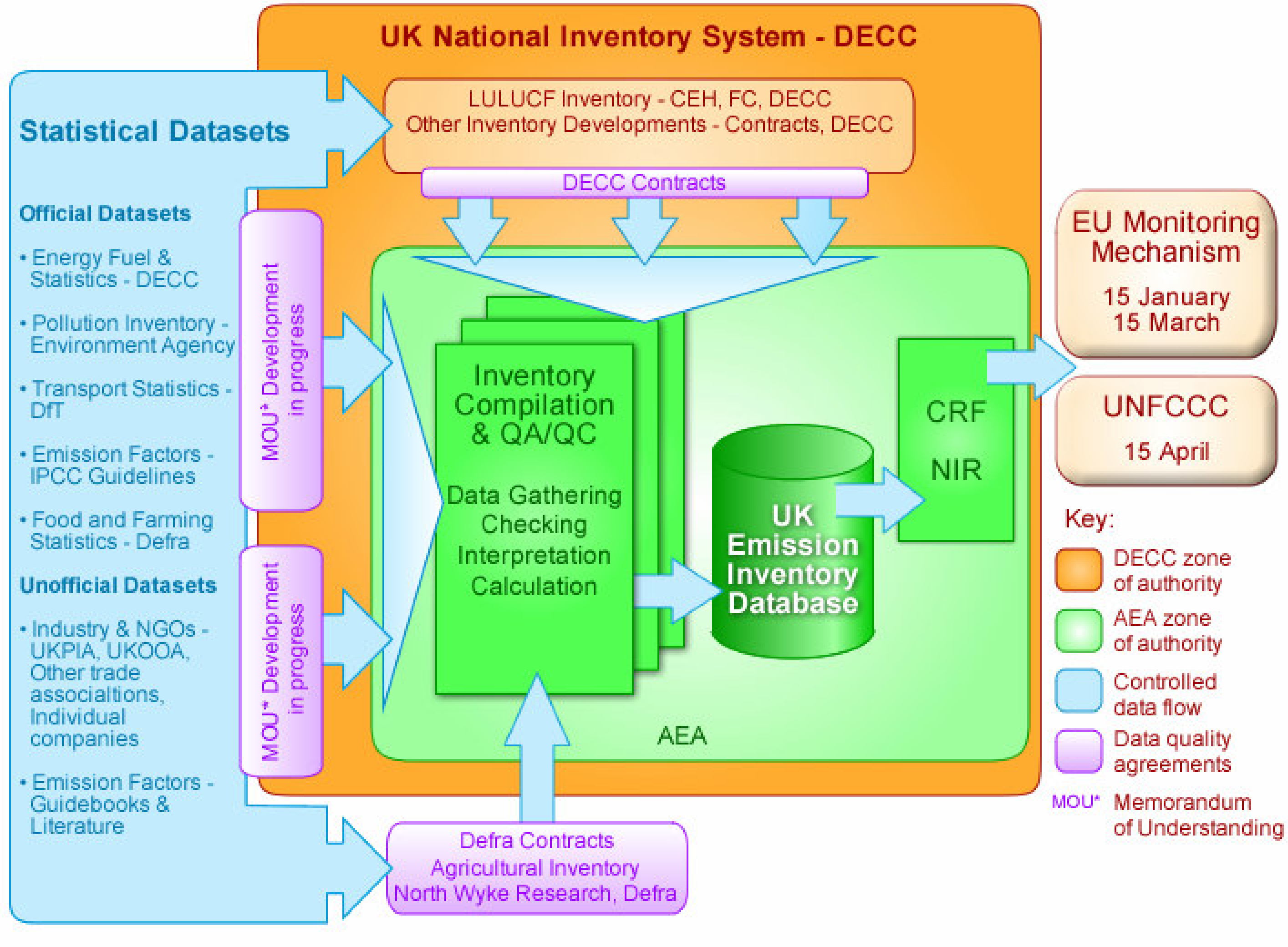
1.2.1 The UK Greenhouse Gas National Inventory System (UK NIS)

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 DECC 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. DECC 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 DECC, and produces disaggregated estimates for the Devolved Administrations within the UK.

Key Data Providers include other Government Departments such as Department for Business, Enterprise and Regulatory Reform (BERR), Department for Environment, Food and Rural Affairs (Defra) 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).

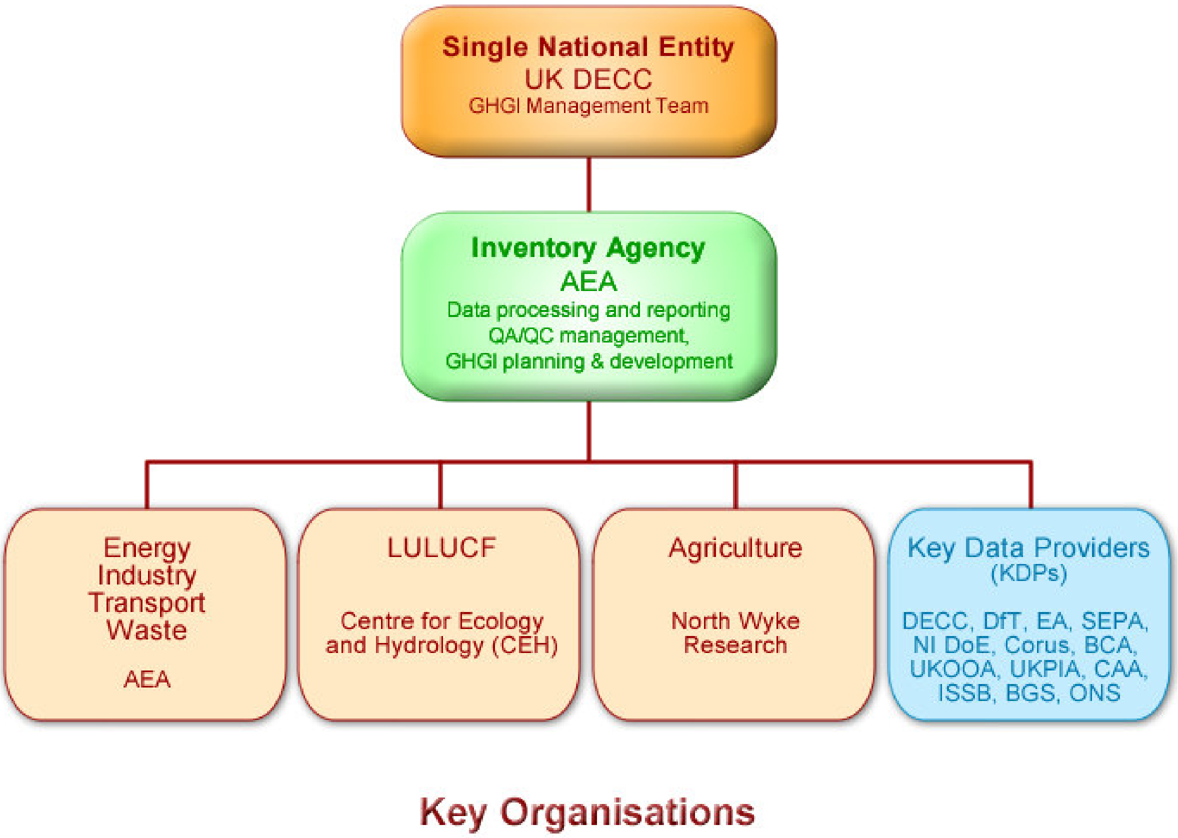
Figure 1.1a: Main elements for the preparation of the UK greenhouse gas inventory



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 summarise the roles and responsibilities of key stakeholders in the UK NIS.

1.2.2.1 Single National Entity – DECC

Since its creation in October 2008, the UK Government Department of Energy and Climate Change (DECC) has been appointed as the Single National Entity for the UK and this has been confirmed in writing to the UN Executive Secretary. DECC 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). DECC is responsible for the institutional, legal and procedural arrangements for the national system and for the strategic development of the national inventory.

Within DECC, the Climate, Energy, Science and Analysis (CESA) Division administers this responsibility. CESA 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, DECC 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; and
- Definition of performance criteria for NIS key organisations.

Development of Legal & Contractual Infrastructure

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

1.2.2.2 Inventory Agency - AEA

AEA under contract to DECC 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 DECC (formerly 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 DECC to deliver the NIS;
- Review of current NIS performance and assessment of required development action; and
- Scheduling of tasks and responsibilities to deliver GHG inventory and NIS.

Preparation
- Drafting of agreements with key data providers; and
- 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; and
- Management of inventory QA/QC plans, programmes and activities.

Inventory Compilation

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

CEH under contract to DECC 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.

North Wyke, under contract to Defra, is responsible for the preparation and development of the agriculture inventory. North Wyke 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; and
- Communication with DECC, 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 Department of Business, Enterprise and Regulatory Reform (BERR). The BERR energy statistics department is now part of DECC.

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; and
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.
North Wyke Research 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), Government Departments and from other sources.

Both DECC and Defra also fund research contracts to provide emissions estimates for certain sources such as fluorinated gases, landfill methane and to provide estimates for previously unreported sub-sectors such as methane from abandoned coal mines, included for the first time in the UK's inventory submitted in 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 DECC.

1.2.2.4 Changes to the National System

The Single National Entity is now the newly created Government Department of Energy and Climate Change (DECC).

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); and
- Statistics of Trade Act (UK energy statistics from BERR).

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[3]. This legislation makes provision for DECC'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

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

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, DECC proposes to introduce data supply agreements with relevant organizations during 2009, 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; and
- 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 DECC 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 DECC.

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, DECC 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
DECC 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; and • Provide Secretariat to Steering Committee. • Provide a statistical check of emissions data used to derive climate change indicators • Adviser to CCC on technical and scientific issues.	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. Publication of DECC climate change indicators
Defra Land Management Improvement Division	• 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.
DECC	• Provide fuel use and fuel characterisation datasets from the EU-ETS for use by both BERR and 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.
DECC 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).
DECC 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
BERR Energy (note that the Energy team from BERR recently joined DECC)	• 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 BERR 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.

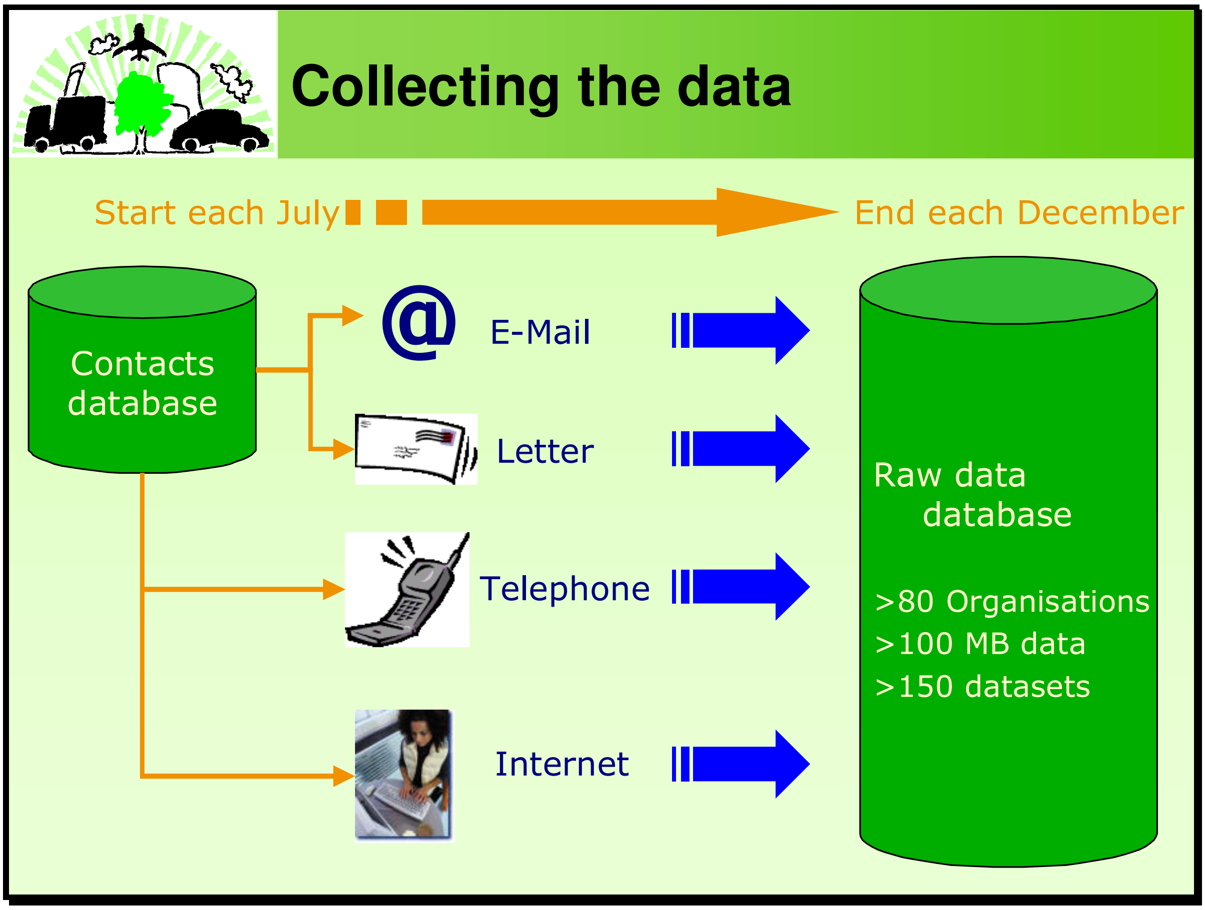
Table 1.3: Special Advisors to the UK GHG National Inventory Steering Committee

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; and • 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 (North Wyke)	• Prepare and develop agricultural inventory and deliver on time for incorporation into national inventory; and • 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; and • Participate in sectoral expert panels as required.	Contractor responsible for LULUCF inventory; activity data, methods, emission factors, emissions and removals estimation.
DECC 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.
DECC 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 June, 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, as follows:

- ***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 Request***
  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.

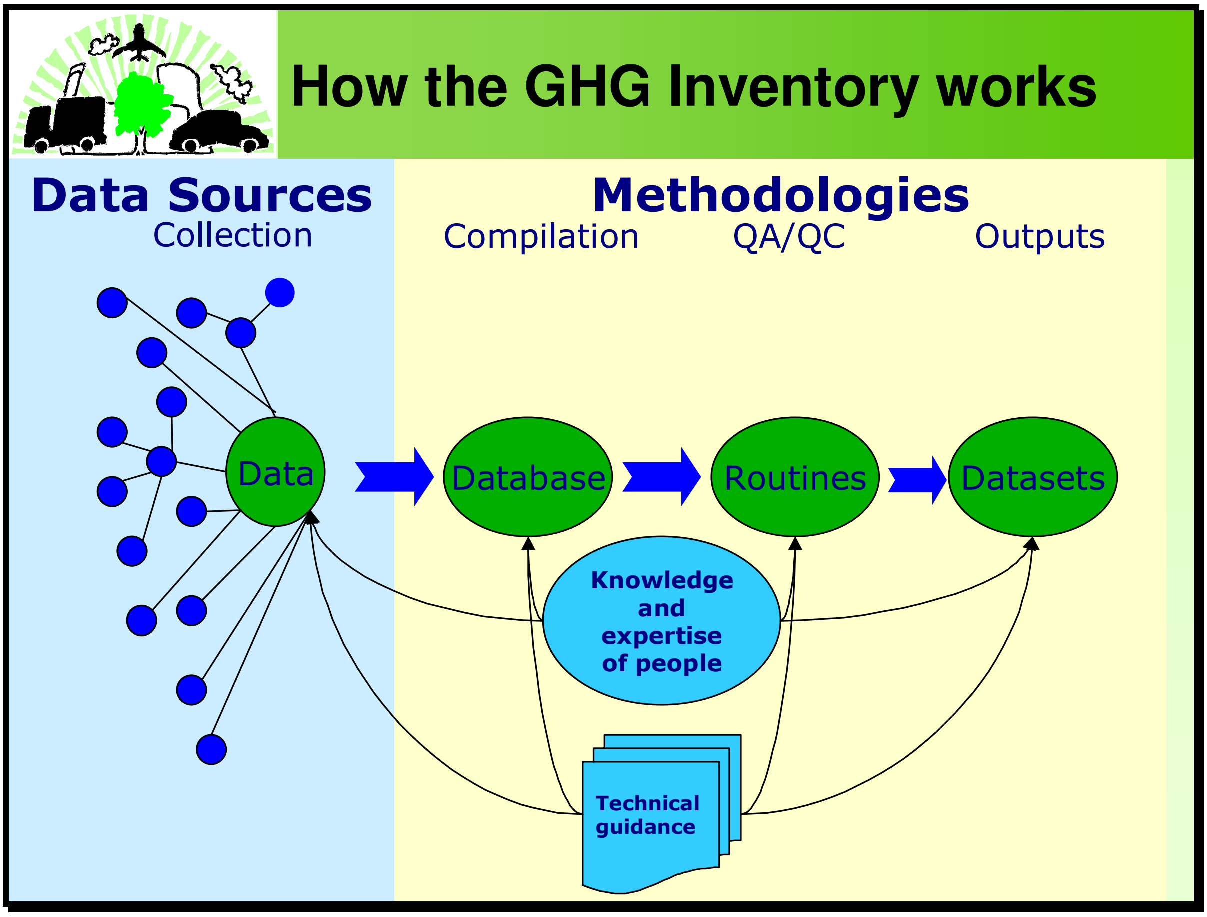
- ***Report Review***
  The reports are reviewed: internally; by external contributing agencies; and by DECC (formerly Defra). Errors and omissions are then rectified.

- ***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 1.4 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**); and • 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**); and • Gas leakage data from network operators (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; and • 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); and • Spreadsheet model to estimate emissions of F-gases.
2D	• Emissions calculated based on USEPA Compilation of Air Emission Factors; and • 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.
6A	• The new MELmod model.
6B	• IPCC default method and the Hobson model
6C	• Uses country specific emission factors, partially based on Pollution Inventory data.

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; and • 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); and • Selected domestic and international civil aviation aircraft km flown.
Northern Ireland Department of the Environment	• Traffic count and vehicle km data for Northern Ireland; and • 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; and • 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 categories 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. **Tables 1.6**, **1.7,** and **1.8**, **1.9** summarise the key source categories, for 2007 (the latest reported year), and the base year, derived from the IPCC Approach 1 uncertainty analysis. Details of the key source category analysis are given in **Annex 1**, including an analysis of key source categories in the base year. A trend cannot be calculated for the base year alone, and so the tables for the base year only contain key source categories identified by level.

Table 1.6: Key Source Categories for the latest reported year (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 for the base year (including LULUCF)

IPCC source category	Fuel/Activity	GHG	Reason
4D	Agricultural Soils	N_2O	Level
6A	Solid Waste Disposal	CH_4	Level
1A(stationary)	Oil	CO_2	Level
4B	Manure Management	N_2O	Level
1A1&1A2&1A4&1A5	Other Combustion	N_2O	Level
2B	Nitric Acid Production	N_2O	Level
5B	5B LULUCF	CO_2	Level
1A3b	Auto Fuel	CO_2	Level
5C	5C LULUCF	CO_2	Level
6B	Wastewater Handling	N_2O	Level
4A	Enteric Fermentation	CH_4	Level
5E	5E LULUCF	CO_2	Level
2B	Adipic Acid Production	N2O	Level
5A	5A LULUCF	CO_2	Level
2	Industrial Processes	HFC	Level
1A	Coal	CO_2	Level
1B1	Mining & Solid Fuel Transformation	CH_4	Level
1A3b	Auto Fuel	N_2O	Level

Table 1.8: Key Source Categories for the latest reported year (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

Table 1.9: Key Source Categories for base year (excluding LULUCF)

IPCC source category	Fuel/Activity	GHG	Reason (s)
4D	Agricultural Soils	N_2O	Level
6A	Solid Waste Disposal	CH_4	Level
1A(stationary)	Oil	CO_2	Level
4B	Manure Management	N_2O	Level
1A1&1A2&1A4&1A5	Other Combustion	N_2O	Level
2B	Nitric Acid Production	N_2O	Level
1A3b	Auto Fuel	CO_2	Level
6B	Wastewater Handling	N_2O	Level
4A	Enteric Fermentation	CH_4	Level
2B	Adipic Acid Production	N_2O	Level
2	Industrial Processes	HFC	Level
1A	Coal	CO_2	Level
1B1	Mining & Solid Fuel Transformation	CH_4	Level
1A3b	Auto Fuel	N_2O	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

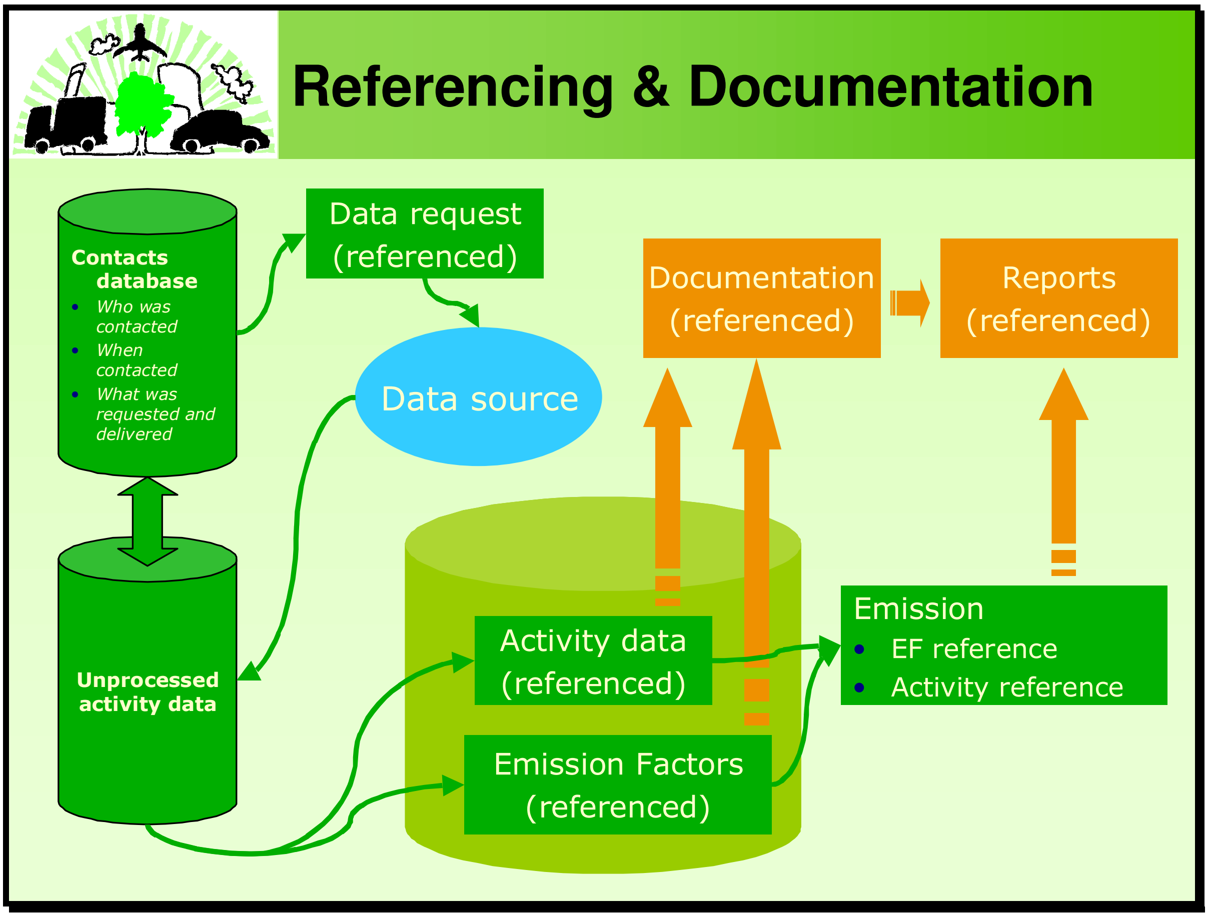
The National Atmospheric Emissions Inventory and the UK Greenhouse Gas Inventory are compiled and maintained by AEA, part of AEA Technology plc. The data compilation and reporting for some source sectors of the UK inventory are performed by other contractors (i.e. North Wyke compile the agriculture sector, 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; and

- 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); and

- 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 BERR (now DECC);

- 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; and

- 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; and

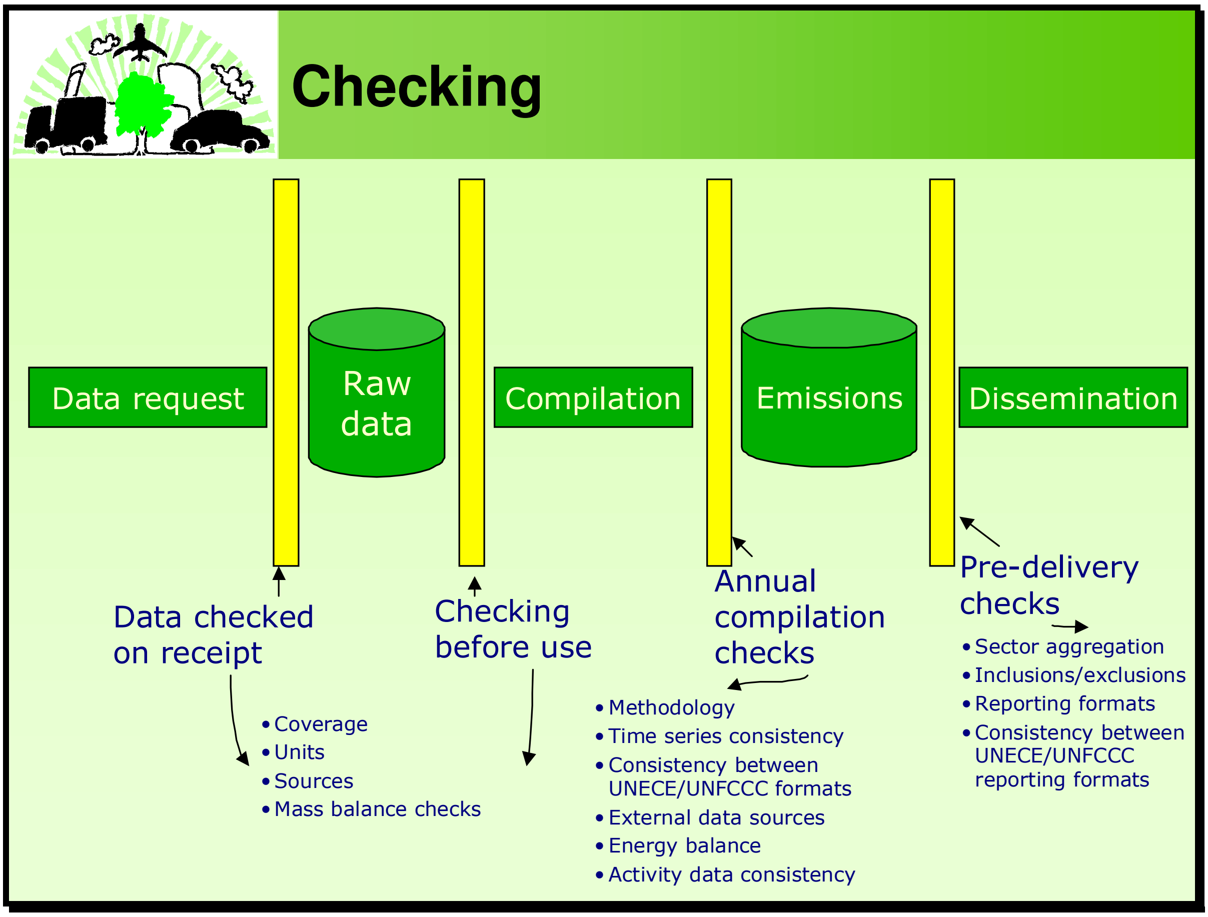
- A ranking exercise is performed according to Approach 1 (error propagation) procedures to identify key source categories and a Monte-Carlo uncertainty evaluation is conducted across the inventory.

6. ***Archiving***
- At the end of each reporting cycle, all the database files, spreadsheets, on-line manuals, 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 2008-2009

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

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 2008. This programme will again be reviewed in 2009 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. BERR, 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

Bilateral Reviews

In July 2008 the UK took part in a bilateral review of the agriculture inventory with experts from the French inventory team. This covered emissions of both greenhouse gases and other pollutants. The objectives of the review were to develop emissions inventory capacity in collaboration with France, and to provide elements of expert peer review to meet quality assurance requirements under national inventory systems e.g. Article 5, paragraph 1, of the Kyoto Protocol and European Union Monitoring Mechanism (EUMM) e.g. 280/2004/EC. Specific activities undertaken included sharing good practice between the UK and France and the development of ideas for efficient future technical collaboration.

The current inventory workplan includes similar bilateral reviews for other sectors, covering Industry, Transport and Waste.

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.

DECC have also recently funded an external peer review of the research programme that provides LULUCF emissions estimates to the Greenhouse Gas Inventory. This review is currently ongoing.

1.6.7 Verification

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

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

1.6.8 Treatment of Confidentiality

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

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

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

1.7 GENERAL UNCERTAINTY EVALUATION

The UK GHG inventory estimates uncertainties using both 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 13% in 2007. The trend in the total GWP weighted emissions expressed as the fall between 1990 and 2007 is -17.8%, with 95% of the values found to lie within the range -20.1% to -15.7%. 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 UK BERR (now DECC) 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.

BERR advises that the geographical coverage of the statistics is the United Kingdom (BERR, 2008). 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 BERR 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)[4] 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 as follows:

- 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

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

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.

For the first time in 2009, the UK has prepared and submitted two separate inventories, each with a different geographical coverage so as to fulfil reporting requirements of both the EUMM and UNFCCC. For the EUMM submission, the geographical coverage included the United Kingdom plus Gibraltar. Both Crown Dependencies and other Overseas Territories were excluded. For the UNFCCC, the UK, Gibraltar, Crown Dependencies and Overseas Territories (Gibraltar, the Falkland Islands, the Cayman Islands, Montserrat, Bermuda and Gibraltar) were all included. Details of the methods used to disaggregate the fuel use in the CDs from the UK totals presented in DUKES are detailed in Annex 3.9.

1.10 UK GREENHOUSE GAS REGISTRY

1.10.1 Background information

The UK Greenhouse Gas Registry is operated and mainted by the Environment Agency on the behalf of DECC. A full description of the UK Registry system is presented in the UK's Initial Report under the Kyoto Protocol.[5] 2008 was the first year the UK Registry was operating under the Kyoto Protocol rules. Connection was established during October 2008 and the reporting year ended on the 31st December 2008.

1.10.2 Summary of information reported in the SEF tables

The UK issued 3,412,080,630 AAUs under the Kyoto Protocol following agreement with the UNFCCC. After establishing the connection to the ITL, the UK Registry was made available to EU ETS operators and market participants from late October 2008. During the remainder of the year, units were exchanged with 27 other Registries operating within the Kyoto rules as confirmed by the UNFCCC.

In total, the UK Registry received 195,468,637 AAUs and 128,774,640 CERs. Conversely, 154,160,461 AAUs and 103,671,234 CERs were externally transferred to other national registries. Account holders voluntarily cancelled 80 AAUs and 345,826 CERS. There were no transactions of any kind involving RMUs, ERUs tCERs or lCERs. All of these additions and subtractions were undertaken by account holders of person and operator holding accounts, i.e. the UK Government did not initiate any transactions or receive any units into Party Holding Accounts.

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

Full details are available in the SEF tables, submitted to the EUMM in January 2009[6], the full tables are shown in Annex 13.

1.10.3 Discrepancies and notifications

The UK did not carry out any transactions in response to notifications, as none were received from the ITL.

1.10.4 Publicly accessible information

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/.

1.10.5 Calculation of the commitment period reserve (CPR)

The Annex to Decision 11/CMP.1 (paragraph 6) specifies that: '*each Party included in Annex I shall maintain, in its national registry, a commitment period reserve which should not drop below 90 per cent of the Party's assigned amount calculated pursuant to Article 3, paragraphs 7 and 8 of the Kyoto Protocol, or 100 per cent of five times its most recently reviewed inventory,* ***whichever is lowest***'.

Therefore the **UK's commitment period reserve** is calculated as:

Either
90% of the UK's assigned amount – see above
= 0.9 x 3,412,080,630 tonnes CO2 equivalent
= 3,070,872,567 tonnes CO2 equivalent.
or
100% of 5 x most recently reviewed inventory (2006)
= 5 x 653,825,066 tonnes CO2 equivalent
= 3,269,125,332 tonnes CO2 equivalent

The lower of the two numbers is that calculated as 90 per cent of the UK's assigned amount. The UK's Commitment Period Reserve is therefore **3,070,872,567 tonnes of CO2 equivalent (or assigned amount units)**.

1.10.6 KP-LULUCF accounting

The UK intends to account for Article 3.3 and 3.4 LULUCF activities for the entire commitment period, rather than annually. This is because the periodic nature of forest surveys (eg National Inventory of Woodland and Trees) means that a more detailed and accurate assessment, based on the best possible data, will be possible at the end of the first commitment period.

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[6] http://cdr.eionet.europa.eu/gb/eu/ghgmm/envsw82na/2009-01-15_Registry_Data_for_EC_GB_v2.xls/manage_document

1.11 INFORMATION ON MINIMIZATION OF ADVERSE IMPACTS IN ACCORDANCE WITH ARTICLE 3, PARAGRAPH 14

The UK is strongly committed to ensuring that trade policies promote long term sustainable development and want the benefits from the reduction or elimination of tariffs on some products which developing countries export to be long lasting and maximised. Ensuring that potential negative environmental impacts of trade liberalisation are addressed is essential for the long-term sustainability of the benefits to developing country economies of improved market access and the UK continues to push for robust impact assessments of trade negotiations.

The UK has a renewable initiative which provides a fund to underwrite UK renewable technology sale to the developing world, promoting the liberalising environmental Goods and services under the Doha process which promotes a low carbon future in a pro-development dialogue. In addition, The UK is also strongly committed to provide Aid for Trade to developing countries, and especially the poorest among them, to help build their capacity to trade, integrate into global markets while also addressing any adjustment costs that might arise from more liberalisation, within the context of sustainable development. The UK has just adopted its first Aid for Trade strategy and has formally committed to spend at least £400 million per year by 2010 as Aid for Trade at national, regional and global levels.

The UK Foreign and Commonwealth Office (FCO) funded a capacity building project on the Review of the Kingdom of Saudi Arabia (KSA)'s First National Communication to the United Nations Framework Convention on Climate Change. This resulted in a report containing a series of suggestions for improvement to the inventory and reporting on Nationally applicable Mitigation Actions and on the development of an energy efficiency strategy. Another project on Energy Efficiency Best Practice is currently under development. The work would include GAP analysis of energy demand and current energy management practices by sector and a summary of energy and carbon saving potential as well as related sectoral environmental benefits. The work would also include a review of best practice in neighbouring countries and how these might translate to potential changes in the KSA.

This capacity building project is an illustration of how the UK is a) strengthening the capacity of developing country Parties identified in Article 4, paragraphs 8 and 9, of the Convention for improving efficiency in upstream and downstream activities relating to fossil fuels, taking into consideration the need to improve the environmental efficiency of these activities b) assisting developing country Parties which are highly dependent on the export and consumption of fossil fuels in diversifying their economies

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 2007, the total direct greenhouse gas net emissions (including LULUCF emissions) in the UK were estimated to be 638.5 Mt CO_2 equivalent. This was some 17.8% below the 1990 level. There was a reduction of about 18.2% 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 time series.

The following sections summarise the emission trends between 1990-2007 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.

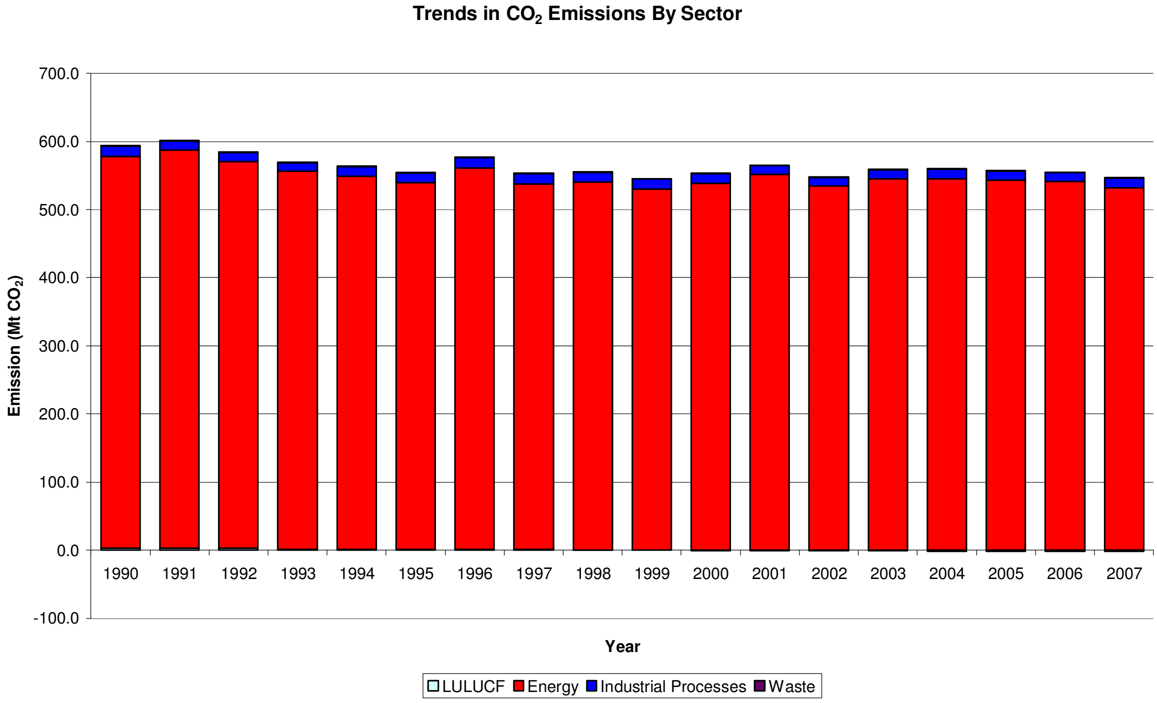
2.2 EMISSION TRENDS BY GAS

The tables shown in **ES2** together with **Figure 2.4** show that the largest contributor to global warming is carbon dioxide at 85% of the weighted emission. Methane contributes 8% and nitrous oxide 5%. In spite of their high GWPs the contribution of halocarbons is small at around 1.7% of the total. This is because their mass emissions are very small. Overall the total weighted emission has fallen by 17.8% since 1990 (18.2% relative to the fixed base year under the Kyoto Protocol), with emissions of all gases declining.

2.2.1 Carbon Dioxide

In 2007, CO_2 emissions were 544.6 Mt CO_2 equivalent, 8.3% below the 1990 level. Emissions have returned to approximately 1999 levels after a rise due to higher coal burn relative to gas and in some years reduced nuclear output and lower outside temperatures. The trend in CO_2 emissions is illustrated in **Figure 2.1,** which shows that the total emissions are dominated by the energy sector, which is the main driver for the declining trend in emission.

Figure 2.1: **CO_2 emissions trend by source**



2.2.2 Methane

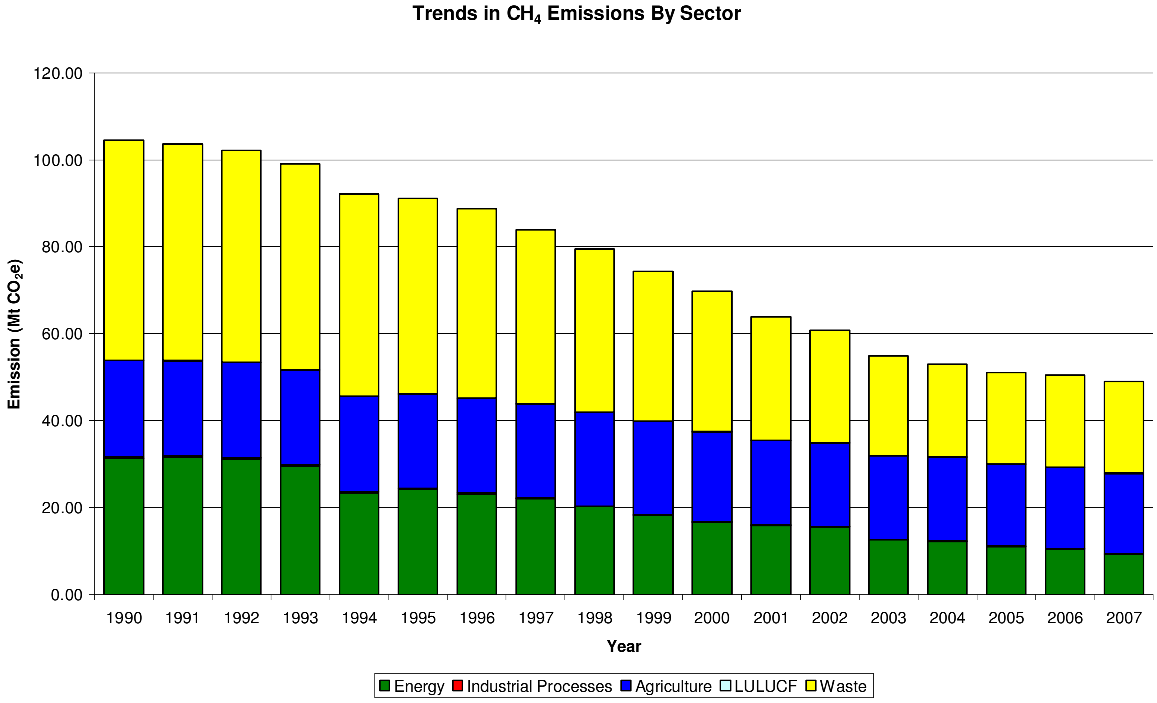
Figure 2.2 illustrates the trend in emissions of methane, broken down by source. Methane is the second most significant greenhouse gas in the UK after CO_2. In 2007, methane emissions were 49.0 Mt CO_2 equivalent.

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. Emissions from all these sources have declined since 1990, and the main reasons for these are summarised below:

- In the energy sector, reduced coal mining activity, and improvements to the gas distribution network have contributed to an over-all decrease in emissions of 70% since 1990. Decreases in this sector have contributed 40% to the total decrease in methane emissions.
- Total emissions in the waste sector have decreased by 58%. This due to increased implementation of methane recovery systems. The reduction in emissions in this sector is responsible for 53% of the total decrease in methane emissions since 1990.
- Emissions from agriculture have decreased by 7% since 1990, following the trend of decreasing livestock numbers.

Since 1990, emissions of methane have decreased by 53%. Emissions from LULUCF and Industrial Processes are not significant sources of methane in comparison to the other sectors.

Figure 2.2: Trends in CH_4 Emissions by Sector



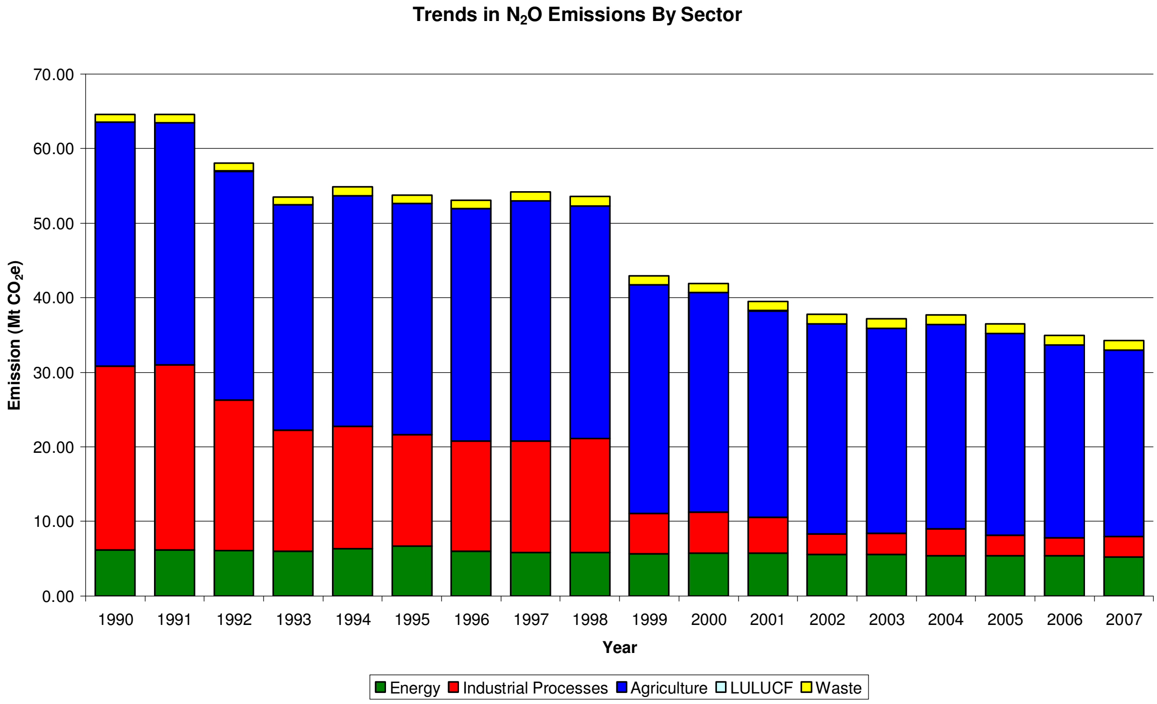
2.2.3 Nitrous Oxide

Figure 2.3 illustrates the trend in emissions of nitrous oxide. The main anthropogenic sources are agriculture, transport, industrial processes, and coal combustion. In 2007, emissions of nitrous oxide were 34.3 Mt CO_2 equivalent. Emissions have declined 47% since 1990, and the main reasons for this reduction are summarised below:

- The agriculture sector is a major source of N_2O emissions, contributing 73% to total emissions of N_2O. Emissions from this sector have decreased by 23% since 1990, mostly due to a decrease in emissions from sector 4D, agricultural soils, driven predominantly by a fall in synthetic fertiliser application.
- Although the total emission is dominated by agriculture, the trend in emissions across the time series is driven by a significant reduction in emissions from Industrial Processes. In 1990, nitric and adipic acid production were both significant sources of N_2O, contributing 38% to total N_2O emissions. In 2007, these sources accounted for only 8%. This has been a result of plant closures, and the installation of emissions abatement equipment at the nitric acid plant in 1998 (the effect of this can be seen in **Figure 2.3**). Emissions from Industrial Processes have decreased by 89% since 1990, contributing 72% to the total decline in N_2O emissions.
- Fuel combustion is also a significant N_2O source, with total emissions from the energy sector contributing 15% to total N_2O emissions in 2007. Emissions from this sector have decreased by 16% since 1990. The most significant sources within this sector are road transport, industrial combustion and power generation. Both industrial combustion and power generation have shown decreases in emissions since 1990. Road transport emissions increased steadily from 1990 to 1999 due to the increase in cars with 3-way catalysts in the fleet. From 2000 onwards, however, emissions from this source have

started to decrease due to the improvements in catalyst technology in newer vehicles. Emissions in 2007 are only 6% higher than emissions in 1990.

Figure 2.3: Trends in N_2O Emissions by Sector



2.2.4 F-Gases

Emissions of the F-gases (HFCs, PFCs, and SF_6) totalled 10.6 Mt CO_2 equivalent in 2007. Since 1990 the overall decrease in their emissions has been 23%, due mainly to the fall in emissions from F-Gas manufacture, due to the installation of abatement equipment at two of the three manufacturers.

2.3 EMISSION TRENDS BY SOURCE

Weighted greenhouse gas emissions broken down by sector are shown in **Figure 2.5**. 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 (20%). 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 11% 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 21% 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 48%, 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 4% to greenhouse gas emission in 2007. 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 57% since 1990 and this is mostly due to the implementation of methane recovery systems.

2.4 EMISSION TRENDS FOR INDIRECT GREENHOUSE GASES AND SO2

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 2.6**.

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 2007, the total emissions were 1488 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 2007, the total emissions were 2105 Gg, of which 90% were from the energy sector. Since 1990, emissions of CO have decreased by 76%. 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 2007, total emissions of NMVOCs were 940 Gg, of which 43% 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 64%. 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 2007 were 596 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 85%. 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 2.4: **UK Net Emissions of Greenhouse Gases Weighted by GWP**

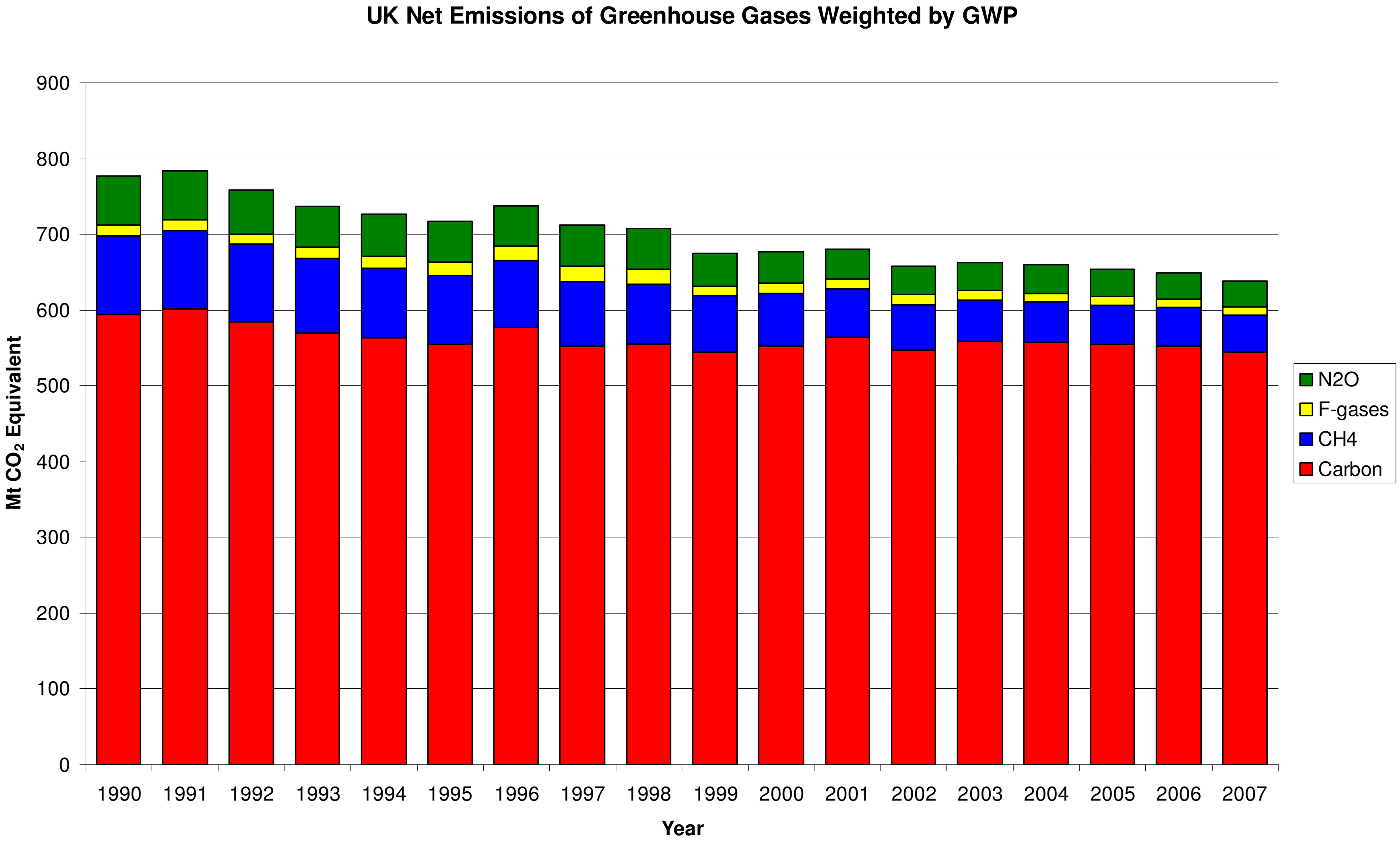
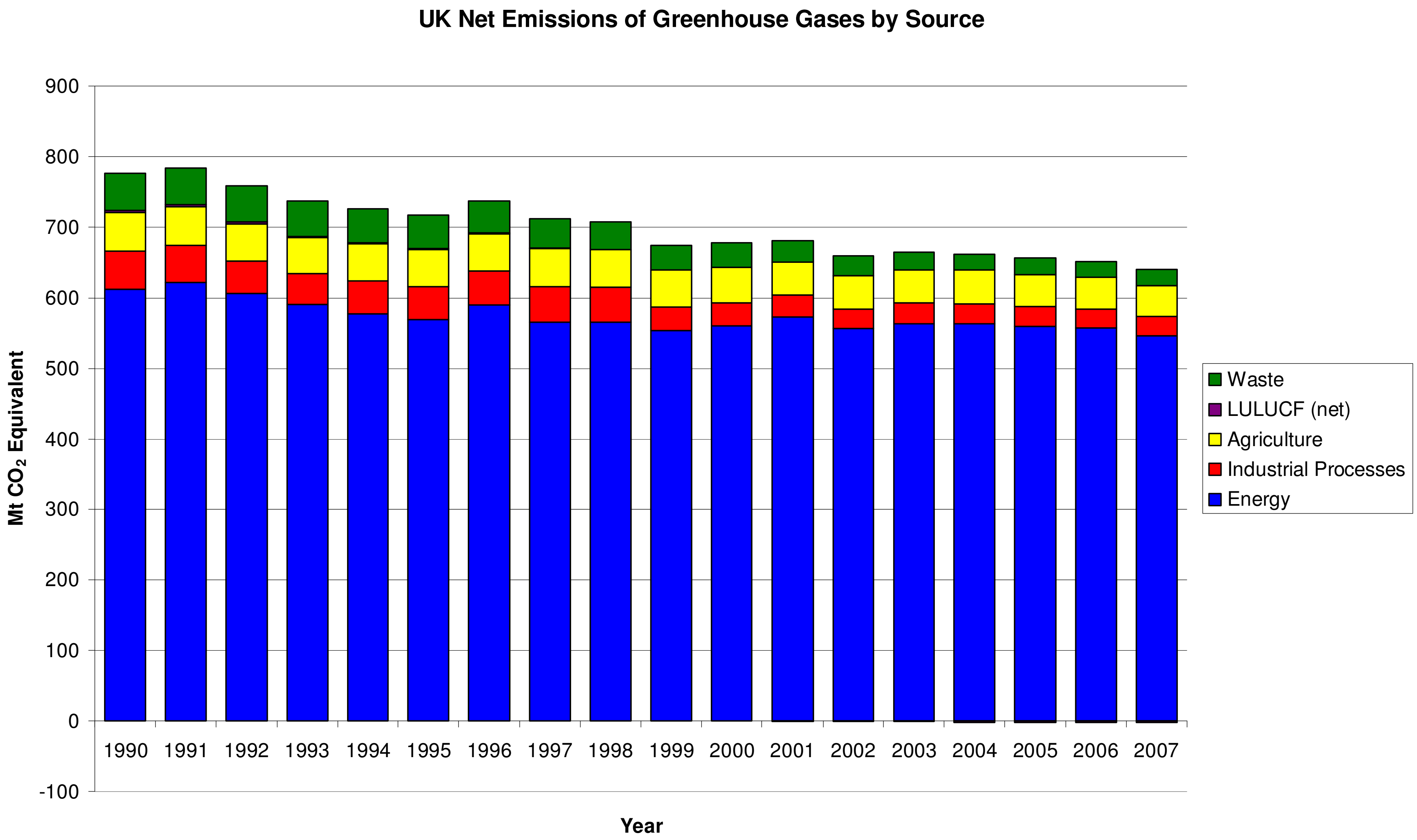
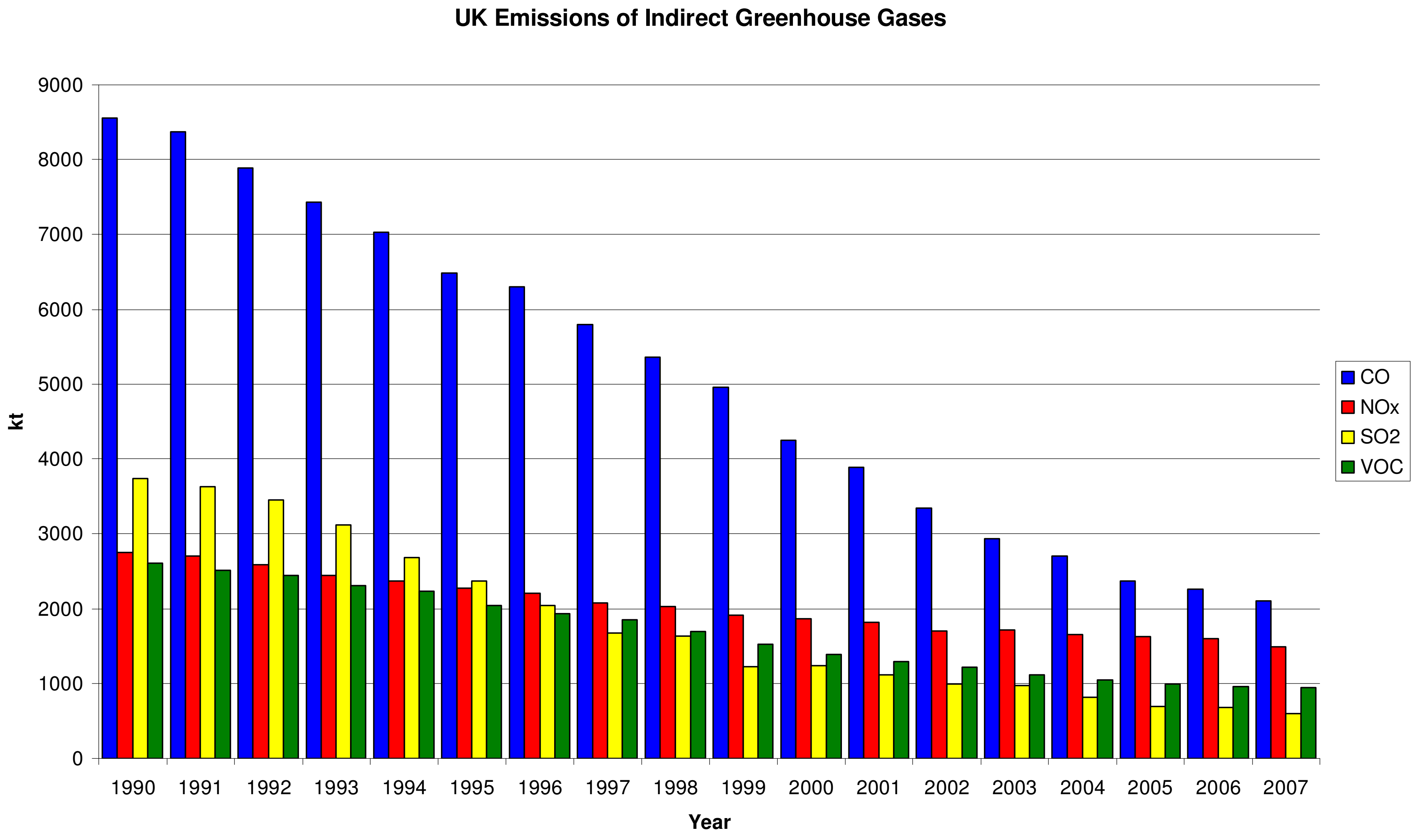


Figure 2.5: UK Net Emissions of Greenhouse Gases by Source



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

Figure 2.6: UK 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 2007, 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 51 Mtonnes of coal were burnt at 17 power stations during 2007, while approximately 10,913 Mtherms of natural gas were consumed at 37 large power stations and 10 small (<50MWth) regional stations (mostly Combined-Cycle Gas Turbines, CCGTs). Heavy fuel oil was the main fuel at 3 facilities, and gas oil or burning oil was used by 13 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 22 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 2007, there were four coke ovens at steelworks and one independent coke oven. A further three coke ovens have closed in the last five 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, 2008) 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.

For some sectors, emissions data are available for individual sites, either from the Environment Agency for England and Wales (EA, 2008), via the Pollution Inventory (PI); from the Scottish Environment Protection Agency (SEPA, 2008), 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, 2008). 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_2O	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 BERR 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, BERR (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 BERR.

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 and EUETS data for some fuels from 2005 onwards • Key sources of carbon EF data include: UKPIA, Association of Electricity Producers, Powertech, Transco.
CH_4, N_2O	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_2O.

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 BERR (now DECC) 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 Re-Calculations

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.

Following a review of EUETS data, the carbon emission factors for coal, fuel and natural gas use in power stations and petroleum coke and fuel oil use in refineries have been updated for the years 2005-2007. These data were felt to be the best available data for these years. Earlier years (1990-2004) remain unchanged from previous inventories as the data presented in the 2004 Carbon Factors Review (Baggott et al, 2004) remains the best available source of data for the earlier years in the time series.

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 2006 inventory (2008 NIR). Comparisons are made between the current inventory (1990-2007) and the previous inventory (1990-2006) for the year 2006.

3.2.4.1.1 ***Carbon Dioxide (CO_2)***

- Overall there has been a decrease in estimated emissions for 2006 of 1709 Gg CO_2 from sector 1A1. This 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 a decrease of 1475 Gg CO_2 from power stations due to a combination of revision to energy statistics in DUKES (BERR, 2008) and the introduction of EUETS based emission factors for coal and fuel oil fired power stations;
- There has been an increase of 168 Gg CO_2 from refineries due to a combination of revision to energy statistics in DUKES (BERR, 2008) and the introduction of EUETS based emission factors for coal and fuel oil fired power stations;
- Burning oil emissions have been included from refineries for the first time in this inventory. These emission totalled 2 Gg CO_2;
- There has been an increase in estimated emissions of 426 Gg CO_2 from offshore oil and gas own use due to a revision to the emission factors for natural gas.
- Some revisions have occurred due to a reallocation of fuels from the Other Industry sector to Power Stations to account for the fuels used to generate power in the Crown Dependencies. This is because the fuels allocated to power stations in the UK inventory refer to power stations in the UK only, whereas the commodity balance totals in DUKES also include the Crown Dependencies. Therefore in order to maintain the over all fuel balance with the national energy statistics, whilst retaining the accuracy of the estimates for UK power stations, fuel has been reallocated from the Other Industry sector.

3.2.4.1.2 ***Methane (CH_4)***

- Overall there has been an increase in estimated emissions for 2006 of 0.71 Gg CH_4 from sector 1A1;
- A major cause of this increase was the inclusion this year for the first time of wood burnt in powerstations as a new source. This caused an increase of 0.24 Gg CH_4;
- Energy statistics revisions to fuel oil use in power stations caused an increase of 0.07 Gg CH_4;
- The methodology for including emissions from crown dependencies has changed for MSW in powerstations. For the first time emissions are separate from the UK. This caused an increase of 0.04 Gg CH_4;
- There has been an increase in estimated emissions of 0.36 Gg CH_4 from offshore oil and gas own use due to a revision to the emission factors for natural gas.

3.2.4.1.3 ***Nitrous oxide (N_2O)***

- Overall there has been an increase in estimated emissions for 2006 of 0.13 Gg N_2O from sector 1A1;
- A major cause of this increase was the inclusion this year for the first time of wood burnt in powerstations as a new source. This caused an increase of 0.03 Gg N_2O;
- There has been an increase in estimated emissions of 0.09 Gg N_2O from offshore oil and gas own use due to a revision to the emission factors for natural gas.

3.2.4.1.4 ***Nitrogen Oxides (NO_X)***

- Some of the NO_x emitted by coal-fired power stations has, for the first time, been assumed to be from the combustion of co-fired wood and other solid biomass.

Previously, all emissions were assumed to come from the coal and other fossil fuels only. This change results in a re-allocation of 2 Gg NO_x from coal to wood.

- Changes in assumptions about fuels used by oil-fired power stations result in an increase of 5 Gg NO_x for fuel oil and a decrease of 2 Gg for waste oil.
- Emission estimates for offshore oil and gas installations have been revised with estimated emissions of NO_x from combustion of natural gas increasing by 3 Gg.

3.2.4.1.5 *Carbon Monoxide (CO)*

- Some of the CO emitted by coal-fired power stations has, for the first time, been assumed to be from the combustion of co-fired wood and other solid biomass. Previously, all emissions were assumed to come from the coal and other fossil fuels only. Due to this and other revisions, estimates of emissions from use of coal fall by 4Gg CO, while emissions from wood are 8 Gg CO.
- Emissions from landfill gas engines increase by 3 Gg due to a revision to the emission factor.
- Emission estimates for offshore oil and gas installations have been revised with estimated emissions of CO from combustion of natural gas increasing by 1 Gg.

3.2.4.1.6 *Sulphur Dioxide (SO_2)*

- Revisions to fuel consumption data for power stations result in changes in emission estimates for fuel oil (+9 Gg), waste oil (- 1 Gg) and sour gas (- 3 Gg).

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_2O	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 BERR 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. Emission factors for coal use by autogenerators for 2005 to 2007 are now based on EU ETS data.
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.

3.3.4 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 BERR 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 unverified 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 BERR (through fuel re-allocations between sectors).

3.3.5 Source Specific Re-Calculations

Following a review of EU-ETS data, the carbon emission factors for coal use in autogenerators were updated for 2005-2007 inclusive. Pre 2005 data remained unchanged. The update to the emission factors for only part of the time series can be justified as for this sector, it is considered that EUETS data is the best available data for the later years. Pre EU-ETS, the carbon factors review carried out in 2004 remains the best available source of carbon factors.

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 2006 inventory (2008 NIR). Comparisons are made between the current inventory (1990-2007) and the previous inventory (1990-2006) for the year 2006.

3.3.5.1.1 *Carbon Dioxide (CO_2)*

- Estimated emissions of CO_2 from 1A2 have decreased by 666 Gg CO_2. The main reasons for these changes are given below;
- A large proportion of this reduction is from lubricants in Other Industrial Combustion. There has been a decrease of 591 Gg CO_2 due to a revision to reflect significant reduction of the use of this fuel due to the Waste incineration Directive;
- A reduction of 590 Gg CO_2 has also occurred through a revision of energy statistics in the Other Industrial Combustion sector;

- A further 470 Gg CO_2 decrease has occurred through a revision of energy statistics in the Other Industrial Combustion sector for burning fuel oil;
- Emissions from iron and steel combustion plant from fuel oil decreased by 121 Gg CO_2 due to revisions to energy statistics;
- There has been a 52 Gg CO_2 decrease through a revision of energy statistics in the Other Industrial Combustion sector for burning gas oil;
- Emissions from iron and steel combustion plant from natural gas increased by 43 Gg CO_2 due to revisions to energy statistics;
- There has been an increase of 1303 Gg CO_2 due to a combination of a reallocation of fuels used in lime production and a revision to the emission factor used for coke used in industrial combustion;
- An increase of 49 Gg CO_2 occurred from blast furnace gas and coke used in blast furnaces and sinter plants due to revision of the emission factors used;
- There was a decrease of 107 Gg CO_2 for coal in autogenerators due to a combination of the introduction of EUETS emission factors and revision to energy statistics;
- Some revisions have occurred due to a reallocation of fuels from the Other Industry sector to Power Stations to account for the fuels used to generate power in the Crown Dependencies. This is because the fuels allocated to power stations in the UK inventory refer to power stations in the UK only, whereas the commodity balance totals in DUKES also include the Crown Dependencies. Therefore in order to maintain the over all fuel balance with the national energy statistics, whilst retaining the accuracy of the estimates for UK power stations, fuel has been reallocated from the Other Industry sector.

3.3.5.1.2 *Methane (CH_4)*

- There was an overall increase in emissions of 0.07 Gg CH_4. The major cause of this decrease was a revision to the energy statistics for natural gas in Other Industrial Combustion. This caused an increase in emissions of 0.12 Gg CH_4.

3.3.5.1.3 *Nitrous Oxide (N_2O)*

- There has been an overall decrease of 0.04 Gg N_2O from 1A2. This was mainly caused by revision to gas oil energy statistics for industrial off-road machinery.

3.3.5.1.4 *Nitrogen Oxides (NO_x)*

- There have been a series of recalculations to estimated emissions from natural gas combustion by industrial plant due to revisions to emission factors so that the estimates take account of the typically higher emissions from stationary engines when compared with, for example, boilers. Estimates increase by 27 Gg.

3.3.5.1.5 *Carbon Monoxide (CO)*

- Estimated emissions from industrial combustion of natural gas have increased by 19 Gg due to revisions to emission factors to include the contribution from stationary engines.
- Estimates emissions from industrial combustion of wood have increased by 10 gG due to a upwards revision to both the emission factor used and the conversion factor used to convert the activity data from energy to mass terms.

3.3.5.1.6 *Sulphur Dioxide (SO_2)*

- Estimated emissions from industrial combustion of waste lubricants have fallen by 2 Gg following a review of the methodology used to generate activity data for waste oil.
- Estimates for industrial fuel oil combustion are also 2 Gg lower, due to revisions to consumption data.
- A decrease of 1 Gg occurs for cement clinker production due to the incorporation of updated data on emissions reported by process operators.

3.3.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

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 and LPG.

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[7]. 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

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[7] 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.

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 BERR 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.

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 Re-Calculations

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

3.4.5.1.1 *Carbon Dioxide (CO_2)*

- Emissions from 1A3 Transport have increased overall by 196 Gg CO_2, due to changes in estimates for road transport and civil aviation.
- Estimated emissions from category 1A3a Aviation decreased by 45 Gg CO_2 This was due to a combination of corrections to the previous year's data and an improvement to the methodology; this involved improvement to the allocation of aviation spirit;
- Although there has been no change in total CO_2 emissions from road transport in the UK, there are revisions in the allocation between vehicle types due to revisions in activity data

used for individual vehicle categories, including speed data and the petrol/diesel mix for cars on different road type. Improvements have been made to emissions from the Overseas Territories and the Crown Dependencies.

3.4.5.1.2 *Methane (CH_4)*

- There has been an increase in the estimated methane emissions from road transport of 0.37 Gg for 2006. This was due to the change in speed data used for different road types and the increased activity assumed for diesel cars relative to petrol cars.

3.4.5.1.3 *Nitrous oxide (N_2O)*

- There has been a large decrease in the estimate of nitrous oxide emissions from road transport in all years (12.5 Gg in 2006) due to the change in vehicle emission factors used, combined with changes in activity data. The new emission factors imply road transport emissions are now declining since 1999 due to the penetration of lower emitting petrol cars in the fleet.

3.4.5.1.4 *Nitrogen Oxides (NOx)*

- Emission estimates for road transport in 2006 decreased by 39Gg due to the use of new vehicle emission factors combined with changes in activity data (speeds, fuel mix of cars on different roads and the variation in car mileage with age). Emissions are lower in 2007 than 2006 due to increased penetration of cleaner vehicles.

3.4.5.1.5 *Carbon Monoxide (CO)*

- Emission estimates for road transport in 2006 decreased by 69Gg due to changes in activity data (speeds, fuel mix of cars on different roads and the variation in car mileage with age). Emissions are lower in 2007 than 2006 due to increased penetration of cleaner vehicles.

3.4.5.1.6 *Non-Methane Volatile Organic Compounds (NMVOC)*

- Emission estimates for road transport in 2006 decreased by 1.5Gg due to changes in activity data (speeds, fuel mix of cars on different roads and the variation in car mileage with age). Emissions are lower in 2007 than 2006 due to increased penetration of cleaner vehicles.

3.4.6 Source Specific Planned Improvements

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

3.5 SOURCE CATEGORY 1A4 – OTHER SOURCES

3.5.1 Source Category Description

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

- ***Commercial/Institutional*** – emissions from fuel combustion in commercial and institutional buildings;

- ***Residential*** – emissions from fuel combustion in households; and
- ***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 BERR 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 Re-Calculations

Recalculations in this sector are detailed by individual gas below.

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 2006 inventory (2008 NIR). Comparisons are made between the current inventory (1990-2007) and the previous inventory (1990-2006) for the year 2006.

3.5.5.1.1 ***Carbon Dioxide (CO_2)***

- Overall CO_2 emissions from 1A4 decreased by 53 Gg CO_2. Although this is a relatively small overall change, there have been some more significant changes within the sector. The main reasons for these changes are highlighted below;
- 1A4a emissions from natural gas decreased by 370 Gg CO_2 due to revisions to national energy statistics;
- 1A4b emissions from natural gas increased by 270 Gg CO_2 due to revisions to national energy statistics;
- All other changes to CO2 emissions from sector 1A4 occurred due to revisions to national energy statistics.

3.5.5.1.2 ***Methane (CH_4)***

- There was an overall increase in emissions from 1A4 of 1.64 Gg CH_4. The main reasons for this change are highlighted below;
- The majority of this change was an increase of 1.49 Gg CH_4 due to the revision of the emission factor used for domestic combustion of wood;
- Other minor changes were due to revision to national energy statistics.

3.5.5.1.3 ***Nitrous Oxide (N_2O)***

- The main change was an increase of 0.01 Gg N_2O due to the revision of the emission factor used for domestic combustion of wood;
- Other minor changes were due to revision to natural gas consumption in national energy statistics.

3.5.5.1.4 ***Nitrogen Oxides (NOx)***

- Emission estimates for gas combustion by the miscellaneous industrial/commercial sector rose by 5 Gg due to revisions to emission factors to include the contribution from stationary engines.

3.5.5.1.5 ***Carbon Monoxide (CO)***

- Estimated emissions of CO from domestic combustion of wood increased by 25 Gg as a result of revision to the GCV given in DUKES.
- A revision to the emission factor for CO from domestic coal fires leads to a reduction in estimates of 5 Gg.
- Revised energy statistics reduces CO emission estimates for domestic coke combustion by 1 Gg.

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

- Estimated emissions of NMVOC from domestic combustion of wood increased by 8 Gg as a result of revision to the GCV given in DUKES.

3.5.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

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	1A5	All fuels	EFs vary somewhat across time series based on the UK carbon factor review in 2004.
CH_4, N_2O	1A5	All fuels	EFs are constant over the entire time series

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 Re-Calculations

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. In 2007, the shipping emission contributed 18% to total bunker emissions, with aviation contributing the remaining 82%. 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 2007), emissions estimated by the Reference Approach have fallen by 3.7 % compared with 8.3% 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 BERR 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 Re-Calculations

3.12.5.1 Re-Calculation by Gas

There were no significant changes

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, through their annual emissions reporting mechanism to the UK regulatory agency (the Department of Energy & Climate Change), 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 1995-2007. Additional 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. In recent years these EU ETS data have been used by operators to update their EEMS emission estimates for combustion processes, ensuring consistency between EEMS and EU ETS, and by the Inventory Agency as a useful Quality Check on time series consistency of carbon emission factors.

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 terminals are also based on annual emissions data reported by process operators under the EEMS system, regulated by DECC. These onshore sites also report emissions data 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 some terminals, occasional data gaps are evident in the EEMS data, most notably for methane and NMVOC emissions from oil loading activities. In these instances, the emission estimates reported under IPC/IPPC are used to provide an indication of the level of emissions in that year, but the longer time series of the EEMS data for Scottish sites has led the Inventory Agency to use the EEMS data as the primary data source for these terminals.

For the EEMS reporting cycle for 2006 data, a new online system of operator reporting was implemented by DECC. 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).

In the 2007 dataset, many of these problems had been resolved, as the DECC Oil & Gas team of regulators had engaged with several operators to identify and resolve reporting gaps and inconsistencies. One or two non-reporting sites for some sources were still evident, however.

To resolve these data gaps, the Inventory Agency agreed the following actions with DECC (Furneaux, 2008):

- Onshore loading: Two sites had omitted to report in 2007, and data have been extrapolated from earlier years;
- Onshore Fugitive sources: Several sites had omitted to report the quite minor fugitive emissions data estimates in 2007, and all of these were estimated based on extrapolation of previous data and comparison against PI/SPRI data;
- Onshore Own Gas use: One site had omitted to report in 2007, and data have been extrapolated from previous years.

Some methodological revisions have been made in the 1990-2007 data compilation, following discussion with the DECC Oil & Gas team, and the DECC Energy Statistics team. There are two reporting systems from upstream oil & gas processing in the UK; the EEMS system provides emissions data to the DECC Oil & Gas team, whilst the Petroleum Processing Reporting System (PPRS) is used to report some supplementary data to the DECC Energy Statistics team, including data on gas flaring & venting volumes at offshore and onshore installation. The former system meets an environmental emissions reporting requirement, whilst the latter meets other regulatory licensing reporting requirements. Whilst the two systems might be expected to reflect similar trends in activities, where reported activities coincide (such as gas flaring and venting), consultation with the DECC teams has indicated that the two systems are largely independent.

Further to this, the development of the EEMS dataset has enabled greater access to reported activity data that have been used to calculate the emissions. These EEMS-derived activity data enable greater analysis of the oil & gas emissions and related emission factors.

In the compilation of the 1990-2007 inventory data, therefore, where previously the EEMS emissions were reported alongside the PPRS activity data (e.g. in the case of gas flaring and venting), the EEMS-derived activity data are now used. In most cases, this has led to an improvement in data transparency and easier query of Implied Emission Factor trends. However, the EEMS activity data are only available back to 1997, and hence the activity data back to 1990 have been extrapolated using the PPRS time series.

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, 2008) 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 petrol 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 1995-2007. 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 2008 by DECC and Oil and Gas UK now provides a more consistent time series of data for the range of activities within this sector. However, whilst the EEMS data quality appears to be improving over recent years, the completeness of emissions reported via the EEMS reporting system is still subject to uncertainty as reporting gaps for some sites are still evident. The Inventory Agency continues to work with the regulatory agency, DECC, in the continued development of emission estimates from this sector. Full details are given in **Annex 3 A3.3.8.2**.

3.13.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. 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 (2007) data submission indicate that there is still some further improvement to the QA/QC of the source data by operators regulators alike, but improvements compared to the 2006 dataset are evident.

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 Re-Calculations

A number of recalculations have been made due to new data becoming available for 2006 in the oil & gas exploration and production sector, or new estimates based on interpolation and extrapolation of existing data. (See **Section A3.3.8** for details).

3.13.5.1 Recalculation by Gas

The following section describes the main changes that have occurred in sector 1B2 per pollutant since the publication of the 2006 inventory. Comparisons are made between the current inventory (1990-2007) and the previous inventory (1990-2006) for the year 2006.

3.13.5.1.1 *Carbon Dioxide (CO_2)*

- Emissions from 1B2a have increased slightly by 8 Gg CO_2, due to an increase in estimates of fugitive emissions (from previously unreported sites) partly offset by a new lower estimate for emissions from well testing in 2006;
- Estimated emissions from category 1B2c (flaring) have increased by 66 Gg CO_2, due to increased estimates from three onshore terminals.

3.13.5.1.2 *Methane (CH_4)*

- There has been a small increase in estimated methane emissions from 1B2a of 0.12 Gg. Increased estimates from fugitive and oil loading & storage emissions are partly offset by estimated reductions in estimates for methane emissions from well testing;
- Emissions from 1B2c (flaring) increased by 0.32 Gg CH_4, due to increased estimates of emissions from three onshore terminals, whilst emissions from 1b2c (venting) also increased by 1.79 Gg CH_4 due to increased estimates of emissions from three (different) onshore terminals.

3.13.5.1.3 ***Carbon Monoxide (CO)***

- Emissions from 1B2a have decreased by 0.29 Gg, due to reduced estimates of emissions from well testing in 2006;
- Emissions from 1B2c (flaring) have increased by 0.23 Gg due to increased estimates of emissions from three onshore terminals

3.13.5.1.4 ***Non Methane Volatile Organic Compounds (NMVOCs)***

- Emissions from 1B2a have increased by 28.4 Gg, due to increased estimates of emissions from oil loading at three onshore terminals where no data have been submitted by operators;
- Revisions to emissions from flaring and venting for several sites have also led to increases of around 1.1 Gg NMVOC.

3.13.6 Source Specific Planned Improvements

The significant revisions undertaken through consultation with DECC and Oil & Gas UK in the 1990-2007 inventory compilation cycle have resolved a number of errors evident in the 2006 dataset, although some data gaps and inconsistencies remain. Further consultation with DECC is planned for 2009, to try to resolve the remaining site data issues, notably a handful of oil & gas terminals that report an inconsistent scope of emissions to the EEMS system each year. Some data gaps in 2007 have been filled through extrapolation of historic data, in consultation with DECC, and these sites will be prioritised for further contact during 2009.

3.14 GENERAL COMMENTS ON QA/QC

3.14.1 DECC Energy Balance Data

DECC provides the majority of the energy statistics required for compilation of the NAEI and the GHGI. These statistics are obtained from the DECC 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 (ONS, 2002)* – and as such is subject to regular QA audits and reviews.

DECC include 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, DECC 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. DECC also uses an energy balance approach to verify that individual returns are sensible. Any queries are followed up with the reporting companies. DECC 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 DECC 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:

- Consistency in the techniques used to compile activity data;
- Correct choice of source and fuel specific emission factors for each year of the inventory; and
- 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 DECC 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 15 sites producing cement clinker during 2007.

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 (2008), 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 to 2007 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; and
- 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 2001-2007 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 Re-Calculations

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

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 2007. 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, 2008). 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 130t 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 Re-Calculations

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

4.3.6 Source Specific Planned Improvements

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

4.4 SOURCE CATEGORY 2A3 – LIMESTONE & DOLOMITE USE

4.4.1 Source Category Description

Limestone and dolomite are added to sinter where they are calcined, the products subsequently acting as slag formers in blast furnaces. Some limestone or dolomite may be added directly to blast furnaces instead of 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 Re-Calculations

A revision has been made to the estimates of gypsum produced by FGD processes using data on carbon dioxide emissions from these processes. This leads to an increase in the emission estimate of 56 Gg CO_2 in 2006.

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 coke to calcine limestone, thereby producing lime and CO_2. The CO_2 resulting from combustion of the coke is reported under 1A2f, while the CO_2 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, 2008). 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, 2008).

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; and
- 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 Re-Calculations

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, 2008).

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 Re-Calculations

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 2007, 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, 2008). 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, 2008 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 Re-Calculations

Due to some refinement of the method used to estimate the contribution of fuel combustion to emissions from Fletton brickworks, there has been a decrease of 12 Gg CO_2 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 2007, 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:

a) Natural gas equivalent to carbon sequestrated in methanol (see above);
b) Natural gas equivalent to the CO_2 emitted from ammonia manufacture; and
c) 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 Re-Calculations

Revised emissions data have been supplied by one operator, leading to a reduction in estimated emissions of 771 Gg of CO_2.

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 2007. 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 1990-2007 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); and
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 Re-Calculations

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, 2008). 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.

In the 2007 NIR, a major recalculation was made to emissions from this sector. This was because improved methods were implemented by the plant operator to estimate emissions. Previously, the emission factor used was based on a literature factor, but in response to an improvement condition in the plant's PPC (Pollution Prevention and Control) permit, new emission factors based on measurement data are now used.

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 Re-Calculations

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 2007 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; and
- 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 2007. 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, 2008). 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, 2008). 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 (2008). 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 (2008). 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 Re-Calculations

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

- Changes to the emissions data given in the Pollution Inventory and other sources; and
- The influence of emissions data for 2007, 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 2006 might previously been filled using emissions reported for 2005, whereas now the mean of the 2005 and 2007 emissions would be used).

The various re-calculations have usually resulted in very small changes in emissions from these sources compared with values in the last version of the inventory.

4.13.5.1 Re-Calculation by Gas

The following section describes the main changes that have occurred in sector 2A5 per pollutant since the publication of the 2006 inventory (2008 NIR). Comparisons are made between the current inventory (1990-2007) and the previous inventory (1990-2006) for the year 2006.

4.13.5.1.1 ***CH_4***

- Emission estimates for methane have increased by 1 Gg due to inclusion of a chemical process previously missing from the estimates.

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 BERR 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 Re-Calculations

Estimated emissions of CO have increased by 7 Gg due to a change from using literature factors for blast furnace emissions and use of data reported by process operators instead.

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. 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. 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 were provided directly by the operators.

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 Re-Calculations

Emissions of PFCs have been corrected, since emissions from the Scottish plant were omitted in later years in the 2008 NIR.

4.16.6 Source Specific Planned Improvements

Emissions of PFCs have recently been reviewed and updated as part of a DECC funded project to update emissions and projections of F-gases (AEA, 2008). Further work in this area is also being planned.

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 (two of which have now closed)). Alloy production involves the use of primary magnesium ingots, recycled scrap material and second-generation magnesium materials (i.e. material already made into alloys) for the production of different alloys. Both die and sand casters use these magnesium alloys to produce specific components for a wide range of industries. For the casting industry, SF_6 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 1998-2007 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.

As part of a recent study to update the F-gas inventory, castings operators were re-contacted to provide activity data for recent years (the previous survey was conducted in 2004). Some of the operators provided new data, while for others assumed values for SF_6 use were used based on the data provided for other years.

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 SF_6 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 1998-2007, 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 Re-Calculations

Emissions from castings operators have been revised for 2005 and 2006 based on new data provided by the operators.

4.17.6 Source Specific Planned Improvements

The F-gas inventory was reviewed and updated in 2008 (AEA, 2008) and further work is also planned to improve this part of the 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, 2008). 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 Re-Calculations

No significant re-calculations 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, 2008). Production of the wood products is estimated from data published by the Office of National Statistics (2008). 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 Re-Calculations

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 (2008), 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 Re-Calculations

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 were operating HCFC 22 plants, one of

which closed in 2008. 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; and
- 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 AEA (2008). 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. As a requirement of participation in the scheme, their reported emissions are verified annually via external and independent auditors. 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 for two of the operating plant, where full speciated emissions data were provided by one of the operators for most of the time series.

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.

The revised, speciated data supplied by one of the operators also included other sources of fugitive emissions that had not previously been captured in the greenhouse gas inventory. These emissions have been included in the totals for sector 2E.

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 and 2007 emissions have shown a decrease.

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 Re-Calculations

The inclusion of fully speciated emissions data from one of the operators has led to a change in the GWP weighted emissions from 1998 to 2006. This is because the mix of HFCs has a different GWP to the previous assumptions, and because a new fugitive source has been identified and included in the totals.

4.21.6 Source Specific Planned Improvements

The F-gas inventory was reviewed and updated in 2008 (AEA, 2008). Further work in this area is also planned.

4.22 SOURCE CATEGORY 2F1 – REFRIGERATION AND AIR CONDITIONING EQUIPMENT

4.22.1 Source Category Description

HFCs and HFC blends have been widely used as replacement refrigerants across virtually all refrigeration sub-sectors. They generally share many of the properties of CFC and HCFC refrigerants, namely low toxicity, zero and/or varying degrees of flammability and acceptable materials compatibility. Emissions of HFCs can occur at various stages of the refrigeration/air-conditioning product life-cycle:

- During the refrigeration equipment manufacturing process;
- Over the operational lifetime of the refrigeration or air-conditioning unit; and
- At disposal of the refrigeration or air-conditioning unit.

This emission category contains aggregated emission estimates from the following sector sub-divisions:

- Domestic refrigeration (including refrigerators, chest freezers, upright freezers and fridge-freezers);
- Other small hermetic refrigeration units (including through the wall air-conditioners, retail equipment, drinking water coolers etc);
- Small commercial distributed systems (including pub cellar coolers, small chill and cold stores);
- Supermarket systems;
- Industrial systems;
- Building air conditioning systems (direct use of refrigerant);
- Building air-conditioning chillers (indirect use of refrigerant);
- Refrigerated transport (refrigerated lorries, containers etc) using conventional refrigeration technology; and
- 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) and AEA (2008). 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). As part of the recent update to the F-gas inventory and projections (AEA, 2008), a range of stakeholders were re-contacted to review the parameters in the model, including emission factors and typical refrigerant blends in use. This has led to some changes in the GWP weighted emissions totals.

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) and AEA (2008).

4.22.3 Uncertainties and Time Series Consistency

Estimates of the uncertainties associated with time series data for this sector were made in AEA (2008), 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 Re-Calculations

Emissions in this category in 2006 have increased by around 798kt CO_2e, resulting mainly from the changes to the refrigerant blends in use across most of the refrigeration sub-sectors.

4.22.6 Source Specific Planned Improvements

As part of the inventory stakeholder consultation workplan, more work is planned to try and obtain improved estimates of the bank size for all of the refrigeration sub-sectors.

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 as follows:

- 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; and
- 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 AEA (2008). 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 (2008), 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 Re-Calculations

Data from 2003 onwards has been recalculated to reflect more up to date data and experience of the emissions from this source. The previous estimates were produced in 2004, when the transition from using HCFCs to HFCs was still ongoing. The assumptions in the model have been revised to reflect the actual consumption and emissions in this sector, rather than using projected data.

4.23.6 Source Specific Planned Improvements

Emissions from this source were reviewed and updated in 2008 (AEA, 2008) and further work is also planned to refine the estimates of F-gas emissions in the 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 12-13 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, updated based on the findings of a recent study (AEA, 2008). 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) and from ASSURE. 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 2.6% by 2005 (an assumption based discussion with industry representatives). There are no emissions from HFC prior to 1995. A full description of the associated methodology used is contained in AEA (2008).

4.24.3 Uncertainties and Time Series Consistency

Estimates of the uncertainties associated with time series data for this sector were made in AEA (2008), based on an understanding of the uncertainties within the sector and from discussion with industry. Uncertainties in emissions over the 1990-2005 period were estimated to be +/- 10%, and estimates from 2005 onwards are thought to be more uncertain (around 20%) since these are based on projections and anecdotal evidence. 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 Re-Calculations

Emissions from this source have been recalculated based on new data supplied in AEA, 2008, which has led to higher estimates for 2003 and lower estimates for 2004 to 2006.

4.24.6 Source Specific Planned Improvements

This sector has recently been updated, and further work is planned to improve UK estimates of F-gas emissions.

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 AEA (2008). 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 AEA (2008), 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 Re-Calculations

A new model has been used to calculate emissions from aerosols. This includes a number of improvements and corrections to the previous model, including the treatment of imported and exported aerosols, and also ensuring that all emissions are captured and occur in the correct year. In addition, projected data that were included for 2005 and 2006 have now been replaced with actual data. These changes have led to an increase in emissions of 251kt CO_2e in 2006.

No recalculations were made to emissions from MDI.

4.25.6 Source Specific Planned Improvements

Further work is planned to improve estimates of F-gas emissions.

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 Re-Calculations

There have been no recalculations made to the emissions data for this sector since the previous submission.

4.26.6 Source Specific Planned Improvements

Further work is planned to improve estimates of F-gas emissions in the UK 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. The use of HFCs in OCFs has been banned under the EC Regulation on fluorinated greenhouse gases (EC 842/2006) from July 4th 2008, except for where their use is safety critical.

4.29.2 Methodological Issues

A full description of the emissions and associated methodology used is contained in AEA (2008). 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 Re-Calculations

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

Further work is planned to improve estimates of F-gas emissions in the UK 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 37% of emissions in 2008.
The main uses of PFCs are as follows:

- 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; and
- 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) and AEA (2008). 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) and reviewed in AEA (2008), 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 +/- 30-60%, 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 Re-Calculations

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

Further work is planned to improve estimates of F-gas emissions in the UK 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; BCF, 2008). 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 Re-Calculations

Some minor recalculations have been made to the estimates for solvent emitted from use of high performance and marine coatings, to take account of updates to activity data provided by the British Coatings Federation (2008). These recalculations lead to an increase in estimated emissions of NMVOC of 2 Gg in 2006.

5.2.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

5.3 SOURCE CATEGORY 3B – DEGREASING AND DRY CLEANING

5.3.1 Source Category Description

This sector covers the use, predominantly of chlorinated solvents, for cleaning and degreasing of surfaces, dry cleaning of clothing and textiles and degreasing of leather.

Chlorinated solvents, including trichloroethene, tetrachloroethene and dichloromethane are widely used in industry to clean metallic, plastic and other surfaces, often using the process of vapour degreasing. Objects to be cleaned are suspended above boiling solvent. Solvent vapour condenses on the object and removes grease and other surface contamination. Cooling tubes at the top of the tank minimise emissions but some solvent is emitted. Cold cleaning is also used with objects being dipped in cold solvent and larger objects may be hand cleaned with solvent-soaked cloths.

Historically, 1,1,1-trichloroethane was also used as a cleaning solvent but this was prohibited due to this solvent's contribution to ozone depletion and use ceased by 1999.

Hydrocarbons and oxygenated solvents are also used as cleaning solvents, generally being used for hand cleaning or cold cleaning of objects.

Dry cleaning involves the use of tetrachloroethene to clean clothes and textiles in special equipment. The solvent is largely recovered and recycled within the machine but emissions do occur, especially in older 'open' machines, where the final drying stage involves venting of solvent-laden vapour to atmosphere.

Sheepskins must be degreased due to their high fat content. Degreasing can be done using either hydrocarbon or chlorinated solvents.

5.3.2 Methodological Issues

Emission estimates for surface cleaning processes are based on estimates of annual consumption and emission factors. Consumption estimates are based on data from UK industry sources and UK and European trade associations, together with some published data. Some extrapolation of data is necessary, using Index of Output data produced annually by the Office for National Statistics (ONS, 2008), 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 Re-Calculations

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 Re-Calculations

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 Re-Calculations

One minor recalculation has been made to the estimates for solvent emitted from use of 'other' inks, to take account of updates to activity data provided by the British Coatings Federation (2008). These recalculations lead to an increase in estimated emissions of NMVOC of 2 Gg in 2006.

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

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 and 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 included here also, but field burning ceased in the UK in 1993.

Annex 3.6 contains more detailed descriptions of the methods used to estimate emissions in this sector.

6.2 SOURCE CATEGORY 4A – ENTERIC FERMENTATION

6.2.1 Source Category Description

Methane is produced as a by-product of enteric fermentation. Enteric fermentation is a digestive process whereby carbohydrates are broken down by micro-organisms into simple molecules. Both ruminant animals (e.g. cattle and sheep), and non-ruminant animals (e.g. pigs and horses) produce CH_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. Hence it is assumed that breeding sheep are alive the whole year but that lambs and other non-breeding sheep are only alive 6 months of a given year (based on Smith and Frost, 2000). These assumptions for lamb can not be improved at the present time as there are no direct measurements of methane emission by lambs in the UK.

6.2.3 Uncertainties and Time Series Consistency

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.2.1** and **Table A7.2.2**, provides estimates of uncertainty according to IPCC source category.

Emissions are calculated from animal population data and appropriate emission factors. The animal population data are collected in an annual census, published by Defra. This is a long running publication and the compilers of the activity data strive to use consistent methods to produce the activity data. The time series consistency of these activity data is very good due to the continuity in data provided.

6.2.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 6.9**.

6.2.5 Source Specific Re-Calculations

Animal numbers for sheep and non-dairy cattle were revised for 2006, leading to a decrease in emissions of 273Gg CO_2e. Emissions from the Overseas Territories have also been updated and improved.

6.2.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

6.3 SOURCE CATEGORY 4B – MANURE MANAGEMENT

6.3.1 Source Category Description

This category reports emissions of methane from animal manures as well as emissions from their manures arising during its storage.

6.3.2 Methodological Issues

6.3.2.1 Methane emissions from animal manures

A more detailed description of the method used and emission factors can be found in **Annex 3**, **Section A3.6**.

Methane is produced from the decomposition of manure under anaerobic conditions. When manure is stored or treated as a liquid in a lagoon, pond or tank it tends to decompose anaerobically and produce a significant quantity of methane. When manure is handled as a solid or when it is deposited on pastures, it tends to decompose aerobically and little or no methane is produced. Hence the system of manure management used affects emission rates. Emissions of methane from animal manures are calculated from animal population data (Defra, 2008a) in the same way as the enteric emissions.

Apart from cattle, lambs and deer, these are all IPCC Tier 1 defaults (IPCC, 1997) and do not change from year to year. The emission factors for lambs are assumed to be 40% of that for adult sheep (Sneath *et al.* 1997). Emission factors for dairy cattle were calculated from the IPCC Tier 2 procedure. There was a revision (in 2002) of the allocation of manure to the different management systems based on new data. This is detailed in **Section 6.3.2.2**. For dairy cattle, the calculations are based on the population of the 'dairy breeding herd' rather than 'dairy cattle in milk' used in earlier inventories. The former includes 'cows in calf but not in milk'. The waste factors used for beef and other cattle are now calculated from the IPCC Tier 2 procedure but do not vary from year to year.

6.3.2.2 Nitrous Oxide emissions from Animal Waste Management Systems

Animals are assumed not to give rise to nitrous oxide emissions directly, but emissions from their manures during storage are calculated for a number of animal waste management systems (AWMS) defined by IPCC. Emissions from the following AWMS are reported under the Manure Management IPCC category:

- Flushing anaerobic lagoons. These are assumed not to be in use in the UK.
- Liquid systems
- Solid storage and dry lot (including farm-yard manure)
- Other systems (including poultry litter, stables)

According to IPCC (1997) guidelines, the following AWMS are reported in the Agricultural Soils category:

- All applied animal manures and slurries
- Pasture range and paddock

Emissions from the combustion of poultry litter for electricity generation are reported under power stations.

The IPCC (1997) method for calculating emissions of N_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 Common Reporting Format 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 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.

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. Assigning this ‘stored in house’ manure to ‘daily spread’ is acceptable only if emissions from the housing phase are thought to be very small. Calculations were performed with the N_2O Inventory of Farmed Livestock to compare housing and storage phases (Sneath *et al.* 1997). For pigs and poultry, the emission factor for housing is the same as or greater than that of storage. It would therefore lead to significant underestimation to use the daily spread emission factor. The FYM in this case has therefore been re-allocated to SSD or ‘other’ as appropriate.

For dairy and non-dairy cattle, the emission factor for the housing phase is around 10% of the storage phase, so the non-stored FYM has been split between SSD and DS to account for this.

Emissions from grazing animals (pasture range and paddock) and daily spread are calculated in the same way as the other AWMS. However, emissions from land spreading of manure that has previously been stored in a) liquid systems, b) solid storage and dry lot and c) other systems, are treated differently. These are discussed in **Annex 3**, **Section A3.6.3.7**.

6.3.3 Uncertainties and Time Series Consistency

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.2.1** and **Table A7.2.2**, provides estimates of uncertainty according to IPCC source category.

Emissions are calculated from animal population data and appropriate emission factors. The animal population data are collected in an annual census, published by Defra. This is a long running publication and the compilers of the activity data strive to use consistent methods to produce the activity data. The time series consistency of these activity data is very good due to the continuity in data provided.

6.3.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC procedures which are discussed in **Section 6.9.**

6.3.5 Source Specific Re-Calculations

Emissions in 2006 have been recalculated to reflect revised animal numbers for non-dairy cattle and sheep. The emission factor for methane emissions from pig wastes has been revised, in line with the value in the 2000 GPG. The emission factor for N_2O from poultry wastes has also been revised in line with the 2000 GPG.

6.3.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review including the use of more detailed emission factors and activity data to allow estimation of the effect of future mitigation policies.

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:

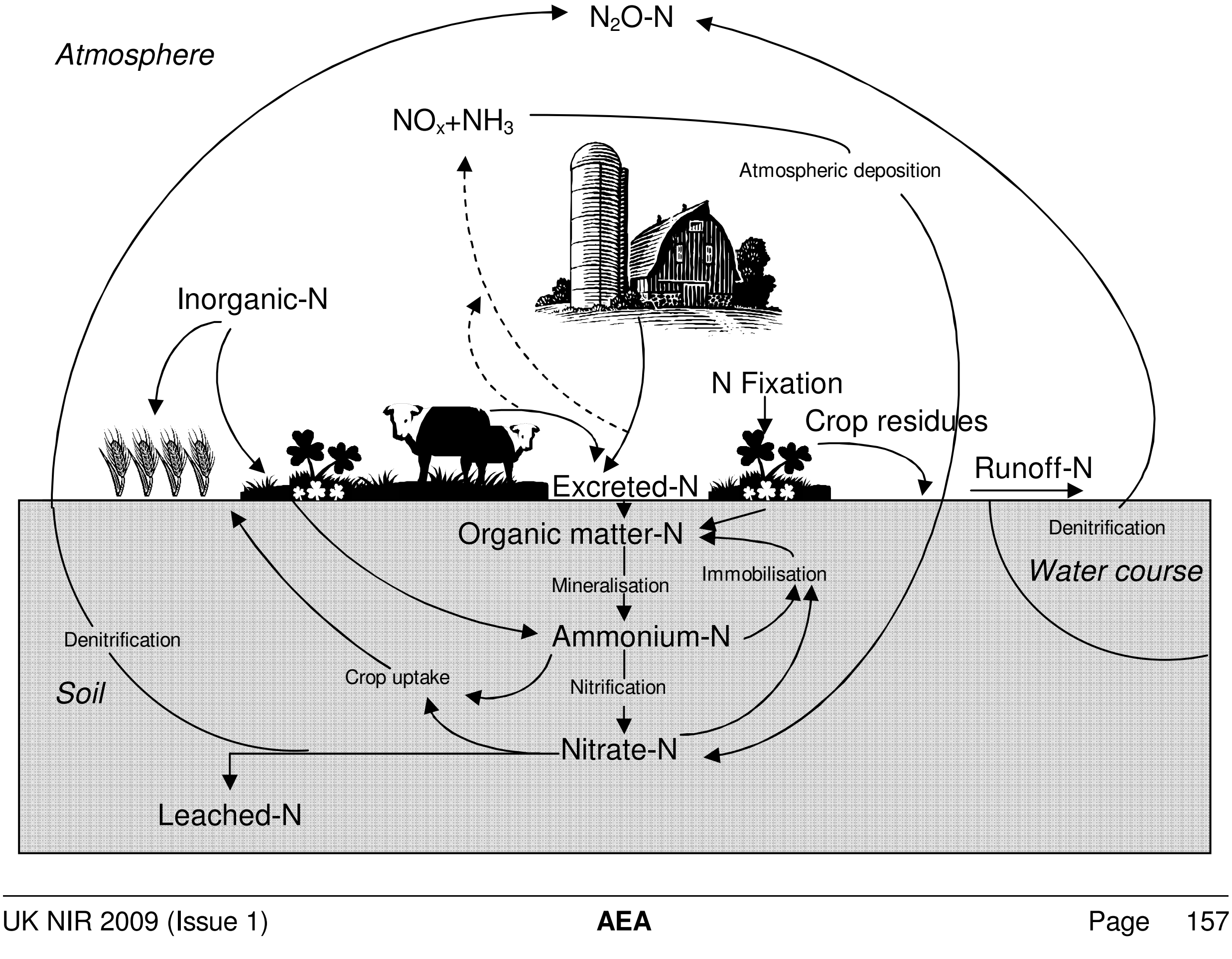
(i) The use of inorganic fertilizer
(ii) Biological fixation of nitrogen by crops
(iii) Ploughing in crop residues
(iv) Cultivation of histosols (organic soils)
(v) Spreading animal manures on land
(vi) Manures dropped by animals grazing in the field

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, 2008a) and fertilizer application rates (BSFP, 2007).

6.5.2.2 Biological Fixation of Nitrogen by crops

Emissions of nitrous oxide from the biological fixation of nitrogen by crops are calculated using the IPCC (1997) methodology and IPCC default emission factors.

The data for the ratio residue/crop are default values found under Agricultural Soils or derived from Table 4.17 in Field Burning of Agricultural Residues (IPCC, 1997). Crop production data are taken from Defra (2008a, 2008b). 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). For this source the calculation of the emission requires estimating the amount of N that is fixed and then the emission factor is applied to this value previously with the result that the Implied Emission Factor reported in the old CRF, which was derived from the ratio N_2O emission: dry matter, was different from the IPCC default value (0.013). In the new CRF this has been modified and the IEF coincides with the IPCC default value.

6.5.2.3 Crop Residues

Emissions of nitrous oxide from the ploughing in of crop residues are calculated using the IPCC (1997) methodology and IPCC default emission factors.

Production data of crops are taken from Defra (2008a, 2008b). Field burning has largely ceased in the UK since 1993. For years prior to 1993, field-burning data were taken from the annual MAFF Straw Disposal Survey (MAFF, 1995).

6.5.2.4 Histosols

Emissions from histosols were estimated using the IPCC (2000) default factor of 8 kg N_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 nitrogen applied to the land and applying IPCC emission factors.

The summation is for all animal types and manure previously stored in categories defined as a) liquid, b) solid storage and dry lot and c) other.

6.5.2.7 Atmospheric deposition of NO_X and NH_3

Indirect emissions of N_2O from the atmospheric deposition of ammonia and NO_x are estimated according to the IPCC (1997) methodology but with corrections to avoid double counting N. The sources of ammonia 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.

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 nitrogen considered, are synthetic fertiliser application and animal manures applied as fertiliser.

6.5.3 Uncertainties and Time Series Consistency

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.2.1** and **Table A7.2.2**, 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.

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 Re-Calculations

The N excretion factors have been revised according to values provided by Ken Smith and Bruce Cottrill (ADAS). These were corrected for all years 1990-2007. 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, 2008).

6.5.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

6.6 SOURCE CATEGORY 4E – PRESCRIBED BURNING OF SAVANNAS

This source is not relevant in the UK.

6.7 SOURCE CATEGORY 4F – FIELD BURNING OF AGRICULTURAL RESIDUES

6.7.1 Source Category Description

This sector covers the emissions of non-CO_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, 2008a) and data on the fraction of crop residues burnt (MAFF, 1995; ADAS, 1995b). Field burning ceased in 1993 in England and Wales. Burning in Scotland and Northern Ireland is considered negligible, so no estimates are reported from 1993 onwards. The carbon dioxide emissions are not estimated because these are part of the annual carbon cycle.

6.7.3 Uncertainties and Time Series Consistency

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.2.1** and **Table A7.2.2**, provides estimates of uncertainty according to IPCC source category.

Field burning ceased in 1994, and emissions are reported as zero after this date.

6.7.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 6.9.**

6.7.5 Source Specific Re-Calculations

There have been no recalculations.

6.7.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

6.8 SOURCE CATEGORY 4G - OTHER

There are no emissions reported in the UK under this category

6.9 GENERAL COMMENTS ON QA/QC

The livestock activity data used for constructing the inventory are supplied annually from the June census by the Defra Economics and Statistics Group, who follow documented QA procedures. Activity data on mineral fertiliser are calculated using application rates from Defra's annual British Survey of Fertiliser Practice (BSFP, 2008) 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, eliminating the need for double entry procedures. Annual comparisons of emission factors and other coefficients used are made by contractors compiling the inventory on behalf of Defra and by Defra itself. Any changes are documented in the spreadsheet and in the accompanying chapter of the National Inventory Report. Hardcopies of the submitted inventories, associated emails and copies of activity data are filed in Government secure files adhering to Government rules on document management.

Defra contractors who work on compiling the agricultural inventory, NWRes, operate strict internal quality assurance systems with a management team for each project overseen by an experienced scientist with expertise in the topic area. A Laboratory Notebook scheme provides quality control through all phases of the research and these are archived in secure facilities at the end of the project. All experiments are approved by a consultant statistician at each of the planning, data analysis and interpretation and synthesis stages. A range of internal checks exists to ensure that projects run to schedule, and internal and external (*viz.* visiting group procedures, etc.) reviews ensure the quality of the outputs.

7 Land-Use, Land Use Change and Forestry (CRF Sector 5)

7.1 OVERVIEW OF SECTOR

This sector contains both sources and sinks of carbon dioxide. The sinks, (or *removals*), are presented as negative quantities. LULUCF is estimated to have been a net sink since 1999, amounting in 2007 to some 1.82 Mt CO_2 equivalent.

There have been improvements in methodology and minor revisions of the data used for this Sector for the 2009 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 (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 2007 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 2929 Gg CO_2 compared to 2928 Gg CO_2 in the 2006 National Inventory Report. For 2006 a net removal of -1816 Gg CO_2 is estimated here compared to a net removal of -1953 Gg CO_2 in the 2006 Inventory. These differences are due to improved methods for determining harvested wood products and other minor data revisions.

Included are the annual land use transition matrices for the UK in 1990 and 2007 (**Table 7.1 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 2007 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 2006-2007

From: To:	Forest	Cropland	Grassland	Wet-lands	Settlements	Other Land	Total (final)
Forest	*2 426 780*	973	8 720	-	497	-	2 436 970
Cropland	0	*5 539 894*	95 948	-	942	-	5 636 785
Grassland	625	83 447	*12 512 822*	-	4 662	-	12 601 556
Wetlands	-	-	-	-	-	-	-
Settlements	445	2 475	13 462	-	*2 107 680*	-	2 124 062
Other Land	-	-	-	-	-	1633621	1 633 621
Total (initial)	2 427 849	5 616 789	12 630 952	-	2 113 782	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 assumed to apply to newly planted forests with ‘poor’ soils only, 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. The C-Flow model produces separate gains and losses for carbon stock change in living biomass, rather than net change. A detailed description of the method can be found in **Annex 3**, **Section 3.7.1** for biomass, dead mass and soil.

Deforestation associated with harvested wood products is included in this year's inventory; the removal of timber from harvesting or thinning operations is considered as deforestation and therefore should be reported. Deforestation is the result of either a land use change or thinning. It is assumed that a change in land use will be to Grasslands or Settlements and will be reported in Sector 5.C.2 and 5.E.2 respectively. Forest land which is thinned will undergo a reduction in area; these changes are reported in 5.A.1. A detailed description of method used can be found in **Annex 3, Section 3.7.10.**

Wildfires on forest land only affect a small area of the UK and do not result in land use conversion. The approach (described in **Annex 3, Section 3.7.5**) is Tier 2, using country-specific activity data and default emission factors. There is no information on the age and type of forest that is burnt by 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 were 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 Settlements 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 to 2007 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 has been developed, and will be released in March this year. This 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 Re-Calculations

The estimates of emissions and removals due to afforestation were updated with planting statistics for 2007.

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 started 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 CO_2, *i.e.* there is an ongoing change in soil carbon stock.

7.3.1.3 Application of Lime (5.B.1)

Emissions of carbon dioxide from the application of limestone, chalk and dolomite to cropland were estimated using the method described in the IPCC 1996 Guidelines (IPCC, 1997a, b, c). Data on the use of limestone, chalk and dolomite for agricultural purposes is reported in 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 the total is published because of commercial confidentiality rules for small quantities (Office of National Statistics 2007). The data for 2008 were unavailable for inclusion in this year's inventory; figures were assumed to be equal to the values estimated for 2007 at the time of the 2006 inventory. 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 2007. A fourth CEH Countryside Survey took place during 2007 which should allow the matrices to be updated in 2010.

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 2010.

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 is 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 Re-Calculations

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 2007 emissions due to liming have been estimated; the new data were not available in time for this year's inventory. Values are assumed to be equal to those estimated for 2007 at the time of the 2006 inventory. The availability of this data for future reports is being evaluated.

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 re-calculations 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. 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 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. New data for 2008 were unavailable for this year’s report; figures were assumed to be equal to the values estimated for 2007 at the time of the 2006 inventory. 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 Re-Calculations

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 2003-2007 were estimated by extrapolation from earlier years.

7.4.5.2 Peat Extraction

Only peat used in horticulture is reported in this category. Peat used as a fuel is reported in the Energy Sector of the UK Inventory.

7.4.5.3 Application of Lime to Grassland

The 2007 estimates of emissions due to liming have been assumed to be equal to those estimated for 2007 at the time of the 2006 inventory, due the unavailability of data for this year's inventory.

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

No recalculations were undertaken for this category.

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 will be reported on in due course.

7.5 CATEGORY 5D – WETLANDS

7.5.1 Source/Sink Category Description

In the UK, Wetlands will either be saturated land (e.g. bogs, marshes) and, due to the classifications used in the Countryside Survey, will fall into the Grassland category or into open water (e.g. lakes, rivers, reservoirs), which is included in the Other Land category. Table 5.D. (Wetlands) is therefore completed with 'IE' (Included Elsewhere).

7.6 CATEGORY 5E – SETTLEMENTS

7.6.1 Source/sink Category Description

Category 5.E (Settlements) is disaggregated into 5.E.1 Settlements remaining Settlements and 5.E.2 Land converted to Settlements. The area of Settlements in Category 5.E.1 is considered not to have long term changes in carbon stock. Category 5.E.2 is disaggregated into conversions from Forest Land, Cropland and Grassland. These conversions are further disaggregated by a) the four geographical areas of England, Scotland, Wales and Northern Ireland and b) two time periods, 1950 - 1989 and 1990 onwards. Biomass burning emissions 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 Re-Calculations

7.6.5.1 Emissions Due to Biomass Burning after Conversion of Forest Land to Settlements

No recalculations were undertaken for this category.

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

No recalculations were undertaken for this category.

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 Re-Calculations

The afforestation activity data (which is also the activity data for the HWP activity) has been updated with new values for 2007.

The total LULUCF emissions from the Overseas Territories and Crown Dependencies 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. However, the emissions estimated from Harvested Wood Products 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

The Centre for Ecology and Hydrology has put in place high quality assurance standards, and selects subcontractors from professional organisations who meet those standards. The general standards are as follows:

- 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; and
- 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.

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.

8.2.2 UK Waste Management Disposal to Land Legislation and Guidance

The legal basis of regulation of landfills in the UK comes from two European Union directives:

- Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control (the “IPPC Directive), and
- Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste (the “Landfill Directive”).

The IPPC Directive is designed to prevent, reduce and eliminate pollution at source through the efficient use of natural resources and to help industrial operators move towards greater environmental sustainability. The directive was originally implemented by the Pollution Prevention and Control (England and Wales) Regulations 2000, made under the Pollution Prevention Control Act 1999, but these regulations have since been superseded by the Environmental Permitting Regulations 2008. Under IPPC, a system of permits covers plant operating conditions, emission limits for certain substances to air, land and water and annual reporting of pollutant releases.

IPPC requires that industrial (and agricultural) processes with a high potential to cause pollution require an Environmental Permit to operate, and that permit can only be issued if certain environmental conditions are met. Landfilling of waste is subject to IPPC, except for very small sites receiving less than 10 tonnes of waste per day, or 25,000 tonnes/ year.

The Environmental Permit specifies the emission limits for relevant pollutants and operating conditions, based on Best Available Techniques (BAT), taking into account the technical characteristics of the installation, its geographic location and local environmental conditions. Measures beyond BAT may also be required, to achieve desired Environmental Quality Standards.

The Landfill Directive aims to reduce the pollution potential from landfilled waste that can impact on surface water, groundwater, soil, air, and also contribute to climate change. In England and Wales the directive is applied under the Landfill (England and Wales) Regulations 2002, also made under the Pollution Prevention Control Act 1999, and must be fully implemented by July 2009. In Scotland, the Directive is implemented through the Landfill (Scotland) Regulations 2003, as amended.

The Directive aims to improve standards of landfilling across Europe by setting specific requirements for the design and operation of landfills, and for the types of waste that can be accepted in landfills. All landfills are required to comply with the Directive's requirements, although a transitional period is allowed for landfills existing at 16 July 2001. In accordance with the Article 4 of the Directive, landfills are classified on the basis of the types of waste they are licensed to receive, namely Hazardous, Non-Hazardous or Inert waste. Because Non-Hazardous landfills receive the predominant amount of biodegradable waste, this type of landfill accounts for nearly all the methane emitted from UK landfills, with emissions from Inert and Hazardous waste landfills being considered negligible.

The Landfill Directive sets demanding targets to reduce the amount of biodegradable municipal waste sent to landfill, and compliance with these targets is a key driver for UK waste management policy. In addition, the Directive defines the requirements for the issue and contents of an Environmental Permit, and outlines the principles by which landfills must be managed and operated. The Directive requires in particular that "Appropriate measures shall be taken in order to control the accumulation and migration of landfill gas" and that "Landfill gas shall be collected from all landfills receiving biodegradable waste and the landfill gas must be treated and used. If the gas collected cannot be used to produce energy, it must be flared.".

The principle regulator for processes controlled under the IPPC Directive, including landfills, in the UK is the Environment Agency, which has jurisdiction in England and Wales where the greatest number of regulated sites are located. A similar role is fulfilled in Scotland by the Scottish Environmental Protection Agency (SEPA) and in Northern Ireland by the NI Environment Agency (formerly the Environment and Heritage Service).

Extensive guidance for operators of landfill sites is available from the UK environmental regulators. This includes a series of Technical Guidance notes (TGNs) prepared by the Environment Agency on specific aspects of landfill management including gas control. These guidance notes include:

- TGN03: Guidance on the management of Landfill Gas. This document is an update to Waste Management Paper No.27, published in 1994.
- TGN04: Guidance on monitoring trace components in landfill
- TGN05: Guidance for monitoring enclosed landfill gas flares.
- TGN06: Guidance on gas treatment technologies for landfill gas engines.
- TGN07: Guidance on monitoring landfill gas surface.
- TGN08: Guidance for monitoring landfill gas engine emissions.
- Guidance on Landfill Gas Flaring

8.2.3 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 using 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 has just completed a study to revise the model used to estimate emissions from the managed waste disposal on land. The new model (MELMod-UK) offers considerable advantages to the user in terms of transparency of approach, utility and ease of use. An additional landfill type has been added that may be useful for modelling new developments in landfill practices. MELMod-UK is based on the first-order decay (FOD) methodology described in the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. The model has been tested against the previous national assessment model and the two models yield identical results from the same input data. MELMod-UK allows the use of the updated modelling approach for estimating methane generation described in the 2006 IPCC Guidelines and this avoids the small errors in integrating the exponential decay curve inherent in the approach described in previous editions of the Guidelines.

The UK method divides the waste stream into four categories of waste: rapidly degrading, moderately degrading, slowly degrading, and inert. These categories are each assigned a characteristic decay rate. The decay rates were revised slightly for the 2002 version of the model (LQM, 2003) and these revised rates are still used. They are 0.046 year^{-1} (for slowly degrading waste), 0.076 year^{-1} (moderately degrading waste) and 0.116 year^{-1} (rapidly degrading waste), and are within the range of 0.030 to 0.200 year^{-1} quoted in the Good Practice Guidance.

The model uses waste disposal data from 1945 to the present, a period equivalent to over four half lives for the slowly degrading waste (i.e. with a decay rate of 0.046 year^{-1}, equivalent to a 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 that reflect greater use of landfill gas collection for utilisation and disposal by flaring, as 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 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 Recovery 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 up to the UK on the basis of population, assuming that 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 based on Environment Agency data; for 2002. Estimates for commercial and industrial waste for the years between 1997 (the last year of estimates given by Brown *et al* (1999) and 2002 were estimated by linear interpolation between these years. After 2002, the commercial and industrial waste arisings were assumed to remain constant. The composition of commercial and industrial waste, based on the Strategic Waste Management Assessment, has been assumed to be constant from 1999.

As part of the improvement of the UK assessment model undertaken this year, a review of waste arisings data was completed. This review found that 2002 data for commercial and industrial waste arisings given by Golders was based on England and Wales only, rather than the UK as a whole, and that this error consequently affected estimates for commercial and industrial waste from 1998 onwards. This has now been corrected in the current NIR report. Its impact on previously reported emissions of methane is shown in Table 8.1. For the last reported year (2006), emissions have increased from 924 ktonnes to 965 ktonnes of methane.

Table 8.1: Comparison of waste landfilled and methane emitted from UK landfills, based on 2006 NIR methodology and current methodology.

	2006 Methodology		2007 Methodology	
Year	Waste to landfill (Mtonnes)	Methane Emitted (ktonnes)	Waste to landfill (Mtonnes)	Methane Emitted (ktonnes)
1990	81.83	2,363	81.83	2,363
1991	81.77	2,329	81.77	2,329
1992	81.72	2,270	81.72	2,270
1993	81.66	2,212	81.66	2,212
1994	81.61	2,167	81.61	2,167
1995	81.56	2,099	81.56	2,099
1996	78.17	2,027	78.17	2,027
1997	72.86	1,866	72.86	1,866
1998	65.63	1,735	74.01	1,748
1999	63.84	1,577	71.99	1,598
2000	62.05	1,472	69.98	1,501
2001	60.27	1,277	67.96	1,308
2002	58.48	1,162	65.94	1,195
2003	58.48	1,016	65.94	1,048
2004	58.48	943	65.94	977
2005	58.47	927	65.94	964
2006	58.47	924	65.94	965
2007	58.48	919	65.94	963

Degradable organic carbon (DOC) was estimated assuming that the DOC arises solely from the cellulose and hemi-cellulose content of the waste, in accordance with the previous methodology. 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 (F) is generally taken to be 50% for modern landfills, which is in line with the Guidance. For old shallow sites it is taken to be 30% to reflect a higher degree of oxidation. All sites in the UK are managed, and therefore have a methane correction factor of 1.0.

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.

8.2.4 Uncertainties and Time Series Consistency

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.2.1** and **Table A7.2.2**, 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 (i.e. is converted to methane and carbon dioxide), 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 MELmod 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.

8.2.5 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 8.2**. 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.

As stated above the UK undertook a development of the model to improve its transparency and usability. This new model (MELmod –UK) produces identical data as its predecessors with the same input data. As part of the development and validation of MELMod-UK two calculation engines were produced. Calculation Engine 1 is based on the previous UK models using IPCC 2000 equations and is used to produce the emission data for the inventory. Calculation Engine 2 is based on the IPCC 2006 model equations. Previous approaches to validating the UK estimates had been to enter the UK data using IPCC defaults as comparisons of DOC, DOC_F and K (half-life) values were difficult make.

MELmod takes another approach which allows the UK specific factors to be modelled with the IPCC model. It does this by calculating the amount of DOC, DOC_F the UK produces and applies this to the IPCC calculation.. 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 8.2 show that there is negligible difference between the UK estimation of methane generated based on IPCC Guidelines 2000 (Calculation engine 1) and that given by the 2006 IPCC model methodology (Calculation engine 2). It is therefore considered MELmod is validated and has therefore been used in the compilation oif this inventory.

Table 8.2: Amount of methane generated compared with the IPCC Tier 2 model.

Year	Mass of waste landfilled (Mt)			Mass of waste landfilled as reported in CRF* Excluding inorganic industrial waste (Mt)	UK	IPCC	Difference (%)
					MELmod v1.11 Calculation Engine 1	MELmod v1.11 Calculation Engine 2	
	MSW	C&I	Combined waste streams		Methane generated (kt)	Methane generated (kt)	
1990	18.19	81.83	100.02	75.65	2947	2954	0.21
1991	18.84	81.77	100.61	76.57	3024	3030	0.20
1992	19.47	81.72	101.19	77.49	3098	3104	0.19
1993	20.09	81.66	101.76	78.39	3170	3175	0.18
1994	20.71	81.61	102.32	79.28	3240	3246	0.17
1995	23.83	81.56	105.39	82.69	3294	3298	0.13
1996	24.76	78.17	102.93	74.00	3330	3333	0.09
1997	26.14	72.86	99.00	67.19	3352	3354	0.06
1998	25.94	74.01	99.95	64.62	3389	3392	0.09
1999	27.03	71.99	99.02	64.49	3425	3428	0.09
2000	27.54	69.98	97.51	63.78	3461	3463	0.08
2001	26.87	67.96	94.82	61.89	3492	3495	0.08
2002	27.18	65.94	93.13	61.00	3523	3525	0.07
2003	26.41	65.94	92.35	60.22	3551	3553	0.07
2004	25.48	65.94	91.43	59.29	3577	3579	0.06
2005	24.19	65.94	90.13	58.00	3600	3601	0.05
2006	21.69	65.94	87.63	55.50	3617	3619	0.04
2007	20.06	65.94	86.00	53.87	3631	3632	0.03
Total					**60,718**	**60,780**	

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

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. DECC is also considering commissioning further work on measurement of 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 and on the NAEI website.

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, 2008). 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, 2008); 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 Re-Calculations

Methane and N_2O emissions have increased by 0.3 kt CO_2eq and 0.01 kt CO_2eq, respectively, as a result of revisions made to estimates from Overseas Territories and Crown Dependencies.

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 the UK is evaluating whether the current estimation methodology needs to be revised. 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 continues to make efforts to review these estimates of emissions and underlying factors and activity data, and has attended meetings with UKWIR.

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 current 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 (2008). Data on the annual number of cremations is available from the Cremation Society of Great Britain (2008).

All UK plant used to incinerate municipal solid waste (MSW) 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 are reported under 6C and are generally based on Pollution Inventory data for the period 1993-1997 with use of literature factors generally for the period 1990-1992 to reflect the higher emissions likely from UK MSW incinerators in that period before plant shutdowns and upgrades occured in the 1993-1995 period.

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 Re-Calculations

There has been a small (5 Gg) increase in 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.

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

Emissions from LULUCF activities in the Overseas Territories and Crown Dependencies are reported in Sector 7 of the CRF. This is because there was not a suitable category within Sector 5 to report these emissions.

10 Re-Calculations and Improvements

This section of the report summarises the recalculations and improvements made to the UK GHG inventory since the 2008 NIR (2006 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 2007 GHG inventory, please see **Annex 6**.

Each year, the UK greenhouse inventory is as follows:

- ***Updated*** Existing activity data and/or emissions factors may be revised; and
- ***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 following:

- The methodology used to estimate emissions; and/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 2006; this report gives emission estimates for 2006, and includes estimates for the year 2007 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 RE-CALCULATIONS

Table 10.1 and **Table 10.2** summarise the recalculations that have occurred in estimates of the direct GHGs since the 2008 NIR (2006 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 2006 (**Table 10.1**) and the base year (**Table 10.2**).

Table 8(a) s1 and Table 8 (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 re-calculation with respect to the previous submission, is calculated as follows:

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

Where

LS = Latest Submission (2007 inventory; 2009 NIR); and
PS = Previous Submission (2006 inventory, 2008 NIR).

The percentages expressed in this way are consistent with those calculated in the CRF in Table 8 (a) s1 and Table 8 (a) s1.

For changes in earlier years' data, the corresponding CRF tables for that year should be referred to.

Table 10.1: Re-Calculations of direct GHG emissions for the year 2006 in the UK 2009 NIR (2007 inventory).

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2007 inventory minus emissions in 2006 inventory)	Change in emissions (%) (Percentage change relative to the 2006 inventory)	Brief description of reasons for Re-Calculation
1A1			
CO_2	-1708.99	-0.79	• The major change has been a decrease of emissions from power stations due to a combination of revision to energy statistics in DUKES (BERR, 2008) and the introduction of EUETS based emission factors for coal and fuel oil fired power stations; • There has been an increase of emissions from refineries also due to a combination of revision to energy statistics in DUKES (BERR, 2008), and the inclusion of emission factors from EUETS for petroleum coke and fuel oil; • Burning oil emissions have been included from refineries for the first time in this inventory; • There has been an increase in estimated emissions from offshore oil and gas combustion due to a revision to the emission factors for natural gas. • The methodology for including emissions from crown dependencies has changed. For the first time emissions are separate from the UK, and power station emissions in the CDs are additional to the emissions from UK power stations (fuel reallocated from IA2)
CH_4	+14.81	+6.67	• A major cause of the increase in emissions was the inclusion this year for the first time of wood burnt in power stations as a new source; • Energy statistics revisions to fuel oil use in power stations have also caused an increase in emissions; • The methodology for including emissions from crown dependencies has changed. For the first time emissions are separate from the UK, and power station emissions in the CDs are additional to the emissions from UK power stations (fuel reallocated from IA2); • There has been an increase in estimated emissions from offshore own gas combustion due to a revision to the emission factor for natural gas.
N_2O	+40.94	+2.48	• There has been an increase in estimated emissions from offshore own gas combustion due to a revision to the emission factor for natural gas. • Emissions in 1A1a increased due to the inclusion of emissions from wood in power stations; • There was also an increase in emissions from fuel oil use in power stations due to revisions to both the activity data and emission factor; • The methodology for including emissions from crown dependencies has changed. For the first time emissions are separate from the UK, and power station emissions in the CDs are additional to the emissions from UK power stations (fuel reallocated from IA2)

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2007 inventory minus emissions in 2006 inventory)	Change in emissions (%) (Percentage change relative to the 2006 inventory)	Brief description of reasons for Re-Calculation
1A2			
CO_2	-665.67	-0.81	• A large proportion of this reduction is from lubricants in Other Industrial Combustion. This is due to a revision to reflect a significant reduction of the use of this fuel due to the Waste Incineration Directive; • A further decrease has occurred through a revision of energy statistics in the Other Industrial Combustion sector for fuel oil, gas oil and LPG. Emissions from gas oil and fuel oil use have also been affected by a reallocation of these fuels to power generation in the Crown Dependencies; • Emissions from iron and steel combustion plant from fuel oil and natural gas decreased due to revisions to energy statistics; • An increase in emissions occurred from blast furnace gas, coke used in blast furnaces and sinter plants due to revision of the emission factors used; • There was a decrease of emissions from coal in autogenerators due to a combination of the introduction of EUETS emission factors and revision to energy statistics;
CH_4	+1.45	+0.53	• The major cause for the decrease in CH_4 emissions from 1A2 was a revision to the energy statistics for natural gas in Other Industrial Combustion.
N_2O	-12.69	-0.94	• There has been an overall decrease in emissions of N_2O from 1A2. This was mainly caused by revision to the emission factor used for gas oil in industrial off-road machinery.
1A3			
CO_2	+196.37	+0.15	• There has been a major methodology change resulting in reallocation of emissions within the road transport sector. Changes include review of speed data for different road and area types; vehicle km data and fleet composition data; • There has been a revision to HGV fuel consumption used due to revised figures from DfT on mpg fuel efficiency for different sizes of HGVs, this affects years 1993-2007 (overall fuel total remains based on DUKES). • Estimates for civil aviation have been updated and corrected. • Improvements have been made to the calculation of road transport emissions in the Overseas Territories.
CH_4	+8.34	+5.23	• There has been a major methodology change resulting in reallocation of emissions within the road transport sector. Changes include review of speed data for different road and area types; vehicle km data and fleet composition data; • There has been a revision to HGV fuel consumption used due to revised figures from DfT on mpg fuel efficiency for different sizes of HGVs, this affects years 1993-2007 (overall fuel total remains based on DUKES).
N_2O	-3881.26	-69.73	• For N_2O, road transport emission factors have been revised to be based on COPERT4 and the Emissions Inventory Guidebook, this has had a major effect on emissions in this sector;
1A4			

Source category and GHG	**Change in emissions ($GgCO_2eq$)** (Emissions in 2007 inventory minus emissions in 2006 inventory)	**Change in emissions (%)** (Percentage change relative to the 2006 inventory)	**Brief description of reasons for Re-Calculation**
CO_2	-269.54	-0.25	- There has been a large decrease in emissions from sector 1A4a due to revisions to national energy statistics for gas consumption; - This has been largely offset by an increase in emissions from 1A4b, due a revision to national energy statistics for gas and coal; - There were further smaller changes in this sector caused by revisions to national energy statistics.
CH_4	+34.23	+7.23	- The majority of the change to CH_4 emissions for this sector was due to the revision of the emission factor used for domestic combustion of wood; - Other minor changes were caused by revision to national energy statistics.
N_2O	+4.45	+0.72	- The main change for N_2O emissions in this sector was due to the revision of the emission factor used for domestic combustion of wood; - Other minor changes were due to revision to natural gas consumption in national energy statistics.
1A5			*No change to emissions in this sector*
1B1			
CO_2	-0.92	-0.66	- Emissions have been revised due to an emission factor revision for coke oven gas, and changes in the carbon balance for SSF production.
CH_4	-0.09	-0.00	- Revisions to activity data for SSF and coke production
1B2			
CO_2	+74.72	+1.55	- Revision to methodology used for estimating offshore emissions; - Revisions to data supplied for activities and emission factors.
CH_4	+164.96	+3.13	- Dominant factor is the change in gas leakage data provided by the operator networks; - Revision to methodology used for estimating offshore emissions; - Revisions to data supplied for activities and emission factors.
N_2O	+0.41	+1.08	- Revision to methodology used for estimating offshore emissions; - Revisions to data supplied for activities and emission factors.
2A			
CO_2	+44.43	+0.53	- The major change is a revision to activity data used to calculate emissions from FGD in power stations; - Updates to fuel use assumptions for Fletton bricks.
CH_4	-0.06	-0.34	- Updates to fuel use assumptions for Fletton bricks

Source category and GHG	**Change in emissions ($GgCO_2eq$)** (Emissions in 2007 inventory minus emissions in 2006 inventory)	**Change in emissions (%)** (Percentage change relative to the 2006 inventory)	**Brief description of reasons for Re-Calculation**
2B			
CO_2	-709.86	-20.70	- Emissions for this sector have changed mainly due to changes in Ammonia Production, caused by a revision to emissions data supplied by one of the operators.
CH_4	+29.41	+77.45	- Changes have occurred due to revisions to data from sources such as the PI, and the use of new 2007 data for interpolation where there are gaps in the data.
2C			
CO_2	-8.05	-0.38	- Aluminium production data was revised - The emission factor used for blast furnace gas has been revised to use data reported by operators.
PFCs	+5.16	+4.19	- An increase in PFC emissions occurred due the inclusion of data that was omitted in the 2006 inventory.
SF_6	-4.03	-2.20	- There has been a revision to estimates of SF_6 use by castings operators, based on direct communication with the plant operators.
2E			
HFC	+84.34	+27.82	- The emission estimates have been reviewed in consultation with plant operators, and revised to reflect the correct GWP weighted mixture of gases and to ensure that all fugitive sources were captured.
2F			
HFC	+696.54	+7.8	- There have been changes to various sectors, based on a project to update the F-Gas inventory. - Emissions from refrigeration have been revised to reflect the mix of gases currently in use and updated leakage rates, as advised by industry representatives. - Emissions from aerosols have been updated to reflect actual data (rather than projections) - Emissions from foams have been updated to reflect the observed trends since the full phase out of HCFC was completed. - Emissions from fire fighting have been revised based on information from industry representatives.
4A			
CH_4	-301.97	-1.87	- A decrease in emissions from this sector occurred due to revision to livestock numbers for other cattle and sheep. - Reallocation of some emissions from OTs and CDs to 4B
4B			

Source category and GHG	**Change in emissions ($GgCO_2eq$)** (Emissions in 2007 inventory minus emissions in 2006 inventory)	**Change in emissions (%)** (Percentage change relative to the 2006 inventory)	**Brief description of reasons for Re-Calculation**
CH_4	+412.49	+16.26	• Emissions in this sector increased significantly due to a change to the emissions factor for AWMS for swine. This emissions factor is now taken from the IPCC Good Practice Guidelines 2000; • A small decrease in emissions from this sector occurred due to a revision to livestock numbers for other cattle and sheep. • Reallocation of OT and CD emissions from 4A.
N_2O	+386.41	+28%	• The main cause for the increase in emissions in this sector is the update to the emission factor used for poultry – but not laying hens – to use the value in IPCC Good Practice Guidelines 2000; • N excretion rate changed for dairy cattle and goats. • Reallocation of OT and CD emissions from sector 4G
4D			
N_2O	+165.18	+0.69	• Crop production data corrected • Emissions affected by changes to animal numbers and Nex rates.
4G			
N_2O	-64.72	-100	• Sector 4G no longer used for OTs and CDs in the NIR report (reallocated to 4B). Emissions are still reported in this sector in the CRF.
5A			
CO_2	+20.93	-0.14	• The estimates of emissions and removals have changed due to a revisions to the emission factors for biomass burning on forest land; • A small change has also occurred due to revision to area data for forests in Northern Ireland.
CH_4	+1.36	+11.33	• The estimates of emissions have changed due to revisions to the emission factors for biomass burning on forest land.
N_2O	+0.14	+5.56	• The estimates of emissions have changed due to revisions to the emission factors for biomass burning on forest land
5B			*No change to emissions in this sector*
5C			
CO_2	+195.72	-2.45	• The estimates of emissions and removals have changed due to a method change. Previously, harvested wood products (5G) accounted for as a result of deforestation with no corresponding loss of living biomass. Living biomass now accounted for in C2 and E2.
5E			

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2007 inventory minus emissions in 2006 inventory)	Change in emissions (%) (Percentage change relative to the 2006 inventory)	Brief description of reasons for Re-Calculation
CO_2	+110.08	+1.77	• The estimates of emissions and removals have changed due to a method change. Previously, harvested wood products (5G) accounted for as a result of deforestation with no corresponding loss of living biomass. Living biomass now accounted for in C2 and E2.
5G			
CO_2	-131.08	+36.99	• The afforestation data has been updated.
6A			
CH_4	+852.71	+4.38	• There has been an increase in estimated emissions from this sector due to revision the inclusion of commercial and industrial waste arisings from Scotland and Northern Ireland
6C			
CO_2	+5.25	+1.19	• There has been a change in emission factor used for chemical waste incineration
CH_4	+3.53	+119.62	• Change to emission factors used for OT waste incineration
N_2O	+0.15	+0.31	• Change to emission factors used for OT waste incineration

Table 10.2: Re-Calculations of direct GHG emissions for the base year in the UK 2009 NIR (2007 inventory).

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2007 inventory minus emissions in 2006 inventory)	Change in emissions (%) (Percentage change relative to the 2006 inventory)	Brief description of reasons for Re-Calculation
1A1			
CO_2	+747.05	+0.32	• The main changes occurred in sector 1A1a, owing to the new method for disaggregation of fuel use in the CDs. This has meant that fuel has been reallocated from sector 1A2a to power generation. • Emissions from the Overseas Territories have also been recalculated based on up to date GHGI emission factors, and in some cases new data • Emissions from offshore own gas consumption have been revised to reflect a new emission factor.
CH_4	+60.00	+41.72	• The main change has occurred due to a method update for estimating emissions for gas separation plant and offshore own gas use using new analysis of data in the EEMS database from DECC Oil and Gas regulation division; • There has also been a revision to emission factors for offshore oil and gas own gas consumption and LPG and OPG combustion in gas separation plant. • Small changes have also occurred through the improvement to the methodology for including overseas territories.
N_2O	+141.84	+7.52	• The main change has occurred due to a method update for estimating emissions for gas separation plant and offshore own gas use using new analysis of data in the EEMS database from DECC Oil and Gas regulation division; • There has also been a revision to emission factors for offshore oil and gas own gas consumption and LPG and OPG combustion in gas separation plant. • Small changes have also occurred through the improvement to the methodology for including overseas territories.
1A2			
CO_2	-376.60	-0.38	• The majority of this change is due to the reallocation of fuel from this sector to account for power generation emissions in the Crown Dependencies • There has been a reallocation of fuel use in sub-sectors of 1A2f following better information about fuels used historically in lime production, which has led to an increase in emissions from coke use.
CH_4	-0.76	-0.23	• The majority of this change is due to the reallocation of fuel from this sector to account for power generation emissions in the Crown Dependencies • There has been a reallocation of fuel use in sub-sectors of 1A2f following better information about fuels used historically in lime production, which has led to an increase in emissions from coke use.

Source category and GHG	**Change in emissions ($GgCO_2eq$)** (Emissions in 2007 inventory minus emissions in 2006 inventory)	**Change in emissions (%)** (Percentage change relative to the 2006 inventory)	**Brief description of reasons for Re-Calculation**
N_2O	+7.17	+0.44	• The majority of this change is due to the reallocation of fuel from this sector to account for power generation emissions in the Crown Dependencies • There has been a reallocation of fuel use in sub-sectors of 1A2f following better information about fuels used historically in lime production, which has led to a significant increase in emissions from coke use, which has offset the decrease caused by the fuel reallocation for the Crown Dependencies.
1A3			
CO_2	219.82	+0.2	• There has been an increase in emissions from aviation due to corrections to the model • Road transport emissions have changed due to updates to the emissions from the OTs and CDs
CH_4	79.17	+12.7	• There has been a major methodology change resulting in reallocation of emission. Changes include review of speed data for different road and area types; vehicle km data and fleet composition data • There has been a change to emissions from aviation due to corrections to the model • Road transport emissions have changed due to updates to the emissions from the OTs and CDs
N_2O	155.97	+12.0	• There has been a major methodology change resulting in reallocation of emission. Changes include review of speed data for different road and area types; vehicle km data and fleet composition data • There has been a major change to emission factors for N_2O throughout the transport sector. Emission factors have been revised using COPERT4 and the Emissions Inventory Guidebook. • There has been an increase in emissions from aviation due to corrections to the model • Road transport emissions have changed due to updates to the emissions from the OTs and CDs
1A4			
CO_2	+18.50	+0.02	• There has been an increase to calculated emissions from the Overseas Territories due to the use of updated emission factors from the GHGI
CH_4	+0.18	+0.01	• There has been an increase to calculated emissions from the Overseas Territories due to the use of updated emission factors from the GHGI
N_2O	-2.10	-0.22	• There has been an decrease in calculated emissions from the Overseas Territories due to the use of updated emission factors from the GHGI
1A5			*No change to emissions in this sector*
2A			*No change to emissions in this sector*

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2007 inventory minus emissions in 2006 inventory)	Change in emissions (%) (Percentage change relative to the 2006 inventory)	Brief description of reasons for Re-Calculation
2B			
CH_4	+32.83	+24.03	• Revision to production index data used to calculate emissions from the chemical industry.
2C			*No change to emissions in this sector*
2E			*No change to emissions in this sector*
2F			
HFC	+85.20	5.6	• There have been revisions to estimated emissions from aerosols due to an update to the model • Refrigeration sector emissions have been updated to reflect the refrigerant mixes and leakage rates advised by industry representatives
4A			
CH_4	-31.77	-0.17	• The changes to this sector have occurred through revisions to the estimates for overseas territories – some emissions reallocated to sector 4B
4B			
CH_4	+665.58	+22.77	• The main change has been made to the emission factors for manure management for pig waste. The emission factors have been updated to use the value in the IPCC 2000 Good Practice Guidelines. • Some emissions for OTs and CDs reallocated from sector 4A to 4B
N_2O	+500.73	+29.11	• The main change has been made to emission factors for manure management for other animal waste. The emission factors have been updated to use the value in the IPCC 2000 Good Practice Guidelines. • Reallocation of emissions from 4G for OTs and CDs to 4B
4D			
N_2O	+2.98	+0.01	• Emissions in this sector have been affected by changes to Nex rates used for certain anumals
4G			
N_2O	-70.13	-100	• Sector 4G no longer used for OTs and CDs in the NIR report (reallocated to 4B). Emissions are still reported in this sector in the CRF.
5A			
CO_2	+0.59	+0.00	• There has been a minor update to the emission factor for land converted to forest land;
5B			*No change to emissions in this sector*
5C			*No change to emissions in this sector*

Source category and GHG	**Change in emissions ($GgCO_2eq$)** (Emissions in 2007 inventory minus emissions in 2006 inventory)	**Change in emissions (%)** (Percentage change relative to the 2006 inventory)	**Brief description of reasons for Re-Calculation**
CO_2	+55.97	+0.90	• The estimates of emissions and removals have changed due to a method change. Previously, harvested wood products (5G) accounted for as a result of deforestation with no corresponding loss of living biomass. Living biomass now accounted for in C2 and E2.
5E			
CO_2	+170.12	-2.46	• The estimates of emissions and removals have changed due to a method change. Previously, harvested wood products (5G) accounted for as a result of deforestation with no corresponding loss of living biomass. Living biomass now accounted for in C2 and E2.
5G			
CO_2	-201.33	-13.83	• Harvested wood products from deforestation have been included
6A			*No change to emissions in this sector*
6B			
CH_4	-0.13	-0.02	• Small changes have occurred through the improvement to the methodology for including overseas territories.
N_2O	-0.30	-0.03	• Small changes have occurred through the improvement to the methodology for including overseas territories.
6C			*No change to emissions in this sector*

10.2 IMPLICATIONS FOR EMISSION LEVELS

The implications for emission levels in the year 2006 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 re-calculations and improvements made in the 2007 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 2006 inventory.

Figure 10.1 summarises the effect of the recalculations in the 2009 NIR (2007 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 2006 and 2007, according to IPCC source sector. A negative difference indicates a decline in GWP emission between the inventory presented in the 2009 NIR (2007 inventory), and the inventory presented in the 2008 NIR (2006 inventory). The LULUCF totals are presented as net emissions.

Figure 10.2 summarises the effect of the recalculations in the 2009 NIR in terms of the following:

- 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 2006 and 2007.

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

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

Where

LS = Latest Submission (2007 inventory; 2009 NIR); and
PS = Previous Submission (2006 inventory, 2008 NIR).

The percentages expressed in this way are consistent with those calculated in the CRF in Table 8(a) s1 and Table 8 (a) s1.

The current inventory is affected by a number of time series changes, including a major reallocation of vehicle kilometres in road transport, improvements to the model for estimating emissions from UK landfill, and changes to the N_2O emission factor taken from COPERT4 and the Emissions Inventory Guidebook.

For later years, totals have also been affected by significant revisions to national fuel use statistics (BERR, 2008). 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

- Re-calculations in the base year have led to a net increase in emissions of 2,350 Gg CO_2 eq;
- The largest single change to emissions in the base year was an increase of 949 Gg CO_2 eq in IPCC sector 1A1, although this has been partially offset by a decrease in emissions from 1A2. These changes reflect the reallocation of fuels between the two sectors to account for power generation emissions from the Crown Dependencies, and improved estimates of emissions from the Overseas Territories.
- Emissions to sector 6B have increased through an increase of 666 Gg CO_2 eq of CH_4 and 501 Gg CO_2 eq of N_2O. The main reason for this increase is the update to emission factors to use the IPCC 2000 Good Practice Guidelines. There have also been some minor increases to emissions in this sector through the inclusion of manure management emissions from overseas territories;

Reasons for changes in GWP emissions in 2006

- Re-calculations in 2006 have led to a decrease in emissions of 3,873 Gg CO_2 eq;
- Total emissions from fuel combustion (1A) have decreased by 6,020 Gg CO_2 eq mostly because of changes to the transport sector methodology (N_2O from road transport) and changes to national statistics;
- The most significant changes to the inventory for 2006 occurred in the energy industries sector. Emissions in sector 1A1 decreased by 1,653 Gg CO_2eq. This decrease was a result of a number of changes, the most significant being changes to national energy statistics, and an introduction of EUETS based emissions factors for coal, coke, fuel oil and natural gas burnt at power stations and petroleum coke and fuel oil burnt in refineries;
- Emissions from 1A2 decreased by 677 Gg CO_2 eq due mainly to revisions to national statistics, and a reallocation of fuel from this sector to account for emissions from power stations in the Crown Dependencies. A reduction of 591 Gg CO_2 eq occurred due to a revision to reflect a significant reduction in the use of lubricants in other industrial combustion due to the Waste Incineration Directive. These reductions were partially offset by an increase in emissions of 1,271 Gg CO_2 due to a reallocation of fuels in the lime industry following updated information from industry;
- Emissions from 1A3 decreased by 3,677 Gg CO_2 eq due mainly to a revision to N_2O emission factors. These were revised to incorporate COPERT4 and Emissions Inventory Guidebook emission factors and account for a decrease of 3,881 Gg CO_2 emissions. There was also a major methodology change including a review of speed data for different road and area types, vehicle km data and fleet composition. A revision to mpg fuel efficiency for HGVs of different sizes has also been made;
- The other most significant changes were a revision to the emission factor used for ammonia production, a change to the F-gas emission model following consultation with industry for sector 2F, and updated to emission factors for manure management to use values in the IPCC 2000 Good Practice Guidance.

Figure 10.1: **Time series of changes in GWP emissions between the inventory presented in the current and the previous NIR, according to IPCC source sector.**

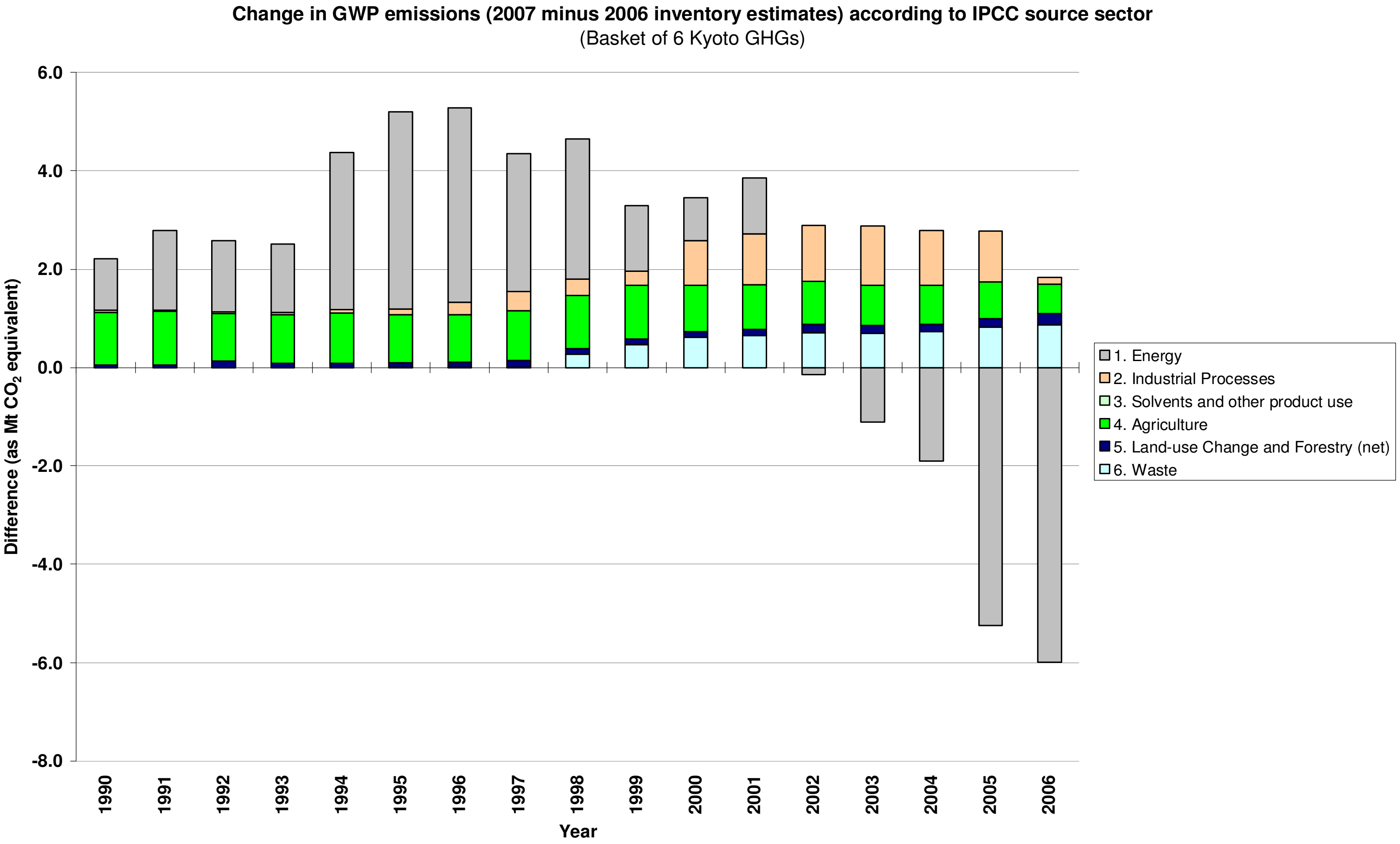
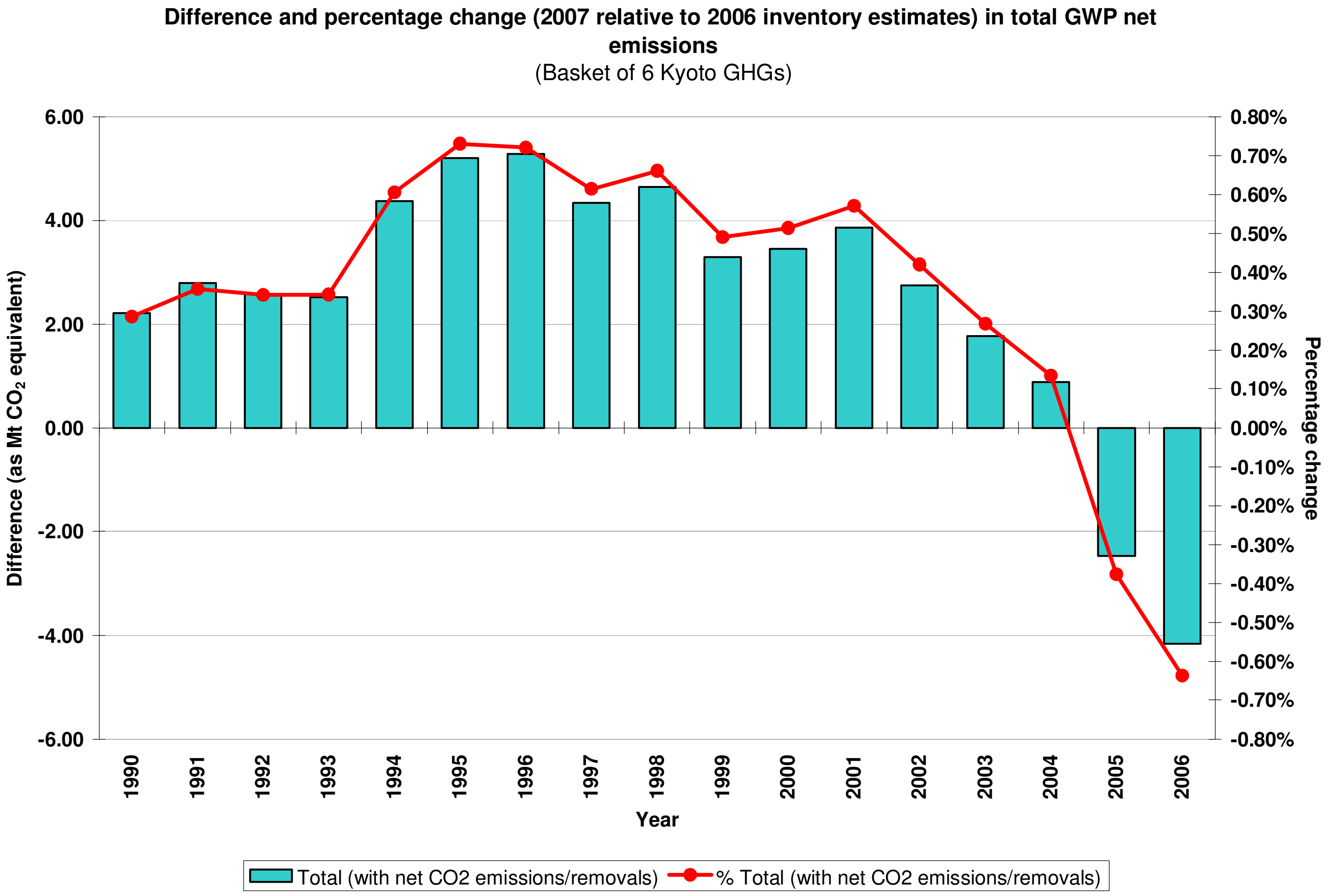


Figure 10.2: Time series of changes in total net GWP emissions, and percentage changes in total net GWP emissions, between the inventory presented in the current and the previous NIR.



10.3.1 Response to the Review Process

There has been one review of the UKs GHG inventory since the publication of the 2008 NIR.

The UNFCCC conducted a Centralised Review of both the 2007 and 2008 greenhouse gas inventory submission (2007 NIR and 2008 NIR)in accordance with decision 22/CMP.1. In accordance with the conclusions of the Subsidiary Body for Implementation at its twenty-seventh session, the focus of the review was on the most recent (2008) submission. The review took place from 15-20 September 2008 in Bonn, Germany. The review follows on from the In-Country Review of the 2006 greenhouse gas inventory (London, 12-17 March 2007).

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, 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.

ERT comment	**Actions**
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.
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 DECC. 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.

ERT comment	Actions
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 dissagregated data we can obtain. However, we are starting a new project to improve the inventory methodology and this will dissagregate the input data , so as information becomes available this dissagregated 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.
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.

ERT comment	Actions
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.
LULUCF - The United Kingdom experts further informed the ERT that they are working on the issues of afforested drained peat land, N_2O 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.

ERT comment	Actions
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 N_2O 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 (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 CH_4 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 – N_2O and CH_4 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 CO_2 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 uncertainties associated with N2O 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_2O 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.
Centralised Review – September 2008	
NB These are the responses to the Draft Report, as of 3rd March 2009 and therefore may change before final submission to the UNFCCC on 23rd March	
Cross Cutting: Provide more information in the NIR on Quality Assurance procedures and the external review of the inventory	Noted
NIR: Insufficient trend analysis in Chp2. Recommend that UK present in detail in the appropriate chapter of the NIR the general trend analysis for overall GHG emissions (including explanation for trend variations by gas and by sector)	Chapter 2 has been extended
NIR: Minor inconsistencies between data in the NIR and CRF summary table 3 (especially agriculture). Address these in the next submission	Noted.
Energy & LULUCF: Several categories not estimated and insufficient information provided in CRF table 9(a) and annex 5 of the NIR. Estimate and report in next annual submission the emissions from categories currently reported as NE, giving priority to the largest sources.	Noted

ERT comment	Actions
CRF: Table 9 not populated. Provide complete information on the categories reported as IE in both the CRF and NIR	Noted
Transparency: Transparency could be further improved by enhancing the explanation and justification for the allocation of AD and the adoption of new EFs, in particular where these do not result in a recalculation of the entire time series	Noted
Verification and QA/QC : Provide more information on QA activities in the NIR in next submission	Noted
Follow up from previous reviews: Noted that the following recommendations from previous reviews not yet implemented: • Reporting F-gas emissions by species • Including explanations on CO2 emissions from cement production in the NIR • Including the estimation of CH4 and N2O emissions from industrial wastewater in the NIR	- DECC requested not to specify F gases - We are unsure of what is required regarding the cement production. There is an explanation in the NIR regarding time series variation - Industrial waste water is under review in conjunction with DECC. It is not clear yet as to what will be done regarding this sector.
Areas for further improvement – cross cutting: • Information on QA procedures and the external review of the inventory should be more detailed in the NIR • General trend analysis for the overall GHG emissions should be presented in detail in the relevant chapter of the NIR • Consistency between NIR and CRF should be further improved	Noted – see comments in appropriate sections above
Feedstocks and non-energy use: NG used as a feedstock for manufacture of ammonia, methanol and acetic acid. Provide detailed background information in the NIR together with a full description o f the fractions of carbon stored for the fuels listed in CRF table 1.A.(d)	Noted. We will try to incorporate this in the 2010 submission.
Feedstocks and non-energy use: Assess whether the default values for the fractions of carbon stored correspond to its national circumstances given the significant differences in apparent energy consumption and CO2 emissions between sectoral and reference approaches	Noted.
Stationary Combustion: Compare facility level data with activity data received from the EUETS and with activity data received from facilities temporarily excluded from emissions trading. Address any discrepancies found and provide detailed background information on the reallocation issue in next submission	Noted
Stationary Combustion; CO2 IEFs – provide the explanation in the NIR which was given during the review, along with information on the CO2 EF for MSW and the disaggregated fuel consumption data for OTs (all fuels), CDs (MSW) and scrap tyres	From the 2009 submission this will no longer be relevant because OT fuel use will be included in the categories in which it occurs

ERT comment	Actions
Stationary Combustion: Solid fuels in manufacturing industries and construction – all emissions currently reported under other. Should be reported in correct sub-categories in future submissions as this will increase transparency	Noted
*Fugitive Emissions:*Currently no documentation in the NIR describing the methodology for fugitive CO2 emissions from oil production. Recommend providing a description of the estimation methodology for these sources in next submission	Noted. There has been a thorough review of the data available for this sector, with further information supplied in this NIR report.
QA/QC: Carry out an evaluation of the EA's QA/QC procedures and report results in next annual submission. Also make use of the contacts database and cite personal communication when justifying key assumptions	It is not appropriate for AEA to evaluate a Governments QA/QC programme. We would recommend that this comment is altered. We can ask the EA for an update on their QA/QC procedures and report these findings in the NIR in 2010, but we can not evaluate them.
F-gases: Recommends reporting F-gas emissions by species in metric tonnes, the unit used in the sectoral background data tables	Noted. This may be possible in the 2010 submission
Solvent use: Reported as NE. Encouraged to provide estimates for these gases	Noted.
Adipic Acid: Major revision carried out to the estimation of emissions from adipic acid production, but the document on which the revision was based was not included in the list of references in the NIR. Increase the transparency of reporting by justifying the change to a lower EF in the NIR in the next submission	Information was provided during the review so can this be included in the NIR
F-gases: Document the recalculation transparency regarding the new model in the NIR. Assess the effect of the change in methodology on the overall consumption patterns of HFCs in different applications	The work incorporated as a result of the F-gas review is documented in the 2009 submission
Chemical Industry: Waste chemicals burnt. During the review we provided references for old and new EFs and an explanation as to the rationale behind the changes. Add these references together with explanations to the NIR	Noted. We will try to include this information in the 2009 submission
Al Production (PFCs); Document recalculation transparently. Include explanation of how time series consistency has been maintained following the introduction of a new data source that replaces the PI data	Noted. This was a mistake in the 2008 submission. It is fixed in the 2009 submission.
Landfill; Provide detailed info on any improvements	The 2009 submission details improvements made to the waste model.
Landfill Recommend the collection of updated survey data according to IPCC GPG to avoid overestimation of the amount of recovery	Noted.

ERT comment	Actions
Wastewater Handling: Inconsistency in time series in emissions from human sewage, due to different data sources being used for per capita protein consumption. Recommend reviewing assumption and providing an explanation for the difference between what is used and the figures provided by the UK to the Food and Agriculture Organisation of the UN	Noted. There is a comment under 6B in the 2009 NIR
Wastewater Handling; Emissions from industrial waste water reported as NE due to lack of AD. Recommend including these emissions in future submissions	Noted. We will try to follow this up through stakeholder consultation and report progress in the 2010 NIR
Wastewater Handling; Emissions from industrial waste water reported as NE due to lack of AD. Recommend including these emissions in future submissions	Noted. We will try to follow this up through stakeholder consultation and report progress in the 2010 NIR
Waste Incineration; UK uses country-specific EFs for estimating CO2 emissions from waste incineration. Not enough clarity on geographical coverage. Recommend that the UK estimate emissions from incinerators in Scotland and NI.	During the review we provided information explaining that currently there are no large incinerators in Scotland or NI but minor ones may exist. We will try to pick up with stakeholder consultation budget and report on progress in the 2010 NIR.
National System; ERT encourages the UK to secure the formal agreements between Defra and key data providers and to provide information in the NIR	Noted. AEA and DECC are working together to try to finalise the Data Supply Agreements.
Commitment Period Reserve; Recommend that the UK include information on its commitment period reserve in next annual submission	Noted. We have highlighted this recommendation to DECC who are responsible for reporting the Commitment Period Reserve information

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 re-calculations sections in the appropriate chapters of this report.

- **Introduction of EU-ETS factors for CO_2**: Factors based on EU-ETS returns introduced for the following sectors and fuels:
    - Power Stations – coal – for 2005, 2006, 2007
    - Power Stations – fuel oil – for 2005, 2006, 2007
    - Power Stations – natural gas – for 2005, (interpolated 2006, 2007)
    - Autogenerators – coal – 2005, 2006, 2007
    - Refineries – fuel oil - 2005, (interpolated 2006, 2007)
    - Refineries – Petroleum coke – 2005, 2006, 2007
- **Offshore oil and gas** – Updated method for estimating emissions using new analysis of data in the EEMS database.
- **Aviation** – Update to the method to allocate aviation spirit to both TOL and cruise.
- **Road Transport** – Major methodology change resulting in reallocation of emissions between sub-categories. Changes include review of speed data for different road and area types, vehicle kilometre data and fleet composition data. For N_2O, emission factors updated in line with COPERT IV.
- **F-gases** – Introduction of some of the results from the Review of F gases in the UK work carried out over summer 2008.

- **LULUCF** – Method update to account for loss of living biomass due to harvested wood products.
- **Landfill methane** – Inclusion of activity data that was previously omitted from the model (affects from 1998 onwards). Emissions from the C&I waste decay in Scotland had been omitted from the previous inventory.
- **Agriculture** – For N_2O, there was an update to the emission factor for poultry Animal Waste Management Systems (AWMS) (excluding laying hens) under the other manure category. For CH_4, there was an update to the emission factor for pig swine from AWMS.

A centralised review took place in September 2008, 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. During 2008 the BERR energy team and the Defra climate teams formed the Department of Energy and Climate Change (DECC), references in this document refer to correct name at the time of original publication.

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11.12 ANNEX 3, SECTOR 4

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11.13 ANNEX 3, SECTOR 5

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12 Acknowledgements

We are grateful for the contributions, advice and support from the following people listed in **Table 12.1** during the compilation of this National Inventory Report (NIR). The Key Data Providers are listed in **Table 12.2**.

Table 12.1: Contributors to this National Inventory Report and the CRF

Person	Technical work area and responsibility
Main authors	
Brophy, Nicola	Author of Annex 6, co-author of Chapter 2, co-author of Chapter 10, contributions to Chapter 3
Choudrie, Sarah	Project Manager for the UK Greenhouse Gas Inventory with overall responsibility for the NIR and the CRF[8]. Contributions to most chapters, co-author of energy sector text, author of Chapter 1, Annex 4 and 5.
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.
Jackson, Joanna	Manager of NIR and CRF submission, co-author of Chapter 2 and Chapter 10, F-gases sector expert, lead author of Annex 7, Final Users expert, manager of Overseas Territories and Crown Dependencies inventory compilation.
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 and industry; contributions to most chapters. Developments to the methods used to estimate GHG emissions from the non-energy use of fuels and stored carbon.
Thistlethwaite, Glen	Compilation of emission estimates, in particular the offshore sector and cement. Main author of chapters and annexes for 1B and Annex 11
Thomson, Amanda	Co-author of all sections on Land Use Change and Forestry. Compilation of Sector 5 of the CRF.
Watterson, John	Co-author of Uncertainties Chapter and Key Category Analysis. Author of Waste water treatement sections. 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	
Brown, Keith	Contributions to landfill sections of report and the development of the MELmod model
Dyson, Kirstie	Contributions to LULUCF Inventory compilation and text
Goodwin, Justin	Assistance with Final Users calculations

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[8] The UK greenhouse gas inventory is part of the UK National Atmospheric Emissions Inventory contract. The UK National Atmospheric Emissions Inventory is funded by the UK Department for Environment, Food & Rural Affairs and is contracted to AEA Technology.

Person	**Technical work area and responsibility**
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
Pierce, Martin	Development of off road machinery emissions estimate
Ruddock, Kate	Assistance with compilation of LULUCF estimates for the OTs and CDs.
Stuart Sneddon	Compilation of rail emissions estimates and text for this sector
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 and report formatting
Dagnet, Yamide[9]	Suggestions and improvements to draft versions of the NIR
Mackintosh, John[10]	Suggestions and improvements to draft versions of the NIR
Penman, Jim[11]	Suggestions and improvements to draft versions of the NIR

Table 12.2: Key Data Providers to the Greenhouse Gas Inventory

Company
UKPIA
UKOOA
Environment Agency
DECC (previously part of BERR)
PowerTech
British Cement Association
UK Gas Distribution Networks
Corus
DFT
UK Coal
Kemira
NIDoE
SEPA

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[9] Climate and Energy: Science and Analysis, Department for Energy and Climate Change

[10] Climate and Energy: Science and Analysis, Department for Energy and Climate Change

[11] Climate and Energy: Science and Analysis, Department for Energy and Climate Change