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UK Greenhouse Gas Inventory, 1990 to 2009

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 2011 to the United Nations Framework Convention on Climate Change (UNFCCC). It contains national greenhouse gas emission estimates for the period 1990-2009, and the descriptions of the methods used to produce the estimates. The report is prepared in accordance with decision 18/CP.8[1] and follows the structure outlined in the *Annotated outline of the National Inventory Report including reporting elements under the Kyoto Protoco[2]l*. This submission constitutes the UK's 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 datasets 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, Energy, Science and Analysis team, 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 18**.

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.

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[1] FCCC Decision 18/CP.8. Guidelines for the preparation of national communications by Parties included in

[2] http://unfccc.int/files/national_reports/annex_i_ghg_inventories/reporting_requirements/application/pdf/annotated_nir_outline.pdf

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 BACKGROUND INFORMATION ON GREENHOUSE GAS INVENTORIES, CLIMATE CHANGE AND SUPPLEMENTARY INFORMATION REQUIRED UNDER ARTICLE 7, PARAGRAPH 1, OF THE KYOTO PROTOCOL

ES.1.1 Background information on climate change (e.g as it pertains to the national context)

In response to the threat of climate change, the Kyoto Protocol was established. Under this agreement, the UK reduction target is -12.5% on 1990 levels. The UK needs to achieve this reduction during the first commitment period of the Kyoto Protocol which runs from 2008 to 2012.

The UK has set itself even more stringent domestic targets, including an emission reduction target of 34% by 2020 on 1990 levels. This target is included in the ***Climate Change Act*** which became UK Law on the 26th November 2008. This legislation introduced a new, more ambitious and legally binding target for the UK to reduce GHG emissions to 80% below the base year by 2050 with legally binding five year GHG budgets.

In April 2009 the UK Government announced the levels of the first three five-year carbon budgets, starting in 2008, requiring the UK to cut emissions by 34% on 1990 levels by 2020. The UK's Low Carbon Transition Plan, published in July 2009, sets out the route-map to achieving that 34% reduction in GHG emissions by 2020. The first *Annual statement of emissions* was published on 18th March 2010 and it reports to parliament on progress towards the carbon budgets, relating to the year 2008.

Further information on the UK's action to tackle climate change can be found on the following Government Department websites:

www.decc.gov.uk
ww2.defra.gov.uk

ES.1.2 Background information on greenhouse gas inventories

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 2011. It contains GHG emissions estimates for the period 1990 to 2009, 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 follows the structure outlined in the *Annotated outline of the National Inventory Report including reporting elements under the Kyoto Protocol*[3]

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[3] http://unfccc.int/files/national_reports/annex_i_ghg_inventories/reporting_requirements/application/pdf/annotated_nir_outline.pdf

The UK's GHG inventory is compiled under contract to the UK Department for Energy and Climate Change (DECC) by AEA. 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 Farming and Food Science Team 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, Defra and the Devolved Administrations also fund research contracts to provide improved emissions estimates for certain sources such as fluorinated gases, landfill methane, enteric fermentation and shipping.

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

- Carbon dioxide (CO_2);
- Methane (CH_4);
- Nitrous oxide (N_2O);
- 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).

The structure of this report is as follows:

- 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.
- Chapter 10 presents information on recalculations, improvements and a summary of responses to review processes.
- Chapter 11 details KP-LULUCF reporting
- Chapter 12 contains information on accounting of Kyoto units
- Chapters 13 and 14 contain information regarding changes to the National System and the National Registry
- Chapter 15 contains information on the minimisation of adverse impacts in accordance with Article 3, paragraph 14.

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 for these three purposes differs to some extent, because of the following:

1. Domestic goals for CO_2 are based on the UK only, excluding all emissions from the UK's Crown Dependencies and Overseas Territories;
2. The Kyoto commitment extends coverage to the UK's Crown Dependencies (Guernsey, Jersey and the Isle of Man) and Overseas Territories that have ratified the Kyoto Protocol (the Cayman Islands, the Falkland Islands, Bermuda, Monserrat and Gibraltar);
3. The UK's commitments under the EU Monitoring Mechanism, which has been set up to enable the EU to monitor progress against its Kyoto Protocol target, only includes the UK and Gibraltar, since the Crown Dependencies and other Overseas Territories are not part of the EU.

Coverage 2 is used for the data in the CRF tables submitted to the UNFCCC and Coverage 3 is used for the data in the CRF tables submitted under the EUMM. Emissions data for Coverage 1 are reported here for information only. Tables ES2.1 to ES3.1 show CO_2 and the direct greenhouse gases, disaggregated by gas and by sector for geographical Coverage 2. Tables ES3.2 and ES3.3 show emissions for the Kyoto basket based on Coverage 2 and 3, respectively.

Table ES4 has data on indirect greenhouse gas emissions, for geographical coverage 2.

ES.1.3 Background information on supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol.

Background information on supplementary information required under Article 7, Paragraph 1 of the Kyoto Protocol is presented in **Chapter 1, Section 1.1.3**.

ES.2 SUMMARY OF NATIONAL EMISSION AND REMOVAL RELATED TRENDS, AND EMISSIONS AND REMOVALS FROM KP-LULUCF ACTIVITIES

ES.2.1 GHG Inventory

Table ES2.1: Emissions of GHGs in terms of carbon dioxide equivalent emissions including all estimated GHG emissions from the Crown Dependencies and relevant Overseas Territories, 1990-2009. (Mt CO_2 Equivalent)

Table ES1	**Mt CO_2 Equivalent**																				**% change**
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**1990 - 2009**
CO_2 (Including net LULUCF)	591.1	598.2	581.2	566.3	560.6	552.3	574.3	550.2	553.2	543.9	551.0	563.0	545.4	555.2	554.4	551.6	548.3	539.9	527.2	475.8	-20%
CO_2 (Excluding net LULUCF)	588.0	595.2	578.7	564.9	559.3	550.6	572.9	549.1	552.7	543.6	551.4	563.8	547.2	557.3	557.6	555.3	552.2	544.1	531.8	480.6	-18%
CH_4 (Including net LULUCF)	110.6	108.1	104.8	100.3	92.0	90.4	87.4	81.9	77.2	71.8	67.0	61.2	58.1	52.3	50.5	48.8	47.4	45.9	44.7	43.8	-60%
CH_4 (Excluding net LULUCF)	110.6	108.0	104.8	100.3	92.0	90.4	87.4	81.9	77.1	71.8	66.9	61.1	58.1	52.2	50.4	48.8	47.4	45.9	44.7	43.8	-60%
N_2O (Including net LULUCF)	67.8	67.7	61.1	56.5	57.6	56.3	56.2	57.2	56.6	46.0	44.9	42.4	40.8	40.1	40.7	39.5	37.7	37.2	36.5	34.6	-49%
N_2O (Excluding net LULUCF)	67.0	67.0	60.3	55.7	56.8	55.5	55.4	56.4	55.8	45.2	44.2	41.7	40.0	39.4	40.0	38.9	37.0	36.6	35.8	34.0	-49%
HFCs	11.4	11.9	12.3	13.1	14.0	15.5	16.6	19.0	16.8	10.0	8.7	9.4	9.6	10.4	9.5	10.3	10.6	10.6	10.9	10.9	-4%
PFCs	1.4	1.2	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.1	-90%
SF_6	1.0	1.1	1.1	1.2	1.2	1.2	1.3	1.2	1.3	1.4	1.8	1.4	1.5	1.3	1.1	1.1	0.9	0.8	0.7	0.7	-36%
Total (Emissions including net GHG from LULUCF)	**783.3**	**788.1**	**761.2**	**737.9**	**725.9**	**716.1**	**736.2**	**709.9**	**705.4**	**673.5**	**673.9**	**677.7**	**655.8**	**659.7**	**656.6**	**651.7**	**645.2**	**634.7**	**620.1**	**566.0**	**-28%**
Total (Emissions excluding net GHG from LULUCF)	**779.4**	**784.3**	**757.9**	**735.6**	**723.8**	**713.7**	**734.0**	**708.0**	**704.1**	**672.4**	**673.5**	**677.8**	**656.7**	**661.0**	**659.0**	**654.6**	**648.4**	**638.2**	**624.1**	**570.1**	**-27%**

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 ES2.1 presents the UK Greenhouse Gas Inventory totals by gas, both including and excluding net emissions from LULUCF. The largest contribution to total emissions is CO_2, which contributed 84% to total net emissions in 2009. Methane emissions account for the next largest share (8%), and N_2O emissions make up a further 6%. Emissions of all gases have decreased since 1990, contributing to an overall decrease of 28%.

ES.2.2 KP-LULUCF activities

KP-LULUCF activities relate to 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).

Table **ES2.2** details the emissions and removals from these activities which are included in the UK's emissions total for reporting under the Kyoto Protocol.

Table ES 2.2 KP-LULUCF activities (Mt CO_2e)

Table ES 2.2	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Article 3.3		0.4	0.5	0.6	0.5	0.3	0.1	-0.1	-0.4	-0.6	-0.6
Article 3.4 (capped at -0.37 MtC)		-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4
Article 3.7	0.4										

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Article 3.3	-0.7	-0.7	-0.9	-1.2	-1.4	-1.7	-1.9	-2.0	-2.1	-2.2
Article 3.4 (capped at -0.37 MtC)	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4
Article 3.7										

ES.3 OVERVIEW OF SOURCE AND SINK CATEGORY EMISSION ESTIMATES AND TRENDS, INCLUDING KP-LULUCF ACTIVITIES

ES.3.1 GHG Inventory

Table ES3.1 details total net emissions of GHGs, aggregated by IPCC sector.

Table ES3.1 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 ES3.1	**Aggregated emission trends per source category (Mt CO_2 equivalent)**																			
Source Category	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
1. Energy	608.9	618.5	602.2	586.7	573.9	565.9	586.2	561.3	563.1	552.2	558.8	571.7	555.2	561.6	561.0	557.4	554.2	544.0	531.8	484.2
2. Industrial Processes	54.0	52.3	46.9	43.8	46.2	46.4	48.2	50.7	48.7	32.0	31.0	29.2	26.8	28.4	28.6	28.6	27.7	29.0	28.1	22.7
3. Solvents and Other Product Use[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4. Agriculture	57.3	56.8	55.0	54.3	55.2	55.1	55.4	55.8	54.9	54.3	52.1	49.0	49.3	48.6	48.6	48.4	46.8	46.0	45.5	45.0
5. LULUCF	3.9	3.9	3.3	2.3	2.1	2.5	2.2	1.9	1.4	1.1	0.4	-0.1	-1.0	-1.3	-2.4	-3.0	-3.2	-3.5	-4.0	-4.1
6. Waste	59.1	56.6	53.7	50.9	48.5	46.3	44.3	40.2	37.3	33.9	31.7	27.9	25.5	22.5	20.8	20.2	19.7	19.2	18.6	18.1
Total (net emissions)	**783.3**	**788.1**	**761.2**	**737.9**	**725.9**	**716.1**	**736.2**	**709.9**	**705.4**	**673.5**	**673.9**	**677.7**	**655.8**	**659.7**	**656.6**	**651.7**	**645.2**	**634.7**	**620.1**	**566.0**

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.

The largest contribution to greenhouse gas emissions arises from the energy sector. In 2009 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 20%.

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 2009. 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 2009. 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 2009 this contributed around 3% to the national total. This sector leads to emissions of 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 2009 are 69% below 1990 levels.

Total net emissions have decreased by 28% since 1990.

ES.3.2 KP-LULUCF Activities

ES.3.2 provides the time series of the UK Kyoto basket of emissions (UNFCCC geographical coverage), and ES.3.3 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 KP-LULUCF activities.

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 2009 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.3.3, 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 ES3.2 **Kyoto basket of emissions, and emissions associated with Articles 3.3, 3.4 and 3.7, 1990-2009 (in Mt CO_2 equivalent) – UNFCCC Coverage.**

Table ES3.2	**Mt CO_2 Equivalent**																					**% Changes**	
	Base Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**1990-2009**	**Base Year - 2009**
CO_2	588.0	588.0	595.2	578.7	564.9	559.3	550.6	572.9	549.1	552.7	543.6	551.4	563.8	547.2	557.3	557.6	555.3	552.2	544.1	531.8	480.6	-18%	-18%
CH_4	110.6	110.6	108.0	104.8	100.3	92.0	90.4	87.4	81.9	77.1	71.8	66.9	61.1	58.1	52.2	50.4	48.8	47.4	45.9	44.7	43.8	-60%	-60%
N_2O	67.0	67.0	67.0	60.3	55.7	56.8	55.5	55.4	56.4	55.8	45.2	44.2	41.7	40.0	39.4	40.0	38.9	37.0	36.6	35.8	34.0	-49%	-49%
HFCs	15.5	11.4	11.9	12.3	13.1	14.0	15.5	16.6	19.0	16.8	10.0	8.7	9.4	9.6	10.4	9.5	10.3	10.6	10.6	10.9	10.9	-4%	-29%
PFCs	0.5	1.4	1.2	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.1	-90%	-68%
SF_6	1.2	1.0	1.1	1.1	1.2	1.2	1.2	1.3	1.2	1.3	1.4	1.8	1.4	1.5	1.3	1.1	1.1	0.9	0.8	0.7	0.7	-36%	-47%
Grand Total	**782.7**	**779.4**	**784.3**	**757.9**	**735.6**	**723.8**	**713.7**	**734.0**	**708.0**	**704.1**	**672.4**	**673.5**	**677.8**	**656.7**	**661.0**	**659.0**	**654.6**	**648.4**	**638.2**	**624.1**	**570.1**	**-27%**	**-27%**
Article 3.3		0.4	0.5	0.6	0.5	0.3	0.1	-0.1	-0.4	-0.6	-0.6	-0.7	-0.7	-0.9	-1.2	-1.4	-1.7	-1.9	-2.0	-2.1	-2.2		
Article 3.4 (capped at -0.37 MtC)		-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4		
Article 3.7	0.4																						
Kyoto Protocol Total	**783.1**	**778.4**	**783.4**	**757.1**	**734.7**	**722.8**	**712.4**	**732.5**	**706.3**	**702.1**	**670.4**	**671.4**	**675.8**	**654.4**	**658.5**	**656.2**	**651.6**	**645.2**	**634.8**	**620.7**	**566.5**	**-27%**	**-28%**
Fixed Base Year	**779.9**																						**-27%**

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 ES3.3 Kyoto basket of emissions, and emissions associated with Articles 3.3, 3.4 and 3.7, 1990-2009 (in Mt CO_2 equivalent) – EUMM Coverage.

ES3.3	**Mt CO_2 Equivalent**																					**% Changes**	
	Base Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**1990-2009**	**Base Year - 2009**
CO_2	585.3	585.3	592.5	576.0	562.2	556.5	547.8	569.9	546.0	549.4	540.5	548.3	560.9	544.3	554.5	554.7	552.3	549.0	540.7	528.6	477.2	-18%	-18%
CH_4	110.1	110.1	107.6	104.3	99.8	91.5	89.8	86.9	81.4	76.6	71.3	66.5	60.7	57.7	51.8	50.1	48.4	47.0	45.5	44.3	43.4	-61%	-61%
N_2O	66.9	66.9	66.9	60.3	55.6	56.7	55.4	55.3	56.3	55.7	45.1	44.1	41.6	39.9	39.3	39.9	38.8	36.9	36.5	35.7	33.9	-49%	-49%
HFCs	15.4	11.4	11.9	12.3	13.1	14.0	15.4	16.6	19.0	16.8	10.0	8.7	9.3	9.5	10.4	9.4	10.2	10.5	10.5	10.8	10.9	-5%	-30%
PFCs	0.5	1.4	1.2	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.1	-90%	-68%
SF_6	1.2	1.0	1.1	1.1	1.2	1.2	1.2	1.3	1.2	1.3	1.4	1.8	1.4	1.5	1.3	1.1	1.1	0.9	0.8	0.7	0.7	-36%	-47%
Grand Total	779.5	780.0	784.8	757.9	734.5	722.5	712.6	732.6	706.2	701.5	669.7	670.2	674.2	652.2	656.2	653.1	648.0	641.4	630.6	616.3	562.1	-28%	-28%
Article 3.3		0.4	0.5	0.6	0.5	0.3	0.1	-0.1	-0.4	-0.6	-0.6	-0.7	-0.7	-0.9	-1.2	-1.4	-1.7	-1.9	-2.0	-2.1	-2.2		
Article 3.4 (capped at -0.37 MtC)		-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4		
Article 3.7	0.4																						
Kyoto Protocol Total	779.9	779.1	784.0	757.1	733.6	721.5	711.3	731.1	704.5	699.6	667.7	668.2	672.1	649.9	653.7	650.3	644.9	638.2	627.2	612.8	558.6	-28%	-28%
Fixed Base Year	776.3																						-28%

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.4 OTHER INFORMATION

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 ES4.1 Emissions of Indirect Greenhouse Gases in the UK, 1990-2009 (in kt).

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
NO_x	2,692	2,591	2,533	2,386	2,292	2,187	2,099	1,962	1,926	1,834
CO	9,030	9,244	8,837	8,508	8,054	7,546	7,600	7,106	6,821	6,476
NMVOC	2,711	2,655	2,582	2,460	2,373	2,189	2,111	2,025	1,881	1,703
SO_2	3,726	3,565	3,484	3,143	2,680	2,372	2,027	1,666	1,645	1,262

Gas	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
NO_x	1,794	1,758	1,669	1,639	1,591	1,558	1,500	1,419	1,256	1,091
CO	5,709	5,353	4,708	4,212	3,906	3,497	3,290	3,069	2,889	2,280
NMVOC	1,566	1,465	1,375	1,250	1,156	1,082	1,035	1,005	930	827
SO_2	1,264	1,152	1,024	1,002	834	701	667	590	502	401

Footnotes:

Geographical coverage of the emissions in the table includes emissions from the Crown Dependencies and Overseas Territories

Since 1990, emissions of all indirect gases have decreased. The largest source of emissions for all the indirect gases is the energy sector. For NO_x, CO and SO_2, over 90% of emissions arise from activities within this sector. For NMVOC, 41.8% of emissions are energy related, with other significant contributions from both the industrial processes and solvent sectors.

Contacts

This work is part of the Climate, 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://ghgi.decc.gov.uk/.

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Figures (in the main report) **Section**

Document Revision History

Issue	Revision History
Issue - Draft	Reviewed by DECC
Issue 1	Incorporates comments, submitted to EUMM
Issue 2	Includes annex for End User emissions and extended information for refrigerated transport. Submitted to the UNFCCC.

1 Introduction

This is the UK's 2010 National Inventory Report (NIR). From 2010 onwards, the NIR contains new information required for reporting under the Kyoto Protocol (decision 15/CMP.1).

The national inventory report (NIR), as established by decision 18/CP.8, is one element of the annual greenhouse gas (GHG) inventory that is required to be submitted to the UNFCCC by Annex I Parties to the Convention on 15th April of each year. The other elements of this submission include the reporting of GHG emissions by sources and removals by sinks in the common reporting format (CRF) tables, and any other additional information in support of this submission.

The UK is an Annex I Party to the Convention and is also a Party to the Kyoto Protocol. This means the UK is required to report supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol, with the inventory submission due under the Convention, in accordance with paragraph 3(a) of decision 15/CMP.1. This NIR contains this supplementary information in the appropriate sections.

1.1 BACKGROUND INFORMATION ON GREENHOUSE GAS INVENTORIES, CLIMATE CHANGE

1.1.1 Background information on Climate Change

There is strong evidence that since the early twentieth century the change in the earth's climate is linked to the release of greenhouse gases from human activities. The greenhouse gases that are released contribute to a process known as the greenhouse effect.

The greenhouse effect is a naturally occurring process which controls the temperature of the earth. However the release of extra greenhouse gases from human activities contributes to this process and traps extra heat within the earth's atmosphere, causing a warming effect. This increase in the earth's temperature has adverse impacts and these impacts will need to be managed and adapted to, both now and in the future, as the climate changes.

In response to this threat, the Kyoto Protocol was established. Countries that have signed and ratified the Kyoto Protocol are legally bound to reduce their greenhouse gas emissions by an agreed amount. A single European Union Kyoto Protocol reduction target for greenhouse gas emissions of -8% compared to base-year levels was negotiated, and a Burden Sharing Agreement allocates the target between Member States of the European Union. Under this agreement, the UK reduction target is -12.5% on base-year levels. The UK needs to achieve this reduction during the first commitment period of the Kyoto Protocol which runs from 2008 to 2012.

The UK has set itself even more stringent domestic targets, including an emission reduction target of 34% by 2020 on 1990 levels. This target is included in the ***Climate Change Act.***

The UK's Climate Change Programme published in March 2006, described 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 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 legislation introduced a new, more ambitious and legally binding target for the UK 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) was set up to advise the UK Government on the scope and level of UK carbon budgets. The CCC published its first advice to the UK Government on the 1st December 2008.

In response to the CCC's recommendations, in April 2009 the UK Government announced the levels of the first three five-year carbon budgets, starting in 2008, requiring the UK to cut emissions by 34% on 1990 levels by 2020. In July 2009, the UK Government released its Low Carbon Transition Plan, which plots out how emissions reductions by sector could enable the carbon budgets to 2022 to be met.

Further information on the UK's action to tackle climate change can be found on the following Government Department websites:

www.decc.gov.uk
ww2.defra.gov.uk/environment/climate/

1.1.2 Background information on Greenhouse Gas Inventories

1.1.2.1 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).

The UK's National Inventory Report (NIR) is prepared in accordance with decision 18/CP.8[4] and follows the structure outlined in the document FCCC/SBSTA/2006/9[5]. In addition to this, the UK also reports GHG emissions by sources and removals by sinks in the Common Reporting Format (CRF) tables. The estimates are consistent with the IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories (IPCC, 1997a, b, c), Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000) and the IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry (IPCC, 2003).

This report and corresponding CRF tables provide annual emission estimates submitted by the UK to the UNFCCC for the period 1990 to 2008. Estimates for emissions from Energy,

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[4] 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.

[5] Updated UNFCCC reporting guidelines on annual inventories following incorporation of the provisions of decision 14/CP.11. See http://unfccc.int/resource/docs/2006/sbsta/eng/09.pdf

Industrial Processes, Solvents and Waste are compiled by AEA, under contract to the Department of Energy and Climate Change (DECC). Emissions and removals from land use change and forestry are provided by the Centre of Ecology and Hydrology (CEH) under contract to DECC and agricultural emissions by North Wyke Research, under contract to the Department of Environment, Food and Rural Affairs (Defra).

To fulfil both European Union Monitoring Mechanism (EUMM) and UNFCCC reporting requirements the UK has prepared two sets of CRF tables and has officially reported both sets. These two sets of tables present emission estimates for different geographical coverages:

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

The main part of the report presents GHG emissions for the years 1990-2009, and discusses the reasons for the trends and any changes in the estimates due to revisions made since the last inventory. 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 National Atmospheric Emissions Inventory (NAEI). It contains mappings between IPCC, NAEI source categories and fuel types as well as 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 (CRF) Tables. These datasets are included on a CD ROM attached to this report.

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.

1.1.2.2 Geographical coverage of UK emissions

As mentioned in **Section 1.1.2.1**, the UK compiles and reports two different sets of CRF tables, each with a different geographical coverage of emissions to fulfil the reporting requirements of both the EUMM and the UNFCCC.

A major source of activity data for the UK inventory is provided by UK DECC through their publication the Digest of UK Environmental Statistics (DUKES) (see **Table 1.6**), and the geographical coverage of DUKES helps define the geographical coverage of the inventory. DECC advises that the geographical coverage of the statistics is the United Kingdom (DECC, 2010). 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 DECC accords with that of the "economic territory of the United Kingdom" used by the UK Office for National Statistics, which in turn accords with the definition required to be used under the European System of Accounts (ESA95).

The geographical coverage of the UK inventory presented in this NIR has been extended to include emissions from the UK's Crown Dependencies (CDs) and the UK's Overseas Territories (OTs)[6] who have joined, or are likely to join, the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol.

The UK has two types of associated territories, which are 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 their defence and international relations. The Crown Dependencies 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.

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

1.1.2.3 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.

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

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 (GWP) of these gases and hence the total global warming potential of all UK greenhouse gases.

1.1.2.4 Global Warming Potentials of the Greenhouse Gases

The direct greenhouse gases have different effectiveness in radiative forcing. The 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
HFC-23	11,700
HFC-32	650
HFC-125	2,800
HFC-134a	1,300
HFC-143a	3,800
HFC-152a	140
HFC-227ea	2,900
HFC-236fa	6,300
HFC-43-10mee	1,300
PFCs	6,500-9,200
PFC-14	6,500
PFC-116	9,200
PFC-218	7,000
PFC-318	8,700
PFC-3-1-10	7,000
PFC-5-1-14	7,400
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).

1.1.3 Background information on supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol

Information relating to the supplementary information required under Article 7, Paragraph 1 of the Kyoto Protocol can be found in the relevant sections of this report.

Table 1.2 below summarises the background information relating to the supplementary information and cross-references the reader to the appropriate part of the report for more detailed information.

Table 1.2 Background information on supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol

Reporting Element	Background Information
Supplementary inventory information for activities under Article 3, Paragraphs 3 and 4	The reporting of KP-LULUCF is carried out by the Centre for Ecology and Hydrology (CEH) on behalf of DECC. The UK has chosen to elect Forest Management (FM) as an activity under Article 3.4. The calculations follow the same method and use the same models as the UNFCCC estimates for LULUCF, which are also prepared by CEH. Further information can be found in Chapter 11.
Information on Kyoto Protocol units	The UK National Registry is operated and maintained by the Environment Agency on behalf of DECC. Information on accounting of Kyoto Protocol units, including a summary of information reported in the standard electronic format (SEF) tables is provided in Chapter 12. SEF tables including information for the period 01.01.2009 to 31.12.2009 can be found in Annex 6 of this report.
Changes in National Systems	The UK National System is managed and maintained by DECC, who are the Single National Entity. Changes to the national System are reported in Chapter 13 of this report.
Changes in National Registry	The UK National Registry is operated and maintained by the Environment Agency on behalf of DECC. The National Registry currently sits outside of the National System for the inventory, but is represented on the National Inventory Steering Committee. All changes in the National Registry are reported in Chapter 14.
Minimisation of adverse impacts in accordance with Article 3, Paragraph 14	The UK has undertaken several assessments, reviews and analysis projects to better understand the impacts its policies could have on developing countries, and how

Reporting Element	Background Information
	they could be addressed. We have supported several knowledge transfer, research collaboration and capacity building. Further details on the UK's efforts to minimise adverse impacts is provided in Chapter 15.

1.2 INSTITUTIONAL ARRANGEMENTS FOR INVENTORY PREPARATION

1.2.1 Institutional, legal and procedural arrangements for compiling the UK inventory

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) team 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 Farming and Food Science Team 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). The KP-LULUCF information is also produced by CEH. The mechanism for generating the KP-LULUCF data and the quality control and assurance procedures applied are an integral part of the UK's National System.

1.2.1.1 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 1.1 shows the main elements the UK NIS, including provision of data to the European Union under the terms of the EUMM. DECC is the **Single National Entity** responsible for submitting the UK's GHGI to the UNFCCC. The Inventory Agency is AEA, who are responsible for compiling the GHGI on behalf of DECC, and produces disaggregated estimates for the Devolved Administrations within the UK.

KDPs include other Government Departments such as Department for Environment, Food and Rural Affairs (Defra) and the Department for Transport (DfT), Non-Departmental Public Bodies such as the Environment Agency for England and Wales (EA), the Northern Ireland Environment Agency and the Scottish Environment Protection Agency (SEPA), private companies such as Corus, and business organisations such as UK Petroleum Industry Association (UKPIA) and the British Cement Association (BCA).

Figure 1.2 summarises the key organisational structure of the UK NIS and **Section 1.2.2** includes further detailed information on the roles and responsibilities of each of the key organisations.

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

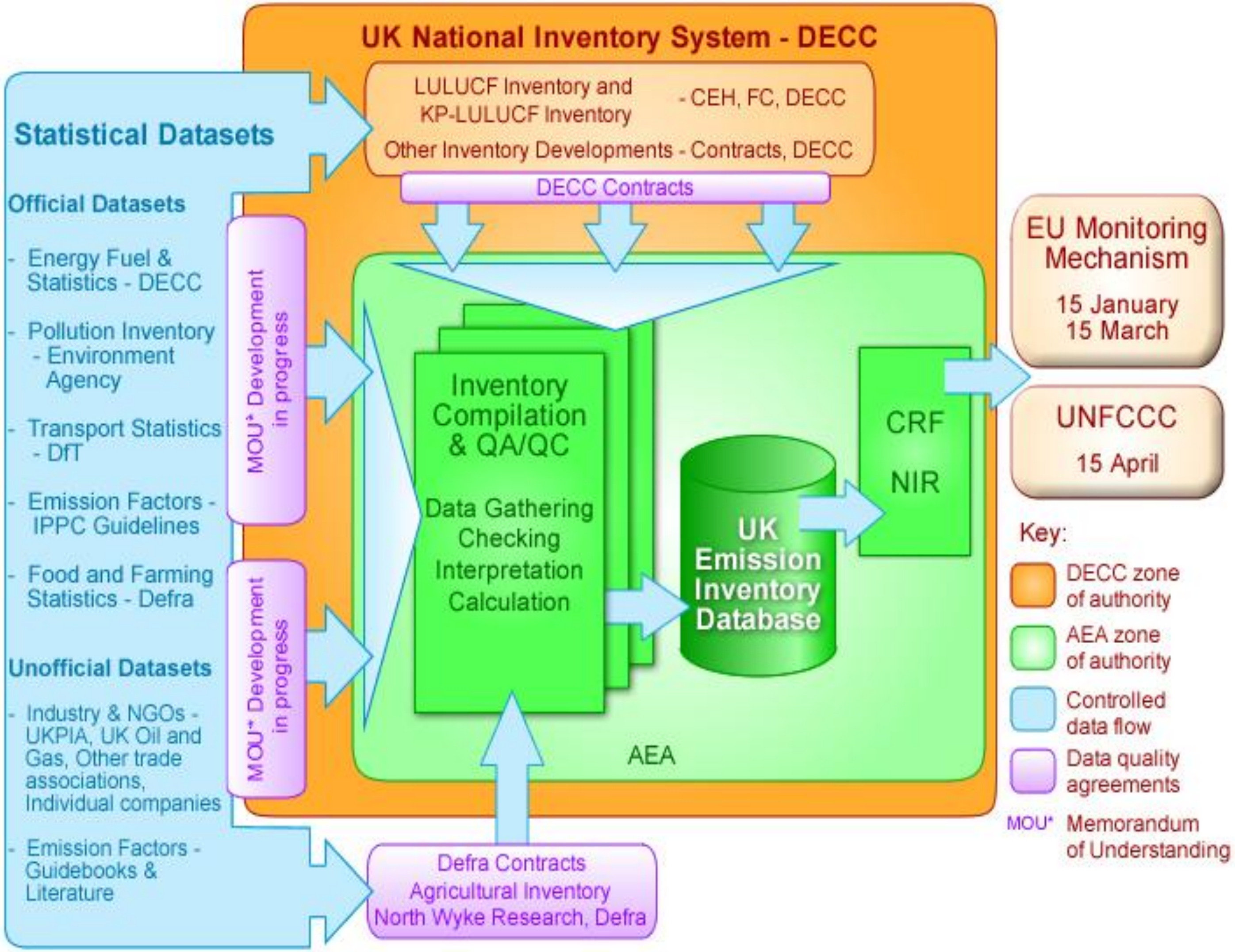
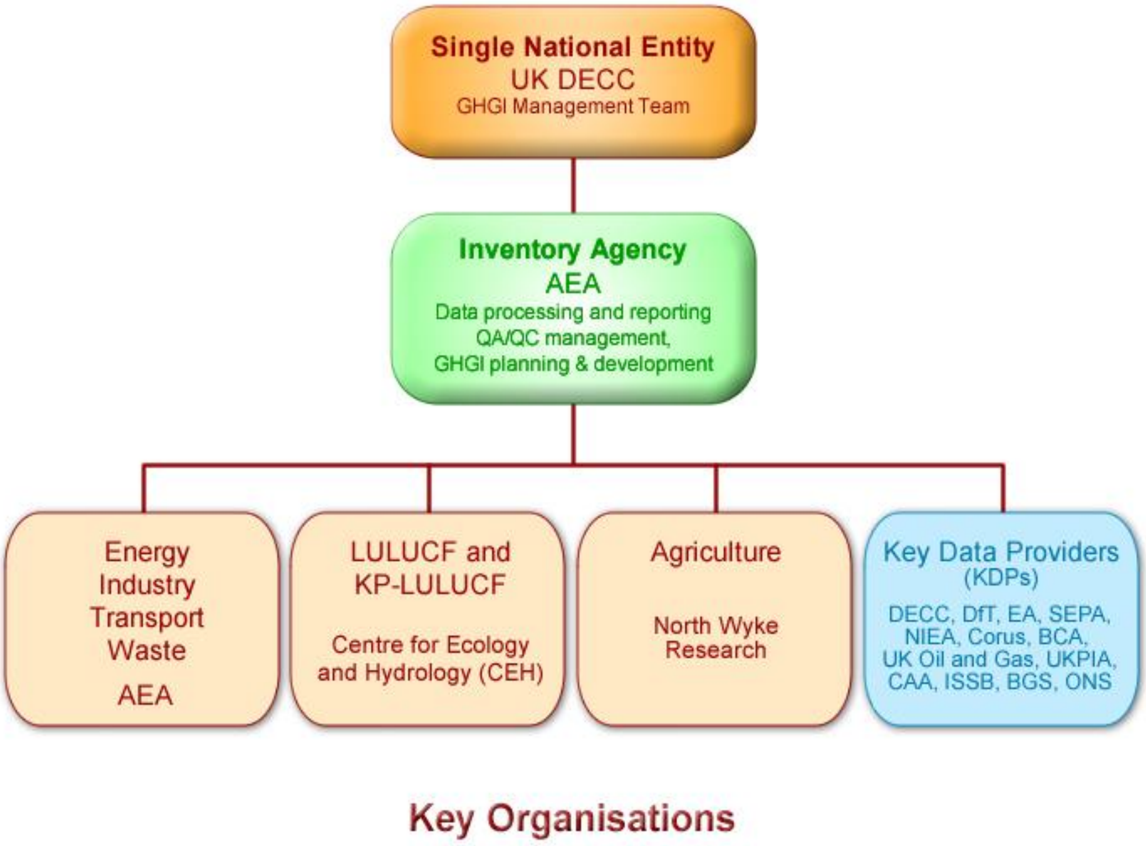


Figure 1.2 Key organisational structure of the UK National Inventory System



1.2.1.2 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 DECC).

Recognising the fact that such a system of data collection might not meet the standards required under the Kyoto Protocol, the UK Government introduced legislation specifically for national inventory purposes which took effect from November 2005[7]. 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 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.

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

To ensure that the system works most effectively as it currently stands and to minimise the need for legislative action, DECC has embarked upon a programme of implementing formal Data Supply Agreements with relevant organisations to build upon existing relationships with KDPs. These agreements formalise the acquisition of data and clarify the main requirements of quality, format, security and timely delivery of data for the national inventory. The first DSA is now in place, with the DfT. Further DSAs are expected to be finalised before the 2012 GHGI submission.

1.2.2 Overview of Inventory Planning

As summarised in **Section 1.2.1**, the UK has designated authorities with clear roles and responsibilities. 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; 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 GHGI and NIS.

Preparation

- Drafting technical schedules to Data Supply Agreements with key data providers; and
- Review of source data & identification of developments required to improve GHGI data quality.

Management

- Documentation & archiving;
- Dissemination of information regarding the NIS to KDPs; 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 and the KP-LULUCF inventory. CEH conduct specific research in the LULUCF sector and provide finalised data to AEA for inclusion within the UK GHG inventory.

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 provides finalised GHG emissions data to AEA for inclusion within the UK inventory.

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 by the Inventory Agency;

- Management of their data acquisition, processing & reporting systems, taking regard for inventory QA/QC requirements and responding to Inventory Agency requests for clarifications;
- 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 UK 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 (PI) for England & Wales;
b) The Scottish Environment Protection Agency’s Scottish Pollutant Release Inventory (SPRI); and
c) The Northern Ireland Environment Agency’s Inventory of Statutory Releases (ISR).

Reporting annual emission estimates to these UK inventories is a statutory requirement for industrial operators of installations regulated under the Integrated Pollution Prevention and Control (IPPC) regulations and Environmental Permitting Regulations (EPR). The scope of the annual reporting requirements is defined by the site IPPC or EPR permit conditions and the reporting thresholds for specific pollutants. The data from these inventories is also used to quality check data provided by companies directly to AEA.

North Wyke Research compiles the inventory for agricultural emissions using agricultural statistics from Defra and the Devolved Administrations.

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 periodic research contracts to provide emission estimates for certain sources such as fluorinated gases, landfill methane and to provide estimates for previously unreported emission sources.

1.2.2.4 Pre-Submission Review and Approval of the UK GHGI

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.

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 body, the National Inventory Steering Committee (NISC), which is 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. The NISC is responsible for agreeing the priorities for the UK GHGI improvement programme. Furthermore, in 2011 the NISC members contributed and coordinated a thorough review of the content of the NIR to allow appropriate non-NISC colleagues to make recommendations to the Inventory Agency for improvements in the report as well as themselves.

Table 1.3 and **Table 1.4** 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. These tables include 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 development of the inventory is driven through the NISC, which meets twice a year to discuss the outcomes of recent peer, internal and expert reviews and to agree the prioritisation, funding, implementation and review of items on the UK inventory improvement programme. The Key Category Analysis and the uncertainty analysis, as well as recommendations from reviews of the UK GHG inventory are used as guidance to help the members of the NISC make decisions on which improvements are the most important. Key categories with high uncertainty are given priority over non-key categories or categories with a low uncertainty. The annual inventory review feedback from the UNFCCC and European Union Monitoring Mechanism (EUMM), as well as sector-specific peer- or bilateral review findings are also considered to guide decisions on UK GHGI improvement priorities.

Table 1.3 UK GHG National Inventory Steering Committee

Organisation	Role in relation to NISC	Key NISC responsibilities
DECC Climate Energy Science and Analysis (CESA)	• GHG inventory manager • Manager of GHG research contracts • DECC annual climate change statistics and indicators	• Administer functions of Single National Entity for the UK Nation System; • Overall responsibility for inventory development, compilation and reporting; • Manage GHG inventory research contracts • Act as NISC Chair • Ensure that UK GHGI conforms to EU and UN international standards and requirements
Defra – Atmosphere and Local Environment Programme (ALE)	• AQ inventory manager • Manager of AQ research contracts	• Ensure that UK AQ inventory conforms to EU and UN international standards and requirements • Overall responsibility for AQ inventory development, compilation and reporting, including ensuring that AQ impacts are taken into consideration within GHG inventory improvement projects
Defra	• Liaison between Defra and NISC	• Provide an analytical overview of all relevant Defra sectors • Provide link with Defra climate change mitigation team • Maintain open dialogue between DECC and Defra, especially to aid in the co-ordination of research and data pertaining to agriculture and waste sectors, which fall predominantly under Defra's remit
DECC – National Climate Change	• UK Climate Change Programme • Climate Change Act • Carbon budgets	• Inform NISC of UK programme developments • Explore links between inventory and carbon budgets and potential requirements for either area
DECC – National Climate Change, Carbon Markets	• EU ETS • EU ETS Registry • EC Effort Sharing Decision	• Provide EU ETS fuel use and fuel characterisation datasets for determining industrial fuel use statistics and GHG emission from combustion sources • Provide updates of developments on the Effort Sharing Decision and EU ETS and any implications for future reporting requirements • Improve links between EU ETS registry and GHG inventory

Organisation	Role in relation to NISC	Key NISC responsibilities
DECC – International Climate Change and Energy (ICCE)	• International negotiations • EUMM • UNFCCC	• Feed international emissions inventory expectations back to the NISC to ensure the UK complies and develops the inventory accordingly • Provide information on future international developments and changes to expectations • Provide advice on the implications of domestic changes to the inventory in an international arena
DECC – Climate, Energy, Science and Analysis (CESA) – LULUCF	• LULUCF Inventory manager	• Provide LULUCF inventory data that conforms to EU and UNFCCC international standards and requirements, through management and review of the CEH inventory submissions • Work with the NISC to ensure highest quality data
Defra –Farming and Food Science	• Agriculture Inventory Manager	• Providing agriculture inventory data that conforms to EU and UN international standards and requirements, through management and review of the North Wyke inventory submissions • Work with the NISC to ensure highest quality data
Defra – Water policy	• Waste water	• To provide water policy expertise to the inventory • To assist in improving waste water data quality
Defra – Waste	• Waste	• To provide waste policy expertise to the inventory, including landfill waste • To assist in improving landfill waste data quality
DECC – Energy Statistics (DUKES)	• Energy statistics	• Annual publication of Digest of UK Energy Statistics • Providing energy statistics to inform the UK inventory

Organisation	Role in relation to NISC	Key NISC responsibilities
Regulators: - Environment Agency for England and Wales - Scottish Environment Protection Agency - Northern Ireland Environment Agency	- Regulators of IPPC/EPR - Collation of annual Pollution inventories (PI, SPRI, ISR) - EU ETS regulators	- Management, compilation, QA/QC and reporting of pollutant emission inventories/registers under IPCC/EPR, and EU ETS annual emission reporting - Ensure that the pollutant emission inventories for industrial processes regulated under IPCC/EPR (PI, SPRI, ISR) are presented in the required format and timescale for inventory estimation and reporting - Collate information from annual emission reports for EU ETS and provide the detailed energy and emissions data to DECC and the Inventory Agency.
DECC oil and gas Offshore Regulator	- Regulator of system of environmental emissions reporting governing offshore oil & gas operators	- Regulation of the upstream oil & gas exploration and production industry. This includes management of the EEMS reporting system of activity data and environmental emissions from all offshore installations and onshore terminals, provided to the Inventory Agency for use in the GHGI
Department for Communities and Local Government (CLG)	- Housing statistics - Local Government issues	- Publication of housing statistics each year; coordination of technical requirements of local authorities to assist in action on climate change - Providing housing statistics to inform the UK inventory
Department for Transport (DfT)	- Transport	- Publication of transport statistics each year - Providing transport statistics to inform the UK inventory - Prioritising and facilitating transport-specific improvement items within the UK GHGi improvement programme
Devolved Administrations	- Assist DECC in the management of emission inventories for the Devolved Administrations (Scotland, Wales, Northern Ireland)	- General review function for completeness and accuracy of inventory from a devolved perspective - Review aspects of the UK GHG inventory that correspond to devolved issues, ensuring the integration of local datasets and specific research where appropriate. - Work with DECC to prioritise and fund projects within the inventory improvement programme aimed at national and sub-national datasets.

Organisation	Role in relation to NISC	Key NISC responsibilities
GHG inventory contractor (AEA)	• UK greenhouse gas inventory compilation, development, quality management, documentation, archiving and reporting	• Contractor responsible for UK GHG inventory; activity data, methods, emission factors, emissions estimation, reporting and archiving • Deliver annual NIR and CRF submission to the UN and EU • Participate in sector expert panels as required
Agricultural inventory contractor (North Wyke)	• Agriculture Inventory compilation and development	• Contractor responsible for agriculture inventory; activity data, methods, emission factors and emission estimation • Prepare and develop agricultural inventory and deliver on time for incorporation into national inventory • Participate in sector expert panels as required
LULUCF inventory contractor (CEH)	• LULUCF inventory	• Contractor responsible for LULUCF inventory; activity data, methods, emission factors and removals estimation • Prepare and develop LULUCF inventory of emissions and removals and deliver on time for incorporation into the national inventory • Participate in sector expert panels as required
DECC – Energy Analysis	• Energy modelling and projections	• Produce UK CO_2 projections

Table 1.4 Special Advisors to the UK GHG National Inventory Steering Committee[8]

Organisation	Role in relation to NISC	Key NISC responsibilities
Met Office/Bristol University	• Atmospheric measurements and interpretation to underpin inventory verification	• Provide atmospheric measurements and interpretation of data for use in inventory data verification • Prepare comparison between estimated and observed emissions for the NIR
External reviewers	• Representation of industries, industry organisations and independent experts in the development of the national inventory	• Participate in sector expert panels and review / contribute data and methods to improve inventory estimates and support the inventory improvement programme. (Expert advisors and reviewers may be drawn from a wide range of organisations, such as: ONS, UKPIA, Oil & Gas UK, Tata steel, Electricity Supply Industry, Transco, gas distribution network operators, fuel suppliers)

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[8] Attendance at NISC meetings is subject to specific requirements

1.2.2.5 UK Inventory Improvement Programme

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 sources such as EMEP-CORINAIR and the US EPA, or from specific research programmes sponsored by DECC and other UK Departments.

The UK GHG National Inventory Steering Committee (NISC) is a formal cross-Government Steering Committee that was established in 2006 to provide an independent group of inventory stakeholders to assist in the review and improvement of the UK inventory. One of the main roles 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.

In recent years the NISC has established a more formal system of inventory improvements, with NISC members from across various Government Departments taking responsibility for scoping and commissioning new research aimed at improving inventory data quality. This achieves the dual aims of (i) progressing research to improve the UK GHGI data quality, and (ii) developing inter-Departmental/Agency working relationships to integrate inventory-related information from across Government.

During 2010-11, research commissioned via the UK GHGI Improvement Programme and completed in time for inclusion in the 2011 submission included:

- A review of public sector energy and emissions data, to identify potential new sources of activity data to help inform national and sub-national emission estimates in this sector;
- A review of refinery and upstream oil & gas sector emissions data, to research and reconcile data reporting inconsistencies between reporting mechanisms (IPPC, EU ETS, EEMS);
- Detailed analysis of EU ETS energy data and comparison of sector estimates against UK energy statistics, to resolve data inconsistencies;
- Revision of the natural gas distribution network leakage model and consultation with industry to generate new emission estimates for gas leakage at point of use;
- Revision to the data management systems and reporting of emissions from the upstream oil & gas sector, to provide a more detailed reporting structure that presents separate emission estimates from oil production installations and gas production installations. This has improved the data transparency and also enables a more accurate analysis of end user GHGI emission estimates in the UK;
- Revision to the data management and reporting of aviation emissions from Overseas Territories, to resolve data reporting inconsistencies;
- Research to obtain detailed regional vehicle fleet information, to refine and improve the UK road transport emissions model;
- Consultation with UK water companies and regulatory experts within Defra to review available activity and emissions data for water treatment and sewage sludge disposal activities in the UK, to improve the estimation method within the UK GHGI;
- Work to improve the UK's inventory reporting systems to allow speciated reporting of HFCs and PFCs in the CRF.

In addition to the above, there are a number of ongoing improvement tasks which have not been completed in time for the 2011 submission, including:

- Analysis of Phase III EU ETS baseline data, to identify where new source data from operators may improve sector-specific estimates in the inventory;
- Analysis of new datasets from environmental regulators from new policy initiatives in the UK, such as the Carbon Reduction Commitment Energy Efficiency Scheme, to research any new sector energy and emissions data to improve the inventory accuracy and transparency;
- Review of IPPC/EPR and EU ETS documentation for priority sites in sectors including the chemical and food & drink sectors, to resolve emissions reporting inconsistencies between reporting mechanisms such as IPPC/EPR and EU ETS;
- Review of Net Calorific Value data for industrial secondary gaseous fuels (coke oven gas, blast furnace gas, refinery fuel gas/other petroleum gases), to research inconsistencies between EU ETS and GHGI;
- Review of the time series of energy statistics and inventory agency data management systems in order to assess the scope for reporting industrial combustion estimates for 1a2b,c,d, and e separately, to improve the transparency of the GHGI (which currently has all of these sector estimates reported together, combined with 1A2f);
- Review of potential new data sources of activity data in the rail sector, to improve the detail and accuracy of the UK GHGI emission estimates in that sector, and improve the local and regional emission estimates;
- Review of potential new data sources of activity data in the inland waterways sector, to assess whether national energy statistics represent the sector accurately, and whether re-allocation of fuel use between sectors is required to present new estimates for this sector;
- Development and publication of new inventory method summaries and user guidance notes, to improve the accessibility of UK GHGI materials to a wider non-technical audience in the UK, predominantly aimed at improving communications with Departmental policy leads;
- Review of Climate Change action plans and strategy documents from Devolved Governments, to identify new data sources that may be of use to improve the accuracy and transparency of GHGI sector estimates in the future.
- Review of data sources and methodologies to estimate methane emissions from operating and abandoned coal mines.

The progress from these improvement projects and consideration of future research priorities for the UK GHGI will be addressed at the next NISC meeting in summer 2011.

Agriculture Inventory Improvements

The UK GHG agricultural inventory is undergoing large improvements in order to better quantify the emissions and reduce uncertainty. Consortia of a wide range of scientific expertise has been put together to fulfil the requirements for improving the UK GHG agricultural inventory.

The improvement plan comprises:

1) Restructuring the inventory to improve spatial and temporal disaggregation and incorporation of Tier 2 methodology in those areas where both measurement and activity data are available. Also to allow the inventory to reflect the effect of mitigation strategies (DEFRA project AC0112).

2) Data mining to collate and review existing experimental agricultural data to deliver a set of country specific (Tier 2) emission factors and supporting farm practice data to enable an improved mapping of nitrous oxide and methane emissions for the United Kingdom with an assessment of uncertainty (DEFRA project AC0114).
3) Measurements at field scale of CH_4 emissions from enteric fermentation to develop Tier 2 methodology (DEFRA project AC0115).
4) Measurements at field scale of direct N_2O emissions at a range of UK sites to develop new country specific emission factors for inorganic N fertiliser, manure applications and urine and dung deposition by grazing livestock (EF1, EF3) (DEFRA project AC0116). In addition, measurements of indirect N_2O losses are planned at three sites where drainage is collected and the N_2O loss from leached/drained N is quantified (EF_5)
5) Measurements at field scale of NH_3 emissions from manure management systems (DEFRA project AC0112).
6) Development of emission factors for N_2O from animal manure management systems from existing data (DEFRA project AC0112).
7) Assessment of the effect of mitigation strategies, specifically the use of nitrification inhibitors and optimising fertiliser timing on N_2O emission from soils

1.2.3 Overview of inventory preparation and management, including for supplementary information required under Article 7, Paragraph 1 of the Kyoto Protocol

For details of inventory preparation, see **Section 1.3**.

The Environment Agency is appointed as the UK Registry Administrator for the EU ETS /Kyoto Registry by DECC. The UK for this purpose comprises England, Wales, Scotland, Northern Ireland, Offshore installations and Gibraltar. The Environment Agency is a Government Agency.

Responsibilities of the Environment Agency include:

- Managing the contractors responsible for maintaining the computer systems (Siemens for software/hosting the Registry and Trustis for digital certificates);
- Conform to the Kyoto Protocol and the COP/MOP decisions as implemented by the UNFCCC;
- Conform to the EU Registries Regulations as amended from time to time;
- Allow access for authorised users. See Terms and Conditions at http://emissionsregistry.environment-agency.gov.uk/Default.aspx
- Act on instructions from Competent Authorities to manage accounts;
- Assist registry users

DECC is currently implementing a Data Supply Agreement with the Environment Agency to ensure that the specific responsibilities of the Agency are more formally agreed. (This agreement is expected to be finalised during spring 2011.)

1.3 INVENTORY PREPARATION

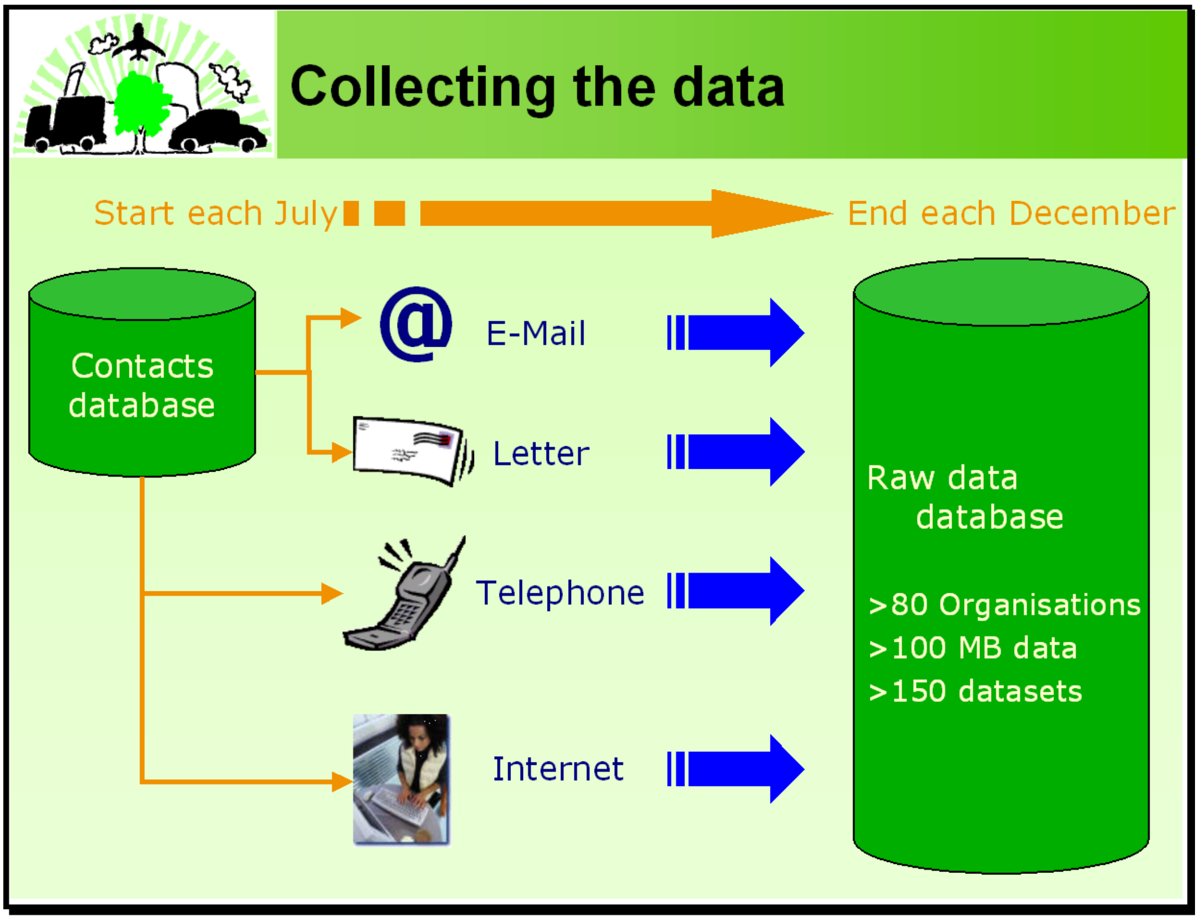
1.3.1 GHG Inventory and KP- LULUCF Inventory

The present UK GHG inventory for the period 1990-2009 was compiled in accordance 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), and the Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC, 2003). As already highlighted in this Chapter, the KP-LULUCF is prepared by CEH, who also prepare Sector 5 LULUCF emission estimates.

1.3.2 Data collection, processing and storage, including for LULUCF Inventory

Figure 1.3 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 1.3 Data collection for the UK greenhouse gas inventory



The following activities are carried out annually during inventory compilation, and meet the requirements of the Tier 1 QA/QC procedures (as outlined in Table 8.1 of the Good Practice Guidance: IPCC, 2000):

- ***Method Improvement***
  Improvements to calculation methods are normally implemented before the inventory is compiled. These improvements may be based on recommendations of UNFCCC (In Depth Reviews, In Country Reviews), EUMM reviews, bilateral and peer reviews and relevant research sponsored by DECC, 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.
- ***Quality Checking Routines***
  A series of quality checking routines are conducted to detect anomalies in the estimates (such as time series variations, year to year changes, outlier implied emission factors). 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. 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.
- ***Data archiving***
  At the end of each inventory cycle, all data, spreadsheets, databases and reports are archived, allowing all data to remain traceable, should it be needed in future years.

North Wyke Research and CEH, who are the sector experts for Agriculture and LULUCF (including KP LULUCF), respectively, have their own systems in place for data collection, processing, quality checking, archiving, documentation and reporting.

As the Inventory Agency responsible for compiling the overall inventory estimates, AEA receive completed emission estimates from these organisations as part of the annual data collection process, and combine the datasets within the CRF submissions and within the National Inventory Report.

1.3.3 Quality assurance/quality control (QA/QC) procedures and extensive review of GHG inventory and KP-LULUCF Inventory

The QA/QC plan for the UK inventory is detailed in **Section 1.6**. Since the KP-LULUCF inventory is compiled within the structure of the National Inventory System, the estimates are subject to the same QA/QC procedures as the rest of the UK inventory. For further details of QA/QC in the LULUCF sectors, see **Chapter 7**, **Section 7.9**.

1.4 METHODOLOGIES AND DATA SOURCES

1.4.1 GHG 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 which mostly correspond to the detailed sectoral Tier 2/3 methods in the IPCC Guidelines. **Figure 1.4** below shows the data flow through the UK GHG inventory.

Figure 1.4 **Data flow through the UK greenhouse gas inventory**

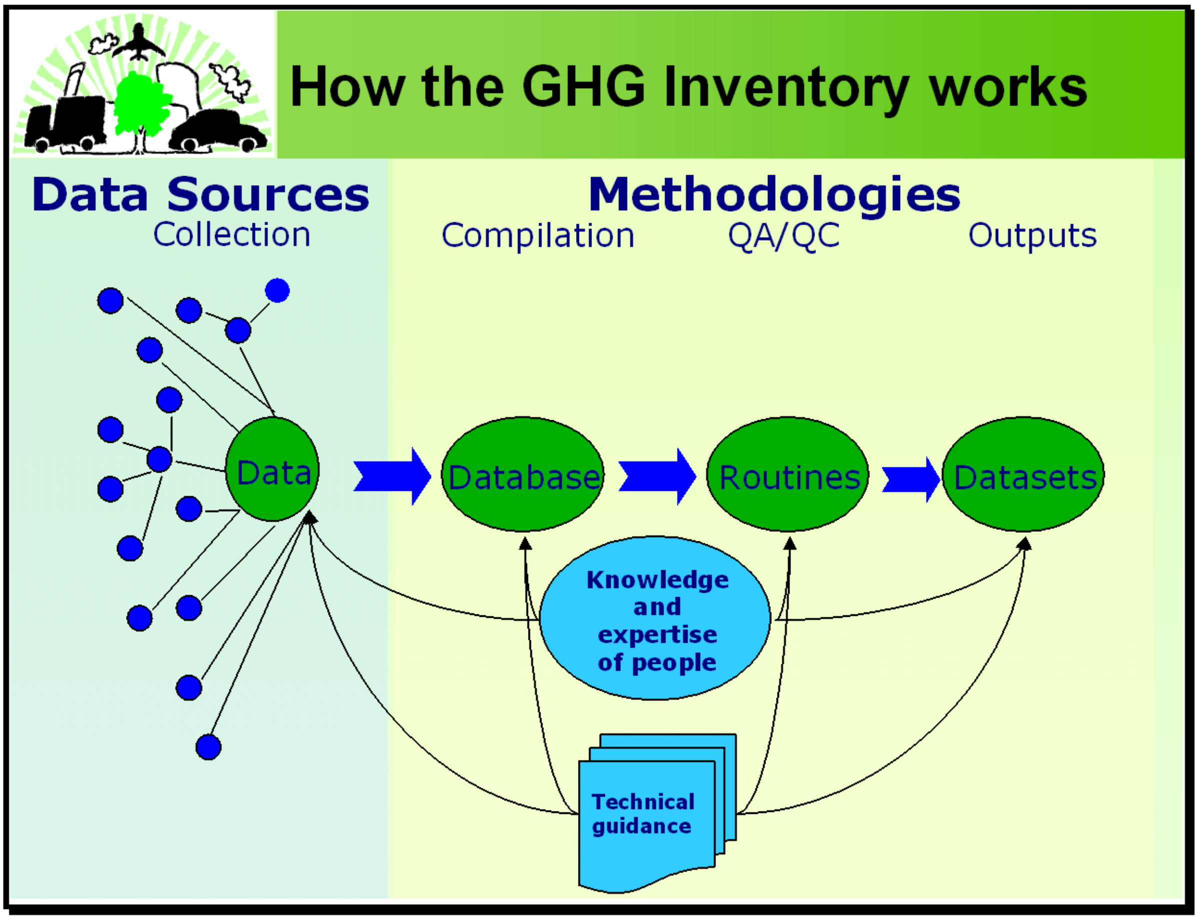


Table 1.5 provides a brief summary of the methods used to estimate UK GHG emissions, which are described in more detail in the subsequent Chapters and Appendices.

Table 1.5 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**); • DECC 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 4.2.2**).
2B	• Emissions calculated based on data from industry and the PI/SPRI/ISR; 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 MELmod model.
6B	• IPCC default method and UK water company data
6C	• Uses country specific EFs, partially based on PI/SPRI/ISR 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 1.6**. All sources are updated annually.

Table 1.6 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 of Energy and Climate Change)	• 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 for Regional Development	• 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 Pollutant Release Inventory (Scottish Environment 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.
DECC Oil and Gas	• Detailed EEMS inventory of oil & gas installation 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.

1.4.2 KP- LULUCF inventory

The methodology and data sources used for preparing the KP-LULUCF inventory are described in **Chapter 11**.

1.5 DESCRIPTION OF KEY SOURCE CATEGORIES

1.5.1 GHG Inventory (including and excluding LULUCF)

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. **Table 1.7**, **Table 1.8, Table 1.9** and **Table 1.10** summarise the key source categories, for 2008 (the latest reported year), and the base year, derived from the IPCC Approach 1 uncertainty analysis. Tables are included for the analysis with and without LULUCF. 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.

During the 2010 Centralised Review of the UK GHGI, the Expert Review Team (ERT) recommended that emissions from cement production (2A1) should also be treated as a Key Category, due to the magnitude of the emission. On this basis, emissions from cement production will now be considered as a key source category.

Table 1.7 Key Source Categories for the latest reported year (including LULUCF)

IPCC source category	Fuel/Activity	GHG	Reason (s)
1A(stationary)	Oil	CO_2	Level
1A	Natural Gas	CO_2	Level
1A3b	Auto Fuel	CO_2	Level
5A	5A LUCF	CO_2	Level
5B	5B LUCF	CO_2	Level
5C	5C LUCF	CO_2	Level
5E	5E LUCF	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 1.8 Key Source Categories for the base year (including LULUCF)

IPCC source category	Fuel/Activity	GHG	Reason
1A	Coal	CO_2	Level
1A(stationary)	Oil	CO_2	Level
1A3b	Auto Fuel	CO_2	Level
5A	5A LUCF	CO_2	Level
5B	5B LUCF	CO_2	Level
5C	5C LUCF	CO_2	Level
5E	5E LUCF	CO_2	Level
1B1	Coal Mining	CH_4	Level
4A	Enteric Fermentation	CH_4	Level
6A	Solid Waste Disposal	CH_4	Level

IPCC source category	Fuel/Activity	GHG	Reason
1A1&1A2&1A4&1A5	Other Combustion	N_2O	Level
1A3b	Auto Fuel	N_2O	Level
2B	Adipic Acid Production	N_2O	Level
2B	Nitric Acid Production	N_2O	Level
4B	Manure Management	N_2O	Level
4D	Agricultural Soils	N_2O	Level
6B	Wastewater Handling	N_2O	Level
2	Industrial Processes	HFC	Level

Table 1.9 Key Source Categories for the latest reported year (excluding LULUCF)

IPCC source category	Fuel/Activity	GHG	Reason (s)
1A(stationary)	Oil	CO_2	Level, Trend
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
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 1.10 Key Source Categories for base year (excluding LULUCF)

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

1.5.2 KP-LULUCF Inventory

A separate uncertainty analysis has been completed for the Key Categories for Land Use, Land-Use Change and Forestry Activities under the Kyoto Protocol. The full details of this analysis are given in Table NIR 3, reproduced in **Table A1.2.1** in **Annex 1**. This analysis indicates the key categories of emissions and removals are (KP category, gas, associated UNFCCC category):

- Afforestation and Reforestation, CO_2, Conversion to Forest Land
- Deforestation, CO_2, Conversion to Grassland; conversion to Settlements
- Forest Management, CO_2, Conversion to Forest Land

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

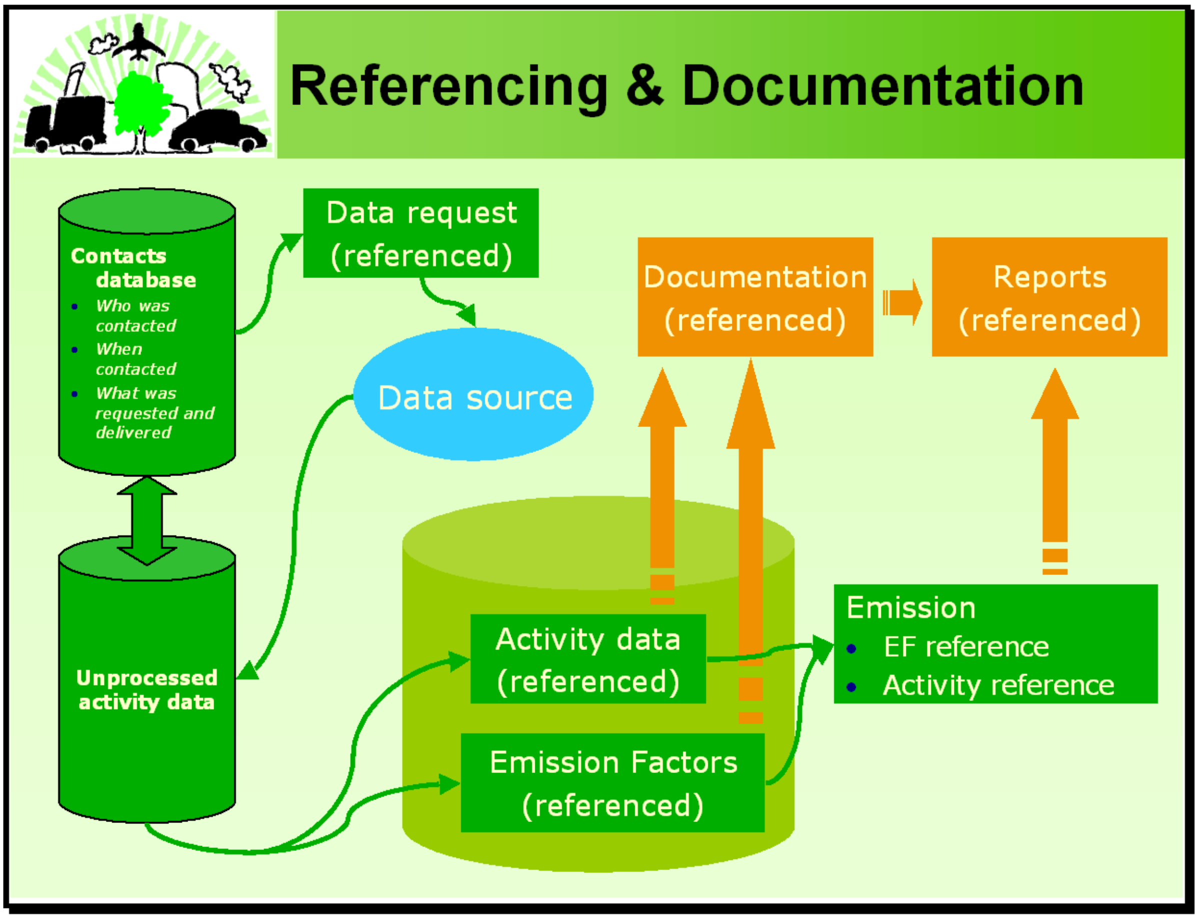
The National Atmospheric Emissions Inventory and the UK Greenhouse Gas Inventory are compiled and maintained by AEA, part of AEA Technology plc. The data compilation and reporting for some source sectors of the UK inventory are performed by other contractors (i.e. North Wyke compile the agriculture sector, 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 1.5** 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 9001:2008. 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 9001:2008, and was last audited in October 2009 by Lloyds.

Figure 1.5 System of referencing and documentation used within UK greenhouse gas inventory



The system incorporates the following activities (see **Figure 1.5**), 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 QA/QC 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 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.

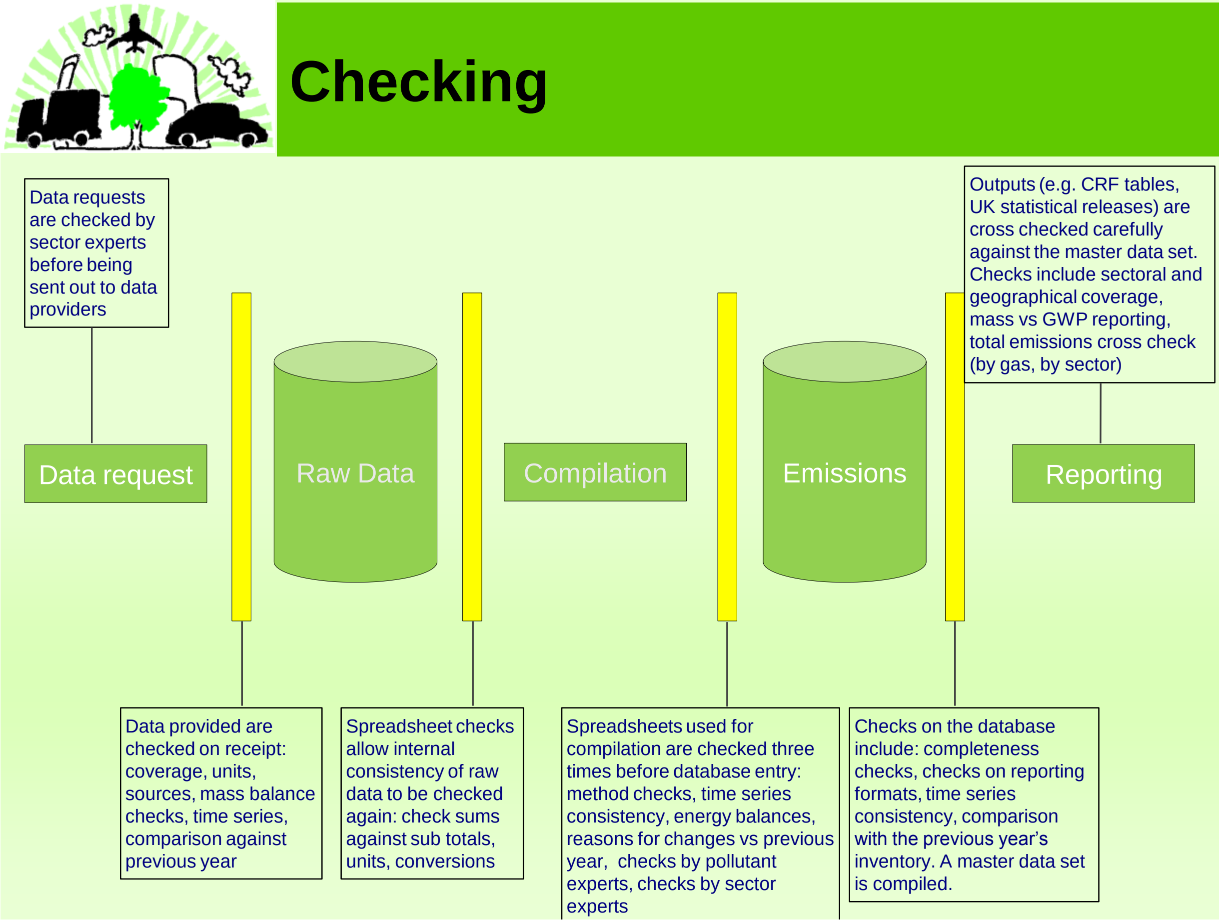
6. ***Archiving***

- 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 1.6 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)



Data requests are checked by sector experts before being sent out to data providers

Outputs (e.g. CRF tables, UK statistical releases) are cross checked carefully against the master data set. Checks include sectoral and geographical coverage, mass vs GWP reporting, total emissions cross check (by gas, by sector)

Data provided are checked on receipt: coverage, units, sources, mass balance checks, time series, comparison against previous year

Spreadsheet checks allow internal consistency of raw data to be checked again: check sums against sub totals, units, conversions

Spreadsheets used for compilation are checked three times before database entry: method checks, time series consistency, energy balances, reasons for changes vs previous year, checks by pollutant experts, checks by sector experts

Checks on the database include: completeness checks, checks on reporting formats, time series consistency, comparison with the previous year’s inventory. A master data set is compiled.

1.6.1.1 Special QA/QC activities undertaken in 2010-2011

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

Stakeholder Consultation 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. This programme of stakeholder consultation has included:

- Industry consultation to revise the source data and industry model used to generate estimates of methane leakage from the UK gas network, including revisions of: gas compositional analysis (method change), local/regional gas consumption data (data quality checks), and leakage data by network.
- Consultation with DECC DUKES and the regulators of the EU ETS data collection and reporting systems to determine sector-specific and fuel-specific quality parameters for the UK, and to resolve any data inconsistencies between published UK energy statistics and the EU ETS data for the latest year.
- Industry consultation with the water and sewerage companies in the UK, leading to a revision of the estimation methodology and several underlying datasets used to

generate the estimates of methane emissions from waste water treatment and sewage sludge treatment and disposal.

- Meetings with sector experts from the environmental regulatory agencies in the UK (EA, SEPA, NIEA) to explore site-specific and sector-wide issues to address source-specific emission factor uncertainties and obtain up to date information regarding site-specific activities, abatement and so on.
- Consultation with the UK refinery trade association and the environmental regulatory agency officers for the refinery sector, to resolve energy and emissions data reporting inconsistencies from specific refinery operators.
- Consultation with DECC Oil & Gas and individual environmental regulatory officers and operators to resolve data gaps and inconsistencies within reported emissions data for onshore oil & gas terminals and offshore installations also.
- Consultation with traffic statisticians in DfT and in N Ireland's regional government on consistency in trends in vehicle km by vehicle and road type
- Meeting with transport policy and statistics officials at DfT to discuss the overall methodology and input data needs for the road transport and rail sectors. This has led to the establishment of a more formalised data supply procedure for DfT in the inventory compilation process.
- Consultation with the Office of Rail Regulation, Association of Train Operating Companies and DfT to agree a consistent methodology and activity data for the rail sector. A new source of activity data for the rail inventory was agreed with these stakeholders for use in the 2009 inventory.
- Consultation and meetings with DECC, Defra, DfT and Entec on a new 'bottom-up' methodology for shipping emissions based on detailed shipping movement data and harmonisation with national energy statistics for domestic and international shipping. A new methodology was formally agreed between all stakeholders to be used in the 2009 inventory.

Integrated UK and Devolved Administration GHG Inventory Improvement Programme

During 2009-10, the UK GHGI improvement programme was developed to integrate inventory research needs for the devolved Governments of Scotland, Wales and Northern Ireland, following a review of GHG inventory data (including estimation methods, source data, emission factors, assumptions) used to prepare the sub-UK Devolved Administration GHG emission inventories in summer 2009. The 2009-10 programme comprised a series of sector-specific improvement studies, including: a review of public sector energy and emissions data, a review of oil and gas sector emissions data, and analysis of EU ETS energy data and comparison of sector estimates against UK energy statistics.

1.6.1.2 Future Development of the QA/QC System

The UK inventory has an improvement programme, which itemises and prioritises planned improvements to the inventory. This is developed and updated in consultation with the National Inventory Steering Committee (NISC).

1.6.1.3 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. DECC, North Wyke and BGS) would qualify as the *National Statistical Agencies* referred to in the Guidance. Other organisations (e.g. CEH) compile significant parts of the Inventory; data compiled by other organisations are used to compile significant parts of the inventory (e.g. the Pollution Inventory). We are contacting these organisations and inviting them to show how their QA/QC systems comply with IPCC Good Practice Guidance.

1.6.1.4 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. This information provides a key contribution to the inventory improvement programme, which ensures that improvements to the inventory are implemented as necessary.

1.6.1.5 Bilateral reviews, External Peer Review and Internal Reviews

Bilateral Reviews

During February 2010, the UK took part in a trilateral review with the Austrian and German inventory teams, focussing on emissions of F-gases. The object of the review was to share methods, experiences and potential data sources across the three teams and to provide recommendations on how to improve each of the inventories for these sectors. The recommendations for the UK will be added to the UK GHGI improvement programme for consideration by the NISC.

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.

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.

1.6.1.6 Capacity building and knowledge sharing

The UK actively participates in capacity building and knowledge sharing activities with other countries. The list below highlights some recent examples of these activities.

1. Knowledge sharing with the Russian statistical agency who compile the GHG inventory for Russia.
2. Capacity building activities in South Africa in the agricultural sector
3. Knowledge sharing with the Sao Paulo inventory team
4. Capacity building activities in Saudi Arabia – assistance with the production of their second National Communication and suggestions for the improvements of their greenhouse gas inventory.
5. Work with the Malta Environmental Protection Agency to set up a National Inventory System to produce both greenhouse gas and air quality pollutant inventories.
6. The F-gases trilateral review with Austria and Germany included knowledge sharing between the three reporting parties.

1.6.2 Verification

Verification is covered as part of the QA/QC checks and by the background research undertaken by DECC. In addition, DECC has a research programme that delivers continuous high-frequency atmospheric observations of the Kyoto gases and a range of other trace gases at the Mace Head Atmospheric Research Station on the west coast of the Republic 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.

DECC are intending to expand the Atmospheric Observation network to include three additional sites, to be located at Edinburgh, Tacolneston, and Ridge Hill. These sites would result in significant increases in spatial and temporal resolution, enabling Devolved Administration emission estimates from Atmospheric Observations as well as decreasing the uncertainties associated with all the analytical outputs of this project.

The complete results of this verification and a more detailed description of the modelling method used are given in **Annex 10**.

1.6.3 Treatment of Confidentiality

Much 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 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.

Detailed EU ETS data are also supplied by the regulators to the Inventory Agency, which allows further analysis of the data to develop new emission factors or to cross check fuel use data with other sources. This detailed data set is not publically available, and therefore information obtained from the analysis of this data is suitably aggregated before it can be explicitly reported within the CRF tables or the NIR.

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://naei.defra.gov.uk

1.7 GENERAL UNCERTAINTY EVALUATION

1.7.1 GHG Inventory

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 16% in 1990 and 17% in 2009. The trend in the total GWP weighted emissions expressed as the fall between 1990 and 2009 is -28%, with 95% of the values found to lie within the range -25% to -31%. 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**.

1.7.2 KP – LULUCF Inventory

Uncertainty assessment and quantification of the inventory has been undertaken during 2007-2009 with particular focus on the forest carbon modelling components (van Oijen 2007; 2008; 2009). The carbon flow model, CFlow (Dewar and Cannell 1992), is used to model carbon pools and fluxes in UK forests (described in Annex 3.7). The uncertainty arising from the inputs, parameters and model structure of CFlow has been examined, and it has also been compared with a more complex process-based model, BASFOR (van Oijen and Thomson, submitted). Full detail of the uncertainty work carried out can be found in **Chapter 11, Section 11.3.1.5**.

1.8 GENERAL ASSESSMENT OF COMPLETENESS

1.8.1 GHG Inventory

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.

1.8.2 KP – LULUCF Inventory

Completeness of the KP-LULUCF inventory is reported in **Chapter 11, Section 11.3.1.2**

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 2009, the total direct greenhouse gas net emissions (including net LULUCF emissions) in the UK were estimated to be 566 Mt CO_2 equivalent (based on full UNFCCC coverage). This was 27.7% below the 1990 level.

The following sections summarise the emission trends between 1990-2009 for the aggregated greenhouse gases, both by gas and by source. Unless otherwise indicated, percentages quoted are relative to net emissions (i.e. emissions including removals from LULUCF). The geographical coverage used for calculating all figures is full UNFCCC coverage – i.e. UK including Crown Dependencies and relevant Overseas Territories.

The percentage changes presented in this chapter are calculated from emission estimates held at full precision within a database, therefore they may differ slightly from those that could be calculated from rounded figures presented in this report.

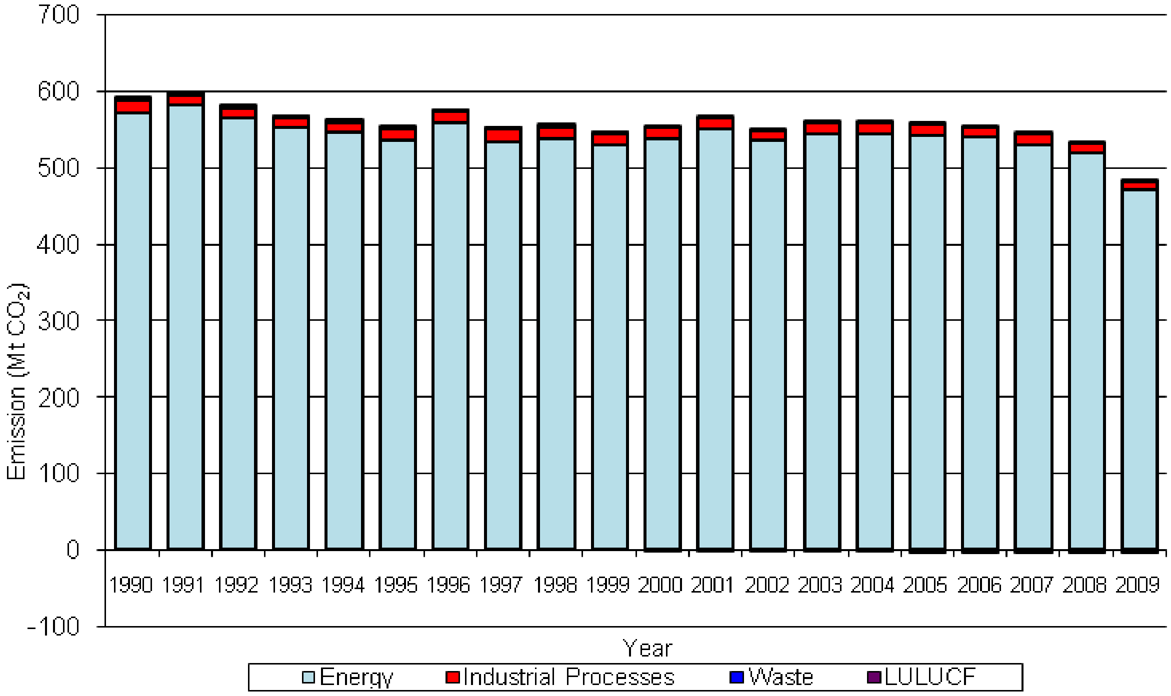
2.2 EMISSION TRENDS BY GAS

The largest contributor to global warming is carbon dioxide at 84% of the weighted emission in 2009. Methane contributes 8% and nitrous oxide 6%. In spite of their high GWPs the contribution of halocarbons is small at around 2% of the total. This is because their mass emissions are very small. Overall the total weighted emission has fallen by almost 28% since 1990.

2.2.1 Carbon Dioxide

In 2009, CO_2 emissions were 475.8 Mt CO_2 equivalent, 19.5% below the 1990 level. 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. Emissions from the energy sector decreased by 9% from 2008 to 2009, reflecting a decrease in demand for fuel and electricity, probably caused by the economic downturn.

Figure 2.1 **UK CO_2 Emissions Trend by Source**



2.2.2 Methane

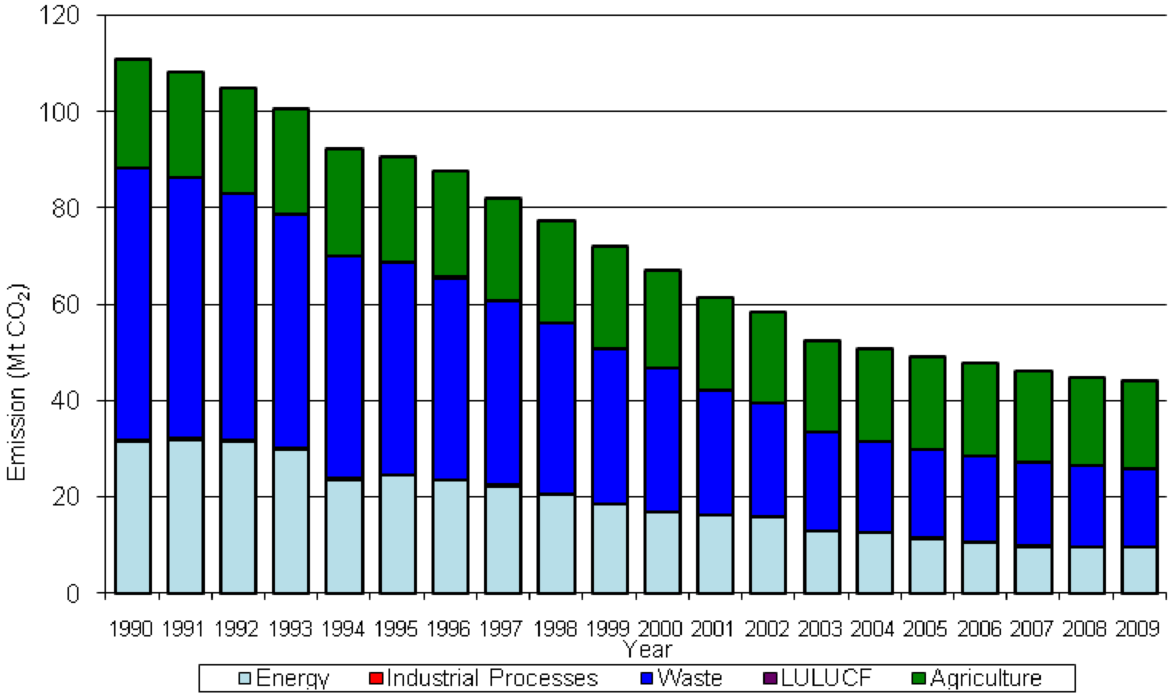
Figure 2.2 illustrates the trend in emissions of methane, broken down by source. Methane is the second most significant greenhouse gas in the UK after CO_2. In 2009, methane emissions were 43.8 Mt CO_2 equivalent.

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 this are:

- In the energy sector, reduced coal mining activity, and improvements to the gas distribution network have contributed to an overall decrease in emissions of 71% since 1990. Decreases in this sector have contributed 33% to the total decrease in methane emissions.
- Total emissions in the waste sector have decreased by 71% due to increased implementation of methane recovery systems at landfill sites. The reduction in emissions in this sector is responsible for 60% of the total decrease in methane emissions since 1990.
- Emissions from agriculture have decreased by 19% since 1990, following the trend of decreasing livestock numbers.

Since 1990, emissions of methane have decreased by 60.4%. Emissions from LULUCF and Industrial Processes are not significant sources of methane, contributing less than 0.3% of the total in 2009. Emissions from Industrial Processes have decreased by 58%, whilst LULUCF emissions have increased by 60%.

Figure 2.2 **UK Trends in CH_4 Emissions by Sector**



2.2.3 Nitrous Oxide

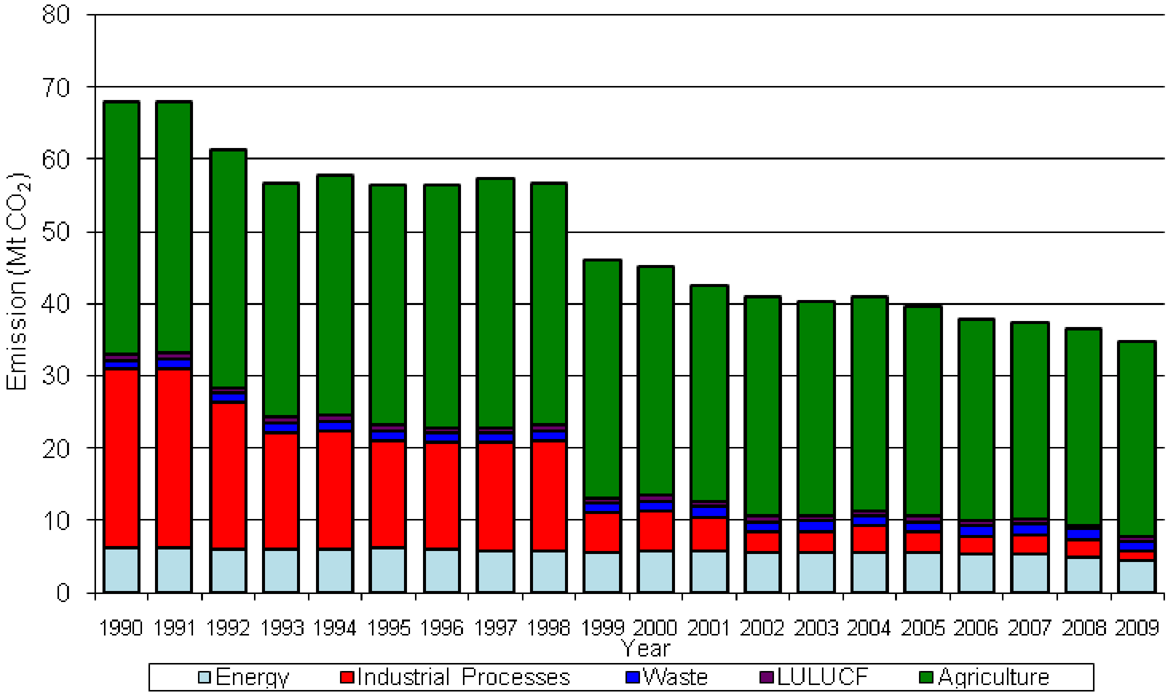
Figure 2.3 illustrates the trend in emissions of nitrous oxide. The main anthropogenic sources are agriculture, transport, industrial processes, and coal combustion. In 2009, emissions of nitrous oxide were 34.6 Mt CO_2 equivalent. Emissions have declined 49% since 1990, and the main reasons for this reduction are:

- The agriculture sector is a major source of N_2O emissions, contributing 78% 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 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 36% to total N_2O emissions. In 2009, these sources accounted for only 3.4%. This has been a result of plant closures combined with the installation of abatement equipment at the adipic acid plant in 1998 (the effect of this can be seen in **Figure 2.3**). Emissions from Industrial Processes have decreased by 95% since 1990, contributing 71% 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 13% to total N_2O emissions in 2009. Emissions from this sector have decreased by 28% 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, since early catalysts led to an increase in N_2O emissions whilst decreasing emissions of other pollutants. From 2000 onwards, however, emissions from this source have started to decrease due to the improvements in catalyst technology in newer vehicles. Emissions in 2009 are now 17% lower than emissions in 1990.

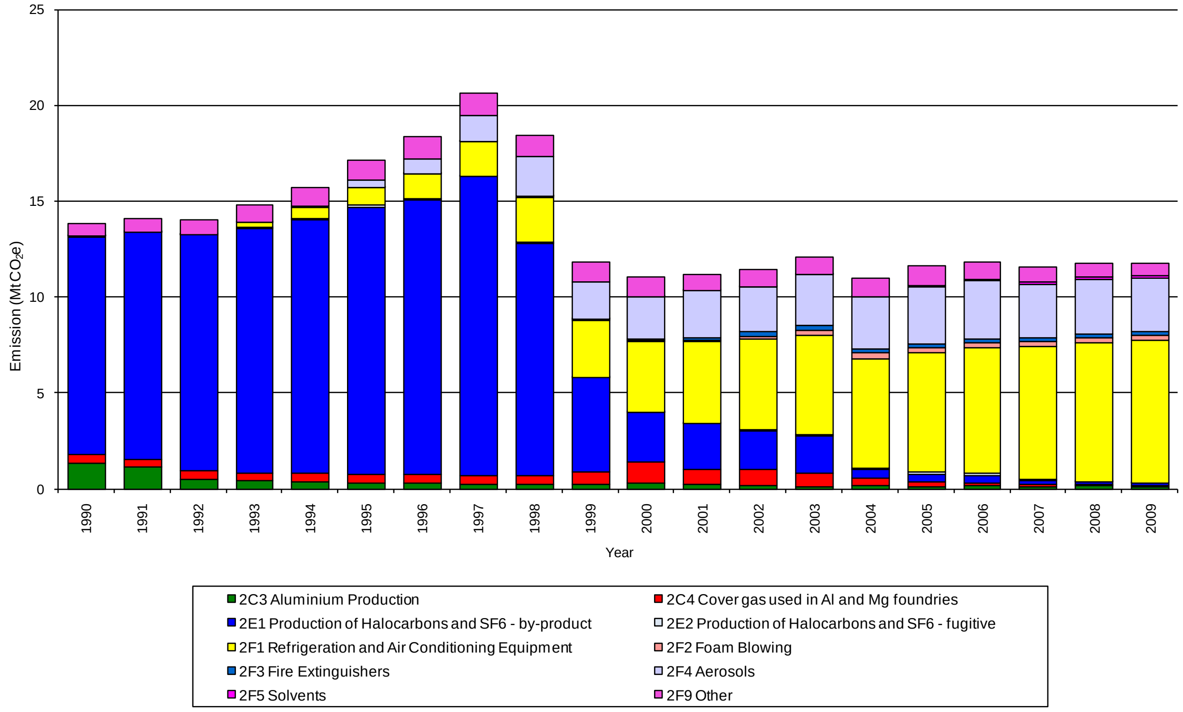
Figure 2.3 UK Trends in N_2O Emissions by Sector



2.2.4 Fluorinated-Gases

Emissions of the F-gases (HFCs, PFCs, and SF_6 – see **Section 1.1.2.3**) totalled 11.7 Mt CO_2 equivalent in 2009. Since 1995 the overall decrease in their emissions has been 32%, due mainly to the fall in emissions from F-Gas manufacture (2E1, HFC by product emissions from HCFC manufacture), due to the installation of abatement equipment at the two manufacturers. Emissions from certain end use sectors, such as refrigeration (2F1) are continuing to grow.

Figure 2.4 UK emissions of F-gases by sector



2.3 EMISSION TRENDS BY CATEGORY

Total greenhouse gas emissions broken down by sector are shown in **Figure 2.5**. The largest contribution is from the energy sector, which contributes some 85.5% to the total emissions. Within this category the largest contributions arise from the energy industries and transport. 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 20% since 1990, primarily due to fuel switching to less carbon-intensive energy sources (e.g. coal to gas in the power sector) and reduced energy intensity of the economy. A decline in emissions of around 9% is also seen between 2008 and 2009. This is driven mostly by decreases in the power generation (1A1a) and other industrial combustion (1A2f) categories, and may be as a result of the recent economic downturn.

The next largest contribution comes from the agricultural sector. This contributes approximately 8% 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 (IPCC 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 of F-gases. Since 1990, this category has seen a decline in emissions, mostly due to changes in the emissions from the chemical production and metal processing industries.

Land Use, Land-use Change and Forestry (LULUCF) contains sinks as well as sources of CO_2 emissions. LULUCF has been a net sink since 2001. Emissions from this source occur for CO_2, N_2O and CH_4.

Emissions from the waste sector contributed 3.2% to greenhouse gas emission in 2009. Emissions consist of CO_2, N_2O and CH_4 from waste incineration, and CH_4 from solid waste disposal on land, and both CH_4 and N_2O from wastewater handling. Overall emissions from the waste sector have decreased by 69% since 1990 and this is mostly due to the implementation of methane recovery systems at UK landfill sites, and reductions in the amount of waste disposed of at landfill sites.

2.4 EMISSION TRENDS FOR INDIRECT GREENHOUSE GASES AND SO_2

The indirect greenhouse gases in the UK consist of Nitrogen Oxides (NO_x), Carbon Monoxide (CO), Non-Methane Volatile Organic Compounds (NMVOC) and Sulphur dioxide (SO_2). Of these, NO_x, CO and NMVOC can increase tropospheric ozone concentration and hence radiative forcing. Sulphur dioxide contributes to aerosol formation in the atmosphere. This is believed to have a negative net radiative forcing effect, tending to cool the surface. Emission trends for the indirect greenhouse gases are shown in **Figure 2.7**.

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 2009, the total emissions were 1091 Gg, with 99.7% of these emissions arising from the energy sector. Since 1990, emissions have decreased by 59%, 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 2009, the total emissions were 2280 Gg, of which 93.3% were from the energy sector. Since 1990, emissions of CO have decreased by 75%. The majority of this reduction is due to improvements in vehicle technology within the road transport category

In 2009, total emissions of NMVOCs were 827 Gg, of which 42% 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 70%. 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 2009 were 400.7 Gg. Of this, 96.6% 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 89%. 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, as well as the application of Flue Gas Desulphurisation abatement equipment on several of the largest coal-fired power stations in the UK.

Figure 2.5 **UK Net Emissions of Greenhouse Gases Weighted by GWP**

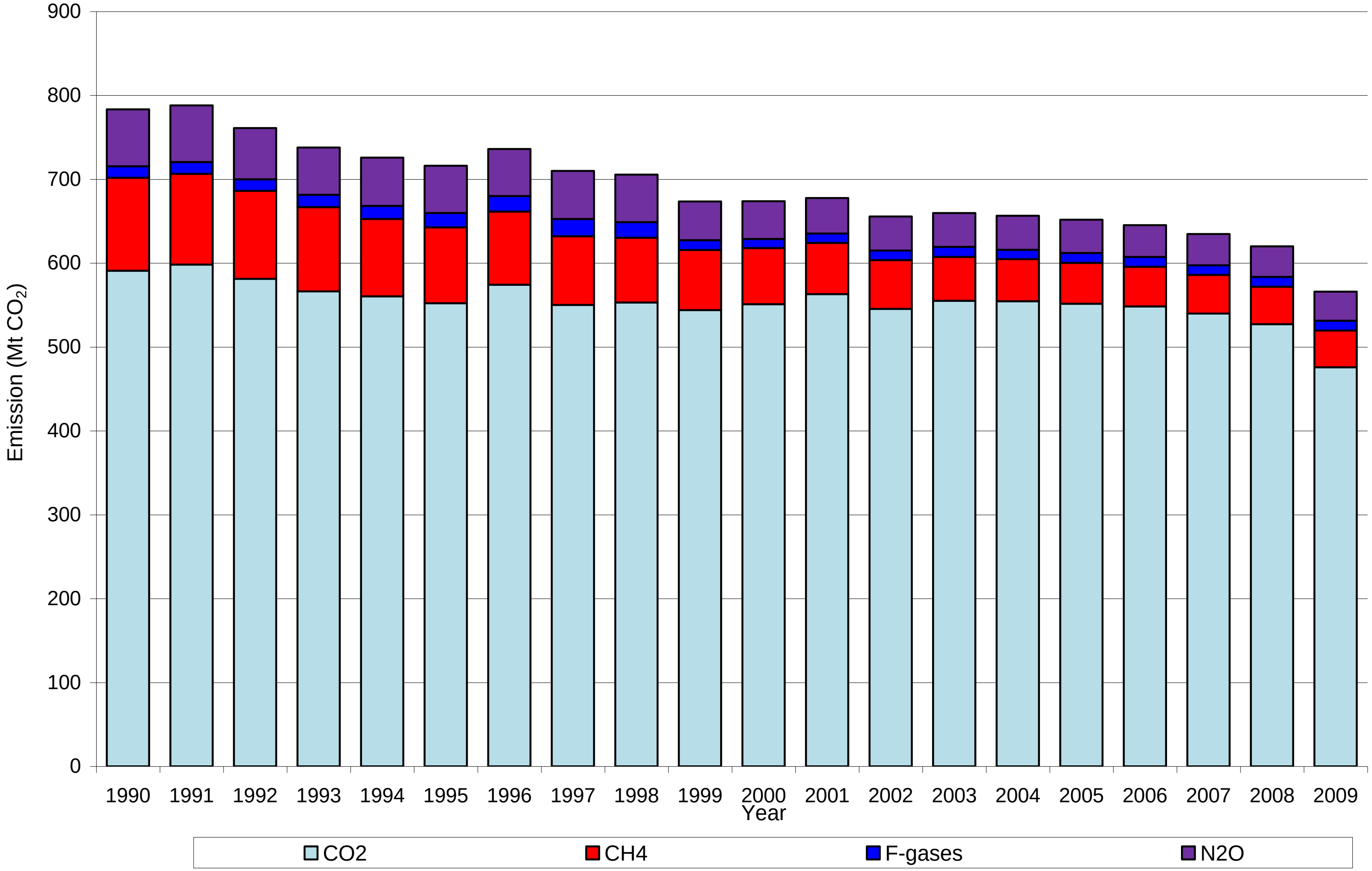
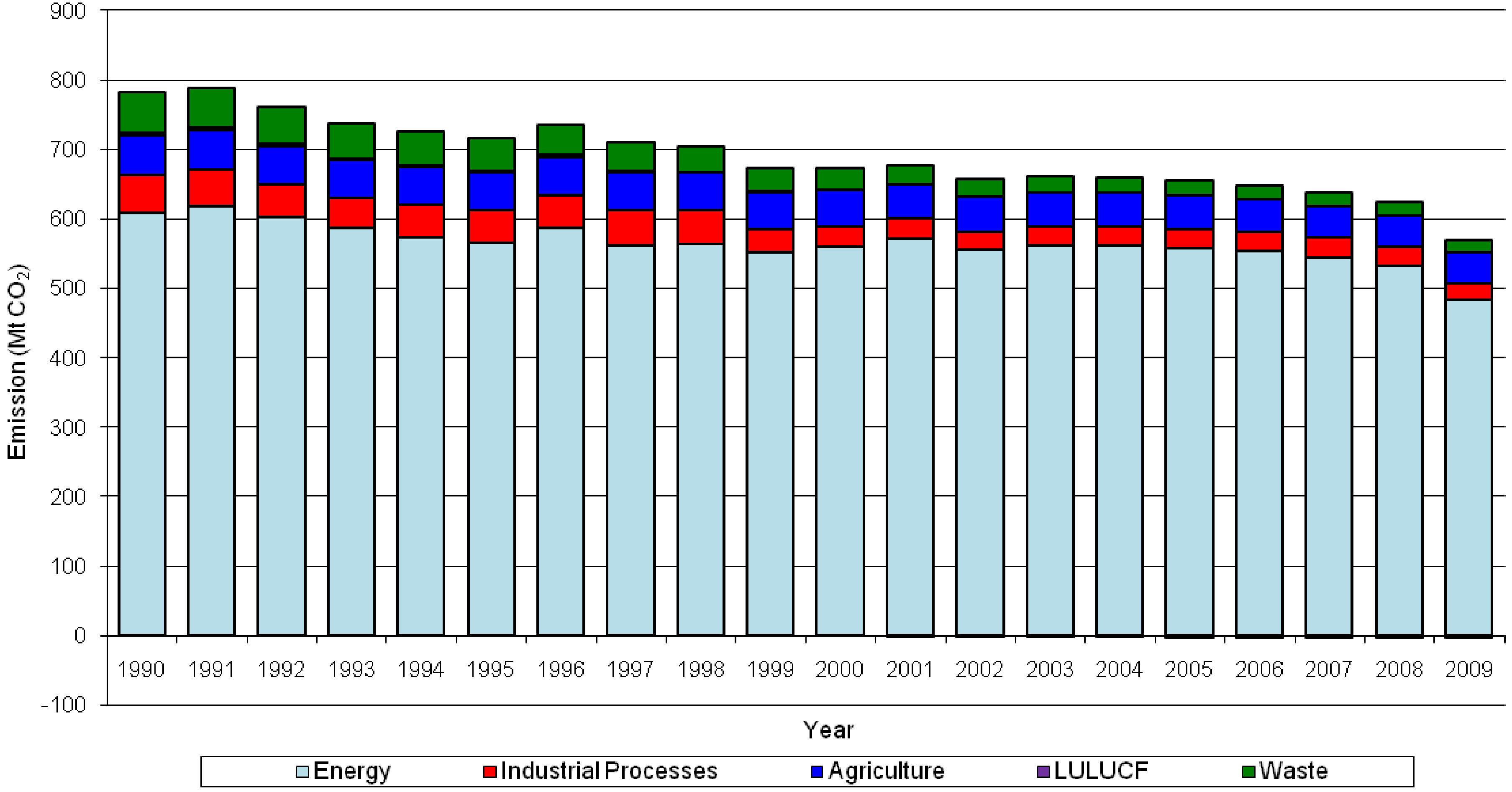
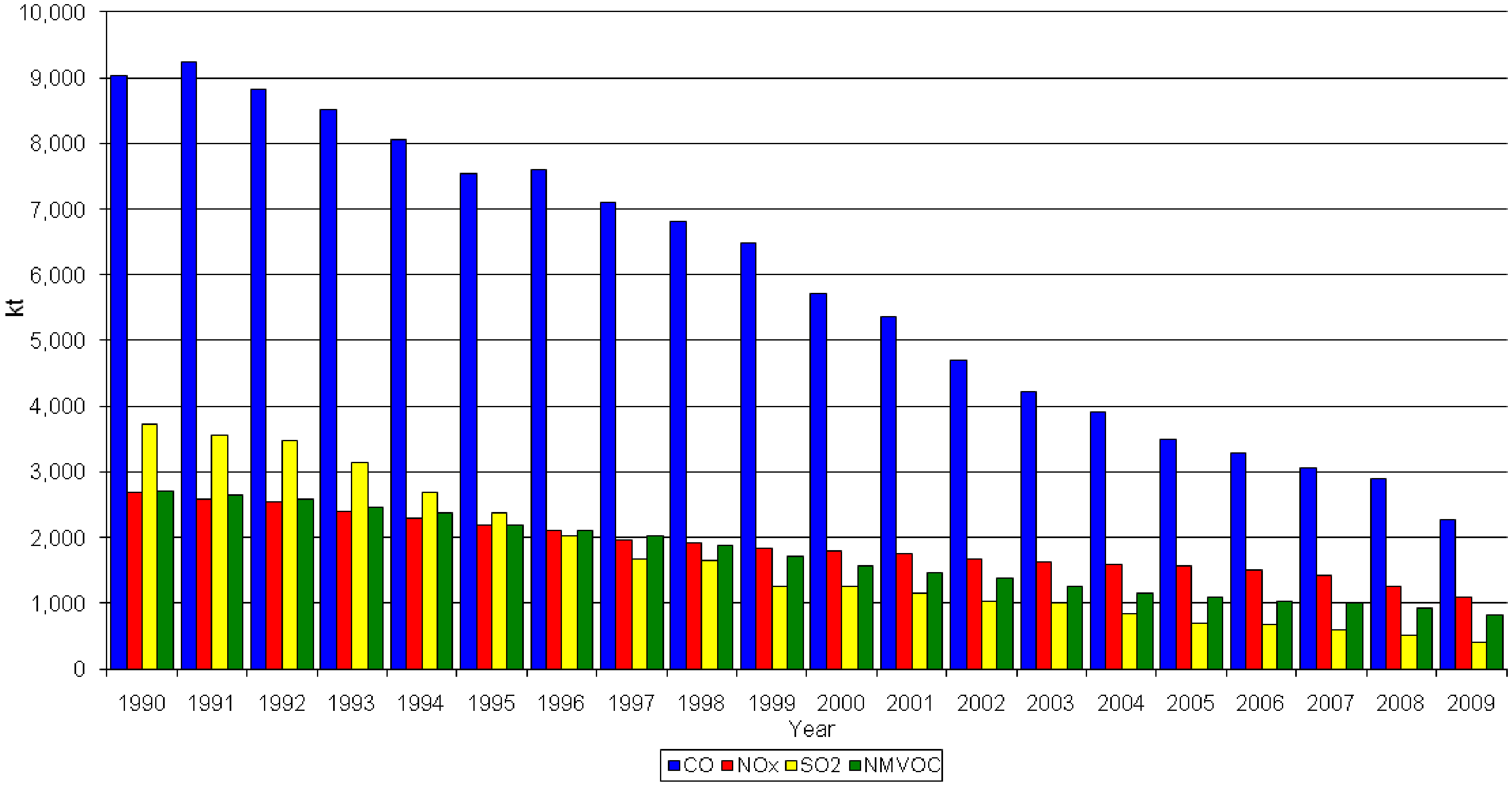


Figure 2.6 **UK Net Emissions of Greenhouse Gases by Source**



‘Solvent and Other Product Use’ is not shown in **Figure 2.6** as it has zero emissions for all years.

Figure 2.7 **UK Emissions of Indirect Greenhouse Gases**



2.5 EMISSION TRENDS FOR KP-LULUCF INVENTORY IN AGGREGATE AND BY ACTIVITY, AND BY GAS

Figure 2.8 shows net emissions/removals from afforestation, reforestation and deforestation activities (Article 3.3). These activities were a net source of emissions in 1990, becoming a net sink from 1996 onwards. The total net emission/removal is dominated by CO_2 from afforestation and reforestation.

Figure 2.9 shows the net emissions and removals of greenhouse gases from forest management activities (Article 3.4). In accordance with the Annex to Decision 16/CMP.1, credits from Forest Management are capped in the first commitment period. For the UK the cap is a relatively modest 0.37 MtC (1.36 $MtCO_2$) per year, or 6.78 $MtCO_2$ for the whole commitment period.

Figure 2.8 **Article 3.3 Emissions and Removals, by gas and by activity**

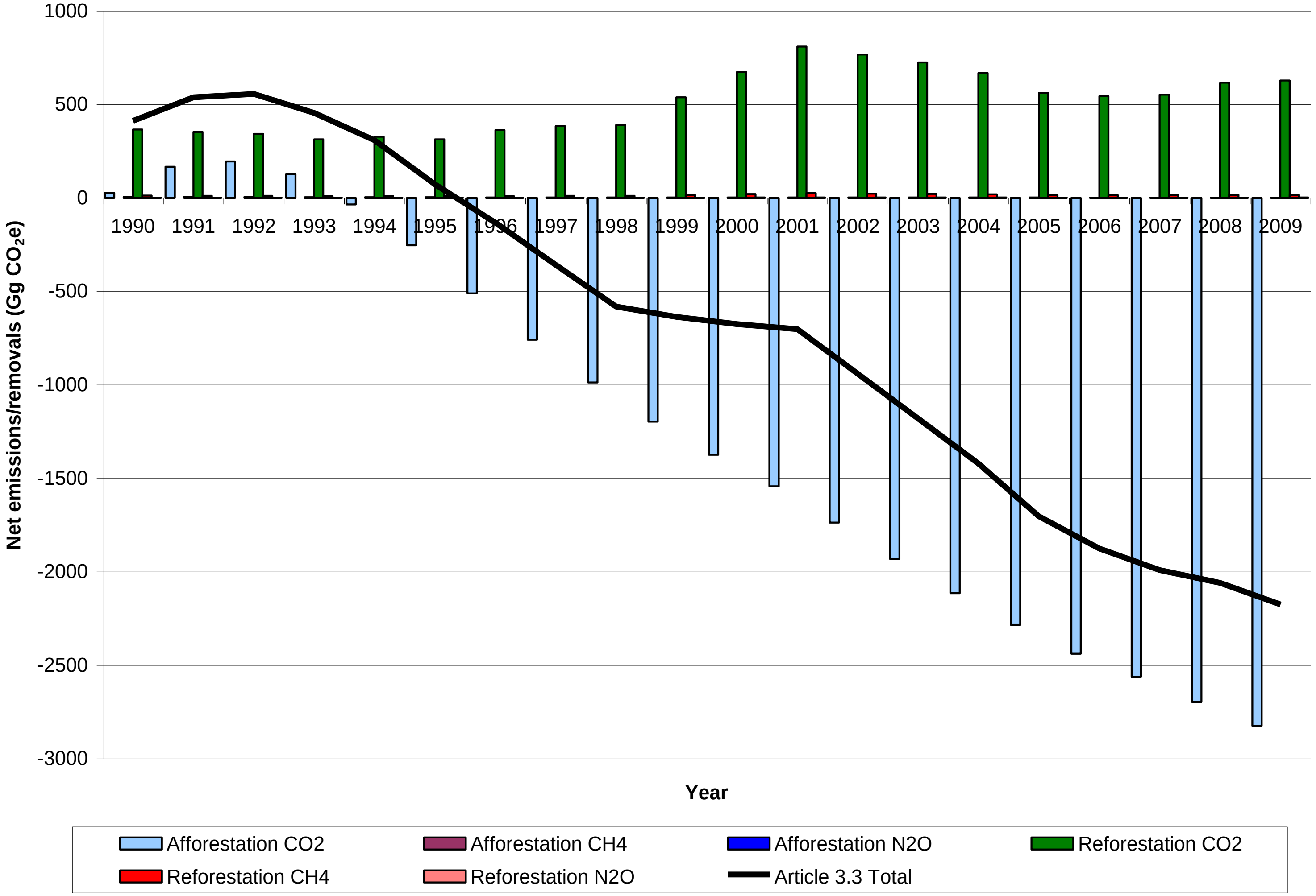
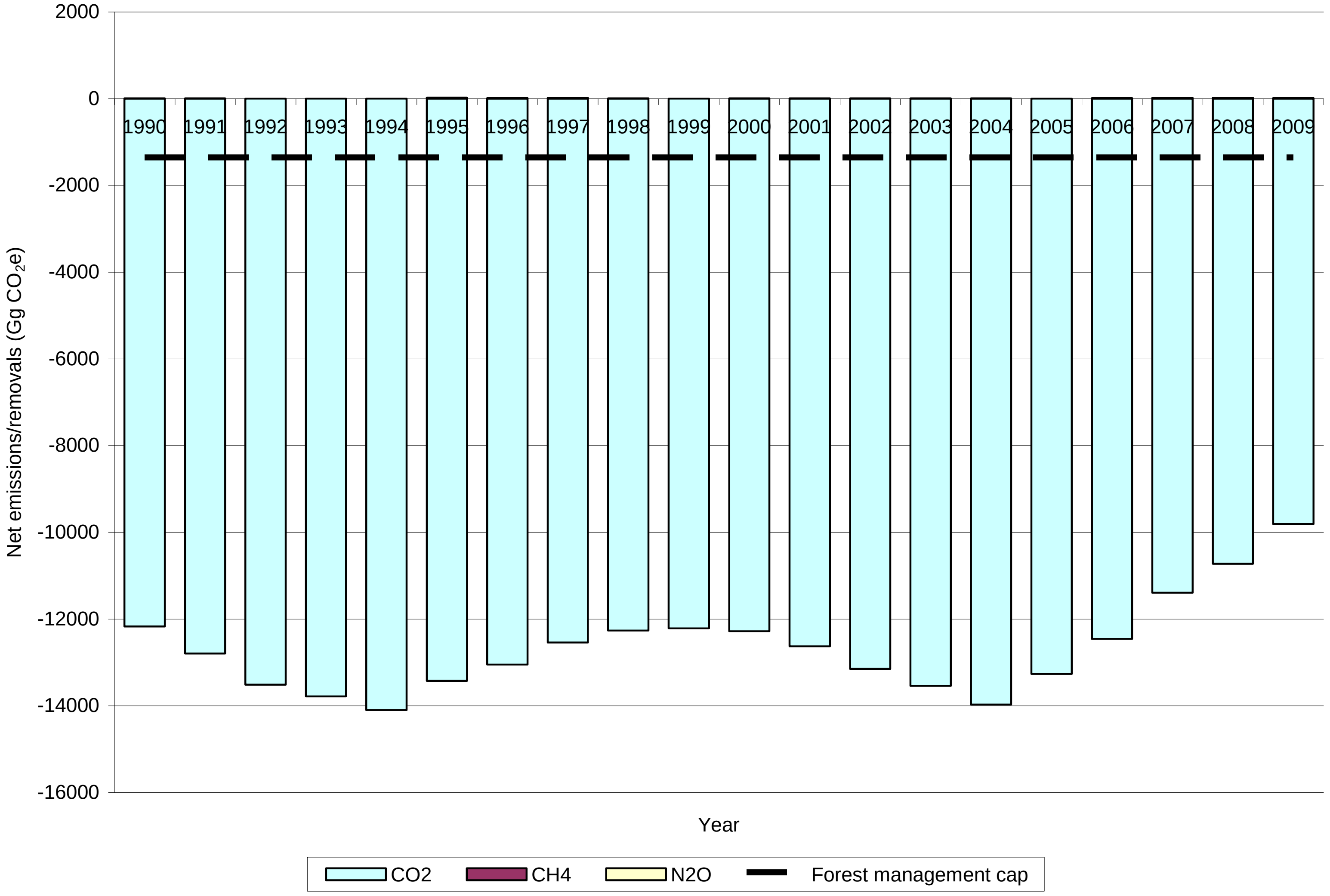


Figure 2.9 **Article 3.4 Emissions and removals, by gas**



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 2009, 84% 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 FUEL COMBUSTION (CRF 1.A)

3.2.1 Comparison of Sectoral and Reference approaches

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

Summary Table 7B of the IPCC Guidelines[9] 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 2% lower to 2% 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 2009), emissions estimated by the Reference Approach have fallen by 15.7% compared with 17.8% for the sectoral approach. A more detailed discussion of the reasons for this difference is 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 (1998).

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[9] http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/tab3.pdf

3.2.2 International Bunker Fuels (memo item)

International bunker emissions (international aviation and shipping) are not included in the national total but are reported separately. A new bottom-up method based on detailed shipping movement data has been used to estimate domestic shipping emissions and this has led to a re-allocation of emissions between domestic and international bunkers. The new method has increased the allocation of total shipping emissions to international bunkers. In 2009, the shipping emission contributed 24% to total bunker emissions, with aviation contributing the remaining 76%. From 1990-2006, estimated emissions from international aviation more than doubled, but have been slowly declining since 2006.

These estimates are consistent with the revised Tier 3 method now adopted for aviation and described in **Annex 3**, **Section 3.3.5.1** and the revised Tier 2 method now adopted for shipping described in **Annex 3, Section 3.3.5.4.**

In response to feedback from the Expert Review Team, the inventory agency has confirmed with the UK national energy statistics team at DECC that the UK allocations of bunker fuels reported within DUKES are consistent with the data submitted to EUROSTAT and the IEA across the full time-series. Note, however, that the UK inventory memo item estimates for international shipping deviate from the reported DUKES (and IEA/EUROSTAT) data due to reallocation of some of the bunker fuels to military aviation and shipping based on data from the Defence Fuels Group of the MoD; these emissions are included in national inventory estimates and not in the International bunkers estimate.

Furthermore, the revisions to the shipping methodology described above have led to changes in the domestic/international split in fuel use allocation for marine fuels from the allocations in the national energy statistics (DUKES) and submissions to IEA/EUROSTAT.

3.2.3 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**. More details on non-energy use of fuels and stored carbon is contained in **Annex 3.3.9**.

3.2.4 Capture and storage of CO_2 from Flue gases

Currently in the UK, CO_2 emitted from flue gases is not captured and stored.

3.2.5 Country specific issues

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

3.2.6 Source Category 1A1 – Energy Industries

3.2.6.1 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 38 Mtonnes of coal were burnt at 18 power stations during 2009, while approximately 11,110 Mtherms of natural gas were consumed at 48 large power stations and 15 small (<50MWth) regional stations (mostly Combined-Cycle Gas Turbines, CCGTs). Heavy fuel oil was the main fuel at 3 large facilities, and gas oil or burning oil was used by 5 large and 22 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, another site burns straw, yet another burns wood, whilst many coal-fired power stations have increased the use of 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 plants 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), 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 11 oil refineries, 3 of these being small specialist refineries employing simple processes such as distillation to produce solvents or bitumens only. The remaining 8 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 2009, there were four coke ovens at steelworks and one independent coke oven. A further three coke ovens have closed in the last six 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.

3.2.6.2 Methodological Issues

Most emissions are estimated by applying an emission factor to an appropriate statistic such as fuel consumption data (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 (DECC, 2010) are applied to emission factors to give an estimation of emissions. 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, with the exception of gas oil, and petroleum coke. For gas oil, an estimate of emissions from coastal shipping is made, and the remainder of the fuel allocated to both national navigation and marine bunkers in DUKES is all allocated to international shipping. This is explained further in **Annex 3, Section A3.3.5.4.** For petroleum coke, statistics that are available through sources such as EU ETS returns, indicate higher fuel use in the UK than is implied by the energy statistics. The data sources for petroleum coke use are described in each of the sectors where this fuel is used.

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 System (EU ETS). 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, 2010), via the Pollution Inventory (PI); from the Scottish Environment Protection Agency (SEPA, 2010), 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, 2010). 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**.

Carbon emission factors for coal, fuel oil, natural gas and sour gas use in power stations and fuel oil use in refineries are based on data reported to the EU Emissions Trading System (EU ETS) for the years 2005-2009. These data are of high quality, and available for all significant UK plants - some very small power stations, e.g. on remote islands, will not report to EU ETS but their fuel use will be trivial. Due to the use of site-specific data, carbon emission factors for these source categories are Tier 3. EU ETS data are not available before 2005, therefore emission factors for the earlier years must be calculated in a different way. Carbon emission factors were the subject of an in-depth review during 2004, with revised emission factors for the period 1990-2003, generated after extensive consultation with fuel suppliers and users, published in Baggott et al, 2004. These emission factors are Tier 2, but rely upon significant quantities of site-specific data (e.g. for coal-fired power stations) or other high quality data such as gas composition data provided by the gas suppliers. They are considered to be the best available data for the period 1990-2003 since alternative approaches such as extrapolation from the EU ETS data are not considered sufficiently reliable. In the case of 2004, there are no data either from the review or from the EU ETS. Currently, the gap is generally filled by extrapolation from the 2003 data, however a better approach might be to interpolate between the 2003 and 2005 values. The approach will be reviewed next year.

Data from the EU ETS are also used to estimate carbon emissions from combustion of petroleum coke at refineries. This petroleum coke is in the form of carbon deposits that build up on catalysts used in cracking processes. The deposits must be removed periodically or they reduce the effectiveness of the catalyst, and so a catalyst regeneration section is included in the catalytic cracking unit. The carbon deposits both form and are burnt off in the cracking unit, so quantifying the mass of petroleum coke burnt has relied upon estimation to a greater extent than for other fuels, which can be directly measured. For the years 2005-2008 however, carbon emissions from catalyst regeneration are available from the EU ETS. The emissions are quantified by site operators within EU ETS using either a mass balance approach or, increasingly, by monitoring carbon dioxide emitted in the flue gases from the catalyst regenerator. Data are available for all UK refineries. The carbon emissions available from the EU ETS are not consistent with estimates of petroleum coke consumption given in UK energy statistics, but are used because they are the best data available. This decision was agreed in close consultation with the UK energy statistics team in DECC, as it is a deviation from reported UK energy statistics on refinery petroleum coke use. Before 2005, emissions are calculated using the activity data given in UK energy statistics and the emission factor proposed in Baggott et al, 2004. Carbon factors for OPG (2008 and 2009) and fuel oil (2006 to 2009) use in refineries are now also based on EU ETS data. The EU ETS emission factor for OPG is also used for OPG use in other sectors. See **Annex 11** for further details.

The carbon emission factor used for combustion of MSW has been reviewed and is now considered to need improvement. Two options exist for doing this: either the IPCC Tier 1 approach involving use of default data, or the IPCC Tier 2 approach involving the use of country-specific data. It would be good practice to use the Tier 2 approach if possible, but the availability of UK-specific data needs to be assessed and there was insufficient time to do this within this inventory cycle. This assessment will be added to the UK improvements programme list and prioritised accordingly. Once this assessment has been completed the approach for MSW combustion will then be revised to either the Tier 1 or Tier 2 IPCC method. This improvement is planned for the 2012 inventory submission.

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.

3.2.6.3 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.

Most of the core activity data for this source category is derived from the DECC publication, DUKES. **Section 3.5** 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 A3.2.1)**. Background energy data for the calculation of these emissions are taken from the most up to date version of DUKES. In the DUKES published in 2002, DECC (formally DTI) stopped collecting the activity data about oil and gas extraction previously used to estimate these emissions. For the 2011 inventory, EU ETS data have been used for the years 2008 and 2009, emissions for 2003 to 2007 have been interpolated. For more information about how EU ETS data have been used, refer to **Annex 11**.

Emissions from petroleum coke consumption in refineries are based on DUKES data and an emission factor (UKPIA, 2010) from 1990 to 2004, and EU ETS emissions data from 2005 onwards. As explained in **Section 3.2.6.2**, the EU ETS emissions data imply that the DUKES data are not consistent with the data presented in DUKES for this sector. The time series of fuel consumption presented in DUKES has been compared with the estimates derived from the EU ETS data and the UKPIA emission factor. The differences are mostly small, and represent an underestimate in DUKES from 2005 to 2008, and an over estimate in 2009. This does not imply a systematic under or overestimate that could be corrected for by applying an average scaling factor to data from earlier years, therefore the DUKES data has been retained from 1990 to 2004.

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 EU ETS data for some fuels from 2005 onwards • Key sources of carbon EF data include: UKPIA, Association of Electricity Producers, Powertech, Transco, EU-ETS
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.

3.2.6.4 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**.

The core publication for Activity Data is the annual DECC publication – *DUKES* – 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, NIEA) 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.

3.2.6.5 Source Specific Recalculations

The method for calculating emissions from power stations has been reviewed and gaps in the power stations database in the early part of the time series have been investigated and the emissions revised accordingly. This primarily affects emissions from fuel oil combustion in coal and oil fired power stations.

3.2.6.6 Recalculation by Gas

The following section describes the main changes that have occurred in sector 1A1 per pollutant since the publication of the 2008 inventory (2010 NIR). Comparisons are made between the current inventory (1990-2009) and the previous inventory (1990-2008) for the year 2008.

3.2.6.6.1 *Carbon Dioxide (CO_2)*

- Overall there has been a decrease in estimated emissions for 2008 of 498 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 increase are described below;
- There has been a decrease of 740 Gg CO_2 from natural gas fired power stations due to revisions to the UK energy statistics, and a correction to carbon emissions factor for natural gas, based on EU ETS data.
- Emissions from natural gas used in refineries have increased by 569 Gg CO2 due to a revision in the activity statistics reported in DUKES (DECC, 2010).
- There has been a decrease of 334 Gg CO_2 from OPG in gas separation plants, due to a method change to use EU ETS data for this source.
- There has been a decrease of 174 Gg CO_2 in estimated emissions from OPG use at refineries due to a revision to the emission factor to make use of the EU ETS data.
- There has been an increase in the reported use of natural gas for gas production in DUKES (DECC, 2010), leading to an increase in estimated emissions of 173 Gg CO_2.

3.2.6.6.2 *Methane (CH4)*

- Overall there has been an increase in estimated emissions for 2008 of 0.04 Gg CH_4, resulting primarily from small changes to the activity statistics in DUKES (DECC, 2010).

3.2.6.6.3 *Nitrous oxide (N2O)*

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

3.2.6.6.4 *Nitrogen Oxides (NOX)*

- There has been a small net reduction of 3 Gg in estimated emissions due to small recalculations for various sources primarily relating to the offshore oil & gas industry.

3.2.6.6.5 *Carbon Monoxide (CO)*

- An increase in estimated emissions of 2 Gg is due to the use of updated information in the calculation of emissions from power stations.

3.2.6.6.6 *Sulphur Dioxide (SO2)*

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

3.2.6.6.7 *Volatile Organic Compounds (VOC)*

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

3.2.6.7 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. Additional work is currently ongoing to better characterise (e.g. carbon content and calorific value) non standard gaseous fuels.

3.2.7 Source Category 1A2 – Manufacturing Industries and Construction

3.2.7.1 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. The allocation of activities and emissions between combustion and process source categories for iron and steel and other “contact industries” in the UK GHGI are as consistent as possible with data provided directly from operators (e.g. Corus integrated steelworks data), UK energy statistics and EU ETS (where process emissions are reported separately from combustion emissions)

Emissions from fuel used by other industrial sectors (e.g. chemicals, non-ferrous metals, food & drink) are currently reported as ‘other industry,’ although a project is currently ongoing to investigate the availability and quality of data available in order to provide a disaggregated time series of emissions.

Carbon monoxide emissions reported in the Pollution Inventory from two soda ash manufacturing processes are also reported under 1A2. These emissions are assumed to occur due to the presence of CO in the CO_2 gas that is produced in the associated coke-fired lime kilns (so the CO is, in effect, an emission from the lime kilns).

Emissions from industrial off-road machinery, such as generators and cement mixers, are also reported in this sector.

3.2.7.2 Methodological Issues

Emissions of direct greenhouse gases for stationary combustion sources 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.

For industrial off-road machinery, emissions are modelled based on a survey to obtain equipment population data for one year, and statistical data to create a full time series, combined with assumptions for hours of usage, equipment age and type, and power output. The method for calculating these emissions is described in **Annex 3, Section A3.3.7.1**.

3.2.7.3 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.

Most of the core activity data for this source category is derived from the DECC publication the Digest of UK Energy Statistics. **Section 3.5** 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 2009 are now based on EU ETS data. Emission factors for lime kilns are also 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.

3.2.7.4 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**. Allocations of fuel use are primarily derived from DECC 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 led to amendments to fuel allocations reported by DECC (through fuel re-allocations between sectors).

3.2.7.5 Source Specific Recalculations

The method revision for power stations (see **Section 3.2.6.6)** has led to a reallocation of fuel oil from this sector to ensure consistency with the UK fuel balance. The method for calculating emissions from lime kilns has been revised, prompted by an inter-comparison between the GHG inventory, EU ETS and Pollution Inventory data. A time series of fuel consumption data for this sector has been constructed based on fuel data reported in the EU ETS data set and CO_2 emissions data reported to the Pollution Inventory. The main impact of this is a reallocation between sub categories within 1A2.

3.2.7.6 Recalculation by Gas

The following section describes the main changes that have occurred in sector 1A2 per pollutant since the publication of the 2008 inventory (2010 NIR). Comparisons are made between the current inventory (1990-2009) and the previous inventory (1990-2008) for the year 2008.

3.2.7.6.1 *Carbon Dioxide (CO_2)*

- Estimated emissions of CO_2 from 1A2 have increased by 2,818 Gg CO_2. The main reasons for this change are given below;
- There has been an increase in emissions of 1,298 Gg CO_2 due to a revision to the reported natural gas use in DUKES (DECC, 2010) in other industry, reported in 1A2f.
- Emissions from gas oil use in industrial off road machinery have increased by 603 Gg CO_2, due to a change to the modelling approach used. This breaks down the industrial machinery category into more detailed sub categories, allowing industry specific statistics to be used to drive emissions from this sector. This is explained in **Annex 3, Section 3.3.7.1**.
- Emissions from lubricant combustion have increased by 321 Gg CO_2, using new data on the fate of waste oils from the Oil Recycling Association (Pers. Comm., 2010).
- For lime kilns, emissions from natural gas use have increased by 216 Gg CO_2, based on a method improvement for this source (see **Section 3.2.7.5**).
- Emissions from coal use in iron and steel have increased by 173 Gg CO_2 based on a revision to the energy statistics for this source (DECC, 2010).
- A new estimate of petroleum coke use in other industry has been included for the first time, based on EU ETS data. This has led to an additional emission of 120 Gg CO_2.

3.2.7.6.2 *Methane (CH_4)*

- There was an overall increase in emissions of 0.33 Gg CH_4. The reasons for this change are given below;
- The main change (+0.13 Gg CH_4) is from a revision to the activity statistics for industrial natural gas use (DECC 2010).

- Emissions from off road machinery using petrol have increased by 0.09 Gg CH_4, due to a method revision to better reflect activity in individual industrial sectors. This is explained in **Annex 3, Section 3.3.7.1**.
- Emissions from wood combustion have increased by 0.07 Gg CH_4, based on revised energy statistics (DECC, 2010)

3.2.7.6.3 *Nitrous Oxide (N_2O)*

- There has been an overall increase of 0.3 Gg N_2O from 1A2.
- The largest change is an increase of 0.24 Gg N_2O from off road machinery using gas oil, due to a method revision to better reflect activity in individual industrial sectors. This is explained in **Annex 3, Section 3.3.7.1**.
- Following the recommendation from the ERT, emission factors have been identified and included for waste, waste solvents and scrap tyres used in the cement industry. This accounts for an increase of 0.02 Gg N_2O in this sector. The new factors are IPCC defaults (IPCC, 1997).

3.2.7.6.4 *Nitrogen Oxides (NO_x)*

- Estimated emissions from natural gas combustion by industrial plant increase by 4 Gg due to updated activity data.
- Emission estimates for industrial off-road vehicles increase by 8 Gg mainly due to updates to activity data for gas oil.

3.2.7.6.5 *Carbon Monoxide (CO)*

- Estimated emissions from industrial combustion of wood have increased by 11 Gg due to use of updated activity data. Estimated emissions from natural gas increase by 3 Gg for a similar reason.
- An additional source, the use of petroleum coke as a fuel by industry, has added an estimated 2 Gg to emissions.
- Emission estimates for industrial off-road vehicles increase by 29 Gg due to updates to activity data for both gas oil and petrol.

3.2.7.6.6 *Sulphur Dioxide (SO_2)*

- Estimated emissions from industrial combustion of coal have risen by 2 Gg, following minor updates to activity data.
- An additional source, the use of petroleum coke as a fuel by industry, has added an estimated 6 Gg to emissions.
- Activity data for waste lubricants used as fuels have been revised, leading to an increase in estimated emissions of 1 Gg.

3.2.7.6.7 *Volatile Organic Compounds (VOC)*

- Emission estimates for industrial off-road vehicles increase by 2 Gg due to revisions to activity data for gas oil and petrol.

3.2.7.7 Source Specific Planned Improvements

A study is currently ongoing to identify a consistent time series of fuel consumption data in order to report emissions in the sub categories of 1A2 (categories 1A2a-f). Depending on the outcome of this study, this greater detail will be included in the 2012 inventory submission. This is not likely to change the emission totals for this sector, but will provide further detail.

3.2.8 Source Category 1A3 – Transport

3.2.8.1 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. Emissions from consumption of coal used to power steam trains were included across the time-series in the 2009 inventory.

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

Emissions from vehicles running on natural gas are not estimated. The number of such vehicles in the UK is extremely small and there are no separate figures from DECC on the amount of gas used by road transport, nor are there useable data on the total numbers of vehicles equipped to run on gas from vehicle licensing sources. The small amount of gas that is used in the road transport sector would currently be allocated to other sources in DUKES.

Emissions of CH_4 and N_2O from LPG consumption by road transport have been calculated for the first time. This is in response to the UNFCCC Expert Review of the UK inventory.

The UK does not include CH_4 or N_2O emissions from lubricants. However, as emissions arise from the unintended combustion of lubricants in the engine, then all exhaust emission factors will include the contribution of lubricants as well the main fuel to the pollutant emissions when the vehicles or engines were tested. Hence, the emissions of CH_4 and N_2O (and other air pollutants) from lubricants are included implicitly in the exhaust emissions for each engine and fuel type.

3.2.8.2 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[10]. Emissions from aviation comprise of 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.** For the 2009 inventory, flights between the UK and relevant overseas territories have been included as domestic aviation. Previous inventories included flights from the UK to overseas territories as international aviation, recorded as a memo item. Flights from overseas territories to the UK were not included in previous inventories.

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

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** where a number of improvements are described.

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

A new method has been used to estimate coastal and international marine emissions producing a revised time-series for the 2009 inventory. A bottom-up method based on detailed shipping movement data for different vessel types, fuels and journeys has been used to estimate domestic (coastal) shipping emissions. A revised estimate for international marine emissions is derived by difference between total fuel consumption statistics for marine fuels and fuel consumption by domestic shipping. The new approach represents an IPCC Tier 2 method and is described in detail in **Annex 3, Section 3.3.5.4**

3.2.8.3 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.

Some of the core activity data for this source category are derived from DECC publication the Digest of UK Energy Statistics. **Section 3.5** 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. Other statistical sources from the Department for Transport were used to provide time-series consistency in the new approach used for shipping emissions.

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 and off-road machinery, time varying EFs used appropriate to emission standards in force and age profile of vehicle/machinery fleet.

3.2.8.4 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**.

3.2.8.5 Source Specific Recalculations

These are detailed in **Section 3.2.8.6**.

3.2.8.6 Recalculation by Gas

The following section describes the main changes that have occurred in sector 1A3 per pollutant since the publication of the 2008 inventory. Comparisons are made between the current inventory (1990-2009) and the previous inventory (1990-2008) for the year 2008.

3.2.8.6.1 *Carbon Dioxide (CO2)*

- Emissions from 1A3 Transport have decreased overall by 2,397.9 Gg CO_2, mostly due to changes in estimates for rail and coastal shipping.
- Estimated emissions from category 1A3a Aviation increased by 186 Gg CO_2. This was primarily due to inclusion of emissions between the UK and relevant overseas territories as domestic emissions
- A small change in total road transport emissions is due to a change in the estimates of total road fuels used by off-road machinery.
- Although there has been very little overall 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 traffic activity data and other assumptions on the fleet.
- Estimated emissions from rail decreased by 262 Gg CO_2 due to updated estimates of passenger and freight rail fuel consumption figures reported by the Office of Rail Regulation and Association of Train Operating Companies.
- Estimates of emissions for coastal shipping decreased by 3,754 GgCO_2 due to a change in methodology based on detailed shipping movement data instead of estimates from national energy statistics, which are uncertain in terms of the split in the consumption of fuel between coastal shipping and international marine bunkers.

3.2.8.6.2 *Methane (CH_4)*

Among the transport sectors, methane emissions are dominated by road transport. The main change in road transport emissions occurred by the inclusion of methane emissions from vehicles running on LPG. The small increase in total road transport emissions was almost offset by a reduction in coastal shipping emissions due to the change in methodology.

3.2.8.6.3 *Nitrous oxide (N_2O)*

Among the transport sectors, N_2O emissions are dominated by road transport and there are very small changes in estimates for this sector (0.01Gg) due to changes in traffic activity data. Emissions of N_2O from road transport are lower in 2009 compared with 2008 due to increased penetration of lower emitting petrol cars. The main changes in transport emissions are due to decreases in estimates for rail and coastal shipping, the latter due to changes in methodology.

3.2.8.6.4 *Nitrogen Oxides (NOx)*

Emission estimates for road transport in 2008 decreased by 7 Gg. This was mainly due to changes in HGV vehicle km activity data. Emissions are lower in 2009 than 2008 due to increased penetration of cleaner vehicles. The new methodology for coastal shipping has led to a reduction of 88 Gg in the estimate of emissions for 2008.

3.2.8.6.5 *Carbon Monoxide (CO)*

Emission estimates for road transport in 2008 increased by 10 Gg. This was mainly due to changes in emissions from petrol LGVs due to use of revised activity data. Emissions are lower in 2009 than 2008 due to increased penetration of cleaner vehicles. The new methodology for coastal shipping has led to a reduction of 9 Gg in the estimate of emissions for 2008.

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

Emission estimates for road transport in 2008 increased by 4 Gg mainly due to a new methodology for calculating evaporative emissions from petrol vehicles. Emissions are lower in 2009 than 2008 due to increased penetration of cleaner vehicles. The new methodology for coastal shipping has led to a reduction of 4 Gg in the estimate of emissions for 2008.

3.2.8.7 Source Specific Planned Improvements

Emission factors, activity data and estimating methodology are continuously kept under review as new information emerges. Particular attention is currently being given to the rail sector and inland waterways sector.

3.2.9 Source Category 1A4 – Other Sources

3.2.9.1 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 (including household and garden machinery); and
- ***Agriculture/Forestry/Fishing*** – emissions from fuel combustion in these sectors, including both stationary and mobile sources.

Emissions from the burning of municipal solid waste (MSW) to generate heat are currently reported under CRF source category 1A4, although these will be reallocated in the 2012 submission, following the advice from the ERT. 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.

3.2.9.2 Methodological Issues

The inventory methodology includes a reallocation of gas oil from the industrial, commercial and public sectors to off-road vehicles and mobile machinery. 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 3.2.6.2**) 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.

Emissions from fishing vessels are included in this sector. These are compiled alongside shipping emissions, and the method is described in **Section 3.2.8**.

3.2.9.3 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.

Most of the core activity data for this source category is derived from the DECC publication the Digest of UK Energy Statistics. **Section 3.5** 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.

3.2.9.4 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**.

3.2.9.5 Source Specific Recalculations

For agricultural mobile machinery, emissions from 2005 onwards have been recalculated to use actual historic data (gas oil use in agriculture) as a driver for equipment usage instead of earlier projections data. New information on the use of petroleum coke in the domestic sector has been obtained from Coal Products Limited (Pers. Comm., 2010) and has been used to improve inventory estimates in this sector.

3.2.9.6 Recalculation by Gas

The following section describes the main changes that have occurred in sector 1A4 per pollutant since the publication of the 2008 inventory (2010 NIR). Comparisons are made between the current inventory (1990-2009) and the previous inventory (1990-2008) for the year 2008.

3.2.9.6.1 *Carbon Dioxide (CO_2)*

- Overall CO_2 emissions from 1A4 decreased by 2,710 Gg CO_2. The main reasons for these changes are highlighted below;
- Natural gas use statistics in domestic, public administration, and miscellaneous commercial and industrial categories have been revised (DECC, 2010), leading to a decrease of 2,508 Gg CO_2
- Estimated emissions from peat combustion in the domestic sector have decreased by 413 Gg CO_2, based on a revised estimate of peat use made in consultation with CEH (Pers. Comm., 2010)
- Estimated emissions from petroleum coke use in the domestic sector increased by 305 Gg CO_2 based on new research (see **Section 3.2.9.5)**.
- Emissions from fishing vessels are now reported explicitly, and are included in sector 1A4c, leading to an increase of 14 Gg CO_2 in this sector (see **Section 3.2.8** for more details).

3.2.9.6.2 *Methane (CH_4)*

- There was an overall decrease in emissions from 1A4 of 0.77 Gg CH_4. The main reasons for this change are highlighted below;
- Emissions from peat consumption decreased by 1.27 Gg CH_4, based on a revised estimate of peat use made in consultation with CEH (Pers. Comm., 2010)
- This was partially offset by an increase of 0.76 Gg CH_4 from straw combustion in agriculture based on a revision to the activity statistics in DUKES (DECC, 2010).

3.2.9.6.3 *Nitrous Oxide (N_2O)*

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

3.2.9.6.4 *Nitrogen Oxides (NOx)*

- A major revision in the methodology for estimating emissions from domestic gas combustion leads to a reduction of 61 Gg. The new methodology estimates how improvements in domestic gas-fired boiler leads to reductions in the overall NOx emission factor over time as boilers are replaced, whereas the previous methodology assumed a constant emission factor over the entire time series.
- Updated activity data leads to a 1 Gg decrease in estimated emissions from gas combustion by the public & miscellaneous industrial/commercial sectors.
- Estimated emissions from agricultural machinery decrease by 1 Gg due to small revisions to both the activity data and the emission factor.

3.2.9.6.5 *Carbon Monoxide (CO)*

- Estimates of the use of petroleum coke in domestic smokeless/non-smokeless fuels have been revised, following consultation with fuel suppliers, leading to a 16 Gg increase in estimated emissions
- Activity data for domestic use of peat have also been revised, resulting in estimated emissions decreasing by 21 Gg
- Energy statistics for the use of straw as a fuel by the agricultural sector have been updated, leading to an increase in estimates of 13 Gg.
- Emission estimates for domestic combustion of solid smokeless fuels increase by 2 Gg due to updates to the emission factor.
- Estimated emissions from agricultural machinery decrease by 1 Gg due to small revisions to both the activity data and the emission factor.

3.2.9.6.6 *Sulphur Dioxide (SO_2)*

- Estimates of the use of petroleum coke in domestic smokeless/non-smokeless fuels have been revised, following consultation with fuel suppliers, leading to a 15 Gg increase in estimated emissions.

3.2.9.6.7 *Volatile Organic Compounds (VOC)*

- Activity data for domestic use of peat have been revised, resulting in estimated emissions decreasing by 7 Gg
- Energy statistics for the use of straw as a fuel by the agricultural sector have been updated, leading to an increase in estimates of 2 Gg.

3.2.9.7 Source Specific Planned Improvements

Research is planned into the energy data for used for public sector emissions, although the scope of this work is not yet finalised. Emission factors and activity data are kept under review.

3.2.10 Source Category 1A5 – Other

3.2.10.1 Source Category Description

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

3.2.10.2 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**).

3.2.10.3 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.

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 and was improved in the current version of the inventory by new time-series data provided back to 2003.

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

3.2.10.4 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**.

3.2.10.5 Source Specific Recalculations

Recalculations by gas are described in **Section 3.2.10.6**.

3.2.10.6 Recalculation by Gas

The main changes in the emissions of all pollutants are due to changes in military fuel consumption in 2008 based on information from the MoD.

3.2.10.7 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.

3.3 FUGITIVE EMISSIONS FROM SOLID FUELS OIL AND NATURAL GAS (CRF 1.B)

3.3.1 Source category 1B1 – Solid Fuels

3.3.1.1 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 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.

3.3.1.2 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 A3.3.30**.

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 A3.3.30**.

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 closed 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.**

3.3.1.3 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 DECC publication the Digest of UK Energy Statistics.

Section 3.5 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**.

3.3.1.4 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**.

3.3.1.5 Source Specific Recalculations

There were no significant changes.

3.3.1.6 Re-Calculation by Gas

Emissions of CO_2 increased by 104 Gg in 2008 due to a revision to coal use for SSF production (DECC, 2010). There were no other significant changes in this sector.

3.3.1.7 Source Specific Planned Improvements

A project is now ongoing to re-visit the analysis of emissions from abandoned coal mines. The findings of this research will be included in the 2012 inventory submission. Emission factors and activity data will be kept under review.

3.3.2 Source category 1B2 – Oil and Natural Gas

3.3.2.1 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 plants 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.

An additional source of GHG emissions from oil & gas exploration that is not included within the UK inventory is the release of methane-containing gases from underground reservoirs following drilling blowouts at the seabed. There has been some research evidence to suggest that a major blowout on the UK Continental Shelf occurred following drilling activity in November 1990, which has led to a release of methane-containing gases over many years. It is unknown whether this release is “additional” to background emissions from natural depressurisation of reservoirs through sea-bed pockmarks. These emissions are not reported within any regulatory system in the UK and no estimates of mass emissions have been made.

Emissions of CO_2, CH_4, CO, N_2O, NO_x, SO_2, and VOC occur at refineries due to venting of process plants for reasons of safety, from flaring of waste products, leakages from process plants, 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.

Consultation with gas network operators during 2010 has confirmed that emissions from gas leakage at point of use (i.e. downstream from gas meters) are not included within their network leakage models. New estimates for point of use leaks have therefore been made for the first time in this inventory, covering emissions from domestic and commercial sources, reported within 1B2bv.

3.3.2.2 Methodological Issues

Emission estimates for the upstream 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 1995-2009. 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 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 Environment 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. After initial teething problems with this new system, the data quality and completeness in annual returns from operators has improved, and there is an industry-regulator panel of experts that manages the development of the EEMS reporting system and underlying guidance.

Data reporting problems such as perceived gaps and inconsistencies are resolved by the DECC Oil & Gas team of regulators and the Inventory Agency through direct consultation with installation operators. Data quality checks on installation data in the current inventory cycle identified several outliers in implied emission factors and time-series inconsistencies for specific sites, and these have been reviewed with the DECC regulators to resolve the data for the national inventory. The Inventory Agency agreed the following actions with DECC (Furneaux, 2010):

- Offshore gas flaring, 2008: data revised for four offshore platforms, three due to new operator data, one to correct reported activity data;
- Offshore process emissions, 2008: revised operator data provided for one platform;
- Offshore fugitive and venting emissions, 2008: revised operator data provided for four platforms;
- Offshore gas combustion, 2008: data revised for four platforms by operators, with estimates derived for non-CO_2 GHGs using IEFs from previous year;
- Offshore well testing, 2008: revised data for well testing emissions from oil and gas exploration activities provided by DECC;
- Onshore flaring, 2008: emission estimates from two terminals revised based on new operator data, one via EEMS and the other via IPPC data (due to missing data in EEMS);
- Onshore fugitive emissions, 2008: estimates from eight terminals have been revised, seven of them from new operator data and one based on IPPC-reported data (due to missing data in EEMS);
- Onshore gas consumption, 2008: data revised for two terminals based on new operator data;
- Onshore oil loading and storage tank emissions, 2008: data for one terminal has been updated with new operator data;
- Offshore fugitives and flaring, 2009: emissions from one site amended to resolve incorrect activity data submissions by operator;
- Offshore process emissions, 2009: operator contacted to correct acid gas venting emissions estimates, following analysis of time-series consistency problems;

- Onshore gas consumption, 2009: activity data corrected for one terminal where IEFs were out by orders of magnitude;
- Onshore flaring, 2009: emission estimates corrected for one terminal, to address large inconsistencies between IPPC and EEMS data.

The inventory compilation method was overhauled in the 1990-2007 submission, to take advantage of developments in the EEMS dataset from the DECC Oil & Gas team, which enabled greater access to reported activity data that have been used to calculate the emissions for the following sources:

- Gas flaring;
- Gas combustion;
- Well testing; and
- Oil loading (onshore and offshore)

[Activity data are not routinely collected via EEMS for sources including: fugitive releases, direct process activities, oil storage or gas venting. The emissions from these sources are reported as annual estimates by operators and used directly within the inventory.]

These EEMS-derived activity data enable greater analysis of the oil & gas emissions and related emission factors at the installation level, providing a high degree of data transparency and improving the level of detail for performing quality checks by source, by site, by year. For those sources, 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 are extrapolated using the oil and gas production time-series that were collected at that time for the purposes of energy data reporting.

The Petroleum Processing Reporting System (PPRS) is used to report data to the DECC Energy Statistics team as part of the wider system of regulation of oil & gas extraction and production permitting system, and to inform upstream energy market trends. These data reported via the PPRS include data on gas flaring volumes at offshore and onshore installations, as well as oil and gas production data. It is these data (that are collected independently of the EEMS environmental data) that are used to extrapolate the activity data back to 1990, whilst the emission estimates are retained from the 1998 UKOOA study. Hence the reported Implied Emission Factors from 1990-1996 inclusive are an artefact of the method that uses the best available data but cannot be derived using a consistent approach across the time series due to the data limitations in the early part of the time series.

During 2010, analysis was completed in consultation with oil and gas industry regulators and operators to allocate each installation to either the oil or gas industry, in order that separate emission estimates may be derived from the EEMS dataset and reported in the appropriate IPCC sectors. For installations where oil and gas are co-produced in associated terminals, regulator information has been used to assess whether the site is predominantly an oil or gas production installation. This improvement has led to much more detailed reporting of emissions, greater transparency of emission estimates and will also improve the accuracy of the UK GHG emission estimates by end user categories, as the emissions from upstream oil and upstream gas industry can now be managed separately. This development means that for the first time the following IPCC sectors are used in the UK inventory (whereas previously the gas production estimates were combined with the equivalent oil production IPCC sectors):

- 1B2bi: Gas Exploration (emissions from well testing in gas exploration);
- 1B2bii: Gas Production and Processing (emissions from gas processes and storage);
- 1B2cii: Gas Production: Venting; and
- 1B2cii: Gas Production: Flaring

For the years 1990 to 1997 inclusive, the installation-specific EEMS data were not available (1990-2005) or are not regarded as a good quality dataset (1996, 1997). The allocation of sites to oil and gas industries does not therefore provide an improvement to the detail or transparency of the estimates in the early part of the time series. This is unfortunate, but the data simply do not exist to generate any more accurate, detailed estimates. In order to present a plausible trend in overall emissions for the oil and gas sectors back to 1990, a relatively simplistic approach has been adopted to divide the industry estimates between oil and gas back to 1990.

For flaring, gas consumption and well testing emissions the oil:gas ratio of activity data in 1998 has been used to extrapolate back the activities to 1990, retaining the previous emission factors for the "oil and gas" sources.

For process and fugitive sources, oil storage and venting emissions, where the EEMS data are simply presented as emissions data without any underlying activity and emission factor information, the estimates for the early part of the time series are simply based on the oil:gas ratio (for each pollutant) from 1998.

Refinery Process Emissions

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, 2010) and are incorporated directly into the GHGI. The UKPIA estimates are compiled by the refinery operators using agreed industry standard methods.

Natural Gas Transmission and Distribution Leakage

Emission estimates from leaks from the natural gas distribution network in the UK are provided by the gas network operators: Transco, UKD, Scotia Gas, Northern Gas Networks, Wales and West, Phoenix gas. Natural gas compositional analysis is provided by the gas network operators and emissions of methane, carbon dioxide and NMVOCs from leaks are included within the inventory. The estimates are derived from industry models that calculate the leakages from:

- Losses from High Pressure Mains (UK Transco);
- Losses from Low Pressure Distribution Network (UKD, Scotia Gas, Northern Gas Networks, Wales & West, Phoenix Gas); and
- Other losses, from Above Ground Installations and other sources (UK Transco).

During 2010, consultation with the gas network operators confirmed that the scope of the network leakage model used by each operator did not include estimates of gas leakage downstream from the gas meter, i.e. at the point of use. Therefore, new estimates have been derived for gas leakage at the point of use during this inventory cycle, using data on the numbers of gas appliances in the UK in the commercial and domestic sectors. These new estimates have been included within the gas network leakage data in 1B2bii, and represent around 0.5% of the total gas leakage emissions from the transmission and distribution system in the UK in 2009.

An additional method improvement was implemented during 2010 following consultation with the gas network operators, to correct a previous methodological error. The gas compositional data provided by the network operators in 2010 prompted enquiries by the Inventory Agency as the number of gas compositional analyses per network varied greatly in the data submission to the Inventory Agency. Each of the gas network operators obtain their compositional analysis from a central system of data logging from the automated sampling and analysis network that was operated previously under the Transco ownership, prior to the network being opened up to greater market competition. Through consultation with the network operators the Inventory Agency identified that in some cases a limited (i.e. not fully representative) dataset of gas compositions had previously been provided for some local distribution zones, indicating that the derived UK average composition was incorrect. Supplementary data was therefore obtained from the central database of gas compositional analysis, and the UK average composition re-calculated using this more comprehensive, representative data. The calculation of the reported UK average gas composition is derived from the sum-product of the annual Local Distribution Zone (LDZ) compositional data and the estimated gas consumption through each of the LDZs, to provide an average gas composition.

The emissions from these leakage sources are reported within the CRF as follows:

- 1B2biv: Gas Distribution (includes transmission and distribution leakage emissions, as well as those from other sources such as AGIs)
- 1B2bv: Other leakage (point of use leakage emissions)

Further consultation with the gas network operators in 2011 will seek to determine whether gas transmission leakage emissions can be published discretely within 1B2biii across the full time series, in future inventories. For now they are included within the 1B2biv sector in the CRF.

Petroleum Products Distribution

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**.

3.3.2.3 Uncertainties and Time Series Consistency

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

The emission estimates for the offshore industry are based on the Oil and Gas UK EEMS dataset for 1995-2009. 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 dataset provided in 2010 by DECC and

Oil and Gas UK 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**.

The emission estimates from refineries, the gas supply network and from petrol distribution are all derived based on consistent methods across the time series using industry standard methods and a UK-specific gas network model. Uncertainties arise primarily from the use of emission factors for different process designs and delivery systems, especially in the refinery storage, transfer and petrol distribution systems.

Uncertainties in the emission estimates from leakage from the gas transmission and distribution network, however, stem predominantly from the assumptions within the industry model that derives mass leakage estimates based on input data such as network pipe replacement (plastic replacing old metal pipelines) and activities/incidents at Above Ground Installations; for these sources the methane content of the gas released is known to a high degree of accuracy, but the mass emitted is based on industry calculations.

3.3.2.4 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**. 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 (2009) data submission indicate that there is still some further improvement to the QA/QC of the source data by operators and regulators alike. Furthermore there are inconsistencies evident from oil and gas terminal submissions to different reporting mechanisms. During 2010, the Inventory Agency conducted research to review the emissions data reported by oil and gas terminal operators, refinery operators and several petrochemical manufacturers, using data from EEMS (for the oil and gas sites), IPPC (for all sites) and EU ETS (for all sites). The report can be found at:

http://www.airquality.co.uk/archive/reports/cat07/1005251107_DA_Improvement_Report_Industry_Task_May2010_Issue_1.pdf

In many cases, the research enabled the Inventory Agency to clarify the difference in reporting scope between the different mechanisms. However, the research also identified several reporting errors, and has led to several revisions of the source data for oil and gas terminals, and also provided feedback to regulators to help identify where QA/QC of emissions data has previously been inconsistent.

3.3.2.5 Source Specific Recalculations

A number of recalculations have been made due to revisions to source data in the oil and gas sector due to the 2010 research and revisions from operator data through EEMS, the correction of the gas leakage methodology, and the addition of the gas leakage at point of use estimates. (See **Section A3.3.8** for details).

3.3.2.6 Recalculation by Gas

The following section describes the main changes that have occurred in sector 1B2 per pollutant since the publication of the 1990-2008 inventory. Comparisons are made between the current inventory (1990-2009) and the previous inventory (1990-2008) for the year 2008.

3.3.2.6.1 *Carbon Dioxide (CO_2)*

- Total emissions of CO_2 from category 1B2 have decreased by 141 Gg CO_2.
- Emissions from oil production direct process sources (1B2aii) have been revised downwards by 76 Gg CO2, following a revision to the installation estimates from one offshore platform (Elgin PUQ) which had mis-reported emissions from non-standard operation of its amine plant and flash gas cooler system.
- Emissions from oil production flaring (1B2c) has also been revised downwards by 62 Gg CO_2, following revision of flaring estimates from one terminal site (Hound Point) following the research into EU ETS, EEMS and IPPC inventory data from the site. Small revisions to gas venting data in the same IPCC sector have also been made (decreased by 6 Gg CO_2) for a number of sites, due to revised operator data.
- Emissions from oil and gas production well testing in 2008 have been revised within the EEMS system across several sites, leading to overall increases in emissions from this source (1B2aii_oil and 1B2bi_gas) of just under 2 Gg CO_2.
- The revisions to the gas compositional analysis method and the inclusion of the new source of gas leakage at the point of use (both amendments within 1B2bii) have led to increases in emissions by 1 Gg CO_2.

3.3.2.6.2 *Methane (CH4)*

- Overall, emissions of methane from category 1B2 have been revised down by 21 Gg CO_2-eq.
- Emissions from 1B2bii (natural gas leakage) have been revised down by 41 Gg CO_2-eq, despite the addition of the new estimates for leakage at the point of use. The reduction in emission estimates is due to the correction to the gas compositional analysis methodology through the use of a more representative dataset for gas composition from across several LDZs which has reduced the average UK methane content of natural gas in 2008.
- Emissions from oil loading (1B2aiii) have been reduced by 10 Gg CO_2-eq, due to correction of data from one offshore rig (Foinavon) and the improvement research to compare EEMS data with IPPC inventory data which led to a reduction in estimates of loading emissions from one terminal (Hound Point).
- Emissions from processes and fugitives (1B2aii_oil and 1B2bi_gas) have increased by 30 Gg CO_2-eq, primarily due to new emission estimates for fugitive releases from one terminal (Easington) and several other revisions to previous site data.
- Emissions from 1B2c (flaring) increased by 2.4 Gg CO_2-eq, due to increased estimates of emissions from three offshore platforms (Marathon Brae).

3.3.2.6.3 *Carbon Monoxide (CO)*

- Emissions from 1B2c (flaring) increased by 0.1 kt CO, due to increased estimates of emissions from three offshore platforms (Marathon Brae) and one terminal (Hound Point).

3.3.2.6.4 *Non Methane Volatile Organic Compounds (NMVOCs)*

- Emissions from oil loading (1B2aiii) have been reduced by 2.5 kt NMVOC, due to decreased estimates for one offshore rig (Foinavon) and one terminal (Hound Point).

- Emissions from flaring (1B2c) have been reduced by 0.5 kt NMVOC, with increased estimates at three offshore rigs (Marathon Brae) all exceeded by a reduction in emission estimates from one terminal (Hound Point). In this same IPCC sector, however, the venting emissions have increased by 0.5 kt due to a reported increase at one offshore rig (Elgin PUQ).
- Emissions from fugitive sources (1B2aii_oil and 1B2bi_gas) have decreased by 0.7 kt with revised 2008 operator data from 7 terminals and 5 production installations.

3.3.2.7 Source Specific Planned Improvements

The data from the EEMS reporting system will be reviewed with the regulatory body during 2011, to address site-specific reporting inconsistencies. The gas leakage estimates from the transmission and distribution networks will be reviewed with the network operators, and the compositional analysis data will be kept under close review in order to ensure that a representative dataset is used within future inventory compilation. It is planned within the 2012 submission that the gas network leakage emission estimates will be reported in greater detail, rather than all included within the IPCC sector 1B2bii.

3.4 GENERAL COMMENTS ON QA/QC

3.4.1 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.

3.4.2 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.

3.5 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 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.

The EU ETS has, for 2005 onwards, provided a source of high quality data on emissions from some industrial processes, especially cement production. In other cases, the data is limited due to opt-outs for processes that were already part of other schemes. The GHGI has made use of EU ETS data wherever possible to improve emission estimates.

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 (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 13 sites producing cement clinker during 2009.

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 (2010), 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 2009 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 carbon/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 up until 1998, before declining again. Since 2007, production has fallen very sharply, with production in 2009 reaching its lowest point in the time series.

The initial large drop in clinker production over the period 1990-1993 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 downward trend in production over the period 1994-2007 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. The sharp decrease in production since 2007 is linked to the recession, which has caused a decline in construction and therefore demand for cement. A number of cement kilns were closed or mothballed during 2008 and 2009.

4.2.4 Source Specific QA/QC and Verification

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

4.2.5 Source Specific Recalculations

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 14 UK sites during 2009. Two of these produce lime for use on-site in the Solvay process and four 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, 2009). The use of consumption data rather than production data is simpler and probably more reliable since it is not necessary to consider the different types of lime produced. An emission factor of 120 t carbon/kt limestone was used, based on the stoichiometry of the chemical reaction and assuming pure limestone. For dolomite, an emission factor of 130 t carbon/kt dolomite would have been appropriate; however dolomite calcination data are not given separately by the British Geological Survey, but included in the limestone data. The use of the limestone factor for this dolomite calcination will cause a small under-estimate of emissions. Dolomite calcination is believed to be a small proportion of the total hence the underestimate is unlikely to be significant. The limestone calcination data exclude limestone calcined in the chemical industry since a large proportion of this is used 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.

Data for the latest year are not available in time for inclusion in the inventory. Therefore, it has been the practice to assume that limestone calcinations are the same in the latest year (in this case, 2009) as in the previous year. Actual data for 2009 will be available in time for the next version of the inventory, and will be included then.

4.3.3 Uncertainties and Time Series Consistency

Uncertainty in the emission factor used for this source is 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 in theory very good due to the continuity in data provided by the British Geological Survey. However, less detailed information has been available since 2003, requiring that we estimate the limestone used by the chemical industry. Furthermore, data are not available for the latest year in the inventory, due to the publication of these data after the completion of the inventory. So, although uncertainty in the earlier part of the time series is low, uncertainty has increased significantly in recent years due to the lack of data on chemical industry consumption, and the need to estimate consumption in the latest year. Uncertainty in the activity data for 2009 is particularly high, since EU ETS fuel consumption data show a large decrease between 2008 and 2009 and this will presumably reflect a lowering in production. The current inventory methodology involves using the 2008 activity data as a temporary measure until data for 2009 become available but in this case this almost certainly leads to an overestimate in the activity data.

Use of EU ETS data may help to reduce uncertainties in the future by providing an alternative source of activity data.

4.3.4 Source-specific QA/QC and Verification

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

4.3.5 Source Specific Recalculations

In the previous version of the inventory, activity data were not available for 2008, and so the 2007 value was used. For this version, 2008 data are now available and are used instead. This leads to a decrease in the estimated emissions of 249 Gg of CO_2.

4.3.6 Source Specific Planned Improvements

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

4.4 SOURCE CATEGORY 2A3 – LIMESTONE & DOLOMITE USE

4.4.1 Source Category Description

Limestone and dolomite are added to sinter where they are calcined, the products subsequently acting as slag formers in blast furnaces. Some limestone or dolomite may be added directly to blast furnaces instead of being sintered first, but this is ignored for the GHGI with all emissions being assumed to occur from the sinter strand instead. Limestone and dolomite are also used as sources of CaO and MgO in the manufacture of soda-lime glasses, as fluxing agents for basic oxygen furnaces in the steel industry, and for the liming of soils by the agricultural sector. Agricultural use is covered in **Chapter 5** of this report.

Use of limestone and dolomite in sinter production, basic oxygen furnaces, and glass manufacture all result 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 present in flue gases, being converted to gypsum, with CO_2 being evolved.

The UK had three operational steel-making sites during 2009 and approximately 20 large glassworks manufacturing soda-lime type glasses. FGD was operational on five UK power stations by the end of 2009.

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 calcination, 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. The British Geological Survey has previously been the source of data on the consumption of limestone and dolomite by the glass industry. However, the data available for the last ten years are very incomplete and in the years before that show surprising year on year variations that do not fit well with estimates of glass production. An alternative approach has therefore been adopted this year. This is based on a detailed, site by site survey of raw material usage, carried out in 2006 (GTS, 2008), and this yields estimates of dolomite and limestone use by sector. These data are extrapolated to all other years in the time series. Data on the usage of limestone and dolomite for steel production are available from the Iron & Steel Statistics Bureau (2009). Gypsum produced in FGD plant is available from the British Geological Survey (2009), with the exception of two of the five plant in 2009. In these cases, the production of gypsum in 2009.is assumed to be the same as in 2008.

Corus UK Ltd has provided analytical data for the carbon content of limestone and dolomite used at their steelworks (Corus, 2005), 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 all of the emission factors and some of the activity data 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. In the case of limestone and dolomite use by the glass industry, the methodology is based on the extrapolation of highly accurate activity data for one year to all other years based on estimates of glass production. Because the estimates of glass production are themselves quite uncertain, these activity data for the glass industry are more uncertain. The lack of gypsum production data for two of five power stations in 2009 means that activity data for that year are more uncertain than the rest of the time series.

4.4.4 Source Specific QA/QC and Verification

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

4.4.5 Source Specific Recalculations

Updates to activity data lead to decreases in estimated emissions of 64 Gg CO_2 for limestone use in sinter plant, and 17 Gg CO_2 for dolomite use in basic oxygen furnaces. Estimates of gypsum production in FGD systems have also been updated, in this case leading to an increase in estimated emissions of 16 Gg CO_2. Some small updates to glass production estimates used to derive limestone use leads to an increase in the emission estimates of 4 Gg CO_2.

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 an assumption that the consumption of soda ash in the production of soda-lime glass is 20% of the mass of glass produced - a figure which is based on data provided by the glass industry (British Glass, 2001). Glass production data are available on an annual basis for container glass only (British Glass, 2010), and production of other types of glass has to be estimated based on data for a limited number of years (British Glass, 2001; EIPPCB, 2000), extrapolated to other years on the basis of estimated plant capacity. 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. 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.

An emission factor of 113 kt carbon/Mt soda ash, based on the stoichiometric relationship between carbon and soda ash is used.
Emissions of CO from soda ash production are estimated based on emissions data reported in the Pollution Inventory (Environment Agency, 2010).

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 Recalculations

Some minor revisions to the estimates of glass production lead to a downward revision in the CO_2 emission estimate of 12 Gg for 2008.

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 (DECC, 2010).

4.7.3 Uncertainties and Time Series Consistency

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

The estimates of NMVOC from road paving are quite uncertain, due particularly due the long-term extrapolation of a single set of consumption data. Emissions occur due only to the use of specialised bitumen products containing kerosene and it is unclear whether the extrapolation using consumption of bitumen for all applications will be reliable.

4.7.4 Source Specific QA/QC and Verification

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

4.7.5 Source Specific Recalculations

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

4.7.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.8 SOURCE CATEGORY 2A7 – OTHER MINERAL PRODUCTS

4.8.1 Source Category Description

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

At the start of 2008, Fletton bricks were being manufactured at two sites in Southern England using the Lower Oxford Clay, however one of these brickworks closed in February 2008. The Lower Oxford 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 results in SO_2 emissions as well.

Glass fibres were manufactured at one site in the UK during 2008, and glass wool was manufactured at eight 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.

Nitrous oxide emissions from glass production, Fletton brick production and asphalt are not estimated since no suitable methods or data exist. Emissions from these sources are believed to be very small.

4.8.2 Methodological Issues

Emissions data for Fletton brickworks during recent years are available from the Pollution Inventory (Environment Agency, 2010). 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 first estimating the likely emissions from coal and gas burnt in the brick kilns and then subtracting these estimates, which are included in source category 1A2f, from the emissions reported in the Pollution Inventory.

The Pollution Inventory emissions data are available back to 1998, although SO_2 emissions data extend back to 1993. Emissions prior to these years have therefore been derived by assuming that emission factors remain at the level calculated for 1998 (or 1993 in the case of SO_2).

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 one glass wool producer 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, 2009 and an emission factor of 8.73 g/t coated roadstone, which is the average of emission factors given by US EPA, 2007 for various types of batch roadstone coating plant.

4.8.3 Uncertainties and Time Series Consistency

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

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

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

4.8.4 Source Specific QA/QC and Verification

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

4.8.5 Source Specific Recalculations

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

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 the by-products CO and CO_2 which are formed, are not captured and used, 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 2008, one of which also produced acetic acid. Methanol production, which was carried out at a different UK site, ceased in 2001.

Methane and nitrous oxide emissions are reported as not estimated. Manufacturers do not report emissions from these pollutants and they are therefore assumed to be negligible.

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 respectively.

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 Recalculations

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

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. At the end of 2009, nitric acid was being manufactured at 2 UK sites with a total of 4 production plants. One of the plants has NO_x/N_2O abatement fitted to all units since commissioning (pre-1990), while the other three plants have no nitrous oxide abatement fitted to any units.

4.10.2 Methodological Issues

Across the 1990-2009 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 kt 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 / kt 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 kt N_2O /Mt 100% acid produced for some plant in 1990-1993. A similar approach has been used for the nitric acid plant in Northern Ireland prior to 2001.

The nitric acid plant emissions data are considered to be reliable since they are subject to internal QA/QC checks by the plant operators and the Environment Agency before being reported in the Pollution Inventory. More details have been obtained regarding the abatement plant and N_2O monitoring methodologies at the one UK plant with N_2O abatement fitted, and this has clarified some previous uncertainties regarding their process emissions.

4.10.4 Source Specific QA/QC and Verification

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

4.10.5 Source Specific Recalculations

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

4.10.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.11 SOURCE CATEGORY 2B3 – ADIPIC ACID PRODUCTION

4.11.1 Source Category Description

Adipic acid is manufactured in a multi-stage process from cyclohexane via oxidation with nitric acid. Nitrous oxide is produced as a breakdown product from the nitric acid. A single company produced adipic acid in the UK until closure of the plant in April 2009.

4.11.2 Methodological issues

Production data and emission estimates have been estimated based on data provided by the process operator (Invista, 2010). The emission estimates are based on the use of plant-specific emission factors for unabated flue gases, which were determined through a series of measurements on the plant, combined with plant production data and data on the proportion of flue gases that are unabated. In 1998 an N_2O abatement system was fitted to the plant. The abatement system is a thermal oxidation unit and is reported by the operators to be 99.99% efficient at N_2O destruction. In 2004 it was operational 92.6 % of the time (when compared to plant operation). Variation in the extent to which this abatement plant is operational, account for the large variations in emission factors for the adipic acid plant since 1999.

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

4.11.3 Uncertainties and Time Series Consistency

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

Emissions of N_2O from adipic acid production are now taken from emissions reported in the Pollution Inventory, with more process-specific details also provided directly by the plant operators. In the early 1990s, emissions were received direct from the plant operators.

The level of uncertainty associated with reported emissions of N_2O is not fully understood. However these data are considered to be reliable since they are subject to internal QA/QC checks within the company producing the adipic acid, and QA/QC checks by the Environment Agency before being reported in the Pollution Inventory.

Fluctuations in the N_2O EF from this plant are apparent since the installation of the abatement plant. Following direct consultation with the plant operators, it has been determined that the variability of emissions is due to the varying level of availability of the abatement plant. A small change in the availability of the abatement system can have a very significant impact upon overall plant emissions and hence upon the annual IEF calculated.

4.11.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. During summer 2005, consultation between Defra, AEA, plant operators and the UK Meteorological Office was conducted to discuss factors affecting emissions from the adipic acid plant, including: plant design, abatement design, abatement efficiency and availability, emission measurement techniques, historic stack emission datasets and data to support periodic fluctuations in reported emissions. These discussions were intended to clarify the relationship between annual emission totals reported by the plant operators and emissions verification work conducted by the Met Office using ambient N_2O concentration measurements from the Mace Head observatory in Ireland. The meeting prompted exchange of detailed plant emissions data and recalculation of back-trajectory emission models.

4.11.5 Source Specific Recalculations

No recalculations have been made for emission estimates in this category

4.11.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.12 SOURCE CATEGORY 2B4 – CARBIDE PRODUCTION

This category does not occur in the UK.

4.13 SOURCE CATEGORY 2B5 – OTHER

4.13.1 Source Category Description

The UK has a large chemical manufacturing sector and emissions of methane, carbon monoxide, NO_x, SO_2, and NMVOC in the inventory are treated in some detail to reflect the many different types of process. All of these emission sources are reported under 2B5.

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.

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 2009 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 in the UK 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 was being produced at two sites at the start of 2008, although one then closed at the end of that year, with the other closing in early 2009. Carbon black is manufactured 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 2008. Pigment manufacture relates to a single plant where sulphur was burnt as part of the manufacturing process – this site closed in 2008. The sulphur oxides produced were largely consumed in the process, although some emissions did 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

The quantity of waste recovered for use as a fuel is 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. Instead the carbon content is assumed to be the same as for waste solvents used as a fuel by the cement industry.

In the case of other pollutants, emissions data for chemical processes located in England and Wales are available in the Pollution Inventory (Environment Agency, 2010). 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, 2010). 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 (2010). 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 (2010). 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 were reported in the early years of the Pollution Inventory. As a result, the data have to be interpreted using expert judgement.

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

The reliability of emission estimates from 2002 onwards may deteriorate for at least some of the sources included in this sector. This is due to changes in the reporting requirements for the Pollution Inventory and other regulator's inventories, with the *de minimis* limits for reporting of emissions of some pollutants being raised. This will lead to a slightly increased need for extrapolation of data from one year to another.

4.13.4 Source Specific QA/QC and Verification

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

4.13.5 Source Specific Recalculations

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 2009, 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 2008 might previously been filled using emissions reported for 2007, whereas now the mean of the 2007 and 2009 emissions would be used).

The various recalculations have usually resulted in very small changes in emissions from these sources compared with values in the last version of the inventory. The most significant changes are for CO, where estimated emissions have increased by 3 Gg, and NMVOC, where estimated emissions have decreased by 1 Gg.

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.

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 A3.4.3**, 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.

Emissions from integrated steelworks are currently split between 1A2a, 1B1b, and 2C1. Following a review of the allocation of these emissions, it is apparent that some emissions currently allocated to 1A2a would be more properly allocated to 2C1 in accordance with IPCC guidance. It is recommended that these emissions be reallocated for the next version of the inventory.

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 DECC 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**.

Additional checks are undertaken for emissions from integrated steelworks with a comparison of the results of the carbon balance approach used, with emissions reported by the operator of UK integrated steelworks. This comparison is made more difficult by differences in the scope of data from different sources but the analysis still demonstrates that the carbon balance gives emission estimates that are close to those available from EU ETS sources. Incorporation of EU ETS/operator data into the inventory methodology is under review, although the differences in scope currently make it difficult to make progress in this area.

4.14.5 Source Specific Recalculations

An update to UK energy statistics for losses (i.e. flaring) of blast furnace gas decrease estimated emissions of CO_2 by 3 Gg.

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 two sites in the UK. A third site closed during 2009, and a fourth process closed in mid 2000. All of the operational sites and the recently-closed process use the pre-baked anode process, whereas the plant that closed in 2000 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.

Emissions of methane are not estimated as there is no methodology available and emissions are considered to be negligible.

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.

There are two main aluminium smelting operators in the UK. All emissions of PFCs (CF_4 and C_2F_6) occur during the aluminium smelting process during so called “anode effects”. The estimates were based on estimates of emissions provided by the aluminium-smelting sector. These estimates were derived from records of the number and duration of “anode effects”.

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. **Table A 3.4.5** in **Annex 3** provides the EFs used to estimate PFC emissions.

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. Large reductions in emissions of PFCs have occurred over the last 10 years through the switch to point feeder technology. Point feeder technology is regarded as the best technology for feeding aluminium oxide into the electrolytic cells. This technology allows more regulated feeding at controlled intervals, ensuring an operating process with fewer anode effects. The move to point feeder technology not only reduces PFC emissions but improves the efficiency of the production process.

A more detailed description of the methodology used to calculate emission estimates for this sector is provided in AEA (2004; 2008).

The EFs used are given in **Annex 3**, **Table A 3.4.5**

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 and Wales plant emissions, or obtained from the Scottish Pollutant Release Inventory, produced by the Scottish Environment Protection Agency (SEPA).

Activity data are taken from BGS data sets for all years except 2005, 2007 and 2008 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 these years.

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 and 2007 is only slightly higher (<0.4%) than the BGS number and supports the view that the BGS data are reliable, although the discrepancy in the 2008 data is larger (3.4%).

4.16.4 Source Specific QA/QC and Verification

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

4.16.5 Source Specific Recalculations

Emissions of PFCs in 2008 have been revised, based on updated data from one of the plant operators. This has led to a decrease in emissions of 0.5kt CO_2eq. Alcan Lynemouth updated their reported PFC estimates in for 2008 and slightly revised downwards estimates of emissions of CF_4 and C_2F_6. The resulted in a change in the total GWP weighted PFC of -0.5 kt CO2 eq.

4.16.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

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.

SF_6 can also be used as a cover gas in aluminium foundries, although no emissions are currently reported by any of the operating plants in the Pollution Inventory. Emissions from the use of SF_6 in the UK are therefore reported as Not Occurring.

4.17.2 Methodological Issues

Magnesium alloy production
An IPCC Tier 2 methodology is used to estimate emissions.

For magnesium alloy production, emissions from 1998-2008 were estimated based on the SF_6 emission data reported by the company to the UK's Pollution Inventory. These data are considered accurate. Earlier emissions, before 1998, are estimated based on consultations with the manufacturers.

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. The assumptions used to estimate emissions are that only 90% as much HFC134a is needed in comparison to SF_6 (consultation with industry; AEA, 2005; AEA 2008), and that 90% of the HFC cover gas used is destroyed in the production process (CSIRO 2005).

In 2008, for the first time, emissions of HFCs have been reported in the Pollution Inventory, and therefore this figure has been used for the year 2008, and subsequent GHG inventories.

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 in the CRF under 2C5 ‘Other metal production’. This is because the CRF Reporter does not allow reporting of HFC emissions under the 2C4 sector category. Reporting under 2C5 allows separate reporting of SF_6 as tonnes of SF_6, and HFCs, as CO_2 equivalent.

Aluminium alloy production
No emissions of SF_6 are currently reported by any of the aluminium foundries in the Pollution Inventory. Emissions from the use of SF_6 in the UK are therefore reported as Not Occurring.

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 1998-2008, 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 accurate.

The reported HFC emission in 2008 is much higher than the calculated emissions for 2004-2007. This is based on operator reported data to the regulator and is therefore considered to be accurate. A large decrease in the reported SF_6 emission has also been observed, indicating that the increased HFC emission is as a result of the continuing change over from SF_6 to HFC use.

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**, and details of verification of emissions are given in **Annex 10**.

Trilateral F-gas Peer Review
A trilateral meeting of F-gas sector experts from the UK, Austria and Germany was held in Vienna, February 2011. Although not a formal review, each country reviewed the completeness, consistency and transparency of the parts of the NIRs reporting F-gases. Some of the improvements that could be made to the transparency and completeness of the UK NIR identified in that review have been incorporated in this NIR, and others will be considered for future implementation.

4.17.5 Source Specific Recalculations

There have been no recalculations to this sector.

4.17.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.18 SOURCE CATEGORY 2C5 – OTHER METAL PRODUCTION

4.18.1 Source Category Description

UK production of many non-ferrous metals has been relatively small for many years and has declined further in recent years with the closure of the only primary lead/zinc producer in 2003 and the only secondary copper production process in 1999.

The primary lead/zinc process, the secondary copper process, and some of the secondary lead processes involve the use of coke as a reductant and emissions of CO and SO_2 from these processes are 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**), but it is recommended that this be reviewed and, if possible, emissions reported here in future. 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. This leads to elevated emissions of CO. A few other non-ferrous metal plants have very minor emissions of CO as well.

Carbon monoxide is used as a reagent 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. Separate estimates for category 2C5 are not available.

4.18.2 Methodological Issues

Emission estimates for these processes are derived from emissions data available from the Pollution Inventory (Environment Agency, 2010). For earlier years, where no emissions data are available, emission estimates are made by extrapolation based on production of the relevant type of metal.

4.18.3 Uncertainties and Time Series Consistency

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

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

4.18.4 Source Specific QA/QC and Verification

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

4.18.5 Source Specific Recalculations

No significant recalculations have been made.

4.18.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.19 SOURCE CATEGORY 2D1 – PULP AND PAPER & WOOD PROCESSING

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, 2010). Production of the wood products is estimated from data published by the Office of National Statistics (2009). These data are given as areas or volumes of product depending upon the type of product and must be converted to a mass basis by making assumptions about the thickness and/or density of the products.

4.19.3 Uncertainties and Time Series Consistency

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

4.19.4 Source Specific QA/QC and Verification

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

4.19.5 Source Specific Recalculations

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

4.19.6 Source Specific Planned improvements

Emission factors and activity data will be kept under review.

4.20 SOURCE CATEGORY 2D2 – FOOD AND DRINK

4.20.1 Source Category Description

A number of food and drink manufacturing processes give rise to emissions of NMVOC. Most significant are emissions of ethanol from whisky maturation. Whisky is matured for a period of years in wooden barrels. This process develops the character of the whisky but an inevitable consequence is that spirit evaporates from the barrel. Other spirit manufacturing stages such as fermentation, distillation, casking (whisky only) and drying of spent grains also give rise to NMVOC emissions although these emissions are relatively small in comparison with those from maturation. Whisky manufacture is confined mainly to Scotland, which had 6 large grain distilleries and approximately 90 smaller malt distilleries at the end of 2009, although one of the grain distilleries closed in 2010. 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.

Emissions of CO_2 from this category are not estimated since no appropriate data are available.

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 (2009), and so emissions can be calculated by applying an annual emission rate factor with the average volume of whisky in storage for each year. This is more accurate than using an overall emission factor applied to whisky production since whiskies are stored for varying lengths of time and stock levels will rise or fall depending upon production, demand and changes in the length of maturation required.

4.20.3 Uncertainties and Time Series Consistency

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

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

4.20.4 Source Specific QA/QC and Verification

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

4.20.5 Source Specific Recalculations

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

4.20.6 Source Specific Planned improvements

Emission factors and activity data will be kept under review.

4.21 SOURCE CATEGORY 2E – PRODUCTION OF HALOCARBONS AND SF_6

4.21.1 Source Category Description

Emissions arise from the UK manufacture of HFCs, PFCs and HCFC 22. HFC 23 is a by-product of HCFC 22 manufacture. There are two single manufacturers of HFCs and PFCs respectively in the UK, and two companies were operating HCFC 22 plants, one of which closed in 2008, and the second closed at the end of 2009. 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 Systems. 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 HCFC 22.

Emissions from the production of HCFC-22 are reported under 2E1.2 and are combined with fugitive emissions from HFC and PFC manufacture, to protect commercial confidential data.

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 oxidiser pollution abatement equipment at one of the UK manufacturing sites. Fugitive HFC emissions from both an HCFC22 plant and HFC manufacturing plant (run by the same operator) are treated using the same thermal oxidiser unit. Emissions also decrease in 2004, reflecting the installation of a thermal oxidiser at the second of the UK's HCFC22 manufacturing sites. This was installed in late 2003, and 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. Emissions declined sharply in 2007 and 2008.

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 are given in **Annex 10**. 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 System.

Trilateral F-gas Peer Review
A trilateral meeting of F-gas sector experts from the UK, Austria and Germany was held in Vienna, February 2011. Although not a formal review, each country reviewed the completeness, consistency and transparency of the parts of the NIRs reporting F-gases.

Some of the improvements that could be made to the transparency and completeness of the UK NIR identified in that review have been incorporated in this NIR, and others will be considered for future implementation.

4.21.5 Source Specific Recalculations

There have been no recalculations to emissions from this sector.

4.21.6 Source Specific Planned Improvements

The F-gas inventory was reviewed and updated in 2008 (AEA, 2008). Emission factors and activity data are kept under review.

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) (R1);
- Other small hermetic refrigeration units (including through the wall air-conditioners, retail equipment, drinking water coolers etc) (R2);
- Small commercial distributed systems (including pub cellar coolers, small chill and cold stores) (R3);
- Supermarket systems (R4);
- Industrial systems (R5);
- Building air conditioning systems (direct use of refrigerant) (R6);
- Building air-conditioning chillers (indirect use of refrigerant) (R7);
- Refrigerated transport (refrigerated lorries, containers etc) using conventional refrigeration technology (R8); and
- Mobile air conditioning (air-conditioning systems for cars and other vehicles) (R9).

The UK inventory uses a code (R1 to R9) to refer to these sector sub-divisions.

4.22.2 Methodological Issues

A full description of the methodology used for this sector is contained in AEA (2010). A summary is given here, including the approach to verification of the total HFC use.

The AEA 2010 study to update the HFC historic inventory and projections

The study (AEA, 2010) concentrated on deriving an accurate set of projections of emissions, but this necessarily meant that the entire time series of emissions had to be reviewed, from 1990 onwards. To successfully derive accurate projections, it was very important that the bank size of HFCs in the UK was reviewed and if necessary adjusted. A questionnaire was sent out in 2010 to a selection of the important manufacturers and distributors containing questions to enable the bank size of HFCs in the emissions model to be reviewed and updated. The list was compiled in conjunction with Defra and BIS. About 30 people were contacted, mainly in the distribution sectors. Through this consultation, refrigerant sales statistics were identified and these have been used to validate and verify the emission estimates for this sector, as discussed below.

British Refrigeration Association (BRA) HFC sales data and data returns under the F-gas regulations

A discussion with one of the manufacturers identified a key report containing a comprehensive set of UK HFC sales data into the refrigeration sector by the British Refrigeration Association (BRA). At this time, the only official reporting requirement for companies is under the F-gas regulations. Article 6 of Regulations (EC) No 842/2006 on certain fluorinated greenhouse gases requires companies that produce, import, or export more than one metric tonne of fluorinated GHGs report certain activities to the European Commission annually, beginning in 2008. The data provides accurate information on the volume of HFCs imported and exported at the EU level by species, however the data is not disaggregated into the quantities going in and out of each Member State. In addition, the data in the F-gas regulation forms are new HFCs imported into the EU and does not track the currently existing bank size of the HFCs already being used in the EU. There are no other reporting requirements for companies to report their HFC usage/sales within the UK and the BRA report is considered to be the only report that contains data on HFC sales into the refrigeration sector in the UK. The use of this BRA data to verify the total HFC use in the UK is discussed below.

Methodology

The general methodology used to estimate emissions from refrigeration and air conditioning equipment 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.

Emissions at manufacture are calculated by applying a suitable emission factor the amount of refrigerant fluid used in new equipment manufactured or installed in the UK.

Annual emissions from leakage during use are calculated by applying an emission factor to the amount of refrigerant fluid installed in existing equipment in a given year. The model is set up to allow year specific emission factors to be applied. For example, the leakage rate for new equipment may be much lower than for older equipment, therefore it is important that the model can reflect this.

Emissions at disposal are calculated as a proportion of the amount of fluid remaining in equipment at the end of its life.

The UK model is set up to include additional refrigerant fluid used to top up units that are already in use.

The general methodology corresponds to the IPCC Tier 2 -'bottom-up'- approach for domestic refrigeration and mobile air conditioning, and the IPCC Tier 2 –'top-down'- approach for other refrigerant sub sectors.

The methods used to estimate emissions from each sector are summarised in the sections below. Where possible, the emission factors from the sector sub-divisions have been summarised in **Annex 3 Section A3.4.5.1**. Three key emission factors are quoted: the product manufacturing factor (PM), the product life factor (PLF) and the disposal loss factor (D). These factors are reported to provide transparency in the UK NIR.

Domestic refrigeration (including refrigerators, chest freezers, upright freezers and fridge-freezers) *(R1)*

The method used to estimate emissions from the domestic refrigeration sector is based is based on a stock model. The method of calculation is an IPCC Tier 2 bottom-up method. Emissions from the domestic refrigeration sector were estimated using UK stock estimates of refrigerators, fridge-freezers, chest-freezers and upright freezers from the UK Market Transformation Programme (MTP, 2008). The balance of home production and imported units was based on Office of National Statistics "ProdCom" statistics.

In the EU, industry has indicated that all domestic refrigeration units imported into the UK is based on hydrocarbons, although refrigeration units manufactured in the US still use HFC refrigerants. HC- 600a is the primary hydrocarbon refrigerant used, with some systems using blends of HC-600a and HC-290.

Other small hermetic refrigeration units (*R2****) and small commercial distributed systems*** *(R3)*

The method used to estimate emissions from small hermetic refrigeration units and small commercial distributed systems is based is based on a fluid bank model. The method of calculation is an IPCC Tier 2 top down method, but expert judgement is used to divide the fluid sales data between subsectors.

From a global perspective, HFC-134a is the dominant refrigerant, replaced by HC-600a in some bottle coolers and water fountains and by HC-290 in other equipment such as ice cream freezers. For low temperature equipment R-404A can also be used. Some vending machines have moved towards the use of CO_2. For most of these systems, the refrigerating circuit is virtually hermetic and emission during their lifetime is very low. Most of the refrigeration release takes place at the end of life and effective recovery/decommissioning is therefore essential.

In condensing units and centralised systems, the dominant refrigerant is HFC-134a, HCFC-22 and R-404A. High GWP refrigerants are being replaced by several "intermediate" HFC blends designed for the retrofit of current installations. CO_2 is also an option for this type of equipment. In Northern Europe, HC-290 or even HC-1270 are used as refrigerants.

In centralised systems, for low temperature applications, R-502 has been used widely in Europe. HCFC- 22 is still the most used refrigerant in commercial centralised systems globally. In 2006, the refrigerant bank was estimated at 547,000 tonnes with 60% in centralised systems, 33 % in condensing units, and 7 % in stand-alone equipments.

One end-user in this sector specified that they are still 100% relying on the use of HFCs, predominantly R404a (65%) and R134a (10%), whilst still using a significant amount of R22 (25%) in 2008.

Supermarket systems *(R4)*
The method used to estimate emissions from small supermarket systems is based is based on a fluid bank model. The method of calculation is an IPCC Tier 2 top down method.

Total refrigerant use in refrigeration and air conditioning is dominated by the use in this sub-sector although many supermarkets have made public announcements that they will cut their overall carbon footprint by making a significant change from their currently chillers using HFCs to using low GWP replacements. They have targeted refrigeration due to the proportion of their total GHG emissions accounted for by the use of refrigerants.

The most commonly used refrigerant is still R404a and that some of the supermarkets still have HCFC systems in place. The HCFC systems are being phased out very quickly due to the ban of virgin fluids for top-up from 2010. The findings from the AEA (2010) study showed that supermarkets are still relying heavily on HFC refrigerants with high GWPs although they are being replaced with either lower GWP HFCs or other alternatives.

Many companies are also working to reduce the leakage rate of currently existing systems before making the full transformation to lower GWP systems. At the beginning of this decade, it was estimated that the leakage rate of refrigerants from supermarket chillers was as high as 50%, however, this has been reduced to 10-15% which has reduced carbon footprints of supermarkets drastically.

Supermarket refrigeration policy is changing rapidly, and therefore HFC use in the supermarket refrigeration sector is likely to change significantly in the near future. This sector will be kept under review.

As part of the AEA (2010) update, discussions were conducted with people responsible for, or with an important contribution to, refrigeration policy in supermarkets with large market shares in the UK.

Industrial refrigeration *(R5)*
The method used to estimate emissions from industrial refrigeration is based on a fluid bank model. The method of calculation is an IPCC Tier 2 top down method, but expert judgement is used to divide the fluid sales data between subsectors.

The TEAP report (2009) states that, ‘large refrigeration systems predominantly use ammonia due to the relatively low capital cost for the equipment and excellent operating performance”. There is emerging trend towards the use of CO_2 in industrial systems when direct ammonia systems are not feasible, either in cascade with low charge ammonia or HFC systems. Carbon dioxide is most suitable in colder climates where it is easier to make efficient systems (TEAP 2009).

The long lifetime of industrial systems (15 years) means that the larger number of systems installed historically lead to a relatively high level of emissions, even when the installation of new HFC based systems has begun to fall.

Building air conditioning systems (direct use of refrigerant) *(R6)*
The method used to estimate emissions from building air conditioning systems is based on a fluid bank model. The method of calculation is an IPCC Tier 2 top down method.

In developed countries, HFC refrigerants have been the dominant replacement for HCFC-22 under the Montreal Protocol. The most widely used replacement is R-410A, followed by R-407C. Over time, the industry has moved to the use of R-410A because of its size, cost and serviceability advantages. Hydrocarbons have been used in some low charge applications, such as portable air units and split system air conditioners. Broader use of hydrocarbon refrigerants in unitary air conditioners will be much more difficult, because of the flammable property of hydrocarbons. The current candidate replacement refrigerants have technical difficulties, such as flammability, toxicity, peak load efficiency, and economic feasibility. Therefore, this sector is still at the very early stages of developing and applying low GWP replacements (TEAP 2009).

Building air-conditioning chillers (indirect use of refrigerant) *(R7)*
The method used to estimate emissions from industrial refrigeration is based on a fluid bank model. The method of calculation is an IPCC Tier 2 top down method, but expert judgement is used to divide the fluid sales data between subsectors.

Air conditioning facilities in commercial buildings, building complexes and production facilities are commonly supplied by water chillers. The two main types of chillers are the vapour compression chillers and the absorption chillers of which only the former uses refrigerants. In these vapour compression chillers, HFC emissions occur from the installation and during the use of the chiller. In absorption chillers, water is used as the refrigerant and they are commonly used outside Europe.

Since the phase out of HCFC-22, new chillers have moved to using R-407C, HFC-134a and R-410A. Chillers using ammonia and hydrocarbons as the refrigerant are also available in Europe, typically in mid-range capacity. HFC-245fa was developed for the use in centrifugal chillers, however its use to date has been limited (TEAP 2009).

Refrigerated transport *(R8)*
This sub sector is treated in the same way as stationary refrigeration and air conditioning systems, with the total input of refrigerant fluid based on information about the typical refrigerant blends in use within the sector, and a degree of expert judgement used to allocate refrigerant fluid to this specific sector. The calculation is based on the IPCC Tier 2 top down method. The refrigeration model used is described at the start of this methodology section, with the key parameters set out in **Annex 3 Section A3.4.5.1.**

The UNFCCC review of the 2010 Inventory submission recommended amending the Product Life Factor (PLF) used for this source to a value within the IPCC default range. Since the UK model is in balance with the refrigerant sales data supplied by BRA, it is not possible to change the PLF in isolation. Increasing the PLF alone would require an increase to the refrigerant fluid inputs to the system. This is because refrigerant units are topped up each year to replace the amount of fluid lost during usage. This would result in greater volumes of refrigerants in the system than the volumes reported in the BRA sales data.

In order to address the UNFCCC's recommendation in the 2011 Inventory submission, the PLF has been increased to the suggested value of 32.5%, and the model has been kept in balance with the BRA sales data by decreasing the amount of fluid input into new refrigerated transport systems.

The revision to the model has been made such that there is no change to the total emissions from refrigerated transport. This constraint has led to a small inconsistency when comparing the emissions totals by species with the emissions total by blend. This difference amounts to less than 0.2% of the emissions total for refrigerated transport across all years. The inputs by blend are used to compare with the BRA data. Since this difference is small, the indicative data by blend can still be used as a useful cross comparison.

This is an interim update. A research project is planned for 2011 to improve the refrigeration model. It is intended that the outputs of this research will lead to improvements to the model, which will then be fed into the 2012, or a future, Inventory submission.

Mobile air conditioning *(R9)*
The method used to estimate emissions from mobile air conditioning is based on the IPCC Tier 2 bottom up method. The UK model currently only considers emissions from UK passenger cars and vans.

Vehicle registration numbers are taken from data provided by the Society of Motor Manufacturers and Traders (SMMT). The data are split into car and light commercial vehicles.

The model assumes the air conditioning system has an average fill of approximately 0.6 kg of fluid.
In the UK, as in other parts of Europe, mobile air-conditioning (MAC) market for passenger and commercial vehicles grew rapidly in the UK during the 1990s. Until around 1993, CFC-12 was the common refrigerant used in vehicle mobile air-conditioning, after which it was replaced by HFC-134a, the current standard.

Mobile air-conditioning units in vehicles are not hermetically sealed. Due to design and the mechanically demanding working conditions of MAC units and the maintenance regimes likely to have been encountered in practice, lifetime emissions equivalent to 4 charges/vehicle have historically been estimated for CFC systems (assuming 1 system recharge every 3 years) (UNEP, 1998). New systems are estimated as leaking around 6-8% per year, and industry believes leakage rates of 4-5% or lower will be achieved in the future (CNE 2000).

The reduction in leakage rates has largely been because of improved design and efficiency gains, together with improved fluid recovery at maintenance and decommissioning. Further improvements in leakage and recovery rates will undoubtedly occur, but the underlying penetration of MAC technology in the automotive sector means that HFC emissions are predicted to increase steadily until 2009.

The MAC Directive is expected to have a significant impact on emissions from Mobile Air Conditioning, as it will lead to a phase out of HFC 134a used in this sector. Potential replacements include hydrocarbons, CO_2 and other, as yet not approved, chemicals such as HFO-1234yf. Lower GWP HFCs have also been suggested, although based on UK stakeholder consultation, this is not expected to be a long-term alternative.

Speciation of emissions
Before the 2011 NIR, the F-gas model was set up to calculate emissions based on the use of the same blend of HFCs across the time series in each of the sectors. Consultation with industry (as part of the project to update the F-gas projections in 2008) indicated that this assumption was too simplistic, and the accuracy of the estimates of HFC emissions in each year could be improved considering the transition between refrigerant blends within each sub sector. The AEA 2010 work further modified the model to better deal with the transitions between the species, which has become more important due to the phase out of HCFC R22 and an increased use in lower GWP HFCs.

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

General
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 10**.

The HFC sales chain is heavily segmented. This means that it is difficult to estimate the use of refrigerants by the sectors under the overall refrigeration sector. Necessarily therefore the error associated increases when this is split this into the sub categories within the refrigeration sector.

Use of BRA HFC sales data for verification of total UK HFC use
The acquisition of data from BRA on sales of fluids into the refrigeration sector (in full) has allowed verification of this aspect of the model, by providing a data set against which the estimates of fluid use by subsector can be compared on a fluid by fluid basis.

In order to use the BRA data for verification, the refrigeration sector model was first improved to allow explicit estimation of fluids used for topping up systems; (which was assumed to equal leakage rates for non-hermetically sealed systems) and hence total consumption of fluids (i.e. for both initial charging of systems and for topping up) on an annual basis. The internal consistency of the model was also improved through changes to ensure that losses at manufacture were not double counted in decommissioning losses, and that leakage from systems which are not topped up, is calculated cumulatively.

Once these changes had been made, consumption as predicted by the model was compared with the BRA data. A three year rolling average was used for the BRA data to minimise fluctuations caused by changes in stock level. Initial comparisons indicated that at a total HFC use level, the model tends to overestimate consumption from 1997 until 2002, indicating that it assumed a quicker uptake of HFC refrigerants than was observed. From 2003 onwards the model underestimates use, indicating that usage is higher than was originally forecast. Disparities were larger at the individual fluid level.

Use of any one fluid is typically dominated by one or two subsectors. Efforts on improving reconciliation between estimated usage and the BRA data for a particular fluid were, therefore, focussed on these sectors. For example, HFC-134a is mainly used for mobile air conditioning. R404A and R507 are used in a variety of systems but predominantly supermarket and industrial refrigeration systems, and the main use of R407c and R410 in the model is air conditioning systems. The root mean square of the difference between the BRA and modelled data was used as an indicator of the quality of the fit between the BRA sales data and estimated usage. At the total fluid usage level this error was reduced by a factor of 4.6. The BRA data has not been reproduced in this report because it is commercially confidential.

Trilateral F-gas Peer Review
A trilateral meeting of F-gas sector experts from the UK, Austria and Germany was held in Vienna, February 2011. Although not a formal review, each country reviewed the completeness, consistency and transparency of the parts of the NIRs reporting F-gases. Some of the improvements that could be made to the transparency and completeness of the UK NIR identified in that review have been incorporated in this NIR, and others will be considered for future implementation.

2008 Workshop Peer Review
The refrigeration sector model contains estimates of HFC fluids going into each of nine sub-sectors, with emissions then estimated on the basis of:

- emissions associated with initial charging of appliance/systems with fluids;
- leakage rates of appliances or refrigeration systems in that sub-sector;
- losses at decommissioning of the appliance/system;
- assumptions about the mix of HFC fluids used in the sub-sector.

Assumptions about leakage rates and the mix of HFC fluids in each sub-sector were peer reviewed, by a workshop of experts in 2008, and losses during manufacture/initial charging and at decommissioning are generally based on factors recommended by the IPCC or the recommendations from the workshop.

Peer Review of the refrigeration component of the F-gas model
The refrigeration model, assumptions and estimates of emissions from the refrigeration sector, were reviewed by SKM Enviros, who have a good overview of the use of HFCs in the refrigeration sector as operators of the F-gas support service for Defra. The review occurred in July 2010.

4.22.5 Source Specific Recalculations

The model used to calculate emissions from this sector has undergone a number of significant changes and improvements against the model used to produce data for the 2009 NIR. These are:

- Refrigerant fluids have been speciated at the input stage of the model, rather than speciating the emissions output. This has changed the time profile of the GWP weighted emissions.

- Refrigerant fluid input into the model has been separated out, into the amount filled into new units, and the amount used for topping up existing units. The previous model did not explicitly contain data on the amount used to top up units.
- Input data (refrigerant fluid filled into new products, and used for topping up existing products) has been verified against sales data. The previous estimates were based on consultation and expert judgement, and therefore the use of sales data is considered to be a significant improvement to the estimates.

Emissions of HFCs and PFCs in 2008 have been revised for some sources since the 2010 NIR.

Emissions in commercial refrigeration, and industrial refrigeration have been revised following advice on the likely use of HFCs in each refrigeration sector from the Peer Review of the F-gas model by SKM Enviros, completed as part of the HFC consumption and emissions forecasting review (AEA, 2010). This has led to an overall change in HFC emissions of +0.57 Mt CO2 eq. from commercial refrigeration, and 0.69 Mt CO2 eq. from industrial refrigeration.

4.22.6 Source Specific Planned Improvements

Activity data and emission factors will be kept under review. Supermarket refrigeration policy is changing rapidly, and therefore HFC use in the supermarket refrigeration sector is likely to change significantly in the near future. This sector will be kept under review. Improvements to the refrigeration and air conditioning model are planned for 2011, and it is anticipated this will involve a rebuild of this model.

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 (see **Table 4.1**). 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.

Table 4.1 Banned uses of HCFCs under EC Regulations

Date of ban	Banned in production of…
1 October 2000	Polyurethane (PU) integral skin foams Polyethylene foams
1 January 2002	Extruded polystyrene (XPS) (except in insulated transport)
1 January 2003	PU foams for appliances PU flexible face laminate foams PU sandwich panels (except in insulated transport)
1 January 2004	All foams including PU spray and block foams and foams used in insulated transport

4.23.2 Methodological Issues

The methodology used to estimates emissions corresponds to the IPCC Tier 2 'bottom-up' approach. The emission factors from the sector have been summarised in **Annex 3 Section A3.4.5.3**.

Emissions are considered separately from the following categories of foams:

> PU Appliances (F1); PU Flexibly faced laminate (F2); PU Discontinuous Panel (F3); PU Continuous Panel (F4); PU, PIR, Phenolic block (F5); PIR, Phenolic flexibly faced laminate (F6); PU Spray/injected/pipe-in-pipe (F7); Extruded polystyrene (XPS) (F8); Polyethylene Foam (F9); Integral Skin Foam (F10)

A full description of the emissions and associated methodology used for this sector is contained in AEA (2010). 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 species used for foam blowing are given in **Annex 3**, **Section A3.4.5.3**.

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 are given in **Annex 10**.

Trilateral F-gas Peer Review
A trilateral meeting of F-gas sector experts from the UK, Austria and Germany was held in Vienna, February 2011. Although not a formal review, each country reviewed the completeness, consistency and transparency of the parts of the NIRs reporting F-gases. Some of the improvements that could be made to the transparency and completeness of the UK NIR identified in that review have been incorporated in this NIR, and others will be considered for future implementation.

4.23.5 Source Specific Recalculations

Emissions of HFCs have been revised. This revision was part of the HFC consumption and emissions forecasting review (AEA, 2010). Emissions from the use of HFCs in foams were reviewed and the historic and projected time series were revised. This led to an overall change in HFC emissions of -0.14 kt CO_2 eq in 2008.

4.23.6 Source Specific Planned improvements

Emission factors and activity data will be kept under review.

4.24 SOURCE CATEGORY 2F3 – FIRE EXTINGUISHERS

4.24.1 Source Category Description

In the UK, manufacturers of fixed suppression systems for fire fighting have been using HFCs as an alternative to Halons for the past 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.

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

The methodology used to estimates emissions corresponds to an IPCC Tier 2 method. The emission factors for HFC use in the sector have been summarised in **Annex 3 Section A3.4.5.4**.

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). The sector was reviewed in 2010 (AEA, 2010). No updates were introduced.

Emissions of PFCs were < 1kt on a GWP basis in 2009, no emissions occur from 2010 onwards.

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 are given in **Annex 10**.

Trilateral F-gas Peer Review

A trilateral meeting of F-gas sector experts from the UK, Austria and Germany was held in Vienna, February 2011. Although not a formal review, each country reviewed the completeness, consistency and transparency of the parts of the NIRs reporting F-gases. Some of the improvements that could be made to the transparency and completeness of the UK NIR identified in that review have been incorporated in this NIR, and others will be considered for future implementation.

4.24.5 Source Specific Recalculations

There have been no source specific recalculations this year.

4.24.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

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.

Most aerosols use hydrocarbon propellants, with a relatively small proportion of the market favouring DME. Compressed gases are used in very few aerosols since they suffer from a number of disadvantages compared with liquefied gas propellants such as DME and hydrocarbons. HFCs are used only in a few specialist applications, which can be categorised as industrial or non-industrial. Most of these are considered critical (as defined by BAMA (British Aerosol Manufacturers Association) and agreed by Defra) with regard to the use of HFCs as propellants. The most important industrial applications in volume terms are air dusters and pipe freezing products; other applications include specialised lubricants and surface treatments, and specialised insecticides. The main non-industrial applications in the UK are novelty products, such as ‘silly string’, where the use of HFC is considered critical due to the need for non-flammable propellants. The use of HFCs for novelty applications is now 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

Aerosols

The methodology used to estimates emissions corresponds to an IPCC Tier 2 method. The emission factors from the sector have been summarised in **Annex 3 Section A3.4.5.5.**

A full description of the emissions and associated methodology used for this sector is contained in AEA (2008). Emissions from the sector were reviewed in 2010 (AEA, 2010), but left unchanged.

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.

Metered Dose Inhalers (MDIs)
The methodology used to estimates emissions corresponds to an IPCC Tier 2 method. The emission factors from the sector have been summarised in **Annex 3 Section A3.4.5.5**.

The MDI methodology is follows an IPCC Tier 2 bottom-up analysis, based on estimates of the number of units (inhalers) used annually and estimates of the amount of HFC in each inhaler. Data on MDI use in 2001 was provided by the major UK manufacturers of MDIs; the trend from 2001 to 2010 is based on estimate of UK share of estimated EU emissions in 2010 (ECCP, 2001).

Although the amount of HFC in each inhaler differs between manufacturers, an average amount was calculated of 17 g/MDI. 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.

The date the estimates from this sector were last updated is 2005. Emissions from the sector were reviewed in 2010 (AEA, 2010), but left unchanged.

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 are given in **Annex 10**.

Trilateral F-gas Peer Review

A trilateral meeting of F-gas sector experts from the UK, Austria and Germany was held in Vienna, February 2011. Although not a formal review, each country reviewed the completeness, consistency and transparency of the parts of the NIRs reporting F-gases. Some of the improvements that could be made to the transparency and completeness of the UK NIR identified in that review have been incorporated in this NIR, and others will be considered for future implementation.

4.25.5 Source Specific Recalculations

Emissions from the use of HFCs in aerosols were updated with more recent estimates of HFC usage in aerosols from BAMA. In 2008, this led to an overall change in HFC emissions of -0.14 kt CO_2 eq in 2008.

4.25.6 Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

4.26 SOURCE CATEGORY 2F5 – SOLVENTS

4.26.1 Source Category Description

HFCs can be used as solvents in a range of applications such as precision cleaning to replace CFCs, HCFCs or 1,1,1-trichloroethane, the use of all of which have been or will be phased out as a result of the Montreal Protocol. In recent years, HFCs have been developed that are used for precision cleaning in sectors such as aerospace and electronics. CFCs were used as solvents in precision cleaning before being replaced by certain HCFCs, namely HCFC-141-b. As an ozone depleting substance, this HCFC has started to be replaced by HFC-43-10mee, albeit slowly. Due to only being used as a replacement in recent years, the amount of this HFC being sold in the UK market at present is thought to be insignificant relative to other UK sources of HFCs. However, future growth could be high, depending on their use as a replacement to HCFC-141b over the next 10 years.

4.26.2 Methodological Issues

The methodology used to estimates emissions corresponds to an IPCC Tier 2 method. Emission factors are not quoted for this sector, as the data available only allows estimates of “lifetime” emissions to be calculated.

UK estimates of emissions from this source are based on a European evaluation of emissions from this sector (Harnisch and Schwarz, 2003), subsequently disaggregated to provide a top-down UK estimate.

A full description of the emissions and associated methodology used is contained in AEA (2004). Emissions from the sector were reviewed in 2010 (AEA, 2010), but left unchanged.

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 AEA (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 are given in **Annex 10**.

Trilateral F-gas Peer Review
A trilateral meeting of F-gas sector experts from the UK, Austria and Germany was held in Vienna, February 2011. Although not a formal review, each country reviewed the completeness, consistency and transparency of the parts of the NIRs reporting F-gases. Some of the improvements that could be made to the transparency and completeness of the UK NIR identified in that review have been incorporated in this NIR, and others will be considered for future implementation.

4.26.5 Source Specific Recalculations

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

4.26.6 Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

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.

The electronics industry is one of the largest sources of PFC emissions in the UK. 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%.

4.27.2 Methodological Issues

The methodology used to estimates emissions corresponds to an IPCC Tier 1 method.

Emissions of PFC and SF_6 emissions from electronics are based on data supplied by UK MEAC – the UK Microelectronics Environmental Advisory Committee (in conjunction with the UK DTI). UK MEAC gave 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 (the "heel" amount, 10%), the amount converted to other products (between 20% and 80% depending on the gas) and the amount fed to abatement. The general equation used to calculate the emissions is given later in this section.

The estimates of HFC and SF_6 emissions are based on consumption data (purchases) from 2001, which were supplied by the UK MEAC / DTI. The data supplied were the purchases, used by the semiconductor industry, of SF_6 and NF_3, and the following PFC species: C_2F_6, CF_4, CHF_3, C_3F_8, and C_4F_8. Estimates of PFC and SF_6 consumptions in the years before and after 2001 are made from assumptions about the annual growth rates, and the annual rate of change of usage per unit consumption. Both these sets of data are supplied by MEAC.

Estimates of emissions in the time series are based on i) the consumption of gases in sector and ii) assumptions about growth rate in sector, gas use and abatement.

Emissions of PFCs for previous years were extrapolated backwards (to 1990) assuming an annual 15% growth in the production of semiconductors in the UK up until 1999. A sharp decline in growth is then assumed in 2001, and from 2006 onwards, a growth of 10% is assumed and this growth then declines slowly from 2013 onwards.

An annual increase in the amount of PFCs used per unit production is assumed. PFC specific usage data are used to estimate emissions. Across the time series C_2F_6 consumption dominates total PFC consumption. This figure is 3% from 1990 to 1996, as production methods required more PFCs for finer and more complex etching processes. A gradual decrease to 0% in 1999 and –1% in 2000 is assumed as measures to reduce use of PFCs begin to be implemented. The figure then declines to -2% until 2004, and then declines further to -8% until 2010 and is assumed constant at -1% into the future.

Emission estimates of PFC and SF_6 emissions were calculated using modification of an equation provided by the World Semiconductor Council (WSC). For example, the equation below is used for the estimation of CF_4.

$$\text{Emissions for } PFC_i = PFCi*(1-h)[(1-C_i)(1-A_i)*GWP_i + B_i*GWP_{CF4}*(1-A_{CF4})]$$

h = fraction of gas_i remaining in container (heel)
PFC_i = purchases of gas_i = kgs_i
kgs_i = mass of gas_i purchased
GWP_i = 100 yr global warming potential of gas_i
C_i = average utilization factor of gas_i (average for all etch and CVD processes)
  = $1-EF_i$
EF_i = average emission factor of gas_i (average for all etch and CVD processes)
B_i = mass of CF_4 created per unit mass of PFC_i transformed
A_i = fraction of PFC_i destroyed by abatement = $a_{i,j}*V_a$

A_{CF4} = fraction of PFC_i converted to CF_4 and destroyed by abatement = $a_{CF4} * V_a$
$a_{i,j}$ = average destruction efficiency of abatement $tool_j$ for gas_i
a_{CF4} = average destruction efficiency of abatement $tool_j$ for CF_4
V_a = fraction of gas_i that is fed into the abatement tools

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**.

A full description of the emissions and associated methodology used is contained in AEAT (2004). The estimates were reviewed in 2008 and last updated in 2004.

4.27.3 Uncertainties and Time-Series Consistency

Estimates of emissions are based on very limited data and are therefore uncertain.

Emissions of C_2F_6 dominate total PFC emissions, on a GWP basis, and are approximately 70% of total PFC emissions, across the time series. Emissions of SF_6 are between 11% and 17% of total GWP weighted emissions (PFC and SF_6) from semiconductor manufacture across the time series

4.27.4 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 are given in **Annex 10**.

Trilateral F-gas Peer Review
A trilateral meeting of F-gas sector experts from the UK, Austria and Germany was held in Vienna, February 2011. Although not a formal review, each country reviewed the completeness, consistency and transparency of the parts of the NIRs reporting F-gases. Some of the improvements that could be made to the transparency and completeness of the UK NIR identified in that review have been incorporated in this NIR, and others will be considered for future implementation.

4.27.5 Source Specific Recalculations

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

4.27.6 Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

4.28 SOURCE CATEGORY 2F7 – ELECTRICAL EQUIPMENT

4.28.1 Source Category Description

SF_6 is released from activities in this source sector.

Sulphur hexafluoride has been used in high and medium voltage switch gear and transformers since the mid-1960s. The physical properties of the gas make it uniquely 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 advantages of SF_6 equipment are that it is more efficient, more compact, less complex and less costly. It also avoids the problems associated with the earlier technologies, namely oil leaks, fire risk, safety and noise. The only disadvantages of SF_6 are that it is a potent greenhouse gas; its breakdown products can be toxic or corrosive and that it is less effective at very low temperatures. Currently, there are no alternative fluids that have the same properties as SF_6. There has been research in the use of nitrogen / SF_6 mixtures with the aim of reducing the amount of SF_6 contained in an item of equipment. However, such applications are confined to its use as an insulator since the arc quenching properties of the mixtures are inferior. Hence, it is not yet clear whether gas mixtures could be used to reduce consumption and emissions on a significant scale.

4.28.2 Methodological Issues

The method used to estimate emissions is based is based on a fluid bank model. The method of calculation is an IPCC Tier 2 method.

BEAMA (representing equipment manufacturers) and the Electricity Association (representing electricity transmission and distribution) were able to provide limited data on SF_6 bank sizes. The Electricity Association (for electricity transmission and distribution) provided SF_6 bank size data for 1995 and 2000.

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 following the method originally applied by (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. Projections were made using the model based on an assumed increase in the fluid bank to 2025 based on advice provided by the utilities. Future leakage rates and recovery rates were estimated assuming improved equipment specification and improving repair and recovery practices.

The key assumptions used in the emissions model for this work are provided in **Annex 3**, **Section A3.4.5.8.**

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**.

A full description of the emissions and associated methodology used is contained in AEAT (2004). The estimates were reviewed in 2008 and last updated in 2004.

4.28.3 Uncertainties and Time-Series Consistency

Estimates of emissions are based on very limited data and are therefore uncertain.

4.28.4 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 are given in **Annex 10**.

Trilateral F-gas Peer Review
A trilateral meeting of F-gas sector experts from the UK, Austria and Germany was held in Vienna, February 2011. Although not a formal review, each country reviewed the completeness, consistency and transparency of the parts of the NIRs reporting F-gases. Some of the improvements that could be made to the transparency and completeness of the UK NIR identified in that review have been incorporated in this NIR, and others will be considered for future implementation.

4.28.5 Source Specific Recalculations

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

4.28.6 Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

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

The method of calculation is an IPCC Tier 2 method.

A full description of the emissions and associated methodology used is contained in AEA (2004). UK estimates of emissions from this source were based on a European evaluation of emissions from this sector (Harnisch and Schwarz, 2003), subsequently disaggregated by GDP to provide a top-down UK estimate.

It has been very difficult to establish the exact size of the UK import market and, therefore, hard to generate an accurate estimate of emissions from the use of this product.

Harnisch and Schwarz (2003) estimated EU emissions from OCFs as follows:

- 1996: 4,000 kt CO_2 equivalent per annum (3100 tonnes of HFC 134a)
- 2000: 1,700 kt CO_2 equivalent per annum (1200 tonnes of HFC 134a; 1000 tonnes of HFC 152a)
- 2010: 2,320 kt CO_2 equivalent per annum (1636 tonnes of HFC 134a; 1364 tonnes of HFC 152a)

Emissions in tonnes of CO_2 equivalent have reduced between 1996 and 2000 due to the use of HFCs with lower GWP values, and the manufacture of cans containing less HFC. The emissions increase in 2010 due to greater use of this product within the EU market. The UK emissions for these three years have been calculated on the basis of GDP, at 19% of the EU total. In 2000, 23 million OCF cans that contained HFCs were sold in Germany while 7 million where sold to the rest of the EU market. An assumption has been made that Germany accounts for 77% of the total EU emission. Out of the remaining 23%, the UK accounts for 24%, based on a percentage of total EU GDP (excluding Germany). This is equivalent to 1.68 million cans.

The estimates of HFCs assume that the ban on F gas use in one component foams (banned from July 2008 under the F Gas regulations) has been successful, and this success has been confirmed with the UK Defra F-gas regulation team.

The estimates were reviewed in 2008 and last updated in 2008.

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 are given in **Annex 10**.

Trilateral F-gas Peer Review
A trilateral meeting of F-gas sector experts from the UK, Austria and Germany was held in Vienna, February 2011. Although not a formal review, each country reviewed the completeness, consistency and transparency of the parts of the NIRs reporting F-gases. Some of the improvements that could be made to the transparency and completeness of the UK NIR identified in that review have been incorporated in this NIR, and others will be considered for future implementation.

4.29.5 Source Specific Recalculations

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

4.29.6 Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

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

4.30.1 Source Category Description

This category, combining three sources (training shoes, semiconductors and electrical transmissions and distribution), has been created to preserve the confidentiality of estimates of emissions of SF_6 and PFCs used in training shoes. PFCs were used in the 1980s and briefly in the 2000s. SF_6 was used in the 1990s and the early years of the 2000s.

A sports goods manufacturer selling shoes in the UK used SF_6 as a cushioning material in a range of training shoes from 1990 to 2003. Prior to 1990, the manufacturer used perfluoroethane (a PFC) for cushioning. SF_6 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.

The manufacturer committed itself to eliminating SF_6 from its training shoes by 30 June 2003 – a goal which was achieved. It had originally planned to replace all SF_6 applications with nitrogen-filled cushioning but technical difficulties mean it had to switch temporarily to perfluoropropane (a PFC) in some high-performance applications. Discussions with he manufacturer have confirmed that they are no longer using PFCs or SF_6.

Cushioning units typically outlast the lifetime of the training shoe because the rate of diffusion of SF_6 is so slow. In the UK, training shoes are generally sent to landfill at the end of their useful lives, where any SF_6 or PFC will eventually leak to the atmosphere.

All emissions of F-gases from the UK Overseas Territories and Crown Dependencies are reported in this sector.

4.30.2 Methodological Issues

Estimates of emissions from sports-shoes were based on a bottom-up Tier 2 estimate, using activity data supplied in confidence by the manufacturer.

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).

Emissions of PFCs from training shoes are combined with emissions from semiconductor manufacturing in source category 2F8b for reasons of commercial confidentiality.

Emissions of SF_6 from training shoes are combined with emissions from semiconductor manufacturing and electrical insulation in source category 2F8b for reasons of commercial confidentiality.

The estimates were reviewed in 2008 and last updated in 2004.
Emissions estimates for the Crown Dependencies and Overseas Territories are calculated by scaling UK emission estimates based on suitable statistics such as GVA or population. This is described in **Annex 3**.

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 verification of emissions are given in **Annex 10**.

Trilateral F-gas Peer Review
A trilateral meeting of F-gas sector experts from the UK, Austria and Germany was held in Vienna, February 2011. Although not a formal review, each country reviewed the completeness, consistency and transparency of the parts of the NIRs reporting F-gases. Some of the improvements that could be made to the transparency and completeness of the UK NIR identified in that review have been incorporated in this NIR, and others will be considered for future implementation.

4.30.5 Source Specific Recalculations

There have some minor updates to the estimates of HFC use in the Overseas Territories as a result of updates to activity data supplied, slightly reducing emissions in 2008. Gibraltar updated its population estimates; the estimates of HFC emissions from refrigeration based on the population of the Cayman Islands were replaced with estimates of HFCs supplied directly by the Cayman Islands. These combined changes have led to an overall change in HFC emissions of 5.4 kt CO2 eq.

There have some minor updates to the estimates of PFC use in the Overseas Territories as a result of updates to activity data supplied. Gibraltar updated its population estimates; the estimates of PFC emissions from refrigeration based on the population of the Cayman Islands were replaced with estimates of PFCs supplied directly by the Cayman Islands. These combined changes have led to almost no net effect on emissions.

4.30.6 Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

5 Solvent and Other Product Use (CRF Sector 3)

5.1 OVERVIEW OF SECTOR

Solvents are used in a wide range of processes and products and the GHGI gives detailed estimates to reflect this diversity. Significant quantities of solvent are used both for industrial applications (mainly coatings and cleaning solvents), but also for non-industrial applications (mainly aerosols, decorative paints and consumer products). Emissions of CO_2 for this sector are currently not estimated.

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, 2010). Emission estimates for drum coatings, metal packaging and OEM coatings are estimated instead using a combination of consumption data and emission factors and estimates made on a plant by plant basis using information supplied by the Metal Packaging Manufacturers Association (MPMA, 2000) and the regulators of individual sites.

5.2.3 Uncertainties and Time- Series Consistency

This source does not affect the overall total or trend in UK emissions of direct greenhouse gases and is not included in the Approach 1 (error propagation) or Tier 2 uncertainty analysis.

The data used to estimate emissions from paint application are mostly provided by the British Coating Federation (BCF) and the data are thought to be consistent. Estimates for the drum coating, car coating, and metal packaging coating sectors are based on emissions data collected from regulators for the latter part of the time series with extrapolation to earlier years on the basis of BCF coating consumption data. This extrapolation is thought unlikely to introduce significant problems with the accuracy of estimates.

5.2.4 Source Specific QA/QC and Verification

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

5.2.5 Source Specific Recalculations

The inclusion of updated activity data and emission factors provided by the British Coating Federation has led to a decrease in estimated emissions of 13 Gg.

5.2.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

5.3 SOURCE CATEGORY 3B – DEGREASING & DRY CLEANING

5.3.1 Source Category Description

This sector covers the use, predominantly of chlorinated solvents, for cleaning and degreasing of surfaces, including degreasing of sheepskins and the use of tetrachloroethene for dry cleaning of clothes and textiles.

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.

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

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.

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, 2010), although this is not expected to introduce significant uncertainty into the estimates. Emission factors assume that all hydrocarbon and oxygenated solvent is emitted, while emission factors for chlorinated solvents are lower, reflecting the fact that some solvent is sent for disposal rather than emitted.

Emission estimates for dry cleaning are based on estimates of solvent consumption by the sector. Industry-sourced data are available for some years and estimates for the remaining years are based on a model of the sector, which takes account of changes in the UK population and the numbers of machines of different types and with different emission levels.

Emission estimates for leather degreasing are based on a single estimate of solvent use extrapolated to all years using the Index of Output for the leather industry, which is produced annually by the ONS.

5.3.3 Uncertainties and Time-Series Consistency

This source does not affect the overall total or trend in UK emissions of direct greenhouse gases and is not included in the Approach 1 (error propagation) or Tier 2 uncertainty analysis.

The time series for degreasing emissions uses a consistent methodology, although the activity data used are not of uniform quality for each year, some extrapolation of data being required. This extrapolation is not thought likely to introduce significant problems with the accuracy of estimates. Although perhaps more uncertain than estimates for 3A and 3C, the estimates for source category are still expected to be good.

5.3.4 Source Specific QA/QC and Verification

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

5.3.5 Source Specific Recalculations

No significant recalculations were necessary for this sector.

5.3.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

5.4 SOURCE CATEGORY 3C – CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING

5.4.1 Source Category Description

This sector includes the manufacture of coatings, the coating of films, leather, paper and textiles, and the use of solvents in the manufacture of tyres and other rubber products.

Coating manufacture includes the manufacture of paints, inks, and adhesives, plus specialist coatings for films, leather, paper and textiles.

Film coating includes the manufacture of photographic film, data storage films, hot stamping films and other specialist products. Processes manufacturing hot stamping films can use particularly 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 can include the application of waterproof or fire-proof coatings to textiles and coating of textiles with rubber.

Solvents are used in the manufacture of tyres and other rubber products such as hose, belting and sports goods. The solvent is used for cleaning and also to increase the tackiness of the rubber during joining operations.

5.4.2 Methodological Issues

Emission estimates for coating of film, leather, and textiles as well as estimates for tyre manufacture are based on plant-by-plant emission estimates, made on the basis of information available from regulators.

Emissions from coating manufacture are calculated from the solvent contained in coatings produced in the UK, by assuming that an additional 2.5% of solvent was lost during manufacture.
Emissions from the manufacture of rubber goods other than tyres are based on solvent consumption estimates provided by the British Rubber Manufacturers Association (BRMA, 2001), which are extrapolated to other years on the basis of the Index of Output figures for the rubber industry which are published each year by the ONS.

5.4.3 Uncertainties and Time Series Consistency

This source does not affect the overall total or trend in UK emissions of direct greenhouse gases and is not included in the Approach 1 (error propagation) or Tier 2 uncertainty analysis.

Estimates for sources covered by source category 3C are estimating using a consistent methodology with relatively little extrapolation of data. As with the estimates for source categories 3A and 3B, extrapolation of data is not thought likely to introduce significant problems with the accuracy of estimates.

5.4.4 Source Specific QA/QC and Verification

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

5.4.5 Source-specific recalculations

No significant recalculations were necessary for this sector.

5.4.6 Source Specific Planned Improvements

Emission factors and activity data for the category will be kept under review.

5.5 SOURCE CATEGORY 3D - OTHER

5.5.1 Source Category Description

This category covers a diverse group of sources including paper coating, printing processes, adhesives use, seed oil extraction, wood impregnation, agrochemicals use, aerosols, consumer products and miscellaneous solvent use.

Paper coating processes include solvent used in the manufacture of wallpapers, together with coating of other specialist paper products such as vehicle air filters or colour cards.

Printing processes differ in their requirement for solvent-borne inks and chemicals. Most solvent use occurs from the printing of flexible packaging using flexography and rotogravure printing with solvent-borne inks. Publication gravure printing for magazines and catalogues etc. also uses high solvent inks. Heatset web offset printing, coldset web offset, and sheetfed offset, used for printing magazines, newspapers and other publications, employ paste inks that contain high boiling point hydrocarbons which are driven off and burnt in the case of heatset web offset or absorb into the printed substrate in the case of the other two processes. Offset presses may use solvents in the 'damping solutions', which are used to ensure accurate reproduction of the image. Letterpress printing also uses paste inks that dry by adsorption and is little used now. Paper & board packaging are printed using flexography, rotogravure and offset although, unlike flexible packaging, the flexographic and gravure inks used are generally waterborne. Screen printing, used for high quality colour printing such as art reproduction, textile printing and point of sale printing can use either water or solvent-based inks.

Other, specialist printing processes include printing of roll labels and printing of securities both of which use a variety of printing techniques including offset, letterpress, copperplate (a form of gravure printing with paste inks), flexography, and screen printing. Solvent-borne varnishes may be applied over some printed materials.

Adhesives are used by many industries, although solvent-borne adhesives are becoming increasingly confined to a small number of industry sectors. Construction and pressure-sensitive tapes and labels are the largest users of solvent-borne adhesives. Other sectors include footwear, abrasives, and some furniture manufacture.

Seed oil extraction involves the use of hexane to extract vegetable oil from rape and other seed oils. The solvent is recovered and reused in the process.

Solvents are used in some wood preservatives, although consumption has fallen markedly in the last ten years. Emissions from use of creosote, which does not contain solvent, are also reported under 3D.

Agrochemicals can be supplied in many forms including solid or solutions and some are dissolved in organic solvents, which are emitted when the agrochemical is applied.

Aerosols use organic chemicals both as propellants and as solvents. All use of volatile organic materials in aerosols is reported under CRF source category 3D. Non-aerosol consumer products which contain or can contain significant levels of solvents include fragrances, nail varnish and nail varnish remover, hair styling products, slow release air fresheners, polishes, degreasers, screen wash, and de-icers.

Miscellaneous solvent use includes solvent usage not covered elsewhere and, current, little information is available on the types of uses included. However, it will include applications such as pharmaceutical processes, acetylene storage, flavour extraction, foam blowing, production of asbestos-based products, oil-field chemicals and foundry chemicals.

Nitrous oxide emissions from anaesthesia use are reported as NE since the data are not available and emissions are believed to be small.

5.5.2 Methodological issues

Emission estimates are based on one of three approaches:

1. Estimates are made based on activity data and emission factors supplied by industry sources (printing processes, consumer products, wood preservation)
2. Estimates are made for each process in a sector based on information provided by regulators or process operators (seed oil extraction, pressure sensitive tapes, paper coating)
3. Estimates are based on estimates of solvent consumption supplied by industry sources (adhesives, aerosols, agrochemicals, miscellaneous solvent use).

5.5.3 Uncertainties and time-series consistency

This source does not affect the overall total or trend in UK emissions of direct greenhouse gases and is not included in the Approach 1 (error propagation) or Tier 2 uncertainty analysis.

Estimates for sources covered by source category 3D are estimating using a consistent methodology with relatively little extrapolation of data. Some extrapolation of activity data is required for some sources included in source category 3D as this will limit the accuracy of emission estimates for these sources e.g. industrial adhesives, other solvent use. Other sources included in 3D, including emission estimates for printing and paper coating are likely to be comparable in quality to the estimates for paint application or chemical products (source categories 3A and 3C). Overall, however, the estimate for source category 3D is likely to be more uncertain than those for 3A, 3B and 3C.

5.5.4 Source-specific QA/QC and verification

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

5.5.5 Source-specific recalculations

The inclusion of updated activity data and emission factors for printing processes, provided by the British Coating Federation, has led to an increase in estimated emissions of 2 Gg.

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, 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 currently used to estimate emissions in this sector.

Defra, with contributions from the Devolved Administrations, have funded a large research programme over the next 5 years (delivery in June 2015) aimed at significantly improving the UK GHG inventory methodology for the Agriculture sector. This will include development of Tier 2 methodology (and in some cases assessment of Tier 3) for all key emission sources, conducting new measurements to provide data for development of country-specific emission factors, and identifying (or scoping surveys for) sources of essential agricultural activity, soils and climate input data at an appropriate resolution.

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 (see in http://www.defra.gov.uk/evidence/statistics/foodfarm/landuselivestock/junesurvey/index.htm). 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’. In the current inventory the dairy cattle weights are derived from slaughter weight data, provided by Defra; see **Table A3.6.3** in **Annex 3** for further details and for description of the method used to estimate live weight from slaughter weights.

A Tier 2 methodology is used for the calculation of the enteric emissions from beef cattle, but a time series of cattle weights are not available, and so a constant weight of 500 kg has been assumed. A country specific emission factor is used, assuming a weight of 500 kg.

A Tier 2 methodology is used for the calculation of the emissions from other cattle but weight is not changed from year to year.

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 cannot 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 recalculations

No recalculations were carried out in this sector.

6.2.6 Source-specific planned improvements

Emission factors and activity data will be kept under review. The Tier 2 structure will be incorporated for all key animal categories (cattle and sheep) and calculations included when activity data are available.

6.3 SOURCE CATEGORY 4B – MANURE MANAGEMENT

6.3.1 Source category description

This category reports emissions of CH_4 from animal manures as well as N_2O 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, 2010a) in the same way as the enteric emissions.

In the current inventory the dairy cattle weights are derived from slaughter weight data; see Table A3.6.3 in Annex 3 for further details.

Apart from cattle, lambs and deer, emission factors 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 emissions for beef and other cattle are 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 methodology assumes that 20% of the total manure N applied to soil volatilises as NO_x and NH_3 and therefore does not contribute to N_2O emissions from AWMS application to soil. 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.

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** provides estimates of uncertainty according to IPCC source category.

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

6.3.4 Source-specific QA/QC and verification

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

6.3.5 Source-specific recalculations

No recalculations were carried out in this sector.

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. The Tier 2 structure will be incorporated when activity data are available.

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:

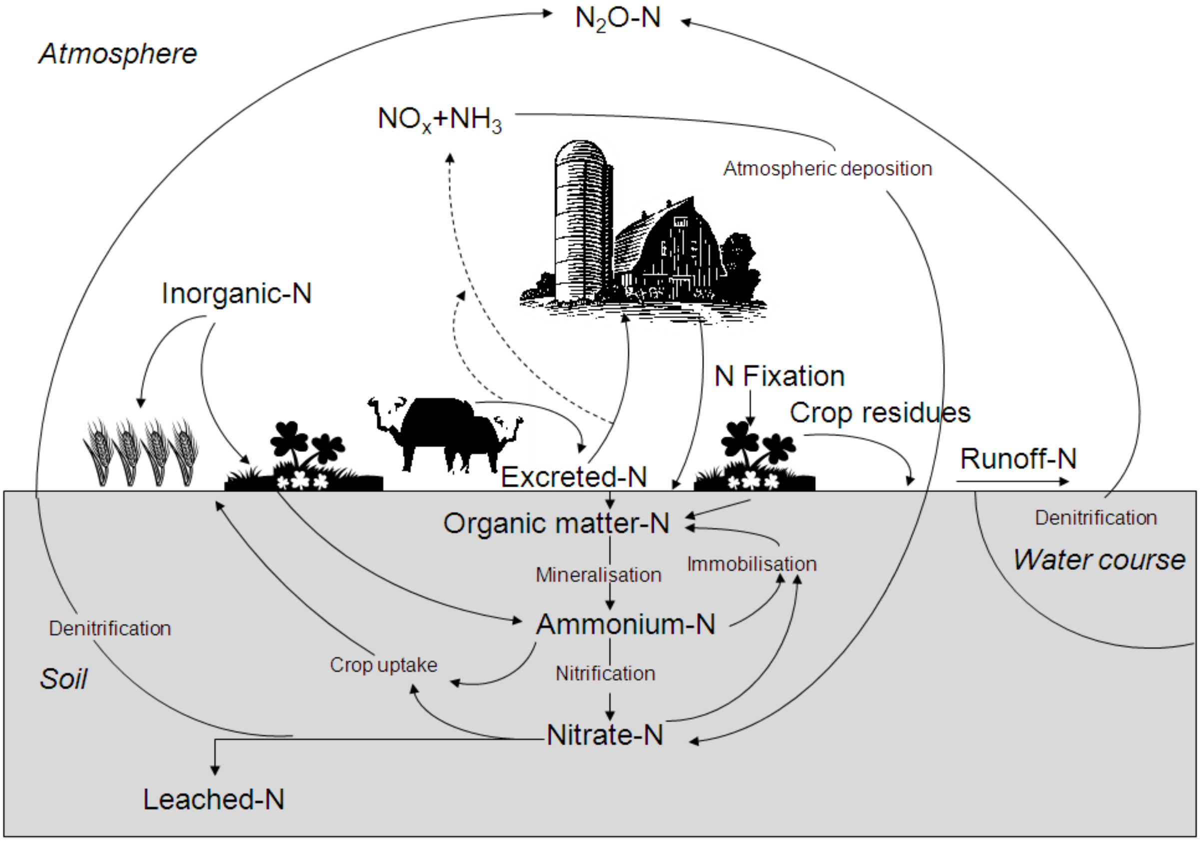
(i) The use of inorganic fertilizer
(ii) Biological fixation of nitrogen by crops
(iii) Ploughing in crop residues
(iv) Cultivation of histosols (organic soils)
(v) Manures dropped by animals grazing in the field
(vi) Spreading animal manures on land
(vii) Application of sewage sludge to land
(viii) Emissions from improved grassland

In addition to these, the following indirect emission sources are estimated:

(ix) Emission of N_2O from atmospheric deposition of agricultural NO_x and NH_3
(x) 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.**



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, 2010a) and fertilizer application rates (BSFP, 2009). Crop areas are from Defra (see in http://www.defra.gov.uk/evidence/statistics/foodfarm/landuselivestock/junesurvey/index.htm).

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 (2010a, 2010b).

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 (2010a, 2010b). 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). Dry matter content of crops data from Burton (1982), Nix (1997), PGRE (1998), BLRA (1998).

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 which varies according to animal category but is generally much larger than the IPCC recommended value (0.23), based on country specific data (**Section A3.6.2.1 Table A 3.6.6**).

6.5.2.6 Organic Fertilizers

Following the IPCC guidance emissions from animal manures and slurries used as organic fertilizers are reported under agricultural soils. 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.

The UK follows the IPCC (1997) methodology. This assumes that 20% of the total manure N applied to soil volatilises as NO_x and NH_3 and therefore does not contribute to N_2O emissions from AWMS.

6.5.2.7 Application of sewage sludge to land

Following the IPCC guidance emissions from sewage sludge used as fertilizer are reported under agricultural soils. The calculation involves estimating the amount of nitrogen contained per dry matter unit of sludge and applying IPCC emission factors. Data sources for the annual production of sewage sludge (as dry matter) were obtained from Brian Chambers (pers. comm. ADAS, 2010) for 1996; from Directive 86/278 for 2004-2006 on the basis of the data contained in the records referred to in Article 10; Sludge used in agriculture (Tonnes dry matter/year); from OFWAT, the Water Commissioner for Scotland and the Northern Ireland regulator, UREGNI for 2008-2009. The amounts for the missing years were derived by interpolation/extrapolation of the available data.

The UK follows the IPCC (1997) methodology. This assumes that 20% of the total sludge N applied to soil volatilises as NO_x and NH_3 and therefore does not contribute to N_2O emissions.

6.5.2.8 Emissions from improved grassland

The total nitrous oxide emission reported also includes a contribution from nitrogen fixation on improved grassland. For this source the calculation of the emission requires estimating the amount of N that is fixed and then the IPCC emission factor is applied to this value. The amount of nitrogen fixed is derived using a fixation rate of 4 kg N/ha/year (Lord, 1997).

6.5.2.9 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 NH_3 and NO_x considered are synthetic fertiliser application, animal manures applied as fertiliser and sewage sludge applied to soils.

The method used corrects for the N content of manures used as fuel.

6.5.2.10 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 and sewage sludge applied to soils.

6.5.3 Uncertainties and time-series consistency

The Tier 1 uncertainty analysis in **Annex 7**, provides estimates of uncertainty according to IPCC source category.

Emissions are calculated from a range of activity data and appropriate emission factors (see **A3.6.3**). Emissions of N_2O from the use of fertilizers are important in this source category. The annual consumption of synthetic fertilizer is estimated based on crop areas (crop area data reported annually by Defra) and fertilizer application rates (reported annually in another Defra publication, the British Survey of Fertiliser Practice). These are both long running datasets and the compilers of the activity data strive to use consistent methods to produce the activity data. The time-series consistency of these activity data is very good due to the continuity in data provided.

6.5.4 Source-specific QA/QC and verification

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

6.5.5 Source-specific recalculations

N excretion factors are kept in agreement with the UK NH_3 inventory (Cottrill and Smith, ADAS, 2002).

6.5.6 Source-specific planned improvements

Emission factors and activity data will be kept under review. UK emission factors are currently under review for:

- EF1, emission factor for direct soil emissions; from a literature review and a field measurement programme.
- EF3, emission factor from manure management systems); from a literature review and a field measurement programme and,
- EF5, nitrogen leaching/runoff factor; from a field measurement programme

The UK is improving the link between the NH_3 and GHG inventories, and incorporating NO_x in a study (desk/experimental) which will review the current value of 20% of N lost as NH_3 and NO_x.

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, 2010a) 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 recalculations

There have been no recalculations.

6.7.6 Source-specific planned improvements

Emission factors and activity data will be kept under review.

6.8 SOURCE CATEGORY 4G - OTHER

There are no emissions reported in the UK under this category.

6.9 GENERAL COMMENTS ON QA/QC

The livestock activity data used for constructing the inventory are supplied annually from the June census by the Defra Economics and Statistics Group, who follow documented QA procedures. Activity data on mineral fertiliser are calculated using application rates from Defra's annual British Survey of Fertiliser Practice (BSFP, 2010) 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 (ww2.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, Rothamsted Research, North Wyke, 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.

The animal number activity data used to be sourced separately from each of the four Devolved Administrations. These data are now provided by the Centre for Ecology and Hydrology (U. Dragotsis) for England, Scotland and Northern Ireland but not Wales. The welsh data are obtained from the Welsh agriculture statistics[11], as they compile animal number data at a finer spatial resolution. These animal number data are also used to generate the NH_3 inventory.

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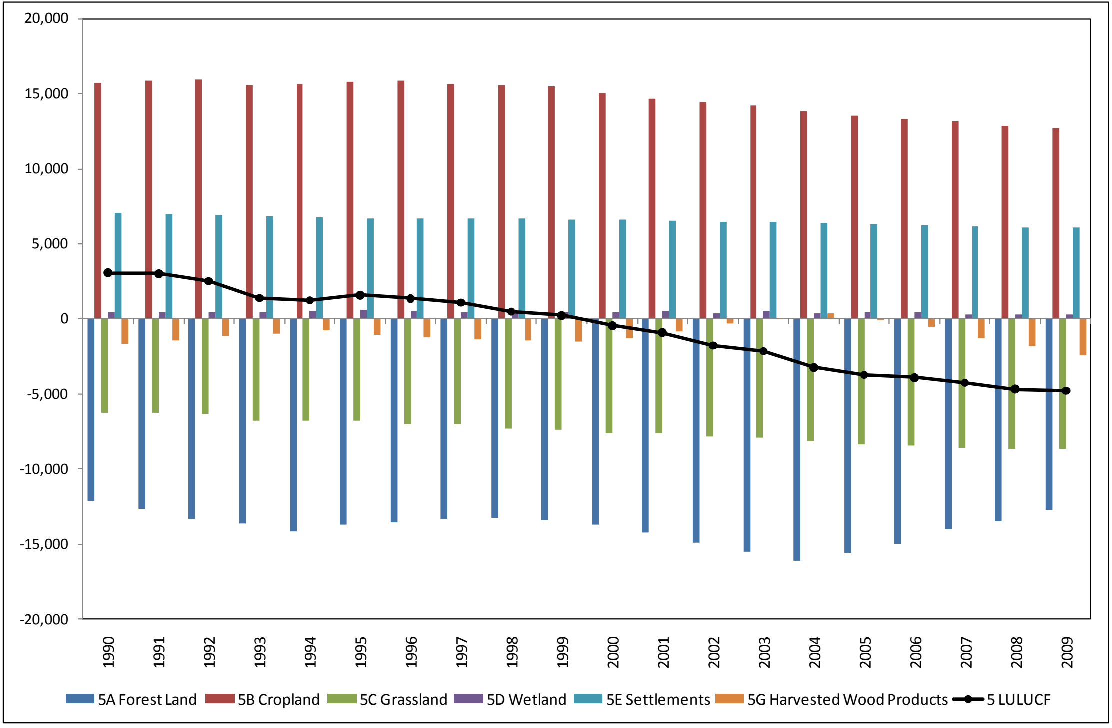
[11] http://wales.gov.uk/topics/statistics/publications/was2008/?lang=en

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

7.1 OVERVIEW OF SECTOR

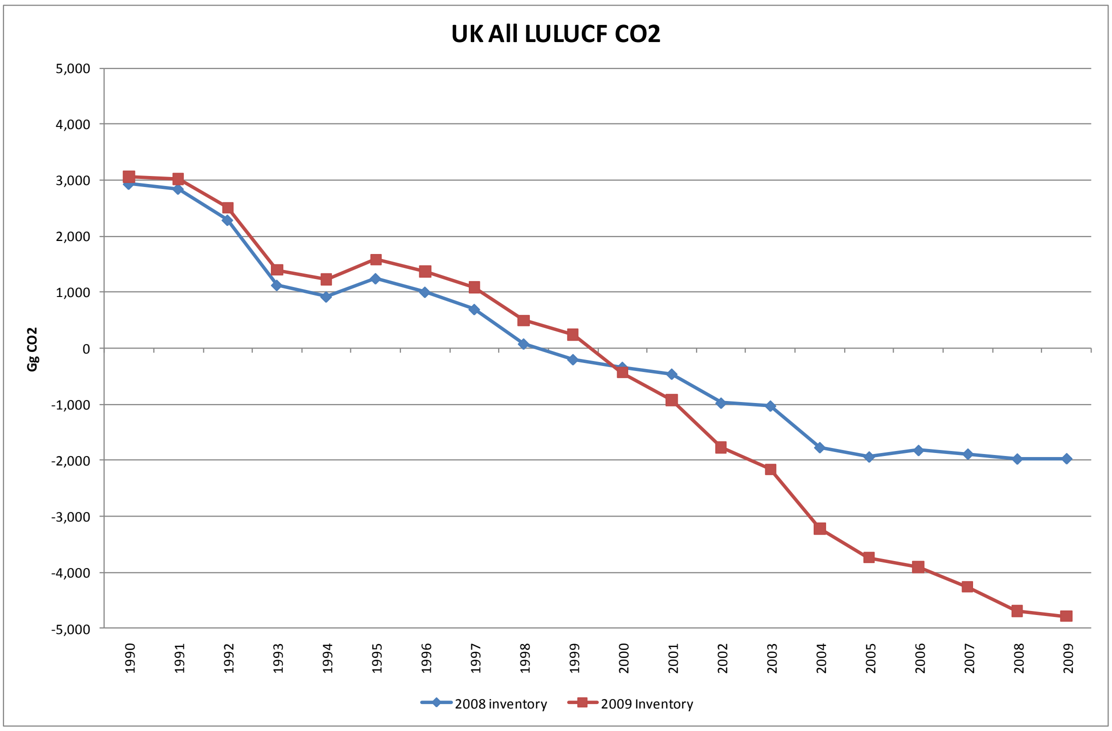
CRF Sector 5 includes carbon stock changes, emissions of greenhouse gases (CO_2, CH_4 and N_2O) by sources and removals of CO_2 by sinks from land use, land use change and forestry activities. Emissions from agriculture are included in CRF Sector 4 Agriculture. Removals of carbon dioxide are conventionally presented as negative quantities. The sector has been a net sink since 2000, with a net removal in 2009 of -4.79 Mt CO_2 equivalent (**Figure 7.1**), or -4.16 Mt CO_2 equivalent when the Overseas Territories and Crown Dependencies (OTs/CDs) are included.

Figure 7.1 LULUCF emissions and removals from the UK 1990-2009



Net emissions in the UK in 1990 are estimated to be 3057 Gg CO_2 (an increase from 2929 Gg CO_2 in the 2008 National Inventory Report). They are 3016 Gg CO_2 with the OTs/CDs included. For 2008 a net removal of -4691 Gg CO_2 is estimated here compared to a net removal of -1886 Gg CO_2 in the 2008 Inventory (**Figure 7.2**). These differences are due to the inclusion of new activity data for land use change between 2000 and 2007, the reporting of on-site emissions for the 5D Wetlands category and other minor revisions to methods, activity data and emission factors.

Figure 7.2 **Changes in net emissions/removals 1990-2009 between the 2008 and 2009 inventories in the UK**



There have been updates to both methods and activity data for this Sector and internal restructuring of the 5A Forest Land category. These are described in this chapter and **Annex 3.7** on methods used to estimate emissions. Activities under Article 3.3 and Article 3.4 of the Kyoto Protocol are reported in **Chapter 11**. Each section of this chapter will discuss carbon stock changes and then GHG emissions. Planned improvements to the inventory are described in the relevant category. Additional information on LULUCF and KP-LULUCF inventory reporting has been made available at http://ecosystemghg.ceh.ac.uk/.

Greenhouse gas emissions and removals from the UK Crown Dependencies (CDs) and Overseas Territories (OTs) are now reported under the relevant categories of CRF Sector 5 rather than in 5.G (Other). The availability of data for the different OTs and CDs is very variable, so that emission estimates can only be made for the Crown Dependencies of Jersey, Guernsey and the Isle of Man and the Overseas Territory of the Falkland Islands. These four comprise over 95% of the area in all the OTs and CDs. Gibraltar wished to produce its own inventory: in this case LULUCF net emissions/removals are likely to be extremely small, given the size of the country (6km^2), and will have little impact on overall numbers. A lack of suitable data for the Caribbean territories (discussed in the 1990-2006 NIR) makes it impossible to create inventories for them at the present time.

Information on the area of each IPCC land category, dominant management practices, land use change, soil types and climate types were compiled for each OT/CD from statistics and personal communications from their government departments and global land/soil cover databases. This allowed Tier 1 level inventories to be constructed for the four OT/CDs, and a Tier 3 approach for Forest Land on the Isle of Man (using the C-Flow model also used for the UK). The estimates have high uncertainty.

7.1.1 The land use transition matrix

Reporting in CRF Sector 5 is based on broad land categories: Forest Land, Cropland, Grassland, Wetlands, Settlements and Other Land. According to the IPCC Good Practice Guidance for LULUCF, all land areas within a country should be assigned to one of these categories. UK definitions for the land use categories are given in the individual category sections in this chapter.

Areas of land use and land use change are compiled from various sources. Areas of forest land come from statistics published by the Forestry Commission. Areas of Cropland, Grassland and Settlements in 1990, 1998 and 2007 come from the Broad Habitat areas reported for each country (England, Scotland, Wales and Northern Ireland) in the Countryside Surveys (Countryside Survey 2009; Norton *et al*. 2009; Smart *et al*. 2009; Cooper *et al*. 2009). The area reported in the Wetlands category is the area undergoing active commercial peat extraction (see section 7.5 for further information). Other Land includes land not identified within the other categories. Areas of land use change to Forest (afforestation) come from planting data provided by the Forestry Commission, areas of land use change from Forest (deforestation) come from Forestry Commission data and the Department for Communities and Local Government. Other land use change data comes from the changes between the three Countryside Surveys (1990, 1998 and 2007), rolled forward to 2009.

The annual land use transition matrices for 1990-1991 and 2008-2009 for the UK are shown in **Table 7.1** and **Table 7.2**. The Standard Area Measurement to mean high water is used for the total area of the UK (24,415 kha) (Office for National Statistics 2009). The full set of annual matrices for the UK and its individual countries are available at the LULUCF inventory website (http://ecosystemghg.ceh.ac.uk/.). 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 land use change fluxes in the LULUCF inventory. The diagonal items (land remaining in the same use, in italics) have an uncertainty attached as there is not a perfect match between the sum across the columns and the sum across the rows. Work is planned for the summer of 2011 to ascertain the uncertainties associated with all components of the land use change area matrix.

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

From: To:	**Forest**	**Cropland**	**Grass-land**	**Wet-lands**	**Settlements**	**Other Land**	**Total (final)**
Forest	*2,595.6 ±3.0*	4.2	23.9	0.0	2.4	0.2	**2,629.3**
Cropland	0.7	*4996.1 ±0.1*	95.9	0.0	0.9	0.0	**5,093.6**
Grassland	15.5	83.4	*13,269.7 ±1.8*	0.0	4.7	3.4	**13,378.4**
Wetlands	0.0	0.0	0.0	*12.6*	0.0	0.0	**12.6**
Settlements	1.7	2.5	13.5	0.0	*1,790.8 ±3.7*	0.2	**1,805.1**
Other Land	0.5	0.4	2.5	0.1	0.8	*1492.7 ±1.0*	**1,496.0**
Total (initial)	**2,611.0**	**5,086.7**	**13,403.8**	**12.7**	**1,803.4**	**1,497.4**	**24,415.0**

Table 7.2 Land use transition matrix, kha, for the UK in 2008-2009

From: To:	**Forest**	**Cropland**	**Grass-land**	**Wet-lands**	**Settle-ments**	**Other Land**	**Total (final)**
Forest	*2823.7 ±0.6*	2.4	13.3	0.0	1.9	0.3	**2,841.0**
Cropland	0.1	*4510.9 ±1.8*	52.1	0.0	0.1	0.0	**4,565.1**
Grassland	14.0	99.0	*13600.6 ±6.3*	0.0	7.7	3.0	**13,730.6**
Wetlands	0.0	0.0	0.0	*7.4*	0.0	0.0	7.4
Settlements	1.0	5.3	10.2	0.0	*1880.1 ±1.0*	1.0	**1,898.5**
Other Land	1.5	1.7	9.4	0.1	0.2	*1368.0 ±8.4*	**1,372.4**
Total (initial)	**2,841.0**	**4,617.5**	**13,679.3**	**7.5**	**1,889.1**	**1,380.7**	**24,415.0**

The areas of land in the different land use categories in the Overseas Territories and Crown Dependencies are shown in **Table 7.3**. There is insufficient data to construct full land use change matrices.

Table 7.3 Land areas with reported GHG emissions in the Overseas Territories and Crown Dependencies, kha

Sub-category	**1990**	**1995**	**2000**	**2005**	**2009**
5A1 Forest remaining forest	1.33	1.99	2.66	3.06	3.38
5A2 land converted to Forest	2.13	1.46	0.80	0.40	0.08
5B1 Cropland remaining Cropland	3.34	3.34	2.87	4.47	4.47
5B2 Land converted to Cropland	0	0.17	0.97	2.75	3.58
5C2 Land converted to Grassland	0.11	2.62	4.73	6.66	8.62

Total land areas: Isle of Man = 56.51 kha, Guernsey = 6.34 kha, Jersey = 12.72 kha, Falkland Islands = 1217.30 kha.

7.2 CATEGORY 5A – FOREST LAND

7.2.1 Description

This category is divided into Category 5.A.1 Forest remaining Forest Land and Category 5.A.2 Land converted to Forest Land. Reporting of carbon stock changes is disaggregated between the four geographical areas of England, Scotland, Wales and Northern Ireland. This category has been restructured to use a 20-year transition period for land use conversion to Forest in the latest inventory. In previous inventories, all land afforested since 1921 was included under 5.A.2 as soil carbon fluxes due to conversion take many decades to reach equilibrium. These fluxes from historical conversion are still reported under the Forest remaining Forest category, so there has been no change in reported emissions/removals in the 5A category overall.

Forest Land is the biggest land use sink in the UK and includes carbon stock gains and losses and GHG emissions from forest management. All UK forests are classified as temperate and about 68% of these have been planted since 1921 on land that had not been forested for many decades.

The UK reports carbon stock changes in all forests planted since 1921 (when the first national survey of forests was undertaken). Forest surveys have been intermittent in the UK and there is not a network of permanent sample plots as exists in other European countries. As a consequence, estimates of carbon stock gains and losses for biomass and soils are modelled based on planting history and yield classes. The area of forest established before 1921 is reported in 5.A.1 – these areas are assumed to be in long-term carbon balance so have no associated carbon stock changes. Work is in progress to re-examine this assumption. The forest area and carbon stock changes in 5.A.1 are adjusted to take account of losses of forest land converted to other categories. Land use change from Cropland, Grassland and Settlements are considered and mineral and organic soils are reported separately.

In the UK nitrogen fertilizers are only applied to forest when it is absolutely necessary. This would occur during the first rotation on ‘poor’ soils, such as reclaimed slag heaps, impoverished brown field sites and upland organic soils. In terms of the inventory, this means that N fertilization is assumed for areas of Settlements converted to Forest Land and Grassland converted to Forest Land on organic soils. N_2O emissions from this fertilization are reported under 5.A.2 in Table 5(I).Nitrogen fertilizers are not generally applied to native woodlands, mature forests or re-planted forests in the UK, so emissions of N_2O from N fertilization of forests (Table 5(I)) for 5.A.1 are reported as Not Occurring.

Reporting of non-CO_2 emissions from forest drainage (Table 5(II)) is not mandatory under the IPCC Good Practice Guidance for LULUCF, and there is currently no activity data for this activity, which is reported as Not Estimated. Work is planned in this area (**Section 7.2.8**)

Controlled burning of forest land (for example for habitat management) does not take place in the UK. Wildfires do occur but the activity data is not sufficient to split between 5.A.1 and 5.A.2. Therefore emissions of greenhouse gases from wildfires are all reported under 5.A.1 in Table 5(V). It is assumed that land use change does not occur following wildfire.

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 and soils under “Net CO_2 emissions/removals”.

7.2.2 Information on approaches used for representing land areas and on land use databases used for the inventory preparation

The UK uses Approach 2 (IPCC 2006) for the representation of land use areas in the inventory, and compiles several different data sources into a non-spatially-explicit land use conversion matrix. The data sources are available at the individual country level (England, Scotland, Wales and Northern Ireland).

The agencies responsible for forests in the UK are the Forestry Commission (England, Scotland and Wales) and the Forest Service (Northern Ireland). The areas of forest planted annually are published in Forest Statistics (described below) and the Forestry Commission also provides a more detailed breakdown of the published numbers. The allocation of land use change from other land use categories is based on the proportional changes in the land use change matrices from the Countryside Survey (although we do not use the areas for conversion to forest from these matrices). This allocation has been updated to incorporate the latest information from the 2007 Countryside Survey.

Forestry Statistics is published each September by the Forestry Commission at http://www.forestry.gov.uk/statistics. It includes national statistics on new planting and restocking, based on operational data for the Forestry Commission/Forest Service estates, grant scheme data and estimates of planting without grant aid. There are annual statistics on woodland area in each country, using operational data for the FC/FS estates, with non-FC woodland based on the 1995-99 National Inventory, adjusted for new planting and sales of FC woodland; at present no adjustment is made for woodland converted to another land use. The sources and methodologies are described in more detail in the Sources section of the publication.

The National Inventory of Woodland and Trees (NIWT) 1995-99 http://www.forestry.gov.uk/inventory provided woodland statistics for Great Britain, countries (England, Wales and Scotland) and regions/counties. The Main Woodland Survey for woods over 2 hectares determined total woodland area using a digital woodland map, and collected field survey data for a sample of around 1% of area using one-hectare sample squares; it was supplemented by a Survey of Small Woodland & Trees. No similar woodland inventory exists for Northern Ireland.

The new National Forest Inventory (NFI) for Great Britain comprises a digital woodland map based on comprehensive aerial photography, a field survey using one-hectare sample squares and a survey of small woods and trees. The digital map and main woods survey now cover all woodland areas down to half a hectare, while the core field survey sample has been reduced to around 0.5% of area. An initial digital woodland map is due to be published in spring 2011. The field survey started in 2009 and should be completed in 2014. Interim results will be used for the softwood production forecast in 2011.

7.2.3 Land-use definitions and the classification system used and their correspondence to the LULUCF categories

The definition of woodland in United Kingdom forestry statistics and used for the greenhouse gas inventory is land under stands of trees with a canopy cover of at least 20% (or having the potential to achieve this), including integral open space, and including felled areas that are awaiting restocking. There is no minimum size for a woodland. The 1995-99 National Inventory of Woodland and Trees mapped all areas down to 2.0 hectares, but information from the survey of small woods and trees was used to calculate areas down to 0.1 hectares, and this was used as the basis for the annual updates in Forestry Statistics. When the annual figures in Forestry Statistics move to using the new NFI, the statistics may switch to using 0.5 hectares as minimum area.

The international definition of forest, as used for the Global Forest Resources Assessment and for State of Europe's Forests, is based on 10% canopy cover, a minimum height at maturity of 5m and minimum area of 0.5 hectares. This is estimated to give similar areas to the current UK woodland statistics, as the UK woodland in areas of 0.1-0.5 hectares balances the unrecorded area with 10-20% canopy cover. If the UK woodland statistics change to 0.5 hectare threshold, it will become necessary to produce an explicit estimate of areas with 10-20% canopy cover, based on the new survey of small woods and trees.

For the Countryside Survey 2007 http://www.countrysidesurvey.org.uk/ field survey, woodland areas are required to have 25% canopy cover at the survey date. According to this definition, the CS woodland area should exclude areas that are awaiting restocking after harvest, and also areas of young trees possibly for 10 years or more after new planting and restocking. The reported definition differed in previous Countryside Surveys, and there is some doubt whether the latest time series is fully consistent. Following Countryside Survey 2000, there was a study comparing the Countryside Survey results (field survey and Land Cover map) with NIWT 1995-99 and other woodland area statistics. Although the total woodland area in NIWT was similar to the two CS sources, the analysis found that the spatial overlap with each was only around 70%. The report included various explanations for differences, but was not able to give a full reconciliation (Howard *et al*. 2003).

7.2.4 Methodological Issues

The carbon uptake by UK forests is calculated by a carbon accounting model, C-Flow, as the net change in the pools of carbon in standing trees, litter, soil and products from harvested material for conifer and broadleaf forests. The method can be described as Tier 3, as defined in the 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. Work is in progress to incorporate more detailed forest management into the inventory (see **Section 7.2.8**). 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 used can be found in **Annex 3.7** for biomass, dead organic matter and soil.

Other greenhouse gas emissions are estimated using Tier 1 or Tier 2 approaches, and are described in **Annex 3.7**.

The September 2010 UNFCCC expert review recommended that the UK use the IPCC 20-year transition period for reporting areas under 5.A.2 Land converted to Forest Land. The C-Flow model has been modified to produce results split using the rolling 20-year transition period (they were previously split at 1990). This restructuring has not affected the overall emissions from the 5A category.

In the 2007 ARR the review team asked the UK to provide evidence to support the assumption of carbon balance in forest established before 1921. Simulations of UK forest conditions using the C-Flow and Forest Research CARBINE carbon accounting models have shown that, in the longer term, carbon stocks neither increase nor decrease. Rather, stocks fluctuate around a long term average value (Dewar, 1990, 1991; Dewar and Cannell, 1992; Thompson and Matthews, 1989). Typically in the UK, the long-term average stock is approached in <100 years after the time of woodland creation. This outcome is observed whether woodlands are left to grow undisturbed to achieve ‘old growth’ conditions or managed for production (Forest Research, recent unpublished model results). The assumption that woodlands in existence before 1921 *collectively* do not exhibit significant long-term changes in biomass stock in reporting periods relevant to the current inventory is consistent with these long-standing results. Further work is being undertaken in this area (see **Section 7.2.8**)

7.2.5 Uncertainties and Time-Series Consistency

The Approach 1 (error propagation) uncertainty analysis in the Annexes provides estimates of uncertainty according to the GPG source category and gas. 5A Forest Land is estimated to have an uncertainty of 25% for net emissions in 1990 and 2009.

The planting statistics used as activity data mostly come from operational systems, for grants and FC planting, and have no measures of statistical uncertainty attached to them. The grant-aided planting is allocated by date of payment, so all the recorded planting should have taken place. The new National Forest Inventory (NFI) map due in spring 2011 should provide better information on the reliability of the planting statistics. This comparison is likely to be limited to woods over 2 hectares, to enable like-with-like comparisons with the previous NIWT map.

The wildfire activity data are estimated to have an uncertainty of 50% for 1990-2004 and 100% for 2005-2009, as these have been extrapolated. The IPCC default of 70% uncertainty is used for the emission factors.

In terms of time series consistency:

- For forest carbon stock changes and N fertilization of forests, time series consistency is good as activity data are obtained consistently from the same national forestry sources.
- For emissions from wildfires, data have been collated from several published sources but all originate from the state forestry agencies so there is good time series consistency for 1990-2004. Data have been extrapolated for 2005-2008.

7.2.6 Category-Specific QA/QC and Verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 7.9**. Information on forest planting and the area affected by wildfires is consistent with that reported to the FAO (2005).

As part of a separate research project, a comparison has been made of the predictions made by the CEH C-Flow model and Forest Research CARBINE model. The results demonstrated that the models produce consistent predictions when given the same input data and assumptions (e.g. about woodland management practices).

The first NFI output will be a new map, which has been delayed from June 2010 to spring 2011, which will be used to assess estimates of total woodland area. The woodland field survey will provide direct assessment of woodland growing stock including species composition, stand structure, tree age (distribution) productivity indices, numbers of trees, and diameter and height distribution. Standing biomass (and carbon) in trees will be derived from these assessments using GB-specific conversion factors and allometric equations. A complete 5-year cycle of ground survey should be completed in 2014, at which point direct verification of tree forest carbon stocks should be possible. The ground survey also includes more qualitative assessments of deadwood biomass which should be sufficient to enable checks on reported estimates. The possibility for the ground survey to also include some form of soil assessments is under consideration but, at the present time, this is not planned as part of the NFI scope. The full National Forest Inventory results are expected to be published in 2015.

Research undertaken as part of the inventory project (Levy and Clark 2009, Bellamy and Rivas-Casado 2009) on the impact of afforestation on soil carbon stocks has produced results that suggest net losses of soil carbon following afforestation rather than the net gains estimated using the inventory methodology (Hargreaves *et al*. 2003). These results are based on a limited number of experimental sites but bear further investigation. Meta-analyses of the impact of afforestation on soil carbon (Post and Kwon 2000; Guo and Gifford 2002) have found both positive and negative effects, with no clear conclusion. Further avenues which could be explored include analysing the CS soils data, where afforestation has taken place in the survey squares since 1984, and the on-going meta-analysis of afforestation chronosequences in the EU FP7 GHG-Europe project (Johann Heinrich von Thünen-Institut, Braunschweig).

7.2.7 Category-Specific Recalculations

There has been internal restructuring of this category so carbon stock changes are now reported under both 5.A.1 and 5.A.2. Therefore the time series of emissions has changed in both sub-categories but the overall emissions from category 5A have changed by less than 1% from the 2008 inventory. This change is due to the adjustment made to take account of losses of forest converted to other land uses.

Allocation of afforestation between different land uses was updated using the latest Countryside Survey data. Conversion of Other Land to Forest was included for the first time, and the area of Grassland converted to Forest was split between pasture grassland and semi-natural grassland.

As a result of the category restructuring, emissions from forest wildfires (5(V)) are now reported under 5.A.1 rather than 5.A.2. There is insufficient information to allow disaggregation between the categories and the majority of the forest area (where is assumed that the majority of the fires will occur) is reported under 5.A.1.

The emission factor used for nitrous oxide emissions from direct nitrogen fertilization of forest land has been updated to that recommended in the IPCC 2006 guidelines.

7.2.8 Category-Specific Planned Improvements

The area reported under 5.A.1 Forest remaining Forest is likely to be revised when the new National Forest Inventory becomes available. National forest statistics do not currently capture forest conversion to other land uses, so a separate adjustment is made to the forest areas and carbon stock changes reported in the inventory. The NFI map due in spring 2011 will establish a new baseline of the total forest area in the UK.

Forest Research has been carrying out an analysis of Forestry Commission GB National Forest Inventory (NFI) data, for a base year of 2005, as well as records maintained in the Forestry Commission Sub-compartment Database (SCDB), for a base year of 2009, to establish the detailed composition of woodlands in England, Scotland and Wales in terms of tree species, growth rates and types of management. The SCDB (which covers slightly less than half of the forest area in Britain) gives detailed, stand-by-stand information about species, growth rate and management prescription. This is being combined with NFI data on the species composition of private woodlands to obtain an overall on the status and management of woodlands in England, Scotland and Wales. Contact has also been made with experts in the Northern Ireland Forest Service with the aim of undertaking a similar exercise for Northern Ireland. At the same time, the Forest Research CARBINE forest carbon accounting model has been significantly upgraded to enable the representation of a much more complete range of tree species and growth rates, as well as many more examples of management prescriptions involving different rotation periods, no thinning, thinning and, where appropriate, management according to ‘continuous cover’ principles and even ‘no management’. New estimates based on this information and the supporting methodology should be available in the summer of 2011.

Forest Research has been seeking to determine a better understanding of the contribution to the carbon balance made by woodlands established before 1921. This has involved analysing the Forestry Commission NFI data for the base year of 2005 in combination with Forestry Commission reports on areas of new planting since 1920. This also involves complex modelling of changes in the age class structure of forest areas, based on species composition, growth rate and management of woodland areas, in particular rotation periods. The aim is to ‘factor out’ post-1920 woodlands from NFI data to obtain a picture of the age class structure, status and management of pre-1921 woodlands. An initial attempt to demonstrate proof of concept through development and application of an appropriate methodology to woodlands in Wales has been successful. The methodology is now being implemented in detail and applied to analysis of woodlands in England, Scotland and Wales. Contact has also been made with experts in the Northern Ireland Forest Service with the aim of undertaking a similar exercise for Northern Ireland. New estimates based on this analysis should be available in summer 2011.

As described earlier, Forest Research is undertaking a major analysis of woodland areas in terms of species composition, growth rates, age class structure and management, with the aim of producing results by summer 2011. These results will only be disaggregated to the level of each country (England, Scotland, Wales and Northern Ireland). At this point it will be appropriate to review the methodology and assess any impacts on reported and projected emissions and removals due to forestry. The possibility of further disaggregation (i.e. to the scale of 20 km squares) can then be explored in subsequent work.

Forest Research has been analysing the spatial distribution of afforestation of soils, and the likelihood of associated drainage and fertilisation, with an initial focus on Scotland. The Scottish Soil Map Classification and the Forestry Commission National Forest Inventory (NFI) map for 2001 have been compared for this purpose, enabling woodland areas to be categorised according to coniferous, broadleaf or mixed species composition and association with deep or shallow peat soils and other major soil types (e.g. brown earths, surface water gleys etc.). Extant and historical Forestry Commission guidance on site establishment practices will be a strong indicator of drainage and fertilisation activities for the woodlands on different soil types. The impacts of woodland establishment (on different soil types) on fluxes of CO_2 and non-CO_2 greenhouse gases are also being assessed as part of this study. The results of the analysis for Scotland should be available by Spring 2011. Work is about to start on a similar analysis for woodlands in Wales with the aim of completing an analysis for England, Scotland and Wales by Autumn 2011. Consideration is being given to extending this study to Northern Ireland.

Improved representation of the fate of forest carbon following harvesting is being achieved by taking more detailed account of woodland composition and management, in particular patterns of thinning and clear felling (on appropriate rotations) as part of the analysis being carried out by Forest Research as described earlier.

7.3 CATEGORY 5B – CROPLAND

7.3.1 Description

The category is disaggregated into 5.B.1 Cropland remaining Cropland and 5.B.2 Land converted to Cropland. Reporting of carbon stock changes is disaggregated between the four geographical areas of England, Scotland, Wales and Northern Ireland. Reporting in category 5.B.2 is currently split between two time periods, pre- and post-1990. This category will be restructured in the next inventory submission to use the 20-year transition period for land use conversion before reporting in the Cropland remaining Cropland sub-category.

Two activities resulted in carbon stock changes are reported under 5B1:

- Non-forest biomass from yield improvements: 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).

- Fenland drainage (England only). Fenland areas of England were drained many decades ago for agriculture (although there was no land use change). The soils in these areas are still emitting CO_2, i.e. there is an ongoing change in soil carbon stock.

Carbon stock changes and biomass burning emissions due to conversion of Forest Land to Cropland are reported for all of the UK from 1990 onwards (emissions occur in the same year as the land use conversion). Carbon stock changes in non-forest biomass and soil due to land use change to Cropland are reported under 5B2. All forms of land use change, including deforestation, are considered and both mineral and organic soils are included.

Nitrous oxide emissions from disturbance associated with land-use conversion to cropland (Table 5(III)) are reported for the first time in this inventory.

Emissions of carbon dioxide from the application of limestone, chalk and dolomite to cropland are reported in Table 5(IV). The amount of agricultural lime applied relates to all areas of Cropland, therefore it will include areas in 5B1 and 5B2.

The emissions from biomass burning arising from forest land conversion to cropland are reported in Table 5(V). Burning of agricultural residues (cereal straw or stubble) is not permitted in England and Wales and strongly discouraged in Scotland and Northern Ireland (NetRegs 2010). Therefore, emissions of non-CO_2 gases from non-forest biomass burning of cropland are not currently reported. There is no activity data for wildfires on non-forest land in the UK.

7.3.2 Information on approaches used for representing land areas and on land use databases used for the inventory preparation

The UK uses Approach 2 (IPCC 2006) for the representation of land use areas in the inventory, and compiles several different data sources into a non-spatially-explicit land use conversion matrix. The data sources are available at the individual country level (England, Scotland, Wales and Northern Ireland).

Data sources that contain area information for reporting carbon stock changes and/or emissions from Cropland are habitat/landscape surveys, published statistics on agricultural lime and an assessment of fenland drainage in England.

Decadal matrices of land use change from 1950 have been developed from the Monitoring Landscape Change project dataset (using a sample survey of aerial photographs in 1947 and 1980) (MLC 1986) and the ITE/CEH Countryside Surveys of 1984, 1990, 1998 and 2007 (Barr *et al*. 1993; Haines-Young *et al*. 2000; Cooper and McCann 2002; Carey *et al*. 2008), which are based on repeated sample field surveys. Case studies of land use matrix development for Scotland and Wales are described in the ECOSSE report (Smith *et al*. 2007), and the same approach has been used to develop matrices for England. Data for Northern Ireland before 1990 is limited but matrices have been developed using agricultural census and forestry data (Cruickshank and Tomlinson 2000): a combination of IPCC Approaches 1 and 2.

The areas of Cropland receiving lime are estimated from the cropland (tillage + bare fallow) area[12] reported in the annual June Agricultural Census and the proportions of arable areas receiving lime reported in the British Survey of Fertiliser Practice (2010).

Areas of lowland wetlands that are emitting carbon due to historical drainage (reported under Cropland remaining Cropland) have been assessed by Bradley (1997) and only occur in England.

7.3.3 Land-use definitions and the classification system used and their correspondence to the LULUCF categories

Cropland is defined in accordance with the Good Practice Guidance (IPCC 2003). For pre-1980 land use matrices cropland is the sum of the Crops and Market Garden land cover types in the Monitoring Landscape Change project (MLC 1986). Orchards should also have been included but were assigned to the Forestland category instead: this will be rectified, but is estimated to have a minor impact given the area of orchards in comparison to either the Cropland or Forestland categories. Post-1980, cropland is the sum of the Arable and Horticulture Broad Habitat types in the Countryside Survey. These have now been re-assigned to a single Broad Habitat class “Arable and horticulture” (Haines-Young *et al*. 2000, Appendix A), defined as:

“All arable crops such as different types of cereal and vegetable crops, together with orchards and more specialist operations such as market gardening and commercial flower growing. Freshly ploughed land, fallow areas, short-term set-aside and annual grass leys[1] are also included in this category.”

7.3.4 Methodological Issues

Changes in biomass and soil carbon due to land use change are estimated using a land use matrix approach. The construction of the land use change matrices, and the incorporation of the latest Countryside Survey data, is described in Annex 3.7. The matrix approach has been updated to use a bottom-up approach (based on 20x20km squares), rather than a top-down approach based on national matrices. A dynamic model of carbon stock change is used with the land use change matrices to estimate soil carbon stock changes due to land use change. This uses a database of soil carbon density for the UK (Milne and Brown 1997;

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[12] This does not include uncropped arable land such as set-aside or land managed in Good Agricultural and Environmental Condition (GAEC12).

Cruickshank *et al*. 1998; Bradley *et al*. 2005) which has been constructed based on information on soil type, land cover and carbon content of soil cores. 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.

In the dynamic model of soil carbon stock change, the change in equilibrium soil 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 soil 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 soil 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 3.7. An adjustment is made to these calculations for each country to remove increases in soil carbon due to afforestation, as the C-Flow model is used to estimate these fluxes.

N_2O emissions from the conversion of Forest Land to Cropland are reported for the first time in this inventory submission. The IPCC Tier 1 methodology is used with the areas of forest land and grassland converted to cropland from the land use change matrices.

7.3.5 Uncertainties and Time-Series Consistency

The Approach 1 (error propagation) uncertainty analysis in the Annexes provides estimates of uncertainty according to the GPG source category and gas. 5B Cropland is estimated to have an uncertainty of 45% for net emissions in 1990 and an uncertainty of 50% for net emissions in 2009.

Recent work on quantifying uncertainties in the inventory has focussed on forest modelling (see **Chapter 11**, **Section 3.1.5**). Two recent COST Actions (603 and 639) have compiled the different datasets, methods and models of uncertainty analysis in Europe but have not reached any conclusions. A proposed new COST Action would produce a recommended method for comprehensive uncertainty analysis of Tier 3 approaches, which could be applied in the UK.

For liming, uncertainty in both the activity data and emission factor 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.

In terms of time series consistency:

- For biomass increases due to yield improvements (5B1) activity data are reported as a constant annual average value.
- For fenland drainage (5B1) the activity data for the model come from a single source which provides good time series consistency.
- For liming (5B) there is good time series consistency as there has been continuity in the published data sources.
- For changes in non-forest biomass and soil carbon stocks due to land use change the data sources for Great Britain have separate good internal consistency.

Consistency between these and Northern Ireland data sources has improved with better methodological integration between land use surveys.

- For emissions due to biomass burning after conversion of Forest Land to Cropland, the time series consistency is medium as the two constituent data series are not both available for each year and the values for much of the period are partially derived from data in one region.

7.3.6 Category-Specific QA/QC and Verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 7.9**.

A resampling of the 1980-based National Soil Inventory (NSI) in England and Wales in 1995-2003 found large losses of soil carbon across all land use types (Bellamy *et al*. 2005). As part of the supporting research for the LULUCF inventory project, Bellamy and Rivas-Casado (2009) attempted to identify NSI sites where there was sufficient land management information to determine the relationship between changes in soil carbon and differences in land management. Unfortunately, there were insufficient co-incident data (for example, none of 1314 Countryside Survey sample sites were closer than 1.9 km to a resampled NSI site) to allow these relationships to be investigated except at Forest Land sites (see section 7.2.6). Further work by Kirk and Bellamy (2010) has concluded that the losses measured between 1980 and 1995 -2003 were mainly due to land use/land management changes before 1980 – so the organic C in the soils were not in equilibrium (due to previous changes in land use/management) when first measured in 1980 and continued to decrease until they were measured again between 1995 – 2003.

7.3.7 Category-Specific Recalculations

Changing the land use/soil carbon model from a top-down to a bottom-up approach resulted in small changes in net carbon stock changes from 1990 to 1999. There are larger changes from 2000 onwards due to the inclusion of new activity data on land use change (Countryside Survey 2007). Land use changes to Cropland between 2000 and 2007 were smaller than previously estimated, producing a smaller net source (11,934 Gg CO_2 in 2008 in the 2009 inventory vs. 14,346 Gg CO_2 in the 2008 inventory).

There were small changes in CO_2 emissions from agricultural liming due to re-assignment of the limed area between Cropland and Grassland (updated activity data).

The post-1990 conversion of forest land to cropland was assumed to be zero in previous inventory submissions. This assumption was re-examined using the latest Countryside Survey data and a small area of forest-crop conversion in England is now included (the areas of forest-crop conversion in Scotland, Wales and Northern Ireland were so small that they were thought to be due to survey classification error than genuine land use change). Carbon stock changes from this source are reported in Table 5.B. The emissions from biomass burning arising from this land conversion are reported in Table 5(V).

N_2O emissions from disturbance associated with land-use conversion to Cropland are estimated using a Tier 1 methodology and reported for the first time in Table 5(III).

7.3.8 Category-Specific Planned Improvements

This category will be internally restructured in the next inventory submission, moving to the IPCC 20-year default period for land remaining in the Land converted to Cropland category. This will resolve the discrepancies between the areas reported in the CRF tables and those in Tables 7.1 and 7.2. It is thought that these discrepancies arise because some cropland (and pasture grassland) is in multi-year rotations and these areas have therefore undergone several land use transitions between 1950 and the current inventory year (with the area changes being cumulatively reported in 5.B.2). Restructuring will allow the total area of Cropland to be made consistent with the cropland area reported in the annual agricultural census or Countryside Survey. Soil carbon stock changes resulting from historical land use change will still be reported in the Cropland remaining Cropland category, and work is planned to resolve the rotational land use change issue.

The weighting used for changes in soil carbon density between different land use types is currently based on the 1990 and 1998 Countryside Survey data. This approach will be updated to include the latest Countryside Data in the next inventory submission.

No account is currently taken of other carbon stock changes in perennial woody biomass on cropland, for example fruit orchards or crops grown for biofuel production. The area of such crops is currently small (orchards cover 23.7 kha in 2008 or 0.4% of the total croppable area (Defra 2009)). This is an area of potential improvement in the inventory, although not a high priority.

A literature review of non-forest biomass yield improvements will be undertaken and the carbon stock change calculations updated accordingly.

A current development project is examining the scope for the effects of land management policies to be better reflected in the inventory. This has a particular focus on soil carbon. An assessment of the availability and quality of activity data and country-specific emission factors is necessary before this development can be implemented. A wider review of data sources is also in progress: this will be used to assess whether there are additional data sources that could be used in the inventory or contribute to uncertainty estimates. The review will also assess other models that could potentially be used, although a full methods comparison is beyond the intended scope of the review.

7.4 CATEGORY 5C – GRASSLAND

7.4.1 Description

The category is disaggregated into 5.C.1 Grassland remaining Grassland and 5.C.2 Land converted to Grassland. Reporting of carbon stock changes is disaggregated between the four geographical areas of England, Scotland, Wales and Northern Ireland. Reporting in category 5.C.2 is currently split between two time periods, pre- and post-1990. This category will be restructured in the next inventory submission to use the 20-year transition period for land use conversion before reporting in the Grassland remaining Grassland sub-category.

Emissions from peat extraction have been moved from the Grassland remaining Grassland to the 5D Wetlands category. Carbon stock changes in non-forest biomass and soil due to land use change to Grassland are reported under 5C2. All forms of land use change, including deforestation, are considered and both mineral and organic soils are included.

Emissions of carbon dioxide from the application of limestone, chalk and dolomite to grassland are reported in Table 5(IV). The amount of agricultural lime applied relates to all areas of Grassland, therefore it will include areas in 5C1 and 5C2.

Emissions of CO_2, CH_4 and N_2O from the burning of forest biomass when Forest Land is converted to Grassland are reported under Table 5(V). There is no activity data for wildfires on non-forest land in the UK.

The data reported for the UK in Sectoral Table 5 in the Information item “Grass Land converted to other Land-Use Categories” includes both changes in carbon stock in biomass and soils under “Net CO_2 emissions/removals”.

7.4.2 Information on approaches used for representing land areas and on land use databases used for the inventory preparation

The approaches used for representing land use areas in the inventory are described in **Section 7.3.2**. The areas of Grassland receiving lime are estimated from the pasture grassland (short term (<5 years old) and permanent (>5 years old)) area reported in the annual June Agricultural Census and the proportion of grassland receiving lime reported in the British Survey of Fertiliser Practice (2010). Areas of Forest Land converted to Grassland (deforestation) are estimated from data compiled by the Forestry Commission on unconditional felling licences (felling licences granted without a requirement to restock) in England 1990-2008 and Great Britain 1999-2001. Areas of converted land for all of Great Britain are extrapolated from the English data for 1990-2008 (based on the 1999-2001 ratios for Great Britain). The land use conversion rate for 2009 is from the rate for the previous ten years using an autoregressive model.

7.4.3 Land-use definitions and the classification system used and their correspondence to the LULUCF categories

Grassland is defined in accordance with the Good Practice Guidance (IPCC 2003). Grazing is the pre-dominant land use, so areas of wetland habitat, such as bogs, are also included in the Grassland category. For pre-1980 land use matrices grassland is the sum of the following land cover types in the Monitoring Landscape Change project (MLC 1986): upland heath, upland smooth grass, upland coarse grass, blanket bog, bracken, lowland rough grass, lowland heather, gorse, neglected grassland, marsh, improved grassland, rough pasture, peat bog, fresh marsh and salt marsh. Post-1980, grassland is the sum of the following Broad Habitat types in the Countryside Survey: improved grassland, neutral grassland, calcareous grassland, acid grassland, bracken, dwarf shrub heath, fen/marsh/swamp, bogs and montane (**Table 7.4**).

Table 7.4 Definitions of Broad Habitat types within the Grassland category (from Haines-Young *et al*. 2000, Appendix A).

Broad habitat type	Definition
Improved grassland	*Improved Grassland* occurs on fertile soils and is characterised by the dominance of a few fast growing species, such as rye-grass and white clover. These grasslands are typically used for grazing and silage, but they can also be managed for recreational purposes. They are often intensively managed using fertiliser and weed control treatments, and may also be ploughed as part of the normal rotation of arable crops but if so, they are only included in this Broad Habitat type if they are more than one year old.

Broad habitat type	Definition
Neutral grassland	*Neutral Grasslands* are found on soils that are neither very acid nor alkaline. Unimproved or semi-improved *Neutral Grasslands* may be managed as hay meadows, pastures or for silage. They differ from *Improved Grassland* in that they are less fertile and contain a wider range of herb and grass species
Calcareous grassland	Vegetation dominated by grasses and herbs on shallow, well-drained soils, which are alkaline, as a result of the weathering of chalk, limestone or other types of base-rich rock.
Acid grassland	Vegetation dominated by grasses and herbs on a range of lime-deficient soils which have been derived from acidic bedrock or from superficial deposits such as sands and gravels.
Bracken	Stands of vegetation greater than 0.25 ha in extent which are dominated by a continuous canopy cover (>95% cover) of bracken (*Pteridium aquilinum*) at the height of the growing season.
Dwarf shrub heath	*Dwarf Shrub Heath* comprises vegetation that has a greater than 25% cover of plant species from the heath family or dwarf gorse species. It generally occurs on well-drained, nutrient poor, acid soils.
Fen, marsh and swamp	This habitat occurs on ground that is permanently, seasonally or periodically waterlogged as a result of ground water or surface run-off. It can occur on peat, peaty soils, or mineral soils. It covers a wide range of wetland vegetation, including fens, flushes, marshy grasslands, rush-pastures, swamps and reedbeds.
Bog	Wetlands that support vegetation that is usually peat-forming and which receive mineral nutrients principally from precipitation rather than ground water. Where bogs have not been modified by surface drying and aeration or heavy grazing the vegetation is dominated by plants tolerant of acid conditions.
Montane habitats	Vegetation types that occur exclusively above the former natural tree-line on mountains. It includes prostrate dwarf shrub heath, snow-bed communities, sedge and rush heaths, and moss heaths.

7.4.4 Methodological Issues

A summary of the land use matrix approach used to estimate changes in biomass and soil carbon due to land use change is given in **Section 7.3.4**. Detailed descriptions of the methods and emission factors used for the activities in this Category can be found in **Annex 3.7**.

7.4.5 Uncertainties and Time-Series Consistency

The uncertainty analysis in the Annexes provides estimates of uncertainty according to the GPG source category and gas. 5C Grassland is estimated to have an uncertainty of 70% for net emissions in 1990 and an uncertainty of 55% for net emissions in 2008. The discussion of recent work on uncertainty in **Section 7.3.5** is also applicable.

For liming, uncertainty in both the activity data and emission factor 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.

In terms of time series consistency:

- For liming (5C) there is good time series consistency as there has been continuity in the published data sources.

- For changes in non-forest biomass and soil carbon stocks due to land use change the data sources for Great Britain have separate good internal consistency.

Consistency between these and Northern Ireland data sources has improved with better methodological integration between land use surveys.

- For emissions due to biomass burning after conversion of Forest Land to Grassland, the time series consistency is medium as the two constituent data series are not both available for each year and the values for much of the period are partially derived from data in one region

7.4.6 Category-Specific QA/QC and Verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 7.9**. Research described in **Section 7.3.6** is also relevant to this section.

7.4.7 Category-Specific Recalculations

Emissions from peat extraction have been moved from the Grassland remaining Grassland to the 5D Wetlands category.

Changing the land use/soil carbon model from a top-down to a bottom-up approach resulted in small changes in net carbon stock changes from 1990 to 1999. There are larger changes from 2000 onwards due to the inclusion of new activity data on land use change (Countryside Survey 2007). Land use changes to Grassland were larger than previously estimated, producing a larger net sink (-9,064 Gg CO_2 in 2008 in the 2009 inventory vs. -8,865 Gg CO_2 in the 2008 inventory).

There were small changes in CO_2 emissions from agricultural liming due to re-assignment of the limed area between Cropland and Grassland (updated activity data).

New activity data on forest conversion to non-urban land use was included, and part of this area was also re-assigned to Forest converted to Cropland. This had a small effect on carbon stock changes and biomass burning emissions.

7.4.8 Category-Specific Planned Improvements

This category will be internally restructured in the next inventory submission, moving to the IPCC 20-year default period for land remaining in the Land converted to Grassland category. This will allow the reporting of areas to be made more consistent with other international reporting (see also **Section 7.3.8**). The review and other planned improvements described in **Section 7.3.8** are also relevant to this section.

Input activity data for deforestation remain a problem but outputs from the National Forest Inventory and map may help to resolve this (see the Forest Land section for further information). The initial focus involves the comparison of ‘snapshot’ woodland area maps from the Forestry Commission’s NIWT (1995-1999) and the new NFI map. In principle, it should be possible to derive provisional deforestation estimates from such a comparison, however technical issues concerning the methods used to prepare the two maps are still being addressed. The publication of the new NFI map has been put back until mid-2011. The intention is that eventually deforestation estimates should be obtained directly from periodic National Forest Inventories (NFIs), as results from these become available.

There is currently no national activity data for wildfires and controlled burning on non-forest land use types. There is a new Vegetation Fire Monitoring Standard in development which may produce useful data in the future but this will only cover England at first. We will investigate the potential for extrapolating burnt areas from the number of fire incidents, for which statistics are available.

7.5 CATEGORY 5D – WETLANDS

7.5.1 Description

According to the IPCC (2006), Wetlands include any land that is covered or saturated by water for all or part of the year, and that does not fall into the Forest Land, Cropland, or Grassland categories. Managed wetlands are those where the water table is artificially changed (i.e. raised or drained) or those created by human activity. Emissions from unmanaged wetlands are not estimated. Methodologies are provided for peatlands that are cleared and drained for peat production (for energy or horticultural purposes) and for areas converted to permanently flooded land (reservoirs).

In the UK, estimates are made of emissions from on-site peat production and off-site emissions from horticultural peat under 5.D.1 Wetlands remaining Wetlands. Information on areas under 5.D.2 Land converted to Wetlands is in development, so no carbon stock changes are currently reported here. N_2O emissions from wetland drainage (as part of peat production) are reported under 5.D.2: they should properly be associated with the area in 5.D.1 but the structure of the CRF tables does not allow this.

In the UK, saturated land (based on the Countryside Survey Broad Habitat classification) such as bogs or marshes will fall into the Grassland category (as it is principally managed for grazing). Land covered by open water (e.g. lakes, rivers, reservoirs) is currently included in the Other Land category.

7.5.2 Information on approaches used for representing land areas and on land use databases used for the inventory preparation

A different approach to that used for other land use categories is necessary, as peat extraction sites are not explicitly identified in the habitat/landscape surveys used for the land use matrix. They are most likely to fall under the “Inland rock” broad habitat (5G Other) or “Bog” broad habitat (5C Grassland) if some vegetation cover remains (Maskell *et al*. 2008). We explored a number of data sources for constructing a robust dataset on the location, extent and type of peat extraction in Great Britain and Northern Ireland. Three data sources were then used in combination to produce an activity dataset with areas of active peat extraction.

- The British Geological Survey (BGS) have supplied the set of Great Britain peat extraction site records from the Directory of Mines and Quarries (Cameron et al. 2008): this gives location, name, operator and council for currently active commercial extraction sites in England (54), Scotland (26) and Wales (2). This Directory does not record the extent of the extraction area. It is updated every three to four years.

- Areas of peat extraction can be clearly seen on Google Earth satellite imagery (using the BGS point locations). Areas can be measured using the Google Earth Pro software (alternative software, such as Feature Manipulation Engine, could also be used). However, the imagery has been taken at varying (but known) dates and coverage is not consistent across the UK.

- There is good information on peat extraction (for both horticultural and fuel use) in Northern Ireland from papers by Tomlinson (2010) and Cruickshank et al. (1995). The research described in these papers was funded by Defra under previous LULUCF inventory development projects.

Most commercial extraction in the UK is undertaken using the vacuum harvesting method. The bare surface of the peat is scarified to 5-10 cm depth, the resulting loose peat is left to dry and then removed. Areas undergoing such extraction are clearly visible on aerial/satellite imagery (**Figure 7.3**). It is inferred that that the areas of existing extraction do not vary in extent from year to year. If a site could not be identified on the Google Earth imagery then it was not included (some areas may not actually be undergoing extraction, or the photographs may not be up-to-date).

Figure 7.3 Peat extraction site visible on Google Earth imagery

7.5.3 Land-use definitions and the classification system used and their correspondence to the LULUCF categories

Peatlands managed for peat extraction are defined as those sites currently registered for commercial extraction where extraction activity is visible on recent aerial/ satellite photographs or by field visits. Peat extraction for domestic use occurs in Northern Ireland and Scotland in the UK. Peat cuttings for domestic extraction are not clearly identifiable on aerial photographs, and ground survey would probably be required to estimate the extent of such activity. This has been done for Northern Ireland but no such work has been undertaken for Scotland.

7.5.4 Methodological Issues

Emissions for this category have been developed on the basis of the Tier 1 default methodology, which does not distinguish between peat extraction production phases (i.e. it includes conversion and vegetation clearing). Emissions are reported under 5.D.1 Wetlands remaining Wetlands (emissions under 5.D.2 Land converted to Wetlands are reported as being “Included Elsewhere”). All carbon in horticultural peat is assumed to be emitted off-site during the extraction year. Methane emissions are assumed to be insignificant but N_2O emissions from drainage are reported (although emissions are considered insignificant on nutrient-poor peatlands). Further information is given in **Annex 3.7**.

7.5.5 Uncertainties and Time-Series Consistency

Uncertainties for the activity data are estimated to be >100% in 1990 and 50% in 2009. Uncertainties in the emission factors are the default IPCC values given in the 2006 Guidelines: -100% to 315% for peat extracted for horticultural use and -98% to 600% for peat extracted for fuel use.

A more detailed uncertainty analysis of this category will be included in the next inventory submission.

Time series consistency for activity data is medium as the time series is based upon interpolation between data for 1991 and 2010.

7.5.6 Category-Specific QA/QC and Verification

The methodology for reporting emissions from 5D Wetlands is still in development. The activity dataset developed was partially verified by comparing the measured areas with reported areas of planning permission (which were available for some extraction sites in England and Scotland). The measured areas either matched or were smaller than the planning permission areas, which is to be expected as it is known that not all areas with planning permission are undergoing active extraction.

7.5.7 Category-Specific Recalculations

Reporting of net emissions/removals from on-site extraction is reported in 5D Wetlands for the first time so there are no recalculations. Reporting of off-site emissions from horticultural peat has been moved from 5.C.1.Grassland remaining Grassland to 5.D.1. The activity data for these emissions has been updated with the latest published information on peat volume sales (ONS 2009). Volumes for 2009 were assumed to be equal to those in 2008.

7.5.8 Category-specific planned improvements

Work is in progress to develop the time series of areas undergoing peat extraction and post-extraction restoration, as suitable data is known to be available in Scotland and Wales. It may be possible to develop a Tier 2 methodology for this category that separates peatlands being converted for peat extraction from those already in production. The method combining site locations with Google Earth imagery could be extended to Northern Ireland if a similar register of commercial extraction sites is available.

Further work on volume conversion factors for off-site emissions from horticultural peat has been undertaken and will be included in the next inventory submission.

Additional work on uncertainty analysis in this category is required.

The area of land converted to permanently Flooded Land is assumed to be small in the UK but activity data will be sought. We also plan to start reporting areas of open water in this category (rather than as part of the Other Land category). It is assumed that there are no emissions associated with such areas.

7.6 CATEGORY 5E – SETTLEMENTS

7.6.1 Description

This category 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. Reporting of carbon stock changes is disaggregated between the four geographical areas of England, Scotland, Wales and Northern Ireland. Reporting in category 5.E.2 is also split between two time periods, pre- and post-1990. This category will be restructured in the next inventory submission to use the 20-year transition period for land use conversion before reporting in the Settlement remaining Settlement sub-category.

Carbon stock changes and biomass burning emissions due to conversion of Forest Land to Settlements are reported for all of the UK from 1990 onwards (emissions occur in the same year as the land use conversion). Carbon stock changes in non-forest biomass and soil due to land use change to Settlement are reported under 5E2. All forms of land use change, including deforestation, are considered and both mineral and organic soils are included.

Emissions of CO_2, CH_4 and N_2O from the burning of forest biomass when Forest Land is converted to Settlement are reported under Table 5(V).

7.6.2 Information on approaches used for representing land areas and on land use databases used for the inventory preparation

The approaches used for representing land use areas in the inventory are described in **Section 7.3.2**. Activity data on areas of Forest Land converted to Settlement (deforestation) is extrapolated from data for England held by the Department of Communities and Local Government (DCLG). They obtain this information from the Ordnance Survey (the national mapping agency) which makes an annual assessment of land use change from the data it collects for map updating. Areas of Forest Land conversion to Settlement are calculated as the sum of all forest land use categories to urban land use categories. (Note that this data set is not thought to be reliable for forest conversion in rural areas because the resurveying frequency is too low).

7.6.3 Land-use definitions and the classification system used and their correspondence to the LULUCF categories

Settlement is defined in accordance with the Good Practice Guidance (IPCC 2003). For pre-1980 land use matrices Settlement land is the sum of the Built-up, Urban open, Transport, Mineral workings and Derelict land cover types in the Monitoring Landscape Change project (MLC 1986). Post-1980, Settlement land corresponds to the “Built-up and Gardens” and “Boundary and linear features” Broad Habitat types in the Countryside Survey (Haines-Young *et al*. 2000, Appendix A), defined as:

Built-up and Gardens: “Covers urban and rural settlements, farm buildings, caravan parks and other man-made built structures such as industrial estates, retail parks, waste and derelict ground, urban parkland and urban transport infrastructure. It also includes domestic gardens and allotments.”

Boundary and linear features: “a diverse range of linearly arranged landscape features such as hedgerows, walls, stone and earth banks, grass strips and dry ditches. This habitat type also includes some of the built components of the rural landscape including roads, tracks and railways and their associated narrow verges of semi-natural habitat.”

Some components of the “Boundary and linear features” Broad Habitat type could fall under the definition of Cropland or Grassland. It is not possible to disaggregate this Broad Habitat further and the assignment to a single land use category avoids double-counting. In the latest 2007 Countryside Survey the “Boundary and linear features” Broad Habitat type covered 2% of the UK land area.

7.6.4 Methodological Issues

A summary of the land use matrix approach used to estimate changes in biomass and soil carbon due to land use change is given in **Section 7.3.4**. Detailed descriptions of the methods and emission factors used for the activities in this Category can be found in **Annex 3.7**.

7.6.5 Uncertainties and Time-Series Consistency

The uncertainty analysis in the Annexes provides estimates of uncertainty according to the GPG source category and gas. 5E Settlement is estimated to have an uncertainty of 35% for net emissions in 1990 and an uncertainty of 50% for net emissions in 2008. The discussion of recent work on uncertainty in **Section 7.3.5** is also applicable.

In terms of time series consistency:

- For changes in non-forest biomass and soil carbon stocks due to land use change the data sources for Great Britain have separate good internal consistency. Consistency between these and Northern Ireland data sources has improved with better methodological integration between land use surveys.

- For emissions due to biomass burning after conversion of Forest Land to Settlement, there is good time series consistency as there has been continuity in the activity data source.

7.6.6 Category-Specific QA/QC and Verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 7.9**. Research described in **Section 7.3.6** is also relevant to this section.

7.6.7 Category-Specific Recalculations

Changing the land use/soil carbon model from a top-down to a bottom-up approach resulted in small changes in net carbon stock changes from 1990 to 1999.Changes from 2000 onwards are due to the inclusion of new activity data on land use change (Countryside Survey 2007). Land use changes to Settlement were smaller than previously estimated, producing a slightly smaller net source (6,068 Gg CO_2 in 2008 in the 2009 inventory vs. 6,220 Gg CO_2 in the 2008 inventory).

The dataset on deforestation to Settlement was revised for 2005-2007. A five-year moving average has been applied on the recommendation of the data suppliers (Department of Communities and Local Government). The area of deforestation in 2008 to 2009 has been estimated by extrapolation from earlier years. This has had a small effect on carbon stock changes and emissions of greenhouse gases during biomass burning.

7.6.8 Category-Specific Planned Improvements

This category will be internally restructured in the next inventory submission, moving to the IPCC 20-year default period for land remaining in the Land converted to Settlement category. The review and other planned improvements described in **Section 7.3.8** are also relevant to this section.
Input activity data for deforestation remain a problem but outputs from the National Forest Inventory and map may help to resolve this (see the Forest Land section and **Section 7.4.8** for further information).

7.7 CATEGORY 5F – OTHER LAND

7.7.1 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).

7.7.2 Information on approaches used for representing land areas and on land use databases used for the inventory preparation

The approaches used for representing land use areas in the inventory are described in **Section 7.3.2**.

7.7.3 Land-use definitions and the classification system used and their correspondence to the LULUCF categories

Other Land is defined as areas that do not fall into the other land use categories. For pre-1980 land use matrices Other Land is the sum of the Bare rock, Sand/shingle, Inland water and Coastal water land cover types in the Monitoring Landscape Change project (MLC

1986). Post-1980, Other Land contains the Inland rock, Standing water and Canals and Rivers and Streams Broad Habitat types in the Countryside Survey (**Table 7.5**).

Table 7.5 Definitions of Broad Habitat types included in Other Land (Haines-Young *et al*. 2000, Appendix A)

Broad habitat type	**Definitions**
Inland rock	Habitat types that occur on both natural and artificial exposed rock surfaces, such as inland cliffs, caves, screes and limestone pavements, as well as various forms of excavations and waste tips, such as quarries and quarry waste.
Standing Waters and Canals	This Broad Habitat category includes lakes, meres and pools, as well as man-made water bodies such as reservoirs, canals, ponds, gravel pits and water-filled ditches.
Rivers and Streams	This category includes rivers and streams from bank top to bank top; where there are no distinctive banks or banks are never overtopped, it includes the extent of the mean annual flood.

7.7.4 Category-specific planned improvements

We have started reporting areas in the CRF Table for this category. The planned restructuring of the Cropland, Grassland and Settlement categories in the next inventory submission will improve consistency in area reporting. The intention is to start reporting areas of open water in the Wetlands category.

7.8 CATEGORY 5G – OTHER

7.8.1 Description

Changes in stocks of carbon in harvested wood products (HWP) are reported here. These HWP stocks result from normal forest management processes (thinning and harvesting) and from conversion of Forest Land to Cropland, Grassland or Settlements (deforestation), as recommended by a previous ERT.

7.8.2 Methodological Issues

A description of the method used to account for changes in stocks of carbon in HWP is in **Annex 3.7**. 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. Changes in carbon stocks from HWP arising from deforestation (conversion of Forest Land to Grassland or Settlement) are estimated using a look-up table of annual HWP stock changes generated by C-Flow.

7.8.3 Uncertainties and Time-Series Consistency

The uncertainty analysis in the Annexes provides estimates of uncertainty according to IPCC source category and gas. 5G is estimated to have an uncertainty of 30% for net emissions in 1990 and 2008.

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 Category-Specific QA/QC and Verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 7.9** Work is currently being undertaken to verify the modelled Harvested Wood Products estimates by comparison with the Forestry Commission model forecasts.

7.8.5 Category-Specific Recalculations

Revisions in the deforestation activity dataset resulted in changes in the pool of harvested wood products (from additions from deforestation). This resulted in a small increase in the source strength of the harvested wood products pool (-1,784 Gg CO_2 in 2008 in the 2009 inventory vs. -1,714 Gg CO_2 in the 2008 inventory).

7.8.6 Category-Specific Planned Improvements

The emission factors and activity data for harvested wood products will be kept under review. A watching brief on the development of methods of HWP estimation has been maintained (Matthews 2009). It is too early to proceed with full implementation of any specific method and preparation of estimates until methodologies have been agreed by the IPCC.

7.9 GENERAL COMMENTS ON QA/QC

The Centre for Ecology and Hydrology (the inventory compiler for the LULUCF sector) has adopted the quality assurance principles set out in the Joint Code of Practice for Research issued by the Biotechnology and Biological Sciences Research Council, the Department for Environment, Food and Rural Affairs, the Food Standards Agency and the Natural Environment Research Council. Quality Assurance is reported to Executive Board as appropriate. In addition projects are managed through Prince2 protocols. The CEH Policy Statement is given below.

- CEH is dedicated to achieving and maintaining the highest possible standards of quality in order to meet the needs of its work programmes and the needs of internal and external customers

- In pursuit of its quality aims, CEH strives to create a working situation that enables all staff to contribute to the continuous and meaningful improvement of a Quality Management System through competence and effective communication

- It is the aim to ensure that all staff at CEH understand and are committed to their individual and collective responsibilities for quality

- To achieve these objectives, the suitability of working practices and the training needs for existing and new members of staff will be appraised by management.

In 2009 the LULUCF inventory project was audited by an independent CEH team to confirm compliance with the Joint Code of Practice, where the project was praised for its high standards.

In addition to internal quality assurance procedures the submitted inventory data is also checked by AEA (the national inventory compilers) and the European Commission).

The project maintains a publicly available website, http://ecosystemghg.ceh.ac.uk/ where the inventory reports and tables are made available. The inventory data is also made available via the CEH Information Gateway http://gateway.ceh.ac.uk/. Technical information on the inventory methods is documented in a 'wiki' available to team members, ensuring continuity. Issue management software is used for project management and tracking issues such as requests for data from stakeholders and external parties.

8 Waste (CRF Sector 6)

8.1 OVERVIEW OF SECTOR

Emissions of GHGs from the waste sector occur from the disposal and treatment of solid wastes and wastewater.

The most important category of the waste sector in the UK is Source Category 6A – Solid Waste Disposal on Land, for which methane is the most important greenhouse gas. Despite significant reductions in recent years, the UK still disposes of appreciable amounts of biodegradable waste to landfills. The decomposition of these materials under anaerobic conditions in landfills results in methane formation, some of which escapes into the atmosphere.

A smaller proportion of solid waste is also disposed of by means of incineration. In this case the most important greenhouse gas is carbon dioxide originating from fossil-derived materials in the waste, principally plastics. Emissions from waste incineration without energy recovery are reported in Source Category 6 C (Waste Incineration). Where energy is recovered from the combustion process, which is the usual case for municipal and similar wastes, then greenhouse gas emissions are reported under Source Category 1A (Fuel Combustion).

Emissions from liquid wastes, through wastewater treatment, are included in Source Sector 6B. The most important greenhouse gases from this sector are methane and nitrous oxide.

Emissions of methane from Solid Waste Disposal on Land (6A) and emissions of nitrous oxide from Wastewater Treatment (6B) are Key Categories.

8.2 SOURCE CATEGORY 6A – SOLID WASTE DISPOSAL ON LAND

8.2.1 Source category description

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 waste disposal sites are not significant sources in the UK.

In addition to methane, anaerobic decomposition also produces an approximately equivalent amount of carbon dioxide and further carbon dioxide is also produced by aerobic decomposition processes. However, as the decaying organic matter originates from biomass sources derived from contemporary crops and forests, we do not need to consider the greenhouse impacts of this carbon dioxide. Waste also contains fossil-derived organic matter, predominantly in the form of plastics, but these are essentially non-biodegradable under landfill conditions[13], and so emissions of fossil-derived carbon dioxide from SWDS are not considered further. Emissions of carbon dioxide from landfills are therefore reported as “Not Estimated” (NE) as they are considered to be entirely biogenic in origin.

Non-methane volatile organic compounds (NMVOCs) are also released by SWDS. These are estimated using an emission factor relating the NMVOC to the amount of methane emitted. An emission factor of 0.01[14] has been used, which is equivalent to 5.65g NMVOC /m^3 landfill gas (Passant, 1993).

Nitrous oxide emissions from landfill are believed to be negligible and are not further considered here.

8.2.1.1 UK Waste Management Disposal to Land Legislation and Guidance

The amount of methane emitted from landfills depends primarily on both the amount of biodegradable carbon landfilled and how the sites are operated to reduce the escape of the methane so produced[15]. Policy measures to reduce methane emissions from landfills have focused on both these aspects. Diverting biodegradable waste away from landfill completely avoids the future formation of methane[16], but of course landfills continue to produce methane for many years from waste that has already been deposited. Improving the efficiency of gas capture from landfills is by nature an “end of pipe” solution, which does not itself prevent the formation of methane, although it does result in an immediate reduction in emissions. In practice, a combination of measures based on both reducing the amount of biodegradable waste landfilled and improving the management of sites have, in the UK, provided the foundations for reducing emissions from this source. These two broad approaches are outlined below.

The most important legislative and regulatory measures that have reduced the emissions of methane from UK landfills, as well as reducing other threats they pose to the environment and human health, derive from the 1999 Landfill Directive[17]. The requirements of the Directive were transposed into national legislation through the Landfill (England and Wales) Regulations 2002, subsequently amended in 2004 and 2005 to transpose the requirements of Council Decision 2003/33/EC on Waste Acceptance Criteria. The provisions were re-transposed as part of the Environmental Permitting (England and Wales) Regulations 2007 and again as part of the Environmental Permitting (England and Wales) Regulations 2010. In Scotland, the Directive is implemented through the Landfill (Scotland) Regulations 2003, as amended, and in Northern Ireland, through the Landfill Regulations (Northern Ireland) 2003a. The provisions of the Landfill Directive are the drivers for both reducing the amount

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[13] This is not the case for biodegradable plastics but these materials currently make up a negligible proportion of waste sent to landfill and so their impact on non-biogenic carbon dioxide emissions has been omitted.

[14] Dimensionless ratio of mass of NMVOC per unit mass of methane.

[15] It is also possible to manage landfill sites aerobically so that methane is not produced. Although this approach has been demonstrated in other European countries, particularly Germany, we are unaware of any UK landfills being managed in this way.

[16] The focus of this chapter is on the release of methane from landfills and its contribution to national greenhouse gas emissions. However, we should remember that there are other serious threats to the environment and human health posed by landfilling biodegradable wastes which are not explicitly addressed in this chapter, but which are also avoided by diverting biodegradable waste from landfills. These threats include potential contamination of ground- and surface waters and surrounding land; emissions of harmful and/or odorous chemicals in the landfill gas causing local air pollution; amenity impacts such as wind-blown litter and dust and potential problems with flies, rodents, gulls and other nuisance species. Landfilling of biodegradable waste can also represent a loss of the value of some organic materials that could be more beneficially composted or digested and the residue used as a soil improver or conditioner. Further consideration of these wider issues is beyond the scope of this chapter.

[17] Council Directive 1999/31/EC on the Landfill of Waste. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1999:182:0001:0019:EN:PDF

of biodegradable waste landfilled and in reducing the amount of methane that is released, through improving landfill design, operation and management.

8.2.1.1.1 *Reducing the amount of biodegradable waste sent to landfill*

Amongst other things, the Landfill Directive requires member states to develop a strategy to reduce the quantity of biodegradable municipal waste sent to landfill to 75% (2006), 50% (2009) and 35% (2016), compared with the amount of biodegradable municipal waste[18] landfilled in the base year (1995). The UK is one of twelve European Union (EU) member states[19] with a heavy reliance on landfill which were granted a derogation of four years for the achievement of the reduction targets. In other words, the target years for these countries are 2010, 2013 and 2020. Meeting and exceeding the Landfill Directive targets is one of the UK government's primary goals for waste management.

Waste policy in the UK is the responsibility of the Devolved Administrations (DAs) of three of the constituent countries of the UK, namely Northern Ireland, Scotland and Wales. Central government (through the Department for the Environment, Food and Rural Affairs – Defra) has responsibility for waste policy in England, which has about 83% of the UK population. Details of the strategic approach and performance against policy goals are available from the respective DA websites (DOENI, 2006, Scottish Government, 2010, Welsh Assembly Government, 2009). Waste policy in England has been published in a series of strategies. The current strategy (Defra, 2007) published in 2007 is currently under review.

As a member of the EU, UK environmental policy and regulations derive from European legislation. There are a number of European Directives applicable in the waste management field in addition to the Landfill Directive. Further information on European waste management legislation and relevant policies and directives is available from the European Commission[20]. This section provides a brief outline of the measures adopted by UK primarily to reduce reliance on landfilling. Further information on the role of other options of waste reduction, reuse, recycling, composting, anaerobic digestion and thermal treatments that are required to process waste diverted from landfills may be found at the websites referred to above.

The UK will achieve its 2010 landfill diversion target to reduce the amount of biodegradable municipal waste sent to landfill by at least 25% compared with the 1995 base year. Figures released in September 2010 for England (Defra, 2010) showed that 14.6 million tonnes of BMW were landfilled in calendar year 2009, compared with the target of 21.7 million tonnes for 2010. Data for the Devolved Administrations (DAs – Northern Ireland, Scotland and Wales) are not yet published, but overall the UK is expected to have met the 2010 target.

In order to achieve this, the UK has relied to a significant extent on economic instruments, supported by regulation, to drive biodegradable waste away from landfill and towards more sustainable options of waste minimisation, reuse, recycling, composting, anaerobic digestion and thermal treatment with energy recovery. These measures have significantly increased the costs of landfill disposal and effectively made alternative treatments more cost-competitive.

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[18] "Municipal waste", according to the Landfill Directive, means waste from households, as well as other waste which, because of its nature or composition, is similar to waste from households.

[19] The others are Bulgaria, Cyprus, Czech Republic, Estonia, Greece, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia.

[20] For example, see Europa Summaries of EU legislation – waste management: http://europa.eu/legislation_summaries/environment/waste_management/index_en.htm

This has been achieved through three principal means: Firstly, tighter regulation of the landfill sector introduced in the early 1990s has driven improvements in design, operation and management needed to meet the environmental protection standards required by the Landfill Directive has been funded through higher disposal fees.

Secondly, the government introduced the Landfill Tax in 1996 as the county's first explicitly environmental tax, with the objectives of ensuring that landfill waste disposal is properly priced to promote greater efficiency in the waste management market and in the economy as a whole, to apply the "polluter pays" principle and promote a more sustainable approach to waste management. The tax is collected from landfill site operators and charged at two levels: The higher level (applied to "active waste" containing organic materials) and a lower rate (applied to "inactive" wastes – such as rubble). The standard rate has been increased steadily since 1996 and in 1999 a "duty escalator" was introduced, providing for annual increases in the standard rate of landfill tax. The present standard rate (in financial year 2010/11) is £48/tonne. This will increase by £8 a year, reaching £80/tonne in 2014/15.

The third measure to drive waste away from landfill is the Landfill Allowance Scheme (LAS), the world's first trading scheme for municipal waste, which came into force in England in April 2005. Whereas the landfill tax applies to all waste sent to landfill, LAS applies only to biodegradable municipal waste (BMW) – in other words, biodegradable waste managed by municipalities.

In England, all the waste disposal authorities (i.e. the municipal departments with a statutory responsibility for disposing of waste collected from households and similar wastes from commercial and other premises) have been issued with an allowance which limits the amount of BMW that can be landfilled in each year, up to 2020. The allowances decrease in time in step with the targets set in the Landfill Directive. The waste disposal authorities are free to select the most cost-effective means of working within their allowances. This may be by investing in more sustainable solutions, such as waste reduction, recycling, composting, thermal treatment etc, depending on local circumstances. As a result of such investment, the authorities concerned would not require their full LAS allowance and so can trade their surplus with other authorities that would otherwise exceed their allowance. A penalty of £150 per tonne is payable to central government for exceeding LAS allowances. The price of surplus allowances is decided by market forces, but obviously the LAS penalty sets the ceiling price. The details of the scheme are given in UK government publications[21]. Similar schemes have been introduced by the devolved administrations of Northern Ireland, Scotland and Wales, but these differ from that in England, mainly to the extent in which trading of allowances takes place. Further information on trends in waste disposed to landfill in the UK is given in the following section.

8.2.1.1.2 *Reducing emissions of methane from landfills*

The regulatory framework under which the competent authorities in the UK control potentially-polluting activities is set by a further European Union Directive, the Integrated Pollution Prevention and Control (IPPC) Directive[22] This Directive, first adopted in 1996 and now incorporated in the industrial emissions (integrated pollution prevention and control) Directive (Recast) – 2010/75/EC, requires certain industrial and agricultural activities to have

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[21] See Department for Environment, Food and Rural Affairs (Defra) website for details. Also see "Beginners' Guide to the Landfill Allowance Trading Scheme". Published by Defra: http://www.defra.gov.uk/environment/waste/localauth/lats/documents/lats-leaflet-0405.pdf

[22] Directive 2008/1/EC of the European Parliament and of the Council of 15th January 2008 concerning integrated pollution prevention and control: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:024:0008:0029:EN:PDF

a permit to operate, including landfills. Permits can only be issued if certain environmental conditions are met, so that the companies themselves bear responsibility for preventing and reducing any pollution they may cause. The permitting requirements are implemented in the UK under the Environmental Permitting (England and Wales) Regulations 2010, which update and combine previous regulations implemented by the Pollution Prevention and Control (England and Wales) Regulations 2000, made under the Pollution Prevention Control Act 1999. Similar provisions apply in Scotland and Northern Ireland. Further information, including compliance guidance is provided by the relevant national regulators (EA, SEPA, NIEA).

Amongst its provisions, the Directive requires the use of Best Available Techniques – “BAT” - (which produce the least waste, use less hazardous substances, enable the substances generated to be recovered and recycled, etc.) for the avoidance of pollution and the prevention of all large-scale pollution. The permit conditions must detail emission limit values for polluting substances (with the exception of greenhouse gases if the emission trading scheme applies); any soil, water and air protection measures required; waste management measures; measures to be taken in exceptional circumstances (leaks, malfunctions, temporary or permanent stoppages, etc.); minimisation of long-distance or trans-boundary pollution; release monitoring, and all other appropriate measures. Landfilling of waste is subject to permitting, except for very small sites receiving small amounts of waste. The current threshold below which IPPC does not apply is less than 10 tonnes of waste per day, or less than 25,000 tonnes/ year.

Permit conditions issued to landfill operators reflect, amongst other things, the requirements set out in the Landfill Directive. 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. Most biodegradable waste landfilled in the UK is categorised as non-hazardous, and so Non-Hazardous landfills account for nearly all the methane emitted from UK landfills, with negligible amounts from Inert and Hazardous waste landfills. All landfills have to comply with the Directive’s requirements, although a transitional period is allowed for landfills in existence at 16 July 2001, which required all landfill sites to meet the requirements of the Directive or close within 8 years (by 16th July 2009. 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.”

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 and Scottish Environment Agency (SEPA) 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 emissions.
- TGN08: Guidance for monitoring landfill gas engine emissions.
- Guidance on Landfill Gas Flaring.

In addition, further guidance is also available on waste acceptance, landfill engineering and technical guidance on permitting.

8.2.2 Methodological issues

The UK approach to calculating emissions of methane from landfills uses a "Tier 2" methodology based national data on waste quantities, composition, properties and disposal practices over several decades. The equations for calculating methane generation use a first-order decay (FOD) methodology.

The Revised 1996 IPCC Guidelines (IPCC, 1997) define the overall approach for calculating methane emission from landfill as the amount of methane (CH_4) generated in the waste, *minus* the amount of methane recovered (for flaring or other combustion process), correcting for the amount of remaining methane that is oxidised to carbon dioxide. This is represented by equation (1):

(1) $$CH_4 \text{ emissions}_{,T} = \left[\Sigma_x CH_4 \text{ generated}_{,T} - R_T \right] (1\text{-}OX_T)$$

where

CH_4 emitted in year T, Gg
T=inventory year
x=waste category or type of material
R_T=recovered CH_4 in year T, Gg
OX_T=oxidation factor in year T (fraction).

Only the methane remaining after subtraction of methane recovered is available for oxidation. Mass units used are Giga grams (Gg, 10^9 grams): one Gg is equivalent to one kilotonne (kt).

The various waste types are allocated to three pools (p) of DDOC that decompose according to their characteristic first order rate constant, k. The three pools are described as Rapidly, Moderately, and Slowly Decomposing Organics (RDO, MDO and SDO, respectively).

Methane generation is calculated by equation (2):

(2) $$Q_{x,T,t,p} = L_{x,t,p} \left(e^{-k_p (T-t)} \left(1 - e^{-k_p}\right)\right)$$

Where:

$Q_{x,T,t,p}$ is the amount of methane generated in year T from a unit of waste type x, landfilled in year t, allocated to pool p;
k_p is the first order rate constant of pool p;
$L_{x,t,p}$ is the specific methane potential of waste type x landfilled in year t in pool p, and
e is the exponential constant.

Equation (2) is based on the methodology described in the 2000 Good Practice Guidance (IPCC, 2000). This in turn uses the approach developed for the 1996 Guidelines (IPCC, 1997), but uses a "normalisation factor" to correct for the small errors introduced into the integration when time is treated as a discrete, as opposed to continuous, variable. This approach has been adopted for previous years' UK NIRs.

The specific methane potential is in turn defined by:

(3) $L_{x,t,p} = DDOC_{x,t,p} . 1/W_{x,t,p} . 16/12$

Where

$W_{x,t,p}$ is the quantity of waste of type x landfilled in year t (dimensions mass) in pool p;
$DDOC_{x,t,p}$ is the dissimilable degradable organic carbon of waste type x assigned to pool p (dimensionless ratio), and
16/12 is an adjustment factor to convert mass of carbon to mass of methane.

The total methane generated in each inventory year (T) is then determined by integrating over all waste types (w), all three decomposition pools (p) and all years in which the waste is landfilled (t):

(4) Total CH_4 generated = Σ ($W_{x,T,t,p} . Q_{x,T,t,p}$)

The IPCC FOD methodology is based on the premise that Dissimilable Degradable Organic Carbon compounds (DDOC)[23] decay under the airless conditions in landfills to form methane, carbon dioxide and a variety of stable decomposition products that remain in the landfill, and represent a sink for carbon. First order means that the rate of reaction is proportional to the amount of reactant (i.e. DDOC) present at any given time. This means that as the reactant is used up, the rate of reaction slows down also. The decomposition process is characterised by an exponential rate constant, k, with dimensions of reciprocal time (units in this case are year^{-1}). The rate constant is related to the half-life ($T_{0.5}$) of the reaction, namely the time taken for the concentration of the reactant to halve, as shown by the following equation:

(5) $T_{0.5} = \ln(2)/k$

where ln(2) is the natural logarithm of 2.

The Revised 1996 IPCC Guideline (IPCC, 1997) define a further term, the Methane Correction Factor (MCF) as a multiplier on methane formation to reflect the fact that shallow or unmanaged dumpsites do not develop extensive anaerobic conditions typical of modern landfills and hence an appreciable proportion of waste decays aerobically and so does not produce methane. For modern landfills, the MCF term is given the value of unity (i.e. all decomposition is anaerobic), but for unmanaged dumpsites a smaller figure may be used. As all solid waste disposal sites in the UK that have received biodegradable wastes are believed to be typical of landfills rather than unmanaged dumpsites, MCF has been assigned a value of unity.

The UK model for calculating landfill emissions has developed over the years to reflect the availability of better input data and improved modelling approaches. The AEA Technology model (Brown et al., 1999) of methane generation from landfill sites was used until 2002. This was updated and revised for Defra in 2003 by Land Quality Management (LQM) (LQM, 2003). Further revision of the LQM version of the model was made in 2005 by the

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[23] DDOC is the amount of degradable organic carbon (DOC) that is converted (ie dissimilated) to methane and carbon dioxide under landfill conditions. DDOC = DOC x DOC_F where DOC_F is the fraction of DOC that dissimilates.

consultants Golder Associates (Golder Associates, 2005) and the 2006 and 2007 NIR and CRF tables contains results from this model.

In 2008, a new model (MELMod) based on the previous methodology but with improved transparency, utility and ease of use and flexibility was developed by AEA (Brown et al., 2008). MELMod has been tested against the previous national assessment model and the two models yield identical results from the same input data. In addition to improving the structure and user-friendliness of the national assessment model, AEA also identified a number of areas for improvement in terms of data quality and emission factors.

In 2010, the UK government commissioned further work to update the activity (i.e. quantities of degradable organic carbon landfilled) and emission factors for landfill methane, building on recommendations made by AEA during their development of MELMod. This work, undertaken by Eunomia (Eunomia Consulting and Research, 2011) has been, and continues to be, under peer review by independent experts from academia, industry, regulators and consultants. Revisions to the MELMod input data and parameters that were approved by the peer reviewers have been implemented for the calculation of the current UK NIR. The principal changes to the input data are summarised in the following sections. In other respects, the model retains the same characteristics used for the estimation of the 2008 landfill methane inventory. Further details on data sources and rationale are given in Eunomia's report.

8.2.2.1.1 *Activity data – quantities and composition of waste landfilled*

Estimates of the quantities of waste sent to landfill over the past 10-15 years have been extensively revised and quantities reduced in the light of published data on both local-authority (LA) controlled wastes[24] and, especially, commercial & industrial (C&I) waste, and on government receipts of revenues derived from the Landfill Tax. The reductions in waste sent to landfill have been driven principally by the Landfill Tax and LAS, which have made landfill more expensive compared with more sustainable waste management options. The recommendations to adopt the revised activity data were endorsed by the peer reviewers.

The revised data were used for LA-controlled and C&I waste from 1995 and 1997, respectively, retaining previous data as already described in the 2008 NIR for earlier years. In order to eliminate discontinuities in the time series of waste to landfill amounts, the new data were spliced into the previous from 1975, using linear interpolation between the previous 1975 data and the revised data for C&I beginning in 1997. It is recognised that considerable uncertainties exist in relation to the amount and composition of waste landfilled, especially prior to 1990, before reliable weighing and waste analysis were widely employed.

MELMod uses waste to landfill 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 IPCC Good Practice Guidelines (IPPC, 1997). It is important to use an appropriate timescale in order to avoid underestimating emissions associated with waste landfilled in previous decades.

Figure 8.1 shows the quantities of LA-controlled and C&I waste sent to landfill used for reporting the 2009 inventory (i.e. this document) over the entire modelled timeframe.

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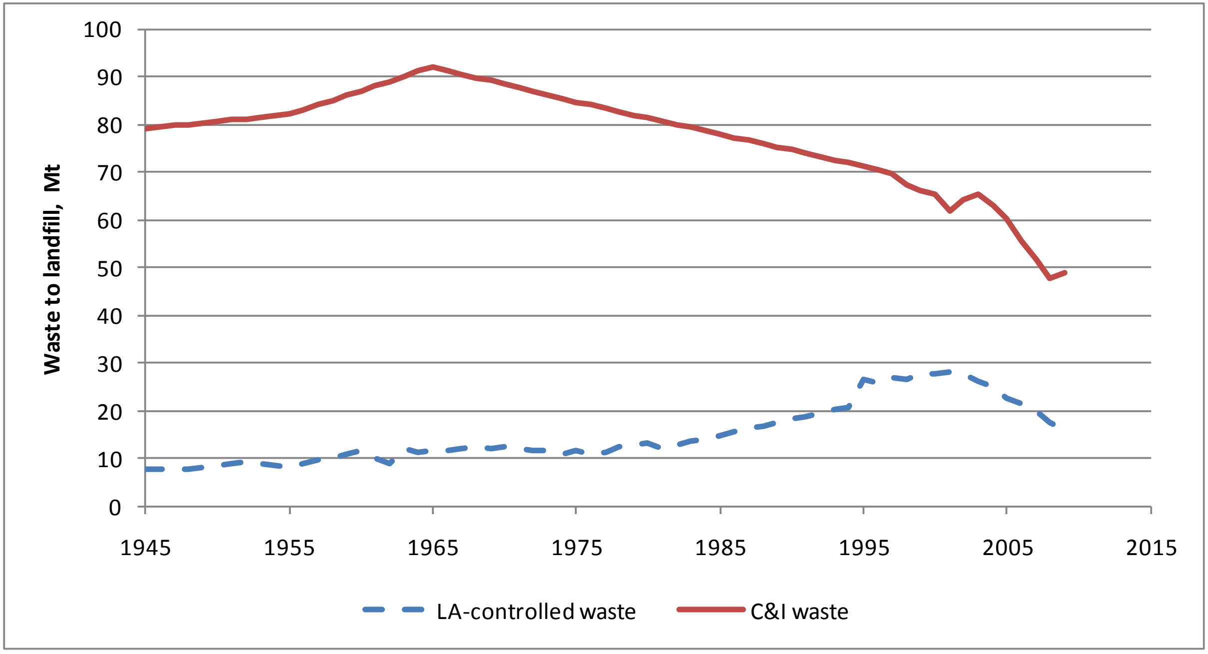
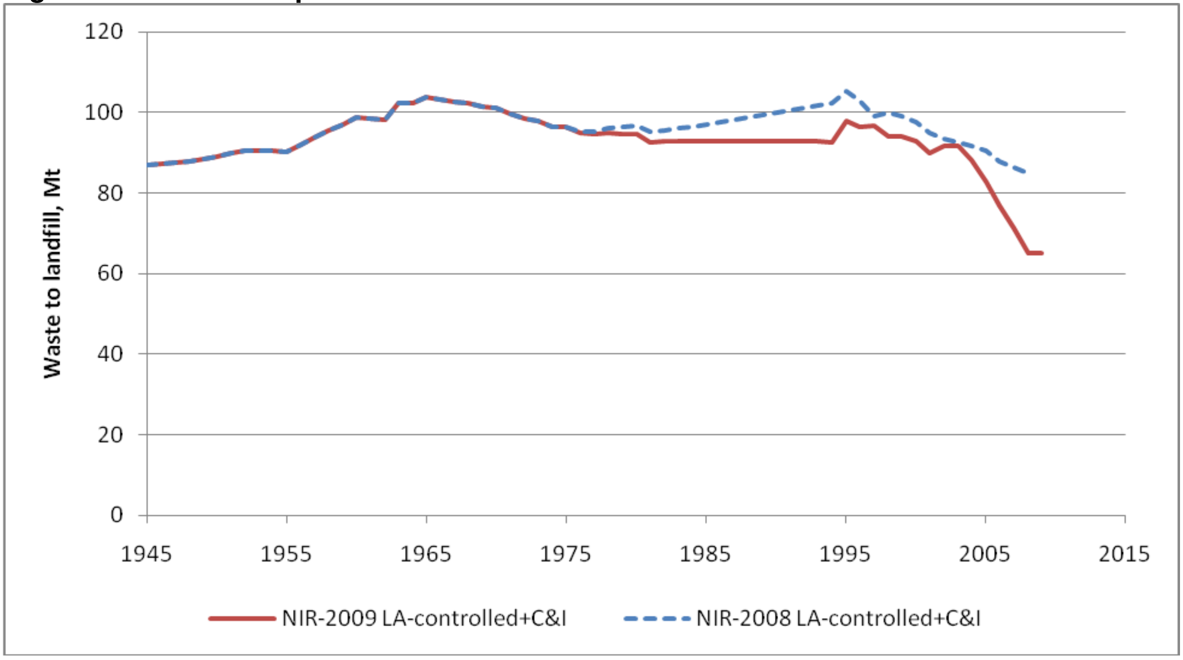
[24] The term “Local Authority Collected Waste” (LACW) includes all wastes collected by local authorities. This LACW was previously described as municipal waste in the UK. The definition of municipal waste in the Landfill Directive refers to ‘household waste and waste of similar composition’, including some waste from commerce. Therefore, the term LACW has replaced municipal waste in Defra Statistics Releases.

Figure 8.1 **Estimated quantities of Local Authority-controlled and Commercial & Industrial waste used for compilation of the 2009 inventory.**



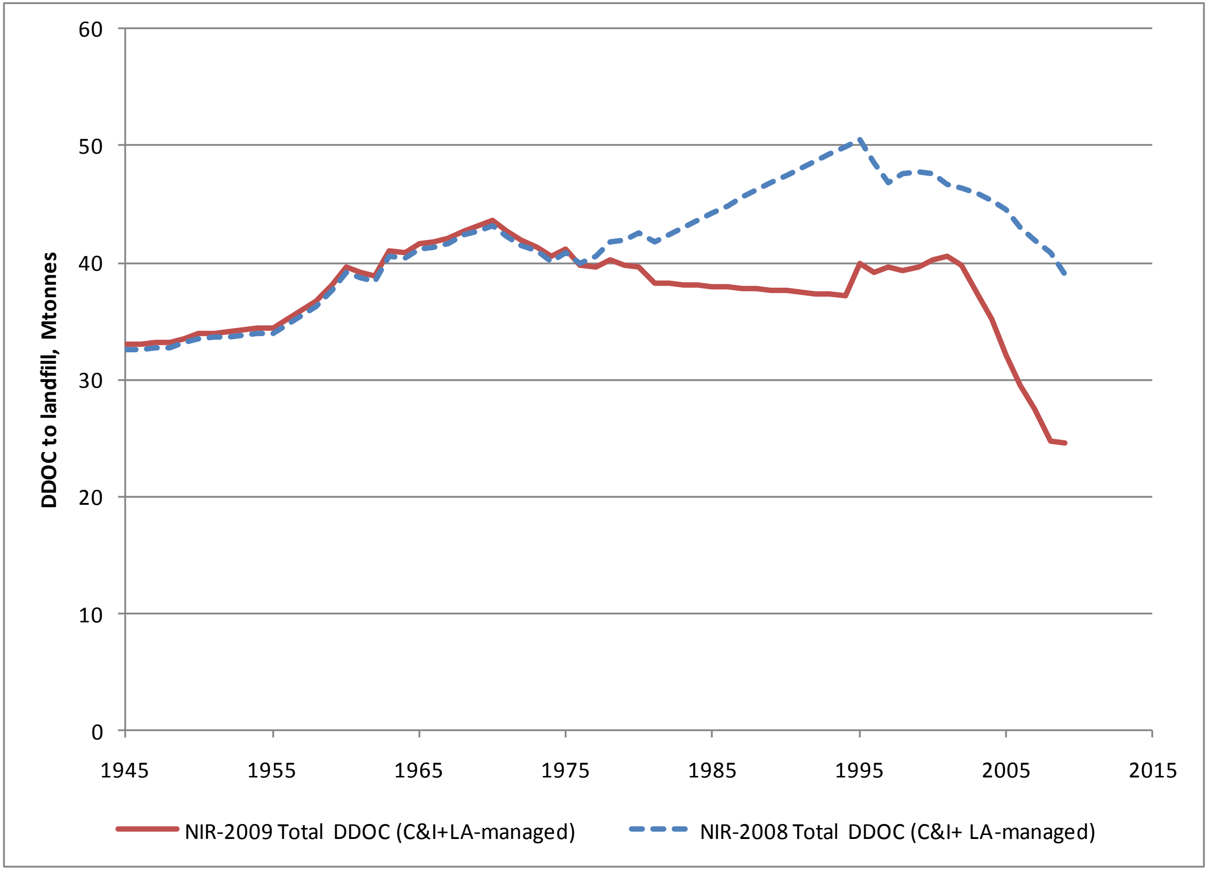
The combined estimate of landfilled LA-controlled and C&I waste has been reduced in this year's inventory report, since 1975, and especially since about 1996, compared with the data used for the compilation of the 2008 NIR (**Figure 8.2**).

Figure 8.2 **Comparison between 2008 and 2009 waste to landfill estimates**



A detailed review of waste composition, in terms of materials, moisture content and dissimilable degradable organic carbon (DDOC) content has been undertaken and the results are described in Eunomia's report (Eunomia, 2011) and summarised in Annex 3. The previous methodology used for inventory reporting for this sector, in which only cellulose and hemicelluloses were considered to contribute to methane formation has been discontinued, since this approach underestimates the importance of other carbon sources, particularly for food wastes. The new methodology, which has been adopted following endorsement by the peer reviewers, calculates the DDOC content of various waste materials through reference to the lignin and non-lignin content. The effects of the revision of data and methodology for estimating total DDOC to landfill is shown in **Figure 8.3**. The current inventory approach shows that significantly less DDOC was landfilled since 1975, and especially since the late 1990s, using the current data and revised methodology.

Figure 8.3 Comparison between 2008 and 2009 DDOC to landfill estimates



8.2.2.1.2 *Emission factors*

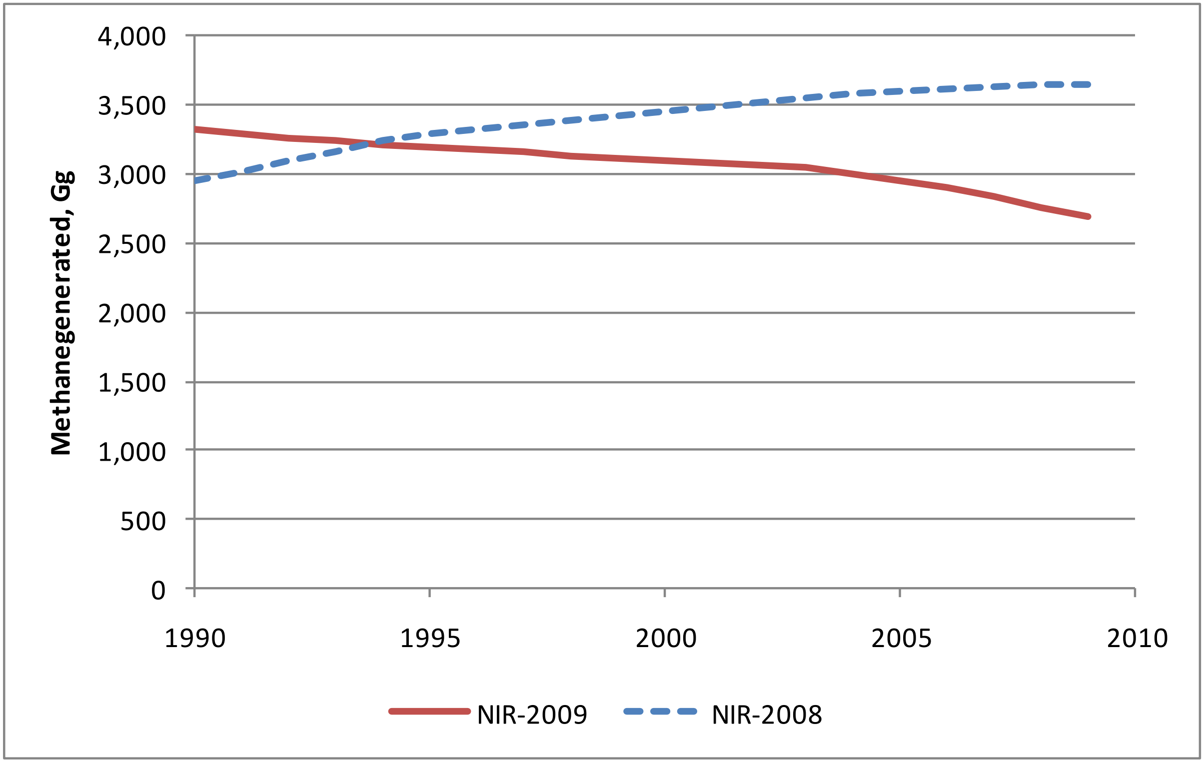
An extensive review of moisture content and degradable carbon content of major categories of materials in waste sent to landfill has been undertaken and has been used to inform the revised values used in MELMod. The approach for determining the proportion of DOC that will decompose under landfill conditions (i.e. DOC_F) has been revised and is now based on evidence from laboratory and landfill reactor studies. This is described in Eunomia's report and summarised in **Annex 3**.

The approach adopted in the previous NIR estimates, which was based on three separate categories of biodegradable waste decomposing at different characteristic rates (so called rapid, moderate and slowly-degrading organic fractions) has been retained for present purposes. However, the method of assignment of materials to each of these pools is now based on the chemical composition, rather than on assumed proportion of each waste material that should report to each pool.

The molar fraction of methane in landfill gas (F) is taken to be 50% for modern landfills and 30% for old shallow sites, which is in line with the IPCC Guidance (IPCC, 1997). These figures are retained from the methodology described in the 2008 NIR.

The amount of methane generated calculated using the new data and methodology for the 2009 NIR is compared in **Figure 8.4** with methane generated according to the 2008 NIR.

Figure 8.4 Comparison between 2008 and 2009 estimates of methane generation

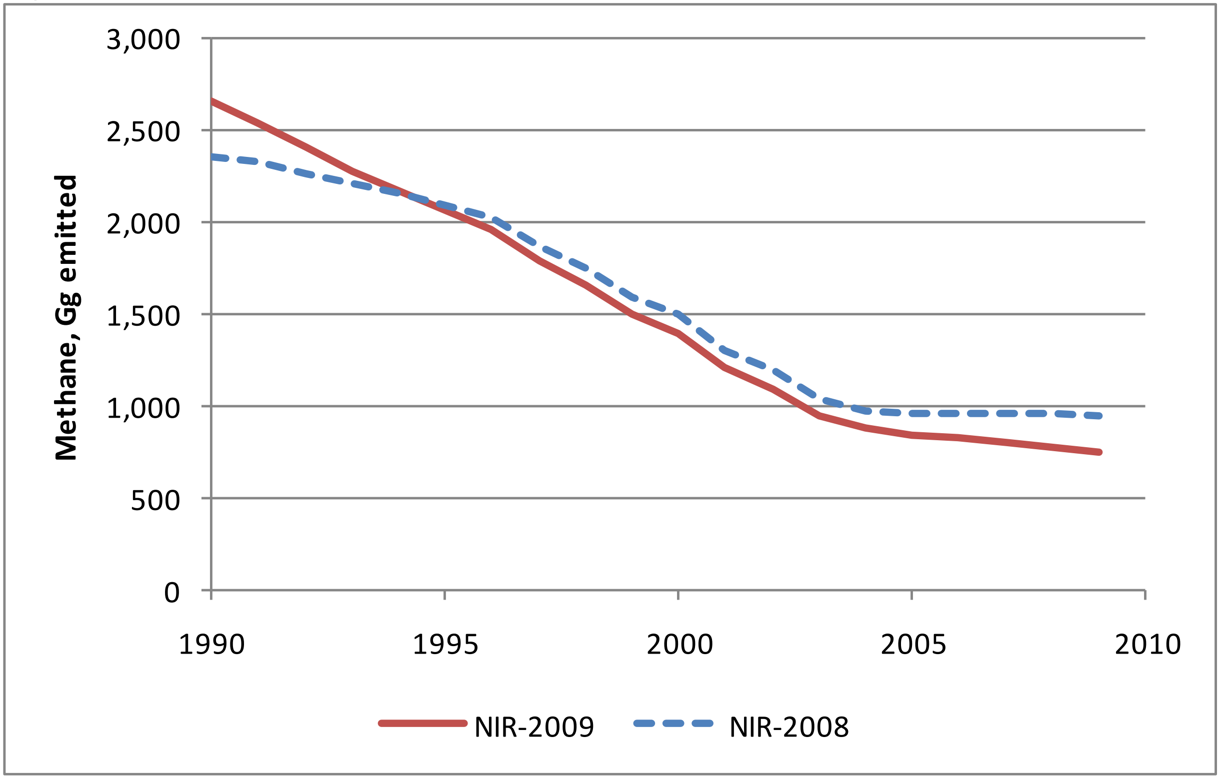


The results indicate that the reduced DDOC to landfill used for the 2009 NIR is reflected in a decrease in methane generated. Furthermore, the revision to the method for allocating DDOC to rapidly, moderately and slowly degrading pools of carbon has resulted in proportionately more reporting to the moderately degrading C pools, compared with rapid and slowly degrading materials.

The peer reviewers decided that there was insufficient evidence to revise the estimated average gas collection efficiency assumed over the lifetime of modern landfills which is therefore retained at the 75% maximum efficiency used in the post 2005 NIRs, with zero recovery from old pre-1980 sites. The proportion of methane that remains uncollected and is oxidised in the surface layers of the landfill is set to 10%, the IPCC default, for all four classes of landfill modelled, a figure retained from all post 2005 NIRs. Further detail is provided in **Appendix 3** of this NIR.

Taking these factors into account, along with the revised estimates of the amount of methane generated results in the current estimate of methane emissions from UK landfills shown in **Figure 8.5**. The corresponding estimate based on the 2008 methodology is shown for comparison. Further details of the quantities of methane formed, recovered, used for power generation, flared, oxidised, and emitted, based on the current data and methodology, are given in **Table A3.8.2** in **Annex 3**. Overall, the current NIR estimates methane emissions from UK landfills to have decreased from 2,667 Gg in 1990 to 756 Gg in 2009.

Figure 8.5 Comparison between 2008 and 2009 estimates of methane emitted



The revised data and methodology indicate that emissions from UK landfills were about 13% higher in 1990 than previously reported, but since 1995, the new approach has indicated increasing less methane to be emitted than the previous methodology. By 2009, emissions are estimated to be almost 21% less when calculated by the revised methodology, compared to the previous approach.

8.2.3 Uncertainties and time-series consistency

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.6.1** to **Table A7.6.5**, 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 1995 they are based on new information compiled by Eunomia (Eunomia, 2011). The new waste to landfill data indicates a significant decrease in the amount of LA-controlled and C&I waste sent to landfill since about 2002 and 2003. Similarly, the approach to calculating DDOC, the main driver behind methane formation, has been reviewed and updated in the light of experimental and field measurements and, where endorsed by peer reviewers, the new data have been incorporated into MELMod.

Uncertainty in collection efficiency is believed to be a major source of uncertainty in overall emission of landfill methane, as discussed further in Appendix 3. Landfill permit conditions require operators to aim for 85% collection efficiency for cells or areas served by gas collection systems and requirements to design and operate landfills to minimise gas escape have strengthened considerably since the 1990s. Reliable data on methane collected for power generation are available (which set a lower limit on the actual gas collection) but better data on landfill gas flaring is needed to determine overall amounts of methane collected. Overall, it is believed that a 75% collection efficiency for methane as an average over the gas-producing life of modern landfills is not excessive, given industry and regulator experience, but further measurements are being pursued to improve confidence in this key factor.

Oxidation of methane in the surface layers of landfills is a further source of uncertainty in overall emissions, but as this only affects methane that is not extracted by a landfill gas collection system, its impact on sites with extensive gas collection is obviously less than in sites lacking active gas collection. According to current estimates, about 69% of methane generated in all UK landfills is recovered – i.e. including old sites without gas collection. The remaining methane is available for oxidation and, in the absence of better data, the IPCC oxidation default factor of 10% is applied to this remainder. There is, however, reason to believe that this may be highly pessimistic, since oxidation rates of 30-90% and higher have widely reported in the literature, and hence emission levels may be over-stated. A particular challenge in deciding on oxidation rates for use in a national landfill model is the high level of variability in field measurements, reflecting a wide range of factors such as nature and porosity of the surface layers, moisture content and temperature, along with methane production rates in the underlying waste.

Some confidence in the current estimate of methane emissions based on the revised national model can be drawn from comparison with the results of a preliminary study that used statistical stratification of landfills, along with site-specific modelling of gas formation (using the Environment Agency's GasSim 2 model), to determine the types of landfill that contribute most to methane emissions. The work was undertaken by Jacobs Engineering (Jacobs Engineering UK Ltd, 2010) for the Environment Agency.

The study estimated total emissions of methane from landfills in England and Wales in 2007 at 732 ± 253 Gg (± 95% confidence interval). To compare this estimate with the current national (UK) estimate, we need to scale up the Jacobs results for England and Wales. This can be done on the basis of relative population. Assuming the population of England and Wales to be 89% of that of the UK (ONS, 2010), the corresponding emissions would be 831±287 Gg methane for the UK. This compares well with the estimate of UK methane emissions for 2007 of 804 Gg methane, based on the revised methodology reported in this NIR (see Table A3.8.2 in Appendix 3).

8.2.4 Source-specific QA/QC and verification

The verification of MELMod has been described in the 2008 NIR. The updating undertaken by Eunomia (Eunomia, 2011) in 2010 has resulted in updating of input data to the model only, with no changes implemented as to calculation methodology other than where indicated above, so no revision of the 2008 NIR is required in this respect.

8.2.5 Source-specific recalculations, if applicable, including changes made in response to the review process

Emissions of methane from this source have decreased by 3.7 Mt CO_2e as a result of the inclusion of the revised data from the Eunomia (Eunomia, 2011) research (detailed in **Section 8.2.2**).

8.2.6 Source-specific planned improvements

Emission factors, model parameters, and activity data will be kept under review including the possible use of weighbridge returns to improve activity data. Defra and the environmental regulatory agencies in the UK are funding a pilot study to measure methane emissions from a representative selection of landfills of different ages and regulatory control regimes whilst simultaneously measuring surface soil methane oxidation rates. This research will be used with estimates of methane flared at landfills to revise the calculations of methane capture rates and hence provide better evidence to support reworked estimates of landfilled waste emissions in the UK. Depending on the results of the pilot study, and any further research in this area, it is possible that MELMod may be further updated in the 2012 NIR.

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 inventory compilation method for methane estimates from water treatment and sewage sludge treatment and disposal is based on activity data from the water industry annual reporting system to UK industry regulators (for 2000 onwards) and an historic time series of sludge treatment data published by Defra (Defra EPSIM data, 2004). The UK Water Industry Research organisation has developed a spreadsheet emissions estimator tool, drawing upon available emission factors for sub-processes within the industry, and each UK water company uses this tool to estimate its annual emissions. From these reported emissions and activity data, implied emission factors for specific emission sub-sources can be derived.

Emissions data have only been made available for the year 2008, and hence the Implied Emission Factors from 2008 have been applied to the activity data across all years. The use of such a limited dataset is not ideal, and the uncertainties in the emission estimates, especially for earlier years in the time series, are regarded as high. Further work is proposed to investigate a more representative time series of emission factors for future inventory work, through further consultation with the industry.

In addition, a detailed split of sewage sludge disposal routes is not available for all companies for all years. Since 1997, each company in England and Wales has reported this level of detail to the industry regulator, OFWAT. In Scotland the data are available since 2002, from the Water Commissioner for Scotland, In Northern Ireland, fully disaggregated data are only available from the water regulator, UREGNI, since 2007. Further research is needed to seek out additional data from the early 2000s in Scotland and Northern Ireland.

Nitrous oxide emissions from the treatment of human sewage are based on the IPCC (1997) default methodology. The most recent average protein consumption per person is based on the Expenditure and Food Survey (Defra, 2009). For the purposes of the 2009 estimates within the inventory, the Expenditure and Food Survey 2009 was not available in time, and therefore the data for 2008 has been used as a best estimate.

8.3.3 Uncertainties and Time-Series Consistency

The most recent average protein consumption per person is based on the Expenditure and Food Survey (Defra, 2009). In previous years there was a step change in the reported protein consumption data between 1996 and 1997. This is because Defra revised their publication (formally National Food Survey) and in doing so revised the method used to calculate protein consumption, but only back to 1997, before which a step change was evident. Defra now produce a time series of the estimates of the small amount of additional protein from consuming meals eaten outside the home; this intake is called “eating out intakes”. This time series is only available from 2000 onwards. For values between 1990 and 2000, an average of the data available has been applied. The sum of the “household intakes” and “eating out intakes” then provides the total protein consumption per year per person. This new data and methodology from Defra improves the consistency in the method and overcomes the step change that was previously evident in the reported data between 1996 and 1997.

8.3.4 Source Specific QA/QC and Verification

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

8.3.5 Source Specific Recalculations

The research during 2010 has engaged with the carbon management experts within UK water companies, water industry policy leads with in Defra, as well as the industry regulators (OFWAT, Water Commissioner for Scotland and UREGNI), and the UK Water Industry Research (UKWIR) panel that develops industry reporting tools. This research has gathered new data on methane and nitrous oxide emissions from several water companies, split out according to sub-source, as outlined in the methodology text above. Six UK water companies have provided new emissions data, and the aggregated factors from their reported activities and emissions have been developed and applied across UK-wide activity statistics available from OFWAT, WCS and UREGNI. From the sub-source-specific activity data and emission estimates, an overall industry methane emission factor has been derived, using the total mass of sewage sludge dry solids arisings as the activity data.

For nitrous oxide emissions from sewage treatment, a consistent time series of protein consumption has been identified and is now in use across the time series, retaining the previous estimation methodology. Consultation with the water industry has identified new data on nitrous oxide emissions from some sources within waste water treatment works, but the scope of these industry data are not thought to be comprehensive, and hence have been disregarded at this stage; further work is needed to confirm the scope of industry estimates and derive new estimates that are based on a more detailed analysis of the UK water industry treatment and disposal systems than the current method provides.

8.3.6 Source Specific Planned improvements

Although good progress has been made in this inventory cycle to improve the methodology for methane emissions from waste water treatment and sewage sludge disposal, further industry consultation is planned to:

i) Further investigate the data available from the UKWIR spreadsheet tool, seeking to ensure that the emission factors applied to the June Returns activity data are representative of the industry activity and emissions from all across the UK;
ii) Seek data inputs from more of the UK water companies, building on the example of those that reported emissions data this year;
iii) Obtain industry feedback on how to improve the emission estimates from earlier in the time series, reviewing the current approach of back-extrapolation of emission factors from more recent research which introduces additional uncertainty;
iv) Investigate further the ongoing industry research into nitrous oxide emissions from water treatment processes, to determine whether a more UK-specific methodology can be developed which provides a comprehensive coverage of emissions.

The investment of time and resources into taking these improvement actions forward will be determined by the NISC, taken in context of the available inventory research budget and the level of priority assigned to these estimates, accounting for their significance in the UK GHGI emission totals.

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 (estimated in AEA Technology, 2002).. 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.

Emissions of CO_2 and N_2O from accidental vehicle fires are not estimated as there are no suitable emission factors available.
N_2O emissions from chemical waste incineration are not estimated as this is a high temperature combustion process and therefore emissions are considered insignificant.

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 Pollution Inventory (Environment Agency, 2010). This only covers England and Wales, but there are not thought to be any plants in Scotland and Northern Ireland. 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 plants 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 for individual years, 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.

Recent activity data for some individual chemical waste, clinical waste and sewage sludge incinerators have been provided by the Environment Agency. These data have been used to improve the estimates for recent UK-level activity.

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 (2010).

All UK plants used to incinerate municipal solid waste (MSW) are now required to be fitted with boilers to raise power and heat, and their emissions are currently reported under CRF source category 1A1 (for electricity generation) and 1A4 (for heat generation), rather than 6C (Waste Incineration). Following a review of procedures, it is now recommended that, in the next version of the inventory, emissions for both electricity and heat generation are reported under 1A1.

Prior to 1997, at least some MSW was burnt in older plant without any 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 Recalculations

Revisions to activity data lead to decreases in estimated emissions for clinical (108 Gg CO_2) and chemical waste incineration (13 Gg CO_2).

8.4.6 Source Specific Planned improvements

Emission estimates for chemical waste incineration currently do not include the burning of chemical wastes in flares and it is unclear whether these emissions might be included in the estimates reported in 2B5. No evidence has been found for any chemical waste incineration processes carried out in Scotland or Northern Ireland, and so emissions in these regions are assumed to be zero. The need to deal with significant gaps in the reported data means that estimates are quite uncertain. Emission estimates for clinical waste, animal carcass and sewage sludge incineration are also quite uncertain and ideally would be improved. However, all incineration processes are relatively minor sources of greenhouse gases and further development of the methodology is not a priority.

9 Other (CRF Sector 7)

9.1 OVERVIEW OF SECTOR

No emissions are reported in Sector 7.

Other (CRF Sector 7) 9

10 Recalculations and Improvements

This section of the report summarises the recalculations and improvements made to the UK GHG inventory since the 2010 NIR (2008 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 2009 GHG inventory, please see **Annex 9**.

Each year, the UK greenhouse inventory is:

- ***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 be revised. Updating also covers 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 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 2008; this report gives emission estimates for 2008, and includes estimates for the year 2009 also.

The inventory may also be *expanded* to include emissions from additional sources if a new source has been identified within the context of the IPCC Guidelines and Good Practice Guidance, and there are sufficient activity data and suitable emission factors.

10.1 EXPLANATIONS AND JUSTIFICATIONS FOR RECALCULATIONS

Table 10.1 and **Table 10.2** summarise the recalculations that have occurred in estimates of the direct GHGs since the 2010 NIR (2008 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 2008 (**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 GWP weighted and 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 (2009 inventory; 2011 NIR); and
PS = Previous Submission (2008 inventory, 2010 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 **Recalculations of direct GHG emissions for the year 2008 in the UK 2011 NIR (2009 inventory) – including KP-LULUCF inventory.**

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2009 inventory minus emissions in 2008 inventory)	Change in emissions (%) (Percentage change relative to the 2008 inventory)	Brief description of reasons for Re-Calculation
1A1			
CO_2	-497.8	0%	The power stations database has been reviewed and the amount of fuel oil allocated to power stations has been reduced. This has also caused a small increase to the amount of MSW allocated to power stations. Petroleum coke activity data revised to be consistent with CITL (Community Independent Transaction Log) values. Revision to the EF for OPG which is now based on EU ETS data and used across the time series.
CH_4	0.8	0%	The power stations database has been reviewed and the amount of fuel oil allocated to power stations has been reduced. This has also caused a small increase to the amount of MSW and natural gas allocated to power stations. Petroleum coke activity data revised to be consistent with CITL values.
N_2O	-6.5	0%	The power stations database has been reviewed and the amount of fuel oil allocated to power stations has been reduced. This has also caused a small increase to the amount of MSW and natural gas allocated to power stations. Petroleum coke activity data revised to be consistent with CITL values.
1A2			
CO_2	2817.9	4%	Revised lime methodology lead to a reallocation of gas consumption in other industrial combustion. Revision to waste oil in cement methodology following research into the impact of the Waste Incineration Directive (WID) has lead to a reallocation of lubricants. EU ETS EFs now used from 2005 for Colliery methane and from 2008 for OPG and petroleum coke; EFs for earlier years are interpolated from these.
CH_4	7.1	3%	Revised lime methodology lead to a reallocation of gas consumption in other industrial combustion. Revision to waste oil in cement methodology following research into the impact of the Waste Incineration Directive (WID) has lead to a reallocation of lubricants. Revised GCVs for LPG gas oil fuel oil lubricants and waste oils.
N_2O	94.2	8%	Revised lime methodology lead to a reallocation of gas consumption in other industrial combustion. Revision to waste oil in cement methodology following research into the impact of the Waste Incineration Directive (WID) has lead to a reallocation of lubricants. New EFs included for OPG and town gas in other industrial combustion and for natural gas, scrap tyres, waste oils, waste solvents and waste in the cement industry. Revised GCVs for coke, petroleum coke, coal, LPG, gas oil, fuel oil, lubricants and waste oils.

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2009 inventory minus emissions in 2008 inventory)	Change in emissions (%) (Percentage change relative to the 2008 inventory)	Brief description of reasons for Re-Calculation
1A3			
CO_2	-3882.7	-3%	Reallocation of shipping emissions between international and domestic based on new port movement data. Reclassification of flights between UK and relevant Overseas Territories as domestic rather than international. Revised activity data for freight railways from the ORR for all years. Revised data for passenger rail from 2005 onwards. Road transport - updated distribution of vkm data between road types and between buses and coaches. Update to vkm data for motorcycles.
CH_4	0.7	0%	Reallocation of shipping emissions between international and domestic based on new port movement data. Reclassification of flights between UK and relevant Overseas Territories as domestic rather than international. Revised activity data for freight railways from the ORR for all years. Revised data for passenger rail from 2005 onwards. Road transport - updated distribution of vkm data between road types and between buses and coaches. Update to vkm data for motorcycles.
N_2O	-60.4	-4%	Reallocation of shipping emissions between international and domestic based on new port movement data. Reclassification of flights between UK and relevant Overseas Territories as domestic rather than international. Revised activity data for freight railways from the ORR for all years. Revised data for passenger rail from 2005 onwards. Road transport - updated distribution of vkm data between road types and between buses and coaches. Update to vkm data for motorcycles.
1A4			
CO_2	-2710.3	-3%	New petroleum coke activity data and a new EF based on carbon content measurements for domestic petroleum coke. The change occurs across the time series. Increase in gas oil allocated to this sector due to changes in the allocation to rail, shipping and off road machinery.
CH_4	-16.2	-3%	New petroleum coke activity data and a new EF based on carbon content measurements for domestic petroleum coke. The change occurs across the time series. Increase in gas oil allocated to this sector due to changes in the allocation to rail, shipping and off road machinery.
N_2O	-14.5	-2%	New petroleum coke activity data and a new EF based on carbon content measurements for domestic petroleum coke. The change occurs across the time series. Increase in gas oil allocated to this sector due to changes in the allocation to rail, shipping and off road machinery.

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2009 inventory minus emissions in 2008 inventory)	Change in emissions (%) (Percentage change relative to the 2008 inventory)	Brief description of reasons for Re-Calculation
1A5			
CO_2	-182.5	-6%	Revised fuel consumption data for military aviation and naval shipping supplied by the defence fuels group.
CH_4	-0.1	-5%	Revised fuel consumption data for military aviation and naval shipping supplied by the defence fuels group.
N_2O	-1.6	-6%	Revised fuel consumption data for military aviation and naval shipping supplied by the defence fuels group.
1B1			
CO_2	104.2	79%	Revision to activity statistics for coke oven gas flaring and SSF production
CH_4	-0.1	0%	Change to the precision of activity statistics used for coal production.
1B2			
CO_2	-141.0	-3%	Revision to method for calculation of weighted average composition of natural gas. Offshore oil and gas processing activities reported separately to aid transparency. New source - gas leakage at point of use.
CH_4	-20.9	0%	Revision to method for calculation of weighted average composition of natural gas. Offshore oil and gas processing activities reported separately to aid transparency. New source - gas leakage at point of use.
N_2O	0.4	1%	Offshore oil and gas processing activities reported separately to aid transparency.
2A			
CO_2	-320.5	-4%	Method for glass production emissions estimates revised to use time series from British Glass
2B			
CO_2	18.4	1%	Revised estimate for breakdown of household products based on revised household statistics
CH_4	-2.5	-4%	Revised estimate for breakdown of household products based on revised household statistics
2C			
CO_2	-3.3	0%	Revision to emission factor for blast furnace gas based on carbon balance approach
PFC	-0.5	0%	Revision to emission data supplied by one of the operators
2F			
HFC	-395.8	-4%	Updates made to emissions from refrigeration and foams based on the peer review of the UK inventory. Revised data for aerosols supplied by BAMA Small revision to statistics for the Overseas Territories
PFC	0.0	0%	Updates made to emissions from refrigeration based on the peer review of the UK inventory. Small revision to statistics for the Overseas Territories

Source category and GHG	**Change in emissions ($GgCO_2eq$)** (Emissions in 2009 inventory minus emissions in 2008 inventory)	**Change in emissions (%)** (Percentage change relative to the 2008 inventory)	**Brief description of reasons for Re-Calculation**
SF6	-0.1	0%	Small revision to statistics for the Overseas Territories
4A			
CH_4	-0.5	0%	Change to live stock statistics for deer
4B			
CH_4	-0.5	0%	Change to live stock statistics for deer
N_2O	0.0	0%	
4D			
N_2O	1716.0	7%	New source - application of sewage sludge to agricultural land. Sewage sludge is now included in non fuel fertilisation for N_2O. Correction to method for nitrogen leaching and run-off to remove correction for N volatilisation
5A			
CO_2	122.2	-1%	Countryside Survey update, and a restructuring of forest categories using 20 year transition rather than pre- and post-1990
CH_4	0.2	2%	Countryside Survey Update - not previously included
N_2O	0.3	14%	Countryside Survey Update
5B			
CO_2	-2398.3	-16%	Splitting grassland conversion between pasture and Semi-natural. Some reallocations between cropland and grassland. LUC methods update (1990-1999), Countryside Survey data update (2000-2009)
CH_4	0.4	-	Reported for first time
N_2O	645.1	-	Reported for first time
5C			
CO_2	-479.1	6%	Some reallocations between cropland and grassland. LUC methods update (1990-1999), Countryside Survey data update (2000-2009)
CH_4	5.1	63%	Countryside Survey data update (2000-2009)
N_2O	0.5	63%	Countryside Survey data update (2000-2009)
5D			
CO_2	282.1	-	Now reporting some wetlands emissions but no requirement to report drainage
N_2O	0.6	-	Now reporting some wetlands emissions but no requirement to report drainage

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2009 inventory minus emissions in 2008 inventory)	Change in emissions (%) (Percentage change relative to the 2008 inventory)	Brief description of reasons for Re-Calculation
5E			
CO_2	-174.3	-3%	LUC methods update (1990-1999), Countryside Survey data update (2000-2009) Felling licence data update
CH_4	1.3	25%	LUC methods update (1990-1999), Countryside Survey data update (2000-2009) Felling licence data update
N_2O	0.1	25%	LUC methods update (1990-1999), Countryside Survey data update (2000-2009) Felling licence data update
5G			
CO_2	14.6	-1%	Felling licence data update
6A			
CH_4	-3736.0	-18%	Major review and update to the model used to estimate emissions from landfilled waste. A new time series of waste sent to landfill and waste composition has been identified and is now used.
6B			
CH_4	-456.3	-56%	Major review and update to method used for estimating methane emissions from waste water treatment. New emission factors obtained from the water companies. New time series of activity data identified and used.
N_2O	125.5	10%	Consistent time series of protein consumption data identified and used.
6C			
CO_2	-120.3	-29%	Reallocation of certain sites from chemical waste incineration to other sectors. Revised activity data for clinical waste incineration identified from 2006 onwards. Earlier years interpolated.
CH_4	-0.2	-4%	Revised activity data identified for clinical waste and sewage sludge incineration. Data for earlier years interpolated. 2008 activity data now used for accidental vehicle fires.
N_2O	-5.5	-11%	Revised activity data identified for clinical waste and sewage sludge incineration. Data for earlier years interpolated.

Table 10.2 Recalculations of direct GHG emissions for the base year in the UK 2011 NIR (2009 inventory).

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2009 inventory minus emissions in 2008 inventory)	Change in emissions (%) (Percentage change relative to the 2008 inventory)	Brief description of reasons for Re-Calculation
1A1			
CO_2	-1908.4	-1%	The power stations database has been reviewed and the amount of fuel oil allocated to power stations has been reduced. Revisions to energy statistics for coal in power stations and natural gas in power stations, refineries and gas production. EU ETS data are now used for sour gas and LPG/OPG at gas separation plant. EF revised for colliery methane (based on time series average for natural gas); for Other Petroleum Gases (OPG) (based on EU ETS data which are used across the time series) and sour gas based on power stations data review.
CH_4	-0.6	0%	The power stations database has been reviewed and the amount of fuel oil allocated to power stations has been reduced. Revisions to energy statistics for coal in power stations and natural gas in power stations refineries and gas production. Emission factors for oils revised due to revisions to the Gross Calorific Value (GCV).
N_2O	-7.1	0%	The power stations database has been reviewed and the amount of fuel oil allocated to power stations has been reduced. Revisions to energy statistics for coal in power stations and natural gas in power stations refineries and gas production. Emission factors for oils and coal revised due to revisions to the GCV.
1A2			
CO_2	1037.7	1%	During the power stations revisions, changes were made to the amount of fuel oil allocated to this sector. Since total fuel oil use in the UK is reconciled with the DUKES data, fuel oil has been reallocated from power stations to other industry. Method of calculating activity data in lime production reviewed and improved. This also causes reallocation of petroleum coke and gas and coal and coke in other industry.

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2009 inventory minus emissions in 2008 inventory)	Change in emissions (%) (Percentage change relative to the 2008 inventory)	Brief description of reasons for Re-Calculation
CH_4	0.6	0%	During the power stations revisions, changes were made to the amount of fuel oil allocated to this sector. Since total fuel oil use in the UK is reconciled with the DUKES data, fuel oil has been reallocated from power stations to other industry. The method for calculating activity data in lime production has been reviewed and improved. This also causes reallocation of petroleum coke and gas and coal and coke in other industry. Emission factors for LPG, gas oil, fuel oil and lubricants revised due to revisions to the GCV.
N_2O	6.7	0%	During the power stations revisions, changes were made to the amount of fuel oil allocated to this sector. Since total fuel oil use in the UK is reconciled with the DUKES data, fuel oil has been reallocated from power stations to other industry. Method of calculating activity data in lime production reviewed and improved. Also causes reallocation of petroleum coke and gas and coal and coke in other industry. The method for calculating activity data in lime production has been reviewed and improved. This also causes reallocation of petroleum coke and gas and coal and coke in other industry. Emission factors for coke, petroleum coke, coal, LPG, gas oil, lubricants and waste oils revised due to revisions to the GCV.
1A3			
CO_2	-2397.9	-2%	Reallocation of shipping emissions between international and domestic based on new port movement data. Reclassification of flights between UK and relevant Overseas Territories as domestic rather than international. DfT provided revised assumptions for fuel efficiency for HGVs in 2008 only, and vkm for HGVs within the LEZ in 2008 only. Road transport - updated distribution of vehicle km (vkm) data between road types and between buses and coaches. Update to vkm data for motorcycles. Revised activity data for freight railways from the Office of Rail Regulation (ORR) for all years. Revised data for passenger rail from 2005 onwards. New source of fuel consumption data from freight and intercity rail.

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2009 inventory minus emissions in 2008 inventory)	Change in emissions (%) (Percentage change relative to the 2008 inventory)	Brief description of reasons for Re-Calculation
CH_4	-1.3	0%	Emissions of CH_4 from LPG vehicles estimated for the first time in 2009 inventory. Reallocation of shipping emissions between international and domestic based on new port movement data. Reclassification of flights between UK and relevant Overseas Territories as domestic rather than international. Road transport - updated distribution of vkm data between road types and between buses and coaches. Update to vkm data for motorcycles. New source of fuel consumption data from freight and intercity rail.
N_2O	-41.3	-3%	Emissions of N_2O from LPG vehicles estimated for the first time in 2009 inventory. Reallocation of shipping emissions between international and domestic based on new port movement data. Reclassification of flights between UK and relevant Overseas as domestic rather than international. Road transport - updated distribution of vkm data between road types and between buses and coaches. Update to vkm data for motorcycles. New source of fuel consumption data from freight and intercity rail.
1A4			
CO_2	48.0	0%	New petroleum coke activity data and a new EF based on carbon content measurements for domestic petroleum coke. The change occurs across the time series. Increase in gas oil allocated to this sector due to changes in the allocation to rail, shipping and off road machinery. Revision to DUKES gas consumption figures.
CH_4	2.3	0%	New petroleum coke activity data and a new EF based on carbon content measurements for domestic petroleum coke. The change occurs across the time series. Increase in gas oil allocated to this sector due to changes in the allocation to rail, shipping and off road machinery. Revision to DUKES gas consumption figures.
N_2O	2.9	0%	New petroleum coke activity data and a new EF based on carbon content measurements for domestic petroleum coke. The change occurs across the time series. Increase in gas oil allocated to this sector due to changes in the allocation to rail, shipping and off road machinery. Revision to DUKES gas consumption figures.

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2009 inventory minus emissions in 2008 inventory)	Change in emissions (%) (Percentage change relative to the 2008 inventory)	Brief description of reasons for Re-Calculation
1B2			
CO_2	-0.1	0%	Revision to method for calculation of weighted average composition of natural gas. Revisions to EEMS. New source - gas leakage at point of use. Offshore oil and gas processing activities reported separately to aid transparency.
CH_4	18.9	0%	Revision to method for calculation of weighted average composition of natural gas. Revisions to EEMS. New source - gas leakage at point of use. Offshore oil and gas processing activities reported separately to aid transparency.
2A			
CO_2	32.2	0%	Method for glass production emissions estimates revised to use time series from British Glass
2F			
HFC	-22.1	-1%	Updates made to emissions from refrigeration based on the peer review of the UK inventory. Small revision to statistics for the Overseas Territories
PFC	0.0	0%	Updates made to emissions from refrigeration based on the peer review of the UK inventory. Small revision to statistics for the Overseas Territories
4A			
CH_4	-0.4	0%	Change to live stock statistics for deer
4B			
CH_4	-0.3	0%	Change to live stock statistics for deer
4D			
N_2O	1684.6	6%	New source - application of sewage sludge to agricultural land. Sewage sludge is now included in non fuel fertilisation for N_2O. Correction to method for nitrogen leaching and run-off to remove correction for N volatilisation
5A			
CO_2	0.0	0%	Countryside Survey update, and a restructuring of forest categories using 20 year transition rather than pre- and post-1990
CH_4	0.0	0%	Countryside Survey data update (2000-2009) - not previously included
N_2O	-1.3	-19%	Countryside Survey data update (2000-2009)

Source category and GHG	**Change in emissions ($GgCO_2eq$)** (Emissions in 2009 inventory minus emissions in 2008 inventory)	**Change in emissions (%)** (Percentage change relative to the 2008 inventory)	**Brief description of reasons for Re-Calculation**
5B			
CO_2	-127.5	-1%	Splitting grassland conversion between pasture and Semi-natural. Some reallocations between cropland and grassland. LUC methods update (1990-1999), Countryside Survey data update (2000-2009)
CH_4	0.1	-	Reported for first time
N_2O	781.8	-	Reported for first time
5C			
CO_2	-130.1	2%	Some reallocations between cropland and grassland. LUC methods update (1990-1999), Countryside Survey data update (2000-2009)
CH_4	-0.1	-4%	Countryside Survey data update (2000-2009)
N_2O	0.0	-4%	Countryside Survey data update (2000-2009)
5D			
CO_2	422.3	-	Now reporting some wetlands emissions but no requirement to report drainage
N_2O	4.0	-	Now reporting some wetlands emissions but no requirement to report drainage
5E			
CO_2	-36.3	-1%	Land Use Change (LUC) methods update (1990-1999), Countryside Survey data update (2000-2009) Felling licence data update
CH_4	9.2	98%	LUC methods update (1990-1999), Countryside Survey data update (2000-2009) Felling licence data update
N_2O	0.9	98%	LUC methods update (1990-1999), Countryside Survey data update (2000-2009) Felling licence data update
5G			
CO_2	73.7	-4%	Felling licence data update
KP-LULUCF Inventory			
3.3 Afforestation			
CO_2	-0.04	0%	Revised area of planting in England in 2008

Source category and GHG	**Change in emissions ($GgCO_2eq$)** (Emissions in 2009 inventory minus emissions in 2008 inventory)	**Change in emissions (%)** (Percentage change relative to the 2008 inventory)	**Brief description of reasons for Re-Calculation**
N_2O	0.00	35%	New Countryside Survey data has changed distribution of land converted to forest, EF has also been changed to that used in the 2006 guidelines
3.3 Deforestation			
CO_2	16.66	3%	Updated activity dataset for all countries
CH_4	0.17	27%	Updated activity dataset for all countries, affects biomass burning emissions
N_2O	0.00	39%	Updated activity dataset for all countries, affects biomass burning emissions. N2O emissions from deforestation to Cropland included for first time.
3.4 Forest Management			
CO_2	-12.52	0%	FM area is adjusted to take account of losses due to deforestation
CH_4	0.01	1%	Wildfire activity data has been revised for 2008
N_2O	0.00	2%	Wildfire activity data has been revised for 2008
6A			
CH_4	6400.1	13%	Major review and update to the model used to estimate emissions from landfilled waste. A new time series of waste sent to landfill and waste composition has been identified and is now used.
6B			
CH_4	-422.3	-60%	Major review and update to method used for estimating methane emissions from waste water treatment. New emission factors obtained from the water companies. New time series of activity data identified and used.
N_2O	217.3	21%	Consistent time series of protein consumption data identified and used.
6C			
CO_2	5.9	0%	Reallocation of certain sites from chemical waste incineration to other sectors.

10.1.1 KP-LULUCF Inventory

Recalculations in the KP LULUCF Inventory are detailed in **Table 11.3** in **Section 11.3**.

10.2 IMPLICATIONS FOR EMISSION LEVELS

10.2.1 GHG Inventory

The implications for emission levels in the year 2008, including the KP-LULUCF inventory are summarised by sector in **Table 10.1**, and the overall effect for individual years is shown in **Figure 10.2**.

10.2.2 KP-LULUCF Inventory

Recalculations in the KP LULUCF Inventory are detailed in **Table 11.3** in **Section 11.3**.

10.3 IMPLICATIONS FOR EMISSION TRENDS, INCLUDING TIME SERIES CONSISTENCY

10.3.1 GHG Inventory

The effects of the recalculations and improvements made in the 2009 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 2008 inventory.

Figure 10.1 summarises the effect of the recalculations in the 2011 NIR (2009 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 2008 and 2009, according to IPCC source sector. A negative difference indicates a decline in GWP emission between the inventory presented in the 2011 NIR (2009 inventory), and the inventory presented in the 2010 NIR (2008 inventory). The LULUCF totals are presented as net emissions.

Figure 10.2 summarises the effect of the recalculations in the 2011 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 2008 and 2009.

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 (2009 inventory; 2011 NIR); and
PS = Previous Submission (2008 inventory, 2010 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 (DECC, 2010). The changes in the time series of GWP emissions in **Figure 10.2** reflect these enhancements. A summary of the key reasons for the changes are given below. More detailed information is given in the sections describing the source-specific recalculations given in **Chapters 3 to 8**.

Reasons for changes in GWP emissions in the base year

- Recalculations in the base year have led to a net increase in emissions of 5674 Gg CO_2 eq;
- The largest single change to emissions in the base year was an increase of 6400 Gg CO_2 eq of CH_4 in IPCC sector 6A1. This follows a review of the inputs to the waste to landfill model.
- Emissions from domestic shipping have decreased by 2381 Gg CO_2 eq following revisions to the shipping model based on research into shipping movements.
- Emissions from agricultural soils have increased by 1685 Gg CO_2 eq of N_2O due to a new source being included in the inventory this year – application of sewage sludge to agricultural land.

Reasons for changes in GWP emissions in 2008

- Recalculations in 2008 have led to a decrease in emissions of 9671 Gg CO_2 eq;
- The largest single change to emissions in 2008 was a decrease of 3736 Gg CO_2 eq of CH_4 in IPCC sector 6A1. This follows a review of the inputs to the waste to landfill model.
- Emissions from domestic shipping have decreased by 3784 Gg CO_2 eq following revisions to the shipping model based on research into shipping movements.
- Other fuel combustion emissions have decreased by 725 Gg CO_2 eq overall, due to a combination of revisions to national energy statistics, revisions to the power stations database and revisions to methodology for estimating fuel consumption in the lime sector.
- Emissions from agricultural soils have increased by 1716 Gg CO_2 eq of N_2O due to a new source being included in the inventory this year – application of sewage sludge to agricultural land.
- Emissions from the LULUCF sector have decreased by 1979 Gg CO_2 eq due mostly to the inclusion of the latest Countryside Survey in the methodology.

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.

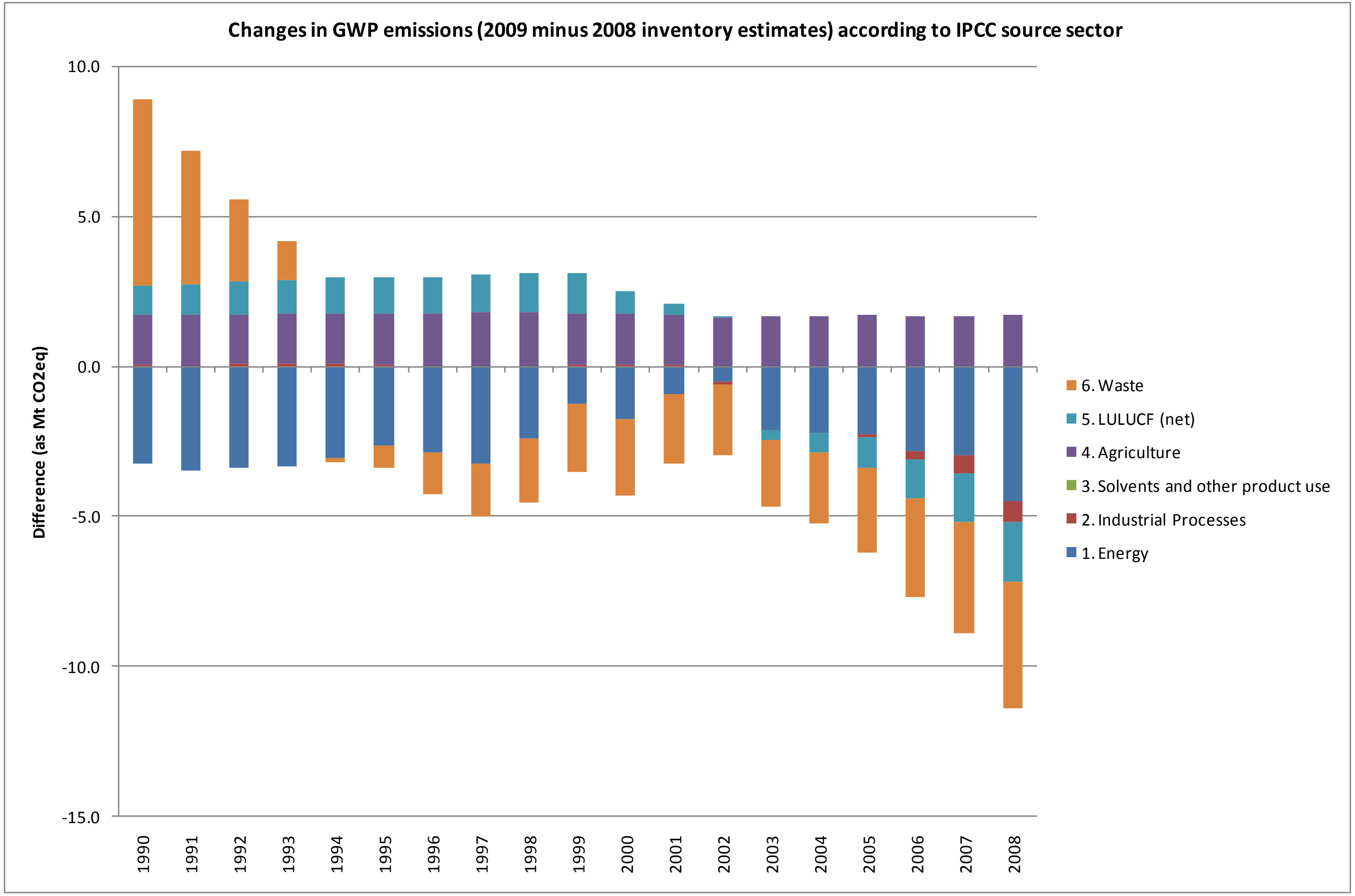
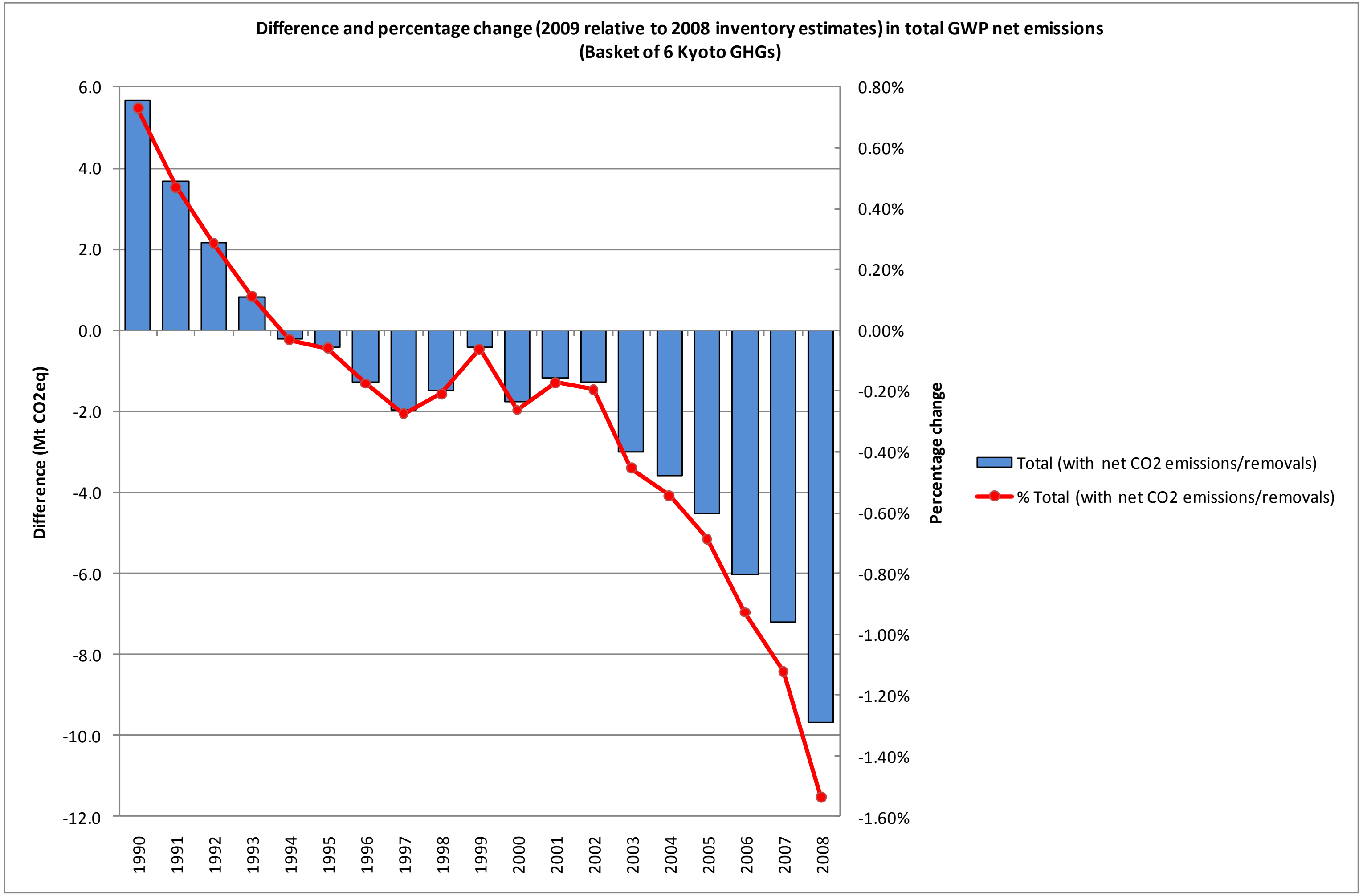


Figure 10.2 Time series of changes in total net GWP emissions, and percentage changes in total net GWP emissions, between the inventory presented in the current and the previous NIR.



10.3.2 KP-LULUCF Inventory

Recalculations in the KP LULUCF Inventory are detailed in **Table 11.3** in **Section 11.3**.

10.4 RESPONSE TO THE REVIEW PROCESS

10.4.1 GHG Inventory

The UNFCCC conducted a Centralised Review of the 2010 greenhouse gas inventory submission (2010 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 (2010) submission. The review took place during September 2010 in Bonn, Germany.

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 Summary of FCCC and EC Review Comments and UK GHGI Responses

Expert Review Team Comment	UK GHGI Actions
UNFCCC Centralised Review, September 2010	
Energy - Noted in ARR 2009 para 51; emissions from manufacturing industries are reported aggregated under CRF 1A2f. This significantly reduces transparency. In your response to the review process you indicated that AD exists but a lot of work was needed to make the appropriate revisions. Could you please give us an update, what progress has been made in this issue?	UK energy statistics do not provide a consistent time-series at a level of detail that enables disaggregation down to 1A2a, b, c, d, e and f back to 1990. This issue is a high priority item on the UK GHGI Improvement Programme, and work is ongoing in consultation with the UK energy stats team in DECC, in order to derive a “best estimate” of the detailed energy breakdown that is needed to underpin estimates back to 1990. We expect to be able to report at a more detailed level within the 1990-2010 inventory.
Energy - According to NIR, time series on refinery use of petroleum coke are not consistent. EU ETS data are used 2005-2008 but emissions 1990-2004 are estimated with an older method. In NIR, you state that you might have to revise 90-04 but that this has not been done yet. What are the plans for submission 2011?	We analysed EU ETS data and found that the figures for petroleum coke burnt at refineries were not consistent with UK energy statistics. We discussed this with the energy statistics team at DECC, and found that there was a known problem with fuel consumption data submitted by a couple of UK refineries. These problems started with the introduction, in 2004, of a new reporting system for refinery fuel use. DECC are modifying the system, to ensure correct data are submitted in future, but the historical data will not be corrected. We have therefore used EU ETS data for 2005-2009 as being the most accurate. The collection of data prior to the introduction of the new reporting system was not affected by these errors, so there is no need to modify these data.
Energy - For source category 1B2b all activity data and emissions are reported under 1B2b iv. You have indicated that you could look at splitting out transmission and distribution losses	This has been identified as a priority task on the UK Inventory Improvement Programme. Work has been conducted in 2010 to clarify the scope of the current estimates and to generate new estimates

Expert Review Team Comment	UK GHGI Actions
but that you would have to talk to the gas companies (the data suppliers) about doing this. Could you please give us an update on this issue, what is the status today?	for a previously missing source: gas leakage at the point of use. The disaggregation of upstream leakage into different sub-sectors has not been completed at this stage. Further work is needed.
Energy - Regarding the use of EU ETS data in the inventory: The NIR is transparent on how EU ETS data are used within the inventory, including the analysis in annex 11. The QC routines also seems to be ok. We would however like to know more about following issues: • How do you account for sources not covered by the EU ETS? More specific: When conducting energy statistics surveys, it is common to use a sample survey and not ask all plants. This because of economic limits and to not put to much burden on smaller respondents. Then there is always some plants that will not respond to the survey. It is normal to make some kind of enumeration for sample error and plants not responding in the data so that published data can represent also small plants and plants not responding. You make an enumeration factor for each sector, and you multiply all data in the energy survey with this factor. You can apply the enumeration on the aggregate level or you can calculate an enumerated fuel consumption for each responding plant, so that each plant will get a little to high fuel consumption, but on the aggregate level it will be OK because of plants not included in the sample and plants not responding. OK. But when you start mixing data sources you might have problems. If you use EU ETS data, how do you assure that emissions from plants not in the energy survey (due to sample or non response) are accounted for correctly? • How do you deal with inconsistencies between EU ETS and energy statistics? With this we mean different definitions for combustion emissions/fugitive emissions/process emissions. • Sometimes only CO2 are reported in the EU ETS. How do you then estimate non-CO2 if data from EU ETS are used?	The EU ETS data is always treated as a sub-set of activity data taken from the UK national energy statistics in DUKES. We do NOT use EU ETS data as a primary data input to the GHGI, but use it as a quality check against national energy statistics. In some sectors (e.g. refineries, coal-fired power stations) we know that the EU ETS is 100% of the sector – i.e. all UK plants report to EU ETS, whereas for most other sectors there is not 100% coverage in EU ETS. In some instances, the UK inventory agency has worked with the UK Government Department (DECC) that compiles the energy statistics to resolve problems where the sum of all plant reporting to EU ETS indicates that the reported DUKES energy allocation for that sector is too low. We also use the EU ETS to inform UK-specific emission factors for fuels and activities where a high % of data in EU ETS are based on Tier 3 fuel analysis. For many other sources where we either have low % coverage of the sector in EU ETS, and/or low % reporting of fuel carbon content to Tier 3 within EU ETS, then the UK GHGI estimates are based on the DUKES activity and reference emission factors from other (non-EU ETS) sources (such as periodic sampling campaigns, direct consultation with operators and trade associations, references such as IPCC emission factors database etc). If your question is focussing on how the energy statistics are compiled to use EU ETS (or otherwise), then the answer is that the UK Government Department (DECC) sends out survey questionnaires to all major fuel suppliers on an annual basis (power operators, refiners, colliers etc) and obtains data back on the sales of fuels to different economic sectors, but the detail of these returns is limited and the main use of this survey is to determine the overall fuel consumption data for the UK. To obtain a more detailed breakdown of consumption patterns, these surveys are supplemented by other surveys conducted by the Office of National Statistics such as the “Fuel Purchases Inquiry” and the “Annual Business Inquiry”, which includes a limited survey of a sample of businesses within certain economic sectors. These surveys are not conducted for all business sectors in every year, so there is a rolling programme of information gathering that is then used by DECC to provide estimates of the share of fuel use within different economic sectors. The results of the fuel sales surveys by DECC of fuel suppliers, and the ONS surveys of fuel consumption patterns within different business sectors are then combined to

Expert Review Team Comment	UK GHGI Actions
	determine the UK annual energy statistics, which are published in DUKES and used to underpin the activity data in the UK GHGI. The use of EU ETS data in this process is currently limited to that of a quality-checking role, i.e. to inform de-minimis allocations of fuel use to specific sectors. The EU ETS data from regulators provides a complete breakdown of emissions such that it is entirely transparent whether the emissions are from fuel combustion, fugitive or process sources. We conduct quality checking to compare (i) fuel use activity data from EU ETS against reported national statistics by sector, (ii) emission estimates from process and fugitive sources against other datasets directly from trade associations and environmental regulators. In many instances, we use the detailed breakdown of emissions within the EU ETS to enable us to improve the allocation of emissions reported under other regulatory systems such as IPPC, where emissions from many sources across an installation are aggregated in IPPC returns. This has become an increasing part of our annual quality checking routines and is incredibly resource-intensive, looking at data at installation level. Once again, where we know that we have a high % coverage of emissions and sites within EU ETS, and a high quality dataset based on new analysis and /or measurement under EU ETS, we then use those data to improve the UK GHGI emission factors. Otherwise we use reference data and periodic UK-specific analysis within the GHGI. In the UK, the EU ETS is entirely CO2. There are NO non-CO2 emissions within the EU ETS in the UK. The estimates of non-CO2 emissions are derived in exactly the same way as they always have been since 1990, and in the days prior to the EU ETS. This is reported within the NIR. We use emission data reported by plant operators under IPC/IPPC/EPR for some sectors (e.g. power, refineries, iron and steel) and we use reference emission factors from resources such as EMEP-CORINAIR, IPCC guidance etc for many other sectors. These factors are all referenced and available via the CRF and the NAEI website.
Energy - Annex 4, reference approach: Where in the inventory do you report emissions from * Offshore flaring and well testing; * Waste incineration; In table 1Ab there is no space for "other fuels", but data can be entered at the bottom of table 1Ac. Has this been done in the inventory?	In the sectoral approach, offshore flaring is reported in 1B2c, well testing in 1B2a. However, as stated in Annex 4, we do not include data for offshore flaring and well testing in the reference approach. This is because these emissions are not derived from activity statistics within the national energy balance, but are taken directly from operator-reported activities and emissions, via the offshore oil & gas sector EEMS reporting system, regulated by UK Government DECC. We exclude all waste incineration from the

Expert Review Team Comment	UK GHGI Actions
	reference approach.
Energy - In the reference approach table 1Ac the apparent energy consumption and the apparent energy consumption excluding feedstocks and non-energy use of fuels are almost identical, even though significant fuel consumption is listed for these purposes. Please note that in the column “apparent energy consumption excluding feedstocks and non-energy use of fuels” you should subtract the amounts reported in table 1Ad(= the amounts reported as carbon stored in table 1Ab). Could you please comment on this?	This has been revised within the latest CRF submission.
Industrial Processes - In 4.2.2 you explain clearly how you determined the EF for 1990-2005, namely using the average EF for 2005 as reported to the ETS. However, as of this year are all activity data for cement clinker production reported now reported as C and in Annex 3.4.1.“Emission factors and activity data for the production of cement are commercially sensitive and therefore confidential.” Therefore, the review team is unable to assess the variability of the EF between 2005 and 2008 due to missing activity data. • Why are all activity data for cement clinker production reported now reported as C whereas until last year all activity data were reported in the CRF? • For assessing the IEF value and its interannual variation, could you please provide the AD time series for 1990-2008? • Could you please explain the interannual variation between 2005 and 2008 and why you assume that the 2005 value is the best estimate for years earlier than 2005?	Activity data were previously reported in error and hence have been removed from the CRF. Activity data at Great Britain level (i.e. England, Scotland and Wales) are publicly available. Therefore to publish the UK statistics would mean that the Northern Ireland figure (one company) could be derived by difference, disclosing commercially confidential information. 2005 to 2008 data are based on year specific data reported by plant operators under EU ETS, which shows some variation. The 2005 data was used for all years prior to 2005 since this was considered to be a better representation of the UK specific emission factor for this source. A number of cement works have closed over the period 2006-2008, so applying data for that period to the years before 2005 would be, in our view, less reliable than using 2005 data.
Industrial Processes - In Annex A11, Table A11.2.1 shows that only 4 of the 15 cement kilns are included in the EU ETS, whereas in 4.2.2 you write “The methodology used for estimating CO2 emissions from calcination is to use data provided by the British Cement Association (2009), which in turn is based on data generated by UK cement clinker producers for the purposes of reporting to the EU Emission Trading Scheme.” • Can you explain to what extent the data to determine the EF are based on the 4 ETS reporting kilns only? • If the EF used for reporting for 2005-2008 is based on data for a selected number of cement plants, can you explain which fraction of cement clinker production that group covers and why you consider the values used to be representative for all cement kilns?	All cement kilns report annual data to the British Cement Association (BCA) and these data reported to the BCA are used for the inventory (i.e. covering all cement kilns). From 2008 all of the cement kilns are covered by EU ETS, whereas in earlier years only 4 sites were reporting under EU ETS, with the remaining sites operating within a different UK trading scheme (“Climate Change Agreements”). The data reported to the BCA are consistent with data reported to the EU ETS, for the subset which reported in earlier years, and now for all cement kilns.

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Industrial Processes - In 1.6.1.1 you write “Consultation with DECC DUKES and the regulators of the EU ETS data collection and reporting systems to determine sector-specific and fuel-specific quality parameters for the UK, and to resolve any data inconsistencies between published UK energy statistics and the EU ETS data for the latest year.” Apparently this check of inconsistencies with data reported to the ETS has been done only for energy-related data. • Could you explain whether or not you also checked the CO2 data from total cement clinker production (non-combustion) and total cement clinker production data you received from BC 2009) corresponded with the ETS data? If so, what was the result?	This comparison can only be done for 2008 onwards due to opt-outs from EU ETS in Phase 1. We will report on this comparison within the NIR.
Industrial Processes - In 4.3.3 it is stated that for 2004-2008 activity data of amount of limestone used were not “estimated” by the BGS, but had to be “estimated” by AEA, introducing additional uncertainty. However, in Table A1.1.6, it seems that the total uncertainty of CO2 in 2008 is estimated at about 5%. • Can you explain how AEA estimated the activity data for 2004-2008 and how the time-series consistency with earlier years is maintained? • Can you explain why the uncertainty in the 2008 AD figure is estimated as small as it seems to be estimated, and just by taking the 2007 figure?	Source data (from BGS) are provided in less detail from 2004 onwards. Prior to 2004, the statistics gave activity data on limestone use for iron and steel, chemical industry (including sodium carbonate manufacture and sugar refining) and a total figure for all uses. From these data, the lime sector allocation was calculated. From 2004, the BGS only provides data for iron and steel and the total. Therefore the inventory agency has extrapolated the estimates for use in the chemicals sector, by assuming that it retains a % share of the (total MINUS iron and steel) lime consistent with 2003, to derive estimates for the lime sector. We believe that this is currently the best way to maintain time-series consistency. Phase II of EU ETS provides activity data for many of the large lime plant, providing a “de-minimis” allocation of limestone for the lime sector. Taking account of the new lime sector data from EU ETS, we have revised the uncertainty allocations within the UK GHGI Monte Carlo uncertainty analysis (Tier 2).
Industrial Processes - The NIR writes: “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.” Perhaps it is explained elsewhere in the NIR, but the actual source of the emissions taken from the EA’s Pollution Inventory and the QA/QC applied when compiling these emissions is unclear. • Could you explain the actual data source of the emissions taken from the Pollution Inventory and what QA/QC was applied by the original data supplier and by the agency that compiled the Pollution Inventory? • In particular, if based on measurements, in which year or how frequently within the year	See **Section 3.2.6.4** of the NIR. It is up to the terms of an installation’s permit to operate under IPPC/EPR that the method applied to estimate the annual emissions is determined. This is a site-specific decision by the regulator. There is a system of data quality checking that underpins the emission estimates from all nitric acid plant (all in England) – refer to the NIR. We have recently received information from the operators of all nitric acid plant that still operate (several have closed in recent years), and all now use Continuous Emission Monitoring systems to estimate the nitrous oxide emissions. As a result of this information, we have revised the uncertainty allocations within the UK GHGI Monte Carlo uncertainty analysis (Tier 2). We requested monitoring and uncertainty information several years ago from plant operators, and some sites were NOT then using CEMS, but based their

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were they taken and how was the representativeness for calculating annual average emissions determined? How does this relate to the overall uncertainty of the emission factor, which is estimated at 230% for both 1990 and 2008 (Annex 7)?	annual estimates on periodic discrete emissions monitoring tests, and hence the uncertainties on the emissions were much higher.
Industrial Processes - For providing activity data in the CRF (and thus IEFs), the NIR states: "Site-specific production estimates are largely based on production capacity reported directly by the plant operators. This approach may overestimate actual production." • When production estimates were based on production capacity, did you use the capacity as proxy for the actual production or did you apply an assumed utilisation factor? • For how many of the 4 sites do you have actual production data? And which fraction of total estimated production does/do this/these cover? • The NA site with N2O abatement, approximately which fraction of the emissions is abated and which fraction of total estimated production does it cover in recent years?	For each site, we obtained data from operators in 1995 on the number of days in the year that the plant was fully utilised, and used that in conjunction with the daily production capacity data (also from operators) to provide production estimates. The NIR text is somewhat misleading and is only applicable to the early years of the timeseries. We now have actual annual production data from all site operators, so the reported data for recent years is not based on production capacity estimates – it is reported to us directly by operators. The need to use production estimates varies across the timeseries, according to the information that has been provided over the years by operators. In summary: - Site #1: Actual production data from 1995 onwards. Production capacity estimate using days per year utilisation from 1990-1994. Site still operating (3 production units). - Site #2: Actual production data from 1998 onwards. Production capacity estimate using days per year utilisation from 1990-1997. Site now closed. Estimate in year of closure based on approx days operating. - Site #3: Actual production data from 1998 onwards. Production capacity estimate using days per year utilisation from 1990-1997. Site still operating. - Site #4: Actual production data from 1998 onwards. Production capacity estimate using days per year utilisation from 1990-1997. Site now closed. Estimate in year of closure based on approx days operating. - Site #5: Actual production data from 1994 onwards. Production capacity estimate using days per year utilisation from 1990-1993. Site now closed. Estimate in year of closure based on approx days operating. - Site #6: Actual production data from 1990 onwards. Site now closed. Estimate in year of closure based on approx days operating. We do not have any data on the amount of nitrous oxide abated at the site. In 2008, the unit with abatement accounted for 46% of total UK production.
Industrial Processes - There seems to be an inconsistent CRF allocation in 2C4: SF6 from aluminium foundries is reported as "NE", whereas there is a non-zero figure reported for "total 2C4'.	Emissions of SF6 and HFCs used as a cover gas in magnesium foundries are reported in 2C5, to allow both gases to be reported together. SF6 from aluminium reported under 2C4 is Not Estimated, SF6 from magnesium is reported under 2C4 as IE – included under 2C5

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Industrial Processes - **Section 4.17.2** mentions reporting HFCs for 2008, but it is actually reported for 2004-2008. And the last par. mentions SF6 where HFC-134a is meant.	HFCs were only in use in large enough quantities to be reported to the Environment Agency's pollution inventory from 2008. Estimates from 2004 onwards were based on direct consultation with the operator. And the last par. mentions SF6 where HFC-134a is meant. Please clarify. The last paragraph in this section reads: Note that actual emissions of SF6 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. This is to say that HFCs and SF6 are reported together in 2C5, since the emissions arise from the same source, and it was considered more transparent to present total emissions from this source in the same category.
Industrial Processes - At present the UK reports 2E emissions only as total CO2-eq emissions, although earlier reviews have recommended the UK to investigate a more detailed better breakdown by gas. In **Section 4.21.2** and in **Table 10.3**, the UK responded that it "continues to investigate" and that it requires more time to consider this and that the CRF populating software needs to be revised significantly. However, current reporting practice continues to inhibit the assessment of consistency and comparability of by-product HFC-23 emissions from HCFC-22, which is usually the largest subcategory, also for 2008. • Since the UK has so far not provided a detailed and source specific answers to the F-gas confidentially issues, could you please explain what hinders the UK in providing gas-specific emissions for HCFC-22 manufacture separately from HFC and PFC production, as all but one other Annex I country do? • Have manufacturers been contacted on this issue?	The manufacturers originally supplied the information to the inventory compilers under the understanding that production data would not be made public, and that emissions data would be aggregated to maintain confidentiality. One of the operators has now closed. Speciated F-gas data are now reported in the CRF, where data are available.
Industrial Processes - **Section 4.21.2** states: "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." Since the data have not been recalculated, this seems to be an old paragraph. • Could you please explain which other sources than production of HFCs, PFCs and HCFC-22 are included in totals of category 2E? • Is it possible to send a file of the report AEA (2008)?	This text has been amended for the current submission • Text provided by one of the plant operators states: INEOS Fluor sends to INEOS Chlor an aqueous product stream that contains some HFCs, which then vent off from a stock tank. These are the additional emissions that are included within sector 2E.
Industrial Processes- Further: "Two of the three manufacturers were members of the UK greenhouse gas Emissions Trading Systems. As a requirement of participation in the	We use the best data available to the inventory team. Data post 1998 are reported in the Pollution Inventory, which is used for regulatory purposes and is therefore considered to be accurate.

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scheme, their reported emissions are verified annually via external and independent auditors." • Are the emissions of the third not-participating manufacture also verified? If so, how?	
Industrial Processes - And: "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." • Which fraction of total CO2-eq emissions reported in the CRF for 2008 was directly reported by the manufacturers and which fraction has – thus – been estimated/calculated from other, full speciated, emissions data?	Emissions from PFC manufacture are based on returns to the Pollution Inventory. Emissions from Ineos Fluor (HFC and HCFC manufacture) are based on speciated emissions from the operator. Emissions from Rhodia (HCFC manufacture) are based on data from the Pollution Inventory. Rhodia closed in 2007, and HCFC manufacture at Ineos Fluor will cease in 2010. For the 2008 value, 8% of the total emission within sector 2E is from the Pollution Inventory, with the remainder based on data from Ineos Fluor.
Industrial Processes - At present the UK applies aggregrate reporting of gases and source categories with this category, although earlier reviews have recommended the UK to investigate a more detailed breakdown by gas and category. A breakdown into individual gases would contribute to the assessment of consistency F-gas emissions from Annex I countries with atmospheric concentration measurements of these gases, which is now hindered by significant missing data from the UK, that contributes about 10 to 20% to Europe's total HFC emissions. Moreover, the actual EFs used and IEFs resulting from the original F-gas calculations are not specified for several of the largest subcategories, not in the CRF and not in the NIR. The current reporting practice therefore inhibits the assessment of consistency and comparability of F-gas emissions from the use of F-gases in a number of the largest subcategories, also for 2008: - HFC emissions from refrigeration subcategories: no IEFs for commercial refrigeration and stationary airco's, since they contains more subcategories with different EFs - PFC emissions from semiconductor manufacture: no category data at all - SF6 from electrical equipment: no category data at all Since this data is missing and a major recalculation has been performed in 2F1: • Could you please provide old and new time-series of total 2F1 F-gas emissions 1990-2007/2008? • Could you please provide the times series 1990-2008 of IEFs and EFs for commercial refrigeration and stationary airco's for the new data and for last year's dataset	New and old models have been forwarded to ERT. The relevant sections of the NIR have been extended to aid transparency, and individual HFC and PFC species are now reported.

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• Is it possible to send a file of the reports AEA (2010) and AEAT (2004)?	
Industrial Processes - 2A1 Cement - CO2 You wish to keep actual UK total clinker production confidential because of the one N.I. plant. However, to enable the review of transparancy and comparabilty of level and trend of the IEF, could you please consider reported 'estimated' UK total clinker production by reporting the public total sum for England, Scotland and Wales plus the capacity of the Northern Ireland plant times an assumed utilisation rate (e.g. 80 or 90%)? Using the clinker data provided, the IEF for 2007 and 2008 has a high interannual variation: + 5.4% in 2007 and -3.4% in 2008 with the IEF in 2007 of 0.575 t CO2/ton clinker. These are both among the highest of all Annex I countries. Since you mention that 2005 to 2008 data are based on year specific data reported by plant operators under EU ETS, which shows some variation and that a number of cement plants are closed during this period, our follow-up questions are: • Is the large IEF variation mainly due to plant closures or due to other reasons? • Has there been special plant-specific QC on the plants that effectively reported high IEFs in 2007? If not, why not? • Have any plants used EU- or UK-ETS default emissions factors (instead of plant-specific factors)? If so, how many and which fraction of total production do they cover approximately in 2008 and before? • If other reasons explain the high IEF value in 2007, should this not be an indication of the interannual variation of the IEF and therefore suggest that using the average of 2005-2008 be a better estimator for pre-2005 IEFs?	We will consider this option, but note that the trade association have specifically requested that these production data are not published. The inter-annual variation is due to the variable utilisation of different production plant over the last few years which have different kiln operational designs (wet, semi-wet, semi-dry, dry, some with pre-calciners, some with pre-heaters) and the data are provided by the cement trade association for the industry as a whole. The UK output from this sector declined significantly during 2008, and the utilisation of some plant has been affected. Due to the different designs of the kilns, the emission factor is sensitive to utilisation of different plant to achieve overall UK sector production. During 2005 to 2007, only 4 plant were reporting within the EU ETS, and therefore there was insufficient plant-specific information to provide a detailed breakdown of total CO2 emissions between combustion and process sources. Hence the data provided by the trade association are the main data source. The emissions data for each site have been checked against IPPC and (where appropriate) EU ETS operator returns, and the sector energy use and process emissions has been checked with the UK Government Department and the trade association which collates all operator data. The variable IEF is explained by different utilisation of different design kilns across the period. What is "special QC"? How is this defined? In 2008, the process emissions within EU ETS are 80% from installation-specific (Tier 3) emission factors, and 20% from UK default (Tier 2) factors. In 2007, less than 2% of sector process emissions were reported using Tier 3 analysis within EU ETS and hence the sector-wide data from the trade association are used. The back-casting of data is subject to uncertainty whichever approach is adopted. Whether the use of the 2005 figure is more or less representative than the use of the average of 2005 to 2008 is purely subjective. It is our opinion that the utilisation of plant in 2005 is the best estimate for earlier years, given that older plant have been decommissioned and newer plant have come into production over recent years; we therefore feel that the 2005 mix of plant design and utilisation is likely to provide the most representative data for earlier years, rather than using the 2005 to 2008 average.
Industrial Processes - 2B2 Nitric acid - N2O We observe an IEF that is a factor 1000 higher than that of other Parties, and assuming that the production level in the UK is similar to that of Germany and France, we expect that the AD	A units error in the activity data in the CRF has been identified and corrected for the 2011 submission.

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figures in the CRF are not in kton but in Mton. • Could you please check the AD unit used and correct in the next submission, if applicable?	
Industrial Processes - 2F Consumption of halocarbons - HFCs You replied: "In the restructure of the NIR, emissions verification was moved to Annex 10". Now that we have assessed this info, it appears that you discloses actual total HFC-134a emissions in Annex 10 Table A10.4.1. • So why did you not at least provide this info on HFC-134a in Table A10.4.1 also in the mean chapter on 2F emissions and include it in the CRF, e.g. in table 2(II) under G. Other (non-specified) in the HFC-134a column?	The total is reported, but the sector breakdown is not. Under the improvement programme, we aim to report speciated emissions where possible across all sectors. From the 2011 submission, speciated data are now reported where available.
Industrial Processes - 2.F.1. Refrigeration and air conditioning (HFCs) The UK report leakage rate for mobile A/C and transport refrigeration that are lower than IPCC defaults and for other Parties. UK indicate that this is based on expert assessments and reference to other studies The ERT would like to ask the UK to provide additional information for the technical justification as to why the leakage rate should be lower than other parties and whether the other studies are relevant to situation in UK?	The leakage rates within this sector were derived for the AEAT (2004) study, and remain unchanged (they have been reviewed, in consultation with stakeholders, but no changes have been made). The leakage rates were based on responses to a questionnaire and extensive stakeholder consultation (within the UK). DECC is planning a thorough rebuild of the refrigeration and air conditioning model in 2011. Within this research we intend to seek updated information on PLFs.
Agriculture - According to the 86/278/EEC Directive (Sewage Sludge), the use of sewage sludge in agriculture is regulated and therefore information is reported to the European Commission. Why UK does not estimate N20 direct and indirect emissions from sewage sludge applied to agricultural soils?	Emission estimates from this source are included within the 1990-2009 inventory submission. Data found at UK level was for the years 1996, 2001-2006, 2008, 2009. A linear regression was used to interpolate for estimating values for missing years.
Agriculture - Page 163. NIR. It is described that "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". Does this has a relevant impact in the number of animals? How it has changed? Which is the justification for this choice?	These comments will be revised in the next submission. This parameter essentially includes all milking cows. The cattle data used are the only source available at this time therefore we cannot make an assessment of the impact of other data. The cattle data is sourced from the Cattle Tracing System. The dairy herd is defined as female cattle of a dairy breed which are aged 2 or more and have a recorded offspring. The categories we use in the June Survey are based on EU Regulation 1165/2008 concerning livestock and meat statistics (supplied by Marc Thomas).
Agriculture - In the Annex of the NIR there is detailed information provided for beef and other cattle. For Dairy cattle, some information is provided in Table A 3.6.3. It is possible to provide the time series of all parameters (NEm, NEl, etc) used for the tier 2 approach for dairy cattle? Which have been the assumptions and which are the references used for country specific parameters?	Yes, we can provide the detail information for the calculation of the Tier 2 for dairy cattle. This will be included in the next submission. Parameter — Assumption NEm — Cfi is default value (0.335) NEfeed — Ca is default (0.17); calculated as proportion of time grazing (0.43) NEl — Milk yield and fat content country specific, otherwise

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	same as guidelines (96-00) GE Digestibility from personal communication Bruce Cottrill from ADAS, UK
Agriculture - IPCC GPG – Digestibility (DE): 60-75% for good pastures, good preserved forages, and grain supplemented forage-based diets. The DE is a crucial parameter while estimating tier 2 approach. Why does UK choose 75% DE for 2008? Which is the justification for this choice?	The digestibility value is country specific and was provided by Bruce Cottrill from ADAS, UK. The reference from which the data was sourced is: MAFF (1990). UK Tables of nutritive value and chemical composition of feeding stuffs. Rowett Research Services Ltd, Bucksburn, Aberdeen
Agriculture - The IEF for dairy cattle is lower respect to the average EU 15 (116 kg/head/year). Is there any explanation for this?	This is due to the use of Tier 2 methodology using UK specific information. It might be that our animals graze for longer.
Agriculture - Why does N excretion rate and weights for beef and other cattle fixed for the whole time series?	N excretion rates: the data available has shown no changes in the time series. Weights for beef and other cattle: there is no information on changes in the time series for these categories.
Agriculture - From the SAI 2010: Table 4.3b CH4 IEF for enteric fermentation: dairy cattle - trend information. We have verified that the IEF dairy 2004/2005 has increased by+15.6. Is there any explanation for this?	The large increase was due to an increase in animal weight of 44%. In the Agriculture in the Uk document from Defra it states that: "From 2005 onwards, the cattle figures were sourced from the Cattle Tracing System (CTS) in England and Wales, the equivalent APHIS system in Northern Ireland and survey data in Scotland and are therefore not directly comparable with earlier years." There has been no correction to account for this step-change. This difference is purely due to a change in the methodology to gather the activity data (Defra).
Agriculture - From the SAI 2010: We have verified that the IEFs for 4B-CH4 are: dairy 26.76 kg/head/year and non-dairy 4.14 kg/head/year. It is possible to explain the difference of these values respect to IPCC values?	This is due to the use of Tier 2 methodology using UK specific information on manure distribution in the different systems. The difference in the IEF is due to the use of Tier 2 for the UK instead of IPCC default for the calculation of the emissions. For dairy cattle: the sources of the CS data are: digestibility from Bruce Cottrill from ADAS; dairy cattle weight from slaughter weight data from Defra; milk characteristics from Defra; animal numbers from census data. For beef: the derivation of the IEF is the result of the weighted average of the different cattle categories. There are three EFs according to the different types of cattle, beef herd, cattle>1 yr old and cattle<1 yr old. We use the default EF for cattle>1 yr old (6 kg/hd/yr) and calculated the EF for others as shown in the spreadsheet attached (Q12 agriculture v2). The parameters used for this one were provided by Defra.
Agriculture - From the SAI 2010: Which is the explanation for having lower N excretion rates compared with IPCC ones for non-dairy, sheep, swine and poultry?	These values are country specific. They are based on a study by ADAS, UK project No. WT0715NVZ.
Agriculture - CRF- Table4s2. Does the Party is planning to collect activity data for estimating emissions from UK Overseas Territories (OTs)	Emissions of methane from enteric fermentation in the OTs and CDs are reported under 4A10. Methane from animal wastes is reported under

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and Crown Dependencies? [OTs are the Cayman Islands, Falkland Islands, Bermuda, Montserrat and Gibraltar]	4B10. N2O emissions from animal waste management systems are currently reported under category 4G to keep them separate from the UK estimates. Other sources are currently not estimated. Emissions are based on activity data collected directly from the OTs and CDs.
Agriculture - Time series: CRF- Table4.B(a)s1. For dairy cattle, the VS values is equal to 0.01 kg dm/head/year. However, the EU-15 average value is 4.65 dm/head/year, and the IPCC default is 4.13 dm/head/year? Is it possible to give an explanation for this value? The same value of 0.01 kg dm/head/year is used for non-dairy. However, IPCC default is 2.68 dm/head/year. Why?	Values given are in a per day basis. The resulting yearly value for 2008 is 3.65 kg DM/head/yr. Different values are used for dairy and beef: For dairy VS=0.01 kg dm/head/day For beef VS=0.00726 kg dm/head/day The IPCC values are expressed in a per year basis, so the ones in the CRF need to be multiplied by 365. The value for dairy is derived as shown in spreadsheet attached. For beef a value close to the default value of 2.65 is used, as explained in the previous response the values reported in the CRF are expressed in a per day basis so need to be multiplied by 365.
Agriculture - Time series: CRF- Table4.B(a)s1. For non-dairy cattle, the Bo parameter is equal to 0.24 m3 CH4/kg VS. However, the IPCC default is 0.17 m3 CH4/kg VS? Is it possible to give an explanation for this value?	The correct value was used in the calculation (0.17) as also stated in the NIR. It is wrongly reported in the CRF and will be corrected in the next submission.
Agriculture - CRF - Table4.Ds1: 4.Other improved grassland. What does this source means? Which is the methodology used for estimations?	Improved grassland is pasture that has been mixed with another species such as a legume. This one is capable of fixing N2 from the atmosphere and is accounted for when considering the total N input to soil. The calculations for determining the amount of N that goes in the soil and can be a source of N2O emissions come from country specific data provided by Eunice Lord from ADAS, UK. The detail of the method is explained in **Section 6.5.2.2** of the NIR.
Agriculture - 4.A.1 Enteric Fermentation -Dairy Cattle The feed digestibility reported by the UK is amongst the highest of the EU parties. Selection of this value result in significantly lower emissions/head than other EU parties. The UK has been asked provide information to the support this value.	IPCC GPG – Digestibility (DE): 60-75% for good pastures, good preserved forages, and grain supplemented forage-based diets. The UK uses 75% DE for 2008 based on the values for gross energy digestibility for different feeds that is obtained from: MAFF (1990), UK Tables of nutritive value and chemical composition of feeding stuffs. Rowett Research Services Ltd, Bucksburn, Aberdeen. The detailed methodology has been provided to the ERT.
LULUCF - Forest Land: CL converted to FL pre-1990 and GL converted to FL pre-1990 is included under Land converted to Forestland, instead under Forestland remaining Forestland. Does the UK approach assuming a 20 years default period for loss of SOC?. Why is land converted more than 20 years ago not included under FL-FL.	The UK assumes a longer time period than 20 years for the stabilisation of SOC under the new land use (the time depends on the country and the land use transition type). We have restructured reporting of emissions from the 5A Forest Land category for the 1990-2009 inventory. FL-FL and Land converted to Forest Land are now split using a 20-year transition period. There have been no changes to overall category emissions/removals due to this restructuring.
LULUCF - Area under Crop Land: Area under crop land (final) according to NIR 7.2 is 5,714.8	We are revising our reporting of areas so that the land use area matrix in the NIR and the areas in

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kha, where as area under CL is 11,615 kha in CRF. This discrepancy needs to be explained. Similarly there is a large difference between CRF and NIR for Grassland. There are small differences between NIR 7.2 and CRF tables for other land categories also. We request clarification for this discrepancy.	the CRF are consistent. The areas of land use remaining in the same land use have been reported if they have an associated emission or removal, but we are revising this so that all areas of land are reported in the CRF tables. This revision is partially completed. We will complete the process in the next inventory submission, when the remaining land use categories will also use a 20-year transition period, which will make it easier to harmonise area reporting.
LULUCF - KP-LULUCF- SOC under A&R under KP: According to Table KP 5 A 1.1 - SOC is reported to be gaining Carbon for Organic soils under A&R and losing / gaining for Mineral soils. Normally one would expect loss of SOC for organic soils and gain for mineral soils. Can you explain this unusual trends.	The UK uses a forest carbon flow model, C-Flow, to model carbon stock changes. This is a Tier 3 model that takes into account SOC losses from planting disturbance: these are large immediately after planting, and then gradually stabilise (based on field studies reported in Hargreaves et al 2003). Most recent planting (since 2000) has been on mineral soils, so SOC losses from planting disturbance are greater than SOC gains from litter inputs on the mineral soils in 2008, but vice versa on the organic soils. Forest mineral soils are projected to have net SOC gains for all countries from 2010.
LULUCF - KP_LULUCF- TABLE 5(KP-I)A.2. SUPPLEMENTARY BACKGROUND DATA ON CARBON STOCK CHANGES AND NET CO2 EMISSIONS : The total area subjected to D is given as 19.76 kha, which may include 0.93 kha subjected to D during 2008 according to KP-NIR-2. The net C stock change for AGB is reported to be 3.4 Mg C/ha. How was this extremely low value of 3.4 Mg C/ha was obtained, for forest area subjected to Deforestation? Is it annual rate of loss? Kindly provide clarification for the reported low value. In fact the loss per ha for D are lower than for Forest Management. How may this discrepancy be explained?"	40% of the biomass removed during deforestation is assumed to be burnt and is reported in Table 5(KP-II)5. The other 60% is treated as an immediate emission to the atmosphere. (This is reported in the documentation box in the CRF). The implied carbon stock change factor for AGB is dividing the emissions from deforestation in 2008 by the area of all deforestation 1990-2008.
LULUCF - NIR **Section 11.2.1** for KP-LULUCF: According to NIR only A&R will be subjected to spatial assessment. But Deforestation seems to be not subjected to spatial assessment. However, spatial assessment is needed for KP Reporting. How will UK address this requirement?.	Forest Research (one of the LULUCF inventory contract partners) is currently working on the spatial assessment of Deforestation data. As such data are not routinely collected this involves data compilation from both state and private forest sources. Forest inventory maps are due to become available in March 2011 which will enable a spatial deforestation dataset to be produced and validated.
LULUCF - Identification of land. Could you please clarify what data is used to identify the land areas for ARD for the different sub-division. It is unclear from the NIR what area data is used for what category, particularly what data is available for Northern Ireland. It would appear that for sub-divisions outside England ARD is being extrapolated. is there any plans to collect actual data for the sub-divisions with no data to test the assumptions are okay or replace with actual estimates.	We have annual planting statistics (and spatial data) for AR in each country in the UK. For Deforestation, two separate datasets have been used, for rural and non-rural deforestation. These cover England 1990-2002/2005 and Great Britain (England, Scotland, Wales) for 1999-2001. Deforestation estimates for Scotland and Wales for 1990-1998 and 2002-2005 are extrapolated from the England numbers using the GB ratios from 1999-2001. Deforestation rates for 2006-2008 are extrapolated forward from the 2005 data. As noted

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	in the response to query 6, the data for deforestation is currently being revised. This will provide data for Scotland, Wales and England up to 2009. We are in consultation with the Northern Ireland Forest Service to obtain evidence to support the statement that deforestation is not occurring, however the outcome of this consultation is not yet confirmed.
LULUCF - Identification of land. Given that UK has used this activity reporting approach for identification of lands what internal auditing and verification methods have you put in place or will put in place to ensure that these approach is not leading to and under or over estimate of emissions. For example could you use the FRA2010 data as a check? Could you compare Nth Ireland with Ireland inventory?	We obtain our activity data from the Forestry Commission and the Forest Service, who are the respective national agencies for Great Britain and Northern Ireland. They are responsible for the management of state-owned forests and for the administration of grants and licences for private forest establishment and deforestation. They also contribute the data for the FRA, so the respective datasets should be equivalent. A forest inventory map for Great Britain is currently in preparation and will be used to validate afforestation and deforestation estimates reported in the inventory, but no results are available from the forest inventory yet. We will discuss verification methods with the Northern Ireland Forest Service to ensure parity between the countries of the UK.
LULUCF - Contact OTs/CDs for further information on the main land use transition categories and use of notification keys, to allow fuller reporting in the CRF	In the 2011 submission, emissions from OTs/CDs are included in Sector 5
Waste - Could the UK provide the timetable on update of the survey data on gas utilisation and flaring (indicated as funded by DECC and the environmental regulatory agencies)?	Defra, who are responsible for the waste sector, are currently reviewing methane emissions from landfills. The review will consider a range of potential surveys for measuring emissions at landfill sites, as well as options for collecting data on gas utilisation and flaring. The aim of the review is to help fill knowledge gaps in this field and we are expecting a decision on the way forward later this year. In the meantime, a review of the UK model for methane emissions from landfills has been conducted and several input parameters in the model have been revised.
Waste - 6.B N2O from human sewage Protein consumption levels in NIR are 30% lower than those in FAO Stat database and for other EU parties. The ERT would like to ask the UK to provide explanation of why there is such a significant difference in these estimates. What is the basis for the UK estimates?	As explained in the previous review, the FAO estimate of per capita protein consumption is based on the supply balance sheets for all commodity items. For each commodity supply balance sheet they will apply factors to the estimate of supply for human consumption to derive total protein consumption and then divide by population to get a per capita figure. They will then add these up across the supply balance sheets to derive a total protein consumption estimate. The FAO estimate is therefore an aggregate calculation based on aggregate commodity supply data. It will use common conversion factors (not specific to any country) to derive food, protein and fat per capita consumption estimates. It will also relate to quantities available for consumption and will not be net of any losses (including e.g. fat

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	trimmed from meat) beyond the farm gate through to retail. These methodological limitations of the FAO estimates are more significant for developed countries such as the UK where a greater proportion of consumption is in the form of processed products. The NIR estimate of protein consumption is derived from the Expenditure and Food Survey. This is a sample household survey in which household record the actual purchases of food they make. UK specific conversion factors are then applied to these individual food items to estimate consumption of protein and other nutrients. The UK specific conversion factors are based on a detailed analysis of the individual types of food purchased and contrasts to the more broad-brush factors used by the FAO. The Expenditure and Food Survey estimate will also be net of any losses through the food chain through to retail as it is based on actual purchases. The only downside to the Expenditure and Food Survey is that it may have an element of under-recording due to purchases of some food items not being included in the diary of survey participants.
EC Consistency Review of the 2010 UK GHGI Submission, March 2010	
Energy – Fugitives 1B2ciii. Will the final NIR contain an explanation for the recalculations for the CO2 IEF in the 1990s.	There is an error in the estimation of the activity data within the latest submission, and the AD and IEFs should be unchanged since the previous submission. We will revise it in the next submission. The emissions are correct and remain unchanged.
Transport – 1A3b biomass emissions of CO2. GB reports CO2 from biomass in road transportation as NO. Are you sure that no biofuels are used? Please check and clarify.	Biofuels are used in the UK. Emissions from biofuels are now estimated and reported in the CRF.
Industrial process – 2A3 Limestone Use. IEF continuously increased by 33% during 1990 and 2008. Is this increase caused by the inclusion of CO2 emissions from gypsum produced in the flue gas desulphurisation process but by exclusion of its activity rate, as indicated in the footnote?	Yes, this is correct.
Industrial Process – 2A7 CO_2 allocation. In WG1 we agreed that the EC MS should report emissions from glass production in 2A7. The UK argued in its response to the EC internal review that - according to the IPCC guidelines - process emissions from limestone and dolomite use should be reported in 2A3, and process emissions from soda ash use in 2A4, and then "other mineral process emissions" in 2A7. This interpretation of the IPCC guidelines is correct. However, relevant for the reporting are not only the IPCC guidelines but also the UNFCCC reporting guidelines which include the CRF tables. As the CRF tables include a separate sub-category "2A71 Glass production" there is	The reallocation of emissions from this source will be made in the 2012 inventory submission.

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a contradiction between IPCC guidelines and UNFCCC reporting guidelines. This is the reason why WG1 discussed this issue and came up with the recommendation to report emissions from glass production under 2A71 in order to have a coherent approach at EC level. Therefore, in the next submission please reallocate emissions from glass production.	
Industrial Process. 2A1 CO_2 emissions. After being at rather constant levels since 2001, CO2 emissions decreased by 15% during 2007 and 2008. As activity data is marked confidential, could you please confirm that the trend of emissions is caused by the activity data or explain instead?	The trend in emissions in cement production is caused by the trend in the production data provided to us direct from industry. Emissions follow activity trend and therefore the decrease in emissions is due to a decrease in activity between 2007 and 2008.
Industrial Process. 2E1 HFCs. Could you please explain the decrease of emissions by -28%	One of the HCFC production plants closed during 2007, leading to a decrease in emissions.
Industrial Process. 2F7 SF_6 AD. SF6 emissions from 2F7 are reported in 2F9 due to confidentiality reasons. During the EC internal review we asked the UK to check if for a number of F-gas emissions the allocation of sources could be improved given the fact that under the E-PRTR emissions are published at plant level. The UK responded that the UK required more time to consider each of these sources in detail and work out where new data (from ePRTR) may impact on the data compilation. Our first question is: what is the status of this work? Our second question refers to SF6 from 2F7. We have seen that the E-PRTR database of the European Community publishes SF6 emissions at company level e.g. for Kelvin Electronics Works (440 kg in 2007), Magnesium Elektron Ltd (4.3 tonnes), Philipps Electronics UK Ltd (142 kg). Therefore, please check if confidentiality is still an issue in this specific case.	A number of categories are aggregated and reported in sector 2F9 to conceal the commercially sensitive data for training shoes. Data for 2F7 are not confidential.
Agriculture - The inter-annual changes of N-excretion rates for dairy cattle 2000-2001, non-dairy cattle 1999-2000, swine 2000-2001 and 2005-2—6 all show poor time series consistency.	An error was found in the calculations of N excreta. In earlier years the calculation referred to the regional data spreadsheet and so the correction in N excretion factors had not filtered through. This matter is now resolved within the 2011 submission.
Agriculture - Total nitrogen excretion calculated from CRF Table 4B(b) as follows: animal population size multiplied by nitrogen excretion per head is not equal to the sum of nitrogen excretion in all animal waste management systems.	(Same error as above, now resolved.)
Agriculture - Fraction of livestock N excreted and deposited onto soil during grazing calculated on basis of information provided in CRF Table 4B(b): Nitrogen excretion from pasture range and paddock divided by the sum of nitrogen excretion of all animal waste systems is not equal to the Fraction GRAZ	(Same error as above, now resolved.)

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taken from CRF Table 4Ds2.	
Agriculture - Values for methane conversion factor in Daily spread AWMS for Cattle is out of range.	Values are for dairy and non dairy cattle 0.1 as the guidelines recommend
LULUCF – AD (all). Definition of each land category, as they are reported in the UNFCCC GHG inventory, and particularities/descriptions for land sub-categories, are not always clearly stated in the NIR. As example, OTL often includes very large area of land and it is not clear what land is actually included here (i.e. description: land cover, geo-physical particularities). Also, the national approach to distinguishing between unmanaged and managed land should be described in a transparent manner. Please ensure that these are provided in the NIR 2010, as to meet the good practice requirements for consistent land representation (IPCC GPG 2003)	This was addressed in the 2010 NIR. Land use category area reporting will be partially revised in the 2011 submission, and completely revised by the 2012 submission.
LULUCF – AD (all). Apparently, inconsistent AD time series, with variation of 22 % of the total area (i.e. the sum of AD of all land uses) and GB in principle agreed to consider whole LU area of the country (The issue was also raised in 2009: LULUCF_201). Please address this issue in the 2010 submission.	This issue is unclear. Land use category area reporting is currently being revised and is reported in the latest inventory submission.
LULUCF – AD 5F1 5F2. AD for this land category is not reported, in the current version of the submission. Please ensure that the "OTL" definition is provided in the NIR 2010.	This was addressed in the 2010 NIR.
LULUCF – AD 5B. CL area reported under UNFCCC is 100 % higher than that reported by UK under FAO Stat. Please ensure the consistency and explain in the NIR 2010 the reasons for such differences.	Land use category area reporting is currently being revised, and will be complete in the 2012 submission.
LULUCF – IEF DOM 5A1. No DOM data submitted in the current version of CRF.	The 5A Forest Land category has been restructured in the latest submission.
LULUCF – IEF OrgSOM 5A2. IEF for C stock change in organic soils is positive (increase of C stock) and has an increasing trend over entire time series. Is that possible? Could it be due to the 100 years long transition period? Why it starts from almost zero in 1990? Please check it and explain it in the NIR 2010 and ensure the consistency with KP reporting.	The forest carbon model takes into account carbon losses from soil disturbance during planting and carbon gains from forest inputs to the soil. Mineral and organic soils are treated in the same way but with different parameter inputs. Historical planting patterns (massive conifer afforestation 1950- 1990 but much lower since) will affect soil inputs and hence the IEF for soil carbon stock change. Additional information will be provided in the 2011 inventory. The UNFCCC inventory is consistent with KP reporting.
LULUCF – AD (5B). Inconsistent reporting of area of organic soils/histosols under cultivation. Please check it and ensure the consistency or explain the difference in the NIR 2011	Noted. Land use category area reporting is currently being revised, and will be complete in the 2012 submission.
LULUCF – AD (all).Definitions of carbon pools and GHG sources, as they are reported in the GHG inventory, are not always specified in the NIR (i.e. definition, additional description). Mostly quantitative parameters for their	Full references for the Tier 3 models, which include quantitative descriptions of parameters, are provided in the NIR text.

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description are necessary (i.e. depth of soil carbon considered for estimations; tree threshold diameter measured, dimensions of root included in the belowground pool). Please add them in the NIR under relevant chapters.	
LULUCF – AD (all). Definitions and quantitative descriptive parameters (i.e. % humus or organic matter content, considered depth) for organic soils and peat lands are largely missing in the NIR submissions. Pleased ensure that they are clearly stated in the NIR 2010 under the relevant chapters, if relevant in the GHG reporting.	Full references, which include quantitative descriptions of parameters, are provided in the NIR text. Reporting of Wetlands has been expanded in the latest inventory submission.
LULUCF – Uncertainty (all). Uncertainty assessment on country's GHG estimate has to be provided (also in order to allow complete EU level uncertainty assessment). If possible, transparent estimates, separated on 1) removal, 2) emission and 3) disturbances, for each land category, would be appropriate. Also, statistic parameters used to describe the uncertainty have to be clearly reported in the NIR (i.e. confidence interval for which statistical coverage; 1 or 2 standard deviations, standard error of the mean), as well as any other relevant information (i.e. distribution type, referenced data, expert guess involvement), as available.	Noted. There is increased documentation of uncertainty assessment in the 2010 NIR but further work is ongoing.
Waste – 6A1 IEF CH_4. The rate of increase of IEF changed in 1995: 1990 - 1995: IEF increased by 4%, whereas during 1995 and 2008 IEF increased by 81%. IEF is highest among MS (66 t/t versus 0.84 t/t = maximum mean value for EU MS). Could you provide an explanation?	CH4 emissions have decreased significantly during this time due to improved landfill practices and an increase in methane recovery. This combined with a reduction in MSW going to SWDS has resulted in an increase in IEF. The data presented in the NIR are correct, there is a units error in the CRF. This has now been corrected within the CRF.
Waste – 6A1 Recovery of CH_4. After an increase of CH4 recovery of 686% during 1990 and 2005, the recovery remained at constant level afterwards. Could you provide an explanation?	Landfill gas recovery increased markedly between 1990 and 2005 as a result of higher standards of landfill design and management, including the more widespread use of efficient gas control and collection measures, which allowed much greater use to be made of landfill gas for electricity generation. Data on power generation from landfill gas is centrally collected and allows a good estimate to be made of methane recovered for this purpose. Some landfill gas is also flared, both at sites too small for commercial exploitation of gas as an energy source but also as backup and standby duty for gas disposal at large sites. Date on the amount of methane flared is much less reliable than that used for energy recovery as there is no reporting obligation on site operators in this respect. The overall landfill gas recovery rate (70% of methane produced) from 2005 onwards is based on industry estimates of gas collection efficiency at sites during the phase of maximal gas production, reduced to reflect estimated collection efficiency over the whole gassing life of a landfill. We have

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	no evidence that gas collection efficiency has continued to increase since 2005, but further research is proposed to reduce this aspect of uncertainty.
Waste – 6A1 Emissions of CH_4. CH4 emissions decreased steadily by 56% during 1990 and 2004. Since 2004 no change in emissions could be observed any more; the level remained constant. Could you explain this trend?	CH4 emissions have been decreasing since 2004, just at a slow rate than during 1990 to 2004. CH4 emissions in 2004 were 977kt in 2008 CH4 emissions were 959.53. The slower rate of reduction in emissions post 2004 is related to the assumed trend in the methane recovery rate (see above).
Waste – 6B2b Emissions of CH_4. CH4 emissions in 1991 seems to be an outlier (low value). As GB indicated that it intends to find new data for this source; could you provide information on this issue?	These data have been revised within the latest inventory cycle, and are now based on UK industry data and an historic time series of sewage sludge treatment and disposal.
Waste – 6B2b IEF CH_4. IEF is rather constant during 1990 and 1998, abruptly decreased between 1998 and 1999 and remained at constant levels afterwards. GB indicated to review the time series for the 2010 submission. Could you provide further information?	These data have been revised within the latest inventory cycle, and are now based on UK industry data and an historic time series of sewage sludge treatment and disposal. There is only limited data available to inform the timeseries of IEFs, however.
Waste – 6B2b Emissions of N_2O. Considering the overall trend, N_2O emissions in 1994 (high) and in 1999 (low) might be outliers.	There is a slight peak in the protein data in 1994 and a slight dip in the data in 1999, which affects the time series of emissions. However, we believe these data to be correct and the best available at this time.
UNFCCC Centralised Review, September 2009	
Cross-cutting - Ensure, to the extent possible that categories currently reported as NE and for which methods exist are estimated, or reasons as to why not included in NIR	The UK has included estimates of emissions for a number of sources that were previously reported as NE in the current submission (e.g. N_2O from scrap tyres, emissions from gas leakage at the point of use), and also reviewed notation keys and amended where appropriate.
Provide more detailed info in CRF table 9(a) on categories reported as not estimated and IE	This table has been reviewed and updated
Include all rationale for recalcs made in CRF table 8(b)	Information is provided in both CRF table 8(b) and in NIR chapter 10
Include a complete description on how the uncertainty analysis is used to prioritise further improvements in the inventory	This text has been reviewed.
Include detailed discussion on completeness and uncertainty analysis in main body of NIR	Completeness and uncertainty analysis are provided in the NIR, with cross references to the relevant annexes where appropriate.
Include more detailed description of the QA procedures implemented and the planning of external peer review activities	Further text has been included in both the 2010 and 2011 NIRs.
Conclude formal MoUs with data providers	A Data Supply Agreement (DSA) is now in place with the UK DfT, and further DSAs are being progressed.
Report fuel consumption and emissions from direct flights between UK and OTs under domestic aviation	This recommendation has been accounted for within the 2011 submission..
Include emissions from LULUCF from CDs and OTs in the LULUCF sector and not sector 7	This has been implemented for the current submission.
Further improve measures in place in national	The measures taken in response to this

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registry with a view to minimising operator errors and ensuring interoperability with other registry systems	recommendation are reported in Chapter 14 of the 2010 NIR submission.
Take appropriate actions to reduce the number of out-of-sequence messages sent by its registry	The measures taken in response to this recommendation are reported in Chapter 14 of the 2010 NIR submission.
Enhance the user interface of the registry	The measures taken in response to this recommendation are reported in Chapter 14 of the 2010 NIR submission.
EC Internal Review of the 2009 UK GHGI Submission	
Industrial Processes - Report CO_2 emissions from glass production under 2A7 instead of 2A3/2A4	The allocation of emissions from this source is currently under discussion within the UK. A decision on whether to reallocate these emissions will be made before the 2012 inventory submission. We believe that reporting emissions under 2A3 and 2A4 aids transparency.
Industrial Processes - 2C1 - Reconsider allocation of process and energy emissions and explain the reasoning if the allocation cannot be improved	We will review the GLs and make any changes necessary. The allocation of emissions between combustion and process sources is open to some degree of interpretation within "contact" processes such as Iron & Steel and cement manufacture. There are some sources currently reported within 1A2a that could arguably be reported within 2C1. The overall emissions are correct and we work closely with Corus to ensure that our UK carbon balance approach provides emissions by source that are consistent with industry estimates.
Industrial Processes - 2C4, 2E1, 2E4 - Check if F-gases from these categories still need to be kept confidential:	Speciated F-Gases are now reported.
Industrial Processes - 2F -Reconsider reporting of unspeciated mix of F gases instead of single gas emissions	See response provided above regarding F-gas reporting.
Industrial Processes - 2F - Include unspeciated mix of f gas emissions in 2F at least in the subcategory where they are emitted	In most cases, emissions are reported in the correct subcategory. Emissions are only aggregated to disguise commercially confidential data.
Industrial Processes - 2A6 - Check if CO_2 emissions from road paving with asphalt can be estimated	This source is under consideration within the UK GHGI improvement programme. It is unlikely to be a large source of GHGs.
Industrial Processes - 2C41 - Check if SF_6 emissions from Al foundries occur and can be estimated	Nothing is reported in the Pollution Inventory, and this source is considered to be NO.
Industrial Processes - 2C5 - Check if Si metal production exists and check if CO_2 emissions from non-ferrous metal production is included in the inventory	We are not aware of any significant production of Si metal in the UK. To the best of our knowledge, all CO2 emissions from non-ferrous metal production is included in the inventory
Industrial Processes - 2F9 - Do SF_6 emissions occur from double glazing and if so, are they estimated	This source is under consideration within the UK GHGI improvement programme. It is unlikely to be a large source of GHGs.

10.4.2 Major Improvements to the Current Inventory

The data and compilation methods used in the UK GHGI are reviewed annually and where appropriate the estimation methodologies are revised and improved. The main methodological changes in the UK inventory during the latest compilation cycle are summarised below. Further details can be found in the appropriate sections of this report.

1)Sector: Waste

Revised landfill assumptions

- A detailed review of waste composition has been undertaken and new activity data have been included in the inventory.
- Methane emissions estimates are now higher in the base year than they have been in previous inventories. From 1995 onward, methane estimates are higher in the 2009 inventory than in previous inventories.

Revisions to wastewater activity data

- Research on wastewater handling involving policy leads, water industry and industry regulators during 2010 has identified new CH_4 emissions data from water companies as well as a consistent time series of protein consumption.
- Methane emissions have decreased due to the updated activity and emissions data.
- Nitrous oxide emissions have increased with the introduction of new protein consumption data.

2) Sector: Energy

Revised split between domestic and international shipping

- New bottom up methodology based on shipping movements to estimate fuel consumption and emissions from domestic shipping
- International shipping fuel consumption is then estimated, keeping total fuel consumption from shipping consistent with DUKES totals.
- Significant reduction in domestic shipping emissions and increase in international shipping emissions.

3)Sector: Agriculture

New source in agricultural soils

- Application of sewage sludge to agricultural land
- Significant increase in N_2O emissions in all years.

4)Sector: LULUCF

Incorporation of new Countryside Survey

- Countryside Survey update periodically and data interpolated for intervening years.
- Overall increase in emissions during early part of time series (~ 1Mt in each year for 1990 – 2000
- Decrease in emissions in later time series

New sources

- N_2O emissions from disturbance associated with land-use conversion to cropland

- Non-CO_2 emissions from drainage of soils and wetlands
- Increase in emissions of N_2O

10.4.3 KP-LULUCF Inventory

3.3 Afforestation

- Revised area of planting in England in 2008 has caused a small increase in CO_2 emissions.
- N2O emissions affected by new Countryside Survey data which have changed distribution of land converted to forest.
- N_2O EF has also been changed to that used in the 2006 guidelines.

3.3 Deforestation

- Updated activity dataset for all countries has affected emissions from all direct GHGs.
- N2O emissions from deforestation to Cropland included for first time.

3.4 Forest Management

- CO2 removals have decrease due to adjustment to FM area to take account of losses due to deforestation.
- N2O and CH4 emissions have been affected by wildfire activity data which have been revised for 2008.

11 KPLULUCF

11.1 GENERAL INFORMATION

11.1.1 Definition of forest

The UK has chosen the following definition of forest and single minimum values (also set out in table NIR.1).

A definition of 'forest' as agreed with the Forestry Commission comprising:

- a minimum area of 0.1 hectares;
- a minimum width of 20 metres;
- tree crown cover of at least 20 per cent, or the potential to achieve it;
- a minimum height of 2 metres, or the potential to achieve it.

This definition includes felled areas awaiting restocking and integral open space (open areas up to 1 hectare) (Forestry Statistics 2010, section 11.1).

These single minimum values are used for reporting UK forestry statistics (Forestry Commission, 2010) and the UK's greenhouse gas inventory submitted under the UNFCCC. The definitions are consistent with information provided by the UK to the FAO. If an international enquiry uses a different minimum definition, for example 0.5 ha in the Global Forest Resource Assessment 2010, the UK areas are adjusted to this different definition (FAO, 2010).

11.1.2 Elected activities under Article 3, paragraph 4 of the Kyoto Protocol

The UK has chosen to elect Forest Management (FM) as an activity under Article 3.4. In accordance with the Annex to Decision 16/CMP.1, credits from Forest Management are capped in the first commitment period. For the UK the cap is 0.37 MtC (1.36 MtCO$_2$) per year, or 6.78 MtCO$_2$ for the whole commitment period.

11.1.3 Description of how the definitions of each activity under Article 3.3 and each elected activity under Article 3.4 have been implemented and applied consistently over time

As a result of the restructuring of the 5A Forestland category of the UNFCCC GHGI, the areas of forest land reported for AR and FM under the Kyoto protocol are now broadly equivalent to the area reported under 5A Forest Land rather than 5A2 (Land converted to Forest Land) (**Figure 11.1**). The data sources and methods remain the same, but the split between 5A1 and 5A2 is now based on a 20-year transition period rather than a fixed point of 1990.

Definitions are consistent with those used in the UNFCCC GHGI. The Afforestation/Reforestation area is land that has been converted to forested land since 1990 (inclusive). However, the Forestry Commission (the state forestry agency) report new planting by ‘planting years’, which run from 1st April to 31st March. In order to be compatible with the requirement to demonstrate that activities under Article 3.3 began on or after 1st January 1990, it is necessary to adjust the planting figures (Forestry Commission, pers. comm.). For example, 1990 will contain planting reported in 1990 (1st April 1989-31st March 1990) and 1991 (1st April 1990-31st March 1991). Therefore, the area reported for Article 3.3 Afforestation/Reforestation in 1990 is the sum of 25% of 1990 planting and 75% of 1991 planting, and so on to the present. The numbers reported in the UNFCCC GHGI are not adjusted (**Figure 11.2**): in 2009 the area of forest established since 1990 was 300,594 ha in the UNFCCC GHGI and 288,601 ha under Article 3.3 Afforestation.

Figure 11.1 **Area of forest in Article 3.3 Afforestation and Article 3.4 Forest Management compared with area of forest established since 1921 in UNFCCC Sector 5A Forest Land**

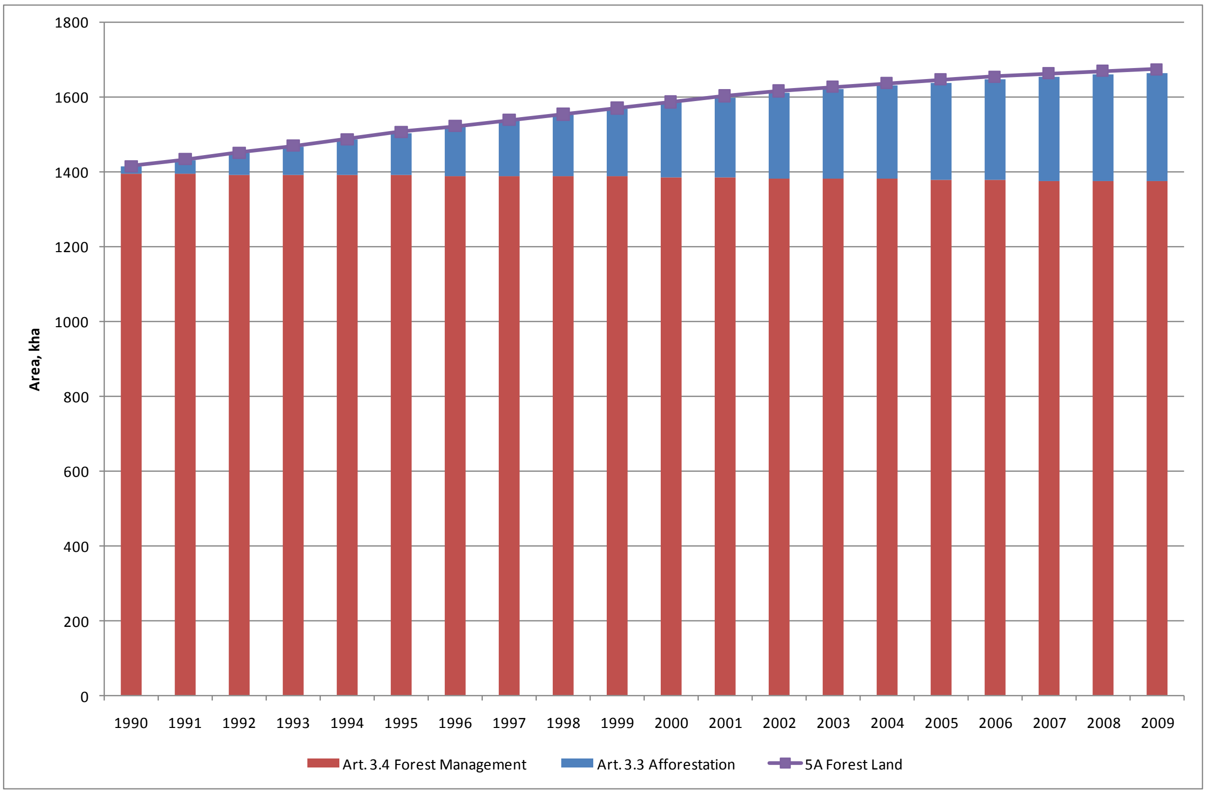
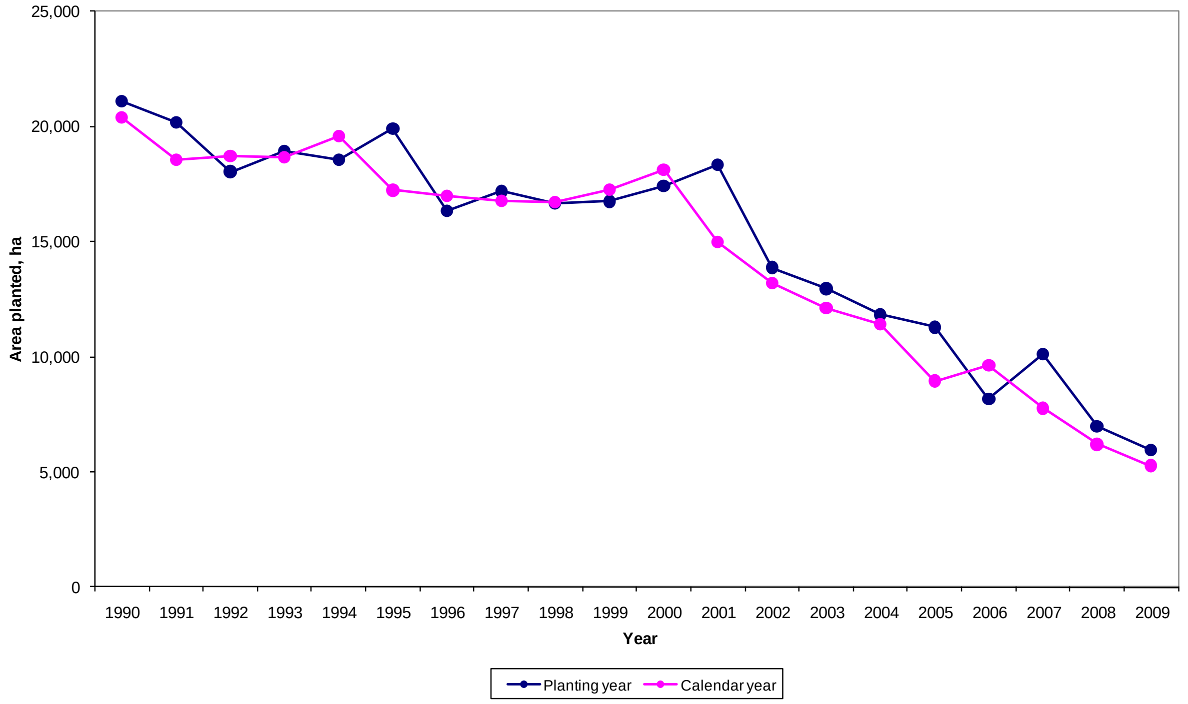


Figure 11.2 **UK afforestation since 1990 in the UNFCCC GHGI (by planting year) and in Article 3.3 (adjusted by calendar year)**



Deforestation since 1990 is taken to be the land area permanently converted from forest land to cropland, grassland or settlement (conversion to cropland is included for the first time following a re-assessment of land use data). Areas of annual forest conversion are reported in the UNFCCC GHGI, and the cumulative total 1990-2009 matches the area reported under Article 3.3 Deforestation.

The Forest Management area is the area converted to forest land between 1921 and 1989 (1,394.49 kha), adjusted to reflect losses from deforestation 1990-2009 (20.94 kha), giving a total of 1375.44 kha in 2009. In the UNFCCC GHGI the deforestation area is deducted from the 5A1 Forest remaining Forest Land area, and carbon stock changes are adjusted accordingly. The area of Forest Management and the area of 5A1 Forest remaining Forest will be directly comparable in 2010 at 1374 kha: 5A1 uses a rolling 20-year transition period.

The afforestation/reforestation datasets are provided by the Forestry Commission and the Forest Service of Northern Ireland (the national forestry agencies) and are consistent with the definition of forest given above. New planting can use planting/seeding or natural colonisation. Data come from administrative systems (state forests) and grant schemes (other woodland) (Forestry Statistics 2010). Areas of planting that are not state-owned or grant-aided (i.e. whether these woodlands are explicitly managed is unknown) are not included in the GHGI or Article 3.3 AR. It is estimated that these contribute less than 0.4 kha annually (possibly an underestimate due to incomplete reporting, according to the Forestry Commission).

There is an assumption of restocking after harvesting, although open habitat can make up 13-20% of stand area on restocking (so stocking density is reduced from its previous level). Therefore, Afforestation and Reforestation under Article 3.3 can be considered together. Thinning is considered to be part of the normal forest management regime. A felling license is required for felling outside the national forest estate; there is a legal requirement to restock under such a license unless an unconditional felling license is granted (in which case this would be formally reported as deforestation). Information on deforestation activities is assembled from data provided by the Forestry Commission and by the Ordnance Survey (the national cartographic agency) through the UK government (**Chapter 7**). To the best of knowledge, these definitions have been applied consistently over time, although larger uncertainties are associated with deforestation estimates compared with afforestation estimates.

11.1.4 Precedence conditions and hierarchy among Art. 3.4 activities

Not applicable, as only Forest Management has been elected under Article 3.4.

11.2 LAND-RELATED INFORMATION

11.2.1 Spatial assessment unit used for determining the area of the units of land under Article 3.3

The spatial assessment units used are the four countries of the UK: England, Scotland, Wales and Northern Ireland (GPG LULUCF Reporting Method 1). There is sufficiently detailed data to allow carbon stock changes for Article 3.3 AR and Article 3.4 FM land to be reported for 20x20km units, but not for the reporting of other emissions or Article 3.3 Deforestation carbon stock changes. Further information on the detailed mapping of AR and FM carbon stock changes will be made available at http://ecosystemghg.ceh.ac.uk/.

For those Overseas Territories and Crown Dependencies that have joined the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol we are guided by what has been compiled for the FAO Forest Resource Assessment 2010 reports (with the assistance of the UK Forestry Commission). These state that there has been no change in the forest areas of these islands since 1990 and only the Cayman Islands and the Isle of Man report forest areas over 1000 ha. We are investigating obtaining additional information for the Isle of Man (the only OT/CD known to have a commercial forestry sector). At present, no estimates of net emissions/removals under KP-LULUCF are made for any of the Overseas Territories/Crown Dependencies.

11.2.2 Methodology used to develop the land transition matrix

The land transition matrix is shown in Table NIR 2 (**Table 11.1**). The same data sources are used for the UNFCCC greenhouse gas inventory and emissions/removals under Articles 3.3 and 3.4. National planting statistics from 1921 to the present are provided by the Forestry Commission and the Northern Ireland Forest Service for each of the countries in the UK. Areas planted since 1990 in this dataset are used in Article 3.3 Afforestation/ Reforestation (**Figure 11.3**). There is currently no detailed information on the age and type of forests subject to deforestation and it is assumed that areas that have been afforested since 1990 will not have been deforested during this period. Estimates of areas in Article 3.3 Deforestation (**Figure 11.4**) are made using Unconditional Felling Licences and the Land Use Change Statistics (LUCS), a survey of land converted to developed use. Further information on these data sources is in **Chapter 7** and a summary is given in

Table 11.2. The area of Article 3.4 Forest Management land is the area of forest planted between 1921 and 1990, adjusted to take account of the area lost by deforestation (**Figure 11.5**). The area of Other Land in table NIR 2 is balanced so that the total area adds up to the land area reported for the UK in **Table 7.2** (24,415 kha) and is constant for all years.

Table 11.1 Table NIR 2 of land area and changes in land areas in 2009

To current inventory year (2009)			Article 3.3 activities		Article 3.4 activities	Other	Total (beginning of year)
From previous inventory year (2008)			Afforestation and Reforestation	Deforestation	Forest Management		
Article 3.3 activities	Afforestation and Reforestation	kha	283.33	0.00			283.33
	Deforestation			19.76			19.76
Article 3.4 activities	Forest Management			1.18	1,375.44		1,376.62
Other			5.27	0.00	0.00	22,730.03	22,735.30
Total (end of year)			288.60	20.94	1,375.44	22,730.03	24,415.01

Figure 11.3 Forest area planted since 1990 in the countries of the United Kingdom

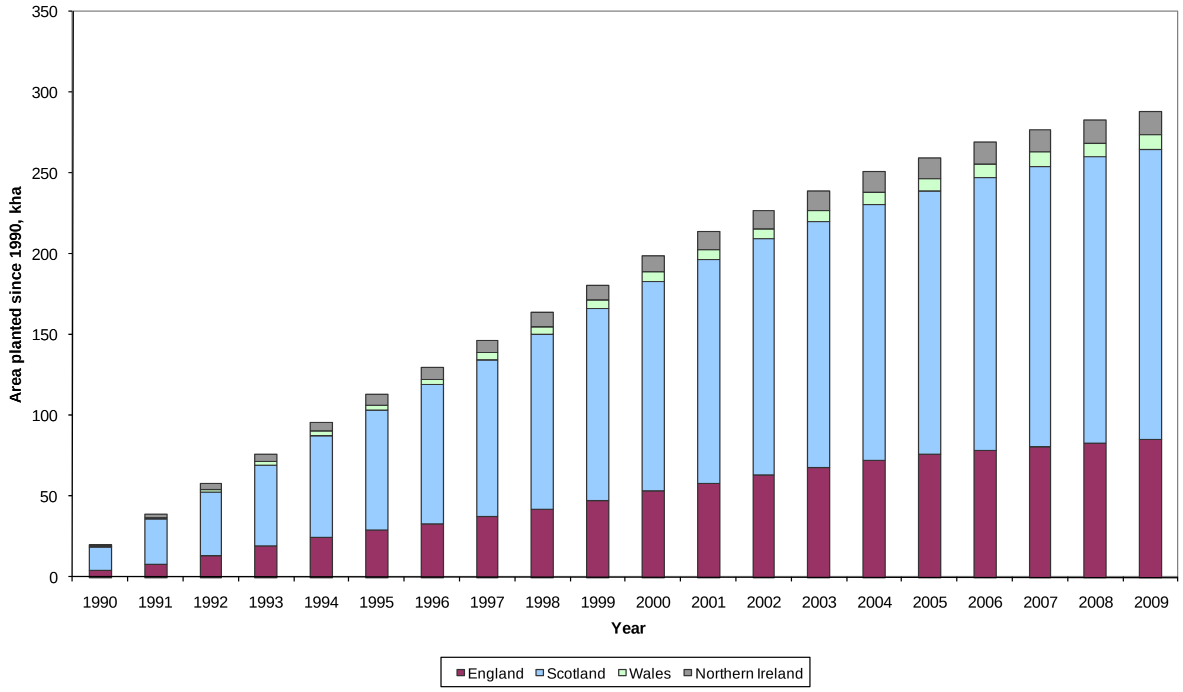


Figure 11.4 Area deforested since 1990 in the countries of the United Kingdom (note different scale from previous figure)

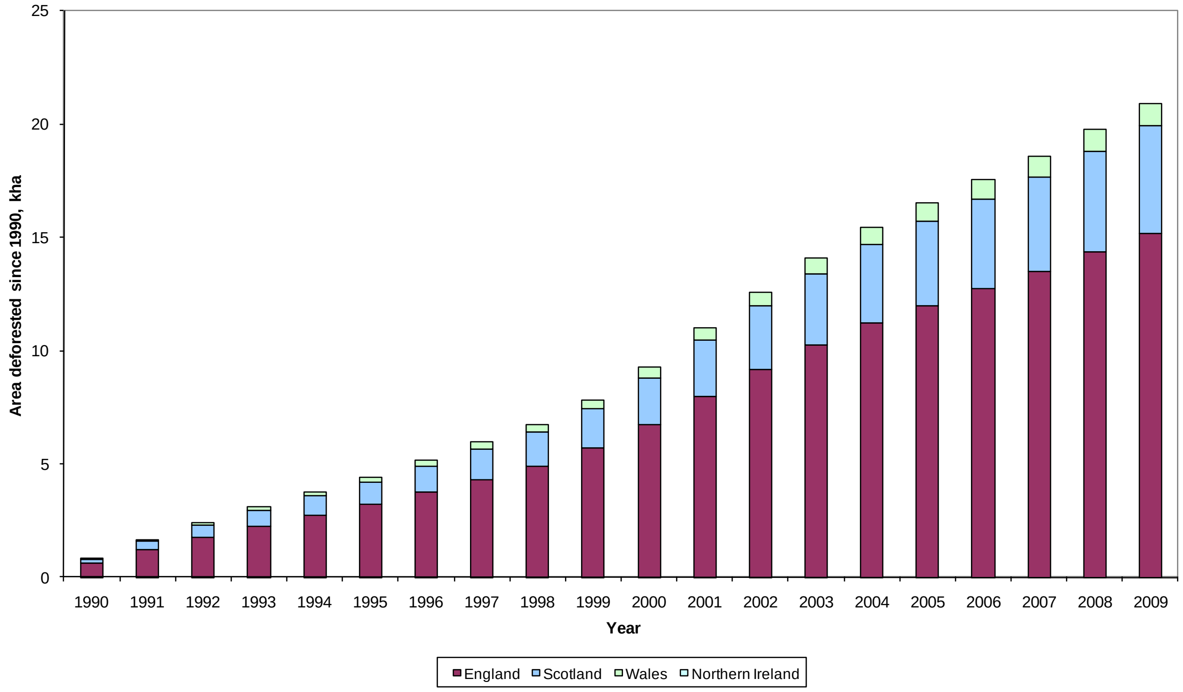


Figure 11.5 Area of Forest Management land 1990-2009 in the countries of the United Kingdom

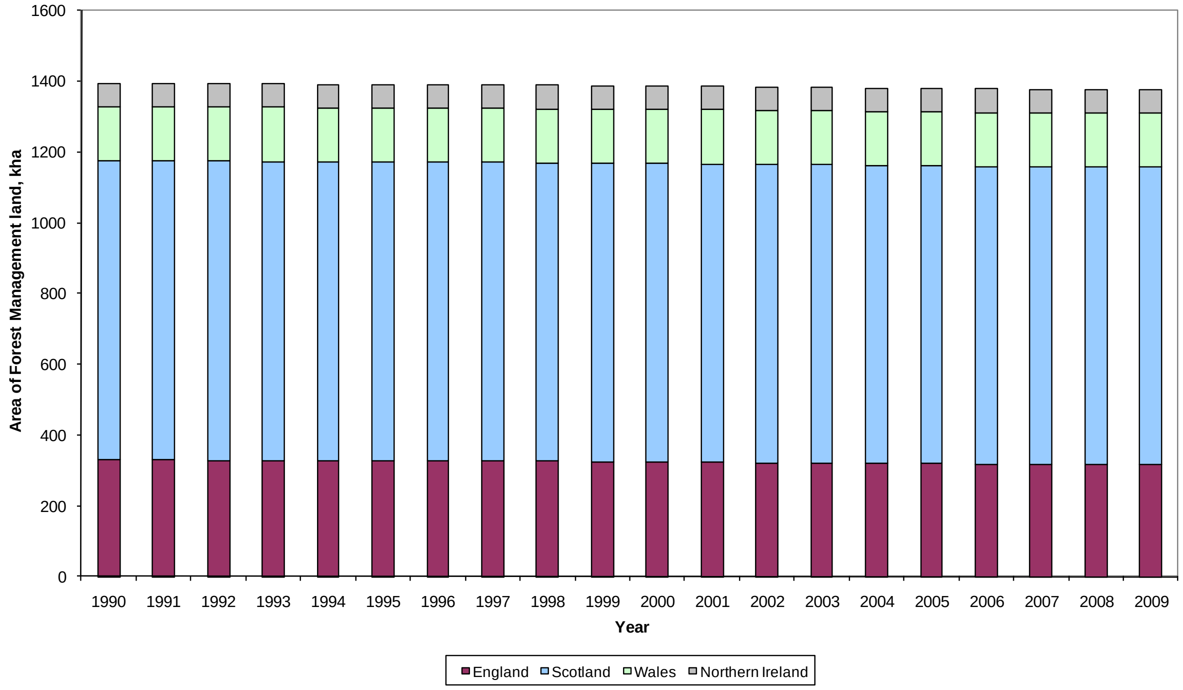


Table 11.2 Data sources on ARD and FM activities

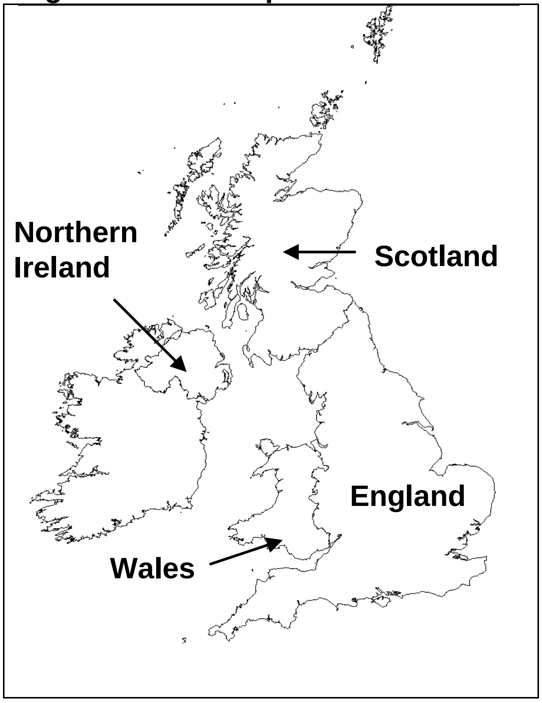
Activity	Dataset	Available scale	Time period	Details
AR & FM	Annual planting statistics	Country (England, Scotland, Wales, Northern Ireland)	1921-present	New planting on previously non-forested land. Updated annually. Categorized into conifer and broadleaved woodland.
D	Forestry Commission Unconditional Felling Licence data	England/Great Britain [1]	1990-2008 (England only), 1999-2001 (Great Britain)	Unconditional Felling Licences are issued for felling without restocking. Used to estimate deforestation in rural areas (primarily for heathland restoration). English data is extrapolated to GB scale and to current reporting year. Omits felling for development purposes, e.g. construction of wind turbines.
D	Land Use Change Statistics (survey of land converted to developed uses)	England only	1990-2007 (updated in 2009)	Estimates of the conversion of forest to urban/developed land use. Based on Ordnance Survey map updates, identifying changes through aerial surveys and other reporting, expected to capture most changes within five years. English data is extrapolated to GB scale and to current reporting year.

[1] There is no deforestation dataset currently available for Northern Ireland, which is reported as Not Occurring. Additional data sources are being investigated and we will report estimates in the next inventory submission.

11.2.3 Maps and database to identify the geographical locations, and the system of identification codes for the geographical locations

The individual countries of the United Kingdom have been used as the geographical units for reporting (**Figure 11.6**). The Forestry Commission and Forest Service maintain administrative systems that allow areas of land to be tracked within each country (sub-compartment databases for state forests and grant scheme data for other woodland).

Figure 11.6 Spatial units used for reporting Kyoto protocol LULUCF activities



11.3 ACTIVITY-SPECIFIC INFORMATION

11.3.1 Methods for carbon stock change and GHG emission and removal estimates

11.3.1.1 Description of the methodologies and the underlying assumptions used

Methods for estimating carbon stock changes in forests (for Article 3.3 Afforestation/Reforestation and Article 3.4 Forest Management) are the same as those used for the UNFCCC greenhouse gas inventory: details are given in annex 3.7. A carbon accounting model, C-Flow, is used to estimate the net change in pools of carbon in living biomass, litter and soil in conifer and broadleaved forests. In the KP CRF tables changes in carbon stock are reported for: above-ground biomass (gains and losses), litter (net changes) and soils (net changes in mineral and organic soils). Carbon stock changes in below-ground biomass and dead wood are reported as Included Elsewhere: below-ground biomass is calculated as part of the above-ground biomass and dead wood is calculated as part of the litter pool.

Annual data on forest planting is provided by the Forestry Commission, at a higher precision than that published in the annual Forestry Statistics and with non-grant-aided planting separated out. Information on state afforestation is stored in the Forestry Commission Sub-Compartment Database (SCDB): this is the stand management database for state-owned and managed forest, containing information on species, age, yield class and management. Non-state forest information comes from the grant schemes by which the government encourages planting and management of private woodland. These schemes cover almost all private woodland planting since 1995: there is a small amount of non-grant aided woodland (mostly in England) which is assumed to be broadleaved natural regeneration but we have no further information on the management or permanence of this area. Areas included are those for which new planting grants have been paid and the planting has actually been completed. The FC will not pay grants prior to the planting taking place so it can be assumed the areas are therefore stocked.

Estimates for carbon stock changes as a result of Article 3.3 Deforestation use the same methods as the UNFCCC greenhouse gas inventory (annex 3.7). During deforestation, 40% of the above-ground biomass is burnt and emissions of CO_2, CH_4 and N_2O are reported in Table 5(KP-II)5. The remaining carbon stock change in biomass is assumed to be immediately lost. This loss (in Gg C) is calculated as:

Stock change = C fraction * % of biomass removed * (area * available biomass) * 0.001

where

carbon fraction = 0.5
proportion of biomass removed = 60%
area = area deforested, ha
available biomass = 240 t/ha (mature broadleaved forest assumed)

Carbon stock changes in soils as a result of deforestation are calculated using the dynamic model of carbon stock change discussed in Annex 3.7. It is not possible to report changes in mineral and organic soils separately since there are no separate activity data. Estimates of deforestation are made for England, Scotland and Wales. There is no activity data available for deforestation in Northern Ireland, and deforestation is reported as Not Occurring. Additional data sources are being investigated and we will report estimates for Northern Ireland in the next inventory submission.

Carbon stock changes due to Forest Management are estimated using the C-Flow model, as described in **Annex 3.7**. It is assumed that all deforestation occurs on Forest Management land, so the area of FM land and carbon stock changes are adjusted to reflect deforestation losses. This was done by running the model with the initial FM land area and calculating the implied carbon stock changes per unit area (as in the CRF tables). The Forest Management land areas were then adjusted to take account of annual deforestation (**Figure 11.5**), and the resulting areas multiplied by the implied carbon stock changes per unit area to give total carbon stock changes.

Greenhouse gas emissions (rather than carbon stock changes) from LULUCF activities under the Kyoto Protocol are reported in Tables 5(KP-II)1-5.

Table 5(KP-II)1. Direct N_2O emissions from N fertilization

The method used to estimate emissions is the same as that used in the UNFCCC greenhouse gas inventory and described in **Annex 3.7**. It is assumed that nitrogen fertilizer is only applied to newly planted forests in the UK (see **Chapter 7** for more information).

Table 5(KP-II)2. N_2O emissions from drainage of soils

According to the Good Practice Guidance, reporting of these emissions is not mandatory so no estimates have been made. There is further discussion on this matter in **Chapter 7** and **Annex 3.7**. Work is planned for this area.

Table 5(KP-II)3. N_2O emissions from disturbance associated with land use conversion to cropland.

Deforestation to Cropland in the UK since 1990 has been re-assessed using new activity data from the latest Countryside Survey and Tier 1 methodology. Estimates of N_2O

emissions from disturbance associated with forest conversion to Cropland are now included in the inventory. Such land use conversions only occur in England, as the very small areas of conversion in the other countries of the UK are assessed as being due to survey classification errors rather than genuine land use change.

Table 5(KP-II)4. Carbon emissions from lime application

No lime is applied to UK forests (Forestry Commission, pers. comm.). It is difficult and economically unviable to apply lime at the heavy rates required (Taylor 1991).

Table 5(KP-II)5. GHG emissions from biomass burning

The method used to estimate emissions is the same as that used in the UNFCCC greenhouse gas inventory and described in Annex 3.7. There is no information on the location of wildfires in forests in the UK, so it is not possible to split burning between Afforestation/Reforestation land and Forest Management land. Therefore, emissions from wildfires are all reported under Forest Management. Wildfires would only affect a very small area of Afforestation/Reforestation land area (less than 1% since 1990) if the burnt areas are distributed in proportion to forest area. We will use this approach in the next submission. As described above, it is assumed that 40% of the standing biomass undergoes controlled burning during deforestation and emissions from that burning are reported in this table. It is assumed that wildfires that cause deforestation do not occur in the UK, as there is a general commitment to maintaining forest area.

11.3.1.2 Justification for omitting any carbon pool or GHG emissions/removals from activities under Article 3.3 and elected activities under Article 3.4

Table 5(KP-I)A.1.2 Article 3.3 activities: Afforestation and Reforestation. Units of land harvested since the beginning of the commitment period

It is assumed that no areas that have been afforested since 1990 have been harvested in the period 1990-2008, so carbon stock changes in this table are reported as NO (not occurring). There is an assumption that the species planted are managed so that they reach maturity (40 years or more) before harvesting.

Table 5(KP-I)A.1.3 Article 3.3 activities: Afforestation and Reforestation. Units of land otherwise subject to elected activities under Article 3.4 (information item)

Only Forest Management has been elected under Article 3.4.

Table 5(KP-I)A.2 Article 3.3 activities: Deforestation

There are no activity data available for deforestation in Northern Ireland and carbon stock changes are reported as Not Occurring. Additional data sources are being investigated and we will report estimates for Northern Ireland in the next inventory submission. If deforestation occurs in the same proportion to total forest area in Northern Ireland as in England, then the cumulative area deforested since 1990 would be approximately 1.2 kha.

Table 5(KP-I)A.2.1 Article 3.3 activities: Deforestation. Units of land otherwise subject to elected activities under Article 3.4 (information item)

Only Forest Management has been elected under Article 3.4. As Deforestation is a permanent loss of forest cover, any unit of land that has been deforested under Article 3.3 cannot also be subject to Forest Management under Article 3.4.

Table 5(KP-II)1. Direct N_2O emissions from N fertilization

It is assumed that nitrogen is only applied to newly planted forests in the UK, therefore no N fertilization occurs on Forest Management land. It is assumed that no areas that have been afforested since 1990 have been harvested in the period 1990-2008 so emissions for A.1.2 are reported as Not Occurring.

Table 5(KP-II)2. N_2O emissions from drainage of soils

Reporting of these emissions is not mandatory and no estimates are made. There is no activity data on the extent of drainage under Forest Management areas but this is currently under investigation.

Table 5(KP-II)3. N_2O emissions from disturbance associated with land use conversion to cropland.

Deforestation to Cropland in the UK since 1990 has been re-assessed using new activity data from the latest Countryside Survey and Tier 1 methodology. Estimates of N_2O emissions from disturbance associated with forest conversion to Cropland are now included in the inventory. Such land use conversions only occur in England, as the very small areas of conversion in the other countries of the UK are assessed as being due to survey classification errors rather than genuine land use change and are reported as NO.

Table 5(KP-II)4. Carbon emissions from lime application

No lime is applied to UK forests (Forestry Commission, pers. comm.), so emissions are reported as Not Occurring.

Table 5(KP-II)5. GHG emissions from biomass burning

There is no controlled burning in UK forests, so this is reported as Not Occurring under Afforestation/Reforestation and Forest Management. There is no information on the location of wildfires in forests in the UK, so it is not possible to split burning between Afforestation/Reforestation land and Forest Management land. Therefore, emissions from wildfires are all reported under Forest Management. There is no activity data collected on wildfires on non-forest land in the UK at present, therefore emissions from wildfires on deforested land cannot be estimated. Wildfires on forest converted to grassland (principally open habitat restoration) are likely to be the principal source. Given the rate of deforestation to grassland averages 550 ha a^{-1} 1990-2009, the area affected by wildfire is conservatively estimated to be less than 100 ha a^{-1}. It is assumed that wildfires on forested land do not result in a permanent loss of forest cover and burnt areas will undergo replanting or natural regeneration.

11.3.1.3 Information on whether or not indirect and natural GHG emissions and removals have been factored out

The UK inventory approach to estimating forest carbon stock changes is based on modelled growth data rather than national-scale measurements of forest annual volume increments. The CFlow model is based on yield class tables, and in principle assumes constant weather and management conditions. Therefore ‘factoring out’ of climate change effects is not required. Work has been undertaken to model the impact of climate, CO_2 and land use change on the carbon balance of terrestrial ecosystems in Great Britain (Levy and Clark 2009) and interaction between these factors. This suggested that interactions are small and the effects of these environmental factors are additive. Nitrogen dynamics were not considered in this work: the extent to which enhanced nitrogen deposition affects forest carbon sequestration remains contentious (Magnani *et al* 2007; Sutton *et al* 2008). Much of the United Kingdom's forest area was established during the 20th century, and forests are still in their first or second rotation. The dynamic effects of the age structure are taken into account in Art 3.3 and Article 3.4 Forest Management, the latter being limited by the FM cap.

11.3.1.4 Changes in data and methods since the previous submission (recalculations)

This is the second official submission of Article 3.3 and Article 3.4 estimates, and some recalculations have been made since the previous submission (**Table 11.3**).

Table 11.3 Recalculations of 2008 emissions/removals in the 2009 KP-LULUCF submission

Category	2008 submission value, Gg	2009 submission value, Gg	Reason for recalculation
Art. 3.3 Afforestation Net CO_2 emissions/removals	-2,696.00	-2,696.04	Revised area of planting in England in 2008
Art. 3.3 Deforestation Net CO_2 emissions/removals	599.95	616.61	Revised activity dataset 1990-2009.
Art. 3.4 Forest Management Net CO_2 emissions/removals	-10,714.36	-10,726.88	The FM area has been adjusted to take account of losses due to deforestation, and net emissions/removals have been updated accordingly
Art. 3.3 Deforestation CH_4 emissions	0.64	0.81	Updated activity dataset 1990-2009, resulting in updated biomass burning estimates.
Art. 3.4 Forest Management CH_4 emissions	0.69	0.70	Wildfire activity data has been revised for 2008.
Art. 3.3 Afforestation N_2O emissions	0.0031	0.0042	New Countryside Survey data has changed distribution of land converted to forest. EF has also been changed to that used in the IPCC 2006 guidelines.
Art.3.3 Deforestation N_2O emissions	0.0044	0.0061	Updated activity dataset 1990-2009, resulting in updated biomass burning estimates. N_2O emissions from deforestation to Cropland are included for the first time.
Art. 3.4 Forest Management N_2O emissions	0.0047	0.0048	Wildfire activity data has been revised for 2008.

11.3.1.5 Uncertainty estimates

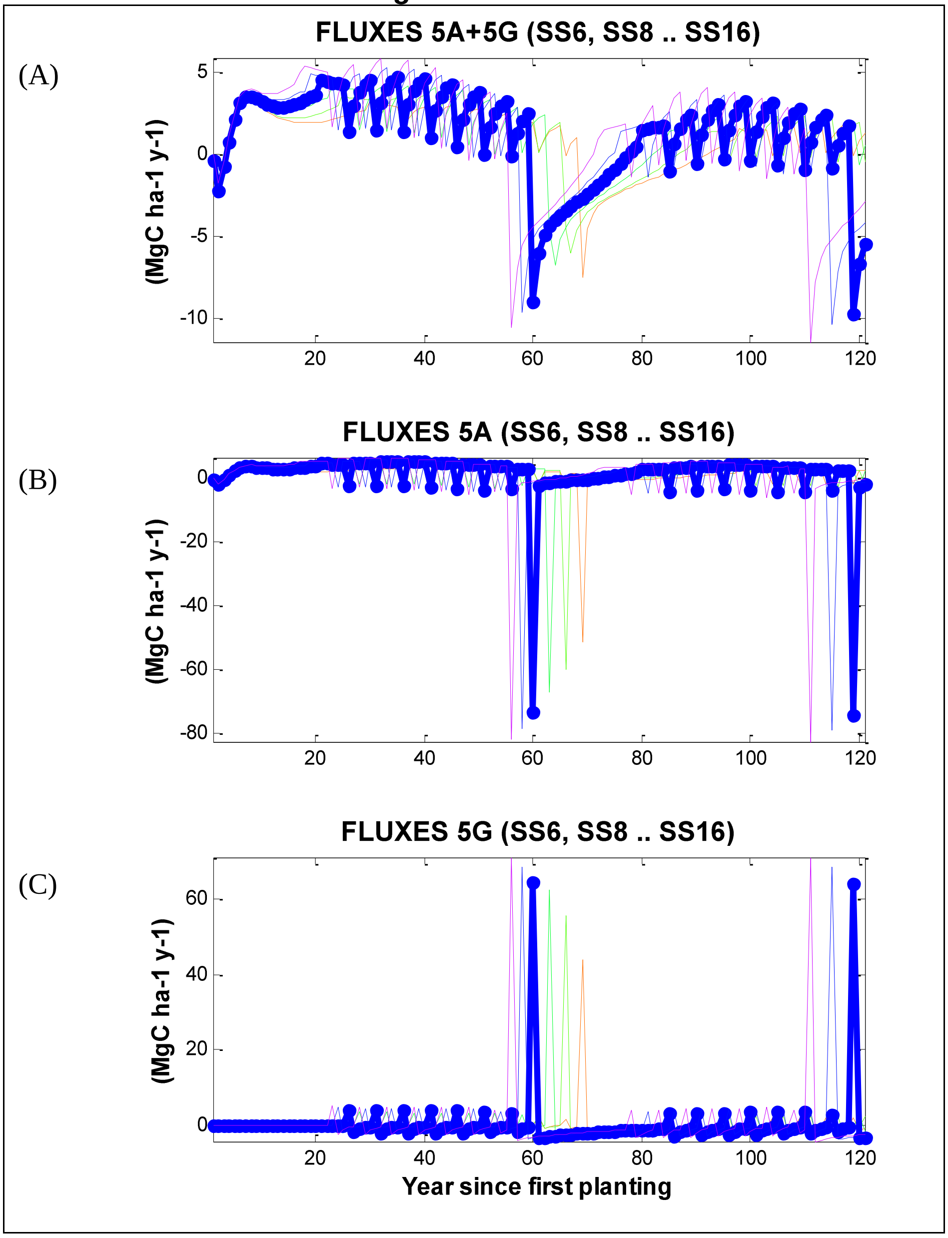
Uncertainty assessment and quantification of the inventory has been undertaken during 2007-2009, with particular focus on the forest carbon modelling components (van Oijen 2007; 2008; 2009; van Oijen and Thomson 2010). The carbon flow model, CFlow (Dewar and Cannell 1992), is used to model carbon pools and fluxes in UK forests (described in Annex 3.7). The uncertainty arising from the inputs, parameters and model structure of CFlow has been examined, and it has also been compared with a more complex process-based model, BASFOR (van Oijen and Thomson, 2010). This work is described in the 1990-2008 national inventory report.

Uncertainty from model inputs.

The IPCC Tier 2 approach for uncertainty quantification recommends quantifying the uncertainties associated with individual input factors by expressing them as probability distribution functions (PDFs). Sampling from the PDFs propagates input uncertainty through the model to the outputs. However, 'knowledge about parameters is generally incomplete; they interact and uncertainty may propagate non-linearly in the calculations. If the only source of information utilized for the PDFs is direct measurement or expert opinion, the resulting output may be overly high' (van Oijen and Thomson, 2010). Bayesian techniques (van Oijen *et al*. 2005, Patenaude *et al*, 2008) have been used in this uncertainty assessment to reduce input uncertainties where possible.

CFlow requires input data on the afforestation rate (ha yr^{-1}) and yield class (mean wood volume production, m^3 ha^{-1} yr^{-1}) for different forest types and regions in the UK. CFlow has near-linearity with respect to the yield class input, i.e. the use of yield class 12 m^3 ha^{-1} yr^{-1} for conifers (used in CFlow) produces a carbon flux time series that closely approximates the mean of yield classes 8,10,12,14 and 16 m^3 ha^{-1} yr^{-1} (van Oijen 2008). The average annual flux over 100 years since first planting for yield class 12 is 1.53 Mg C ha^{-1} yr^{-1} (biomass+litter+soil), with values for other yield classes ranging from 1.18 Mg C ha^{-1} yr^{-1} (-23%, yield class 8) to 1.97 Mg C ha^{-1} yr^{-1} (+29%, yield class 16). However, very large uncertainties can arise when assessing carbon sequestration for specific calendar years with different yield classes as harvesting produces a large flux (**Figure 11.7** B and C). However, when categories 5A and 5G (Forest Land and Harvested Wood Products) are considered together the combined uncertainty is much smaller (**Figure 11.7** A) because of the opposite effect that harvesting has on these two stock pools. It should also be noted that these graphs show the fluxes from a single instance of planting: when spatio-temporal patterns across the UK are combined together these inter-year uncertainties are cancelled out to a large extent.

Figure 11.7 **Comparison of flux time series since first planting from CFlow for Sitka spruce yield class 6,8…16. The default curve (YC12) is shown in bold blue. Lower yield classes are in red-green, higher yield classes in blue-magenta.**



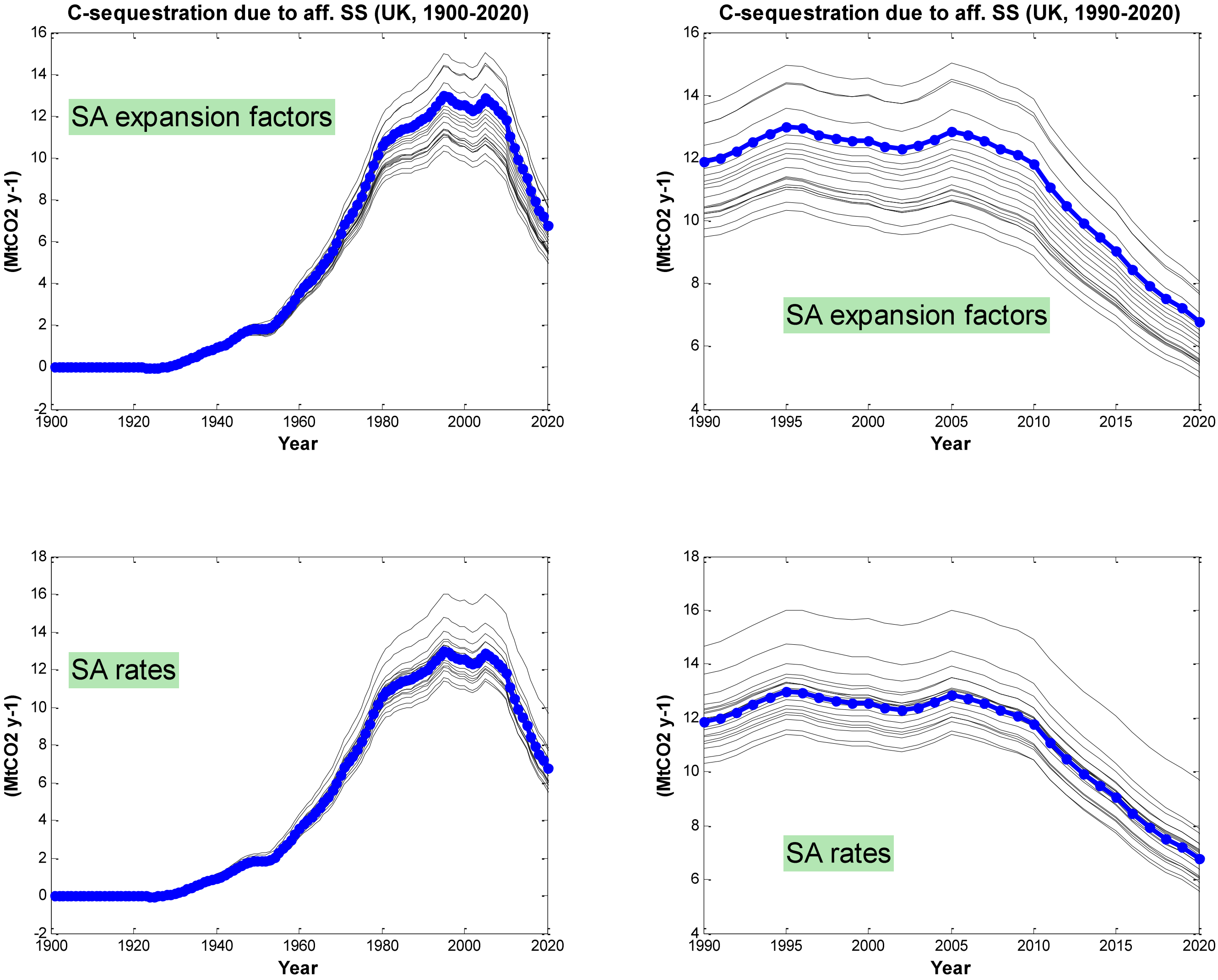
No measures of statistical uncertainty are associated with the planting statistics because they come from administrative systems (assumed to have total coverage) rather than surveys (Forestry Commission, pers. comm.). It should be possible to derive better information on the reliability of the planting statistics when the new National Forest Inventory (NFI) map becomes available in mid-2011: the NFI team are scheduled to produce gross and net change statistics based on the new map during 2011, although details have not yet been finalised. We are looking to this new source to improve our estimates of woodland loss, and it should also provide information about woodland planting that is non-FC and non-grant aided.

Uncertainty from model parameters

Dewar and Cannell (1992) include a sensitivity analysis of CFlow's parameters. The processes and parameters that were most uncertain or variable were: the fractions of woody biomass in branches and woody roots, litter and soil organic matter decomposition rates and the rate of fine root turnover. Other parameters were known to reasonable accuracy and/or had a small impact on carbon storage.

Additional sensitivity analysis was presented in van Oijen (2009). The sensitivity of the biomass expansion factor and turnover rate parameters (controlling the carbon partitioning between trees, litter and soil) were modelled with 30% uncertainty about the default parameters under a uniform distribution (**Figure 11.8**). Changes in parameters do not affect the overall time pattern of carbon sequestration due to afforestation. Of particular relevance to Kyoto Protocol reporting is that there are only minor differences between sink strength in any given year and a reference year, e.g. 1990.

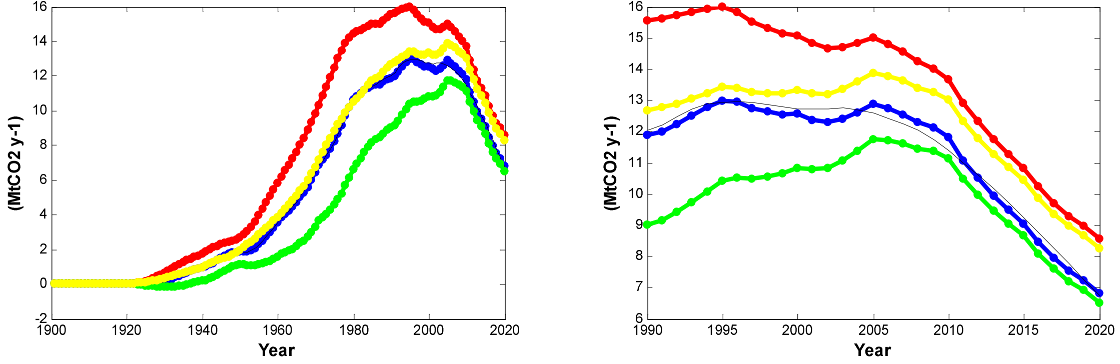
Figure 11.8 **Sensitivity analysis (SA) of 5A+5G to changes in parameters. Top row: changes in expansion factors. Bottom row: changes in turnover rates. Blue lines: default parameterisation. Black lines: sample of 20 parameter vectors from a multivariate uniform distribution where every individual parameter has a range from 0.7 to 1.3 times its default.**



Uncertainty from model structure

Van Oijen (2009) also examined the inclusion of certain processes within CFlow: the gradual loss of pre-existing soil carbon due to planting disturbance and carbon removal by ground vegetation before canopy closure (based on Hargreaves *et al*. 2003). The assumptions regarding the dynamics of these processes do not affect the general pattern of carbon stock change over time but do affect the magnitude of that stock change (**Figure 11.9**). The implementation of both processes was based on a limited amount of empirical information, so the reliability of the current model is to some extent uncertain. However, the existence of these processes is not in doubt- their magnitude and change over time are (so the graphs over-estimate the uncertainty regarding these processes).

Figure 11.9 **Total carbon stock change due to U.K. afforestation (5A+5G). Left: 1900-2020, right: 1990-2020. Blue line: actual inventory method. Red: no emissions from pre-existing soil carbon. Green: no removal by grass growth. Yellow: neither process (i.e. "Red+Green").**



Work using a more complex process-based carbon flow model (BasFor) discovered that uncertainties showed distinct spatial trends across the UK, as a result of heterogeneous environmental conditions (van Oijen and Thomson 2010). This suggests that a simple approach to forestry-related uncertainty (i.e. assuming uncertainty to be a fixed percentage of the absolute flux rate) is not applicable.

This work has not yet produced a simple uncertainty estimate for reporting, so work is continuing in this area. In the interim, an uncertainty of 25% for Article 3.3 Afforestation/Reforestation and Article 3.4 will be used (as estimated for UNFCCC category 5A) and an uncertainty of 50% for Article 3.3 Deforestation (based on expert judgement).

11.3.1.6 Information on other methodological issues

Disturbances. Data is available on fire damage to state-managed forests and extrapolated to privately-managed forests (see **Chapter 7** and **Annex 3.7** for further details). There is no data available on the type of forest burnt by wildfires (species or age) or wildfire locations within each country of the UK. Wildfires are not assumed to result in a permanent change in land use. Damage from windblow is not reported in the UNFCCC inventory, although it does occur in the UK (FAO, 2010; Forestry Commission, 2002). There are currently insufficient data to include the effects of these disturbances in the inventory. If a storm causing extensive, widespread forest destruction occurred (as in the 1987 storm in southern England) then this would be taken account of on an *ad hoc* basis.

Inter-annual variability. The method used to estimate emissions and removals from AR and FM is based on the C-Flow model. This model is not sensitive to inter-annual variation in environmental conditions so these will not affect the annual growth and decay rates. There is an ongoing research project to look at the variation in management conditions across the UK forest estate and over time. The area burnt in wildfires does show inter-annual variation and this is included in the emissions methodology. Where data are missing from the annual time series a Burg regression equation is used to extrapolate the trend from the previous ten years.

11.3.1.7 The year of the onset of an activity, if after 2008

5 274 ha of land were afforested in 2009 and 1 183 ha of land were deforested.

11.4 ARTICLE 3.3

11.4.1 Information that demonstrates that activities began on or after 1 January 1990 and before 31 December 2012 and are directly human-induced

Under the current methodology, the Forestry Commission and the Forest Service of Northern Ireland provide annual data on new planting (on land that has not previously been forested). This information is provided for each country in the UK and the time series extends back before 1990. Data are provided by ‘planting’ year and then adjusted to calendar years as described in **Section 11.1.3**. Information on new planting and restocking are published as separate figures for both state and private woodlands. New planting can use planting/seeding or natural colonisation. Data come from administrative systems (state forests) and grant schemes (other woodland) (Forestry Statistics 2010). Areas of planting that are not state-owned or grant-aided (i.e. whether these woodlands are explicitly managed is unknown) are not included in the GHGI or Article 3.3 AR.

Information on deforestation is assembled from felling licences for deforestation to other rural land uses and information on the conversion of forests to settlement land uses, both of which can thereby be shown to be directly human-induced. The time series of activity data is not sufficiently detailed to demonstrate the exact date of deforestation within a year at present.

11.4.2 Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation

The data sources used for estimating Deforestation do not allow for confusion between harvesting or forest disturbance and deforestation. This is because the unconditional felling licences used for the estimation of rural deforestation are only given when no restocking will occur, and the survey of land converted to developed use describes the conversion of forest land to the settlement category, which precludes re-establishment. A new national forest inventory will be partially completed by the end of the commitment period and will be used to verify deforestation estimates made using these data sources.

11.4.3 Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforested

Restocking is assumed for forest areas that have lost forest cover through harvesting or forest disturbance, unless there is deforestation as described above. Information on the size and location of forest areas that have lost forest cover is not explicitly collected on an annual basis. The area of felled forest awaiting restocking was reported in the National Inventory of Woodland and Trees in the mid-late 1990s: this was 1.4% of the total forest area in England (15,100 ha), 1.8% in Scotland (22,979 ha) and 3.1% in Wales (8,961 ha) (Forestry Commission 2002). A comparable inventory was not available for Northern Ireland but in 2002 410 ha of Forest Service land was awaiting replanting (0.5% of the state forest area) (Forest Service 2002).

11.5 ARTICLE 3.4

11.5.1 Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human-induced

All managed forests (planted between 1921 and 1989) are included in Article 3.4 Forest Management because forest management is an on-going activity. The C-Flow model is used to calculate emissions from this forest area after 1990 that have arisen from thinning, harvesting and restocking. The area under Forest Management is adjusted to reflect losses from deforestation, as recorded in **Section 11.1.3**.

11.5.2 Information relating to Cropland Management, Grazing Land Management and Revegetation, if elected, for the base year

These activities were not elected by the United Kingdom.

11.5.3 Information relating to Forest Management

11.5.3.1 That the definition of forest for this category conforms with the definition in item 11.1 above

Data used for estimating emissions from Forest Management is supplied by the Forestry Commission and complies with their definition of forest land, which is the one used for Article 3.3 and 3.4 activities (**Section 11.1.1**).

11.5.3.2 That forest management is a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner.

The UK has a system of certification for sustainable woodland management under the Forest Stewardship Council (FSC) (http://www.fsc-uk.org/). As of March 2010, 1288 kha of woodland in the UK (45%) was certified under the FSC scheme (Forestry Statistics 2010). The management practices in certified woodlands are reviewed annually. All state-owned forests are certified and an increasing proportion of non-state-owned woodlands are becoming certified (23% in 2009). This does not include all woodland that is managed in a sustainable manner, such as smaller or non-timber producing woodlands where certification is not considered worthwhile. In particular, it may omit many broadleaved woodlands even though they are managed for their social and environmental benefits (Forestry Commission, 2002). In the UK's country report to the Global Forest Resource Assessment 2010 (FAO, 2010) 83% of UK forests are managed for production and 18% are managed for conservation of biodiversity (these have protected status). Only 4% have a primary social services (public access) function, but 55% are listed as having multiple uses, many of which will include social functions.

11.6 OTHER INFORMATION

11.6.1 Key category analysis for Article 3.3 activities and any elected activities under Article 3.4

Three categories are considered to be key: Article 3.3 Afforestation and Reforestation (CO_2), Article 3.3 Deforestation (CO_2) and Article 3.4 Forest Management (CO_2). These have been assessed according to the IPCC good practice guidance for LULUCF **Section 5.4.4**. The numbers have been compared with Table A 1.1.5 Key category analysis for the latest reported year (2009) based on level of emissions (including LULUCF).

Article 3.3 Afforestation and Reforestation (CO_2): The associated UNFCCC category 5A (-12 764 Gg CO_2e) is a key category although the AR component (forest planted since 1990) is not key on its own (i.e. its category contribution (-2 823 Gg CO_2e) is smaller than the smallest UNFCCC key category (1A Natural Gas)). Removals from this category are also predicted to increase over time as a result of tree planting schemes partially focussed on climate change mitigation.

Article 3.3 Deforestation (CO_2): The associated UNFCCC categories (5B, 5C and 5E) are key categories (13 462, -9 280 and 6 061 Gg CO_2e respectively). However, the Deforestation category contribution (648 Gg CO_2e) to these UNFCCC categories is smaller than the smallest UNFCCC key category (1A Natural Gas). The data used in the calculation of deforestation emissions are the most uncertain of the data sources in the KP-LULUCF inventory and are a priority for improvement.

Article 3.4 Forest Management (CO_2): The associated UNFCCC category 5A is a key category (-12 764 Gg CO_2e). The Forest Management category contribution (-9 798 Gg CO_2e) is also greater than other categories in the UNFCCC key category.

These categories are the priority for improvement in the KP-LULUCF inventory, and there is ongoing development (described in **Chapter 7**).

11.6.2 Information relating to Article 6

Not applicable in the United Kingdom.

12 Information on accounting of Kyoto units

12.1 BACKGROUND INFORMATION

The UK Greenhouse Gas Registry is operated and maintained 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.[25] The UK's Standard Electronic Format report for 2010 containing the information required in paragraph 11 of the annex to decision 15/CMP.1 and adhering to the guidelines of the SEF has been submitted to the UNFCCC Secretariat electronically – SEF_GB_2011_1_15-40-56 5-1-2011.xls

12.2 SUMMARY OF INFORMATION REPORTED IN THE SEF TABLES

At the end of 2010, there were 3,571,662,080 AAUs in the UK registry of which 2,925,376,964 were in the party holding account, 385,416,709 in the entity holding account, 13433 in other cancellation accounts and 260,854,974 in the retirement account. The registry also contained a total of 35,971,489 CERs and 4,016,654 ERUs.

In total for 2010, the UK Registry received 579,540,623 AAUs, 16,586,606 ERUs and 153,759,889 CERs. Conversely, 464,498,835 AAUs, 13,332,424 ERUs and 142,494,324 CERs were externally transferred to other national registries. Account holders voluntarily cancelled 10,936 AAUs and 511,719 CERS. There were no transactions of any kind involving ERUs, RMUs, tCERs or lCERs.

Full details are available in the SEF tables; the full tables are shown in **Annex 6**.

12.3 DISCREPANCIES AND NOTIFICATIONS

Information regarding discrepancies and notifications is summarised in **Table 12.1.**

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

Table 12.1 Summary of discrepancies and notifications

Annual Submission Item	Reporting Guidance
15/CMP.1 annex I.E paragraph 12: List of discrepant transactions	The list of discrepant transactions is listed in the table named “R2” in the Excel file included with this submission with the name “SIAR Reports 2010-GB v1.0.xls”. The contents of the Report R2 can also be found in Annex 6 of this document.
15/CMP.1 annex I.E paragraph 13 & 14: List of CDM notifications	No CDM notifications occurred in 2010. Refer to Separate Electronic Attachment “SIAR Reports 2010-GB v1.0.xls” Worksheet R3. The contents of the Report R3 can also be found in Annex 6 of this document.
15/CMP.1 annex I.E paragraph 15: List of non-replacements	No non-replacements occurred in 2010. Refer to Separate Electronic Attachment “SIAR Reports 2010-GB v1.0.xls” Worksheet R4. The contents of the Report R4 can also be found in Annex 6 of this document.
15/CMP.1 annex I.E paragraph 16: List of invalid units	No invalid units exist as at 31 December 2010. Refer to Separate Electronic Attachment “SIAR Reports 2010-GB v1.0.xls” Worksheet R5. The contents of the Report R5 can also be found in Annex 6 of this document.
15/CMP.1 annex I.E paragraph 17 Actions and changes to address discrepancies	Actions and changes are addressed in Chapter 14: Information on Changes to National Register under section Change of discrepancies procedures.

12.4 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.environment-agency.gov.uk/. Further details are summarised in **Table 12.2** below.

Table 12.2 Details of publicly accessible information

Annual Submission Item	Reporting Guidance
15/CMP.1 annex I.E Publicly accessible information	The following information is now deemed publicly accessible and as such is available via the homepage of the UK registry – http://emissionsregistry.environment-agency.gov.uk/ In accordance with the requirements of Annex E to Decision 13/CMP.1, all required information for a Party with an active Kyoto registry is provided with the exceptions as outlined below.
	Account Information (Paragraph 45) Article 78 of the Registry Regulation that came into force in August 2010 requires that representative identification information is held as confidential. Account holders authorised to hold Kyoto units in their account (Paragraph 48) Article 78 of the Registry Regulation that came into force in August 2010 requires that representative identification information is held as confidential. JI projects in UK (Paragraph 46) Note that no Article 6 (Joint Implementation) project is reported as conversion to an ERU under an Article 6 project, as this did not occur in the specified period. The United Kingdom has taken the decision not to host any domestic JI projects, clarification of which is on our registry public pages http://emissionsregistry.environment-agency.gov.uk/ Paragraph 47 a/d/f - Holding and transaction information of units Holding and transaction information is provided on a holding type level, due to more detailed information being declared confidential by EU Regulation. Article 10 of EU Regulation 2216/2004/EC, provides that "All information, including the holdings of all accounts and all transactions made, held in the registries and the Community independent transaction log shall be considered confidential for any purpose other than the implementation of the requirements of this Regulation, Directive 2003/87/EC or national law." Paragraph 47c The United Kingdom is not hosting domestic JI projects as per paragraph 46 above.

	Paragraph 47e The United Kingdom is currently not participating in any LULUCF projects for 2010. Paragraph 47g No ERUs, CERs, AAUs and RMUs have been cancelled on the basis of activities under Article 3, paragraphs 3 and 4 to date. Paragraph 47h No ERUs, CERs, AAUs and RMUs have been cancelled following determination by the Compliance Committee that the Party is not in compliance with its commitment under Article 3, paragraph 1 to date. Paragraph 47j No ERUs, CERs, AAUs nor RMUs have been retired to date. Paragraph 47k There is no previous commitment period to carry ERUs, CERs, and AAUs over from.

12.5 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 (2007)
= 5 x 640,273,265 tonnes CO2 equivalent
= 3,201,366,325 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)**[26].

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[26] For the UK's commitment under the EUMM, the Assigned Amount is 3,396,475,254. The CPR calculated on this basis is 3,056,827,729

The 1990-2007 inventory has been taken as the most recently reviewed inventory, because the report of the 1990-2008 inventory review is not yet finalised.

12.6 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 survey data means that a more detailed and accurate assessment, based on the best possible information, will be possible at the end of the first commitment period.

13 Information on changes in national system

13.1 CHANGES TO THE NATIONAL SYSTEM

There have been no changes to the structure of the UK's National Inventory System since the previous GHGI submission. However, there have been some small changes to the organisations and roles listed in **Table 1.3**:

- DECC – International Climate Change and Energy (ICCE) are now known as International Energy and Climate Change
- The LULUCF Inventory contract is now managed in CESA
- The Northern Ireland regulator has been changed from the Environment and Heritage Service to the Northern Ireland Environment Agency

14 Information on changes in national registry

14.1 CHANGES TO THE UK'S REGISTRY SYSTEM

Changes to the UK registry system are detailed in **Table 14.1**, below.

Table 14.1 Changes to the UK's registry system

Reporting Item	
15/CMP.1 annex II.E paragraph 32.(a) Change of name or contact	Addition of contact details: **Mr. Jason Bailey** Environment Agency Richard Fairclough House Knutsford Road Warrington UK WA4 1HG Email: jason.bailey@environment-agency.gov.uk Telephone: +44 1925 542584 Any previous contact details should be removed.
15/CMP.1 annex II.E paragraph 32.(b) Change of cooperation arrangement	No change of cooperation arrangement occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(c) Change to database or the capacity of National Registry	The changes to UK's registry in 2010 cover changes to software as detailed below. Version 4.3 was implemented in the UK registry in February 2010 and 5.1 in October 2010. Both upgrades (V4.3 and V5.1) have incorporated changes that increased the capacity of the Registry. The following capacity improving measures have been implemented compared to the previously used version. Version 5.0 was not implemented into the live registry and instead released as part of the enhancements included in v5.1
Software Changes Version 4.3: This version included the following changes: • The ability to perform NAP management functions, as per the automatic new entrants and closures process set out in the Registry Regulations. The account application process was also altered slightly in order to meet the NAP management requirements. • The addition of SQL Server Reporting Services 2005 for report generation and management. • Addition of Installation Permit into Force date	

Reporting Item	
Version 5.1: This version included the following changes • Improvements to reconciliation processing. In order to improve performance and reliability, the processing of reconciliation messages was changed from a synchronous to an asynchronous process. This ensures that the Registry responds to ITL messages within an appropriate time period, thus eliminating time-out errors. A windows service is used to process the reconciliation messages; this improves reliability and makes the process more robust by enabling processing failures to be retried. In addition, the reconciliation function was streamlined and is more efficient than in previous versions. This enhances the robustness of the system, necessary as the number and size of transactions increases. • User interface changes to streamline the compliance process, so reducing user errors and improving data integrity. Each new release also includes a 'maintenance' element whereby high-priority legacy bugs are also resolved. These are detailed in the accompanying release notes. SQL Server 2005 was mandated for V4.3 and this has bought improvements in relation to Registry performance, reliability and scalability. The following test reports, test plans and release notes are supporting documentation for the 2 releases, available in Annex 6 - Registry v4.3 Release Notes - Registry v5.1 Release Notes - Registry v4.3 Regression Tests - Registry v5.1 Regression Tests - Registry v4.3 Test Report - Registry v5.1 Test Report - Registry v4.3 Test Plans - Registry v5.1 Test Plans - CITL Test Plan and Results v4.3 - CITL Test Plan and Results v5.1 - CITL Approval Email CITL test scenarios cover the requirements of Annex H testing.	
15/CMP.1 annex II.E paragraph 32.(d) Change of conformance to technical standards	No change in the registry's conformance to technical standards occurred for the reported period. An improved message flow was introduced by the ITL in October 2010 and the registry will incorporate this in 2011 to make use of this improved service. The registry continues to conform to the DES. As this changes has not yet taken place in the registry, this will be reported as part of next year's submission.
15/CMP.1 annex II.E paragraph 32.(e) Change of procedures	As expected previous improvements to the registry have resulted in fewer discrepancies in 2010 compared to the previous year. Only discrepancies with result codes 4003 and 4010 occurred. Compared to 2009 the number of occurrences of 4003 result codes decreased from 1.08 to 0.31 per 100.000 transactions. The occurrences of 4010 result codes decreased from 1.17 to 0.32 per 100.000 transactions. Report R2 provides further details. These remaining discrepancies are inherent to the original transaction message flow as described in the DES. To solve this an improved transaction message flow is supported by ITL since October 2010. Version 5.2, which will be deployed Q1 2011, makes use of this

Reporting Item	
	improved transaction message flow and is expected to significantly reduce the remaining occurrences.
15/CMP.1 annex II.E paragraph 32.(f) Change of Security	The UK registry has continued its use of digital certificates as its two factor authentication mechanism. This has not changed from the previous year. There have been a number of additional security enhancements that were implemented as part of version 5.1 of Greta. These security improvements are; - Removal of phishing by url redirection - Removal of the auto-complete function - Mark cookies as http only. Further details of these changes can be found in section 2.6 of the Registry 5.1 Release Notes attached in Annex 6. There will be several more enhancements planned for early 2011 to further increase security measures.
15/CMP.1 annex II.E paragraph 32.(g) Change of list of publicly available information	No change to the list of publicly available information occurred for the reported period.
15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address	No change of the registry internet address occurred for the reported period.
15/CMP.1 annex II.E paragraph 32.(i) Change of data integrity measure	Version 5.1 of the registry improved the compliance process by streamlining the workflow. This reduces the error rate caused by users with little experience of the registry. Further details of these changes are available in the Registry v5.1 Release Notes and Test Plans in Annex 6. A disaster recovery test was completed during November 2010. One additional step was added in comparison to previous years, however the step was not a significant one and therefore does not require updated readiness documentation, nor is it classed as a significant change.
15/CMP.1 annex II.E paragraph 32.(j) Change of test results	There were no change of test results during the reported period that are already not described in Change to database or the capacity of National Registry.

14.2 CHANGES IN RESPONSE TO REVIEW RECOMMENDATIONS

The following 2 recommendations were made for the UK registry in the last annual review by the Expert Review Team documented in IAR/2009/GB/2/1 in the Summary of Findings. The 2 recommendations are detailed below.

Table 14.2 Changes in response to review centralised review recommendations

Recommendation	Action
Recommendation 1 Ref Nr: 2.4.2.4 Recommendation Nr: 2.4.1.4 *In its next NIR submission, the Party should clearly identify, the nature and extent of changes it has made to the publicly available information and the actions taken to improve the user interface, including providing a clear indication of those elements that are deemed to be confidential.* *Further, the Party should:* - *Immediately update the information publicly available on the Kyoto units held in the national registry and other Kyoto transactions, which was last updated on 1st June 2008.*	The registry updated its publicly available information by providing an updated public reports page found on the registry home page. http://emissionsregistry.environment-agency.gov.uk/ The reports are segregated into the reporting requirements specified by the UNFCCC and the European Commission. The information is easily accessible to anyone and does not require authentication. A user clicks a link to download the report. All information that is deemed as confidential is displayed as such and refers to relevant EU and Registry Regulation where necessary. The information on Kyoto units has been updated showing the latest data, which is also accessible on the registry home page http://emissionsregistry.environment-agency.gov.uk/
Recommendation 2 Ref Nr: 2.4.2.4 Recommendation Nr: 2.4.1.4 *In its next NIR submission, the Party should clearly identify, the nature and extent of changes it has made to the publicly available information and the actions taken to improve the user interface, including providing a clear indication of those elements that are deemed to be confidential.* *Further, the Party should:* - *ensure than any statements made in its NIR in relation to publicly available information are consistent with the information reported in the SEF tables.*	The registry updated its publicly available information by providing an updated public reports page found on the registry home page. http://emissionsregistry.environment-agency.gov.uk/ The reports are segregated into the reporting requirements specified by the UNFCCC and the European Commission. The information is easily accessible to anyone and does not require authentication. A user clicks a link to download the report. All information that is deemed as confidential is displayed as such and refers to relevant EU and Registry Regulation where necessary. The publicly available information accessible via a link on the registry home page are consistent with the figures provided in the tables of the SEF

15 Information on minimization of adverse impacts in accordance with Article 3, paragraph 14

15.1 GENERAL OVERVIEW

The UK believes that a comprehensive and global post-2012 regime with broad coverage of sectors offers the best option to address the issue of response measures. Response measures is not a stand-alone issue and has strong links to technology and capacity building.

Both positive and negative effects must be taken into account. A global transition to a low carbon economy will provide parties with social, economic and sustainable development opportunities, but we acknowlegde that it should address vulnerabilities. We need to ensure that transition to a low carbon economy supports sustainable development processes in all countries, and that effort to assess potential effects of such response measures does not constrain efforts to develop and implement ambitious policies and measures to mitigate climate change.

There is a need for better evidence based information exchange in order to get a better understanding of the actual impacts felt, recognising the need to strengthen and support capacities to compile, analyse and use socio-economic data in assessing potential spill-over effects/response measures.

The UK continues to pursue initiatives that have been mentioned in previous inventory reports and national communications, such as considering food miles, sustainability of the EU Common Agricultural Policy and Trade for Aid. This chapter is not an exhaustive list but instead outlines recent examples of what the UK is doing to understand impacts of response measures on developing countries and actions it is taking to minimize adverse impacts.

15.2 UNDERSTANDING IMPACTS OF RESPONSE MEASURES

Understanding the impacts of response measures is a key step to be able to minimize the adverse impacts. The UK continues to undertake assessments, reviews and analysis projects to better understand the impacts its policies could have on developing countries, and how they could be addressed. Consequently, the UK takes these findings and seeks to apply them in UK and within the EU community in order to minimize adverse impacts in accordance with article 3, paragraph 14. Recent examples of areas where ongoing research and action is taking place are outlined below.

15.2.1 UK research, reports and analysis

The UK has undertaken research to determine the extent of impacts of response measures and uses this information to implement policies in a way that takes into account the impacts of response measures on all developing countries. Examples of areas where research is ongoing are transport biofuels and indirect emissions.

The UK Department of transport has and continues to lead work into understanding Indirect Land Use Change (ILUC) impacts from biofuels. Examples include:

- A study in 2010 to better understand the scale of ILUC impacts of the five biofuels expected to form the main supply of biofuel in the UK in the next ten years: palm, soy and oilseed rape biodiesel and sugarcane and wheat bioethanol. The study succeeds in shedding light on the complexity of calculating ILUC emissions and where there are uncertainties due to both limitations in data and knowledge of how future markets will develop. See http://www.dft.gov.uk/pgr/roads/environment/research/biofuels/

- Research is ongoing to investigate the potential for regional (i.e. sub-national, national and supranational) approaches to avoid ILUC from biofuels production. This project aims to highlight potential actions that may reduce ILUC, reflect the international supply of biofuels, and assess the potential to measure and monitor the regional level actions to avoid ILUC. See http://www.dft.gov.uk/rmd/project.asp?intProjectID=12886

The Department for the Environment, Food and Rural affairs has funded and continues to fund research looking at embedded emissions and sustainable production and consumption, in particular:

- The action and future actions planned to improve the sustainability of key products, services and materials through understanding the environmental impacts throughout their life cycle (from raw materials to end of life). See http://www.defra.gov.uk/environment/business/products/documents/prod-materials-report0708.pdf
- Developing an embedded carbon emissions indicator and the underlying drivers. These projects included calculating and understanding a time series of direct and indirect carbon dioxide emissions associated with UK economic, in particular emissions that are embedded in UK trade, see http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=14606 and http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=16288#RelatedDocuments

15.2.2 Within the EU Community

The UK is an active participant within the EU community and we continue to minimize the adverse effect of our policies and measures through activities such as:

- The EU Emissions Trading System (EU ETS) directive is the EU's main policy mechanism for reducing CO_2 emissions from energy intensive sectors. Through the ETS and the linking directive that allows European facilities to engage in the CDM as a way of meeting their commitments, the EU has increased investments in renewable energy and energy efficiency in developing countries making an important contribution to diversifying the energy mix in those countries.
- A Greenhouse Gas Effort Sharing Decision sets targets for reductions in those sectors of member states’ economies not covered by the EU ETS. For the UK, this

equates to a reduction in emissions in the non-ETS, equivalent to 16 percent below 2005 levels by 2020. For the EU, this is approximately 10%. The decision promotes domestic action and limits the use of international project credits, such as the Clean Development Mechanism (CDM), to meet targets. They are limited (annually) to 3% of Member States' 2005 emissions in the non-ETS.

- A Renewables Directive sets targets for each member state for the proportion of renewable energy generation by 2020. The EU has a 20% renewables target by 2020. The UK's legally binding target is 15%. The Renewables Directive also set every Member State a target of supplying 10% of transport fuel from renewable sources by 2020.
- The Directive on the geological storage of CO_2 outlines a regulatory framework for the safe capture, transport and storage of carbon dioxide in the EU. Up to 300 million allowances from the new entrants reserve of the EU ETS will be used to support the demonstration of carbon capture and storage (CCS) and innovative renewable technologies. The UK's action on CCS are expanded in the sections below.

Further information can be found in the 1990-2009 EU inventory report.

15.3 ACTIONS TO MINIMIZE ADVERSE IMPACTS IN ACCORDANCE WITH ARTICLE 3, PARAGRAPH 14

The UK Government is committed to achieving an ambitious, effective and equitable global deal which will limit global temperature rise to 2°C, and to helping countries adapt to the inevitable impacts of climate change. The transition to a low carbon world requires support to developing countries in their domestic efforts to mitigate and adapt to climate change and to develop their own low carbon economies.

The UK is taking action to minimize adverse impacts in accordance with article 3, paragraph 14 through fast start finance. This involves building the evidence and knowledge to respond to climate change, safeguarding forests and reducing emissions, supporting cleaner, greener growth in developing countries and helping the poorest adapt to the effects of climate change Examples of these activities supporting knowledge transfer, the development and deployment of low carbon technologies, and capacity building are provided in the following sections.

15.3.1 Knowledge transfer

Knowledge transfer can help accelerate the development and deployment of low-carbon technologies to help developing countries mitigate and adapt to climate change.

The UK cooperates in the development, diffusion and transfer of less greenhouse-gas emitting advanced fossil-fuel technologies, and/or technologies relating to fossil fuels that capture and store greenhouse gases, and encouraging their wider use. The UK supports the establishment of a Technology Mechanism (TM), as agreed at COP16 in Cancun 2010, and is already involved with several knowledge transfer initiatives. In addition to the UK's long standing involvement in initiatives such as the Climate Technology Initiative recent actions in this area include:

- In 2010 the UK established the Climate and Development Knowledge Network (CDKN) to provide developing countries access to the latest research, science and best practice on climate change. In response to requests from developing countries themselves, CDKN helps policy-makers and practitioners plan and implement strategies that meet the climate challenges of their country.

- The UK has been piloting the concept of Climate Innovation Centres in developing countries. In 2011 the implementation of the centres in Kenya and India will start and there are plans to develop more in the near future. The climate innovation centres aim to provide a national focal point for innovation in both low carbon and climate resilient technologies, and to help accelerate the development and diffusion of emerging low carbon and adaptation technologies.

15.3.2 Research collaboration

Enhancing global collaboration on research, development and demonstration (RD&D) will be essential to ensure innovation and take-up of climate technologies in developing countries. The UK is cooperating in the technological development of non-energy uses of fossil fuels, and doing so in partnership and supporting developing countries. We are exploring opportunities to support RD&D 'gap-filling' activity on climate technologies (both for mitigation/low carbon development and adaptation activities).

Recent examples of this commitment to collaborative research are 2010-2011 projects on low carbon technology transfer to China and India that the Department of Energy and Climate Change has supports. The main focus of the studies is to provide new empirical evidence to low carbon innovation in developing countries to inform international policy development. Both studies feature a range of low carbon technologies and examine the factors that influence innovation and technology transfer, including technological capacity, access to intellectual property rights and the role of policy frameworks.

The UK is playing a key role on promoting knowledge sharing and capacity building in developing countries on Carbon Capture & Storage (CCS). The UK continues to jointly lead with Australia the CCS initiative under the Clean Energy Ministerial. Furthermore, the UK are active in a number of multi-lateral organisations such as the Carbon Sequestration Leadership Forum (CSLF) which aim to promote this key technology in developing countries and which give these countries a voice; the next CSLF Ministerial meeting will be held in China in September 2011. We are working with the European Commission, Norwegian and Chinese governments to build the capacity to demonstrate carbon capture and storage technology in China through the Near Zero Emissions Coal (NZEC) project and are also assisting the South African CCS Centre in its assessment of the potential CO_2 storage capacity in South Africa.

15.3.3 Capacity Building projects on Renewable Energy & Energy Efficiency

The UK is cooperating in the development, diffusion and transfer of less greenhouse-gas emitting advanced fossil-fuel technologies, and/or technologies relating to fossil fuels that capture and store greenhouse gases, and encouraging their wider use; and through capacity building projects is facilitating the participation of the least developed countries.

The UK is supporting the development of low carbon technology and the increased use of renewable energy to ensure that developing countries can move to a low carbon future that supports economic growth. The UK continues to be part of the International Renewable Energy Agency that is an intergovernmental treaty organisation that aims to promote a rapid transition to the widespread and sustainable use of renewable energy technologies internationally. Similarly, the UK continues to contribute to the Clean Technology Fund, one of the Climate Investment Funds, providing £155m for 2010-11.

It is important to tackle both the supply and the demand side to achieve sustainable low carbon energy. In the 5th National Communication the UK illustrated its continued involvement with multi-lateral partnerships such as the Renewable Energy and Energy Efficiency Partnership, which has the objective of accelerating the deployment of renewable energy and energy efficiency technologies in developing countries. The UK has also been recently active in energy efficiency capacity building, such as:

- The UK are working within the International Partnership for Energy Efficiency Co-operation (IPEEC) to create a space in which developed and key developing countries can work jointly to share experience and learn from each other's policy successes and failures, and identify opportunities for collaborative work to address issues of mutual interest or concern, where such international action can add value to domestic efforts/expertise. A work programme has been developed encompassing a range of activities covering appliance standards and labels, sustainable buildings, financing mechanisms, data collection and indicators, energy management, the role of utilities and capacity building activities. The first policy committee meeting of the IPEEC was held in May 2010.

Low carbon technology needs to be accessible to all. The UK is contributing to capacity building projects to enable access to remote communities in order to help the transfer of less greenhouse-gas emitting advanced fossil-fuel technologies to developing areas.

- DFID-India is supporting renewable energy initiatives in remote areas through rural and tribal development programmes in Madhya Pradesh and Orissa. In Madhya Pradesh, the Power Sector Reform programme to create an efficient, accountable, and financially viable power sector that ceases to be a burden on state finances has been extended to 2012. So far DFID has provided £11m between 2005 and 2009, saving nearly £297 million of government money, helping to fund an increase in state spending in social sectors increased from £108 million in 2005-06 to almost £181 million in 2008-09. Power losses fell from 44% to 37% and carbon emissions were reduced by around 38%.

The UK is assisting developing countries to diversifying their economies to include renewable energy in order to ensure that developing low carbon economies can become sustainable and self-supported. The Department for International Development (DFID) is exploring a range of results-based financing mechanisms that could be used bilaterally or multilaterally to stimulate private sector investment into renewable energy services for the poor by working on two new public-private partnerships that will target low-carbon and adaptation investments in Asia and large-scale renewable energy in Africa. Progress in this area will be updated in future submissions.

Information on minimization of adverse impacts in accordance with Article 3, paragraph 14

15

16 Other information

There is no additional information to include in this chapter.

17 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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Table 18.1 Contributors to this National Inventory Report and the CRF

Person	Technical work area and responsibility
Main authors	
Brown, Keith	Sector expert for solid waste disposal on land
Cardenas, Laura	Sector expert for agriculture; author of all sections on agriculture. Compilation of Sector 4 of the CRF.
MacCarthy, Joanna	Project Manager for the UK Greenhouse Gas Inventory with overall responsibility for the NIR and the CRF[27]. Contributions to most chapters, co-author of energy sector text, author of Chapter 1, Chapter 2, Annex 4 and 5. F-gases sector expert, lead author of Annex 7 and Annex 8 Final Users expert
Murrells, Tim	NAEI transport manager. Contributing author to all sections on transport.
Pang, Yvonne	Approach 1 (error propagation) uncertainty analysis. Responsible for road transport data compilation.
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. Author of Annex 11.
Thistlethwaite, Glen	Compilation of emission estimates, in particular the offshore sector and cement. Main author of chapters and annexes for 1B, co-author of sections relating to waste water treatment, EU ETS, and information about inventory improvements
Thomson, Amanda	Co-author of all sections on Land Use Change and Forestry. Compilation of Sector 5 of the CRF.
Webb, Nicola	Author of Chapter 10, Annex 8 and Annex 9, manager of Overseas Territories and Crown Dependencies inventory compilation.
Watterson, John	Co-author of Uncertainties Chapter and Key Category Analysis. Author of F-gases sections. Development of the inventory.
Contributors	
Champion, Helen[28]	Review of draft NIR and contributions regarding National Inventory System
Ward, Jenny[29]	Author of Chapter 15 and review of draft NIR
Manning, Alistair	Verification of the UK greenhouse gas inventory.
Martinez, Carlos	Compilation of estimates for waste water treatment, contributions to Chapter 2
Misselbrook, Tom	Contributions to agriculture inventory compilation and text
Sneddon, Stuart	Compilation of rail emissions estimates and text for this sector
Wagner, Anne	Assistance with QC of the time series consistency.

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[27] 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 the Department of Energy and Climate Change and is contracted to AEA Technology.

[28] Climate, Energy, Science and Analysis, Department for Energy and Climate Change

[29] Climate, Energy, Science and Analysis, Department for Energy and Climate Change

Person	Technical work area and responsibility
Walker, Charles	Sector expert for aviation in the NAEI.
Additional assistance	
Aston, Clare	Data acquisition
National Inventory Steering Committee	Suggestions and improvements to draft versions of the NIR

Table 18.2 Key Data Providers to the Greenhouse Gas Inventory

Company
UKPIA
UK Oil and Gas
Environment Agency
DECC
Defra
British Cement Association
UK Gas Distribution Networks
Corus
DfT
NIEA
SEPA