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UK Greenhouse Gas Inventory, 1990 to 2010

Annual Report for Submission under the Framework Convention on Climate Change

Main authors Brown K, Cardenas L, MacCarthy J, Murrells T, Pang Y, Passant N, Thistlethwaite G, Thomson A, Webb N.

With contributions from Dore C., Gilhespy S, Goodwin J, Hallsworth S, Hobson M, Manning A, Martinez C, Matthews R, Misselbrook T, Thomas J, Walker C, Walker H, Watterson JD

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AEA
The Gemini Building, Fermi Avenue
Harwell
Didcot
Oxfordshire, OX11 0QR, UK.

Telephone: +44 870 190 3857
Facsimile: +44 870 190 6318

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Report Manager	Name	Jenny Thomas
Approved by	Name	John D Watterson
	Signature	
	Date	13.04.2012

Preface

This is the United Kingdom's National Inventory Report (NIR) submitted in April 2012 to the United Nations Framework Convention on Climate Change (UNFCCC). It contains national greenhouse gas emission estimates for the period 1990-2010, 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 Protocol*[2]. 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.

[1] 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.

[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 normally 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 *Carbon Budgets*.

In May 2009, the UK Government announced the levels of the first three five-year carbon budgets, covering the periods 2008-12, 2013-17 and 2018-2022. The first of these carbon budgets, starting in 2008, requires the UK to cut emissions by 34% on 1990 levels by 2020. The fourth carbon budget, covering the period 2023-27, was set in June 2011. In December 2011, the UK's *Carbon Plan*, which sets out plans for achieving the first four carbon budgets, superseded the UK's *Low Carbon Transition Plan*, published in July 2009. The second *Annual statement of emissions* was published on 31st March 2011; this reports to the UK Parliament on progress towards the first Carbon Budget, in relation to the 2009 reporting year. Further information on the UK's action to tackle climate change can be found on the following Government Department websites:

www.decc.gov.uk
www.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 2012. It contains GHG emissions estimates for the period 1990 to 2010, 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]

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

The UK Greenhouse Gas Inventory is compiled and maintained by a consortium led by AEA of AEA Technology plc – the **Inventory Agency** - under contract to the Climate, Energy, Science and Analysis (CESA) Division in the UK Department of Energy and Climate Change (DECC). AEA is directly responsible for producing the emissions estimates for CRF categories Energy (CRF sector 1), Industrial Processes (CRF sector 2), Solvent and Other Product Use (CRF sector 3), and Waste (CRF Sector 6). AEA is also responsible for inventory planning, data collection, QA/QC and inventory management and archiving. Aether, a partner within the consortium, is responsible for compiling emissions from railways and for the UK's Overseas Territories and Crown Dependencies, and for reviewing, updating and making improvements to the QA/QC procedures that are in place.

Agricultural sector emissions (CRF sector 4) are produced by Rothamsted Research, under contract to the UK Department for Environment, Food and Rural Affairs (Defra). Land Use, 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).

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 the UK Government's own Carbon Budgets. Geographical coverage for these three purposes differs to some extent, because of the following:

1. The UK Government Carbon Budgets apply to the UK only, and exclude 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, 1990-2010. (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	2010	1990 - 2010
CO_2 (Including net LULUCF)	591.8	599.0	582.0	567.0	561.2	553.5	575.2	551.0	554.2	544.9	552.1	563.8	546.6	556.3	556.9	553.1	551.4	543.9	531.1	479.9	497.9	-16%
CO_2 (Excluding net LULUCF)	588.7	595.9	579.5	565.5	559.9	551.8	573.8	549.9	553.8	544.6	552.5	564.7	548.3	558.3	560.0	556.7	555.2	548.1	535.6	484.7	502.4	-15%
CH_4 (Including LULUCF)	97.7	96.8	95.0	91.9	84.7	84.2	82.1	77.6	73.5	68.7	64.2	58.9	56.0	50.2	48.7	47.3	46.0	44.4	43.2	42.1	41.4	-58%
CH_4 (Excluding LULUCF)	97.6	96.8	95.0	91.9	84.7	84.1	82.1	77.5	73.4	68.7	64.2	58.9	56.0	50.2	48.7	47.2	46.0	44.4	43.2	42.1	41.4	-58%
N_2O (Including LULUCF)	67.9	68.1	63.2	58.5	58.9	57.4	57.4	57.8	57.6	46.9	46.1	43.5	41.7	41.2	41.9	40.9	38.9	38.1	37.2	35.2	35.6	-48%
N_2O (Excluding LULUCF)	67.1	67.3	62.4	57.7	58.1	56.6	56.6	57.0	56.8	46.1	45.3	42.8	41.0	40.4	41.1	40.3	38.2	37.5	36.5	34.5	35.0	-48%
HFCs	11.4	11.9	12.3	13.0	13.9	15.3	16.6	19.0	16.9	10.2	9.3	10.2	10.7	11.9	11.2	12.1	12.7	13.0	13.6	14.0	14.3	26%
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	0.2	-84%
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	0.7	-33%
Total (Emissions including net GHG from LULUCF)	771.2	778.0	754.4	732.1	720.5	712.1	733.0	706.9	703.8	672.5	673.9	678.3	656.9	661.2	660.0	654.7	650.2	640.5	625.9	571.9	590.2	-23%
Total (Emissions excluding net GHG from LULUCF)	767.3	774.1	751.0	729.9	718.4	709.6	730.8	705.0	702.6	671.4	673.5	678.4	657.8	662.5	662.4	657.7	653.3	644.0	629.8	576.1	594.0	-23%

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 2010. Methane emissions account for the next largest share (7%), and N_2O emissions make up a further 6%. Emissions of all of these gases have decreased since 1990, contributing to an overall decrease of 23%.

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		0.5	0.6	0.6	0.5	0.4	0.1	-0.1	-0.3	-0.6	-0.5
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	2010
Article 3.3	-0.6	-0.6	-0.7	-1.0	-1.1	-1.6	-1.7	-1.8	-1.8	-2.2	-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
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**	**2010**
1. Energy	609.6	619.3	603.1	587.4	574.6	567.1	587.1	562.4	564.2	553.0	559.5	572.2	555.6	561.7	562.7	557.8	556.2	547.0	534.8	487.6	504.4
2. Industrial Processes	54.1	52.5	47.1	43.8	46.2	46.4	48.2	50.5	49.0	32.4	31.7	30.1	28.2	30.0	30.3	30.6	29.9	31.6	30.8	25.5	26.8
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	0.0
4. Agriculture	57.5	57.2	57.1	56.3	56.5	56.1	56.4	56.2	55.6	54.9	52.9	50.1	50.1	49.6	49.9	50.2	48.6	47.1	46.5	45.8	46.2
5. LULUCF	3.9	3.9	3.3	2.2	2.1	2.5	2.2	1.9	1.2	1.1	0.4	-0.1	-0.9	-1.3	-2.4	-2.9	-3.1	-3.5	-3.9	-4.2	-3.8
6. Waste	46.0	45.1	43.8	42.4	41.2	40.1	39.0	35.9	33.9	31.2	29.4	26.0	23.9	21.1	19.5	19.0	18.6	18.3	17.7	17.2	16.6
Total (net emissions)	**771.2**	**778.0**	**754.4**	**732.1**	**720.5**	**712.1**	**733.0**	**706.9**	**703.8**	**672.5**	**673.9**	**678.3**	**656.9**	**661.2**	**660.0**	**654.7**	**650.2**	**640.5**	**625.9**	**571.9**	**590.2**

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 2010 this contributed 85% 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 17%.

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 20%, 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 5% to the national total in 2010. 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 2010. 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 2010 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 2010 are 64% below 1990 levels.

Total net emissions have decreased by 23% 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 2010 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, 1990-2010 (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	2010	1990-2010	Base Year - 2010
CO_2	588.7	588.7	595.9	579.5	565.5	559.9	551.8	573.8	549.9	553.8	544.6	552.5	564.7	548.3	558.3	560.0	556.7	555.2	548.1	535.6	484.7	502.4	-15%	-15%
CH_4	97.6	97.6	96.8	95.0	91.9	84.7	84.1	82.1	77.5	73.4	68.7	64.2	58.9	56.0	50.2	48.7	47.2	46.0	44.4	43.2	42.1	41.4	-58%	-58%
N_2O	67.1	67.1	67.3	62.4	57.7	58.1	56.6	56.6	57.0	56.8	46.1	45.3	42.8	41.0	40.4	41.1	40.3	38.2	37.5	36.5	34.5	35.0	-48%	-48%
HFCs	15.3	11.4	11.9	12.3	13.0	13.9	15.3	16.6	19.0	16.9	10.2	9.3	10.2	10.7	11.9	11.2	12.1	12.7	13.0	13.6	14.0	14.3	26%	-7%
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	0.2	-84%	-52%
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	0.7	-33%	-44%
Grand Total	770.5	767.3	774.1	751.0	729.9	718.4	709.6	730.8	705.0	702.6	671.4	673.5	678.4	657.8	662.5	662.4	657.7	653.3	644.0	629.8	576.1	594.0	-23%	-23%
Article 3.3		0.5	0.6	0.6	0.5	0.4	0.1	-0.1	-0.3	-0.6	-0.5	-0.6	-0.6	-0.7	-1.0	-1.1	-1.6	-1.7	-1.8	-1.8	-2.2	-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	-1.4		
Article 3.7	0.4																							
Kyoto Protocol Total	770.9	766.4	773.3	750.3	729.1	717.4	708.4	729.3	703.4	700.6	669.6	671.5	676.4	655.7	660.1	659.9	654.7	650.3	640.9	626.7	572.5	590.4	-23%	-23%
Fixed Base Year	779.9																							-24%

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, 1990-2010 (in Mt CO_2 equivalent) – EUMM Coverage.

Table 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	2010	1990-2010	Base Year - 2010
CO_2	586.0	586.0	593.2	576.7	562.7	557.1	548.9	570.8	546.8	550.5	541.5	549.4	561.7	545.3	555.5	557.0	553.7	552.1	544.7	532.4	481.4	499.1	-15%	-15%
CH_4	97.1	97.1	96.3	94.5	91.5	84.3	83.7	81.6	77.1	73.0	68.2	63.8	58.5	55.6	49.8	48.4	46.9	45.6	44.0	42.8	41.8	41.1	-58%	-58%
N_2O	67.0	67.0	67.1	62.3	57.6	58.0	56.5	56.5	56.9	56.7	46.0	45.2	42.6	40.9	40.3	41.0	40.1	38.1	37.4	36.4	34.4	34.9	-48%	-48%
HFCs	15.3	11.4	11.9	12.3	13.0	13.9	15.3	16.5	19.0	16.9	10.2	9.3	10.2	10.6	11.8	11.1	12.0	12.7	13.0	13.5	13.9	14.2	25%	-7%
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	0.2	-84%	-52%
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	0.7	-33%	-44%
Grand Total	767.1	763.9	770.7	747.6	726.5	715.0	706.2	727.2	701.3	698.7	667.7	669.9	674.9	654.3	659.1	658.9	654.1	649.6	640.0	626.1	572.3	590.2	-23%	-23%
Article 3.3		0.5	0.6	0.6	0.5	0.4	0.1	-0.1	-0.3	-0.6	-0.5	-0.6	-0.6	-0.7	-1.0	-1.1	-1.6	-1.7	-1.8	-1.8	-2.2	-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	-1.4		
Article 3.7	0.4																							
Kyoto Protocol Total	767.5	763.0	769.9	746.9	725.7	714.0	704.9	725.7	699.7	696.7	665.8	667.9	672.9	652.2	656.8	656.5	651.1	646.6	636.9	622.9	568.7	586.7	-23%	-24%
Fixed Base Year	776.3																							-24%

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, 1990-2010 (in kt).

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
NO_x	2,896	2,787	2,721	2,551	2,442	2,324	2,218	2,046	1,984	1,867	1,796
CO	9,118	9,323	8,905	8,563	8,098	7,587	7,634	7,123	6,817	6,450	5,672
NMVOC	2,766	2,707	2,629	2,505	2,416	2,231	2,150	2,059	1,911	1,728	1,589
SO_2	3,723	3,562	3,482	3,140	2,679	2,371	2,027	1,665	1,646	1,260	1,239

Gas	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
NO_x	1,767	1,683	1,650	1,598	1,585	1,530	1,466	1,321	1,148	1,110
CO	5,324	4,695	4,208	3,916	3,516	3,290	2,991	2,828	2,318	2,128
NMVOC	1,483	1,391	1,261	1,165	1,089	1,040	1,003	923	823	790
SO_2	1,140	1,020	997	835	710	669	590	495	401	409

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, 38% 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). Rothamsted Research provide the estimates of agricultural emissions.

Technical enquiries should be directed to:

Joanna MacCarthy
AEA Group
The Gemini Building, Fermi Avenue
Harwell
Didcot
Oxfordshire OX11 0QR
UK

Tel: +44 (0) 870 190 3857
Fax: +44 (0) 870 190 6318
E-mail: joanna.maccarthy@aeat.co.uk

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	Submitted to the EUMM on March 13th
Issue 2	Submitted to the UNFCCC on April 13th

1 Introduction

This is the UK's 2012 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's Fifth National Communication to the UNFCCC, described measures to ensure that the UK delivers its legally binding target under the Kyoto Protocol.

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.

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 June 2011, the level of the fourth carbon budget was set in law. The level is set at 1,950 MtCO2e. In December 2011, the Carbon Plan, which sets out plans for achieving the first four carbon budgets superseded the UK's Low Carbon Transition Plan, published in July 2009. The second Annual statement of emissions was published on 31st March 2011 and it reports to parliament on progress towards the carbon budgets, relating to the year 2009.

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

www.decc.gov.uk
www.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).

The UK Greenhouse Gas Inventory is compiled and maintained by a consortium led by AEA of AEA Technology plc – the **Inventory Agency** - under contract to the Climate, Energy, Science and Analysis (CESA) Division in the UK Department of Energy and Climate Change (DECC). AEA is directly responsible for producing the emissions estimates for CRF categories: Energy (CRF sector 1), Industrial Processes (CRF sector 2), Solvent and Other Product Use (CRF sector 3), and Waste (CRF Sector 6). AEA is also responsible for inventory planning, data collection, QA/QC and inventory management and archiving.

[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

Aether, a partner within the consortium, is responsible for compiling emissions from railways and for the overseas territories and crown dependencies, and for reviewing, updating and making improvements to the QA/QC procedures that are in place.

This report and corresponding CRF tables provide annual emission estimates submitted by the UK to the UNFCCC for the period 1990 to 2010. 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 1990-2010, 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 Energy Statistics (DUKES) (see **Table 1-6**). DECC advises that the geographical coverage of the statistics is the United Kingdom (DECC, 2011). 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 or Tier 3 methods in the IPCC Guidelines.

Most sources are reported in the detail required by the CRF. The main exceptions are the emissions of individual halocarbon species, which cannot always be reported individually because some of these are considered commercially sensitive data. Consequently,

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

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-134	1,000
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 01.01.2011 to 31.12.2011 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

Reporting Element	Background Information
	to better understand the impacts its policies could have on developing countries, and how 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 a consortium led by AEA of AEA Technology plc – the **Inventory Agency** - under contract to the Climate, Energy, Science and Analysis (CESA) Division in the UK Department of Energy and Climate Change (DECC). AEA is directly responsible for producing the emissions estimates for CRF categories: Energy (CRF sector 1), Industrial Processes (CRF sector 2), Solvent and Other Product Use (CRF sector 3), and Waste (CRF Sector 6). AEA is also responsible for inventory planning, data collection, QA/QC and inventory management and archiving. Aether, a partner within the consortium, is responsible for compiling emissions from railways and for the overseas territories and crown dependencies, and for reviewing, updating and making improvements to the QA/QC procedures that are in place.

Agricultural sector emissions (CRF sector 4) are produced by Rothamsted Research, under contract to Defra.

Land Use, 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

(consortium), 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

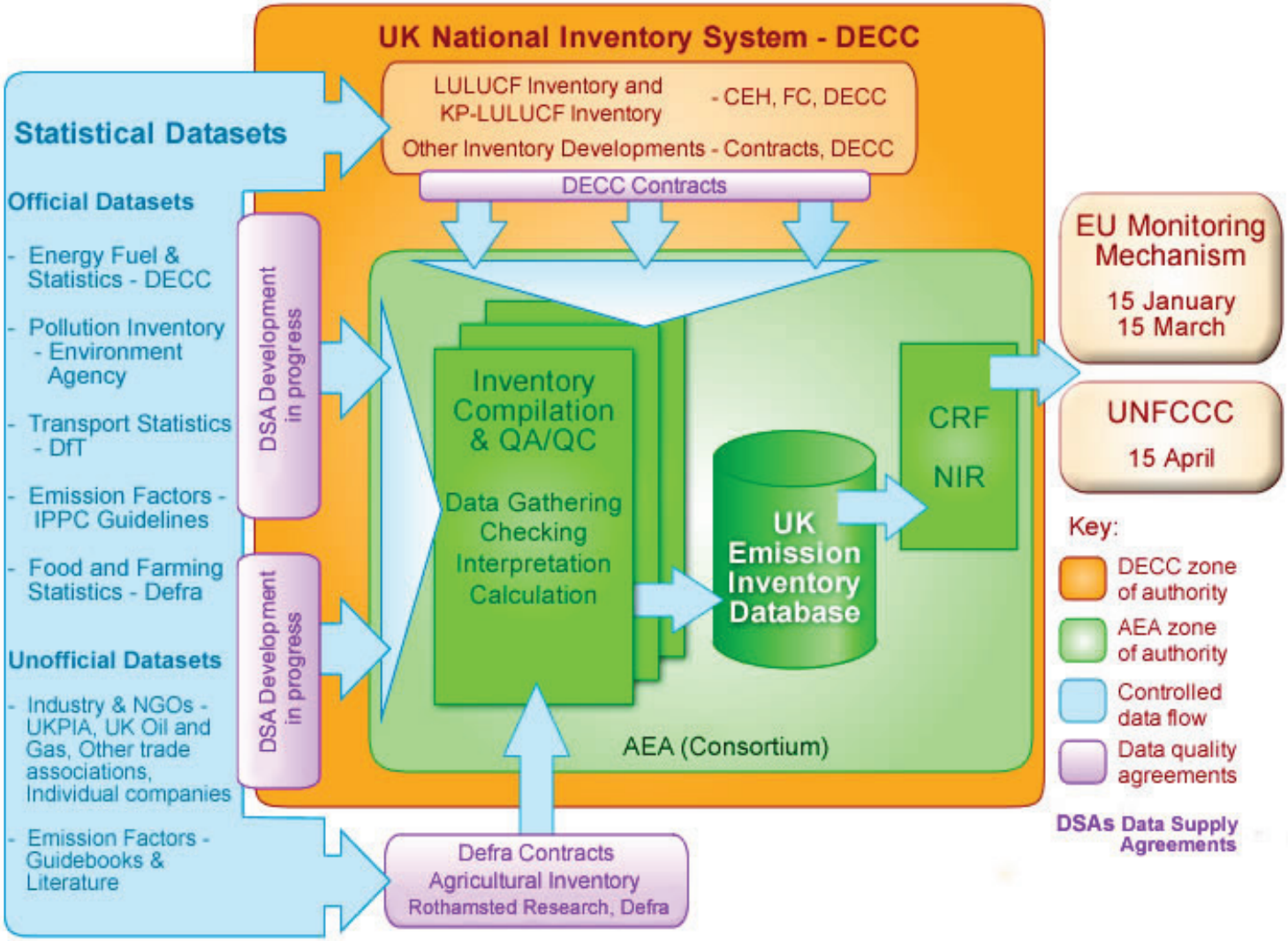
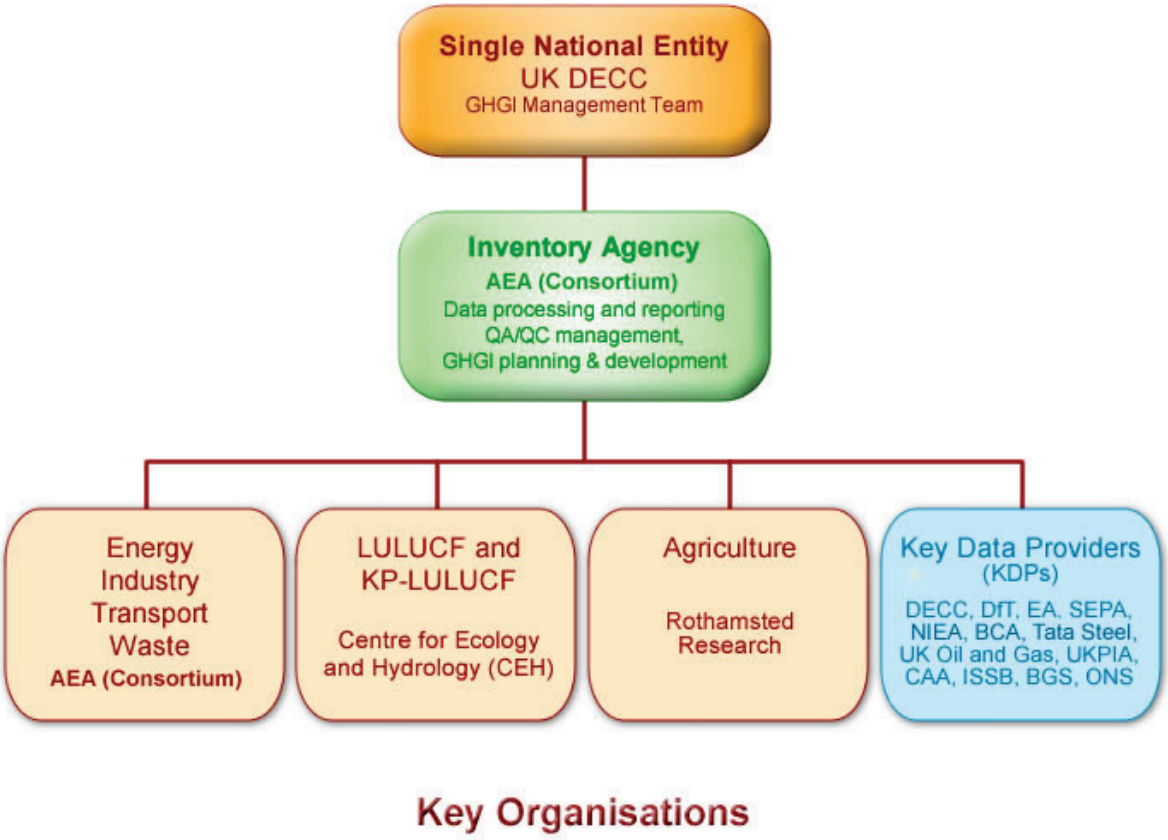


Figure 1-2 Key organisational structure of the UK National Inventory System



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.

[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 is currently in the process of setting up data supply agreements (DSAs) with relevant organisations to build upon existing relationships with data supply organisations. 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. This process is ongoing, through the National Inventory Steering Committee which is a forum of inventory stakeholders that DECC chairs.

There are currently three DSAs in place, with SEPA, NIEA and DfT.

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

A new 3-year contract was established for the Inventory Agency in late 2011 following a competition exercise. AEA lead the consortium responsible for compiling the inventory, under contract to DECC. AEA is responsible for all aspects of national inventory preparation, reporting and quality management. The consortium consists of:

- AEA – lead contractor

- Aether – responsible for emissions estimates from railways and the Overseas Territories (OTs) and Crown Dependencies (CDs), and for improvements to the QA/QC plan
- SKM Enviros – will contribute to the F-gas inventory, in future inventory submissions
- CEH[8] and AMEC – part of the consortium, but with no direct input to the GHG inventory

AEA together with the project partners 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 and processed data and data management tools, documentation and archiving, prioritisation of methodology and 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; and, assisting with Article 8 reviews under the Kyoto Protocol.

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

Planning

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

Preparation

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

Management

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

Inventory Compilation

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

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

[8] The role of CEH under the inventory contract led by AEA is separate to the compilation of the LULUCF inventory, which CEH carry out under contract directly to DECC.

Rothamsted Research (formerly North Wyke), under contract to Defra, is responsible for the preparation and development of the agriculture inventory. Rothamsted Research conducts specific research in the agriculture sector and provides finalised GHG emissions data to AEA for inclusion within the UK GHG 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 for England and Wales;
b) The Scottish Environment Protection Agency's European Pollution Emissions Register;
c) The Northern Ireland Environment Agency's Inventory of Statutory Releases; and
d) EU Emissions Trading System data from the UK regulatory agencies (Environment Agency, Scottish Environmental Protection Agency, Northern Ireland Environment Agency and the Department of Energy and Climate Change Offshore Inspectorate).

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.

Rothamsted 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.

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

1.2.2.4 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. Where inventory improvement research is commissioned by the NISC, the research reports are reviewed and approved for use within the UK GHGI compilation by members of the NISC, managed by DECC, as part of the pre-submission review process.

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, qualitative analysis from inventory agency experts 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.

In recent inventory reviews, the UN Expert Review Teams have indicated that there is no evidence of qualitative analysis by the inventory agency to support the Key Category Analysis in determining the highest priority emission sources in the UK for improvements or more detailed reporting. This qualitative assessment is conducted by the experts of the inventory agencies within the inventory cycle, including through a post-submission review of data sources, methods and feedback from the EUMM and UNFCCC ERTs. In April or May each year, DECC and the inventory agency hold a review meeting, at which the findings of the EU and UN reviews, internal post-submission review and qualitative analysis of source categories are discussed in order to develop a comprehensive list of inventory improvement items for discussion, prioritisation and implementation via the NISC. We are confident that this process ensures that sources that may not be determined as Key Source Categories are identified as priorities for improvement, where that source may be particularly significant in terms of level or trend in the UK inventory.

Table 1-3 UK GHG National Inventory Steering Committee

Organisation	Role in relation to NISC	Key NISC responsibilities
DECC - Climate and Energy: Science and Analysis	• GHG inventory manager • Manager of GHG research contracts • DECC annual climate change statistics and indicators	• Administer functions of Single National Entity for the UK National Inventory System; • Overall responsibility for inventory development, compilation and reporting; • Manage GHG inventory research contracts • Act as NISC Chair • Ensure that UK GHGI conforms to EU and UN international standards and requirements
Defra – Atmosphere and Local Environment (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
Defra	• Liaison between Defra and NISC	• Provide an analytical overview of all relevant Defra sectors • Provide link with Defra climate change mitigation team
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 (ICC)	• 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 and Energy: Science and Analysis	• LULUCF Inventory manager	• Provide LULUCF inventory data that conforms to EU and UNFCCC international standards and requirements • 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 • 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 (DUKES) • Providing energy statistics to inform the UK inventory
Regulators: • Environment Agency for England and Wales • Scottish Environment Protection Agency • Northern Ireland Environment Agency	• Pollution inventory • EU ETS Registry	• Management, compilation, QA/QC and reporting of pollutant emission inventories/registers under IPCC regulations, and EU ETS annual emission reporting • Ensure that the pollutant emission inventories for industrial processes regulated under IPC/IPCC (PI, SPRI, ISR) are presented in the required format and timescale for inventory estimation and reporting • Collate information in annual emission reports for EU ETS

Organisation	Role in relation to NISC	Key NISC responsibilities
DECC oil and gas - Offshore Regulator	• Offshore oil and gas	• Providing offshore oil and gas industry annual activity and emission data to inform the UK inventory • Regulation of the offshore oil and gas industry, including management of the EEMS reporting system of environmental emissions from that sector
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
Devolved Administrations	• Inventories for Devolved Administrations	• 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.
GHG inventory contractor (AEA)	• UK greenhouse gas inventory compilation and development	• 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 sectoral expert panels as required
GHG inventory project partners (Aether)	• Inputs to greenhouse gas inventory compilation and development	• Contractor responsible for emissions from railways, and from Overseas Territories and Crown Dependencies. • Joint role in managing the inventory improvement programme and development of QA/QC procedures
Agricultural inventory contractor (Rothamsted)	• Agriculture Inventory compilation and development	• Contractor responsible for agriculture inventory; activity data, methods, emission factors and emission estimation • Prepare and develop agriculture inventory and deliver on time for incorporation into national inventory • Participate in sectoral expert panels as required

Organisation	Role in relation to NISC	Key NISC responsibilities
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 sectoral 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[9]

Organisation	Role in relation to NISC	Key NISC responsibilities
Met Office/Bristol University	• Atmospheric measurements and interpretation at Mace Head, Ireland	• Provide atmospheric measurements and interpretation of these data collected at Mace Head, 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	• Other experts or representatives may be asked to participate in sectoral expert panels or to review key sources or sources where significant changes to methods, activity data or emission factors have occurred. E.g. ONS, UKPIA, Oil & Gas UK, Tata Steel, Electricity Supply Industry etc.

[9] 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 2011-12, research commissioned via the UK GHGI Improvement Programme and completed in time for inclusion in the 2012 submission included:

- Analysis of EUETS data for UK and Devolved Administration (DA) inventories, including assessment of the traded and non-traded components of the UK and DA inventories;
- Review of new datasets from policy-specific reporting, to assess them for usefulness in GHGI improvement, covering the CRC Energy Efficiency Scheme and Resource Metrics data from industrial operators in England and Wales;
- Review of IPPC documentation for a number of sites around the UK where data reporting inconsistencies were evident between different regulatory reporting systems. The work covered sites in a number of sectors including: paper and pulp, food and drink, ferrous metals, chemical production and gas production;
- Research to review and benchmark UK data for non-standard gaseous fuels against available data from other countries. The work focussed on reported fuel quality data for coke oven gas, blast furnace gas and refinery fuel gas / other petroleum gas;
- Restructuring of the underlying database and spreadsheet system to enable the UK GHG inventory to report the sector 1A2 emission in a more detailed manner. Previously the UK GHGI included estimates of emissions from sectors 1A2b to 1A2f aggregated within 1A2f. Research with the UK DECC energy statistics team has led to generation of a full time series of more detailed energy data for the individual sectors 1A2b, 1A2c, 1A2d and 1A2e, which are now reported separately from 1A2f;
- The gas network leakage model used by the gas supply industry and used to underpin UK GHGI estimates was reviewed in consultation with gas network operators, and estimates for leakage at point of use have been revised;

- Aviation estimates between the UK and Overseas Territories have been researched and the UK method for inventory compilation and reporting of these emissions has been revised to allocate emissions more accurately;
- A scoping study was conducted to research the potential for accessing and processing rail activity data from new sources, to complement the available energy use estimates for the sector;
- Research into activity and emissions from boats operating on inland waterways was conducted, and identified new information on the type of fuels used by these inland vessels, leading to small revisions to the allocation of gas oil and DERV;
- A scoping study into emissions under Phase III of the EUETS aimed to assess the impacts of the extension to scope of the trading system and to seek any additional new data and information on sources to be added to the system. No revisions to the UK GHG inventory were derived from this study, however;
- A review of policy mechanisms and action plans at UK and devolved Government level was conducted to seek new data sources that could provide supplementary activity data or emissions data to inform better source-specific estimates in the UK and DA GHG inventories;
- Research with DECC and restructuring of underlying data processing systems for the oil and gas sector method used to derive estimates for the UK GHG inventory has enabled a greater level of detail and transparency to be built into the estimates for the upstream oil and upstream gas sources. This project has also enabled improvements to the accuracy of the UK end user emission inventory.
- The model used to estimate emissions of F-gases from refrigeration and air conditioning was completely rebuilt in a DECC commissioned study in 2011. The core assumptions for all parameters in the model were reviewed and updated. The model is now a stock based model, replacing the previous approach which in most cases used top down estimates.
- In 2011, DECC commissioned a study to update the emissions from closed coal mines work, to reflect known changes in the mining industry (e.g. mines that closed earlier or remained open longer than projected). The results of this study are included in the 2012 inventory submission.

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. In addition to this planned programme of improvement, a number of revisions were made to the inventory model for this reporting year; see **Section 6.1** for more information.

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 2012.)

1.3 INVENTORY PREPARATION

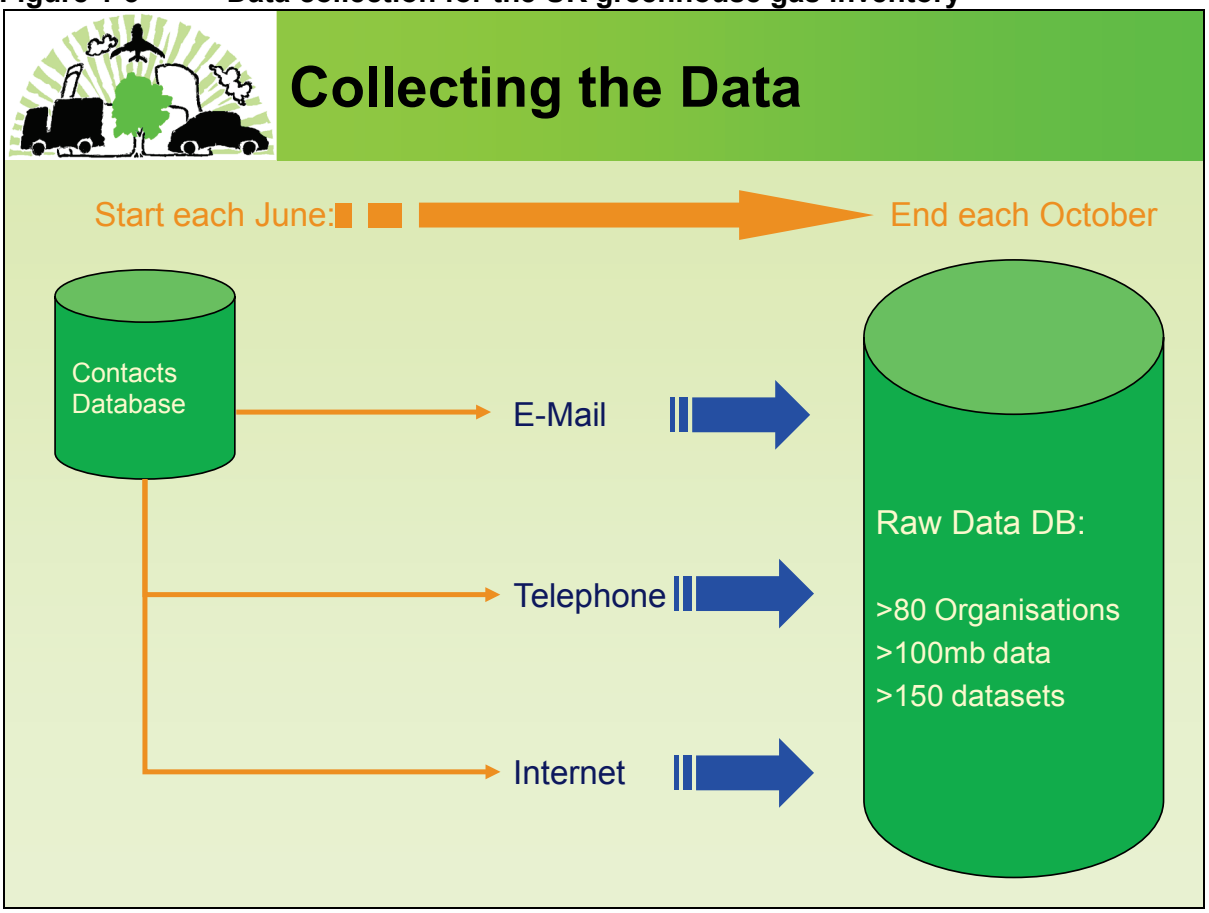
1.3.1 GHG Inventory and KP- LULUCF Inventory

The present UK GHG inventory for the period 1990-2010 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 each year, in order, as the inventory is compiled, as follows:

- ***Method Improvement***
  Improvements to calculation methods are normally implemented before the inventory is compiled. These improvements are in part based on recommendations of UNFCCC (In Depth Reviews, In Country Reviews), EC reviews, peer reviews, bilateral 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.
- ***Emissions Review***
  A series of internal reviews are carried out to detect anomalies in the estimates (time series variations and year to year changes). Errors and omissions are then rectified.
- ***Emissions Reporting (including background data)***
  Estimates of emissions are prepared for the various reporting formats (e.g. IPCC, UNECE etc.).
- ***Report Generation***
  Draft reports are written to satisfy the reporting criteria of the various agencies, e.g. the IPCC.
- ***Report Review***
  The reports are reviewed: internally; by external contributing agencies; and by DECC. 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.

Rothamsted 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. 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

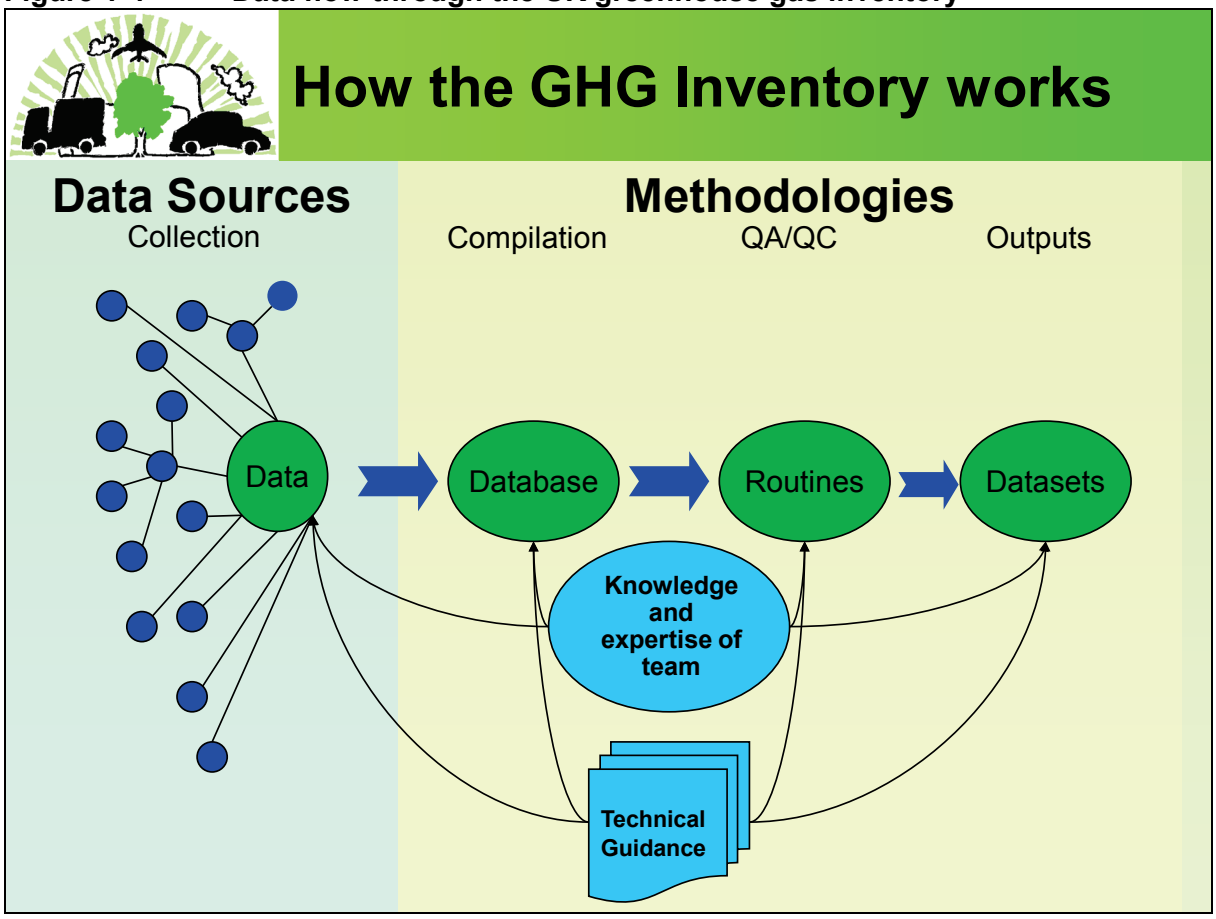


Table 1-5 provides a brief summary of the methods used to estimate UK GHG emissions, which are described in more detail in the subsequent Chapters and Appendices.

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 Pollution Inventory; and • Carbon emissions from certain non-energy uses (NEU) of fuel reported here.
2C	• Iron and Steel - 2 stage carbon balance (see **Annex 3, Section A3.3.3.3** and **A3.4.3.1**); and • Spreadsheet model to estimate emissions of F-gases.
2D	• Emissions calculated based on USEPA Compilation of Air Emission Factors; and • Emissions calculated based on Industry and Government data sources.
2E, 2F	• Spreadsheet model to estimate emissions of F-gases.
3A	• (No direct GHGs emitted from this sector).
3B	• (No direct GHGs emitted from this sector).
3C	• (No direct GHGs emitted from this sector).
3D	• (No direct GHGs emitted from this sector).
4A	• Emissions calculated based on animal population data and appropriate EFs.
4B	• Emissions calculated based on animal population data and appropriate EFs.
4D	• IPCC recommended methodology.
4F	• Emissions calculated based on IPCC methodologies and USEPA EFs.
5	• C-Flow model to estimate emissions from LULUCF.
6A	• The MELmod model.
6B	• IPCC default method and the data from operator returns to the regulator.
6C	• Uses country specific emission factors, partially based on Pollution Inventory data.

The sources of data used are documented in the relevant sections of this NIR though much of the activity data are taken from the key publications listed in **Table 1-6**. 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.

Source (and publisher)	**Relevant activity data contained in the source**
Emissions Trading System (EU ETS regulatory agencies in the UK; data supplied via UK Department of Energy and Climate Change)	• Emissions from installations and characteristics of fuels consumed. • Energy data are aggregated by sector and used to inform inventory estimates. • Fuel quality data are used to derive up to date carbon emission factors for major fuels in energy intensive sectors.
Transport Statistics GB (UK Department for Transport)	• Vehicle km according to vehicle type and road type: • Vehicle licensing statistics (split in vehicle km by fuel type); and • Selected domestic and international civil aviation aircraft km flown.
Northern Ireland Department of the Environment	• Traffic count and vehicle km data for Northern Ireland; and • Information on regulated processes in NI.
Civil Aviation Authority	• Detailed domestic and international civil aviation aircraft km flown.
Pollution Inventory (Environment Agency)	• Information on emissions from regulated processes in England and Wales.
Scottish Environmental Protection Agency	• Information on regulated processes in Scotland.
United Kingdom Petroleum Industry Association	• Refinery emissions; • Lead and sulphur contents of fuels, benzene content of petrol, RVP of petrol.
Oil and Gas UK	• Detailed inventory of oil and gas emissions.
Iron and Steel Statistics Bureau	• Energy production and consumption in the Iron and Steel industry; and • Other statistics regarding the Iron and Steel industry.
United Kingdom Minerals Yearbook (British Geological Society)	• Statistical data on minerals production, consumption and trade.
Annual Abstract of Statistics (Office for National Statistics)	• Population data.
Department for Transport	• Automatic Number Plate Recognition (ANPR) data used to help define fleet composition on different road types in the UK.

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 2010 (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	Coal	CO_2	Level
1A(stationary)	Oil	CO_2	Level, Trend
1A	Natural Gas	CO_2	Level
1A3b	Auto Fuel	CO_2	Level
5A	5A LULUCF	CO_2	Level
5B	5B LULUCF	CO_2	Level
5C	5C LULUCF	CO_2	Level
5E	5E LULUCF	CO_2	Level
4A	Enteric Fermentation	CH_4	Level
6A	Solid Waste Disposal	CH_4	Level, Trend
1A1&1A2&1A4&1A5	Other Combustion	N_2O	Level, Trend
1A3b	Auto Fuel	N_2O	Level
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 (s)
1A	Coal	CO_2	Level
1A(stationary)	Oil	CO_2	Level
1A3b	Auto Fuel	CO_2	Level
5A	5A LULUCF	CO_2	Level
5B	5B LULUCF	CO_2	Level
5C	5C LULUCF	CO_2	Level
5E	5E LULUCF	CO_2	Level
1B1	Mining & Solid Fuel Transformation	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

IPCC source category	Fuel/Activity	GHG	Reason (s)
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	Mining & Solid Fuel Transformation	CH_4	Level
4A	Enteric Fermentation	CH4	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 QA/QC system 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) and is being extended to include a range of ongoing bespoke sector specific QA/QC activities to comply with Tier 2. AEA (the inventory Agency) is also fully accredited to BS EN ISO 9001:2008.

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 (the Inventory Agency), part of AEA Technology plc on behalf of DECC. AEA prepares the GHG submissions to the EC under the EUMM and to the UNFCCC. The data compilation for some source sectors of the UK inventory are performed by other contractors (i.e. Rothamsted Research compile the agriculture sector, CEH compile the land use, land-use change and forestry sector). Many of the data received by AEA for the UK GHGI compilation come from other government departments, agencies, research establishments or consultants. Some of these organisations (e.g. DECC, and BGS) qualify as the UKs National Statistical Agencies referred to in the Guidance and abide by strict statistical QA/QC standards. Other organisations (e.g. CEH, providing the LULUCF estimates and Environment Agency, providing regulated point source data) supply important datasets for the Inventory and have their own QA/QC systems. Whilst these organisations have their own QA/QC systems, AEA is responsible for co-ordinating inventory-wide QA/QC activities relating to the submitted datasets. In addition, AEA is working with organisations to encourage them to demonstrate their own levels of QA/QC that comply with either IPCC Good Practice Guidance or the UK's National Statistics standards.

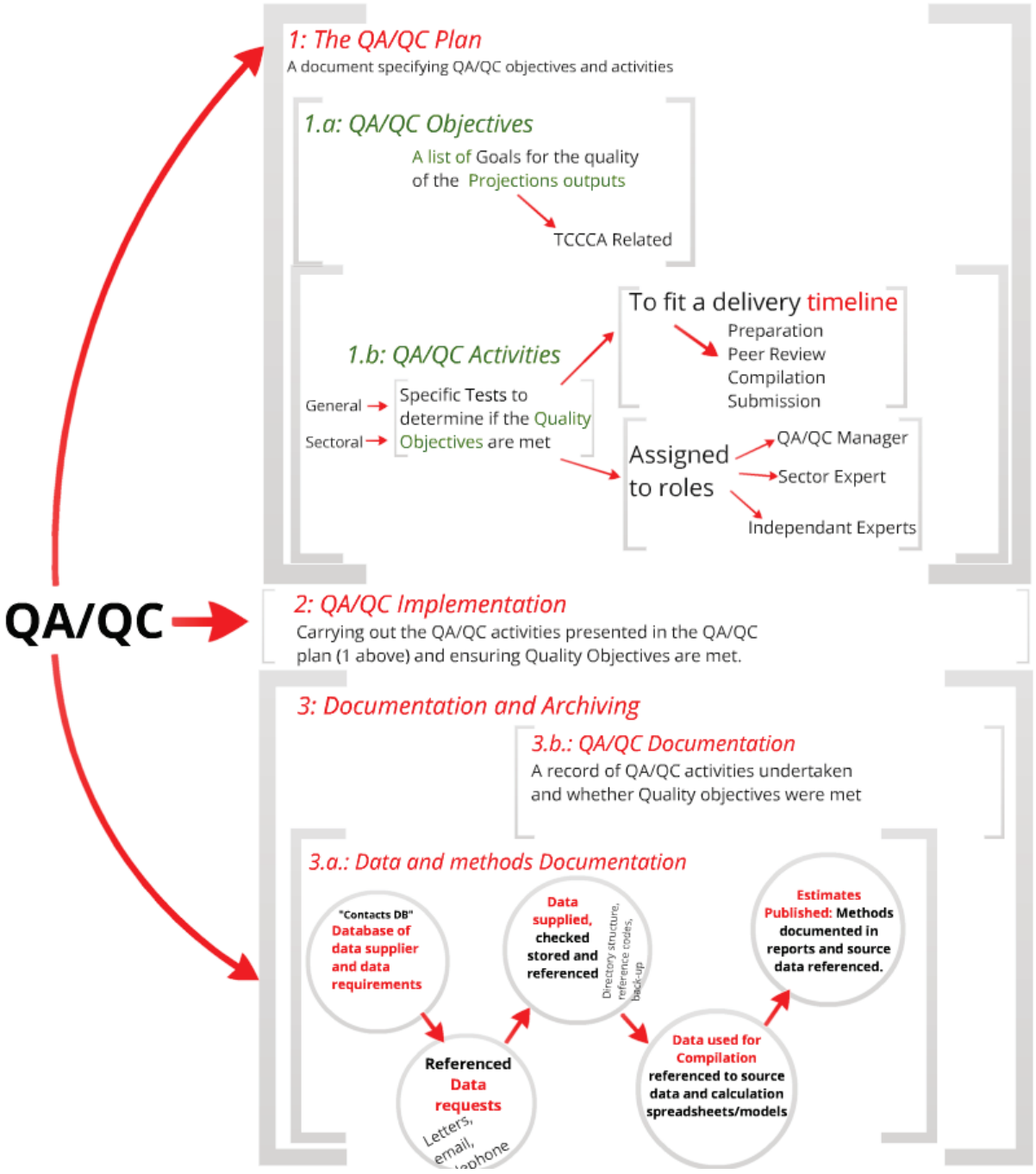
An overview of the UKs GHGI QA/QC system is illustrated in **Figure 1-5** below. The QA/QC system includes three core components.

1. **The QA/QC Plan** which is maintained by the GHGI's QA/QC manager and defines the specific Quality Objectives and QA/QC activities needed. The plan assigns roles, responsibilities and a timeline for completion of QA/QC activities.

2. **QA/QC implementation** which includes the physical undertaking of the QA/QC activities throughout the data gathering, compilation and reporting phases of the annual emission estimation cycle and in accordance with the QA/QC plan.

3. **Documentation and archiving** which includes a) transparent documentation of all data sources, methods, and assumptions; and b) transparent documentation of all QA/QC implementation including records of activities undertaken, findings, recommendations and any necessary actions.

Figure 1-5 QA/QC system used within UK greenhouse gas inventory



Box 1: BS EN ISO 9001:2008 Accreditation:
In addition to the UK's own GHGI specific QA/QC system, through AEA, 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 12 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. Lloyds Register Quality Assurance carried out a three yearly recertification audit of AEA in September and October 2011. AEA successfully passed the recertification, with no major non compliances, and a new certificate was issued. AEA is currently certificated both for the Quality Assurance ISO 9001:2008, including TiCKIT, and Environmental Management System ISO 14001 standard.

Specific details of the QA/QC plan, implementation, documentation and archiving are provided below.

1.6.1.1 Scope of the QA/QC plan

The QA/QC plan covers:

1. Estimation of emissions and reporting to UNFCCC and EUMM (including emissions and removals from all sources and gases).
2. Estimation of emissions and reporting to UNECE (including emissions from all sources and pollutants).
3. Estimation of emissions and reporting to UK National Statistics.

1.6.1.2 Quality Objectives

The key objectives of the QA/QC plan are to ensure that the principles of TCCCA are met and that the estimates of emissions are:

- **Transparent** in:
    - the methods, assumptions, data sources used to compile estimates and on the inclusion of national and EU wide assumptions (e.g. source category detail and the split between EUETS and non EUETS sources, implementation of policies and measures, carbon contents of fuels, site specific estimates, national statistics such as population, GDP, energy prices, carbon prices etc).
    - the documentation of QA/QC activities and their implementation.
- **Complete**: and include all emission/removals, socio-economic assumptions and policies and measures for all required years, categories, gases and scenarios.
- **Consistent**: across trends in emissions for all years (especially where applicable between the historic and projected estimates) and that there is internal consistency in aggregation of emissions.
- **Comparable**: with other reported emission estimates through use of the latest reporting templates, the correct IPCC category level, split between EUETS and non EUETS sources, scenarios, units for parameters and of input parameters with EU assumptions on (e.g. energy prices, energy demand, carbon price, population etc).

- **Accurate**: in the application of methods, use of data sources and inclusion of national and EU wide assumptions.

1.6.1.3 Roles and Responsibilities

Specific responsibilities have been assigned to the different QA/QC activities and to different roles within the emissions estimation process. A QA/QC manager co-ordinates all QA/QC activities and manages the contributions from data suppliers, sector experts and independent experts.

- **QA/QC Manager**: maintains the QA/QC plan, sets quality objectives, co-ordinates QA/QC activities and undertakes cross cutting QA/QC activities.
- **Sectoral Experts**: Perform sector specific QA/QC activities and report to the QA/QC Manager. Sector Experts should also collaborate with **Data suppliers** and other key stakeholders to review estimates and perform QA/QC on supplied material.
- **Knowledge Leaders**: Perform final QA/QC activities on data and report submissions. Knowledge Leaders have been selected for this role due to their recognised technical experience and authority
- **External Review experts:** Provide expert/peer review of projections for specific sectors and report to the **QA/QC Manager.**

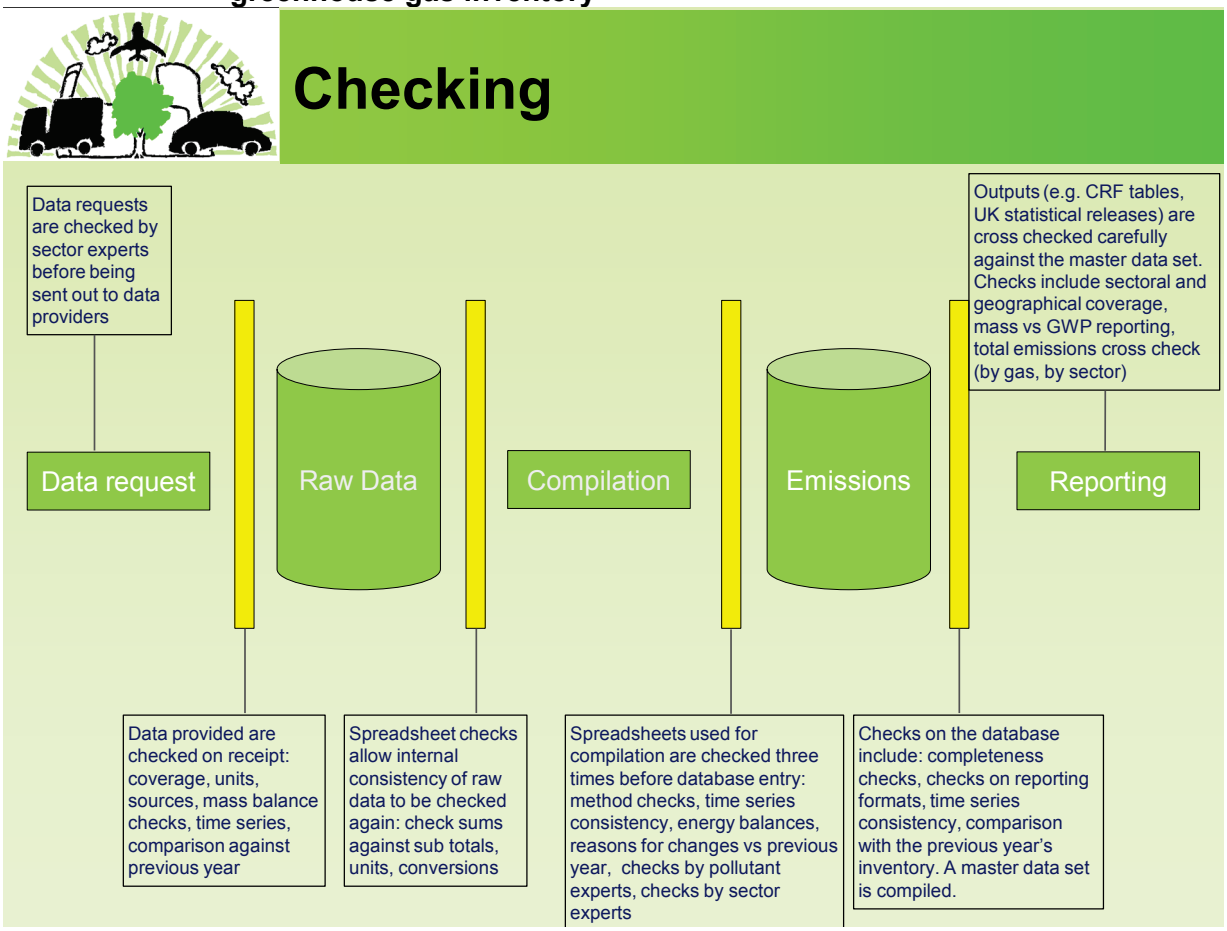
1.6.1.4 Timeline

The QA/QC plan sets out the timeline for QA/QC checks. The timeline is designed to fit in with compilation and reporting requirements.

1.6.1.5 Quality Control and Documentation

The UK's GHGI QC (checking, documentation and archiving) occurs throughout the data gathering, compilation and reporting cycle. **Figure 1-6** illustrates 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.

Figure 1-6 Summary of the system of data checks used within the UK greenhouse gas inventory



Checking and documentation is facilitated by data storage and handling systems and procedures developed specifically for the GHGI compilation that include:

1. **A database of contacts (the "contacts database")** of uniquely referenced data suppliers and users, detailed data requirement specifications (including requirements for supplier QA/QC and uncertainty information) and data supplied to and delivered from the GHGI. This database tracks all data sources and suppliers used for the estimation of emissions with unique references that are used to tag datasets through the inventory compilation process. The contacts database also tracks all products supplied from the GHGI including formal submissions and data supplied in response to informal and ad-hoc data requests.

2. **Individual data processing tools** are used to prepare the majority of source data into suitable activity data (AD) and emission factors (EFs) for UK emissions estimates. These data processing tools (spreadsheets and DBs) include ***QC procedures, summaries and source data referencing***. The QC procedures include ***sector specific checks*** (e.g. energy/mass balance and default emission factor checks for country specific emission factors, and implied emission factor checking). The QC procedures, within each tool/spreadsheet, include ***calculation input/output checking*** cells and flags to identify calculation errors. ***The QC summary*** sheets in

each tool/spreadsheet includes links to QC areas, flags for the QC activities, their status and sign off; details of source data; key assumptions, methods, data processing activities and progress; the scope of activities, gases and years included; relationships with other processing spreadsheets (where inter-dependencies exist); records of authorship; version control and checking. All relevant ***cells in the data processing spreadsheets are colour coded*** as calculation cells, output cells, checking cells or data input cells. All input cells carry a reference to the unique data source and data supplier held in the contacts database so all source data can be traced back to its originator and date of supply. ***All spreadsheets are subject to second-person checking*** prior to data uploading to the NAEI database.

3. **A core database (NAEI database) of AD and EFs** with embedded QC routines and data source and data processing referencing. The database is used for all emission estimates used for reporting (including CRF population), responding to ad-hoc queries or deriving other downstream estimates (e.g. emissions by Devolved Administration and emissions by Local Authority). The detailed AD and EF components used for the emissions estimates are held within the central database and include all sources, activities, gases/pollutants (GHGI and Air Quality Pollutant Inventory). The majority of data in the database are imported directly from the individual data processing tools/spreadsheets (described above). ***Data transparency*** is assisted by all data points in the database carrying a reference that pinpoints either the upstream data processing tools used to derive the data, the external data source and supplier or both. The database also includes details of the date entered, the person uploading the data, its units (to ensure correct calculation), and a revision or recalculation code (which ensures that recalculations of historic data can be easily traced and summarised in reports). ***Automated data import routines*** used to populate the database minimise transcription errors and errors resulting from importing data that has not been properly checked. This process extracts output data from the upstream data processing tools/spreadsheets and can be controlled by the Inventory Agency via a data import dashboard. The automated system ensures that data is only uploaded to the database once it meets specified QA/QC criteria of data checking, completion and consistency. A number of ***detailed QC checking queries***[10] are embedded within the database that support the annual QA activities defined in the QA/QC Plan and include:
    a. Checks with previous submissions for changes due to recalculations or errors at a detailed level, (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)[11].
    b. Assessment of trends and time series consistency for selected key sources.
    c. Mass balance checks 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;
    d. Other activity data checks (e.g. production and consumption with official national statistics).
    e. Implied Emission Factor checks (assessing trends in IEF and comparison with previous submissions).
    f. A consistency check between IPCC output and CORINAIR formatted output.

[10] A full list is included in the QA/QC plan.
[11] 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. **Data extraction checking routines and procedures:** Data exported from the NAEI database and entered into reporting tools (e.g. the CRF Reporter tool) are finally checked against the direct database output totals to ensure that any inconsistencies are identified and rectified prior to submission.

5. **Official annual reports to UNFCCC and UNECE** provide full documentation of inventory estimation methodologies, data sources and assumptions by source sector, key data sources and significant revisions to methods and historic data, where appropriate. In addition the annual report to the UNFCCC includes details of planned prioritising improvements identified by the Inventory Agency and agreed by the National Inventory Steering Committee (NISC), and from Expert and Peer Reviews. Any data presented in reports are checked against accompanying submission datasets and the NAEI database. All outputs (reports, data sets) are checked by a designated "Knowledge Leader," who has many years' experience in compiling and reporting inventories, but was not involved in the compiling the outputs to ensure that any inconsistencies that have not been picked up by automated checks and second person cross checks are rectified before reporting.

6. **Archiving**: At the end of each reporting cycle, all the database files, spreadsheets, on line manuals, electronic source data, records of communications, paper source data, output files representing all calculations for the full timeseries are 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 archived in a Roller Racking system with a simple electronic database of all items references in the archive.

1.6.1.6 Quality Assurance and Verification

This section describes a number of specific QA activities and procedures.

1.6.1.6.1 NISC annual Review

Annually and prior to submission the National Inventory Steering Committee (NISC) review the emissions inventory datasets. The NISC is tasked with the official consideration and approval of the national inventory prior to submission to the UNFCCC. The NISC comprises key stakeholders (see Institutional arrangements section) who have an understanding of the GHG estimates and input data sources. As outlined in **Section 1.2.2.4**, the NISC prioritises and commissions inventory improvement research, the reports from which are then reviewed by NISC experts prior to their acceptance and use within future compilation work, as part of the pre-submission review function of the NISC.

1.6.1.6.2 Stakeholder Consultation with Key Data Providers

The GHGI team have an ongoing programme of one-to-one meetings and engage in detailed discussions with Key Data Providers to help ensure that the inventory is using the best available data.

The UK plans and participates in a series of one-to-one meetings and engagement activities each year.

Stakeholder consultation activities completed to date include a continuing programme of one-to-one meetings or engagement 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:

- Consultation with the DECC team producing DUKES and the regulators of the EUETS data collection and reporting systems to determine sector-specific and fuel-specific quality parameters for the UK; check and resolve any outlier data or inconsistencies between Community Independent Transaction Log (CITL) data and source data from regulators; compare sector- and fuel-specific activity data published in UK energy statistics against the EUETS data for the latest year;
- Linked to the EUETS analysis in the bullet point above, data inconsistencies for the refinery sector were reconciled through consultation with DECC and the UK Petroleum Industries Association, in particular to enable better tracking of data for ancillary combined heat and power (CHP) and power plant on refinery sites following changes in ownership. This research also involved consultation with individual plant operators from the petrochemical production sector, to clarify installation boundaries and reporting inconsistencies;
- Consultation with Defra, the water industry regulator (OFWAT) and water and sewerage companies in the UK, to review the sector emission estimates following a method revision in the previous inventory cycle and to seek out additional new data to better inform the estimates of methane emissions from waste water treatment and sewage sludge treatment and disposal. This has led to a revision of the N_2O estimates, where a small double-count in estimates was identified and corrected;
- Meetings, teleconferences and emails with sector experts and emission inventory analysts 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 Environment Agency also covered analysis of a new energy and emissions dataset for IPPC/EPR-regulated sites in England and Wales (REPI); annual access to the REPI dataset has been added to the scope of the Data Supply Agreement for the Environment Agency. Consultation with SEPA sought clarifications of data revisions following an internal review of Scottish Pollutant Release Inventory data quality during autumn 2011;
- Consultation with the DECC Offshore Inspectorate, oil and gas sector contractors and individual site operators to resolve data gaps and inconsistencies within reported emissions data for onshore oil and gas terminals and offshore installations, including to review and resolve data discrepancies from the EUETS and EEMS emission reporting systems;
- Consultation with the Iron and Steel Statistics Bureau to clarify source data for the sector and research reasons behind data discrepancies for specific fuels / sources between available sector energy estimates and aggregated EUETS data for iron and steel operators;
- Consultation with industry experts to review the allocation of petroleum coke and smokeless solid fuels to the domestic sector;
- Consultation with Defra, Environment Agency, SEPA and NIEA to review available data on municipal, clinical, chemical sewage sludge and other incinerators;
- Consultation with Department for Transport (DfT) vehicle statistics on the use of anonymised Automatic Number Plate Recognition data to get a more accurate fleet composition profile for road transport, i.e. data by vehicle age, fuel and road type;
- Consultation with the Driver Vehicle Licensing Agency (DVLA) and devolved administration Governments of Scotland, Wales and Northern Ireland (DAs) on use

of more DA-specific licensing data (vehicle age, size, fuel type) and trip information to enhance the UK and country-specific inventories;

- Consultation with Emisia and the European Environment Agency (EEA) on use of new NOx emission factors (from COPERT 4 v8.1) for road vehicles;
- Consultation with HM Revenue and Customs (HMRC), the UK Petroleum Industries Association (UKPIA), DfT, fuel suppliers to agriculture and energy statisticians in DECC on terminologies, definitions and use of gas oil and DERV for off-road applications leading to an improved split between gas oil and DERV consumption between different on-road, off-road and industry sectors;
- Consultation with DfT, port and harbour authorities, Environment Agency, Maritime and Coastguard Agency, British Waterways, various boating associations, Office of National Statistics (ONS) and HMRC to gather information on the population, usage and fuel consumption of inland waterways;
- Consultation with aviation statistic experts at DfT on flights from Overseas Territories.
- Consultation with Defence Fuels Group at the Ministry of Defence on revisions to military fuels data for aviation and naval shipping;
- Consultation with the Association of Train Operating Companies (ATOC) and the Office of Rail Regulation (ORR) to improve consistency in fuel consumption and train kilometre data used in the UK inventory for intercity, regional and freight rail and to improve consistency with DfT's current Rail Emissions Model.

1.6.1.6.3 Integrated UK and Devolved Administration GHG Inventory Improvement Programme

During 2011-12, the integrated UK-DA GHGI improvement programme implemented a number of specific research projects to address inventory uncertainties and reporting requirements. These improvements are set out in **Section 1.2.2.5**.

1.6.1.6.4 Post-submission Inventory Review by Inventory Agency and DECC

In the latest inventory cycle, and in response to UNFCCC Expert Review Team feedback regarding the need for more qualitative analysis to identify key source categories in the UK GHGI, DECC and the inventory agency have implemented a more formal process of post-submission review during April / May each year, with meetings to discuss the priorities for future GHG inventory improvement options. The inventory agency conducts an internal review of the latest inventory submission cycle, with sector experts reviewing the source data, methods and uncertainties of the estimates from the latest inventory cycle to derive their recommendations for improvement options. This approach complements the formal Key Category Analysis and ensures that all sources that are particularly significant in terms of level or trend are considered within the inventory improvement programme. DECC and the inventory agency then meet to discuss the findings of the formal EUMM and UNFCCC reviews, the internal post-submission review and compile a comprehensive list of improvement items that are then taken forward in wider discussions at the NISC meetings.

1.6.1.7 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).

1.6.1.8 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, 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.

1.6.1.9 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.

1.6.1.10 Bilateral reviews, External Peer Review and Internal Reviews

Bilateral Reviews

The UKs programme of bilateral reviews is managed by the NISC as part of the improvement programme. Bilateral reviews are initiated with other countries as a means to learn from good practice on other countries as well as to provide independent expertise to review estimates. The UK has participated in a number of bilateral exchanges and the current contract makes allowances for biennial bilateral reviews.
Bilateral review activities to date include:

1. During February 2011 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 have been added to the UK GHGI improvement programme for consideration by the NISC.
2. 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

During 2002, the UK implemented a programme of peer reviews by experts outside of the organisation responsible for the estimates. The UKs programme of peer review is managed by the NISC as part of the improvement programme. External Peer review is applied in two cases:

1) When new methods have been developed for important source categories.
2) On a rolling programme to determine whether methods should be improved due to the availability of new datasets and assumptions (focussing on key categories).

Peer review activities to date include:

1) Peer review in 2002 of CO_2 emissions from fossil fuel (Simmons, 2002). This review provided recommendations which have now been implemented, including: 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.
2) Peer review on agriculture in March 2005. The external reviewers were Prof. Ulrich Daemmgen (Institute of Agroecology, Germany) and Ulrike Doering (Federal Environmental Agency, Germany). 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 have been used to help improve the accuracy of the emission estimates from the agricultural sector.
3) Adipic Acid production peer review and verification consultation between Defra, AEA, plant operators and the UK Meteorological Office in 2005. This was conducted to discuss factors affecting emissions from the adipic acid plant. This included: 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 clarified 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) Peer review of the F-gas emissions from category 2F1 (refrigeration and air conditioning equipment) in a technical workshop in 2008. Assumptions about leakage rates and the mix of HFC fluids in each sub-sector were peer reviewed, by a workshop of experts. Losses during manufacture/initial charging and at decommissioning in the original refrigeration sector model were generally based on factors recommended by the IPCC or the recommendations from this workshop. The model used to estimate emissions of F-gases from refrigeration and air conditioning was completely rebuilt in a DECC commissioned study in 2011 and the findings of this peer review were superseded.
5) Peer review of the refrigeration component of the F-gas model in 2010. 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 model used to estimate emissions of F-gases from refrigeration and air conditioning was completely rebuilt in a DECC commissioned study in 2011 and the findings of this peer review were superseded.
6) DECC have funded an external peer review of the research programme that provides LULUCF emissions estimates to the Greenhouse Gas Inventory in 2009.

7) 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.

1.6.1.11 Capacity building and knowledge sharing

The UK actively participates in capacity building and knowledge sharing activities with other countries. These initiatives are usually led by the NISC but also include some projects lead by AEA and funded by the EU and EEA through the European Topic Centre on Air and Climate Mitigation. 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

DECC has a research programme that derives independent emission estimates for the UK based on 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 UK and European emissions that best support the observations and provide a fully independent estimate of annual emission trends for the UK[12]. The technique has been applied to 2-yearly rolling subsets of the data.

A new 3-year contract was established for this research in early 2011 following a competition exercise. This contract expands on the Atmospheric Observation programme to form a network of sites across the UK in Edinburgh, Norfolk, and Herefordshire. 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**.

[12] Estimates cannot be resolved by source category or sector but do show good agreement with the official UK statistics based estimates.

1.6.3 Treatment of Confidentiality

Much of the data necessary to compile the UK inventory are publicly available. One 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://www.naei.org.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 15% in 1990 and 16% in 2010. The trend in the total GWP weighted emissions expressed as the fall between 1990 and 2010 is -23%, with 95% of the values found to lie within the range -21% to -26%. 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 2010, the total direct greenhouse gas net emissions (including net LULUCF emissions) in the UK were estimated to be 590 Mt CO_2 equivalent (based on full UNFCCC coverage). This was 23.5% below the 1990 level.

The following sections summarise the emission trends between 1990-2010 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.

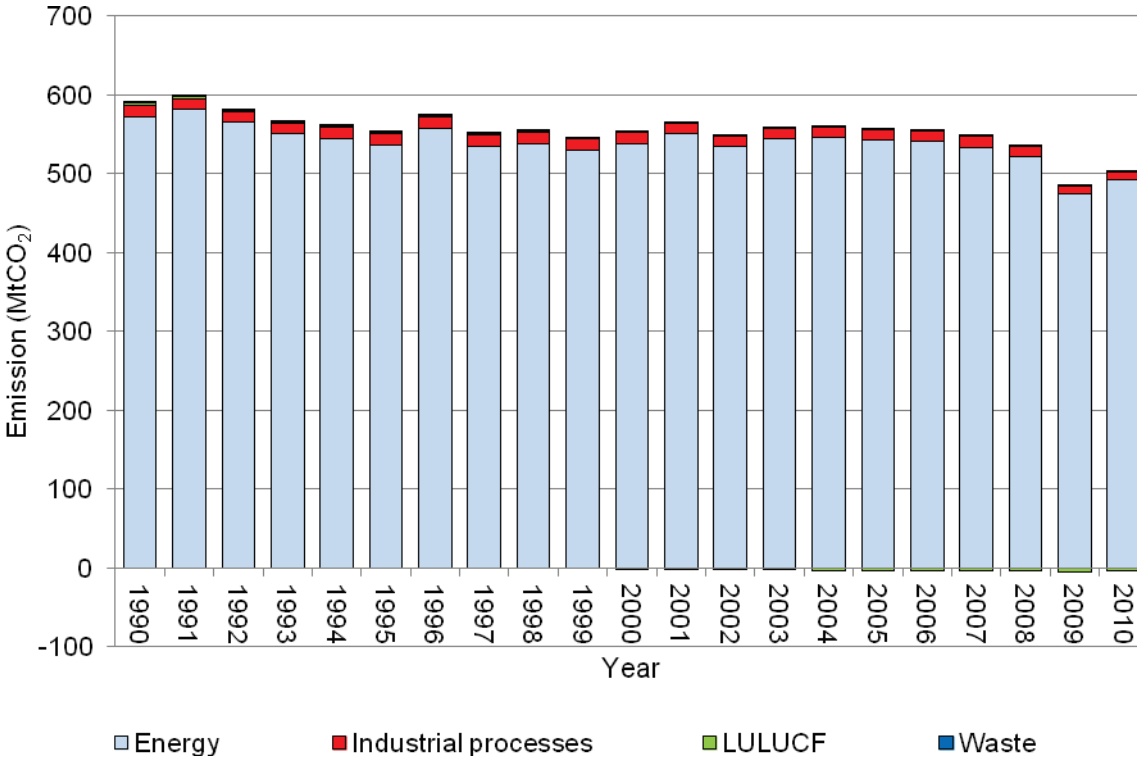
2.2 EMISSION TRENDS BY GAS

The largest contributor to global warming is carbon dioxide at 84% of the weighted emission in 2010. Methane contributes 7% and nitrous oxide 6%. In spite of their high GWPs the contribution of halocarbons is small at around 3% of the total. This is because their mass emissions are very small. Overall the total weighted emission has fallen by almost 23.5% since 1990.

2.2.1 Carbon Dioxide

In 2010, CO_2 emissions were 497.9 Mt CO_2 equivalent, 15.9% 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 increased by 4% from 2009 to 2010 following a decrease from 2008 to 2009.

Figure 2-1 UK CO_2 Emissions Trend by Sector



2.2.2 Methane

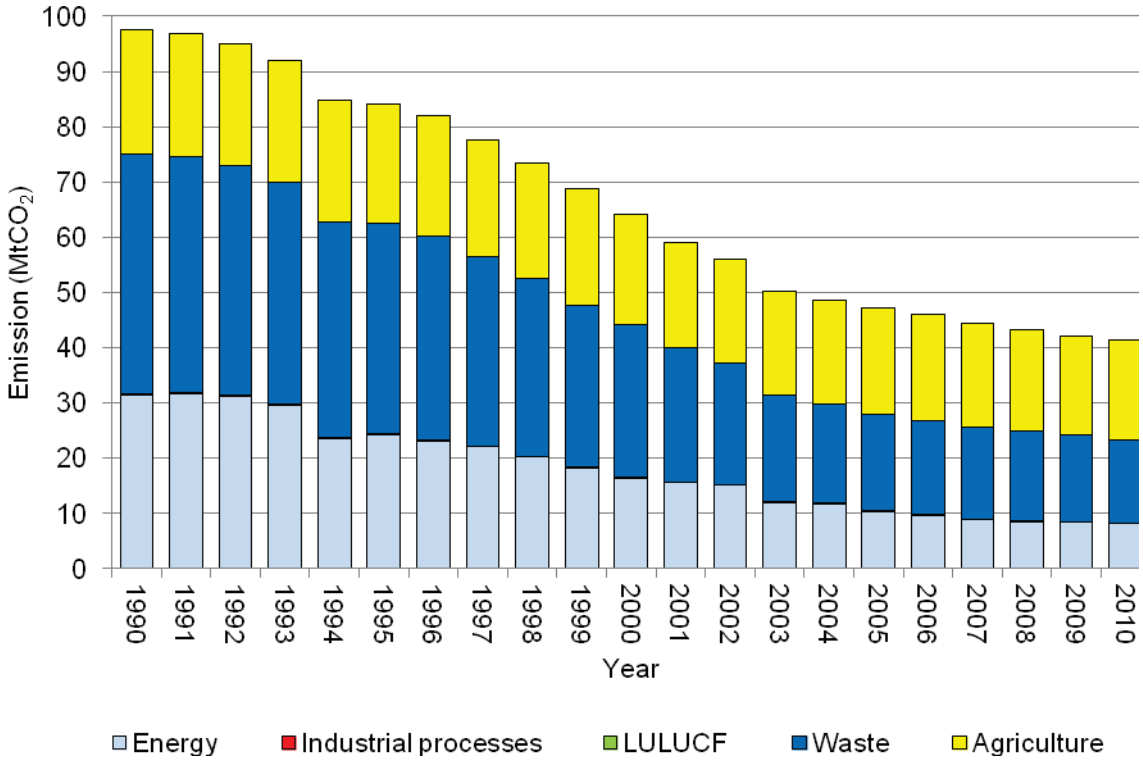
Figure 2.2 illustrates the trend in emissions of methane, broken down by source. Methane is the second most significant greenhouse gas in the UK after CO_2. In 2010, methane emissions were 41.4 Mt CO_2 equivalent.

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 74% since 1990. Decreases in this sector have contributed 41% to the total decrease in methane emissions.
- Total emissions in the waste sector have decreased by 65% due to increased implementation of methane recovery systems at landfill sites. The reduction in emissions in this sector is responsible for 51% of the total decrease in methane emissions since 1990.
- Emissions from agriculture have decreased by 20% since 1990, following the trend of decreasing livestock numbers.

Since 1990, emissions of methane have decreased by 57.6%. Emissions from LULUCF and Industrial Processes are not significant sources of methane, contributing less than 0.3% of the total in 2010. Emissions from Industrial Processes have decreased by 57%, whilst LULUCF emissions have increased by 56%.

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 2010, emissions of nitrous oxide were 35.6 Mt CO_2 equivalent. Emissions have declined 47.5% since 1990, and the main reasons for this reduction are:

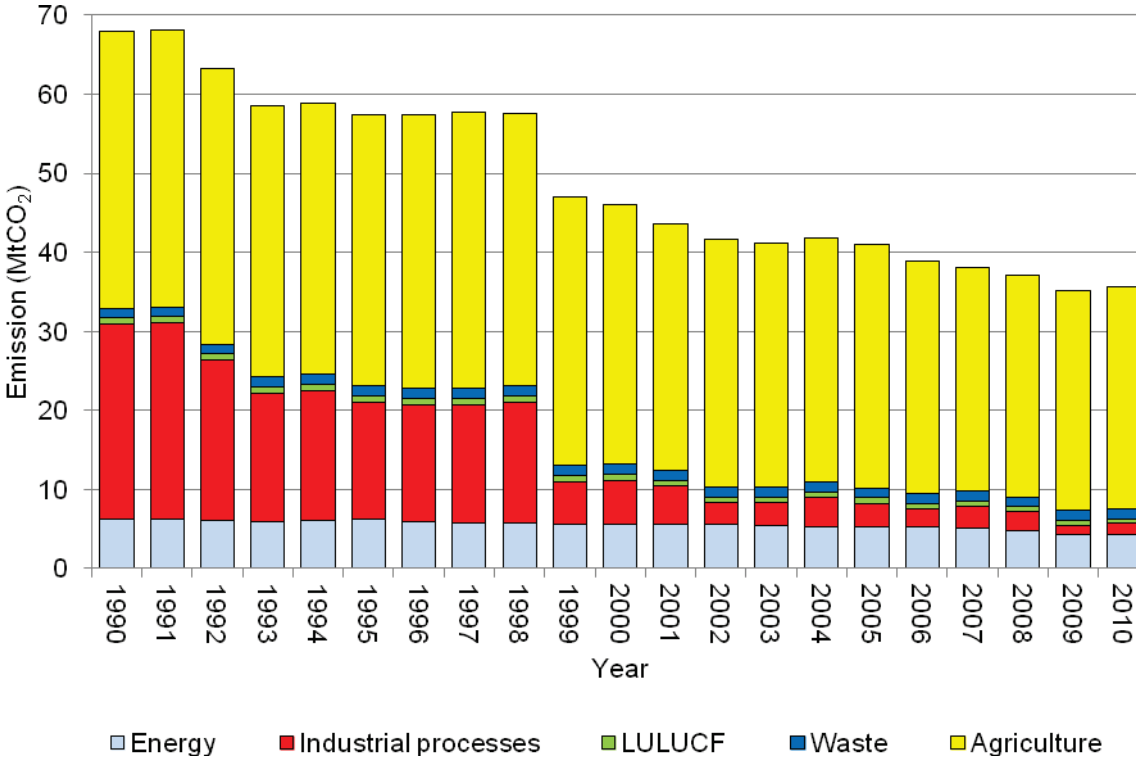
- The agriculture sector is a major source of N_2O emissions, contributing 79% to total emissions of N_2O. Emissions from this sector have decreased by 20% since 1990, mostly due to a decrease in emissions from sector 4D, agricultural soils, driven by a fall in synthetic fertiliser application.

- 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 2010, these sources accounted for only 3.7%. 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 72% to the total decline in N_2O emissions.

- Fuel combustion is also a significant N_2O source, with total emissions from the energy sector contributing 12% to total N_2O emissions in 2010. Emissions from this sector have decreased by 31% 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 2010 are now 28% lower than emissions in 1990.

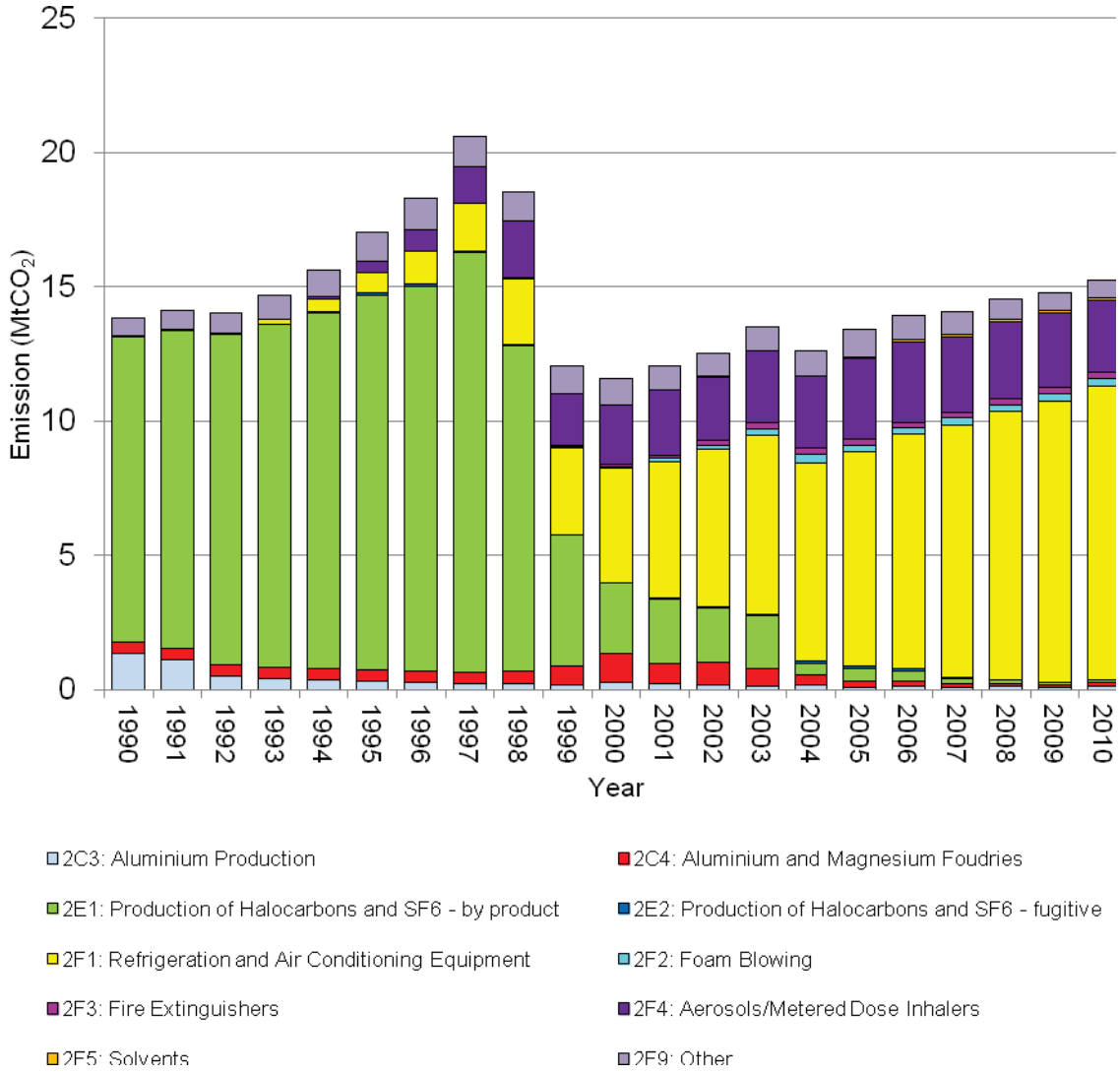
Figure 2-3 UK Trends in N_2O Emissions by Sector



2.2.4 Fluorinated-Gases

Emissions of the F-gases (HFCs, PFCs, and SF_6 – see **Section 1.1.2.3**) totalled 15.2 Mt CO_2 equivalent in 2010. Since 1995 the overall decrease in their emissions has been 11%, 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 of the three. 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 17% 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. However, an increase in emissions of around 3.4% is also seen between 2009 and 2010. This is driven mostly by decreases in the power generation (1A1a) and road transport (1A4b) categories.

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 20% since 1990, reflecting trends in livestock numbers and emissions from fertiliser application.

The industrial processes sector (IPCC Sector 2) contributes 4.5% 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 50%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 2.8% to greenhouse gas emission in 2010. 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 64% 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 2010, the total emissions were 1110 Gg, with 99.7% of these emissions arising from the energy sector. Since 1990, emissions have decreased by 62%, 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 2010, the total emissions were 2128 Gg, of which 95% were from the energy sector. Since 1990, emissions of CO have decreased by 77%. The majority of this reduction is due to improvements in vehicle technology within the road transport category

In 2010, total emissions of NMVOCs were 790 Gg, of which 37.8% 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 71%. 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 2010 were 409 Gg. Of this, 96.8% 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

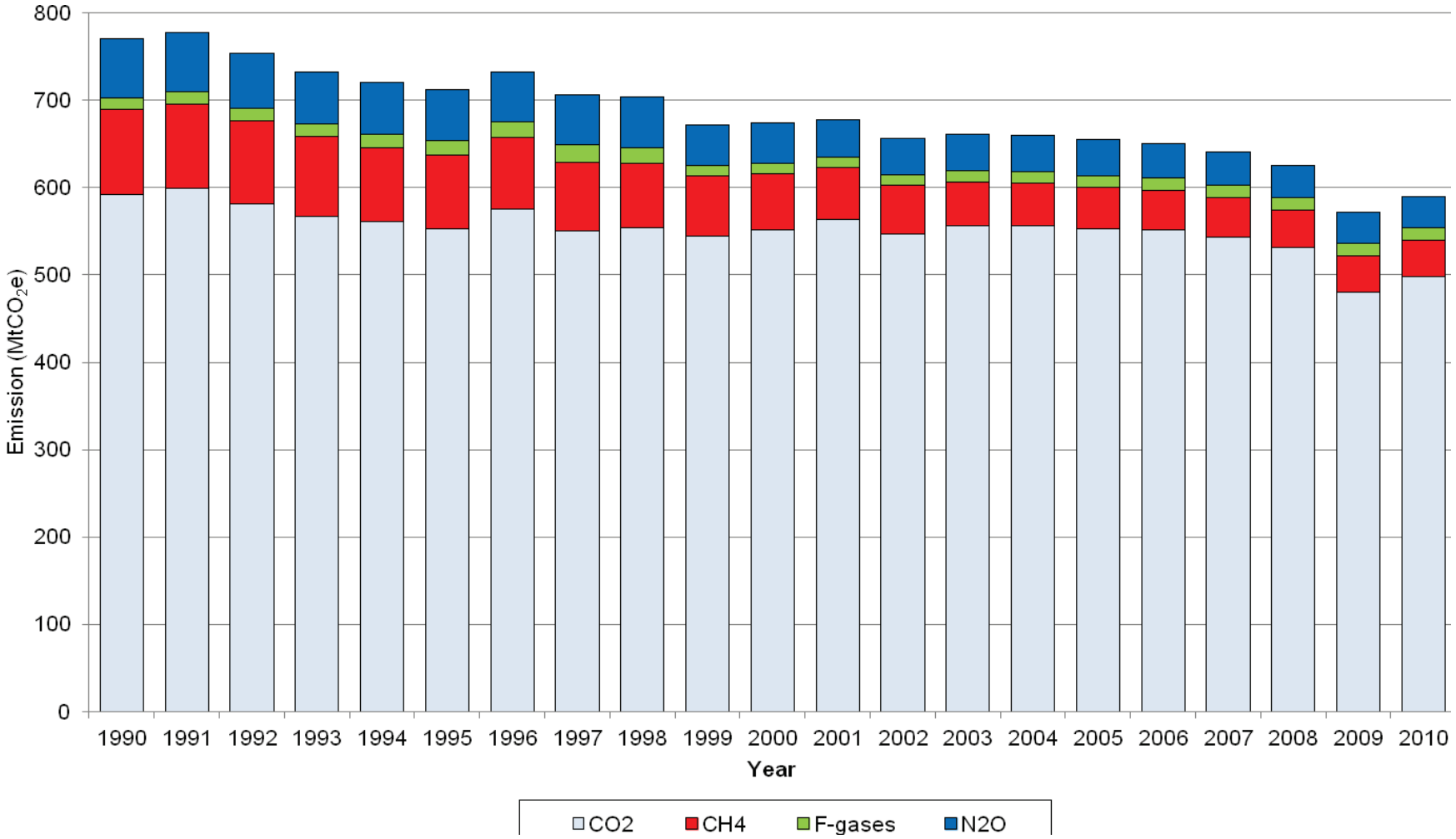
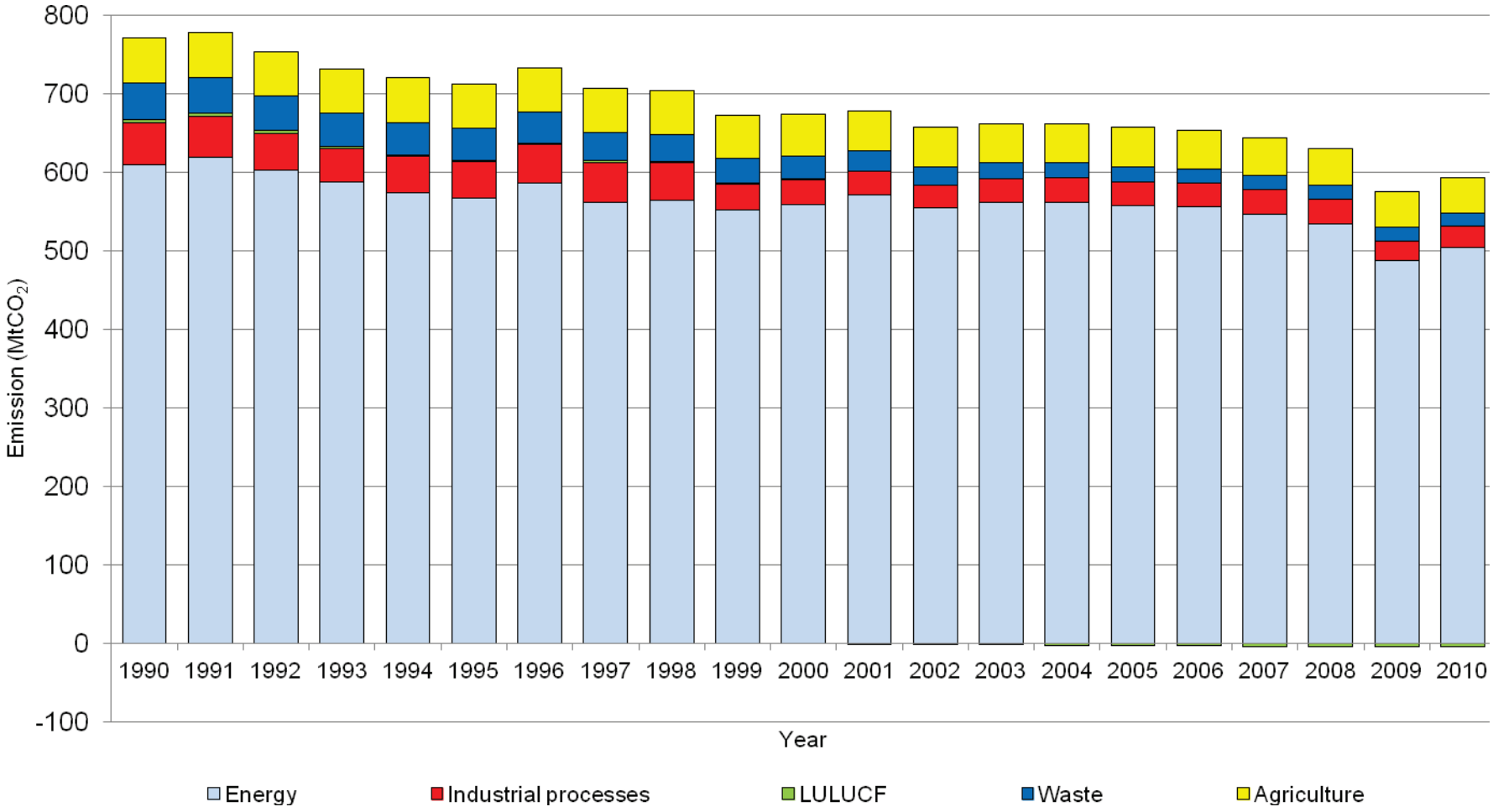
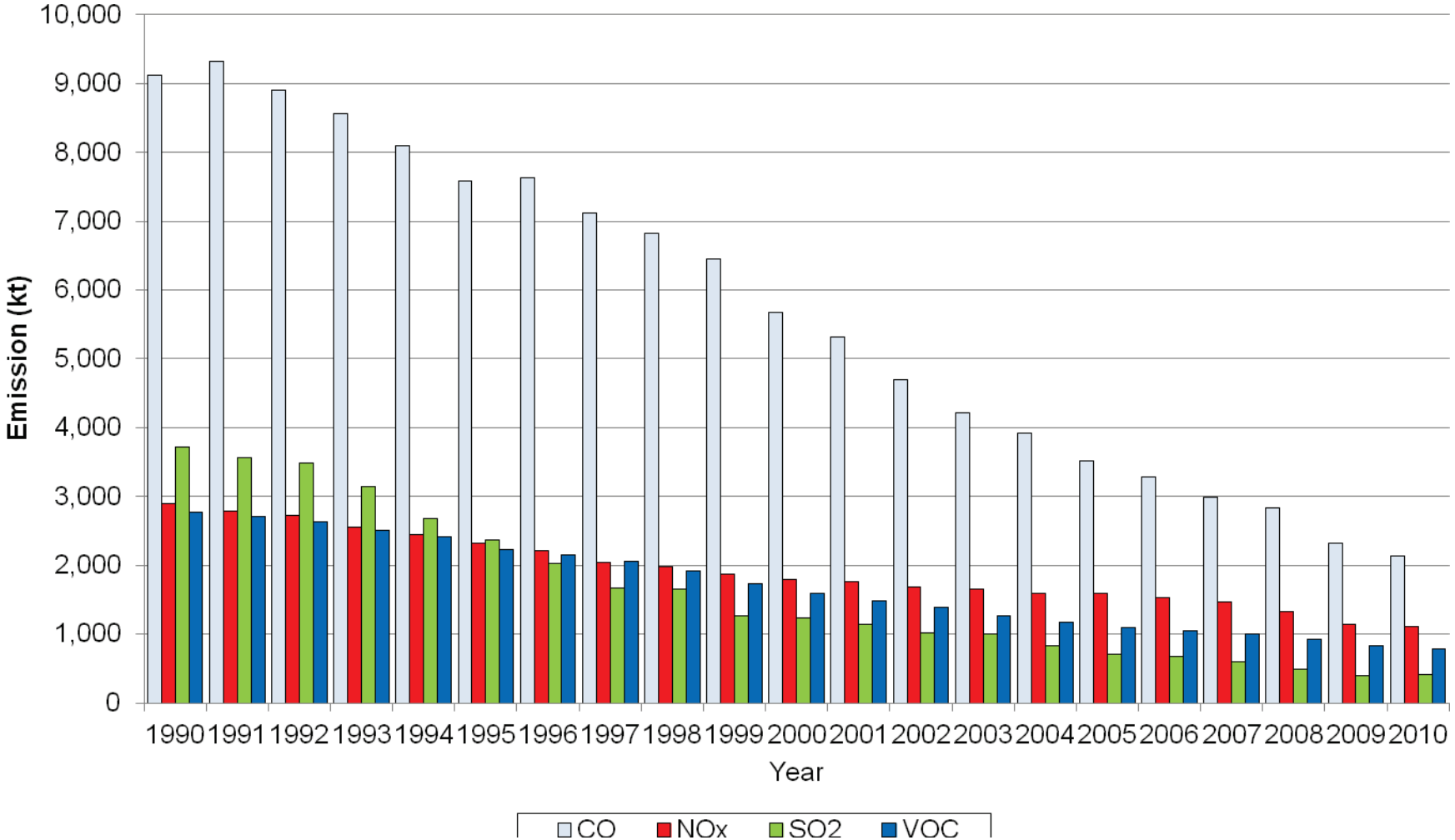


Figure 2-6 UK Net Emissions of Greenhouse Gases by Sector



'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

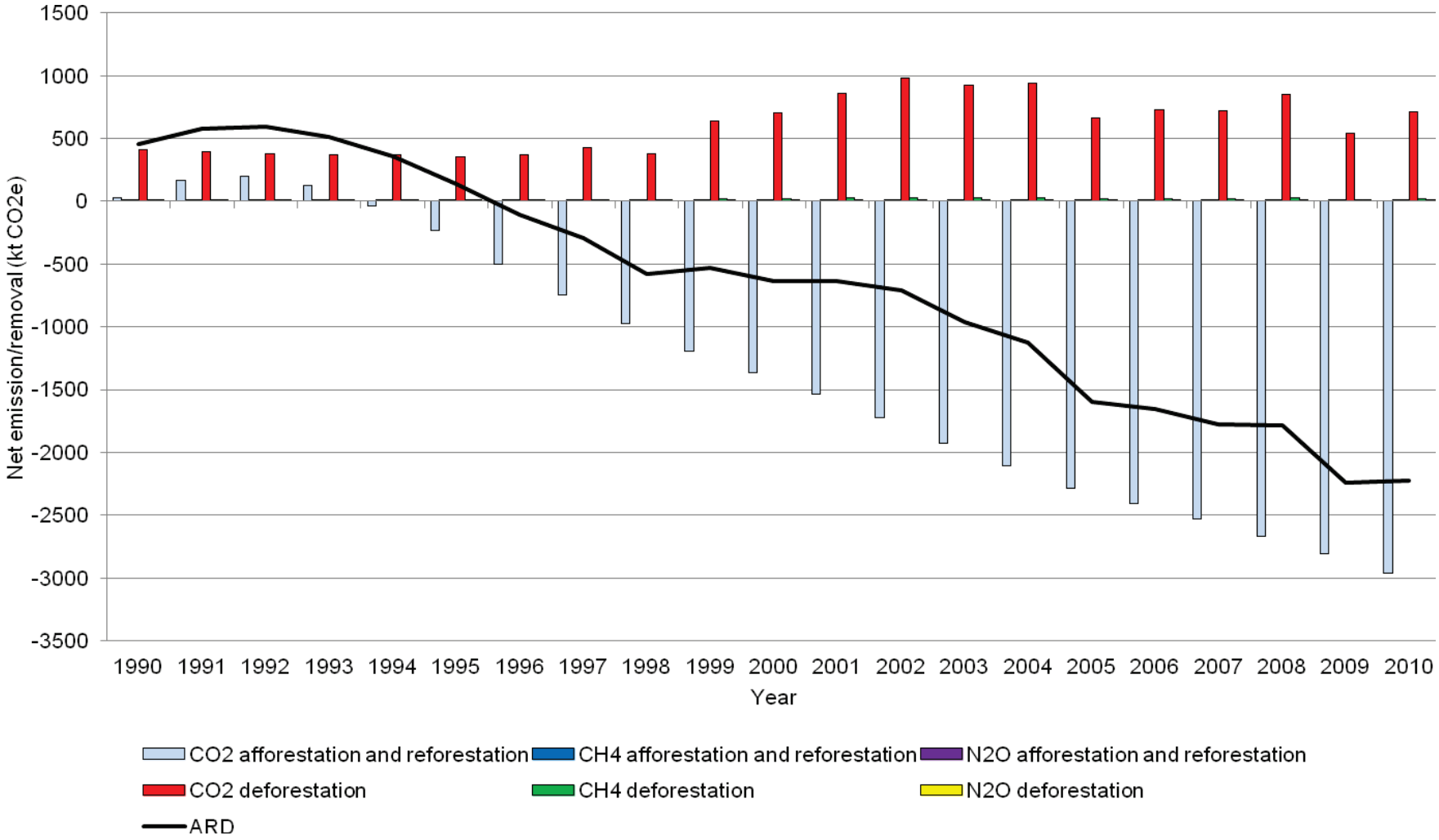
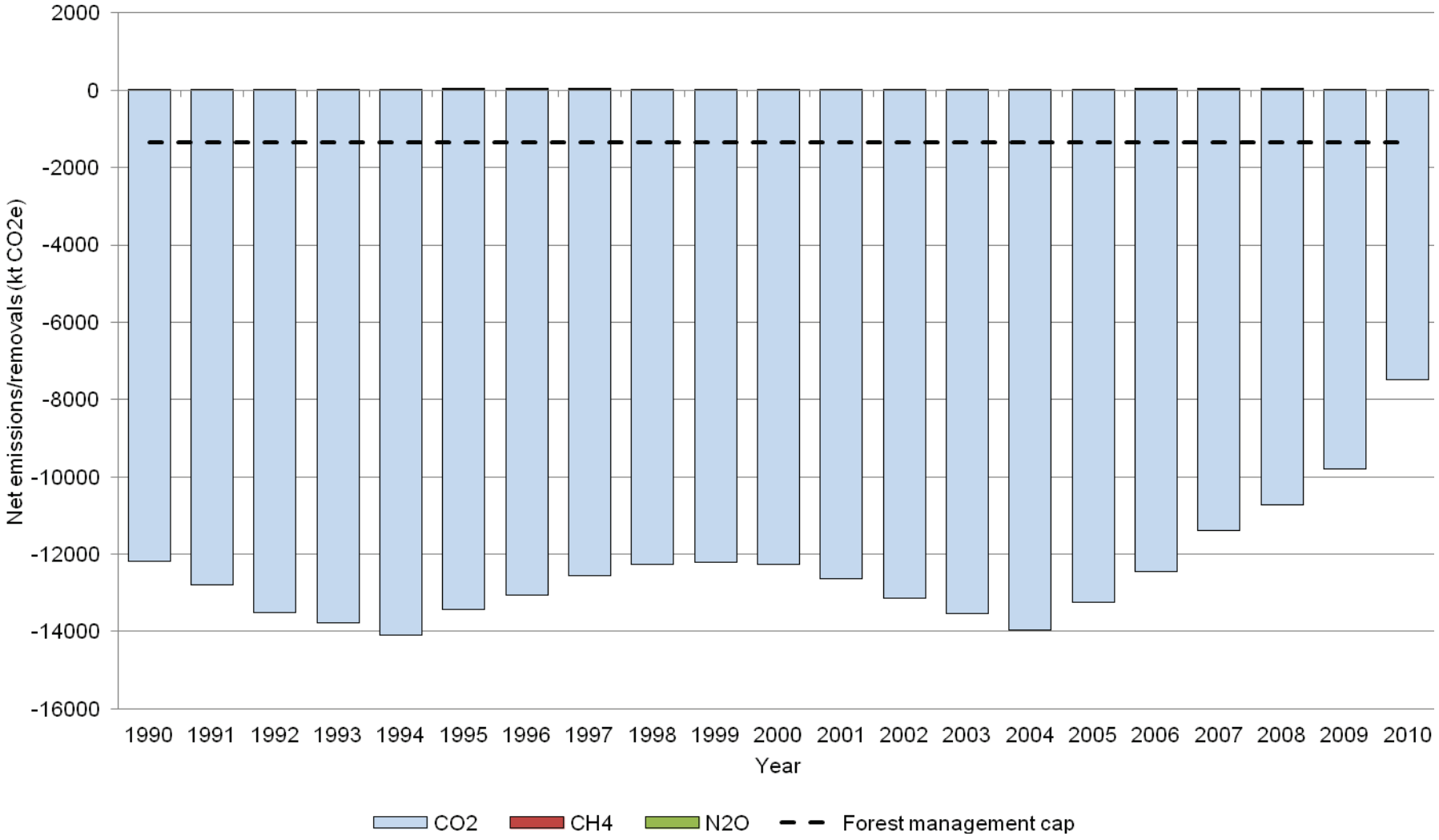


Figure 2-9 Article 3.4 Emissions and removals, by gas



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 2010, 85.5% 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.

A general assessment of completeness for the inventory is included in Annex 5. Within the energy sector, the only known omission is emissions from multilateral operations (a memo item) for which data are not available. Estimated emissions are included in this sector for all relevant UK Overseas Territories and Crown Dependencies. Emissions from the Overseas Territories and Crown Dependencies are included within the CRF submission in the UK emissions totals and UK emission factors are used. For more information on the methodology used, see Annex 3.9.

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[13] includes the IPCC Reference Inventory total for CO_2. 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 Reference Approach typically produces UK CO_2 emission estimates that are between 2% lower to 2% higher than the more detailed Sectoral Approach, due to differences in assumptions of non-energy use and statistical differences between production-side and demand-side fuel estimates within national energy statistics. Reasons for the differences between the two estimates are discussed in **Annex 4**.

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

Over the period (1990 to 2010), emissions estimated by the Reference Approach have fallen by 12.5% compared with 14.0% 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).

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 has been used to estimate domestic inland waterway emissions and this has led to a re-allocation of marine fuels and hence emissions between domestic and international bunkers. The new method has slightly decreased the allocation of total shipping emissions to international bunkers. In 2010, the shipping emission contributed 22% to total bunker emissions, with aviation contributing the remaining 78%. 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 and inland waterways 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

UK energy statistics, given in DUKES, include information on the non-energy use of fuels. The general approach adopted in the UK GHG inventory is to assume that emissions from these non-energy uses of fuels are zero (i.e. the carbon is assumed to be sequestered as products), except for cases where emissions can be identified and emission estimates included in the inventory. More details on the methodologies used to estimate emissions of carbon from specific non-energy uses of fuels are contained in Annex 3.3.9, but a summary of our understanding of the uses to which these fuels are put, and the potential for emissions, is given below.

Ethane, LPG (given separately as propane & butane in the energy statistics), other petroleum gases, and naphtha are all consumed in very significant quantities for non-energy uses. All of these products are believed to be mainly used as feedstocks in chemical manufacturing. Several major petrochemical production facilities that are co-located with oil terminals and refineries are known to be supplied with Natural Gas Liquid (NGL) feedstock

directly from upstream production lines, and the utilise NGL fractions such as ethane, propane and butane in their manufacturing processes. All of the consumption given in DUKES is therefore assumed to be initially stored in chemical products, although some emissions of carbon do then occur during subsequent use or destruction of some of those products e.g. when some waste chemical products are incinerated or used as fuels. Although emissions from incineration and combustion of wastes are estimated, we cannot relate the carbon in these wastes back to individual feedstocks, so it is not possible to generate reliable UK estimates of the proportion of carbon in each individual fuel that is ultimately emitted. Some butane is used as a propellant in aerosols and is emitted as VOC. The UK inventory contains estimates of these VOC emissions, combined with emissions of solvents used in aerosols.

Natural gas is also used as a chemical feedstock for the manufacture of ammonia, methanol and acetic acid. This process is described in **Section 4.9.1**. More details on non-energy use of fuels and stored carbon are contained in **Annex 3.3.9**.

White Spirit and Special Boiling Point (SBP) spirits are used exclusively for non-energy applications, and are listed in CRF Table 1.A(d) within the category 'other oil'. They are used as solvents; SBP spirits are used for industrial applications where quick drying times are needed (e.g. adhesives and other coatings) while white spirit is used as a solvent for decorative paint, as a cleaning solvent and for other applications. Estimates of VOC emissions are included in the UK inventory but no estimates are made of direct emissions of carbon from these products, as they are regarded as "not occurring".

The UK energy balance for gas oil indicates a relatively high allocation of gas oil use in non-energy uses (142kt in 2010, which is around 3% of total UK supply) and these data are reflected in the UK GHG inventory, and the carbon stored is reported in CRF table 1.A(d). There is no detailed information within the energy balance reporting to indicate the applications for non-energy use of gas oil, but the data are based on fuel supplier estimates of fate of their products, and it is assumed that gas oil may be used within some chemical or petrochemical manufacturing process.

Lubricants are listed separately in the UK energy statistics and are used in vehicles and in machinery. The inventory does include estimates of emissions of carbon due to oxidation of lubricants during use, and also includes estimates of emissions from the combustion of waste lubricants and other oils used as fuel.

Bitumen is assumed to be used only for applications where the carbon is stored. By far the most important of these is believed to be the use of bitumen in road dressings. The inventory does include emissions of VOC from 'cut-back' solvents used in certain road dressings, and also assumes that a very small proportion of the carbon in the bitumen itself is emitted as VOC during roadstone-coating but does not include any estimates of direct carbon emissions from uses of bitumen.

Petroleum Coke listed as used in non-energy applications in DUKES actually includes some used as a fuel, for example in cement kilns and other industrial sectors, and in smokeless and non-smokeless fuels for the domestic sector. The UK inventory Agency makes independent estimates of the consumption of petroleum coke in these sectors, based on data provided by industry. The remaining 'non-energy' consumption, following subtraction of these estimates, is then assumed to be the true consumption of petroleum coke for non-energy uses. Some of this consumption is used for applications where carbon emissions do

ultimately occur, such as manufacture of electrodes used in aluminium and steel production. Other applications are assumed to result in storage of carbon.

Coal-tars and benzoles are by-products of coke ovens and are reported in DUKES as used for energy. However, consultation with coke oven operators indicates that all of the coal-tars and benzoles produced are sold for use in the manufacture of chemicals and other products and that the carbon is therefore stored. In the reporting of the UK inventory in the CRF tables, we assume the IPCC default assumption of 6% of coking coal is transformed into coal oils and tars, and then the carbon stored is recorded in the coking coal line of table 1A(b) and under "Coal oils and tars (from coking coal)" in table 1A(d). Some coal-tar pitch is used in the manufacture of electrodes, together with petroleum coke and the carbon ultimately emitted and emissions of carbon from these sources are included in the inventory.

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 40 Mtonnes of coal were burnt at 17 power stations during 2010, while approximately 11,700 Mtherms of natural gas were consumed at 42 large power stations and 11 small (<50MWth) regional stations (mostly Combined-Cycle Gas Turbines, CCGTs). Heavy fuel oil was the main fuel at 4 large facilities, and gas oil or burning oil was used by 4 large and 9 small power stations, as well as being used as a secondary fuel at 10 nuclear 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 (EfW) installations in the UK. Formerly referred to as municipal solid waste (MSW) incinerators, all such installations 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 installations 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 2010, there were four coke ovens at steelworks and one independent coke oven. A further three coke ovens have closed in the last decade, 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, 2011) 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, petroleum coke and OPG. 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. For OPG, analysis of EUETS data from refineries for the 2012 submission identified a discrepancy in activity data between EUETS and DUKES. Based on data from EUETS and the refinery trade association, UKPIA, we identified a systematic under-report in the UK energy balance data for the refinery sector from 2004 onwards. The estimates for 2004 in the UK GHGI are therefore based on UKPIA data, whilst the data for 2005 onwards are based on EUETS data. Prior to 2004 the UK GHGI emission estimates based on DUKES energy data are closely consistent with UKPIA sector estimates, and are therefore retained. Emissions estimates for the refinery sector are explained further in **Annex 3, Section A3.3.3.2.**

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, 2011), via the Pollution Inventory (PI);

from the Scottish Environment Protection Agency (SEPA, 2011), 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, 2011). 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**.

CO_2 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 2005-2010. 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 negligible. Due to the use of site-specific data, CO_2 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 in the future.

Data from the EU ETS are also used to estimate CO_2 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. From 2005 however, CO_2 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 CO_2 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 (2005 onwards) and fuel oil (2006 onwards) 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.

Available data for waste composition have been analysed in order to produce an updated CO_2 emission factor for MSW incineration. This research was conducted in order to produce

a more transparent emission factor, and also to produce a time series which reflects the changing composition of waste between 1990 and 2010. Data were obtained from incinerator operators, which reflected the waste composition data in the early 2000s, however a suitable time series of data has not yet been found. The waste composition data that were obtained indicated a lower carbon content of about 62kt carbon/Mt waste. It was not considered appropriate to apply the lower emission factor across the time series since it was not clear that this was a better representation for all years than the emission factor used previously. We have therefore retained this emission factor, and will continue to conduct research to find a suitable time series of waste composition data, to use in the 2013 NIR submission.

For emissions associated with combustion from upstream oil and gas activities, reported under 1Ac, see **Section 3.3.2.2**.

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 2012 inventory, EU ETS data have been used for the years 2008 to 2010, activity data 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, 2011) 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

Gas oil use in oil and gas extraction has been included in DUKES for the first time this year. This is only from 2005 onwards, so to maintain a consistent time series this has been extrapolated back to 1990. This inclusion in DUKES caused a reallocation of gas oil from

1A2 (other industries) to 1A1. For 1998 onwards, EEMS data have been used to extrapolate this gas oil consumption, for earlier years, DUKES oil and gas extraction data have been used as a scaling factor.

Combustion of MSW, landfill gas and sewage gas for heat generation has also been reallocated from 1A4a to 1A1 in order to report emission in a more appropriate location. This is in response to a recommendation from the UNFCCC's expert review.

Changes have been implemented from 2004 onwards to increase the UK GHGI refinery sector emission estimates to align with EUETS data and trade association (UKPIA) data. In consultation with DECC, a gap in reporting of OPG use in refineries has been identified and resolved, ensuring that the inventory estimates are complete.

EUETS data has been used to inform new estimates in the UK GHGI for OPG and LPG use in the upstream oil and gas terminals for recent years. Consultation with DECC has confirmed that these data were previously collated and reported in UK energy statistics up to 2002, but later estimates were extrapolations. Therefore, the EUETS data has been used in preference for recent years, over-writing previous estimates and improving the accuracy and completeness of the inventory estimates. For more information on the EUETS analysis performed, see Annex 11**.**

A number of revisions to installation data reported within the EEMS dataset for recent years have been implemented, following consultation with the DECC Offshore Inspectorate (the offshore regulatory agency) and site operators.

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 2009 inventory (2011 NIR). Comparisons are made between the current inventory (1990-2010) and the previous inventory (1990-2009) for the year 2009.

3.2.6.6.1 Carbon Dioxide (CO_2)

- Overall there has been an increase in estimated emissions for 2009 of 4559.3 Gg CO_2 from sector 1A1. This has been caused by both energy statistics revisions and emissions reallocations. The more major causes of this increase are described below;
- There has been an increase of 1,680 Gg CO_2 from OPG use in refineries.
- There has been an increase of 1,395 Gg CO_2 from gas oil use in oil and gas extraction which has been included in DUKES for the first time this year.
- There has been an increase in the reported use of natural gas for gas production, power stations and oil refineries in DUKES (DECC, 2011), leading to a total increase in estimated emissions of 861 Gg CO_2.
- There has been an increase of 38 Gg CO_2 due to a reallocation of MSW for heat generation which is now reported in 1A1 rather than 1A4.
- For details of more minor recalculations see **Table 10-1**.

3.2.6.6.2 Methane (CH4)

- Overall there has been an increase in estimated emissions for 2009 of 0.61 Gg CH_4, resulting primarily from the changes to activity data mentioned above, and the reallocation of landfill gas and sewage gas for heat generation from 1A4.

3.2.6.6.3 Nitrous oxide (N2O)

- Overall there has been an increase in estimated emissions for 2009 of 0.13 Gg CH_4, resulting primarily from the changes to activity data mentioned above, and the reallocation of landfill gas and sewage gas for heat generation from 1A4.

3.2.6.6.4 Nitrogen Oxides (NOX)

- There has been an increase of 15 Gg in estimated emissions due to use of revised emission factors for engines burning landfill gas and sewage gas to produce electricity and heat.
- Emission estimates also increase (by 14 Gg) due to the addition of estimates for gas oil use on offshore oil and gas installations. Previously this gas oil had been included in estimates for 1A2.

3.2.6.6.5 Carbon Monoxide (CO)

- An increase in estimated emissions of 3 Gg is due to the reallocation of gas oil to offshore installations mentioned in the previous section..
-

3.2.6.6.6 Sulphur Dioxide (SO2)

- The addition of estimates for SO_2 from the combustion of landfill gas in engines increases emissions by 2 Gg. The changes to gas oil mentioned in the previous two sections increase emissions of SO_2 by 1Gg.

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 and analysis of EUETS data will continue. Additional work is currently on-going to better characterise (e.g. carbon content and calorific value) the full time series of MSW.

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. Tata (formerly Corus) integrated steelworks data), UK energy statistics and EU ETS (where process emissions are reported separately from combustion emissions)

Following a UNFCCC recommendation, this year for the first time emissions for manufacturing industries and construction have been disaggregated to categories 1A2a-f where possible; primarily using activity data from DUKES (DECC, 2011). Emissions from fuel

used by other industrial sectors (e.g. chemicals, non-ferrous metals, food & drink, paper & printing) were previously reported as 'other industry' within 1A2f. Full details of the changes made to activity data in order to implement these improvements are given in Annex 3 (Section A3.3.4.1).

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].						
Chemicals	Emission factors and fuel consumption data[2].						
Non-ferrous metals	Emission factors and fuel consumption data[2].						
Food & drink	Emission factors and fuel consumption data[2].						
Paper & printing	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 onwards 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

A review has been performed this year on the allocation of gas oil to different sectors. Gas oil is used in both off-road transport and machinery diesel engines, and as a fuel for stationary combustion. The varied use of this fuel complicates the means of allocating consumption across the wide range of sectors that use the fuel in the inventory. DUKES provides a breakdown of gas oil consumption in different industry and other sectors, but with high uncertainty and DUKES is unable to distinguish between use of the fuel for stationary combustion and off-road machinery, a distinction which is necessary for the inventory. This review mainly affects sectors 1A2 and 1A4 although include a reallocation of petrol and diesel from road transport to off-road machinery; these changes are explained fully in Annex 3 (Section A3.3.8).

Following a UNFCCC recommendation, this year for the first time, emissions for manufacturing industries and construction have been disaggregated to categories 1A2a-f. This disaggregation has been made for combustion of coal, natural gas, fuel oil, gas oil and electricity (used for the end user inventory). The 1A2 sector total has not been changed as a result of this reallocation and remains consistent with DUKES totals for all fuels except gas

oil. The allocation of gas oil across other sectors has affected the 1A2 sector total; these changes are explained fully in Annex 3 (Section A3.3.4.1).

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 2009 inventory (2011 NIR). Comparisons are made between the current inventory (1990-2010) and the previous inventory (1990-2009) for the year 2009.

3.2.7.6.1 Carbon Dioxide (CO_2)

- Estimated emissions of CO_2 from 1A2 have increased by 146 Gg CO_2. The main reasons for this change are given below;
- There has been a decrease in emissions of 889 Gg CO_2 from industrial off-road machinery. This is due to a combination of results from a review of gas oil consumption and the inclusion of emissions from petrol combustion in this sector for the first time. A full description of the gas oil changes is included in Section A3.3.4.1.
- Additional emissions have been allocated to other industrial combustion for the combustion of OPG following analysis of EU ETS data. This has led to an increase of 480 Gg CO_2. See Annex 11 for further details.
- Emissions from combustion of waste solvents in other industrial combustion have increased by 60 Gg CO_2 due to an updated emission factor.
- The fuel consumption for lime production has been revised in line with data from EU ETS.
- Other recalculations in this sector are mainly due to revisions to the later years of DUKES (DECC, 2011).

3.2.7.6.2 Methane (CH_4)

- There was an overall increase in emissions of 0.02 Gg CH_4. The main causes of these changes are revisions and reallocations to activity data as described above.
- Minor changes to emission factors for fuel oil, gas oil and biomass fuels have been made due to revisions to GCVs.

3.2.7.6.3 Nitrous Oxide (N_2O)

- There has been an overall decrease of 0.04 Gg N_2O from 1A2.
- The largest change is a decrease of 0.05 Gg N_2O from industrial off-road machinery. This is due to a combination of results from a review of gas oil consumption and the inclusion of emissions from petrol combustion in this sector for the first time.
- A small increase, of 0.01 Gg N_2O in this sector has been caused by a revision to wood activity data in DUKES (DECC, 2011).

3.2.7.6.4 Nitrogen Oxides (NO_x)

- Reallocations of fuels from 1A2f to 1A2b-1A2e (as described above) leads to various increases and decreases in estimates but overall emissions for coal, fuel oil, gas oil and natural gas combustion do not change as a result of these reallocations.
- Estimated emissions from natural gas combustion by industrial plant decrease by 18 Gg due to revisions to emission factors and, less significantly, updated activity data.
- Reallocation of gas oil between various sectors leads to decreases in the emission estimate for industrial off-road vehicles of 3 Gg.

3.2.7.6.5 Carbon Monoxide (CO)

- Estimated emissions from industrial combustion of wood have increased by 12 Gg due to use of updated activity data.
- Reallocations of fuels from 1A2f to 1A2b-1A2e leads to various increases and decreases in estimates but overall emissions for coal, fuel oil, gas oil and natural gas combustion do not change as a result of these reallocations.
- Reallocation of gas oil between various sectors leads to decreases in the emission estimate for industrial off-road vehicles of 2 Gg.

3.2.7.6.6 Sulphur Dioxide (SO_2)

- Estimated emissions from industrial combustion of fuel oil have fallen by 2 Gg, following minor updates to emission factors.

3.2.7.6.7 Volatile Organic Compounds (VOC)

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

3.2.7.7 Source Specific Planned Improvements

Emission factors and activity data are kept under review. For full details of the improvement programme see **Section 1.2.2.5**.

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 are also included in the inventory.

Emission estimates from the navigation section (1A3d) cover coastal shipping and international marine. Emissions from UK inland waterways were also reported separately in this year's inventory for the first time.

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 Greenhouse gases from vehicles running on LPG are included.

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[14]. 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.**

During the UNFCCC's expert review of the UK inventory in 2010, the ERT highlighted that reporting emissions for flights between the UK and its Overseas Territories as international had led to an under estimate of emissions in this category. The ERT applied an adjustment to the inventory to include the emissions for this source. In the 2011 inventory submission, flights between the UK and relevant overseas territories were included as domestic aviation. The 2012 inventory submission has included flights originating from Overseas Territories to other overseas destinations in the international aviation figures. Return flights to North Sea oil rigs are also included in international aviation.

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 bottom-up method based on detailed shipping movement data for different vessel types, fuels and journeys is used to estimate domestic (coastal) shipping emissions. A new method has been used in the 2010 inventory to estimate domestic emissions from inland waterways so that this sector could be included explicitly in the inventory for Waterborne Navigation for the first time. The method is based on a study on the population and activities of different classes of vessels. A revised estimate for international marine emissions is derived by difference between total fuel consumption statistics for marine fuels and fuel consumption by domestic coastal shipping and inland waterways. The new approach represents an IPCC Tier 2 method and is described in detail in **Annex 3, Section 3.3.5.4.**

The 2010 inventory includes a re-allocation of gas oil used across a variety of transport, industrial and other sectors. It also covers a re-allocation of small amounts of petrol and road diesel from the road transport sector to other types of off-road machinery and small inland waterway craft. This is described in Annex 3 and is referred to in several places in the transport methodology sections of Annex 3.

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.

[14] 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.

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. The sector allocation of gas oil consumption given in the DECC publication was not considered suitable for the inventory, so the 2010 inventory is derived from a different assignment using various estimation methodologies and data sources developed in a recent study on gas oil consumption across different sectors.

Other important sources of activity data are UK Department for Transport (DfT) 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 approach used for shipping emissions while various other national statistics were used to derive time-series consistency in the new inventories for inland waterways and other off-road sectors.

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 2009 inventory. Comparisons are made between the current inventory (1990-2010) and the previous inventory (1990-2009) for the year 2009.

3.2.8.6.1 Carbon Dioxide (CO_2)

- Emissions from 1A3 Transport have decreased overall by 432.4 Gg CO_2. The changes occurred mainly in the Waterborne Navigation and road transport sectors, through re-allocation of fuel used by international shipping to fuel used by domestic inland waterways and through re-allocation of fuel used by road transport to domestic inland waterways and other off-road machinery.
- Estimated emissions from category 1A3a Aviation increased by 26.9 Gg CO_2. This was primarily due to inclusion of emissions from flights from the relevant Overseas Territories to the UK, and flights between Overseas Territories, as domestic

emissions, in response to a recommendation from the UNFCCC's expert review team.

- Estimates of emissions from road transport are reduced by 1,279 $GgCO_2$ due to a re-allocation of petrol and DERV to the inland waterways and off-road machinery sector, to improve the sectoral accuracy of the UK inventory.
- Within the road transport sector, the allocation of CO_2 emissions among vehicle types has been slightly revised due to a new approach incorporating Automatic Number Plate Recognition data and regional licensing data to define the fuel and age mix of vehicles on different types of roads, accompanied by revisions to some of the fuel consumption factors for HGVs and buses according to new transport statistics.
- Estimated emissions from rail increased by 25 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 domestic waterborne navigation were increased by 995 $GgCO_2$ due to a new approach for estimating emissions from inland waterways which involved re-allocating gas oil previously assumed to be consumed by international shipping and petrol and DERV previously allocated to road transport. Emissions from international shipping were reduced by 421 $GgCO_2$ due to this re-allocation.

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3.2.8.6.2 Methane (CH_4)

Among the transport sectors, methane emissions are dominated by road transport. Estimates of emissions from road transport were reduced by 0.21Gg due to the new method for estimating the composition of the vehicle fleet, particularly affecting emissions from artic HGVs. Estimates for domestic waterborne navigation are increased by 0.16Gg due to allocation of fuel to the inland waterways sector.

3.2.8.6.3 Nitrous oxide (N_2O)

Among the transport sectors, N_2O emissions are dominated by road transport. Estimates of emissions for this sector are reduced by 0.44 Gg mainly due to the revision in N_2O emission factors for HGVs. Within the new time-series, emissions of N_2O from road transport are slightly higher in 2010 compared with 2009, this being due to the penetration of Euro V HGVs and buses which according to the new N_2O emission factors are higher than the corresponding factors for earlier Euro standards.

3.2.8.6.4 Nitrogen Oxides (NOx)

Emission estimates for road transport in 2009 increased by 35 Gg. This was mainly due to the change in emission factors which increased estimates of emissions from petrol cars, diesel cars and vans. This was partially offset by a decrease in estimates for HGVs occurring as a result of the changes in emission factors and introduction of new fleet composition data. Emissions are lower in 2010 than 2009 due to increased penetration of cleaner vehicles. Estimates for domestic waterborne navigation are increased by 9Gg due to allocation of fuel to the inland waterways sector

3.2.8.6.5 Carbon Monoxide (CO)

Emission estimates for road transport in 2009 increased by 7 Gg. This was mainly due to the new method for estimating the composition of the vehicle fleet based on use of ANPR data leading to an increase in estimates for petrol car emissions partially offset by decreases in estimates for diesel vans and artic HGVs. Emissions are lower in 2010 than 2009 due to increased penetration of cleaner vehicles. Estimates for domestic waterborne navigation are increased by 29Gg due to allocation of fuel to the inland waterways sector.

3.2.8.6.6 Non-Methane Volatile Organic Compounds (NMVOC)
Emission estimates for road transport in 2009 decreased by 13 Gg. This was mainly due to the new method for estimating the composition of the vehicle fleet based on use of ANPR data leading to a decrease in estimates for petrol car emissions. Emissions are lower in 2010 than 2009 due to increased penetration of cleaner vehicles. Estimates for domestic waterborne navigation are increased by 5Gg due to allocation of fuel to the inland waterways sector.

3.2.8.7 Source Specific Planned Improvements
Emission factors, activity data and estimating methodology are continuously kept under review as new information emerges.

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), sewage gas and landfill gas to generate heat were previously reported under CRF source category 1A4, although these have been reallocated to 1A1 for 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.

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

Emissions from the burning of municipal solid waste (MSW) to generate heat were previously reported under CRF source category 1A4. These have now been reallocated to sector 1A1a for the 2012 submission, following the advice from the ERT.

A review has been performed this year on the allocation of gas oil to different sectors. Gas oil is used in both off-road transport and machinery diesel engines, and as a fuel for stationary combustion. The varied use of this fuel complicates the means of allocating consumption across the wide range of sectors that use the fuel in the inventory. DUKES provides a breakdown of gas oil consumption in different industry and other sectors, but with high uncertainty and DUKES is unable to distinguish between use of the fuel for stationary combustion and off-road machinery, a distinction which is necessary for the inventory. This review mainly affects sectors 1A2 and 1A4 although include a reallocation of petrol and diesel from road transport to off-road machinery; these changes are explained fully in Annex 3 (Section A3.3.8).

Some small changes have been made to the emissions from the OTs and CDs. Discussions with the Gibraltar Environment Agency have shown that emissions from domestic combustion do not occur and those emissions have now been removed from the inventory. A small correction has also been made to estimates of LPG use in the CDs.

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 2009 inventory (2011 NIR). Comparisons are made between the current inventory (1990-2010) and the previous inventory (1990-2009) for the year 2009.

3.2.9.6.1 Carbon Dioxide (CO_2)

- Overall CO_2 emissions from 1A4 decreased by 469 Gg CO_2. The main reasons for these changes are highlighted below;

- The largest revision to emissions in his sector is a decrease in emissions of 459 Gg CO_2 due to a revision of domestic natural gas consumption in DUKES (DECC, 2011).
- There has been a reallocation of combustion of MSW for heat generation to 1A1; this has caused a decrease of 38 Gg CO_2.
- Small revisions have also been made to domestic combustion data for the crown dependencies and overseas territories, based on updated statistics.
- The remaining differences are due to a combination of DUKES revisions and gas oil reallocations following a recent gas oil allocation review. See **Annex 3** and **Table 10-1** for more information.

3.2.9.6.2 Methane (CH_4)

- There was an overall decrease in emissions from 1A4 of 8.0 Gg CH_4. The main causes of these changes are revisions and reallocations to activity data as described above, plus a reallocation of sewage gas and landfill gas to 1A1 in response to a recommendation by the UNFCCC's expert review.
- Minor changes to emission factors for fuel oil and anthracite have been made due to revisions to GCVs.

3.2.9.6.3 Nitrous Oxide (N_2O)

- There was an overall decrease in emissions from 1A4 of 2.0 Gg N_2O. The main causes of these changes are revisions and reallocations to activity data as described above, plus a reallocation of sewage gas and landfill gas to 1A1 in response to a recommendation by the UNFCCC's expert review.
- Minor changes to emission factors for coal, coke, fuel oil and anthracite have been made due to revisions to GCVs.

3.2.9.6.4 Nitrogen Oxides (NOx)

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

3.2.9.6.5 Carbon Monoxide (CO)

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

3.2.9.6.6 Sulphur Dioxide (SO_2)

- Estimates of emissions from domestic coal combustion have decreased by 2 Gg due to a revision in the emission factor.

3.2.9.6.7 Volatile Organic Compounds (VOC)

- There has been a significant reduction in the emission estimate for domestic combustion of wood and peat following a revision to the emission factor, with emissions decreasing by 19 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. For full details of the improvement programme see **Section 1.2.2.5**.

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. The time-series was improved in the current version of the inventory by new figures for 2008 and 2009.

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

Historically, total consumption by military aviation has been given in ONS (1995) and MOD (2005a) and was assumed to be aviation turbine fuel. A revised, but consistent time series of military aviation fuel was provided by the Safety, Sustainable Development and Continuity Division of the Defence Fuels Group of the MoD (MoD, 2009 and 2010) covering each financial year from 2003/04 to 2009/10. In 2011 the MoD revised their methodology for calculating fuel consumption, which provided revised data for 2008/09 onwards (MoD 2011). The new data also included estimates of aviation spirit and fuel classed as “Casual Uplift”. The latter is drawn from commercial airfields world-wide and assumed not to be included in DUKES.

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 and 2009 based on information from the MoD. See Table 10-1 for the magnitude of changes.

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 System 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. 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 a recent study funded by DECC (WSP, 2011).

Emissions of methane from closed coal mines were first included in the 2006 GHG inventory submission. These estimates were calculated in two studies by White Young Green, one considering historical emissions (1990 to 2004), and the other considering projections (2005 onwards). In 2011, DECC commissioned a study (WSP, 2011) to update this work, to reflect known changes in the mining industry (e.g. mines that closed earlier or remained open longer than projected). The results of this study are included in the 2012 inventory submission for all years.

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

In 2011, DECC commissioned a study (WSP, 2011) to update work looking at emissions from closed coal mines, to reflect known changes in the mining industry (e.g. mines that closed earlier or remained open longer than projected). The results of this study are included in the 2012 inventory submission. This replaces out of date information, improving the accuracy of the inventory.

The main change in emissions results from the better understanding of methane recovery, which has now been subtracted from the gross emission. Emissions from the combustion of colliery methane are included within the energy sector (1A). **Annex 3, Section A3.3.8.1.1.**

3.3.1.6 Re-Calculation by Gas

Emissions of CH_4 decreased by 43 Gg in 2009 due to revisions to emissions from closed coal mines. Revisions have also been made to activity data for SSF production and coke oven gas use in DUKES from 2008 onwards.

3.3.1.7 Source Specific Planned Improvements

Emission factors and activity data are kept under review. For full details of the improvement programme see **Section 1.2.2.5**.

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 confirmed that emissions from gas leakage at point of use (i.e. downstream from gas meters) are not included within their network leakage models. Separate estimates for point of use leaks have therefore been made, 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 1995-2010. 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 System. In recent years, these EUETS data have been used by operators to update their EEMS emission estimates for combustion processes, ensuring consistency between EEMS and EUETS, 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 (Livingston, 2011):

- Oil Production: gas flaring, 2009: revised operator data for carbon dioxide emissions for one platform;
- Oil Production: gas combustion, 2009: revised operator data for carbon dioxide emissions for two sites;
- Oil Production and Gas Production: gas oil use, full inventory time series: revision to UK energy statistics to allocate gas oil to the upstream oil and gas sector has re-allocated emissions of all GHGs from IPCC sector 1A2f (other industry) to 1A1c (Other energy industries). No overall change in total gas oil activity data or emissions.

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, 2011) 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, separate estimates are made for gas leakage at the point of use, 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 2010.

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 2012 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 1995-2010. 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 2011 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 (2010) 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.

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 from operator-reported data through EEMS. (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 1990-2009 inventory. Comparisons are made between the current inventory (1990-2010) and the previous inventory (1990-2009) for the year 2009.

3.3.2.6.1 Carbon Dioxide (CO_2)

- Total emissions of CO_2 from category 1B2 have increased by 29 Gg CO_2 due to revision to gas flaring emission estimates for one offshore rig.

3.3.2.6.2 Methane (CH4)

- Overall, emissions of methane from category 1B2 have increased by less than 1 Gg CO_2e due to increases in operator reported emissions at onshore petroleum facilities that are partly offset by reported reductions in methane emissions from offshore flaring.

3.3.2.6.3 Non Methane Volatile Organic Compounds (NMVOCs)

- Emissions from onshore petroleum processes (1B2ai) have increased by 0.7 Gg NMVOC due to revisions in operator reported data at onshore oil fields.
- Emissions from distribution of oil products (1B2av) have decreased by 0.5 Gg NMVOC.

3.3.2.7 Source Specific Planned Improvements

The data from the EEMS reporting system will be reviewed with the regulatory body during 2012, 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 2013 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 misallocations 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 two 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.

A general assessment of completeness for the inventory is included in Annex 5. Within the industrial processes sector, emissions are not included for:

- Soda ash production. Emissions from fuels are included in 1A2f, and no emissions of CO_2 are assumed to occur during calcination since the carbon is converted into soda ash.
- Asphalt roofing and paving – no method is available for this source, and emissions are considered to be negligible.
- Ferroalloys production – this source is considered to be negligible in the UK
- Food and drink – no appropriate data or methods are available and emissions from this source are considered to be very small.
- N_2O from glass production and fletton bricks – no suitable data or methods have been identified and emissions from this source are considered to be very small.
- Non-CO_2 emissions from ammonia production – the manufacturers do not report emissions of non-CO_2 gases and emissions are considered to be negligible.
- CH_4 from certain iron and steel processes and aluminium production – no data or methods available, emissions are considered to be negligible.

The only emissions from the Overseas Territories and Crown Dependencies that are reported in this sector are estimated emissions from the use of f-gases in products. No other industrial process emissions are assumed to occur in these locations. These emissions are included within the CRF submission under 2F9 and are scaled based on UK emissions. For more information on the methodology used, see Annex 3.9.

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 12 sites producing cement clinker during 2010.

4.2.2 Methodological Issues

The methodology used for estimating CO_2 emissions from calcination is to use data provided by the Mineral Products Association (2011), 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 2010 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).

As part of the data quality checking routine for the sector, we compare emissions reported by the trade association to the aggregated installation specific data from the EU ETS. The EU ETS data explicitly includes emissions from all sources including cement kiln dust. Therefore this quality check ensures that there is complete coverage of all emissions from this sector.

4.2.3 Uncertainties and Time Series Consistency

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

The emission factors used for cement are relatively constant, with only small year on year changes. The trend in emissions reflects the trend in activity data.

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 2010. 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, 2011). 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. For pure limestone, an emission factor of

120 t carbon/kt limestone can be used, based on the stoichiometry of the chemical. For dolomite, an emission factor of 130 t carbon/kt dolomite would be appropriate. However dolomite calcination data are not given separately by the British Geological Survey, but included in the limestone data. The proportion of dolomite within the limestone total is not known, and therefore we have assumed that the mixture contains 15% dolomite. This is in response to a recommendation from the EU's UNFCCC review. 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, 2010) as in the previous year. Actual data for 2010 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 emission factor has been revised to be applicable to both limestone and dolomite calcination, therefore removing the potential for a slight underestimate in emissions. The exclusion of limestone used by the chemicals industry and sugar production may 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.

Analysis of EU ETS data for lime kilns suggests that the British Geological Survey data used in the GHGI significantly underestimate activity levels, however the EU ETS data are subject to some uncertainty and cover all relevant sites only from 2008 onwards. Further research would be necessary in order to determine whether the current GHGI methodology needs to be revised.

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 2009, and so the 2008 value was used. For this version, 2009 data are now available and are used instead. The emission factor has also been revised to account for dolomite, in response to the recommendation from the EU's UNFCCC expert review. These changes have led to a decrease in the estimated emissions of 393 Gg of CO_2.

4.3.6 Source Specific Planned Improvements

EU ETS data have cast doubt on the accuracy of the activity data currently used for this source, in particular the accuracy of data for 2008 onwards. Further research would be needed in order to verify the alternative data for 2008-2010 and also to extend the data back to earlier years. Only then could a decision be made about whether to replace the current inventory activity data with new values.

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 practice is ignored for the GHGI with all additions and, therefore, emissions being assumed to be associated with 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. Glass industry emissions are, however, discussed in **Section 4.8,** while agricultural use is covered in **Chapter 7** of this report.

Use of limestone and dolomite in sinter production and basic oxygen furnaces 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 two operational steel-making sites during 2010 (a third one being mothballed). FGD was operational on five UK power stations at the end of 2010.

4.4.2 Methodological Issues

Data on the usage of limestone and dolomite for steel production are available from the Iron & Steel Statistics Bureau (2010). Gypsum produced in FGD plant is available from the British Geological Survey (2010), with some gaps in the records for 2009-2010 (for example, data are given for four of the five plant in 2010). These gaps are filled either by assuming that gypsum production is the same as in another year for which data are given, or by using Pollution Inventory data on emissions of 'chemical' carbon dioxide (i.e. carbon dioxide from chemical processes rather than 'thermal' carbon dioxide from combustion).

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. An emission factor of 69 t carbon/kt gypsum produced is used in the case of FGD processes, based on the stoichiometry of the chemical reaction, and assuming that all of the carbon dioxide is released to atmosphere.

In the CRF, total emissions from basic oxygen furnaces, sinter production and FGD are reported. The activity data for basic oxygen furnaces and sinter production is the total amount of limestone and dolomite used. This is reported in the CRF. For FGD, the activity data used is the total amount of gypsum produced. This is excluded from reporting in the CRF since it is not considered appropriate to sum limestone and dolomite use with gypsum production. Therefore the implied emission factors from 1994 onwards in the CRF appear to be too high when compared with those of other parties where they present these aggregated activity data in their CRF submissions. Emission factors and activity data are set out below for transparency and comparability with other Parties.

Table 4-1 Activity data and emission factors for limestone and dolomite use

Activity (source)		1990	1995	2000	2005	2010
Dolomite use (Basic oxygen furnaces, sinter production)	Activity data	0.70	0.38	0.34	0.24	0.40
	EF (Mt CO_2/Mt)	0.45	0.45	0.45	0.45	0.45
Limestone use (sinter production)	Activity data	1.99	2.32	2.17	1.95	0.95
	EF (Mt CO_2/Mt)	0.41	0.41	0.41	0.41	0.41
Gypsum produced (power stations FGD)	Activity data	-	600	825	1,185	1,404
	EF (Mt CO_2/Mt)	-	2.5E-04	2.5E-04	2.5E-04	2.5E-04

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. The lack of gypsum production data for some of the power stations in 2009-2010 means that activity data for those years 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 3 Gg CO_2 for limestone used in FGD systems.

The transfer of emissions from glass manufacturing from 2A3 to 2A7 leads to a decrease in emissions reported under 2A3 of 228 Gg CO_2. This reallocation of emissions has been made to improve the harmonisation of reporting across EU Member States.

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

Emissions from soda ash (sodium carbonate, Na_2CO_3) used in the manufacture of soda-lime glasses is reported under source category 2A7. 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 and emissions are not estimated.

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

Emissions of CO from soda ash production are estimated based on emissions data reported in the Pollution Inventory (Environment Agency, 2011).

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.

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

The transfer of emissions from glass manufacturing from 2A4 to 2A7 leads to a decrease in emissions reported under 2A4 of 185 Gg CO_2. This reallocation of emissions has been made to improve the harmonisation of reporting across EU Member States.

4.5.6 Source-specific planned improvements

Emission factors and activity data will be kept under review. There are no specific planned improvements for this source.

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, 2011).

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, glass manufacture, and manufacture of coated roadstone are reported under 2A7. Emissions from glass manufacture include those emissions of carbon dioxide that result from the use of limestone, dolomite and soda ash as sources of CaO, MgO and Na_2O respectively in soda-lime glasses.

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.

The UK is thought to have 17 large glassworks, manufacturing soda-lime type glasses, either for the production of container glass (12 sites) or flat glass (5 sites). There is also 1 site producing continuous filament glass fibre, together with 4 sites producing glass wool and 3 sites producing rock wool. Special and domestic glasses are no longer manufactured on a large scale in the UK, and lead glass production is only on a very small scale.

As well as carbon dioxide emissions resulting from the decomposition of carbonate feedstocks, certain types of glass manufacture will give rise to emissions of other pollutants including NO_X, SO_2 and VOC. Emissions of NO_X and SO_2 can occur during melting due to the breakdown of nitrates and sulphates in the raw materials, while VOC emissions can occur from the use of coating materials for glass fibres. Both continuous filament glass fibre and glass/rock wool manufacture involve the attenuation of molten product into fine fibres, which are then cooled and coated with organic materials. Currently, we do not estimate emissions of NO_X and SO_2 from glass melting due to a lack of suitable data. Emissions are, however, expected to be relatively small.

Carbon dioxide emissions may also occur from the use of other materials in the glass and brick industries, for example other carbonates such as barium carbonate. Emissions are likely to be very small although some emissions data are available through EU ETS sources which may allow a time series of emission estimates to be generated in future.
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 suitable methods or data have not been found. Emissions from these sources are, however, 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, 2011). 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 in the kilns. Emissions from the clay materials are derived 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 site that closed in 2008 was assumed to burn coal, whereas the other site is thought to burn natural gas. This fuel is now, therefore, the only fossil fuel burnt by the Fletton brick industry. 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 from the use of carbonates in glass production are calculated using emission factors based on the stoichiometric relationship between carbon and the related carbonate i.e. 120 t carbon/kt limestone, 130 t carbon/kt dolomite, and 113 kt carbon/Mt soda ash. These factors assume that all of the carbon in the carbonates 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 is now used which takes a detailed, site by site survey of raw material usage, carried out in 2006 (GTS, 2008) as a starting point. The estimates of dolomite and limestone use by sector from this survey are extrapolated to all other years in the time series on the basis of glass production in each year.

Consumption of soda ash is estimated using an assumption that this is equal to 20% of the mass of soda-lime 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, 2011), and production of other types of glass has to be estimated based on data for a limited number of years (e.g. 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 only.

Revisions were made to the activity data for the 2011 NIR, these were due to the inclusion of new data on the use of Calumite for container glass production, as well as revisions to the assumptions made about plant capacities for sites manufacturing other types of glass. The impact of these revisions is not uniform across the time-series therefore the magnitude and sign of the recalculation are also not uniform. 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.

Emissions of NMVOC from glass fibre and glass wool processes in recent years are 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.

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 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.

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.

The emission estimates for the remaining sources are also subject to significant levels of uncertainty, however these are very minor sources of NMVOC emissions only, and are not considered further.

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

The transfer of emissions from glass manufacturing from 2A3 and 2A4 to 2A7 leads to an increase in emissions reported under 2A7 of 410 Gg CO_2. Emissions have been reallocated to this sector for the harmonisation of reporting across EU Member States.

A small correction has been made to the calculation of emissions for one fletton brick manufacturing plant, this has caused a 16 Gg CO_2 increase in emissions for 2009.

Aside from the change in reporting, the emission estimates for glass manufacturing are little changed – just 3 Gg CO_2 lower due to some small updates to glass production estimates used to derive the consumption data for the three types of carbonate feedstock.

4.8.6 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.) Consumption data for limestone and dolomite are available but are incomplete and believed to be unreliable, so further investigation might be worthwhile to identify other options for obtaining activity data.

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 three UK sites by the end of 2010, 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 method change has been implemented in the 1990-2010 inventory cycle regarding emissions of CO_2 from ammonia production where the CO_2 is subsequently used as a feedstock in other production process. In previous inventories, it was assumed that the CO_2 sold by one ammonia plant in the UK was used as a feedstock in methanol production, and was not emitted to atmosphere. In previous inventories, therefore, the amount of CO_2 sold by that ammonia plant was excluded from the UK inventory. Following review of the IPCC guidance, we note that there is no provision for making the assumption that the CO_2 sold for methanol manufacture is not emitted to atmosphere, and hence we have revised the UK estimates of CO_2 emissions from ammonia manufacture to include the CO_2 sold by that one ammonia production plant, increasing the sector emissions.

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

a) Natural gas equivalent to the CO_2 emitted from ammonia manufacture; and
b) Natural gas usage of the acetic acid plant, available from the process operator.

For the first part 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 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

The revision to methodology regarding CO_2 emissions from ammonia production that are sold on for use as feedstocks in other industries has led to a recalculation across the time

series, with an increase in emissions of 170kt CO_2 in 2009. This recalculation has been made to ensure that the estimates are in line with the 1996 IPCC Guidelines.

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 2010, 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.

Emissions can also occur from products from the chemical industry. Sources of emissions include burning of waste products and final products (e.g. flaring and use of wastes as fuels, or burning of candles, firelighters and other products etc.) or degradation of products after

disposal resulting in CO_2 emissions (including breakdown of consumer products such as detergents etc.).

After considering the magnitude of the sources in relation to the national totals, the uncertainty associated with emissions, and the likely reporting requirements in the 2006 IPCC Guidelines, emissions of carbon from the following sources were included in the 2004 GHG inventory (2006 NIR) and subsequent NIRs:

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

A full time series of emissions is included in the inventory, and details of the methodology for these sectors are given in Passant, Watterson & Jackson, 2007.

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, 2011). 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, 2011). 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 (2011). 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 (2011). 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:

- From 2006 onwards revisions have been made to vehicle statistics and sales data for household products, affecting the emissions from the breakdown of consumer products;

- Changes to the emissions data given in the Pollution Inventory and other sources; and
- The influence of emissions data for 2010, 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 2009 might previously been filled using emissions reported for 2008, whereas now the mean of the 2008 and 2010 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, and there are no significant recalculations for this version of the inventory.

4.13.6 Source Specific Planned Improvements

Changes in the methodology are likely to be required from year to year in order to deal with changes in the data available. The intention behind these changes is to try to maintain the quality of estimates at current levels with the resources available.

4.14 SOURCE CATEGORY 2C1 – IRON AND STEEL PRODUCTION

4.14.1 Source Category Description

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

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

Sintering involves the agglomeration of raw materials for the production of pig iron by mixing these materials with fine coke (coke breeze) and placing it on a travelling grate where it is ignited. The heat produced fuses the raw materials together into a porous material called sinter.

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.

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

The use of updated data in the carbon balance leads to an increase in the emission factor generated for blast furnace gas and, thus, an increase in emissions for 2C1 of 61 Gg CO_2.

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.

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).

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

There have been no recalculations of emissions from aluminium manufacture.

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 data from the Pollution Inventory 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 and HFCs.

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 1998-2010, 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 emissions in 2008 to 2010 are 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. Trends in SF_6 and HFC emissions are driven by the data from the operators. Emissions of SF_6 increased from 2009 to 2010, to return to the levels seen in 2007.

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, 2011). 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 (2011). 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 (2011), 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. 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, whereas full speciated emissions data were provided by one of the operators for most of the time series.

All emissions from the production of HFCs, PFCs and HCFC-22 are reported in CRF category 2.E.2. The categories are aggregated at the request of the operators, to protect commercially confidential information. In previous submissions, emissions were reported under category 2E1.2, however a technical problem with the CRF means that these data were then not reported in Table2(II).E, leading to an internal consistency problem in the CRF (although the emissions were still included in the UK's total, so this did not lead to an under estimate). This reallocation has been made in response to a recommendation from the UNFCCC's review of the UK's inventory in 2011.[15]

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

[15] Note that in the EUMM version of the CRF, emissions are still included in category 2E1.2. This will be changed for the 2013 submission. All emissions are included in the totals.

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

Emissions of HFCs for 2009 have been revised as the value used in the previous inventory was a projection based on consultation with the operator. There have been no other 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 for ozone depleting substances across virtually all refrigeration end-uses. 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 end-uses summarized in the table below. As shown, the UK inventory uses a code (RAC-1 to RAC-13) to refer to these sector sub-divisions.

Table 4-2. Model End-Uses and Definitions

Revised Model End-Use		Description
RAC-1	Domestic Refrigeration	Refrigerated appliances including refrigerators, chest freezers, upright freezers, and fridge freezers.
RAC-2	Small Commercial Stand-Alone Refrigeration Units	Small, hermetic, stand-alone refrigeration units including ice cream cabinets and drinking water coolers. These systems are commonly used in retail food stores but are also found in pubs, restaurants, and other hospitality and catering outlets such as hotels, hospitals, and schools.
RAC-3	Condensing Units	Refrigeration systems composed of one (or two) compressor(s), one condenser, and one receiver assembled into a unit, which is located external to the sales area. These units are typically installed in small shops and have refrigeration capacities ranging from 1 kW to 20 kW.
RAC-4	Centralised Refrigeration Systems	Refrigeration systems that are comprised of racks of compressors installed in a machinery room. These systems are commonly used in supermarket applications.
RAC-5	Industrial Systems	Refrigeration systems including industrial process refrigeration and cold storage.
RAC-6	Small Stationary Air Conditioning	Includes small self-contained ACs (including window units) and non-ducted split ACs. Units are used primarily in commercial applications, but there is some use in the residential sector. System cooling capacities typically range from 3 to 12 kW.
RAC-7	Medium Stationary Air Conditioning	Includes ducted split, variable refrigerant flow (VRF) non-ducted split, ducted split, and packaged AC. Units are used in the commercial UK sector. System cooling capacities typically range from 12 to 30 kW.
RAC-8	Large Stationary Air Conditioning (Chillers)	Large, indirect chillers used for commercial comfort air conditioning.
RAC-9	Heat Pumps	Residential and small commercial heat pumps, including air-source heat pumps (ASHP) (air-to-air and air-to-water systems) and ground-source heat pumps (GSHP).
RAC-10	Land Transport Refrigeration	Refrigerated road vehicles (i.e., light commercial vehicles, trucks, trailers) and intermodal containers.
RAC-11	Marine Transport Refrigeration	Refrigerated general cargo ships, container ships and fishing vessels (1,000 GT and above).
RAC-12	Light Duty Mobile Air Conditioning	AC systems for passenger cars and light commercial vehicles (up to 3.5 tonnes). Both of these vehicle types are covered under Directive 2006/40/EC (the MAC Directive).
RAC-13	Other Mobile Air Conditioning	AC systems for trucks (over 3.5 tonnes), buses/coaches, semi-trailers, trailers, and railcars.

4.22.2 Methodological Issues

The ERT in 2010 highlighted that the leakage rate for transport refrigeration was smaller than the range given by the IPCC, and that the UK did not have sufficient evidence to back

up the use of this UK specific emission factor. The 2011 submission contained an interim update to address this issue, which was described in the 2011 NIR. For the 2012 submission, further improvement work has been carried out to ensure that emissions from this sector are fully in line with the IPCC Guidelines, and these changes are described below.

The previous version of the refrigeration/air conditioning inventory model developed by AEA (2010) was updated by ICF International in the summer/autumn of 2011 based on revised industry input and a more transparent, robust Tier 2 modelling approach. Specifically, the model was reorganized from nine to 13 end-uses, for which detailed assumptions were developed to utilise a fully bottom-up approach. Since most end-uses defined by the previous version of the model were modelled using a top-down approach, many input assumptions were developed for the first time. This transition from a largely top-down approach (based on total refrigerant sales data) for estimating the UK's refrigeration and air conditioning emissions to a fully bottom-up approach (based on equipment stocks and average charge size from available market data) was performed in order to improve the accuracy of emissions allocated to end-uses and improve the understanding of the end-uses to better inform policy.

For all end-uses, market data and other country-specific information were considered in the development of assumptions on equipment stocks, market growth, equipment lifetimes, refrigerant market penetrations, charge sizes, manufacturing loss rates, operational loss rates, and disposal loss rates for each end-use across the 1990-2050 time series. To revise and develop new input assumptions, an extensive literature review was conducted and key industry stakeholders were contacted. Priority industry stakeholders were selected across all end-uses and initially contacted to fill data gaps and corroborate information found in the literature. Following the development of preliminary assumptions for all end-uses, draft assumptions were then shared with a broader range of stakeholders to solicit additional industry input and vet assumptions.

In developing modelling input assumptions by end-use, expert judgment was applied to select appropriate values when more than one estimate was provided by literature and/or stakeholders. In general, more weight was given to estimates that are UK- or regional specific and/or more recent. In cases of equal data quality where numerous data points were available, values were selected based on the mid-point of the data range. Where no UK- or EU-specific information was available, the 2000 Intergovernmental Panel on Climate Change (IPCC) Good Practice Guidance default assumptions were relied on to estimate emissions. The 1996 and 2006 IPCC reports were also reviewed and considered, but the latter (most recent) assumptions could not be adopted at this time without additional supporting information, per IPCC guidance.

In the process of finalising the input assumptions, an analysis was conducted to compare estimated refrigerant consumption (calculated as the amount of refrigerant used to manufacture new equipment produced in the UK plus the amount used to service leaking equipment) with annual refrigerant sales data from the British Refrigeration Association (BRA). Following the comparison, assumptions were adjusted as deemed appropriate to further align the model output with the BRA data. A summary table of the 2010 input assumptions is provided below. A full description of the methodology, sources, and input assumptions used to update emission estimates by end-use is contained in ICF (2011).

Table 4-3. Summary of 2010 Input Assumptions by End-Use

Application		2010 Parameters							
CRF Sector	UK Category	Total Stock (units)[a]	Total Sales (units)[a]	Lifetime (years)	Charge (kg)[a]	Refrigerants in New Equipment	Manufacturing Loss Rate	Operational Loss Rate	Disposal Loss Rate
Domestic Refrigeration	Domestic Refrigeration	40,430,000	2,939,680	15	0.10	HFC-134a, HCs	0.6%	0.3%	35%*
Commercial Refrigeration	Small Hermetic Stand-Alone Refrigeration Units	2,400,000	247,400	10	0.5	HFC-134a, R-404A, R-407C, HCs	1%	1.5%	40%*
	Condensing Units	600,000	47,440	14*	5*	HFC-134a, R-404A, R-407A, R-407F,R-410A, R-507, HCs	2%	10%	15%
	Centralised Supermarket Refrigeration Systems	109,100,000 (m^2)	10,135,722 (m^2)	18*	0.26 (kg/m^2)	HFC-134a, R-404A, R-407A, HCs, R-717, R-744	2%	18%	8%
Transport Refrigeration	Land Transport Refrigeration	87,210	13,506	7	4	HFC-134a, R-404A	0.2%	15%	20%
	Marine Transport Refrigeration	527	30	25*	1,500*	R-404A, R-407C, R-717	1%	40%	30%
Industrial Refrigeration	Industrial Systems	20,000	764	25*	65	HFC-134a, R-404A, R-407C, R-410A, R-507, HCs, R-717, R-744	1%	8%	15%
Stationary Air-Conditioning	Small Stationary Air Conditioning	4,590,202	615,160	13	1.5	R-407C, R-410A	0.5%	3%	30%
	Medium Stationary Air Conditioning	630,000	52,268	15	15	R-407C, R-410A	1%	6%*	30%
	Large Stationary Air Conditioning (Chillers)	40,000	2,129	18	180	HFC-134a, R-407C, R-410A, R-717	0.5%	3%	20%
	Heat Pumps	20,270	9,632	15	3	HFC-134a, R-404A, R-407C, R-410A	1%	6%*	35%*
Mobile Air-Conditioning	Light Duty Mobile Air Conditioning	27,859,726	1,340,061	15	0.73	HFC-134a	0.5%	10%	30%
	Other Mobile Air Conditioning	499,168	87,502	10	4*	HFC-134a, R-407C	0.5%	10%	30%

[a] Except where otherwise noted.

* Estimates fall outside of the IPCC (2000) range but are in line with UK- and/or EU-specific estimates provided by industry or in the published literature.

4.22.3 Uncertainties and Time-Series Consistency

Tier 2 quantitative uncertainty analyses for 1995 (base year) and 2010 were conducted to identify the uncertainty associated with the model output. To calculate uncertainty, functional forms were developed to simplify some of the complex aspects of the refrigeration and air-conditioning sector. In particular, because emissions are calculated based on the entire lifetime of equipment, not just equipment put into commission in the current year, simplifying equations were used. The functional forms used variables that included growth rates, lifetimes, emission factors (manufacturing, operational, and disposal emission rates), refrigerant transitions, charge size, disposal quantities, and new and existing stock. Uncertainty was estimated around each variable within the functional forms based on ICF's expert judgment, taking into account the range of estimates provided in the literature and by industry stakeholders. A Monte Carlo simulation analysis was performed and uncertainty bounds were generated using 10,000 simulations.

The results of the analysis indicate a range of approximately 5% below and 6% above the 1995 emission estimate, and approximately +/-5% around the 2010 emission estimate. The most significant sources of uncertainty include the emission factors for centralised supermarket refrigeration systems and marine transport refrigeration—two end-uses with a significant installed base of refrigerant (due to large stock and/or charge size).

4.22.4 Source Specific QA/QC and Verification

End-use input assumptions used to generate the refrigeration and air conditioning emissions were developed based on industry consultation and were peer-reviewed. Further, to verify the emissions estimates generated by the revised model, the results were compared with the sales data provided by BRA. The results of the comparison reveal that the data sets align closely, with the revised model output showing the same trends and totalling only about 5% above the collective annual BRA data for HFCs from 2006-2010.

Historic emissions estimates generated by the revised model were also compared with concentration observations captured by the dispersion model NAME (Numerical Atmospheric dispersion Modelling Environment) for the years 1995 through to 2008. Results of this comparison show that the revised model output aligns significantly more closely to the NAME observations than historic inventory estimates. More information relating to atmospheric measurements and verification of UK emissions estimates is provided in **Annex 10**.

A list of industry stakeholders consulted on the input assumptions, as well as detailed results from the BRA and emission observation comparisons are discussed in more detail in ICF (2011).

4.22.5 Source Specific Recalculations

The model used to estimate emissions from this sector has undergone a significant restructuring since its previous update by AEA in 2010. Specifically, recent improvements to the model include the addition of new end-uses; use of bottom-up data across all end-uses; addition of ozone depleting substances and natural refrigerants (to ascertain overall size of the sector); incorporation of likely future market conditions pertaining to the transition away from HFC refrigerants through to 2050; and enhanced model functionality and transparency. The transition from a largely top-down modelling approach (based on total refrigerant sales data) to a fully bottom-up approach (based on equipment stocks and average charge size

from available market data) was performed in order to improve the accuracy of emissions allocated to end-uses and improve the understanding of the end-uses to better inform policy. The revised emission estimates are 0.13 Mt CO_2e (15%) lower than the previous model output for 1995 and 3.04 Mt CO_2e (41%) higher for 2009. The details of these updates are documented in ICF (2011).

The additional research and model improvements address the concerns raised by the UNFCCC ERT in 2010, relating to the use of country specific operational loss rates for transport refrigeration.

4.22.6 Source Specific Planned Improvements

Emission factors, model parameters, and activity data will be kept under review. A number of potential updates have been identified to further improve upon the emission estimates from this source, including additional stakeholder consultation in the (non-food) industrial refrigeration and marine transport refrigeration sectors. These tasks will be added to the improvement programme; although they are currently not considered a high priority, they should be considered if resources are available.

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 4-4**). 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 4-4 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

There have been no recalculations to emissions from this sector.

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 C4F10) 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. The F gas Regulation banned the sale of new PFC-based systems in 2007. 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 used as propellants in specific aerosols. 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 applications. 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 use of HFCs for novelty applications, such as 'silly string' 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 CO2 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

There have been no recalculations to emissions from this sector.

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, the model currently assumes that future growth could be high, depending on their use as a replacement to HCFC-141b over the next 10 years. This has since shown to be an out of date assumption since it is now accepted that the majority of the sector moved to non-F gas alternatives following the ODS bans, so an increase in HFC use is not likely to happen. A review of this assumption will be added to the GHG inventory improvement programme.

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 2F7 – 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 2F9 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 2F9 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 2F8 – 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 2F9 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 2F9 – 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 2F9 – 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. The use of F gases in footwear was banned in 2006 by the F gas Regulation and discussions with the 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 CO_2 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).

A general assessment of completeness is included in Annex 5. Emissions of CO_2 for this sector are currently not estimated although emissions from this source are considered to be very small. Emissions from the Overseas Territories and Crown Dependencies are included within the CRF submission under 3D5 other non-specified and are scaled, based on UK emissions. For more information on the methodology used, see Annex 3.9.

5.2 SOURCE CATEGORY 3A – PAINT APPLICATION

5.2.1 Source Category Description

Emissions of solvents from the use of both industrial and decorative paints are reported under CRF source category 3A. Both types of paint are further sub-divided in the GHGI:

Table 5-1 Paints and their applications in the UK

Type of paint	Application
Decorative paint: Retail decorative Trade decorative	 'DIY' decorative coatings mainly sold directly to the public 'Professional' decorative coatings mainly sold to decorating contractors

Type of paint	Application
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, 2011). 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

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

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

An update to the industrial output data used to estimate cleaning solvent use leads to an increased emission estimate for VOC of 2Gg.

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

An update to the industrial output data used to extrapolate data on adhesives use leads to a decreased emission estimate for VOC of 5Gg..

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 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.

In addition to this planned programme of improvement, a number of revisions were made to the inventory model for this reporting year:

- Comprehensive restructuring of the inventory spreadsheet model providing explicit data input, calculation and reporting output sheets, thereby improving model transparency, and enabling more streamlined emission reporting and model interrogation. Minor errors in input data and calculations were corrected as part of this.
- Revision of the activity data regarding animal waste management systems for the different livestock sectors, based on revisions incorporated in the UK ammonia emission inventory
- Move to a Tier 2 methodology for the calculation of methane emissions from manure management using country-specific data relating to manure management practices for all livestock categories except deer.
- A number of additional cattle categories have been introduced to allow for more accurate source apportionment of emissions to the ‘Dairy’ and ‘Beef’ sectors. Cattle now comprise the following eight groups: dairy cows, beef cows, dairy heifers, beef heifers, dairy replacements > 1 year, beef all other > 1 year, dairy calves < 1 year, beef calves < 1 year.

Total emissions of CH_4 and N_2O in the UK decreased by 19.7% in 2010 compared to 1990 (Figure 6.1 shows the trend for the 1990-2010 period). Emissions in 2010 were 0.9% higher compared to 2009.

CH_4 emissions in the UK are mostly due to enteric fermentation and manure management (Figure 6.2).

N_2O emissions in the UK are due to direct emissions from N application to soils, indirect emissions from atmospheric deposition and leaching and runoff of N and from manure management (Figure 6.3).

Figure 6-1 Emissions of CH4 and N2O for the time series 1990-2010 (45.9 Mt CO2e in 2010)

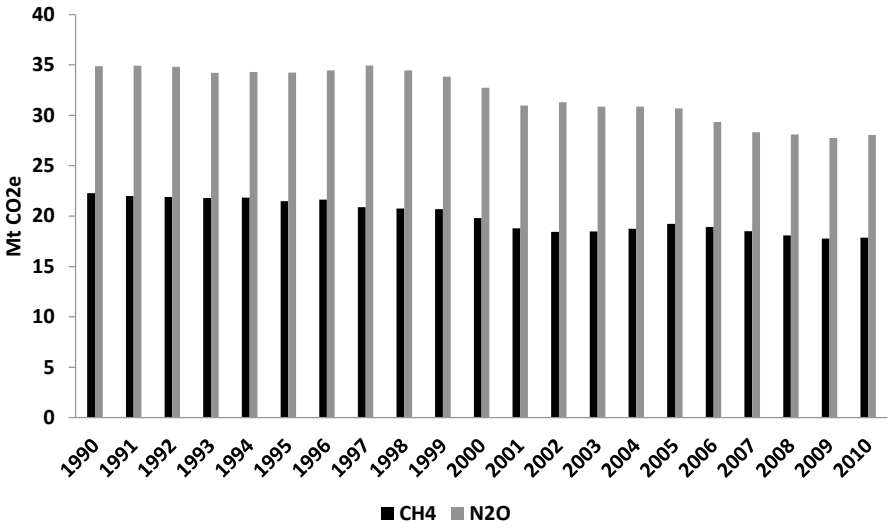


Figure 6-2 Contribution of sources to CH4 emissions for the inventory year 2010 (850.3 kt CH4 in 2010)

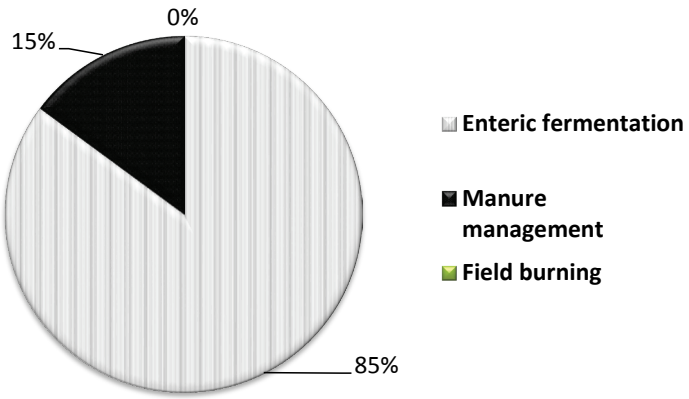
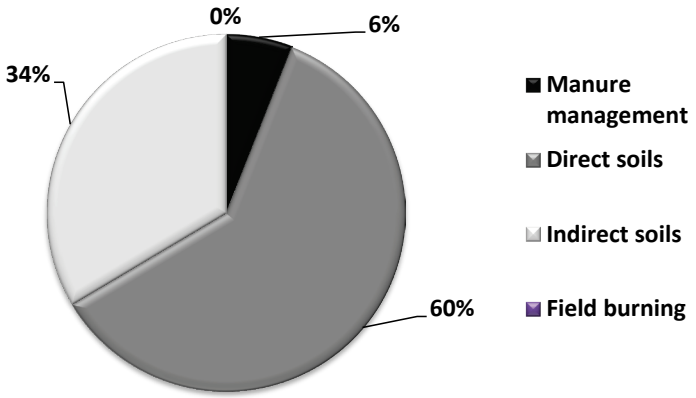


Figure 6-3 Contribution of sources to N2O emissions for the inventory year 2010 (90.5 kt N2O in 2010)



A general assessment of completeness is included in Annex 5. No emissions are reported for categories 4D3 and 4D4 because no emissions have been identified. Emissions for the UK Overseas Territories and Crown Dependencies are included for enteric fermentation and animal wastes. In the CRF submission, emissions from the OTs and CDs are included within 4A 'other' for enteric fermentation while for animal wastes CH_4 is included within 4B 'other' and N_2O is included within 4G 'other' as there is no way of including this within 4B.. For more information on the methodology used, see Annex 3.9.

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/statistics/foodfarm/landuselivestock/junesurvey/). Data for earlier years are often revised so information was taken from the Defra agricultural statistics database.

Apart from dairy and beef cows, 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 (for dairy cows only) are estimated following the IPCC Tier 2 procedure (IPCC, 2000) and vary from year to year. For dairy cows, the calculations are

based on the population of the 'dairy breeding herd' which is defined as dairy cows over two years of age with offspring. In the current inventory the dairy cows 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 cows, but a time series of cattle weights are not available, and so a constant weight of 500 kg has been assumed.

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

The UK sheep production sector has a complex structure, with many different breeds of sheep and a range of hill, upland and lowland rearing and finishing systems. The UK is currently undertaking a programme of work to improve methodology for calculating emissions from this sector, which will include derivation of monthly sheep and lamb population models and country-specific emission factors. The current approach is to assume the IPCC Tier 1 default emission factor for enteric fermentation for all mature sheep (> 1 year old). Lambs have a lower average live weight than mature sheep and the majority have a lifespan of less than 12 months, and should therefore be associated with a lower emission factor than mature sheep. The UK therefore uses a country-specific emission factor for enteric fermentation for lambs derived from the annual emission factor for lambs of 40% of that of mature sheep (Sneath et al., 1997) multiplied by the average lifespan of lambs in the UK of 0.5 years (see **Annex 3**, **Section A3.6.1** for more details).

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 the June annual census, published by Defra. This is a long running publication and the compilers of the activity data strive to use consistent methods to produce the activity data. The time-series consistency of these activity data is very good due to the continuity in data provided.

6.2.4 Source-specific QA/QC and verification

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

6.2.5 Source-specific recalculations

For Dairy cows, the IPCC 2000 Good Practice Guidance Tier 2 methodology for calculating enteric emissions replaced the previously used IPCC 1996 Revised Guidelines methodology. This change led to an increase of 14 Gg CO_2 eq.

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, 2011a) in the same way as the enteric emissions.

The emission factors for manure management are calculated following IPCC Tier 2 methodology but using default IPCC data to estimate the required volatile solids (VS) and methane producing potential (B_o) parameters for each livestock type (except for dairy and beef cows, where a Tier 2 calculation is used to determine VS, and deer where no IPCC data are available). The emission factors were calculated for each livestock type based on the VS, B_o, AWMS breakdown and methane conversion factors according to manure management type (IPCC 2000, Equation 4.17).

Recent revisions to the activity data concerning manure management practices in the UK ammonia emissions inventory, and the greater level of detail contained within that inventory, were incorporated in the revised spreadsheet model of the GHG inventory. These data derive from a number of sources, including published ad-hoc surveys (e.g. Smith et al., 2000c, 2001a, 2001b; Sheppard 1998, 2002; Webb et al., 2001) and, more recently, relevant data from the Farm Practices Survey for England. We now include a time series for AWMS.

For dairy cows, the calculations are based on the population of the 'dairy breeding herd' which is defined as dairy cows over two years of age with offspring. The emissions for beef cows and other cattle are calculated from the IPCC Tier 2 procedure.

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 will arise from N excreted by livestock. Emissions from 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 (i.e. slurry)
- Solid storage and dry lot (including farm-yard manure)

- Other systems (poultry manure without bedding and poultry manure with bedding (poultry litter); IPCC 2000 Good Practice Guidance)

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. Emissions occurring during storage of poultry litter that will later be used for energy generation are included in the agricultural inventory.

Emissions of N_2O from animal waste management are calculated using country-specific data for AWMS breakdown and N excretion and IPCC default emission factors for the specific AWMS.

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 the June 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

A number of changes were made to the calculation of emissions from manure management. A Tier 2 methodology was introduced for CH_4 emissions from manure management for all livestock categories except deer (previously Tier 2 was used only for Dairy and Beef cows and Tier 1 for all other livestock). AWMS breakdown for all livestock categories (and sub-categories) were revised according to recent survey data and historic survey data as used in the UK NH_3 emission inventory. Emissions of CH_4 and N_2O from poultry litter storage prior to incineration have now been included (previously, emissions from any poultry litter destined for incineration were unaccounted). The combined effect of these changes was a reduction in the emission from manure management of 490 Gg CO_2 eq.

6.3.6 Source-specific planned improvements

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

6.4 SOURCE CATEGORY 4C – RICE CULTIVATION

This source is not relevant in the UK.

6.5 SOURCE CATEGORY 4D – AGRICULTURAL SOILS

6.5.1 Source category description

Direct emissions of nitrous oxide from agricultural soils are estimated using the IPCC recommended methodology (IPCC, 1997) but incorporating some UK specific parameters. The IPCC method involves estimating contributions from:

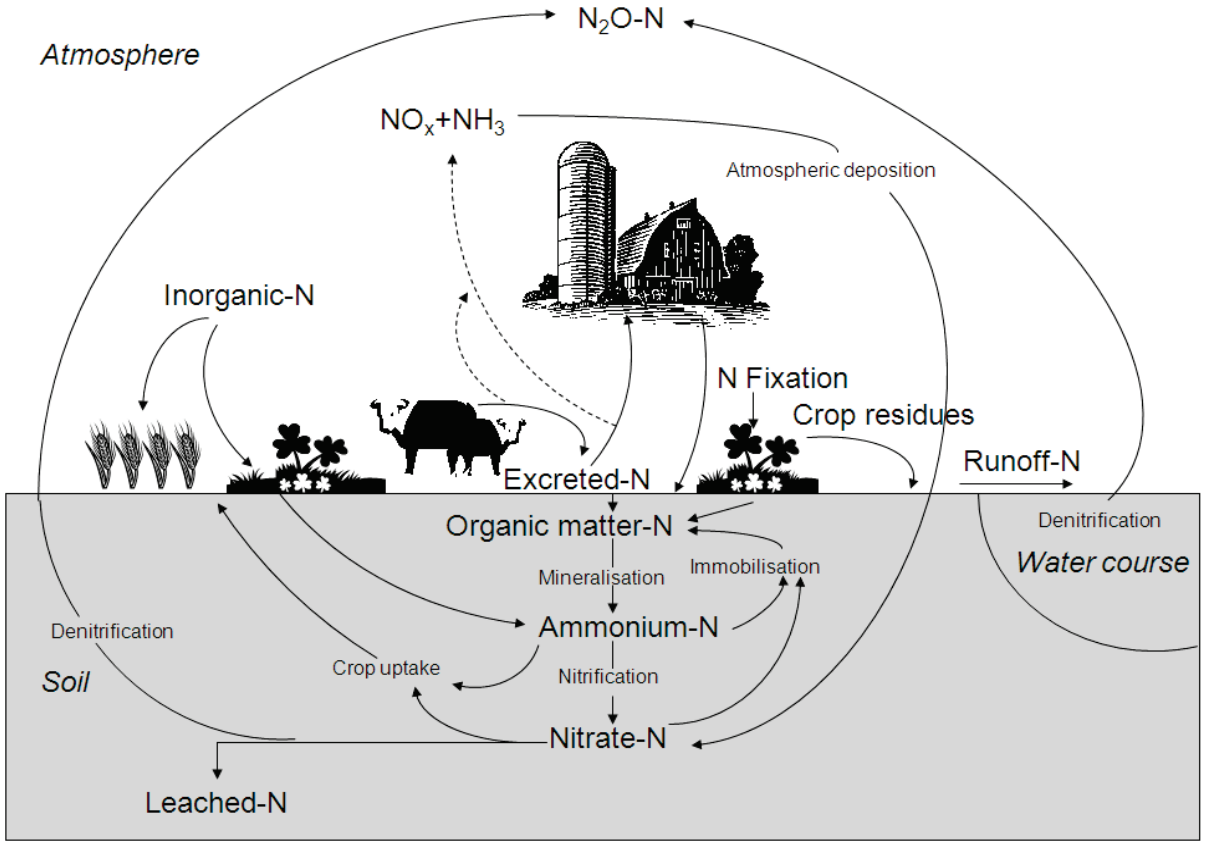
(i) The use of inorganic fertilizer
(ii) Biological fixation of nitrogen by crops
(iii) Crop residues returned to soils
(iv) Cultivation of histosols (organic soils)
(v) Manure deposited by grazing animals in the field
(vi) Application of livestock manures to land
(vii) Application of sewage sludge to 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 and run-off of agricultural nitrate

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 6.4**).

Figure 6-4 Simplified Nitrogen cycle highlighting the steps involved in the production of N2O 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, 2011a) and fertilizer application rates (BSFP, 2009). Crop areas are from Defra (see in http://www.defra.gov.uk/statistics/foodfarm/landuselivestock/junesurvey/).

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 (2011a, 2011b).

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 (2011a, 2011b). 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 contents of crops are derived from Burton (1982), Nix (1997), PGRE (1998), BLRA (1998).

6.5.2.4 Histosols

Emissions from histosols are 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 3.6.5**).

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 (poultry manure without bedding and poultry manure with bedding (litter)).

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 direct N_2O emissions.

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 that is applied to land and applying IPCC emission factors. Data sources for the annual production of sewage sludge (as dry matter) were obtained from OFWAT, the Water Commissioner for Scotland and the Northern Ireland regulator, UREGNI. 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 direct N_2O emissions.

6.5.2.8 Emissions from improved grassland

The total N_2O 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). 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. The sources of nitrogen considered, are synthetic fertiliser application and animal manures applied as fertiliser and sewage sludge applied to soils.

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

6.5.3 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 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

A correction was made to the calculation of direct N_2O emissions from grazing: the N input from grazing animals is no longer adjusted for 20% atmospheric volatilisation, in line with the IPCC guidelines. The proportion of time spent at grazing by cattle was revised according to recent survey data and historic survey data as used in the UK NH_3 emission inventory.

A correction was made to the calculation of N_2O emissions from manure applied to soils. Adjustment to the amount of N applied to account for N_2O losses during manure storage is no longer included, in line with the IPCC guidelines.

The combined effect of these changes was an increase in the emission from soils of 1,150 Gg CO_2 eq.

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, 2011a) 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

Minor corrections were made to the calculation of emissions from field burning, with year-specific values for fraction burned being used for 1990-1993 rather than the same value for each year.

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, 2011) 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, 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 were previously 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 data for Wales are obtained from the Welsh agriculture statistics[16], as they compile animal number data at a finer spatial resolution. These animal number data are also used to generate the NH_3 inventory.

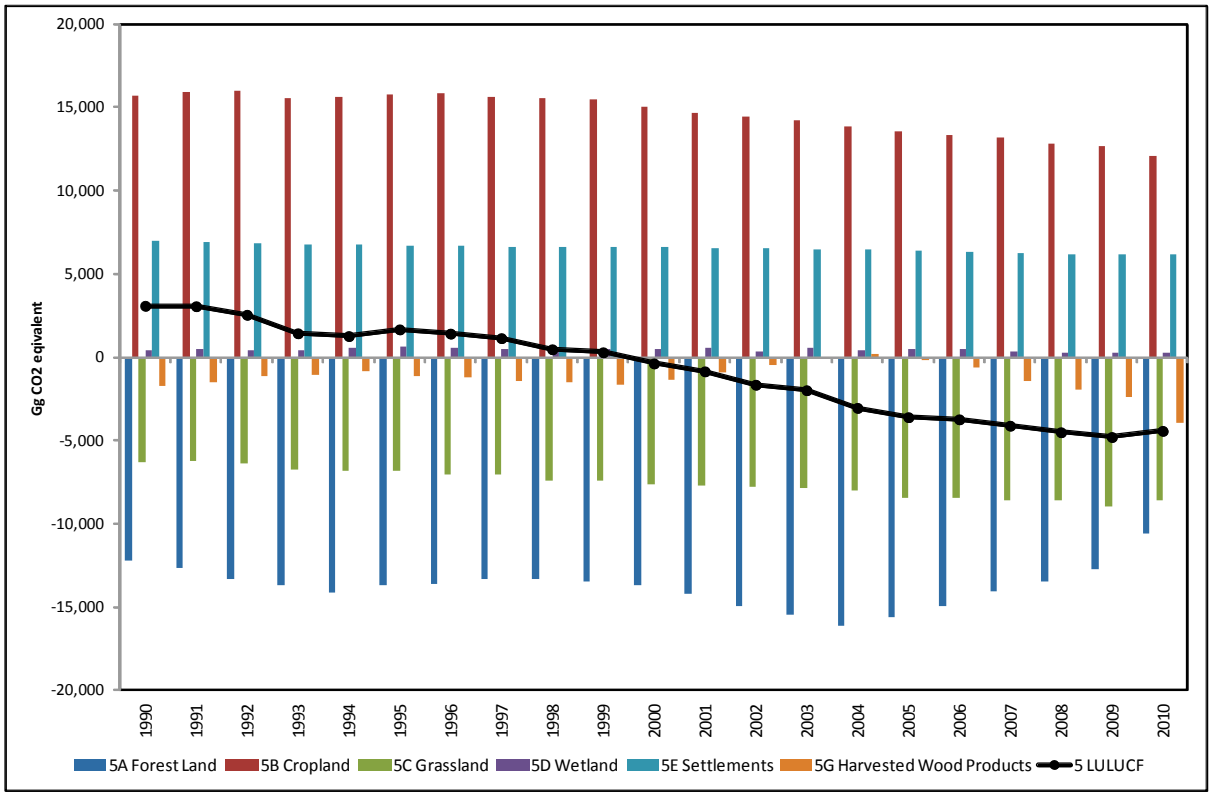
[16] http://wales.gov.uk/topics/statistics/publications/was2008/?lang=en

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

7.1 OVERVIEW OF SECTOR

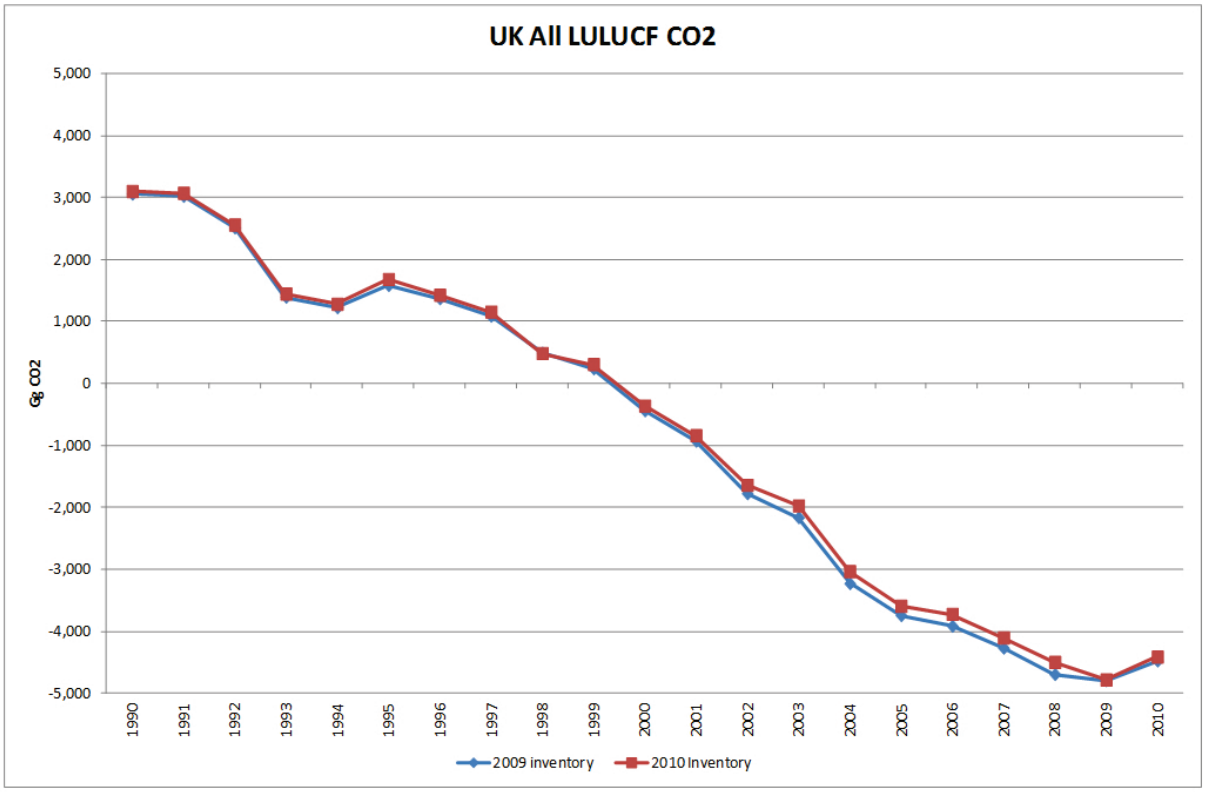
CRF Sector 5 includes carbon stock changes, emissions of greenhouse gases (CO_2, CH_4 and N_2O) by sources and removals of CO_2 by sinks from land use, land use change and forestry activities. Emissions from agriculture are included in CRF Sector 4 Agriculture. Removals of carbon dioxide are conventionally presented as negative quantities. The sector has been a net sink since 2001, with a net removal in 2010 of -3.75 Mt CO_2 equivalent (**Figure 7-1**), or -3.84 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 1990-2010



Net emissions in the UK in 1990 are estimated to be 3099 Gg CO_2 (a small increase from 3057 Gg CO_2 in the 2009 National Inventory Report). They are 3082 Gg CO_2 with the OTs/CDs included. For 2009 a net removal of -4778 Gg CO_2 is estimated here compared to a net removal of -4789 Gg CO_2 in the 2009 Inventory (**Figure 7-2**). These differences are due to the inclusion of new activity data for deforestation and liming since 1990, the inclusion of additional peat extraction areas in the 5D Wetlands category and other minor revisions to methods, activity data and emission factors.

Figure 7-2 Changes in net emissions/removals 1990-2010 between the 2009 and 2010 inventories in the UK



There have been updates to both methods and activity data for this Sector and internal restructuring of the 5B Cropland, 5C Grassland and 5E Settlements categories. 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 will be made available at http://ecosystemghg.ceh.ac.uk/ when it is redeveloped in summer 2012.

Greenhouse gas emissions and removals from the UK Crown Dependencies (CDs) and Overseas Territories (OTs) are reported under the relevant categories of CRF Sector 5. 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 (as discussed in the 1990-2006 NIR) makes it impossible to create inventories for them at the present time (these territories were contacted in 2011 for the preparation of the 1990-2010 inventory but data is still insufficient for inventory compilation).

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) and the area of inland water. 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, the Department for Communities and Local Government and the Countryside Survey dataset. Other land use change data comes from the changes between the three Countryside Surveys (1990, 1998 and 2007), rolled forward to 2010.

The 2011 UN expert review recommended the inclusion of the full set of annual land use change matrices in the NIR. Unfortunately, this review was received too late (late March 2012) to include matrices in this submission. **Table 7-1** showing the areas of land use and land use change (using the default 20-year transition period) has been included this time but a full set of annual land use change matrices will be included in the next submission. The annual land use transition matrices for 1990-1991 and 2009-2010 for the UK are shown in **Table 7-2** and **Table 7-3**. The Standard Area Measurement to mean high water is used for the total area of the UK (24,415 kha) (Office for National Statistics 2011). The area of inland water (164.1 kha) is now explicitly reported in the Wetlands category. 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. Some of this uncertainty is thought to arise from the treatment of management practices which rotate cropland and grassland over short time scales (<10 years). Work is planned for this area.

Table 7-1 Areas of land and land use change in the UK 1990-2010

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
A1. Forest Land remaining Forest Land		2001	2039	2083	2126	2167	2204	2245	2274	2300	2323	2344
A2. Land converted to Forest Land	A2. Total	610	590	564	540	517	498	475	465	458	453	450
	A2.1. Cropland converted to Forest Land	*25*	*25*	*25*	*26*	*27*	*27*	*28*	*29*	*30*	*31*	*32*
	A2.2. Grassland converted to Forest Land	*571*	*552*	*525*	*501*	*477*	*457*	*434*	*422*	*414*	*408*	*402*
	A2.3. Wetlands converted to Forest Land	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*
	A2.4. Settlements converted to Forest Land	*13*	*13*	*13*	*12*	*12*	*12*	*12*	*12*	*13*	*13*	*14*
	A2.5. Other Land converted to Forest Land	*0*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*2*
B1. Cropland remaining Cropland		1692	1765	1839	1913	1986	2060	2134	2207	2281	2355	2507
B2. Land converted to Cropland	B2. Total	2287	2311	2334	2357	2380	2404	2427	2450	2473	2497	2396
	B2.1. Forest Land converted to Cropland	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
	B2.2. Grassland converted to Cropland	*2256*	*2281*	*2305*	*2329*	*2354*	*2378*	*2402*	*2427*	*2451*	*2476*	*2376*
	B2.3. Wetlands converted to Cropland	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*
	B2.4. Settlements converted to Cropland	*30*	*29*	*28*	*27*	*26*	*25*	*24*	*23*	*22*	*21*	*20*
	B2.5. Other Land converted to Cropland	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*
C1. Grassland remaining Grassland		11021	11044	10914	10794	10675	10526	10416	10201	10102	10017	9853
C2. Land converted to Grassland	C2. Total	2026	2074	2122	2170	2219	2267	2315	2363	2411	2460	2409
	C2.1. Forest Land converted to Grassland	*3*	*3*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*5*	*5*

	C2.2. Cropland converted to Grassland	*1934*	*1979*	*2025*	*2070*	*2116*	*2161*	*2207*	*2252*	*2298*	*2343*	*2292*
	C2.3. Wetlands converted to Grassland	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*
	C2.4. Settlements converted to Grassland	*89*	*92*	*94*	*97*	*99*	*101*	*104*	*106*	*109*	*111*	*112*
	C2.5. Other Land converted to Grassland	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*
D1. Wetlands remaining Wetlands		177	177	176	176	176	175	175	175	174	174	174
D2. Land converted to Wetlands		IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
E1. Settlements remaining Settlements		1318	1325	1333	1340	1348	1356	1363	1371	1378	1391	1408
E2. Land converted to Settlements	E2 Total	486	480	474	468	462	456	450	444	439	433	422
	E2.1. Forest Land converted to Settlements	*9*	*10*	*10*	*10*	*10*	*11*	*11*	*11*	*12*	*12*	*12*
	E2.2. Cropland converted to Settlements	*122*	*118*	*114*	*109*	*105*	*101*	*96*	*92*	*88*	*83*	*83*
	E2.3. Grassland converted to Settlements	*354*	*352*	*350*	*349*	*347*	*345*	*343*	*341*	*339*	*338*	*327*
	E2.4. Wetlands converted to Settlements	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*
	E2.5. Other Land converted to Settlements	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*
F1. Other Land remaining Other Land		1632	1568	1577	1553	1606	1712	1705	1794	1834	1849	2085
F2. Land converted to Other Land		0	0	0	1	1	1	2	2	3	3	3

		2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
A1. Forest Land remaining Forest Land		**2346**	**2364**	**2382**	**2402**	**2423**	**2442**	**2464**	**2486**	**2510**	**2599**
A2. Land converted to Forest Land	A2. Total	**443**	**436**	**425**	**415**	**401**	**387**	**373**	**355**	**331**	**306**
	A2.1. Cropland converted to Forest Land	*33*	*33*	*34*	*34*	*34*	*34*	*33*	*33*	*32*	*31*
	A2.2. Grassland converted to Forest Land	*393*	*383*	*370*	*359*	*343*	*329*	*315*	*296*	*273*	*249*
	A2.3. Wetlands converted to Forest Land	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*

	A2.4. Settlements converted to Forest Land	*16*	*18*	*19*	*20*	*21*	*22*	*22*	*23*	*23*	*23*
	A2.5. Other Land converted to Forest Land	*2*	*2*	*2*	*2*	*3*	*3*	*3*	*3*	*3*	*3*
B1. Cropland remaining Cropland		**2660**	**2813**	**2966**	**3118**	**3271**	**3424**	**3577**	**3729**	**3882**	**3979**
B2. Land converted to Cropland	B2. Total	**2296**	**2195**	**2095**	**1994**	**1894**	**1793**	**1693**	**1592**	**1492**	**1400**
	B2.1. Forest Land converted to Cropland	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
	B2.2. Grassland converted to Cropland	*2277*	*2177*	*2077*	*1978*	*1878*	*1779*	*1679*	*1580*	*1480*	*1390*
	B2.3. Wetlands converted to Cropland	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*
	B2.4. Settlements converted to Cropland	*19*	*18*	*17*	*16*	*15*	*14*	*13*	*12*	*11*	*10*
	B2.5. Other Land converted to Cropland	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*
C1. Grassland remaining Grassland		**10096**	**10060**	**10189**	**10218**	**10333**	**10726**	**10631**	**10763**	**10514**	**10507**
C2. Land converted to Grassland	C2. Total	**2360**	**2310**	**2261**	**2211**	**2161**	**2111**	**2061**	**2011**	**1961**	**1873**
	C2.1. Forest Land converted to Grassland	*6*	*8*	*9*	*10*	*10*	*11*	*11*	*12*	*13*	*13*
	C2.2. Cropland converted to Grassland	*2240*	*2188*	*2136*	*2084*	*2032*	*1980*	*1929*	*1877*	*1825*	*1741*
	C2.3. Wetlands converted to Grassland	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*
	C2.4. Settlements converted to Grassland	*114*	*115*	*116*	*117*	*119*	*120*	*121*	*122*	*124*	*119*
	C2.5. Other Land converted to Grassland	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*
D1. Wetlands remaining Wetlands		**173**	**173**	**173**	**172**	**172**	**172**	**172**	**172**	**172**	**171**
D2. Land converted to Wetlands		**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**
E1. Settlements remaining Settlements		**1425**	**1443**	**1460**	**1477**	**1495**	**1512**	**1529**	**1547**	**1565**	**1570**
E2. Land converted to Settlements	E2 Total	**412**	**401**	**391**	**380**	**370**	**359**	**349**	**338**	**327**	**328**
	E2.1. Forest Land converted to Settlements	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*	*13*
	E2.2. Cropland converted to Settlements	*82*	*81*	*81*	*80*	*80*	*79*	*78*	*78*	*77*	*75*
	E2.3. Grassland converted to Settlements	*317*	*307*	*297*	*287*	*277*	*267*	*257*	*247*	*237*	*240*
	E2.4. Wetlands converted to Settlements	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*	*IE*
	E2.5. Other Land converted to Settlements	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*
F1. Other Land remaining Other Land		**1861**	**2009**	**1936**	**1954**	**1921**	**1702**	**1883**	**1811**	**2182**	**2274**
F2. Land converted to Other Land		**4**	**4**	**4**	**4**	**5**	**5**	**5**	**5**	**5**	**5**

Table 7-2 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	*2,609.1 ±0.9*	1.6	18.6	0.0	0.7	0.1	**2,629.3**
Cropland	0.0	*5039.0 ±17.8*	95.9	0.0	0.9	0.0	**5,118.0**
Grassland	0.3	83.4	*12971.4 ±54.9*	0.0	4.7	3.4	**13,118.0**
Wetlands	0.0	0.0	0.0	*176.7 ±0.0*	0.0	0.0	**176.7**
Settlements	0.7	2.5	13.5	0.0	*1,792.3 ±4.1*	0.2	**1,805.1**
Other Land	0.0	0.4	2.5	0.1	0.8	*1596.4 ±32.1*	**1,568.1**
Total (initial)	**2,611.0**	**5,144.7**	**13,047.0**	**176.8**	**1,803.4**	**1,632.1**	**24,415.0**

Table 7-3 Land use transition matrix, kha, for the UK in 2009-2010

From: To:	Forest	Cropland	Grass-land	Wet-lands	Settle-ments	Other Land	Total (final)
Forest	*2869.5 ±29.5*	0.7	4.6	0.0	0.7	0.1	**2,905.0**
Cropland	0.0	*4735.9 ±6.8*	52.1	0.0	0.1	0.0	**4,781.3**
Grassland	0.4	99.0	*12379.2 ±19.3*	0.0	7.7	3.0	**12,380.0**
Wetlands	0.0	0.0	0.0	*171.5 ±0.0*	0.0	0.0	171.5
Settlements	0.6	5.3	10.2	0.0	*1882.2 ±0.8*	1.0	**1,898.5**
Other Land	0.0	1.7	9.4	0.0	0.2	*2225.1 ±42.4*	**2,278.7**
Total (initial)	**2,841.0**	**4,849.3**	**12,474.7**	**171.5**	**1,891.7**	**2,186.8**	**24,415.0**

The areas of land in the different land use categories in the Overseas Territories and Crown Dependencies are shown in **Table 7-4**. There is insufficient data to construct full land use change matrices.

Table 7-4 Land areas with reported GHG emissions in the Overseas Territories and Crown Dependencies, kha

Sub-category	1990	1995	2000	2005	2010
5A1 Forest remaining forest	2.35	3.02	3.70	4.17	4.64
5A2 land converted to Forest	2.13	1.46	0.80	0.40	0.00
5B1 Cropland remaining Cropland	12.02	11.03	9.96	8.58	7.75
5B2.2 Land converted to Cropland (Grassland to Cropland)	0.07	0.15	1.00	1.48	2.44
5C1 Grassland remaining Grassland	1236.64	1257.19	1168.15	1155.31	1133.67
5C2.2 Land converted to Grassland (Cropland to Grassland)	1.70	3.74	7.86	9.46	15.27
5C2.4 Land converted to Grassland (Settlements to Grassland)	0.00	0.00	0.01	0.04	0.07
5E1 Settlements remaining Settlements	9.73	9.97	10.28	10.38	11.07
5E2.3 Land converted to Settlements (Grassland to Settlements)	1.00	0.94	1.00	1.24	1.50
5F1 Other Land remaining Other Land	26.94	4.00	88.38	98.97	110.61
5F2 Land converted to Other Land	0.08	1.15	1.54	2.65	5.64
Caribbean territories	42.00	42.00	42.00	42.00	42.00
Total area	1334.66	1334.66	1334.66	1334.66	1334.66

Total land areas: Isle of Man = 57.20 kha, Guernsey = 6.30 kha, Jersey = 11.87 kha, Falkland Islands = 1217.30 kha, Bermuda = 5.4 kha, Cayman Islands = 26.4 kha, Montserrat = 10.2 kha[17].

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 uses a 20-year transition period for land use conversion to Forest in the latest inventory.

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.

[17] Carribbean territory areas taken from the CIA World Factbook https://www.cia.gov/library/publications/the-world-factbook/index.html

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. 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. From 2010, these are obtained from the National Forest Inventory, adjusted for new planting; at present no adjustment is made for woodland converted to another land use. For earlier years, figures are based on the 1995-99 National Inventory of Woodland and Trees. 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 (http://www.forestry.gov.uk/inventory) comprises a digital woodland map based on comprehensive aerial photography and a field survey using one-hectare sample squares. The digital map and field survey now cover all woodland areas down to 0.5 hectares, while the core field survey sample has been reduced to around 0.5% of area. An initial digital woodland map was published in spring 2011. The field survey started in 2010 and should be completed in 2014. Interim results will be used for the softwood production forecast in 2012.

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 up to 2010.

The definition of woodland has changed slightly between the NIWT and the NFI. The NFI (Forestry Commission 2011) uses a minimum area of 0.5 hectares (rather than 0.1 ha) and a lower integral open space threshold of 0.5 ha (as opposed to 1 ha), which requires a negative adjustment to areas. However, the main differences in 2010 GB woodland cover between the NFI (2982 kha) and previous estimates (2757 kha, Forestry Statistics 2010) arise from identified errors in the previous woodland survey, particularly the under-estimate of woodland areas between 0.5 and 2 hectares. Estimates of woodland loss are still being assessed, which will affect the total woodland area. The NFI area estimates are not used for this inventory submission, but will be used for the next submission once woodland loss estimates are confirmed.

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. The UK report for the Global Forest Resources Assessment 2010 estimated that the area of woodland with 10-20% canopy cover is less than 50 thousand hectares.

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 (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). The area of woodland used in LULUCF reporting is taken from the statistics published by the Forestry Commission.

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

An uncertainty analysis was undertaken in 2011 to reassess sources of uncertainty (input data, model parameters and structural/model choice) in the LULUCF sector and identify priority areas for improvement (**Annex 3.7.13**). Monte Carlo simulations were run to propagate input and parameter uncertainty for different source categories, and the uncertainty arising from model choice was quantified by using alternative sub-models for key processes. 5A Forest Land was estimated to have an uncertainty of 22% for net emissions in 1990 and 2009 (assumed to continue in 2010) (slightly lower than the previous assessment of 25%). The main sources of uncertainty (ranked by standard deviation in output distributions) are afforestation model parameters, afforestation input data, forest soil carbon model choice and afforestation model choice.

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) field survey will provide better information on the reliability of the planting statistics, but the results from this are not yet available.

The wildfire activity data are estimated to have an uncertainty of 50% for 1990-2004 and 100% for 2005-2010, 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 2005-2010.

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, 2010).

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 was a new map, released in spring 2011, which has been used to produce estimates of total woodland area. The NFI 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.

A review of inventory data and models has been undertaken (Levy and Rowland, in review), during which data was collated and critically assessed on soil carbon stocks following afforestation. Generally, soil carbon stocks are assumed to increase after afforestation in the UK, following on as a result of the increased above-ground biomass. C-FLOW predicts that afforestation in the UK since 1920 has produced a carbon sink in the soil equivalent to one third of that sequestered in the above-ground biomass. In fact, in the UK studies which attempt to measure this, soil carbon stocks in forested plots were 15 to 60 % lower than in adjacent unplanted, grassland or moorland (Reay *et al.*, 2001; Chapman *et al*. 2003; Zerva and Mencuccini, 2005; Mitchell *et al*. 2007; Bellamy and Rivas-Casado, 2009; Levy and Clark, 2009). These results are in agreement with global meta-analyses, which have reported mean changes in soil carbon stocks of around -10 %, -7 %, +3 % and -4 % associated with conversion of pasture to forest plantation (Guo and Gifford, 2002; Berthrong *et al.*, 2009; Laganiere *et al.*, 2010; Poeplau *et al.*, 2011, respectively). The treatment of the litter layer in these studies is a significant uncertainty, as it is possible that some of the reported decreases in soil carbon following afforestation were compensated by increases in the above-ground litter layer, but these may not be included in the soil samples.

The suitability of the current soil carbon sub-model in C-Flow (based on Hargreaves *et al*. 2003) could be re-examined: a conservative approach might be to use the same model for soil carbon following land use change as in the rest of the inventory, with the assumption that the national mean approximates the equilibrium value. Alternatively, to represent the temporal pattern, the response functions of Poeplau *et al.*, (2011) might be used, being based on more data, though none of UK origin. The equilibrium forest soil carbon parameters could utilise the FC Biosoil data and CS soils data, and these data sources could

be further analysed for direct evidence of the effect of afforestation. This development proposal will be put to the LULUCF scientific steering committee for consideration as part of the work programme for the coming year.

7.2.7 Category-Specific Recalculations

The overall emissions from category 5A have changed by less than 0.5% from the 2009 inventory. This is due to the adjustment made to take account of losses of forest converted to other land uses (new deforestation activity data became available).

7.2.8 Category-Specific Planned Improvements

The area reported under 5.A.1 Forest remaining Forest is likely to be revised when the final statistics on woodland loss become available from the new National Forest Inventory. 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. Although initial results from the National Forest Inventory became available in spring 2011, further work is being undertaken to resolve areas of woodland loss in the different countries of the UK to the required scale for reporting.

Forest Research has been carrying out an analysis of Forestry Commission GB National Inventory of Woodland and Trees (NIWT) 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 estimate 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 around one quarter 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 analysis of 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 will become available in 2012. Better estimates will be available following completion of the current NFI round in 2014.

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 NIWT 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 2012.

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. 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 NIWT 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.

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 has been restructured in this inventory submission to use the 20-year transition period for land use conversion before reporting in the Cropland remaining Cropland sub-category.

Carbon stock changes in soils arising from historical land use change to Cropland more than 20 years before the inventory reporting year are reported under 5.B.1, along with (i) biomass carbon stock changes from yield improvements and (ii) organic soil emissions from fenland drainage. Carbon stock change from (i) 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). Carbon stock changes from (ii) arise because 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 other land categories to Cropland in the previous 20 years before the reporting year are reported under category 5.B.2 (emissions occur in the same year as the land use conversion). All forms of land use change, including deforestation, are considered and both mineral and organic soils

are included. In some categories, e.g. Forest Land converted to Cropland, the area of land undergoing transition drops away to zero and is subsequently reported as Not Occurring.

Nitrous oxide emissions from disturbance associated with land-use conversion to cropland (Table 5(III)) are reported: these arise from Forest Land and Grassland being converted to Cropland.

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.

Emissions of CO_2, CH_4 and N_2O from biomass burning arising from forest land conversion to cropland are reported in Table 5(V). Burning of agricultural residues (cereal straw or stubble) are reported under category 4F Field Burning of Agricultural Residues. 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 land use 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[18] 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.

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

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

Reporting in category 5.B has been restructured in this inventory submission to use the IPCC default 20-year transition period for land use conversion before reporting in the Cropland remaining Cropland sub-category.

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; 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. Fluxes arising from land use change in the 20 years before the inventory year are reported under 5B2 Land converted to Cropland. Fluxes from historical land use change (more than 20 years before the inventory year) are reported under 5B1 Cropland remaining Cropland. 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 associated with the conversion of land to Cropland are reported using the areas of forest land and grassland converted to cropland from the land use change matrices and the IPCC Tier 1 emission factors.

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 was estimated to have an uncertainty of 52% for net emissions in 1990 and 2009 (assumed to continue in 2010) (slightly higher than the previous assessment of 50%).

Recent work on quantifying uncertainties in the inventory has focussed on forest modelling (see **Chapter 11**, **Section 3.1.5**). The uncertainty analysis (see **Annex 3.7.13**) has been extended to encompass the whole of the existing inventory methodology, applying uncertainty quantification more widely and rigorously to all model parameters and empirical conversion factors, and to quantify the impact of those uncertainties on the inventory.

The areas undergoing land use change are the biggest source of uncertainty in the LULUCF inventory, but model choice and soil carbon parameters are also significant. Work on assimilating more land use data sets is for 2012-2014, which should constrain the high uncertainties associated with area.

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.

Fenland drainage has the largest uncertainties of the minor emissions sources (i.e. not land use change or afforestation) as the effects of drainage are highly uncertain (as is the reversal of such drainage).

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 has improved to high with the introduction of country-specific data sets.

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

There has been internal restructuring of this category so that the IPCC-default 20 year transition period is now used for land use change. Therefore the time series of emissions has changed in both sub-categories, 5B1 and 5B2, but the overall emissions from category 5B have only changed by less than 0.5% from the 2009 inventory, showing an average increase of 28 Gg CO_2 across all years 1990-2009. These changes arise from improvements in activity data rather than the restructuring.

There were small changes in CO_2 emissions from agricultural liming due to re-assignment of the limed area between Cropland and Grassland (increased precision in agricultural data) and the inclusion of updated agricultural lime sales (AMRI 2009). A new source of activity data on agricultural lime purchases in Northern Ireland was included (Northern Ireland Statistical Review 2011). This increased overall emissions slightly as the previously used data sources had been assumed to include Northern Ireland, but in fact were for Great Britain only. According to the published statistics, no dolomite is applied in Northern Ireland so emissions are only reported for limestone application.

There were small differences in the carbon stock changes and biomass burning emissions arising from updated activity data for Forest Land converted to Cropland. These only affect England as the areas of forest-crop conversion in Scotland, Wales and Northern Ireland are so small that they are thought to be due to survey classification error than genuine land use change).

7.3.8 Category-Specific Planned Improvements

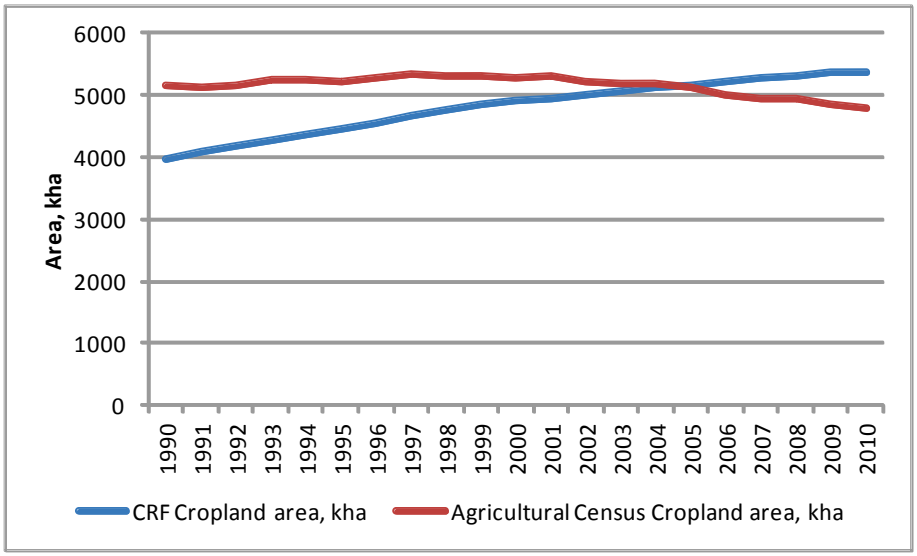
It was hoped that the internal restructuring of the Cropland category would resolve the discrepancies between the Cropland areas reported in the CRF tables and those in Tables 7.1 and 7.2 (Figure 7-3). It is thought that these discrepancies arise because some cropland (and pasture grassland) is in multi-year rotations and these areas have therefore undergone multiple land use transitions between 1950 and the current inventory year (with the area changes being cumulatively reported in 5.B). The soil carbon fluxes from cropland-grassland and grassland-cropland transitions will balance out at the sector level. However, the restructured area data indicates that the majority of cropland in Scotland, Wales and Northern Ireland is under rotational management and therefore the accumulated area of land use change exceeds the area of cropland reported in national statistics. Work will be undertaken before the next inventory submission to resolve this 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 is planned and the carbon stock change calculations updated accordingly.

Figure 7-3 Comparison of Cropland area reported in the CRF and in the land use matrices



A development project, with a focus on soil carbon, has examined the scope for the effects of land management policies to be better reflected in the inventory, through an assessment of the availability and quality of activity data and country-specific emission factors. A wider review of data sources has also been completed: this assessed whether there are additional data sources that could be used in the inventory or contribute to uncertainty estimates. The final reports of these scoping projects are currently in review: once completed, they will be used to inform further inventory development.

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 has been restructured in this inventory submission to use the 20-year transition

period for land use conversion before reporting in the Grassland remaining Grassland sub-category.

Carbon stock changes in soils arising from historical land use change to Grassland more than 20 years before the inventory reporting year are reported under 5.C.1. The area of undisturbed grassland is also reported here, although no emissions are associated with this area, so that the total area of grassland matches that reported in the annual agricultural census.

Carbon stock changes due to the conversion of other land categories to Grassland in the 20 years before the inventory reporting year due to land use change to Grassland are reported under 5.C.2 (emission occur in the same year as the land use conversion). 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 unconditional felling licence data from the Forestry Commission and land conversion ratios from Countryside Survey. The area of unconditional felling licences (felling licences granted without a requirement to restock) in England (1992-present), Scotland (1998-present) and Wales (1996-present) is used to estimate deforestation to rural land uses (available at http://www.forestry.gov.uk/datadownload). Countryside Survey (CS) data (1990-2007) is used to fill gaps in the time series and to estimate deforestation in Northern Ireland (where no suitable activity data is available). Details are given in **Annex 3.7**.

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 not used for peat extraction, 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 7-5**).

Table 7-5 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.
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

Reporting in category 5.C has been restructured in this inventory submission to use the IPCC default 20-year transition period for land use conversion before reporting in the Grassland remaining Grassland sub-category.

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**. Fluxes arising from land use change in the 20 years before the inventory year are reported under 5C2 Land converted to Grassland. Fluxes from historical land use change (more than 20 years before the inventory year) are reported under 5C1 Grassland remaining Grassland. 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 was estimated to have an uncertainty of 52% for net emissions in 1990 and 2009 (assumed to continue in 2010) (slightly lower than the previous assessment of 55%). The uncertainty analysis (see **Annex 3.7.13**) has been extended to encompass the whole of the existing inventory methodology, applying uncertainty quantification more widely and rigorously to all model parameters and empirical conversion factors, and to quantify the impact of those uncertainties on the inventory.

The areas undergoing land use change are the biggest source of uncertainty in the LULUCF inventory, but model choice and soil carbon parameters are also significant. Work on assimilating more land use data sets is for 2012-2014, which should constrain the high uncertainties associated with area.

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 has improved to high with the introduction of country-specific data sets

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

There has been internal restructuring of this category so that the IPCC-default 20 year transition period is now used for land use change. Therefore the time series of emissions has changed in both sub-categories, 5C1 and 5C2, but the overall emissions from category 5C have only changed by less than 1% from the 2009 inventory between 1990 and 2001 and by 0-3% since then. Changes in net emissions ranged from 0.33 Gg CO_2 in 1991 to -283 Gg

CO_2 in 2009. These changes arise from improvements in activity data rather than the restructuring.

There were small changes in CO_2 emissions from agricultural liming due to re-assignment of the limed area between Cropland and Grassland (increased precision in agricultural data) and the updating of other data sets (see **section 7.3.7**).

New activity data on forest conversion to non-urban land use was included (see **section 7.4.2** and **Annex 3.7**), and deforestation to grassland in Northern Ireland was reported for the first time. This reduced net emissions from carbon stock changes and biomass burning.

7.4.8 Category-Specific Planned Improvements

Work on resolving the rotational cropland-grassland management issue (**section 7.3.8**) will be undertaken before the next inventory submission. The review and other planned improvements described in **Section 7.3.8** are also relevant to this section.

Although improvements to the deforestation activity data have been made in this submission, further adjustments will be made once finalised estimates of woodland loss from the National Forest Inventory become available (see **section 7.2** for further details). The Forestry Commission is currently undertaking further work to resolve areas of woodland loss to the required scale for reporting. The intention is that eventually deforestation estimates should be obtained directly from periodic National Forest Inventories (NFIs), as results from these become available.

New spatial data on outdoor fire incidences (covering all the UK) has become available, based on the new Vegetation Fire Monitoring Standard. These data cover the period April 2009-March 2011. It is likely that these data can be used in conjunction with remotely sensed data (e.g. on burnt areas and temperature anomalies) to assess the extent of biomass burning (whether wildfires or controlled burning) on non-forest land use types. Progress in this area will be reported in the next inventory report submission

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.

The area of inland water is reported in this category but no emissions are associated with such areas.

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. 2002, 2008, 2010): this gives location, name, operator and council for currently active commercial extraction sites in England (54), Scotland (23) and Wales (2). This Directory does not record the extent of the extraction area. It is updated regularly but did not report peat extraction before 2002.

- Areas of peat extraction can be clearly seen on Google Earth satellite imagery (using the BGS point locations). Areas can be measured using software such as Feature Manipulation Engine. 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 7-4**). 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 7-4 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.

The area of inland water is taken from the "UK Standard Area Measurements" (ONS 2010). It defines inland water as 'bounded' permanent water bodies, e.g. lakes, lochs and reservoirs, exceeding 1 km^2 (100 hectares) in area. 'Open' tracts of water, e.g. rivers, canals and streams are excluded from this definition.

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). The latest Directory of Mines and Quarries categorises sites as producing horticultural or energy source (fuel) peat. This information is now used to extract the area of nutrient-rich peats that will produce N_2O emissions (following the IPCC Tier 1 methodology). Further information is given in **Annex 3.7**.

The site records in the Directory of Mines and Quarries show that the area under active peat extraction is diminishing but it is not yet clear whether the sites becoming inactive have been converted to another land use or abandoned but not converted (insufficient time has elapsed for this to be clear on the satellite imagery). For the time being, the area that is no longer recorded as under active extraction is reported in the 5.F.2.4 Wetland converted to Other Land category.

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

The inclusion of additional peat extraction sites has increased reported emissions from this category by 14-19% (an average of 69 Gg CO_2 1990-2008). The activity data for these emissions has been updated with the latest published information on peat volume sales (ONS 2010). Volumes for 2010 were assumed to be equal to those in 2009.

7.5.8 Category-specific planned improvements

The time series of active peat extraction sites cannot be extended back further than 2002 from the current data sources. The time scales are currently too short to allow permanent land use change to be identified on satellite imagery when extraction sites are no longer listed as commercially active. We will consider the best way of treating the sites that are no longer active extraction sites.

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. Reporting of carbon stock changes is disaggregated between the four geographical areas of England, Scotland, Wales and Northern Ireland. Reporting in category 5.B has been restructured in this 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 in soils arising from historical land use change to Settlements more than 20 years before the inventory reporting year are reported under 5.E.1. Carbon stock changes and biomass burning emissions due to conversion of Forest Land to Settlements in the previous 20 years before the reporting year are reported under category 5.E.2 (emissions occur in the same year as the land use conversion). 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). Land conversion ratios from Countryside Survey are used for the extrapolation from England to the other countries in the UK. Details are given in **Annex 3.7**

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

Reporting in category 5.E has been restructured in this inventory submission to use the IPCC default 20-year transition period for land use conversion before reporting in the Settlement remaining Settlement sub-category.

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**. Fluxes arising from land use change in the 20 years before the inventory year are reported under 5E2 Land converted to Settlement. Fluxes from historical land use change (more than 20 years before the inventory year) are reported under 5E1 Settlement remaining Settlement. 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 was estimated to have an uncertainty of 52% for net emissions in 1990 and 2009 (assumed to continue in 2010) (slightly higher than the previous assessment of 50%). The uncertainty analysis (see **Annex 3.7.13**) has been extended to encompass the whole of the existing inventory methodology, applying uncertainty quantification more widely and rigorously to all model parameters and empirical conversion factors, and to quantify the impact of those uncertainties on the inventory.

The areas undergoing land use change are the biggest source of uncertainty in the LULUCF inventory, but model choice and soil carbon parameters are also significant. Work on assimilating more land use data sets is for 2012-2014, which should constrain the high uncertainties associated with area.

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

There has been internal restructuring of this category so that the IPCC-default 20 year transition period is now used for land use change. Therefore the time series of emissions has changed in both sub-categories, 5E1 and 5E2, but the overall emissions from category 5E have only changed by less than 1% from the 2009 inventory between 1990 and 2001 and by less than 3% since then. Changes in net emissions ranged from -35 Gg CO_2 in 1991 to 162 Gg CO_2 in 2009. These changes arise from improvements in activity data rather than the restructuring.

The dataset on deforestation to Settlement in England was revised for 1999 and 2008. 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 2009 to 2010 has been estimated by extrapolation from earlier years. These changes and the new extrapolation method (using the Countryside Survey land conversion factors) have had a small effect on carbon stock changes and emissions of greenhouse gases during biomass burning.

7.6.8 Category-Specific Planned Improvements

Although improvements to the deforestation activity data have been made in this submission, further adjustments will be made once finalised estimates of woodland loss from the National Forest Inventory become available (see **section 7.2** for further details). The Forestry Commission is currently undertaking further work to resolve areas of woodland loss to the required scale for reporting. The intention is that eventually deforestation estimates should be obtained directly from periodic National Forest Inventories (NFIs), as results from these become available.

The review and other planned improvements described in **Section 7.3.8** are also relevant to this section.

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). Areas of peat extraction that are no longer reported as active are reported in the 5.F.2.4 Wetland converted to Other Land category.

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 7-6**). As described in **section 7.5**, areas of inland water exceeding 1km^2 are included in 5D Wetlands, but water bodies below this threshold would still be included under Other Land.

Table 7-6 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

None in this 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 was previously estimated to have an uncertainty of 30% for net emissions in 1990 and 2010. The latest uncertainty analysis estimated uncertainty of more than 22% for this category (in line with the uncertainty for 5A Forest Land with an additional unknown uncertainty for the HWP decay term), which is in line with the continued use of the 30% estimate.

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 continues 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 across all years and the category only being a net source in 2004 rather than in 2003 and 2004.

7.8.6 Category-Specific Planned Improvements

The emission factors and activity data for harvested wood products will be kept under review. Work is proceeding to ensure the approach for estimating removals and emissions due to HWP are consistent with methodologies agreed at Cancun and Durban and that underpinning data on UK wood production are reported so as to support implementation of these methodologies.

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.

Forest Research (project partner) is ISO-14001 qualified and carries out its work in accordance with the Joint Code of Practice for Research described above.

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. This will be redeveloped and updated in summer 2012. 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 6C (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.

A general assessment of completeness is included in Annex 5. CO_2 emissions are not reported for category 6.A.1 because these emissions are considered to be biogenic. No CO_2 or N_2O emissions are reported for accidental vehicle fires because no suitable emission factors have been identified and the source is considered to be negligible. No emissions of N_2O or CH_4 are reported from chemical waste incineration since this is a high temperature combustion process and therefore the emissions are assumed to be insignificant.

Where data are available, emission estimates have been made and reported for this sector for the UK OTs and CDs. In the CRF submission, emissions from landfill are included within 6A ‘other’; emissions from wastewater treatment are included within 6B3 ‘other’ and emissions from waste incineration are included in the UK emissions totals with UK emission factors used. For more information on the methodology used, see Annex 3.9.

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 that started receiving waste in 1980 and old unmanaged waste disposal sites that closed prior to 1980.

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[19], 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[20] 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[21]. 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[22], 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

[19] 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.

[20] Dimensionless ratio of mass of NMVOC per unit mass of methane.

[21] 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.

[22] 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.

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[23]. 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 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[24] landfilled in the base year (1995). The UK is one of twelve European Union (EU) member states[25] 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 latest of which was published in 2007 (Defra, 2007). In 2011, the government published a review of the 2007 Waste Strategy for England which sets out its proposed policies to move towards a zero waste economy (Defra, 2011).

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

[23] 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

[24] "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.

[25] The others are Bulgaria, Cyprus, Czech Republic, Estonia, Greece, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia.

Commission[26]. 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 has achieved its 2010 landfill diversion target and has reduced the amount of biodegradable municipal waste sent to landfill by at least 25% compared with the 1995 base year[27].

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.

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 2011/12) is £56/tonne.

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. However, in its waste policy review (Defra, 2011), the Government has indicated that the LAS will be abolished in England from 2013. Note that BMW was redefined in 2010 to incorporate approximately half of C&I waste, so the data from LASs only covered the old definition of municipal waste – that collected by local authorities. The Landfill Tax is the main driver for diverting waste from landfill and the LAS is no longer considered to be an effective tool for delivering the EU landfill diversion targets.

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

[26] For example, see Europa Summaries of EU legislation – waste management: http://europa.eu/legislation_summaries/environment/waste_management/index_en.htm

[27] See Defra website: http://www.defra.gov.uk/news/2010/09/08/landfill-directive-target/

Pollution Prevention and Control (IPPC) Directive[28] 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 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

[28] 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

- 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) $$CH_4 \text{ emissions}_{,T} = \left[\sum_x CH_4 \text{ generated}_{,T} - R_T \right] (1-OX_T)$$

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) $$Q_{x,T,t,p} = L_{x,t,p} \left(e^{-k_p^{(T-t)}} (1- e^{-k_p})\right)$$

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) $L_{x,t,p} = MCF \cdot F. \ DDOC_{x,t,p} \cdot 1/W_{x,t,p} \cdot 16/12$

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),
F is the molar fraction of methane in landfill gas (dimensionless ratio),
MCF is the Methane Correction Factor (dimensionless ratio - see below) 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 = $\Sigma (W_{x,T,t,p} \cdot Q_{x,T,t,p})$

The IPCC FOD methodology is based on the premise that Dissimilable Degradable Organic Carbon compounds (DDOC)[29] 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 disposal sites do not develop extensive anaerobic conditions typical of modern landfills and hence a smaller proportion of waste decays aerobically and so doe note produce methane. For modern landfills, the MCF term is given the value of unity, but for unmanaged dumpsites a smaller figure may be used. As all solid waste disposal sites in the

[29] 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.

UK that have received biodegradable wastes since 1980 are believed to be typical of landfills rather than unmanaged dumpsites, MCF has been assigned a value of unity. MCF has been assigned a value of 0.6 for these old closed landfills that operated up to 1980. This corresponds with the default value for MCF given for uncategorised solid waste disposal sites in the Revised 1996 IPCC Guidelines.

The remaining term in equation 3 is F, the molar fraction of methane in landfill gas. This has been assigned the value of 0.5, the default value given in the Revised 1996 IPCC Guidelines.

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 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) was peer reviewed by independent experts from academia, industry, regulators and consultants in late 2010. Revisions to the MELMod input data and parameters that were approved by the peer reviewers were implemented for the calculation of the previous UK NIR (for 2009), submitted to UNFCCC in April 2011. The principal changes to the input data were summarised in the 2009 NIR. Further details on data sources and rationale are given in Eunomia's report.

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. Further details are given in Appendix 3.

Uncertainty in collection efficiency is believed to be a major source of uncertainty in overall emission of landfill methane, as discussed further in Annex 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 feasible, 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 774 Gg methane, based on the revised methodology reported in this NIR (see Table A3.8.2 in **Annex 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, so no revision of the 2008 NIR is required in this respect.

The changes to the model input data recommended by Eunomia were peer reviewed by independent experts from academia, industry, regulators and consultants in late 2010, before their incorporation into the UK inventory. The implementation of the recommended changes within the model has now also been reviewed, and the changes arising from this review have been incorporated into this submission. The impact of these changes are described in the section below.

8.2.5 Source-specific recalculations, if applicable, including changes made in response to the review process

As mentioned above, the revisions to activity data and emission factors proposed by Eunomia were peer-reviewed in late 2010 and the revised model was used for the calculation of the 2009 inventory, submitted to UNFCCC in April 2011.

In line with the recommendations of the UNFCCC Expert Review Team in relation to the 2009 NIR, a further detailed review of the revised model was undertaken. These checks revealed a number of inconsistencies between the changes recommended in Eunomia's report and their implementation in the model. The model has now been updated and corrected prior to its use in producing the 2012 NIR submission.

The problems were:

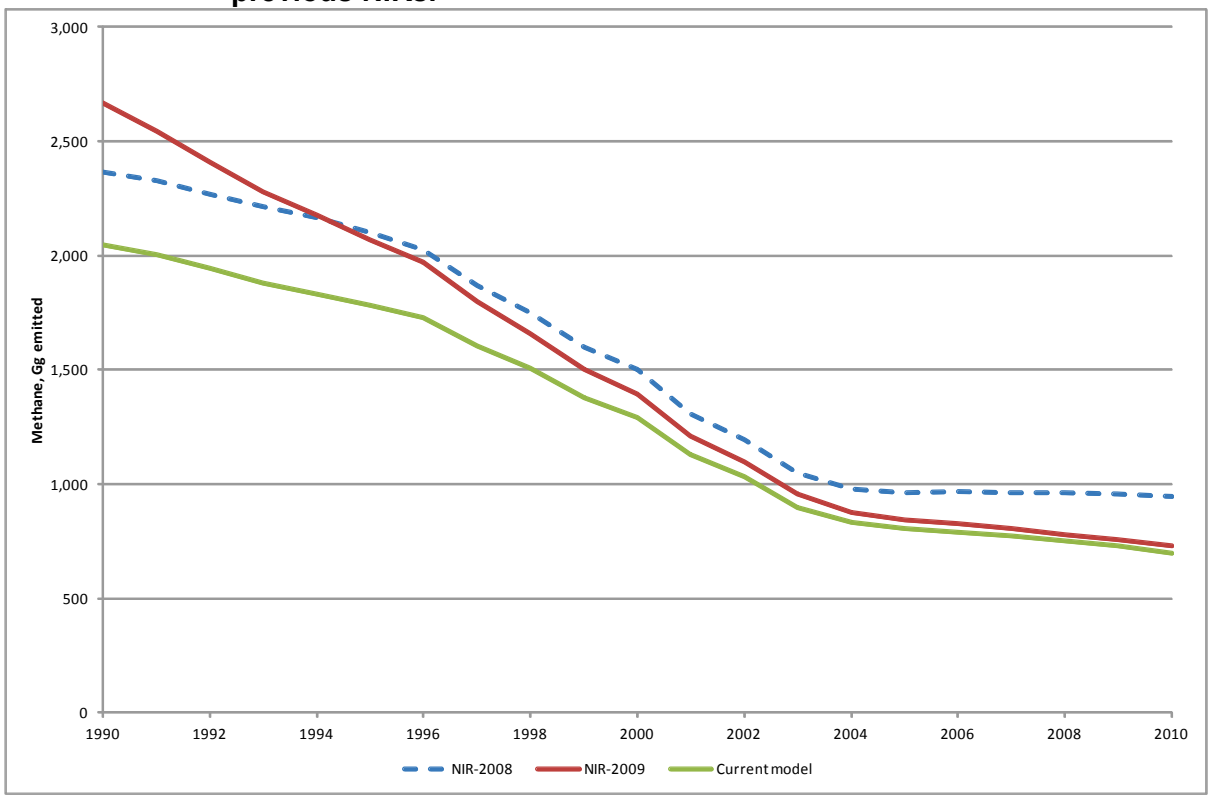
- An overestimation of landfilled DDOC from commercial and industrial (C&I) waste
- Inconsistencies in the implementation of a new method for calculating DDOC values

The implementation of the new calculation of DDOC in waste had a less significant impact. New values were proposed in Eunomia's report, but these had not been consistently applied for all waste types within the model. The revised values, which are now included in the model, are set out in Annex 3.

The effect of these revisions is shown in Figure 1-2, which compares methane emissions calculated by the current model used for reporting this (2012) inventory, with the results from the model used for the 2009 NIR (prior to identification and correction of errors) and the 2008 NIR produced using the previous model.

The impact of the revisions is a reduction of emissions across the time series (compare the lines for "NIR-2009" and "current model"). This effect was greatest in the base year (1990) but decreased over time. In 1990, emissions calculated for the current submission were about 23% less than reported in the previous submission, but by 2010, the difference is only around 4%. The current model follows a shaped time trajectory to that shown in the 2008 NIR (which used the pre-Eunomia model), but is consistently lower than the 2008 NIR.

Figure 8-1 Methane emissions from UK landfills as reported in the current and previous NIRs.



Overall emissions reported for 1990 in this NIR are 2,044 Gg methane, compared with 2,667 Gg reported in the previous submission. Emissions in 2010 are now reported at 699 Gg, compared with 756 Gg in 2009, reported in that year's NIR. 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.

8.2.6 Source-specific planned improvements

Emission factors, model parameters, and activity data will be kept under review. Defra and the environmental regulatory agencies in the UK are funding a small pilot study, with a view to undertaking a wider study to measure methane emissions from a 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 2013 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.

Through consultation with UK water companies, GHG emission estimates derived using the UKWIR spreadsheet tool have been reported to the inventory agency by 5 out of 12 of the UK water companies for the year 2009. Using the company-reported emissions and activity data, these 2009 data have been used to derive company-specific, source-specific Implied Emission Factors; these implied emission factors have then been averaged to derive UK industry factors and used in conjunction with the activity data from regulators and Defra to calculate the UK water industry emissions.

From 1997 to 2008, each of the 10 water companies in England and Wales reported sludge disposal activity within annual submissions (called “June Returns”) to the industry regulator, OFWAT, broken down across 8 sludge disposal routes: incineration, composting, landfill, land reclamation, farmland untreated, farmland conventional, farmland advanced and other.

Since 2009 the data published for each water company within the OFWAT June Returns tables is limited to the total activity for all sludge treated and disposed, with no detailed breakdown of ultimate disposal fate published; for each water company in England and Wales, therefore, the 2008 breakdown across the 8 disposal routes has been used to estimate the detailed activity in 2009 and 2010.

In Scotland, detailed activity data on treatment and disposal have been available since 2002 and continue to be published to 2010, from the Water Commissioner for Scotland.

In Northern Ireland, fully disaggregated data are only available from the water regulator, UREGNI, since 2007; the Defra EPSIM statistics are used to provide activity data for the early part of the time series to 2003, whilst the Northern Ireland activity data published by the regulator for 2007 are extrapolated back to 2004.

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, 2010). For the purposes of the 2010 estimates within the inventory, the Expenditure and Food Survey 2011 was not available in time, and therefore the data for 2009 has been used as a best estimate.

In the 1990-2010 inventory cycle we have revised the methodology for nitrous oxide to remove a double-count that had been introduced in error in the previous inventory cycle; the emission estimates for the agriculture sector in the 1990-2009 GHGI cycle were updated to

include an estimate of nitrous oxide emissions from sewage sludge applied to agricultural soils, and this introduced a double-count to the method used in the IPCC sector 6B. Therefore, in the 1990-2010 cycle, the estimates of nitrous oxide from sewage sludge applied to agricultural land have been retained in the agriculture sector and subtracted from the estimates based on the IPCC default methodology for IPCC sector 6B.

8.3.3 Uncertainties and Time-Series Consistency

As outlined in **Section 8.3.2**, the method for deriving methane emission estimates uses activity data from across the time series, and applies emission factors that are derived from reported emissions data from 2009 from 5 out of 12 UK water companies. These emission factors are then applied to the activity data across the full time series. The emission estimates included in this submission are uncertain due to the limited coverage of the source data used to derive the industry emission factors.

In the review of the previous UK submission, the UNFCCC ERT questioned the accuracy of the source estimates due to uncertainty regarding the applicability of factors derived from one year and from only a sub-set of the UK water industry and then applied to water industry operations throughout the time series. The inventory agency acknowledges that the estimates are somewhat uncertain and that further work is needed to consult across the industry to seek to improve the method. However, we remain confident that the method is an improvement compared to the previous approach which used data from a 1996 study, based on information from the early 1990s and then extrapolated the emission estimates forward based on population trends. The current method, uses a published national set of activity statistics that reflect the changing fate of sewage sludge treatment and disposal. In the UK the water industry has undergone a marked shift in treatment and disposal practices since the Urban Waste Water Treatment Directive of 1999 banned the dumping of sewage to sea. The inventory method for methane uses data from UK companies based on recent research specific to the estimation of non-CO_2 gases from waste water treatment works, and applies the factors to time series of national activity data. See **Annex A3.8.3** for further method details, and **Section 8.3.6** below for an insight into the planned improvements for this source method.

The most recent average protein consumption per person is based on the Expenditure and Food Survey (Defra, 2010). 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.

8.3.4 Source Specific QA/QC and Verification

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

8.3.5 Source Specific Recalculations

Methane emission estimates have been revised due to the use of revised activity data on waste water treatment and sewage sludge treatment and disposal, from the Northern Ireland utility regulator, UREGNI.

Emissions of N_2O have been revised downwards across the time series to remove the double-count with the agricultural soils source, as outlined above. In 2009, this revision reduced 6B nitrous oxide emissions by 0.74 Gg N_2O.

8.3.6 Source Specific Planned improvements

Industry consultation has been initiated during 2012 to:

i) Investigate the data available from the UKWIR spreadsheet tool, to review whether the emission factors applied to the June Returns activity data are representative of the industry activity and emissions;
ii) Seek data inputs from more of the UK water companies, building on the example of those that reported emissions data to date;
iii) Seek industry advice 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 on-going 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.

No new data has been provided to date, but all UK water companies have been contacted to request additional data to improve the current approach and reduce uncertainties in the UK inventory estimates, seeking to ensure that the estimates presented in the inventory are representative of the industry across the UK. 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, 2011). 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 (2011).

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), rather than 6C (Waste Incineration).

MSW and clinical waste incineration in the UK's Overseas Territories and Crown Dependencies is included in the CRF within the same categories as the UK data. The data are not reported separately since the same emission factors are applied to the OT/CD data as for the UK. Therefore no additional information (e.g. differences to emission factors) are obtained through reporting these data separately.

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 occurred in the 1993-1995 period.

The inventory includes estimates for emissions of CO, NOx & VOC from small-scale burning of domestic and garden waste, for example on domestic grates and on garden bonfires. The estimates are very uncertain, being because of the need for expert judgements in order to derive any activity data from waste arisings data, and the lack of emission factors specific to this type of activity.

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

UK emissions in 2009 for waste incineration were revised, decreasing by 9 Gg CO_2, predominantly due to revisions in activity data for clinical waste incineration. Revisions to the methodology used to estimate the quantities of domestic and garden waste burnt on domestic and garden fires led to decreases in 2009 UK emission estimates of 8 Gg CO and 2 Gg VOC.

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.

Available data for waste composition have been analysed in order to produce an updated CO_2 emission factor for MSW incineration. This research was conducted in order to produce a more transparent emission factor, and also to produce a time series which reflects the changing composition of waste between 1990 and 2010. Data were obtained from incinerator operators, which reflected the waste composition data in the early 2000s, however a suitable time series of data has not yet been found. The waste composition data that were obtained indicated a lower carbon content of about 62kt carbon/Mt waste. It was not considered appropriate to apply the lower emission factor across the time series since it was not clear that this was a better representation for all years than the emission factor used previously. We have therefore retained this emission factor, and will continue to conduct research to find a suitable time series of waste composition data, to use in the 2013 NIR submission.

9 Other (CRF Sector 7)

9.1 OVERVIEW OF SECTOR

No emissions are reported in Sector 7.

10 Recalculations and Improvements

This section of the report summarises the recalculations and improvements made to the UK GHG inventory since the 2011 NIR (2009 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 2010 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 2009; this report gives emission estimates for 2009, and includes estimates for the year 2010 also.

The inventory may also be *expanded* to include emissions from additional sources if a new source has been identified within the context of the IPCC Guidelines and Good Practice Guidance, and there are sufficient activity data and suitable emission factors.

10.1 EXPLANATIONS AND JUSTIFICATIONS FOR RE-CALCULATIONS

Table 10.1 and **Table 10.2** summarise the recalculations that have occurred in estimates of the direct GHGs since the 2011 NIR (2009 inventory) was issued. **Table 10-3** gives details of where changes to methodological descriptions have been made and where these descriptions can be found in the main text of this document.

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 2009 (**Table 10.1**) and the base year (**Table 10.2**).

Table 8(a) s1, Table 8 (a) s2 and Table 8(b) 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 (2010 inventory; 2012 NIR); and
PS = Previous Submission (2009 inventory, 2011 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.

All revisions to source data and methods, and all recalculations that are reported in the latest UK GHG inventory are conducted by the inventory agency in agreement with the DECC GHG inventory management team; all major recalculations and systematic improvements to the UK GHG inventory (such as the restructuring of sector 1A2 in the latest inventory cycle) are approved and managed via the NISC, with new outputs approved through the UK's arrangements for pre-submission review. The inventory improvement process that manages the prioritisation and implementation of revisions to inventory data and methods uses the guiding principles of the 1996 IPCC Guidelines and 2000 Good Practice Guidance to govern the decisions over whether to implement changes to inventory estimates or not. For the most significant recalculations to the UK GHG inventory reported in this submission, we have highlighted the key underlying justifications for making the change (see section 10.4.2). The most common justifications for implementing changes that lead to recalculations are:

- ✓Improved **accuracy** of the estimates, e.g. where underlying data from data providers has been revised (such as revisions to UK energy statistics), or where a less uncertain data source has come to light (such as the use of EU ETS activity data to inform energy allocations, in preference to UK energy statistics data sources). This justification also applies where we have sought to use more representative (ideally UK-specific) emission factors in estimation methods (such as the use of emission factors derived from EU ETS analysis in recent years of the inventory time series);
- ✓Improved **transparency** of the inventory estimates, e.g. the restructuring of inventory data reporting to improve the level of detail of the UK inventory (such as the restructuring of 1A2 estimates in this cycle, or the reporting of F-gas estimates by species wherever this is achievable);
- ✓Improved **comparability** of the inventory estimates, e.g. the restructuring of inventory data reporting to enable UK estimates to align more closely with IPCC GLs and GPGs, (such as the re-allocations of limestone and dolomite data in the glass sector from 2A3 and 2A4 to 2A7, which was implemented to enable more harmonised data reporting across EU Member States).

- ✓Improved **completeness** of the inventory estimates, e.g. the addition of emission estimates for new sources that come to light in the UK, or where new data for an existing source indicates that the activity data previously used in the method omitted some portion of the source emissions (such as the use of EU ETS activity data to revise the estimates of emissions from refineries in the UK, where a gap in UK energy data reporting was identified through comparison against EUETS data for the sector);
- ✓Improved **consistency** of the inventory estimates, e.g. to implement new or revised methods that deliver estimates based on more consistent underlying data or assumptions across the time series (such as the revision to the waste water treatment and disposal method in 6B to use the available time series of sewage sludge disposal data rather than extrapolate from an historic industry study, using population data as the key activity to estimate emissions for later years in the time series).

Table 10-1 Re-Calculations of direct GHG emissions for the year 2009 in the UK 2012 NIR (2010 inventory) – including KP-LULUCF inventory.

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2010 inventory minus emissions in 2009 inventory)	Change in emissions (%) (Percentage change relative to the 2009 inventory)	Brief description of reasons for Re-Calculation
1A1			
CO_2	4559.3	3%	• Increase in emissions due to OPG use in refineries following identification of gaps in energy statistics. • Increase in emissions due to gas oil use in oil and gas extraction, which has been included in DUKES for the first time this year. This is only from 2005 onwards, however, it has been extrapolated back to maintain a consistent time series. • Revisions made to activity data in DUKES from 2004 onwards (including power stations, refineries and gas production). • Combustion of MSW for heat generation has been reallocated from 1A4a to 1A1. • Revised GCV for coke, blast furnace gas and coke oven gas - now reported to greater level of accuracy in DUKES.
CH_4	12.8	5%	• Increase in emissions due to OPG use in refineries following identification of gaps in energy statistics • Increase in emissions due to gas oil use in oil and gas extraction, which has been included in DUKES for the first time this year. This is only from 2005 onwards, however, it has been extrapolated back to maintain a consistent time series. • Revisions made to activity data in DUKES from 2004 onwards (including power stations, refineries and gas production). • Combustion of MSW, landfill gas and sewage gas for heat generation has been reallocated from 1A4a to 1A1. • Revised GCV for coke, blast furnace gas and coke oven gas - now reported to greater level of accuracy in DUKES.
N_2O	41.7	3%	• Increase in emissions due to OPG use in refineries following identification of gaps in energy statistics • Increase in emissions due to gas oil use in oil and gas extraction, which has been included in DUKES for the first time this year. This is only from 2005 onwards, however, it has been extrapolated back to maintain a consistent time series. • Revisions made to activity data in DUKES from 2004 onwards (including power stations, refineries and gas production). • Combustion of MSW, landfill gas and sewage gas for heat generation has been reallocated from 1A4a to 1A1. • Revised GCV for coke, blast furnace gas and coke oven gas - now reported to greater level of accuracy in DUKES.

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2010 inventory minus emissions in 2009 inventory)	Change in emissions (%) (Percentage change relative to the 2009 inventory)	Brief description of reasons for Re-Calculation
1A2			
CO_2	145.6	0%	• New research has caused reallocation of gas oil across sectors. The national total remains unchanged. • Re-allocation of petrol and DERV from road transport to off-road machinery. • Fuel consumption data for lime production revised to be in line with EU ETS data. • Emissions from combustion of waste solvents in other industrial combustion have increased due to an updated emission factor. • Additional emissions allocated to OPG use following analysis of EUETS data, where DUKES is noted as an under-report. • Revised GCV for coke, blast furnace gas and coke oven gas - now reported to greater level of accuracy in DUKES. Revisions made to activity data in DUKES for fuel oil from 2000 onwards and other fuels from 2005 onwards.
CH_4	0.5	0%	• New research has caused reallocation of gas oil across sectors. The national total remains unchanged. • Re-allocation of petrol and DERV from road transport to off-road machinery. • Fuel consumption data for lime production revised to be in line with EU ETS data. • Additional emissions allocated to OPG use following analysis of EUETS data, where DUKES is noted as an under-report. • Revised GCV for fuel oil, gas oil and biomass fuels • Revisions made to activity data in DUKES for fuel oil from 2000 onwards and other fuels from 2005 onwards.
N_2O	-12.1	-1%	• New research has caused reallocation of gas oil across sectors. The national total remains unchanged. • Re-allocation of petrol and DERV from road transport to off-road machinery. • Fuel consumption data for lime production revised to be in line with EU ETS data. • Additional emissions allocated to OPG use following analysis of EUETS data, where DUKES is noted as an under-report. • Revised GCV for coal, fuel oil and gas oil. • Revisions made to activity data in DUKES for fuel oil from 2000 onwards and other fuels from 2005 onwards.
1A3			
CO_2	-432.4	0%	• Re-allocation of petrol and DERV from road transport to off-road machinery and inland waterways sectors. Revised vkm and vehicle fleet data.

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2010 inventory minus emissions in 2009 inventory)	Change in emissions (%) (Percentage change relative to the 2009 inventory)	Brief description of reasons for Re-Calculation
			• Revisions to gas oil activity data based on new research. • New source – inland waterways – fuel reallocated from international shipping. • New data source used for flights to and from overseas territories. Flights from OTs to UK now included. Minor changes to aircraft size categories. • Emissions from railways increased 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
CH_4	-0.6	-1%	• Re-allocation of petrol and DERV from road transport to off-road machinery and inland waterways sectors. Revised vkm and vehicle fleet data. • Revisions to gas oil activity data based on new research. • New source – inland waterways – fuel reallocated from international shipping. • New data source used for flights to and from overseas territories. Flights from OTs to UK now included. Minor changes to aircraft size categories. • Emissions from railways increased 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 • Emissions from road transport reduced due to the new method for estimating the composition of the vehicle fleet, particularly affecting emissions from artic HGVs.
N_2O	-130.3	-10%	• Re-allocation of petrol and DERV from road transport to off-road machinery and inland waterways sectors. Revised vkm and vehicle fleet data. • Revisions to gas oil activity data based on new research. • New source – inland waterways – fuel reallocated from international shipping. • New data source used for flights to and from overseas territories. Flights from OTs to UK now included. Minor changes to aircraft size categories. • Emissions from railways increased 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 • Emissions from road transport reduced due to the new method for estimating the composition of the vehicle fleet, particularly affecting emissions from artic HGVs.
1A4			

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2010 inventory minus emissions in 2009 inventory)	Change in emissions (%) (Percentage change relative to the 2009 inventory)	Brief description of reasons for Re-Calculation
CO_2	-468.7	0%	• Combustion of MSW for heat generation has been reallocated from 1A4a to 1A1, following a recommendation from the UNFCCC's review team. • Revisions to gas oil activity data based on new research (this is explained fully in section A3.3.4.1) • Re-allocation of petrol and DERV from road transport to off-road (garden) machinery, following a study in to gas oil definitions and use (see section A3.3.4.1) • Revised assumptions for domestic combustion in Gibraltar - previously assumed some natural gas use (now removed from the inventory). • Correction to LPG activity data for crown dependencies, (Accuracy) • Revised GCV for coke, coal and anthracite - now reported to greater level of accuracy in DUKES. • Revisions made to activity data in DUKES from 2005 onwards.
CH_4	-8.0	-1%	• Combustion of MSW, landfill gas and sewage gas for heat generation has been reallocated from 1A4a to 1A1. • Revisions to gas oil activity data based on new research (this is explained fully in section A3.3.4.1) • Re-allocation of petrol and DERV from road transport to off-road (garden) machinery, following a study in to gas oil definitions and use (see section A3.3.4.1) • Revised assumptions for domestic combustion in Gibraltar - previously assumed some natural gas use (now removed from the inventory). • Correction to LPG activity data for crown dependencies • Revised GCV for fuel oil and anthracite • Revisions made to activity data in DUKES from 2005 onwards.
N_2O	-2.0	0%	• Combustion of MSW, landfill gas and sewage gas for heat generation has been reallocated from 1A4a to 1A1. • Revisions to gas oil activity data based on new research (this is explained fully in section A3.3.4.1) • Re-allocation of petrol and DERV from road transport to off-road (garden) machinery, following a study in to gas oil definitions and use (see section A3.3.4.1) • Revised assumptions for domestic combustion in Gibraltar - previously assumed some natural gas use (now removed from the inventory). • Correction to LPG activity data for crown dependencies • Revised GCV for coal, fuel oil, coke, anthracite and SSF. • Revisions made to activity data in DUKES from 2005 onwards.

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2010 inventory minus emissions in 2009 inventory)	Change in emissions (%) (Percentage change relative to the 2009 inventory)	Brief description of reasons for Re-Calculation
1A5			
CO_2	622.1	26%	• Military aviation spirit included for the first time. • Military Casual Uplift included.
CH_4	0.4	28%	• Military aviation spirit included for the first time. • Military Casual Uplift included.
N_2O	5.9	26%	• Military aviation spirit included for the first time. • Military Casual Uplift included.
1B1			
CO_2	-0.9	-1%	• Revisions made to activity data in DUKES from 2008 onwards.
CH_4	-908.3	-32%	• A review has been conducted on emissions from closed coal mines, to reflect known changes in the mining industry (e.g. mines that closed earlier or remained open longer than projected), and also to reflect the impacts of coal mine methane utilisation. • Revisions made to activity data in DUKES from 2008 onwards.
N_2O	0.0	-1%	• Revisions made to activity data in DUKES from 2008 onwards.
1B2			
CO_2	29.0	1%	• Revisions to operator data from 2008 onwards
CH_4	0.3	0%	• Revisions to operator data from 2008 onwards
N_2O	0.0	0%	• Revisions to operator data from 2008 onwards
2A			
CO_2	-382.8	-7%	• The emission factor for lime production has been revised to reflect the mixture of limestone and dolomite used. • Revisions have been made to emissions from fletton brick manufacture following correction of an error in calculations for one site.

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2010 inventory minus emissions in 2009 inventory)	Change in emissions (%) (Percentage change relative to the 2009 inventory)	Brief description of reasons for Re-Calculation
CH_4	0.0	1%	• Revisions have been made to emissions from fletton brick manufacture following correction of an error in calculations for one site
2B			
CO_2	48.8	2%	• CO_2 recovery is no longer subtracted from the emissions total for ammonia production. This is because it is not clear if the storage is permanent and to ensure compliance with the IPCC guidelines. • From 2006 onwards revisions have been made to vehicle statistics and sales data for household products, affecting the emissions from the breakdown of consumer products.
2C			
CO_2	61.1	5%	• The use of updated data in the carbon balance leads to an increase in the emission factor generated for blast furnace gas and, thus, an increase in emissions. • Revision to energy statistics in 2009.
CH_4	-0.1	-1%	• Revision to energy statistics in 2009.
2E			
HFC	-10.76	-10%	• Correction. Projected value previously used.
2F			
HFC	3048.8	28%	• The refrigeration and air conditioning model has been re built to utilise bottom up data across all categories. All parameters have been reviewed and revised.
PFC	-2.595	-3%	• The refrigeration and air conditioning model has been re built to utilise bottom up data across all categories. All parameters have been reviewed and revised.
4A			
CH_4	68.2	0%	• Animal numbers were revised and updated. • Animal categories have been revised and updated. • The time spent grazing for dairy and beef cattle has been changed. • For dairy cows the Tier 2 methodology for calculating enteric methane was revised from the 1996 Guidelines to the IPCC 2000 Good Practice Guidance.

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2010 inventory minus emissions in 2009 inventory)	Change in emissions (%) (Percentage change relative to the 2009 inventory)	Brief description of reasons for Re-Calculation
4B			
CH_4	-168.0	-6%	• Animal numbers were revised and updated. • Animal categories have been revised and updated. • The time spent grazing for dairy and beef cattle has been changed. • Tier 2 for CH_4 from manure management has been developed. AWMS distribution has been updated.
N_2O	-282.8	-14%	• Animal numbers were revised and updated. • Animal categories have been revised and updated. • Updated N excretion factors for cattle. • AWMS distribution has been updated. • The N_2O-N emitted during manure management is no longer subtracted from the N available to apply to soils.
4D			
N_2O	1149.7	5%	• Animal numbers were revised and updated. • Animal categories have been revised and updated. • Updated N excretion factors for cattle. • AWMS distribution has been updated. • Crop areas, production and categories have been updated. • The N_2O-N emitted during manure management is no longer subtracted from the N available to apply to soils. • Correction to the calculation of direct N_2O from grazing - the N input is no longer corrected for 20% atmospheric deposition. • Crop residues now include all legumes not only Phaseolus beans. • Amended crop residue calculations to account for fraction of residue burnt (applies to wheat, barley, oats, linseed). • Field burning detailed calculations have been amended to include the years 1990-1993.
5A			
CO_2	33.6	0%	• Small changes in net emissions/removals from this category arise from updated activity data and improved reporting of deforestation. • Deforestation data derived from unconditional felling licences was previously only available for England. Felling licence data from Scotland and Wales from the late 1990s onwards are included for the first time, with gap-filling based upon Countryside Survey data used to determine deforestation rates in earlier years.

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2010 inventory minus emissions in 2009 inventory)	Change in emissions (%) (Percentage change relative to the 2009 inventory)	Brief description of reasons for Re-Calculation
CH_4	0.0	0%	• Small changes in net emissions/removals from this category arise from updated activity data and improved reporting of deforestation. • Deforestation data derived from unconditional felling licences was previously only available for England. Felling licence data from Scotland and Wales from the late 1990s onwards are included for the first time, with gap-filling based upon Countryside Survey data used to determine deforestation rates in earlier years.
N_2O	0.0	1%	• Small changes in net emissions/removals from this category arise from updated activity data and improved reporting of deforestation. • Deforestation data derived from unconditional felling licences was previously only available for England. Felling licence data from Scotland and Wales from the late 1990s onwards are included for the first time, with gap-filling based upon Countryside Survey data used to determine deforestation rates in earlier years.
5B			
CO_2	24.4	0%	• Restructuring of sub-category for 20 year transition period. Areas of forest converted to other land uses now reported by country.
CH_4	-0.3	-73%	• Restructuring of sub-category for 20 year transition period. Areas of forest converted to other land uses now reported by country. • New activity data for deforestation
N_2O	0.9	0%	• Restructuring of sub-category for 20 year transition period. Areas of forest converted to other land uses now reported by country. • Emissions from land use change more than 20 years ago not accounted
5C			
CO_2	-282.9	3%	• Restructuring of sub-category for 20 year transition period. Areas of forest converted to other land uses now reported by country. • New activity data for liming and deforestation, undisturbed grassland reported.
CH_4	-7.7	-55%	• Restructuring of sub-category for 20 year transition period. Areas of forest converted to other land uses now reported by country. • New activity data for liming and deforestation
N_2O	-0.8	-55%	• N_2O emissions from disturbance associated with land use conversion to Cropland were included for the first time.

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2010 inventory minus emissions in 2009 inventory)	Change in emissions (%) (Percentage change relative to the 2009 inventory)	Brief description of reasons for Re-Calculation
5D			
CO_2	-18.9	-7%	• Corrections to the land use change model, and the new deforestation and liming data.
N_2O	0.0	-7%	• Corrections to the land use change model, and the new deforestation and liming data.
5E			
CO_2	162.3	3%	• Small changes in net emissions 1990-2010 arose from corrections to the land use change model. Updated activity data on deforestation, particularly Forest converted to Settlements was included, affecting net emissions/removals from this subcategory and associated biomass burning emissions.
CH_4	2.5	43%	• Small changes in net emissions 1990-2010 arose from corrections to the land use change model. Updated activity data on deforestation, particularly Forest converted to Settlements was included, affecting net emissions/removals from this subcategory and associated biomass burning emissions.
N_2O	0.3	43%	• Small changes in net emissions 1990-2010 arose from corrections to the land use change model. Updated activity data on deforestation, particularly Forest converted to Settlements was included, affecting net emissions/removals from this subcategory and associated biomass burning emissions.
5G			
CO_2	-44.1	2%	• Changing inputs to the harvested wood products pool (due to updated activity data for deforestation) resulted in small changes to the carbon emissions/removals from this category.
6A			
CH_4	-698.4	-4%	• Correction to model. Previous version included an error that overestimated DDOC landfilled. This change is fully described in Section 8.2.5.
6B			
CH_4	1.2	0%	• Removal of double count of emissions from sewage sludge applied to agriculture. • Revised emissions due to revised activity data in Northern Ireland.
N_2O	-218.0	-16%	• Removal of double count of emissions from sewage sludge applied to agriculture.
6C			
CO_2	-9.5	-3%	• Activity data for chemical and clinical waste incineration for 2009 replaced with up to date data.

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2010 inventory minus emissions in 2009 inventory)	Change in emissions (%) (Percentage change relative to the 2009 inventory)	Brief description of reasons for Re-Calculation
CH_4	0.0	0%	• Activity data for chemical and clinical waste incineration for 2009 replaced with up to date data.
N_2O	1.7	4%	• Activity data for chemical and clinical waste incineration for 2009 replaced with up to date data.

Table 10-2 Re-Calculations of direct GHG emissions for the base year in the UK 2012 NIR (2010 inventory).

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2010 inventory minus emissions in 2009 inventory)	Change in emissions (%) (Percentage change relative to the 2009 inventory)	Brief description of reasons for Re-Calculation
1A1			
CO_2	1249.6	1%	• Gas oil use in oil and gas extraction -has been included in DUKES for the first time this year. This is only from 2005 onwards, however, it has been extrapolated back to maintain a consistent time series. • Combustion of MSW for heat generation moved from 1A4a to 1A1 • Revised GCV for coke, blast furnace gas and coke oven gas - now reported to greater level of accuracy in DUKES.
CH_4	14.1	7%	• Gas oil use in oil and gas extraction -has been included in DUKES for the first time this year. This is only from 2005 onwards, however, it has been extrapolated back to maintain a consistent time series. • Combustion of MSW, landfill gas and sewage gas for heat generation moved from 1A4a to 1A1 • Revised GCV for fuel oil, gas oil and biomass fuels
N_2O	45.2	2%	• Gas oil use in oil and gas extraction -has been included in DUKES for the first time this year. This is only from 2005 onwards, however, it has been extrapolated back to maintain a consistent time series. • Combustion of MSW, landfill gas and sewage gas for heat generation moved from 1A4a to 1A1 • Revised GCV for coal, fuel oil, gas oil and biomass fuels

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2010 inventory minus emissions in 2009 inventory)	Change in emissions (%) (Percentage change relative to the 2009 inventory)	Brief description of reasons for Re-Calculation
1A2			
CO_2	1260.2	1%	• New research has caused reallocation of gas oil across sectors. National total remains unchanged. • Re-allocation of petrol and DERV from road transport to off-road machinery. • Changes made to lime sector. Fuel combustion assumptions revised in line with the comprehensive data available for later years from EU ETS. • Additional emissions allocated to OPG use following analysis of EUETS data, where DUKES is noted as an under-report. • Revised GCV for coke, blast furnace gas and coke oven gas - now reported to greater level of accuracy in DUKES.
CH_4	2.6	1%	• New research has caused reallocation of gas oil across sectors. National total remains unchanged. Re-allocation of petrol and DERV from road transport to off-road machinery. • Changes made to lime sector. Fuel combustion assumptions revised in line with the comprehensive data available for later years from EU ETS. • Additional emissions allocated to OPG use following analysis of EUETS data, where DUKES is noted as an under-report. • Revised GCV for fuel oil, gas oil and biomass fuels
N_2O	114.1	7%	• New research has caused reallocation of gas oil across sectors. National total remains unchanged. • Re-allocation of petrol and DERV from road transport to off-road machinery. • Changes made to lime sector. Fuel combustion assumptions revised in line with the comprehensive data available for later years from EU ETS. • Additional emissions allocated to OPG use following analysis of EUETS data, where DUKES is noted as an under-report. • Revised GCV for coal, fuel oil and gas oil.
1A3			
CO_2	-488.2	0%	• Re-allocation of petrol and DERV from road transport to off-road machinery and inland waterways sectors. Revised vkm and vehicle fleet data. • Revisions to gas oil activity data based on new research. • New source: inland waterways • New data source used for flights to and from overseas territories. Flights from OTs to UK now included. Minor changes to aircraft size categories.

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2010 inventory minus emissions in 2009 inventory)	Change in emissions (%) (Percentage change relative to the 2009 inventory)	Brief description of reasons for Re-Calculation
CH_4	1.7	0%	• Re-allocation of petrol and DERV from road transport to off-road machinery and inland waterways sectors. Revised vkm and vehicle fleet data. • Revisions to gas oil activity data based on new research. • New source: inland waterways • New data source used for flights to and from overseas territories. Flights from OTs to UK now included. Minor changes to aircraft size categories.
N_2O	3.5	0%	• Re-allocation of petrol and DERV from road transport to off-road machinery and inland waterways sectors. Revised vkm and vehicle fleet data. • Revisions to gas oil activity data based on new research. • New source: inland waterways • New data source used for flights to and from overseas territories. Flights from OTs to UK now included. Minor changes to aircraft size categories. • Revised cold-start trip length data for N_2O • Revised GCV for coal.
1A4			
CO_2	-1450.5	-1%	• Re-allocation of petrol and DERV from road transport to off-road (garden) machinery. • Revisions to gas oil activity data based on new research. • Revised assumptions for domestic combustion in Gibraltar, previously assumed some natural gas use. • Correction to LPG activity data for crown dependencies • Revised GCV for coke, coal and anthracite - now reported to greater level of accuracy in DUKES.
CH_4	-17.4	-1%	• Re-allocation of petrol and DERV from road transport to off-road (garden) machinery. • Revisions to gas oil activity data based on new research. • Revised assumptions for domestic combustion in Gibraltar, previously assumed some natural gas use. • Correction to LPG activity data for crown dependencies • Revised GCV for fuel oil and anthracite

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2010 inventory minus emissions in 2009 inventory)	Change in emissions (%) (Percentage change relative to the 2009 inventory)	Brief description of reasons for Re-Calculation
N_2O	-6.1	-1%	• Re-allocation of petrol and DERV from road transport to off-road (garden) machinery. • Revisions to gas oil activity data based on new research. • Revised assumptions for domestic combustion in Gibraltar, previously assumed some natural gas use. • Correction to LPG activity data for crown dependencies • Revised GCV for coal, fuel oil, coke, anthracite and SSF.
2A			
CO_2	14.9	-0%	• The emission factor for lime production has been revised to reflect the mixture of limetsone and dolomite used.
2B			
CO_2	109.5	4%	• CO2 recovery is no longer subtracted from the emissions total. This is because it is not clear if the storage is permanent and to ensure compliance with the IPCC guidelines.
2F			
HFC	-130.07	-9%	• The refrigeration and air conditioning model has been re built to utilise bottom up data across all categories. All parameters have been reviewed and revised.
PFC	-0.218	0%	• The refrigeration and air conditioning model has been re built to utilise bottom up data across all categories. All parameters have been reviewed and revised.
4A			
CH_4	167.3	1%	• Animal numbers were revised and updated. • Animal categories have been revised and updated. • The time spent grazing for dairy and beef cattle has been changed. • For dairy cows the Tier 2 methodology for calculating enteric methane was revised from the 1996 Guidelines to the IPCC 2000 Good Practice Guidance.
4B			
CH_4	-22.1	-1%	• Animal numbers were revised and updated. • Animal categories have been revised and updated. • The time spent grazing for dairy and beef cattle has been changed.

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2010 inventory minus emissions in 2009 inventory)	Change in emissions (%) (Percentage change relative to the 2009 inventory)	Brief description of reasons for Re-Calculation
			• Tier 2 for CH4 from manure management has been developed.
N_2O	-706.2	-26%	• Animal numbers were revised and updated. • Animal categories have been revised and updated. • Updated N excretion factors for cattle. • AWMS distribution has been updated. • The N2O-N emitted during manure management is no longer subtracted from the N available to apply to soils.
4D			
N_2O	733.6	2%	• Animal numbers were revised and updated. • Animal categories have been revised and updated. • Updated N excretion factors for cattle. • AWMS distribution has been updated. • Crop areas, production and categories have been updated. • The N_2O-N emitted during manure management is no longer subtracted from the N available to apply to soils. • Correction to the calculation of direct N_2O from grazing - the N input is no longer corrected for 20% atmospheric deposition. • Crop residues now include all legumes not only Phaseolus beans. Amended crop residue calculations to account for fraction of residue burnt (applies to wheat, barley, oats, linseed).
5B			
CO_2	37.5	0%	• Restructuring of sub-category for 20 year transition period. Areas of forest converted to other land uses now reported by country.
CH_4	0.0	3%	• Restructuring of sub-category for 20 year transition period. Areas of forest converted to other land uses now reported by country. • New activity data for deforestation
N_2O	-0.2	0%	• Restructuring of sub-category for 20 year transition period. Areas of forest converted to other land uses now reported by country. • Emissions from land use change more than 20 years ago not accounted
5C			

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2010 inventory minus emissions in 2009 inventory)	Change in emissions (%) (Percentage change relative to the 2009 inventory)	Brief description of reasons for Re-Calculation
CO_2	-0.7	0%	• Restructuring of sub-category for 20 year transition period. Areas of forest converted to other land uses now reported by country. • New activity data for liming and deforestation, undisturbed grassland reported for completeness
CH_4	1.0	33%	• Restructuring of sub-category for 20 year transition period. Areas of forest converted to other land uses now reported by country. • New activity data for liming and deforestation
N_2O	0.1	33%	• N2O emissions from disturbance associated with land use conversion to Cropland were included for the first time.
5D			
CO_2	59.5	14%	• Corrections to the land use change model, and the new deforestation and liming data.
N_2O	0.0	0%	• Corrections to the land use change model, and the new deforestation and liming data.
5E			•
CO_2	-26.2	0%	• Small changes in net emissions 1990-2010 arose from corrections to the land use change model. Updated activity data on deforestation, particularly Forest converted to Settlements was included, affecting net emissions/removals from this subcategory and associated biomass burning emissions.
CH_4	-8.5	-46%	• Small changes in net emissions 1990-2010 arose from corrections to the land use change model. Updated activity data on deforestation, particularly Forest converted to Settlements was included, affecting net emissions/removals from this subcategory and associated biomass burning emissions.
N_2O	-0.9	-46%	• Small changes in net emissions 1990-2010 arose from corrections to the land use change model. Updated activity data on deforestation, particularly Forest converted to Settlements was included, affecting net emissions/removals from this subcategory and associated biomass burning emissions.
5G			•
CO_2	-90.2	6%	• Changing inputs to the harvested wood products pool (due to updated activity data for deforestation) resulted in small changes to the carbon emissions/removals from this category.
6A			•
CH_4	-13073.2	-23%	• Correction to model. Previous version included an error that overestimated DDOC landfilled. This change is fully described in Section 8.2.5.

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2010 inventory minus emissions in 2009 inventory)	Change in emissions (%) (Percentage change relative to the 2009 inventory)	Brief description of reasons for Re-Calculation
6B			
CH_4	-0.1	0%	• Removal of double count of emissions from sewage sludge applied to agriculture. • Small revisions to data from Northern Ireland.
N_2O	-85.8	-7%	• Removal of double count of emissions from sewage sludge applied to agriculture. • Small revisions to data from Northern Ireland.
6C			
CO_2	15.1	1%	• Revision to emission factor for clinical waste incineration
•			
• KP-LULUCF Inventory			
• 3.3 Afforestation			
CO_2	17.9	-1%	• New activity data on afforestation • Emissions from wildfires now split between Afforestation land and Forest Management
CH_4	2.1	-	• New activity data on afforestation • Emissions from wildfires now split between Afforestation land and Forest Management
N_2O	0.2	22%	• New activity data on afforestation • Emissions from wildfires now split between Afforestation land and Forest Management
• 3.3 Deforestation			
CO_2	-84.2	-13%	• New activity data for deforestation • Emissions from deforestation in Northern Ireland reported for the first time • Emissions from deforestation to cropland estimated for the first time • Emissions from liming on deforested land reported for first time
CH_4	-2.6	-15%	• New activity data for deforestation • Emissions from deforestation in Northern Ireland reported for the first time • Emissions from deforestation to cropland estimated for the first time • Emissions from liming on deforested land reported for first time

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2010 inventory minus emissions in 2009 inventory)	Change in emissions (%) (Percentage change relative to the 2009 inventory)	Brief description of reasons for Re-Calculation
N_2O	0.6	31%	• New activity data for deforestation • Emissions from deforestation in Northern Ireland reported for the first time • Emissions from deforestation to cropland estimated for the first time • Emissions from liming on deforested land reported for first time
• 3.4 Forest Management			
CO_2	17.6	0%	• Forest management area adjusted to take account of new deforestation activity data • Emissions from wildfires now split between Afforestation land and Forest Management
CH_4	-2.1	-22%	• Forest management area adjusted to take account of new deforestation activity data • Emissions from wildfires now split between Afforestation land and Forest Management
N_2O	-0.2	-22%	• Forest management area adjusted to take account of new deforestation activity data • Emissions from wildfires now split between Afforestation land and Forest Management

Table 10-3 Changes in methodological descriptions

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	DESCRIPTION OF METHODS	RECALCULATIONS	REFERENCE
	Please tick where the latest NIR includes major changes in methodological descriptions compared to the previous year NIR	Please tick where this is also reflected in recalculations compared to the previous year CRF	If ticked please provide some more detailed information for example related to sub-category, gas, reference to pages in the NIR, etc
Total (Net Emissions)			
1. Energy			
A. Fuel Combustion (Sectoral Approach)			
1. Energy Industries	√	√	OPG activity data, section 3.2.6.2. Recalculations - refineries and gas extraction. Reallocation of heat generation. Section 3.2.6.5
2. Manufacturing Industries and Construction	√	√	Reallocation within sector (disaggregation of 1A2f to 1A2b-e). Review of gas oil combustion. Section 3.2.7.5
3. Transport	√	√	Inclusion of inland waterways for first time. Section 3.2.8.2.
4. Other Sectors	√	√	Reallocation of heat generation. Gas oil review. OPG activity data. Section 3.2.9.5
5. Other			
B. Fugitive Emissions from Fuels			
1. Solid Fuels	√	√	Emissions from closed coal mines. Section 3.3.1.2
2. Oil and Natural Gas		√	Section 3.3.2.5
2. Industrial Processes			
A. Mineral Products	√	√	Calculation of new limestone EF Section 4.3.2. Reallocation emissions from the glass industry to 2A7. Section 4.4.5 and 4.5.5
B. Chemical Industry	√	√	CO2 from 2B1; Section 4.9.2
C. Metal Production			
D. Other Production			
E. Production of Halocarbons and SF6			
F. Consumption of Halocarbons and SF6	√	√	Refrigeration model has been reviewed. Section 4.22
G. Other			
3. Solvent and Other Product Use			
4. Agriculture			
A. Enteric Fermentation	√	√	Section 6.2
B. Manure Management	√	√	Section 6.3
C. Rice Cultivation			
D. Agricultural Soils	√	√	Section 6.5.5
E. Prescribed Burning of Savannas			

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	DESCRIPTION OF METHODS Please tick where the latest NIR includes major changes in methodological descriptions compared to the previous year NIR	RECALCULATIONS Please tick where this is also reflected in recalculations compared to the previous year CRF	REFERENCE If ticked please provide some more detailed information for example related to sub-category, gas, reference to pages in the NIR, etc
Total (Net Emissions)			
F. Field Burning of Agricultural Residues			
G. Other			
5. Land Use, Land-Use Change and Forestry			
A. Forest Land	√		Section 7.2
B. Cropland	√	√	Section 7.3
C. Grassland	√	√	Section 7.4
D. Wetlands	√	√	Section 7.5
E. Settlements	√	√	Section 7.6
F. Other Land			
G. Other			
6. Waste			
A. Solid Waste Disposal on Land	√	√	Landfill model. Section 8.2
B. Waste-water Handling	√	√	Removal of double count with agriculture sector. Section 8.3.2
C. Waste Incineration		√	Section 8.4.4
D. Other			
7. Other (as specified in Summary 1.A)			
Memo Items:			
International Bunkers			
Aviation			
Marine	√	√	Reallocation to inland waterways. Section 3.2.8.2
Multilateral Operations			
CO2 Emissions from Biomass			

10.2 IMPLICATIONS FOR EMISSION LEVELS

10.2.1 GHG Inventory

The implications for emission levels in the year 2009, 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**.

10.3 IMPLICATIONS FOR EMISSION TRENDS, INCLUDING TIME SERIES CONSISTENCY

10.3.1 GHG Inventory

The effects of the re-calculations and improvements made in the 2010 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 2009 inventory.

Figure 10.1 summarises the effect of the recalculations in the 2012 NIR (2010 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 2009 and 2010, according to IPCC source sector. A negative difference indicates a decline in GWP emissions between the inventory presented in the 2012 NIR (2010 inventory), and the inventory presented in the 2011 NIR (2009 inventory). The LULUCF totals are presented as net emissions.

Figure 10.2 summarises the effect of the recalculations in the 2012 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 2009 and 2010.

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 (2010 inventory; 2012 NIR); and
PS = Previous Submission (2009 inventory, 2011 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 improvements to the model for estimating emissions from landfill and a revision of the model for estimating emissions from refrigeration and air conditioning.

For later years, totals have also been affected by significant revisions to national fuel use statistics (DECC, 2011). The changes in the time series of GWP emissions in **Figure 10.2** reflect these enhancements. A summary of the key reasons for the changes are given below. More detailed information is given in the sections describing the source-specific recalculations given in **Chapters 3 to 8**.

Reasons for changes in GWP emissions in the base year

- Re-calculations in the base year have led to a net decrease in emissions of 12,286 Gg CO_2 eq;

- The largest single change to emissions in the base year was an increase of 13,073 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 have increased by 588 Gg CO_2 eq following the implementation of changes across the time series to address a small gap in reporting of OPG use in petrochemical plant that are co-located with upstream oil and gas terminals and refinery installations. Consultation with DECC has identified the reasons for the apparent under-report for a small number of UK sites and further work may be implemented to improve the historic time series estimates.

Reasons for changes in GWP emissions in 2009

- Re-calculations in 2009 have led to an increase in emissions of 5,932 Gg CO_2 eq;
- The largest single change to emissions in 2009 was an increase in emissions of 3,049 Gg CO_2 eq of HFCs in IPCC sector 2F due to revisions to the refrigeration and air conditioning model which has been re-built to utilise bottom up data across all categories. All parameters have been reviewed and revised.
- Emissions have increased by 2,163 Gg CO_2 eq following the above changes to OPG use in petrochemical plant.
- Emissions from agricultural soils have increased by 1,150 Gg CO_2 eq of N_2O due to changes in calculations; the N_2O-N emitted during manure management is no longer subtracted from the N available to apply to soils. A correction has also been applied to the calculation of direct N_2O from grazing - the N input is no longer corrected for 20% atmospheric deposition.

Figure 10-1 Time series of changes in GWP emissions between the inventory presented in the current and the previous NIR, according to IPCC source sector.

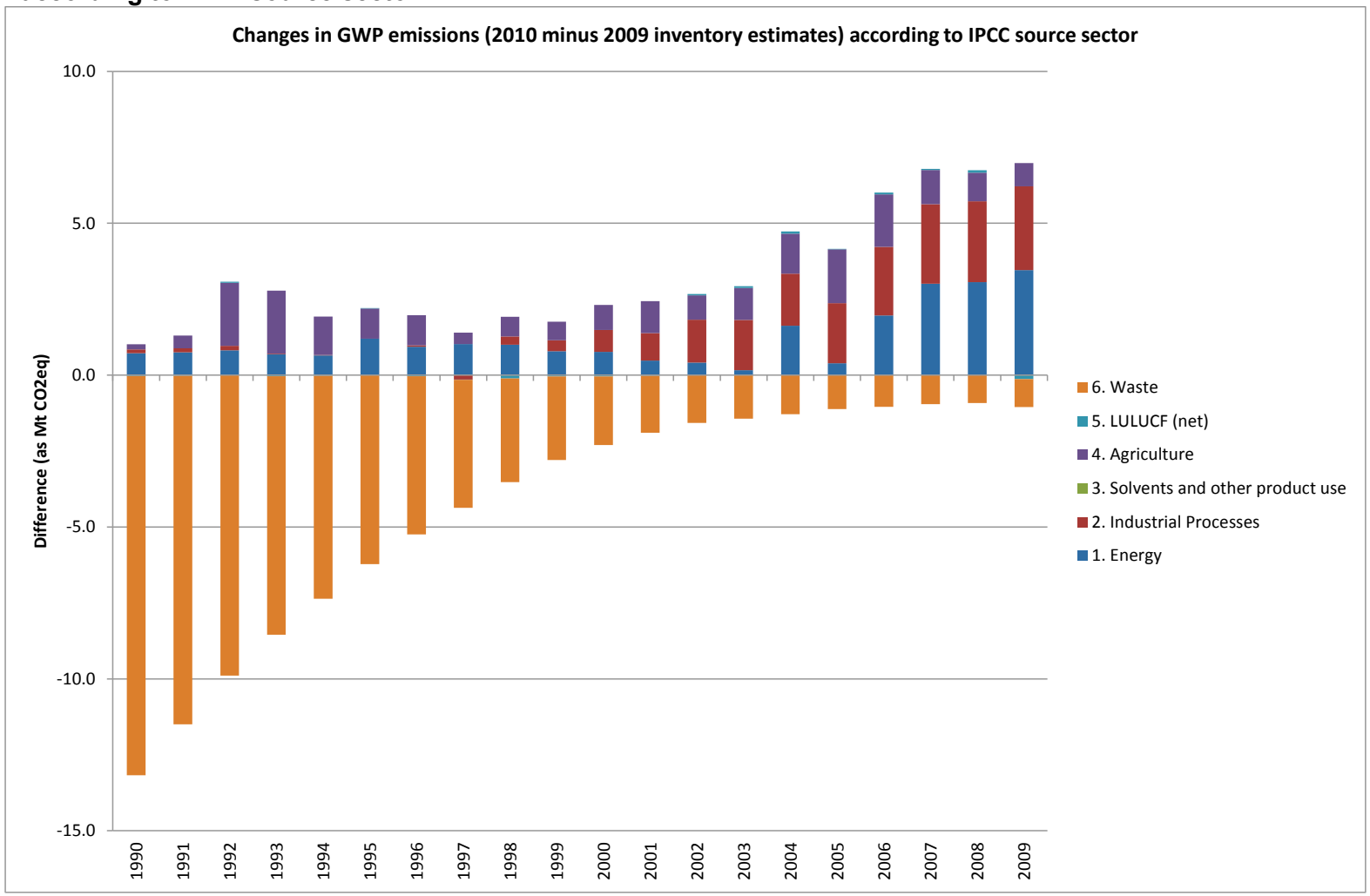
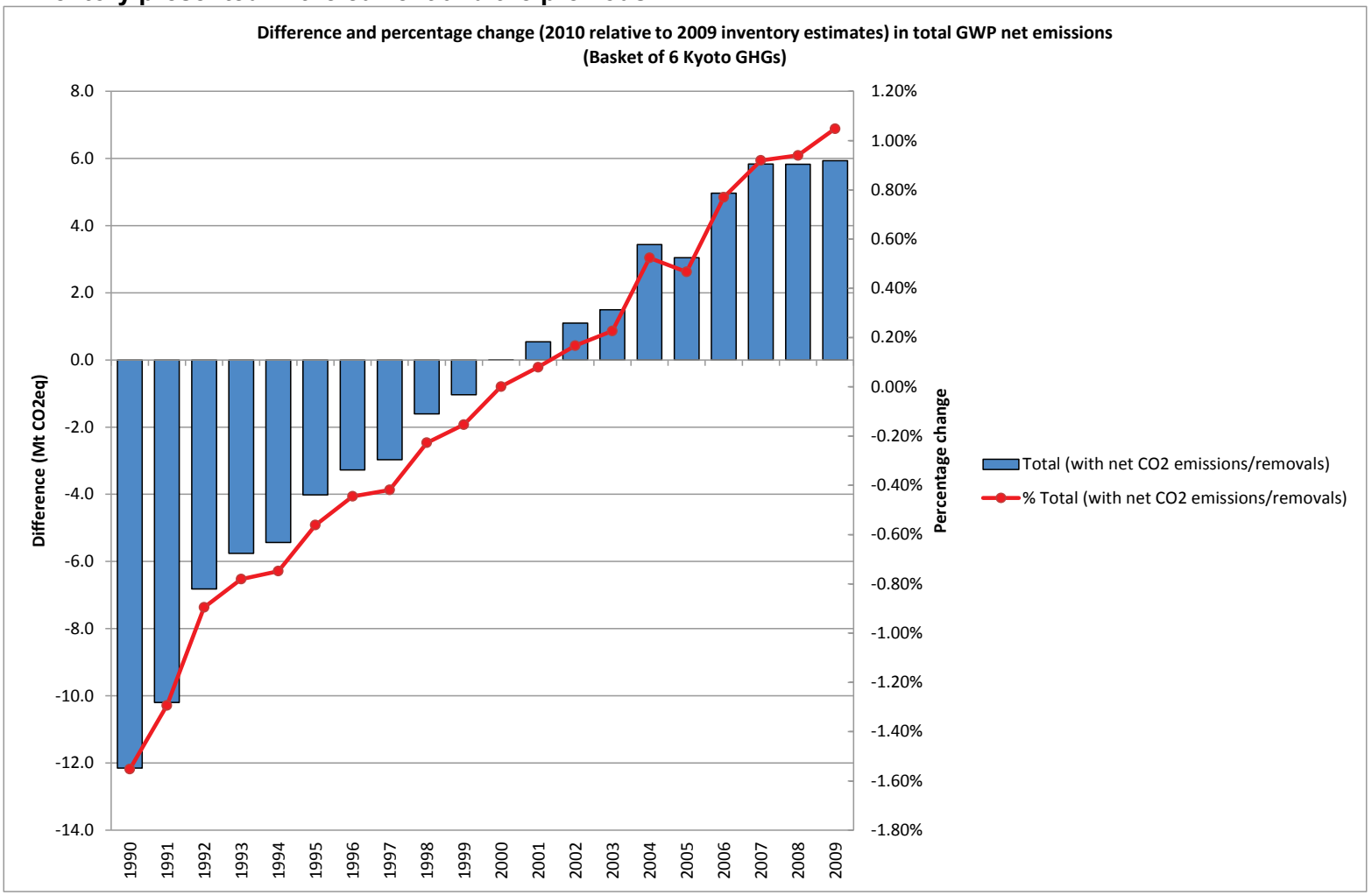


Figure 10-2 Time series of changes in total net GWP emissions, and percentage changes in total net GWP emissions, between the inventory presented in the current and the previous NIR.



10.4 RESPONSE TO THE REVIEW PROCESS

10.4.1 GHG Inventory

The UNFCCC conducted a Centralised Review of the 2011 greenhouse gas inventory submission (2011 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 (2011) submission. The review took place during September 2011 in Bonn, Germany.

Table 10-4 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. This table replaces those previously present in the NIR add presents responses to the overall recommendations from the draft report on the September 2011 UNFCCC centralised review. This report was communicated to the UK in March 2012.

Table 10-4 Brief Details of Improvements to the NIR and the Inventory in response to FCCC Reviews in response to the 2009 reviews.

Expert Review Team Comment	UK GHGI Actions	Time frame
Recommendations from ARR Report : March 2012		
The ERT identifies the following cross-cutting issues for improvement:		
Strengthen the efforts to implement the recommendations of previous review reports, especially those that had already been reiterated from the review before:		
Including, in the main body of the NIR, a complete discussion on completeness	As well as the completeness table in Annex 5, a short discussion on completeness is now included in each methodological chapter.	Included in 2012 submission
Allocating emissions from fuels used in manufacturing industries and construction to the appropriate subcategories	Emissions from fuels used in manufacturing industries are now reported in the appropriate categories where possible. See Section 3.2.7 for more details.	Included in 2012 submission
Reporting emissions of F-gases by species	Where available, speciated emissions of f-gases are reported. Unspeciated emissions are reported for some of the emissions of fugitive PFCs from manufacture, where speciated data are not available, and for the Overseas Territories and Crown Dependencies. Estimates for these locations are made at an aggregated level.	The investigation of reporting further speciated emissions will be added to the improvement programme although this is a low priority.
Improving the reporting on the OTs and CDs by including information on the methods and data used for estimating their emissions and consistent reporting across categories and sectors	More description has been included in the NIR on the methods and data used for estimating these emissions. Where it is possible to include OT and CD emissions within main sectors (not reporting as 'other') this has been done and stated as such in the main chapters.	Further information has been included in the 2012 submission. Reporting will be reviewed and improved for the 2013 submission.
Undertaking a qualitative analysis to ensure that categories which are particularly significant in level or trend are identified as key categories	A qualitative analysis is now done to ensure significant categories are identified. No additional key categories were identified.	Description of qualitative analysis included in **Section 1.2.2.4.**
Including information on the time frame for addressing the recommendations of the review activities	Where possible, the time frame for addressing recommendations is included in the NIR.	Included in **Table 10-4**.

Expert Review Team Comment	UK GHGI Actions	Time frame
Estimating emissions from wildfires on deforestation lands or provide evidence that wildfires do not occur	The assessment of a fire incidence dataset and the potential of remote sensing for reporting wildfires is now underway. New data for UK wildfires is being examined and we will report emissions for this category in the 1990-2011 inventory.	To be reported in 2013 submission.
Improve reporting of KP-LULUCF to ensure complete, accurate and unbiased reporting of KP-LULUCF activities on all lands in the United Kingdom	We have used new activity data to update the deforestation estimates for all countries in the UK. Methods are fully explained in Annex 3.7. We have used NFI data in the latest submission where available, but estimates of woodland loss from the NFI are still being assessed by the Forestry Commission. There is very limited forest area information for the OTs and CDs and the FAO Forest Resource Assessment 2010 reports that there has been no change in the forest area of these territories since 1990 (section 11.2.1). If/when new data becomes available we will include it in the next submission.	Part complete - more information to be included in 2013 submission.
Improve the description of recalculations by providing clear documentation and explanations on the justifications used for the changes made in methodologies, assumptions, data and parameters, and also ensure that any recalculation performed leads to a real improvement of the inventory	All method changes feed into the inventory through the improvement programme and are approved by the NISC at the pre-submission review. Additional descriptions have been included within the main chapter of the NIR on the reasons for recalculations and additional checks have been performed to ensure these descriptions are consistent in chapter 10 as in the methodology chapters.	Improvements have been made to the text in the 2012 submission.
Continue to strengthen QC procedures at the stage of inventory compilation to avoid erroneous entries in CRF tables and mistakes in the text of the NIR	All submissions now undergo a 'knowledge leader check' where a senior member of the team who has not had the responsibility of compiling the CRF, or performing any of the initial cross checks, checks the outputs to ensure consistency with the NIR and our internal database.	Additional checks have been implemented for the 2012 submission.
Improve the transparency of the inventory regarding the presentation of information on OTs and CDs in the CRF (e.g. include distinct AD and emissions from OTs and CDs under waste incineration) and the description of the geographical coverage for each reported category in the NIR	More description has been included in the NIR on the methods and data used for estimating these emissions. Where it is possible to include OT and CD emissions within main sectors (not reporting as 'other') this has been done and stated as such in the main chapters.	The improvement programme includes trying to obtain more detailed information, particularly for the waste sector for the 2013 submission.

Expert Review Team Comment	UK GHGI Actions	Time frame
Continue to improve the consistency and appropriateness of notation keys usage	All submissions now undergo a 'knowledge leader check' where a senior member of the team who has not had the responsibility of compiling the CRF or carrying out initial cross checks, checks the outputs to ensure consistency with the NIR and our internal database.	Additional checks have been carried out for the 2012 submission.
In the course of the review, the ERT formulated a number of sector-specific recommendations relating to the transparency and accuracy of the information presented in the United Kingdom's annual submission. The key recommendations are that the United Kingdom:		
Increase the transparency on reported recalculations in the energy and waste sector as follows: recheck the new data and the changes in the methods, assumptions and parameters used in the estimates and further justify those in the NIR or return to the previous values (e.g. for solid waste disposal on land), until ensuring sufficient evidence to justify the changes; provide justification, description and references for the new EF for CH4 from wastewater handling and ensure it represents the United Kingdom as a whole	Additional text has been included in the waste chapter to explain the rationale for the recalculations performed in the 2011 NIR. The text on recalculations throughout the report has been cross checked with the information presented in Chapter 10. Further information on the rationale for making recalculations has been included throughout the report, and in Section 10.1	Additional text has been included in the 2012 submission.
Improve the information provided on the treatment of feedstocks and nonenergy use of fuels in the inventory	The descriptions in the NIR and inclusion in the CRF have been checked and improved for the 2012 submission.	Additional text has been included in the 2012 submission.
Provide the necessary information on the model used to calculate the actual emissions of HFCs from consumption of halocarbons and SF6 (e.g. the EFs used in the model and the rationale for the selection of those values)	The model for estimating emissions of HFCs from refrigeration has been improved for the 2012 submission and more information included in the NIR.	Additional text has been included in the 2012 submission.
Follow the methodology described in the IPCC good practice guidance for the calculation of N2O emissions from agricultural soils	Emissions from agricultural soils have been recalculated in line with the IPCC GPG.	Recalculation has been made - additional text has been included in the 2012 submission.
Improve the transparency of the agriculture sector by including more information on country-specific EFs and other parameters, such as the lifespan of lambs in the NIR	Additional text on country specific parameters has been included in Annex 3.	Additional text has been included in the 2012 submission.

Expert Review Team Comment	UK GHGI Actions	Time frame
Ensure that there is a full representation of land areas under deforestation by including Northern Ireland, the OTs and CDs for the entire time series (KP-LULUCF)	We have used new activity data to update the deforestation estimates for all countries in the UK. Methods are fully explained in Annex 3.7. We have used NFI data in the latest submission where available, but estimates of woodland loss from the NFI are still being assessed by the Forestry Commission. There is very limited forest area information for the OTs and CDs and the FAO Forest Resource Assessment 2010 reports that there has been no change in the forest area of these territories since 1990 (section 11.2.1). If/when new data becomes available we will include it in the next submission.	Part complete - more information to be included in next submission.
Improve the completeness with respect to unaccounted emissions from the OTs under the waste sector	More description has been included in the NIR on the methods and data used for estimating these emissions. Where it is possible to include OT and CD emissions within main sectors (not reporting as 'other') this has been done and stated as such in the main chapters.	The improvement programme includes trying to obtain more detailed information, particularly for the waste sector for the 2013 submission.
Collect survey data for CH4 recovery and update the AD in order to avoid a possible overestimation of recovered CH4 and provide detailed information on the data	Much better quality data on the amounts of landfill gas flared is now becoming available from the UK's environmental regulators. See Annex Section A3.8.2 for more information.	Additional text has been included in the 2012 submission.

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: Landfill Waste (6A)

Correction of errors in updated landfill model
A detailed review of waste composition was undertaken during 2010 and new activity data have been included in the inventory. Since then, further checks have revealed a number of inconsistencies which have been corrected for the 2012 submission.

How are GHGs affected?
Methane emissions estimates are now 23 % lower in the base year than they have been in previous inventories. This difference decreases and in 2009, methane emissions estimates are 4% lower in the 2012 submission than the 2011 submission.

Justification?
Improved **accuracy**; the recalculation has removed errors from the calculations used for the previous submission. The UNFCCC ERT review feedback from the 2011 submission questioned the use of new input data to the UK model; we note that the use of more waste composition data from across the UK was implemented in the Eunomia research to improve the **completeness** of the inventory input dataset (e.g. to use, for the first time, compositional data from studies in Scotland and Northern Ireland) and therefore to deliver an UK landfill model that was more accurate and more representative of the UK sector. Some implementation errors from that revision to the model have now been corrected, and we are confident that the new UK landfill estimates are more complete and accurate, compared to the 2010 submission.

2) Sector: Waste water treatment (6B)

Revisions to N_2O emissions from wastewater treatment
A correction to the inventory method has been implemented. In the 2011 UK inventory submission, the introduction of reporting of N_2O emissions from sewage sludge applied to agriculture within the agricultural soils section of the UK inventory had introduced a double-count with estimates presented in IPCC 6B; this has been rectified by subtracting the estimate from the component of sludge disposed to agriculture, from the emission totals presented in 6B.

How are GHGs affected?
Nitrous oxide emissions have decreased across the time series.

Justification?
Improved **accuracy**; the recalculation has removed a double-count in emissions from across the time series.

3) Sector: Shipping

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.

How are GHGs affected?
Significant reduction in domestic shipping emissions and increase in international shipping emissions.

Justification?
Improved **accuracy**; the derivation of revised activity data from a detailed, bottom-up study using shipping movement data has enabled a more accurate estimate of domestic and international shipping emissions to be reported, supplementing the available UK energy balance data from DUKES.

4) Sector: Industrial Processes

Revisions to refrigeration and air conditioning model
The additional research and model improvements address the concerns raised by the UNFCCC ERT in 2010, relating to the use of country specific operational loss rates for transport refrigeration.

How are GHGs affected?
A small decrease in emissions of HFCs in the base year. In 2009, these improvements cause an increase in emissions of HFCs of 28%.

Justification?
Improved **transparency** of the UK emission estimates from this model with a more detailed insight into the inventory estimates and source data available in the research report. The revision has also improved the **accuracy** and **comparability** of UK estimates, through a review of the available UK-specific and international emission factors and subsequent recalculations using emission factors determined to be the most representative of UK emissions.

5) Sector: Industrial Combustion

Identification of gap in reporting of OPG combustion
Changes have been implemented across the time series to address a small gap in reporting of OPG use in: (i) petrochemical plant that are co-located with upstream oil and gas terminals, and (ii) refineries. The revisions were implemented following detailed review of data from EU ETS, environmental regulatory agencies and the refinery trade association, UKPIA. Consultation with DECC has identified the reasons for the apparent under-report for a small number of UK sites and further work may be implemented to improve the historic time series estimates.

How are GHGs affected?
Emissions have increased by 588 Gg CO_2 eq in the base year and over 2000 Gg CO_2 eq in 2009.

Justification?
Improved **completeness** of UK estimates. The use of new data from EU ETS and other resources to compare against reported UK energy statistics has enabled a gap in previous estimates to be addressed, in line with the IPCC Guidelines and Good Practice Guidance.

6) Sector: Agricultural Soils

Correction to method
N_2O-N emitted during manure management is no longer subtracted from the N available to apply to soils. A correction has also been applied to the calculation of direct N_2O from grazing - the N input is no longer corrected for 20% atmospheric deposition..

How are GHGs affected?
Emissions from agricultural soils have increased by 1,150 Gg CO_2 eq of N_2O in 2009 due to the above changes in calculations

Justification?
Improved **accuracy**; the recalculation has corrected methodological errors in the previous submission.

6) Sector: Industrial processes

Potential emissions
In response to a recommendation from the UNFCCC's review of the UK's inventory in 2011, the data for potential emissions of HFCs and PFCs in the CRF have been reviewed, and errors in the transcription of information into the CRF rectified. The ratio of potential to actual emissions is now much lower. No errors were found in the reporting of actual emissions.

How are GHGs affected?
This correction has made no difference to actual GHG emissions reported.

10.4.3 KP-LULUCF Inventory

3.3 Afforestation
New activity data has been used for afforestation and emissions from wildfires are now split between Afforestation and Land Management. This has caused a small decrease in Carbon emissions and an increase in CH_4 and N_2O emissions

3.3 Deforestation
Emissions from Deforestation in Northern Ireland; deforestation to cropland and liming on deforested land have been included for the first time

3.4 Forest Management
Forest Management areas have been adjusted to take into account new deforestation activity data and emissions from wildfires are now split between Afforestation and Land Management.

11 KP-LULUCF

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).

A new National Forest Inventory (NFI) has been undertaken in Great Britain (Forestry Commission 2011). This uses a different minimum area of 0.5 hectares and a lower integral open space threshold of 0.5 ha (as opposed to 1 ha), which requires a negative adjustment to areas. However, the main differences in 2010 GB woodland cover between the NFI (2982 kha) and previous estimates (2757 kha, Forestry Statistics 2010) arise from identified errors in the previous woodland survey, particularly the under-estimate of woodland areas between 0.5 and 2 hectares. Estimates of woodland loss are still being assessed, which will affect the total woodland area. The NFI area estimates are not used for this inventory submission, but will be used for the next submission once woodland loss estimates are confirmed.

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 'financial 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**

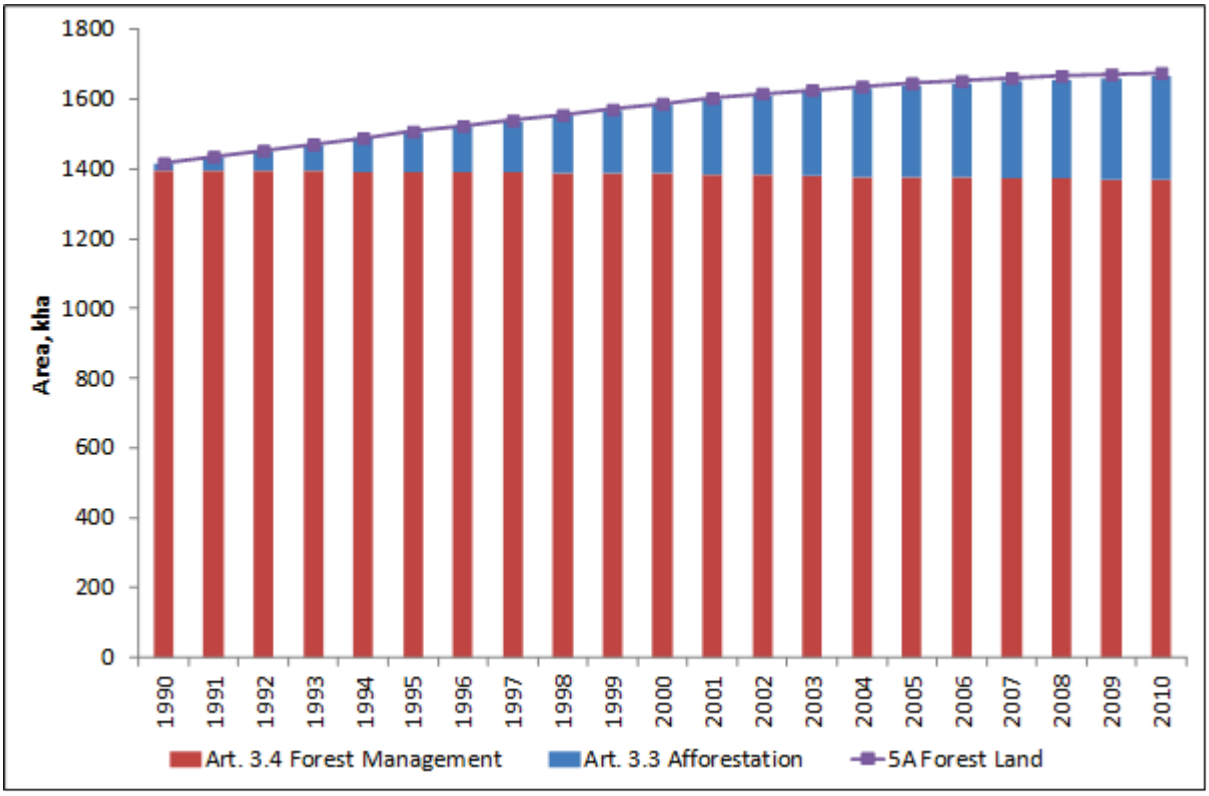
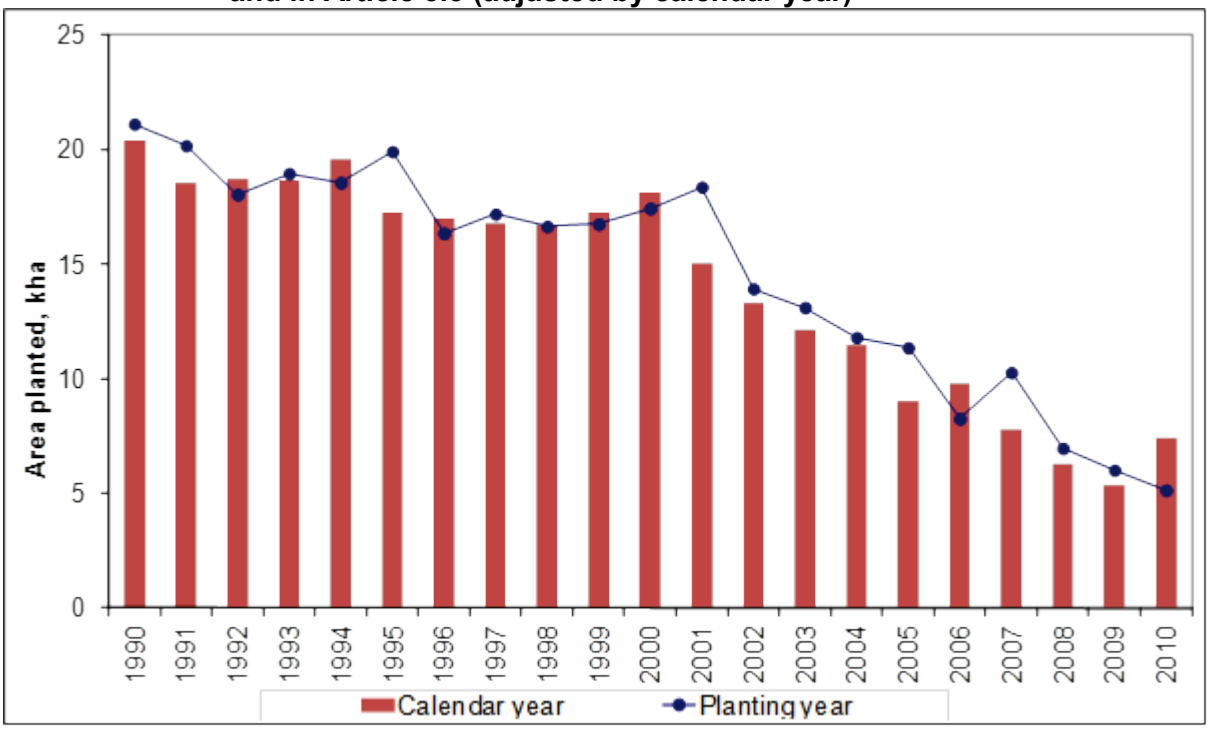


Figure 11-2 UK afforestation since 1990 in the UNFCCC GHGI (by planting year) and in Article 3.3 (adjusted by calendar year)



Deforestation since 1990 is taken to be the land area permanently converted from forest land to cropland, grassland or settlement. Areas of annual forest conversion are reported in the UNFCCC GHGI, and the cumulative total 1990-2010 matches the area reported under Article 3.3 Deforestation (27.74 kha).

New estimates of woodland loss from the National Forest Inventory have yet to be reconciled with inventory reporting, but the Forestry Commission are undertaking further work in this area during 2012. Woodland loss in the NFI is defined as an identifiable permanent removal of woodland cover to change the land use, where the remaining trees on a site no longer have the potential to achieve a minimum coverage of 20% (Forestry Commission 2011). A definitive land use change, such as construction or quarrying is registered as an immediate loss. However, where tree removal is not immediately identifiable as land use change, e.g. during habitat restoration, woodland loss is not registered until permanent change is confirmed after ten years. The area of confirmed woodland loss (unequivocal permanent removal of woodland cover) for Great Britain between 1995-98 and 2010 in the NFI is 498 hectares, although only areas over 5 hectares (England and Wales) and over 20 hectares (Scotland) have been assessed to date (Forestry Commission 2011). The area of confirmed woodland loss will increase significantly once smaller areas of loss are examined. Estimates of intended woodland removal for wind-farm development and habitat restoration over the last decade amount to at least 20-30,000 hectares, which are more comparable with the estimates of deforestation currently used in the KP-LULUCF inventory of 19-22,000 hectares in Great Britain between 1995/98 and 2010.

The Forest Management area is the area converted to forest land between 1921 and 1989 (1,395.19 kha), adjusted to reflect losses from deforestation 1990-2010, giving a total of 1368.86 kha in 2010. 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 post-1921 5A1 Forest remaining Forest are comparable in 2010 at 1368 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 2011). 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 UK uses IPCC Approach 3 (GPG-LULUCF) for tracking areas of afforestation and forest management on a spatially explicit basis. Deforestation areas are tracked using a mixture of Approach 2 and Approach 3 as several sources of information are used: deforestation is identifiable in all sources but not spatially explicit. The data sources and methodology can detect a land use change at a resolution consistent with the forest definition in **Section 11.1.1**. 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/ when it is redeveloped in summer 2012.

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. Gap-filling is done using Countryside Survey land use change data. 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 and Overseas Territories and is constant for all years.

Table 11-1 Table NIR 2 of land area and changes in land areas in 2010 (including area of Overseas Territories and Crown Dependencies)

To current inventory year (2010)			Article 3.3 activities		Article 3.4 activities	Other	Total (beginning of year)
From previous inventory year (2009)			Afforestation and Reforestation	Deforestation	Forest Management		
Article 3.3 activities	Afforestation and Reforestation	kha	289.22	0.00			289.22
	Deforestation			26.34			26.34
Article 3.4 activities	Forest Management			1.41	1,368.86		1,370.27
Other			7.42	0.00	0.00	24,056.42	24,063.84
Total (end of year)			296.64	27.74	1,368.86	24,056.42	25,749.66

Figure 11-3 Forest area planted since 1990 in the countries of the United Kingdom

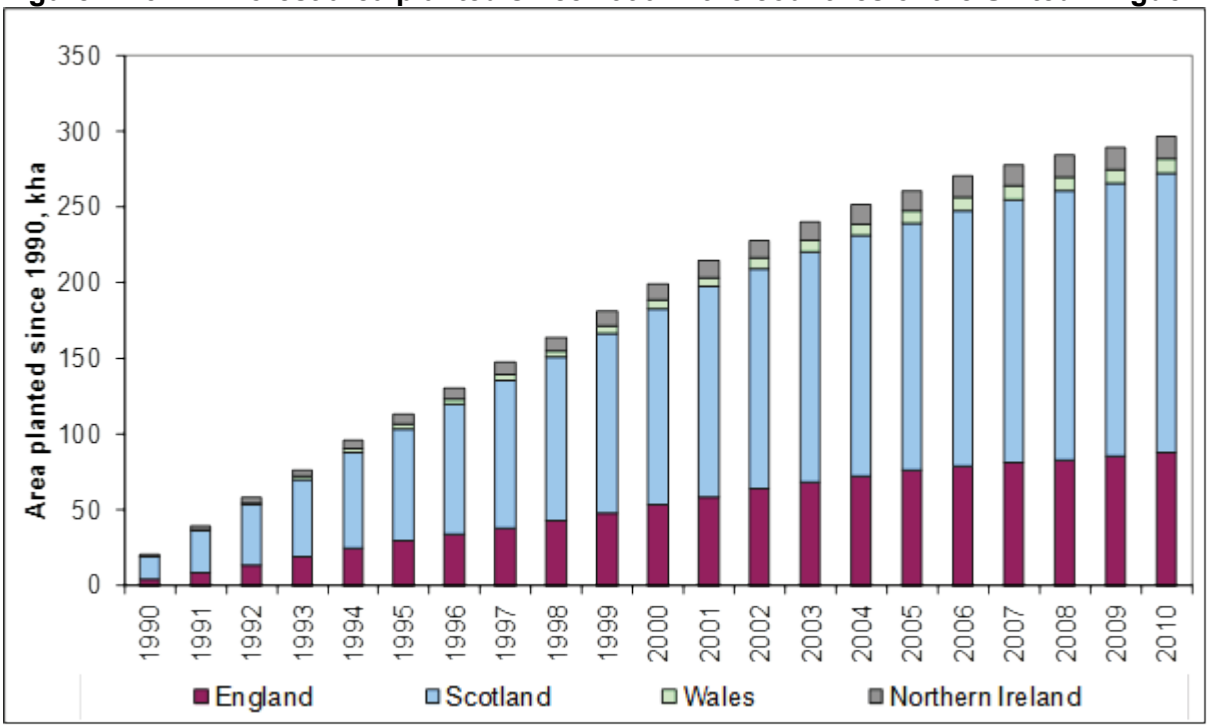


Figure 11-4 Area deforested since 1990 in the countries of the United Kingdom (note different scale from previous figure)

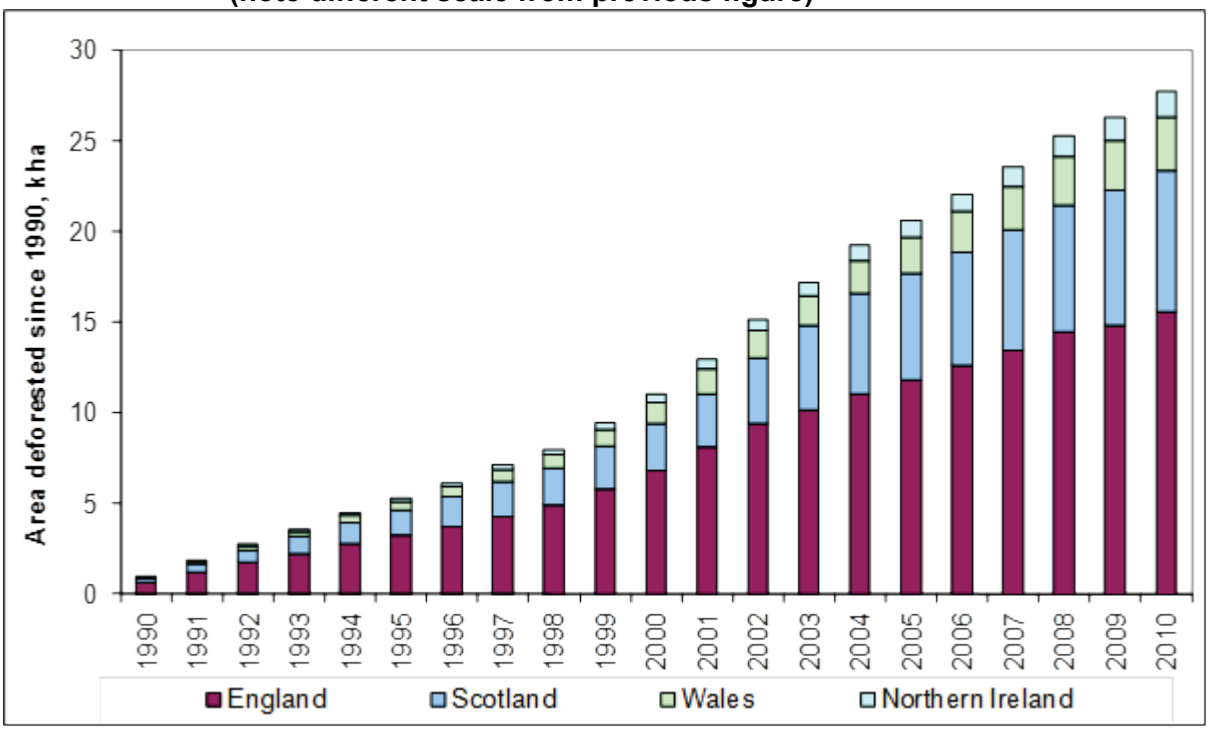


Figure 11-5 Area of Forest Management land 1990-2009 in the countries of the United Kingdom

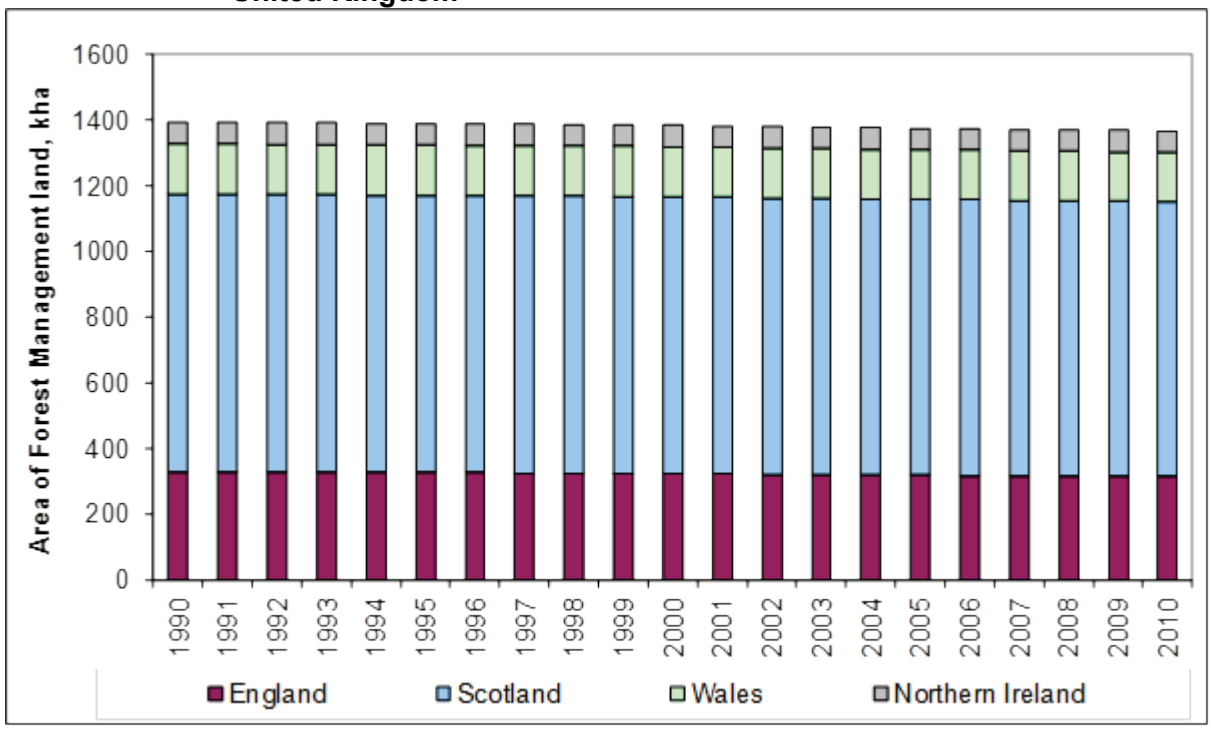


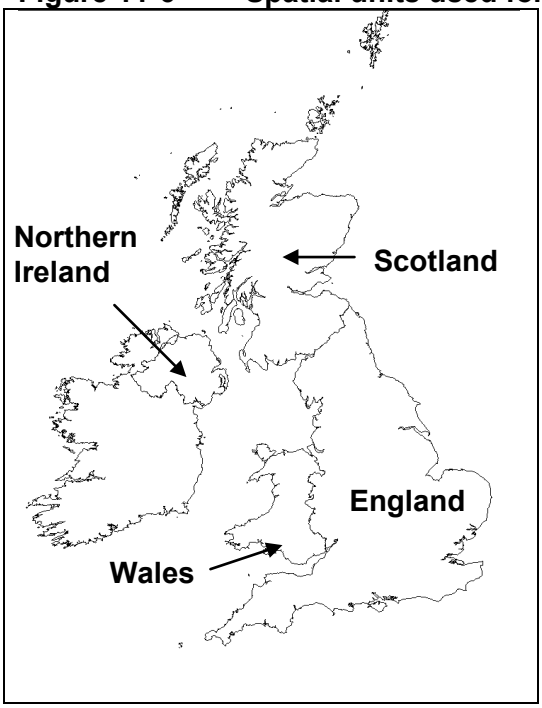
Table 11-2 Data sources on ARD and FM activities

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, Scotland, Wales	England: 1992-2010; Scotland: 1998-2010; Wales: 1996-2010	Unconditional Felling Licences are issued for felling without restocking. Used to estimate deforestation in rural areas (primarily for heathland restoration). Omits felling for development purposes, e.g. construction of wind turbines. Available at http://www.forestry.gov.uk/datadownload
D	Land Use Change Statistics (survey of land converted to developed uses)	England only	1990-2008 (updated in 2010)	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.
D	Countryside Survey (CS) 1990, 1998, 2007	Country (England, Scotland, Wales, Northern Ireland)	1990-2007	Estimated areas of woodland converted to other land uses from CS data (1990, 1998, 2007). There are known issues with CS over-estimating the extent of woodland conversion compared with the extent estimated by the Forestry Commission. This is due to differences in woodland definitions, amongst other causes. However, the CS data can be used to estimate the relative split of woodland conversion between grassland, cropland and settlements, using other known data to 'discount' the CS areas. There is no non-CS data for Northern Ireland so the discount rates for England or Wales are used, depending on availability.

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 is 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 now made for all countries of the UK.

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 assessed using 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 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 existing and newly planted UK forests (Forestry Commission, pers. comm.). It is difficult and economically unviable to apply lime at the heavy rates required (Taylor 1991). It is assumed that land deforested to cropland will undergo some liming (in the same proportion and application rates as other cropland as described in Annex 3.7), although the areas involved are very small (<0.03 kha/year).

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 wildfire emissions have been split between Afforestation/Reforestation land and Forest Management land on the basis of their proportion of the whole forest area (a ratio of 21:79 for the UK). 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.2.1 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 1990-2010 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.

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 established or newly planted UK forests (Forestry Commission, pers. comm.), so emissions are reported as Not Occurring for Afforestation/Reforestation and Forest Management areas. Some liming application occurs on land deforested to Cropland but only in England (see above).

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. No forest wildfires were reported in Northern Ireland in 2010 (although they had occurred in previous years). 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 640 ha a^{-1} 1990-2010, 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 third 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 2009 emissions/removals in the 2010 KP-LULUCF submission

Category	2009 submission value, Gg	2010 submission value, Gg	Reason for recalculation
Art. 3.3 Afforestation Net CO_2 emissions/removals	-2823.99	-2,806.06	Re-assignment of wildfire biomass burning emissions
Art. 3.3 Deforestation Net CO_2 emissions/removals	628.96	544.72	Revised deforestation activity dataset 1990-2010. Inclusion of emissions from liming on deforested land.
Art. 3.4 Forest Management Net CO_2 emissions/removals	-9808.36	-9790.73	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 Afforestation CH_4 emissions	0.00	0.099	Re-assignment of wildfire biomass burning emissions
Art. 3.3 Deforestation CH_4 emissions	0.81	0.693	Revised deforestation activity dataset 1990-2010, resulting in updated biomass burning estimates.
Art. 3.4 Forest Management CH_4 emissions	0.45	0.353	Re-assignment of wildfire biomass burning emissions to Art. 3.3
Art. 3.3 Afforestation N_2O emissions	0.000	0.0007	Re-assignment of wildfire biomass burning emissions
Art.3.3 Deforestation N_2O emissions	0.006	0.0082	Revised deforestation activity dataset 1990-2010.
Art. 3.4 Forest Management N_2O emissions	0.003	0.0024	Re-assignment of wildfire biomass burning emissions to Art. 3.3

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.

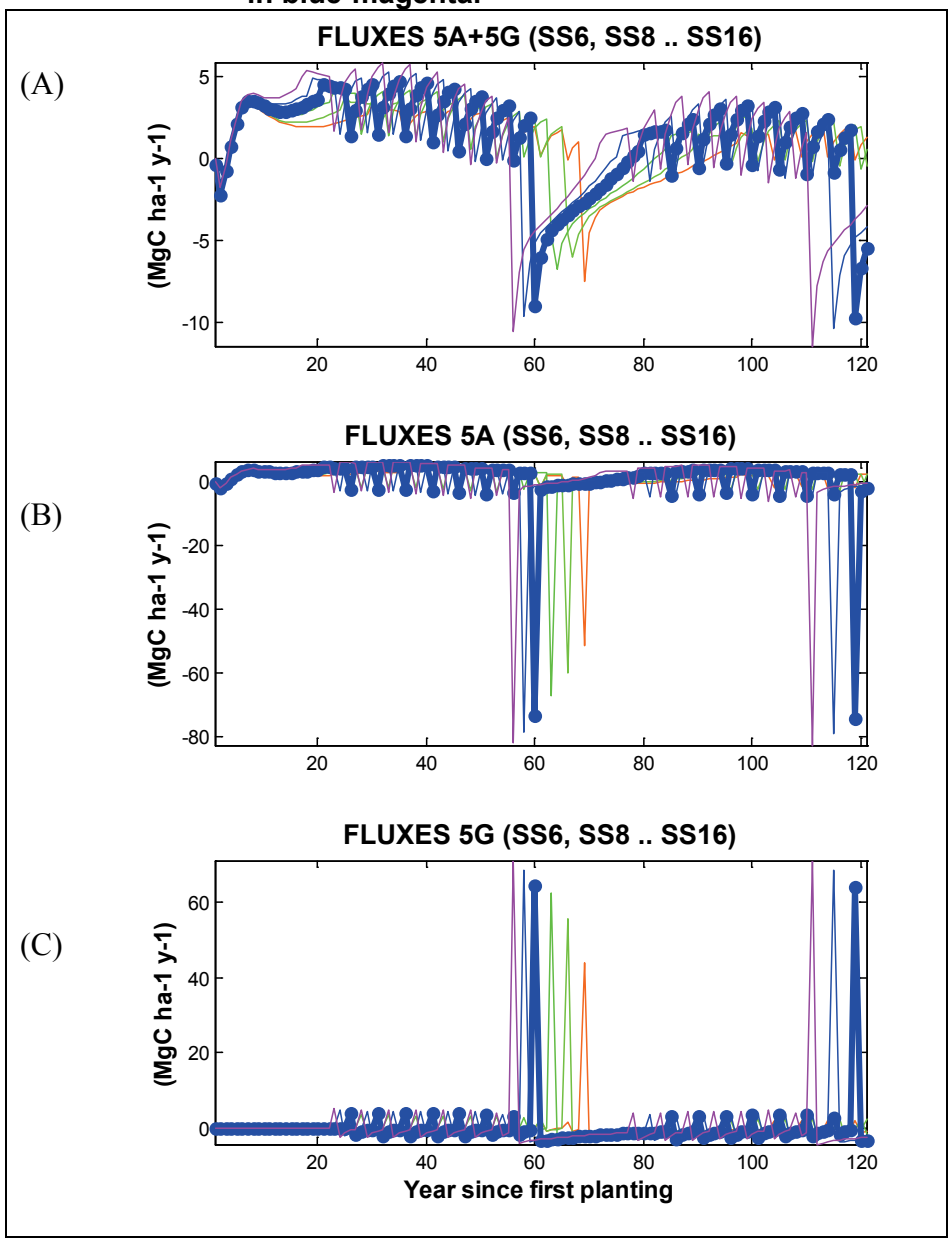
Uncertainty from model inputs.

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.).

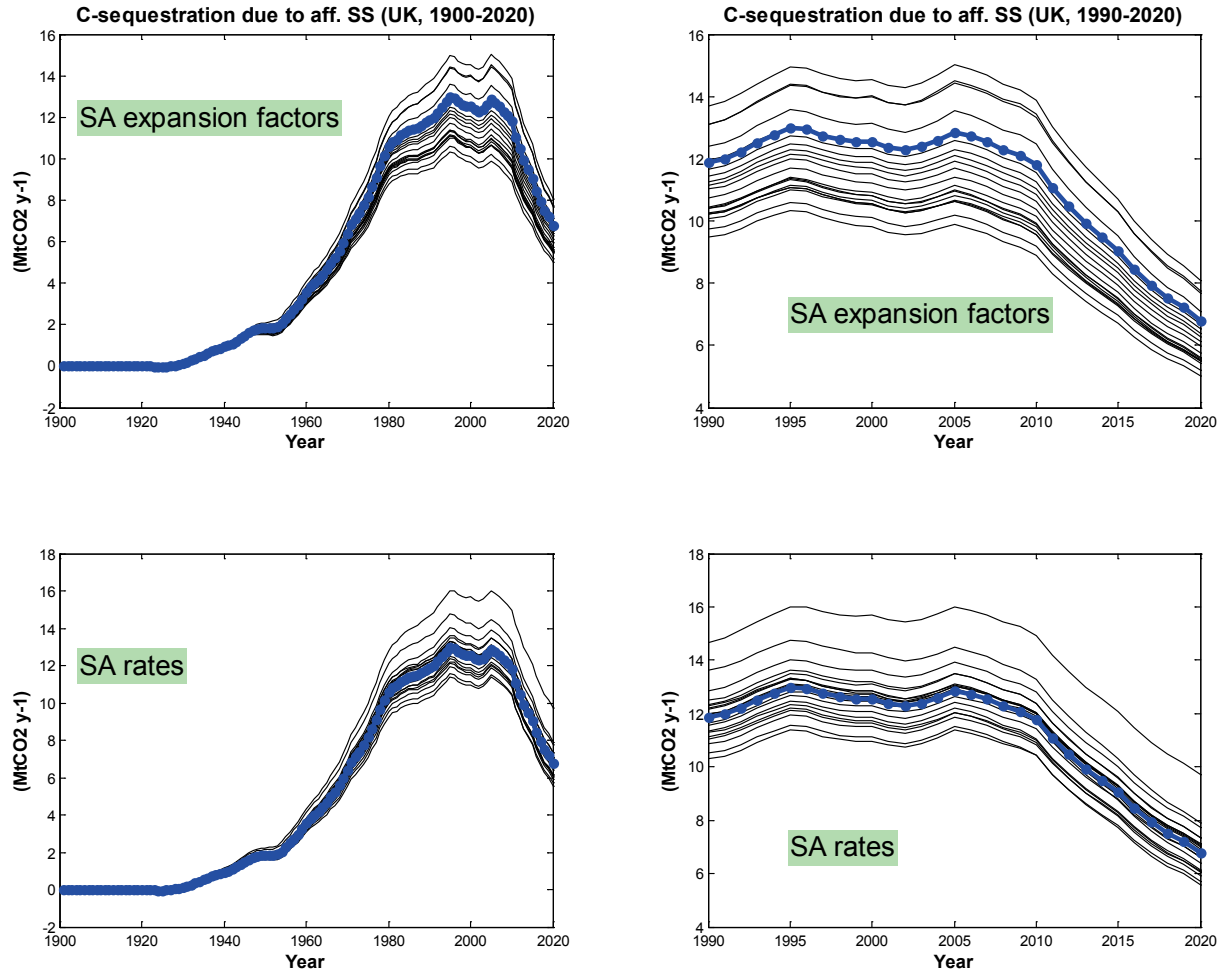
Uncertainty from model parameters

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.

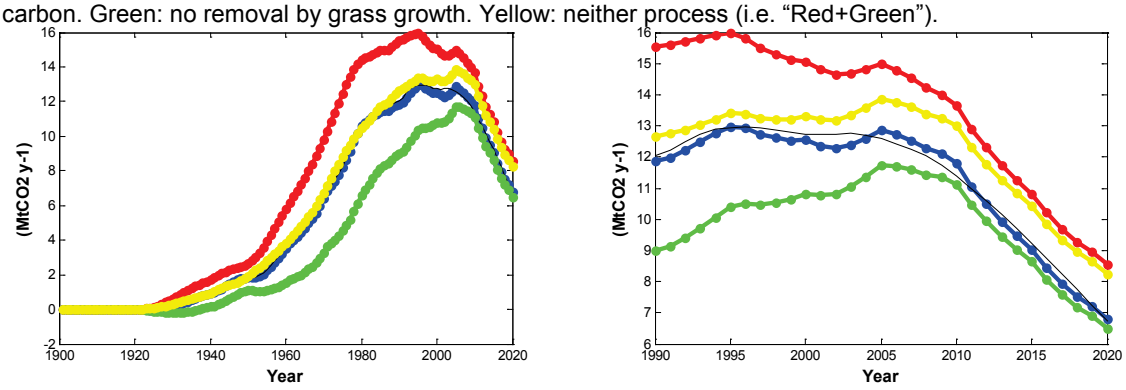


Uncertainty from model structure

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

5 361 ha of land were afforested in 2009 and 7 423 ha of land in 2010. 1 002 ha of land were deforested in 2009 and 1 408 ha in 2010.

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 'financial' 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 2011). 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. The Countryside Survey data (used for gap filling) is adjusted in order that deforestation is not over-estimated. 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 2011, 1325 kha of woodland in the UK (43%) was certified under the FSC scheme (Forestry Statistics 2011). The management practices in certified woodlands are reviewed on a regular basis (3-5 years). All state-owned forests are certified and an increasing proportion of non-state-owned woodlands are becoming certified (21% in 2010). (Note that these percentages have changed with the change in woodland areas from the NIWT to the NFI baseline). 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 (2010) based on level of emissions (including LULUCF).

Article 3.3 Afforestation and Reforestation (CO_2): The associated UNFCCC category 5A (-10 569 Gg CO_2) is a key category although the AR component (forest planted since 1990) is not key on its own (i.e. its category contribution (-2 959 Gg CO_2) is smaller than the smallest UNFCCC key category (1A Coal)). 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 (12 116, -8 541 and 6 216 Gg CO_2 respectively). However, the Deforestation category contribution (710 Gg CO_2) to these UNFCCC categories is smaller than the smallest UNFCCC key category (1A Coal). 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 (-10 569 Gg CO_2). The Forest Management category contribution (-7 498 Gg CO_2) 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's Standard Electronic Format report for 2011 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_2012_1_11-20-42 9-1-2012.xls.

12.2 SUMMARY OF INFORMATION REPORTED IN THE SEF TABLES

At the end of 2011, there were 3,777,966,609 AAUs in the UK registry of which 2,444,524,126 were in the party holding account, 615,721,454 in the entity holding account, 36,229 in other cancellation accounts and 717,684,800 in the retirement account. The registry also contained a total of 74,251,461 CERs and 9,331,535 ERUs.

In total for 2011, the UK Registry received 516,792,658 AAUs, 69,087,318 ERUs, 313,026,233 CERs and 3,900,000 RMUs. Conversely, 310,510,925 AAUs, 63,772,437 ERUs, 275,161,192 CERs and 3,900,000 RMUs were externally transferred to other national registries. Account holders voluntarily cancelled 22,796 AAUs and 414,931 CERS. There were no transactions of any kind involving ERUs, RMUs, tCERs or lCERs.

During 2011, 456,829,826 AAUs, 1,846,470 ERUs and 11,034,440 CERs were retired.

Full details are available in the SEF tables; the full tables are shown in Annex 6.

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 in the reports area at http://emissionsregistry.environment-agency.gov.uk/ .

Table 12-1 Details on Standard electronic format

Annual Submission Item	Reporting Guidance
15/CMP.1 annex I.E paragraph 11: Standard electronic format (SEF)	UK's Standard Electronic Format report for 2011 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 NFCCC Secretariat electronically. SEF_GB_2012_1_11-20-42 9-1-2012.xls The contents of the SEF report (R1) can also be found in Annex 6 of this document.

12.3 DISCREPANCIES AND NOTIFICATIONS

Information regarding discrepancies and notifications is summarised in **Table 12-2.**

Table 12-2 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 "SEF_GB_2012_1_11-20-42 9-1-2012.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 2011. Refer to Separate Electronic Attachment "SIAR Reports 2011-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 2011. Refer to Separate Electronic Attachment "SIAR Reports 2011-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 2011. Refer to Separate Electronic Attachment "SIAR Reports 2011-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 12-3** below.

Table 12-3 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/. 2 links (UNFCCC Public Reports and European Commission Public Reports), are available on this site with direct access to the reports. 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 2011. 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)

Annual Submission Item	Reporting Guidance
15/CMP.1 annex I.E paragraph 18 CPR Calculation	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 the lower of: 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 (2008) = 5 x 633,206,211 tonnes CO_2 equivalent = 3,166,031,055 tonnes CO_2 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 CO_2 equivalent (or assigned amount units)**[30]. The 1990-2008 inventory has been taken as the most recently reviewed inventory, because the report of the 1990-2009 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.

[30] 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

13 Information on changes in national system

13.1 CHANGES TO THE NATIONAL SYSTEM

During 2011, following an open competition exercise, the contract to compile the UK's National Atmospheric Emissions Inventory which delivers both the greenhouse gas inventory and air quality pollutant inventory was awarded to a consortium led by AEA (as set out in section 1.2.2.2).

North Wyke Research, the organisation responsible for compilation of the GHG inventory for agriculture, is now a part of Rothamsted Research. The same team are responsible for the compilation of the agriculture inventory.

Key roles within the National Inventory System are shown in **Table 1.2** in the Introduction.

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	No change in the name or contact information of the registry administrator occurred during the reporting period.
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 2011 cover changes to software as detailed below. Version 5.2 was implemented in the UK registry in April 2011 and version 5.3 in October 2011 Both upgrades (V5.2 and V5.3) have incorporated changes that increased the capacity of the Registry. The following capacity improving measures have been implemented compared to the previously used version.

Software Changes

Version 5.2:
This version included the following changes:

- A number of security enhancements as detailed in the Change of Security section of this chapter.
- Implementing the improved ITL message flow
- Maintenance fixes

Version 5.3:
This version included the following changes

- Further security enhancements as detailed in the Change of Security section of this chapter.
- Data migration enhancements – 2 fields in the registry were made mandatory to aid the migration of data to the new Union Registry being implemented by the European Commission in 2012.

Each new release also includes a 'maintenance' element whereby high-priority legacy bugs are also resolved. These are detailed in the accompanying release notes.

The following test reports, test plans and release notes are supporting documentation for the 2 releases, available in Annex 6

- Registry v5.2 Release Notes

Reporting Item	
- Registry v5.3 Release Notes - Registry v5.2 Regression Tests - Registry v5.3 Regression Tests - Registry v5.2.Test Report - Registry v5.3 Test Report - Registry v5.2 Test Plans - Registry v5.3 Test Plans - CITL Test Plan and Results v4.3 - CITL Test Plan and Results v5.1 - CITL Approval Email 5.2 - CITL Approval Email 5.3 CITL test scenarios cover the requirements of Annex H testing and there are 2 emails in the Annex to confirm European Commission Satisfaction of these requirements. Procedures for using this new functionality has been produced as part of the Registry Administrator guide.	
15/CMP.1 annex II.E paragraph 32.(d) Change of conformance to technical standards	An improved message flow was introduced by the ITL in October 2010 and the Registry incorporated this in 2011 to make use of this improved service as part of the v5.2 release. Release Notes v5.2 of this Annex provides the details of this implementation and the massive reduction in discrepant transactions concludes that this implementation was successful. The registry continues to conform to the DES.
15/CMP.1 annex II.E paragraph 32.(e) Change of procedures	Improvements to the registry have resulted in just 4 discrepancies in 2011. This is a significant decrease compared to 2010. Only discrepancies with result code 5103 occurred, which occurs when an acquiring registry is not available. As this is an error outside of the control of the UK registry, the resolution does not require a technical fix but just a helpdesk call as part of our current procedures. Report R2 provides further details. V5.2 of the UK registry software incorporated the new ITL message flow resulting in these improvements.
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 5.2 and 5.3 of the UK registry software. These security improvements are; - Session Locking - Dual Approval for Registry Administrator Transactions - User logon audit trail - Guarding against man in the middle attacks - Guarding against cross site scripting - Encrypting the ViewState - Out of hours lock - Trusted Accounts Further details of these changes can be found in section 2 of the Registry 5.2 Release Notes and Registry 5.3 Release Notes

Reporting Item	
	attached in Annex 6. Trusted accounts and the out of hours lock functions have not been implemented by the UK registry at present but can be activated immediately should it be required.
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	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.
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.
Previous Annual Review recommendations for the National Registry **IAR/2010-GBR/2/1**	There were no recommendations proposed in IAR/2010-GBR/2/1 in the Summary of Findings.

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 2011 which considered the potential for regional (i.e. sub-national, national and supranational) approaches to avoid ILUC from biofuels production. This work highlighted potential actions that may reduce ILUC, and assessed the potential to measure and monitor any such regional level actions to avoid ILUC. See http://www.dft.gov.uk/publications/regional-level-actions-to-avoid-iluc.

The UK 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 development of an embedded carbon emissions indicator. The aim of this project is to monitor greenhouse gas emissions associated with UK consumption, including those relating to trade flows. This work will provide a high level analysis of the UK national "carbon footprint", and in particular will assess the emissions which are embedded in products which the UK imports and exports. See http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=17729&FromSearch=Y&Publisher=1&SearchText=emissions&GridPage=7&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

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) is the EU's main policy mechanism for reducing CO_2 emissions from energy intensive sectors. Through the EU ETS and the linking directive, which allows European participants in the EU ETS 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.
- Aviation has been included in the EU ETS from 1 January 2012, the most significant expansion of the scope of the System since its inception. We estimate that the inclusion of aviation in the EU ETS will result in emission reductions across the EU of 476 $MtCO_2$ cumulatively for the period 2012-2020.
- A Greenhouse Gas Effort Sharing Decision sets targets for emissions reductions or growth limits in those sectors of Member States' economies not covered by the EU ETS (excluding Land Use, Land Use Change and Forestry). For the UK, the target to reduce emissions in the non-ETS is 16 per cent below 2005 levels by 2020. For the EU as whole, the reduction target is approximately 10 per cent. 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. Furthermore, the UK's International Climate Fund (ICF) will provide £2.9bn of climate finance from 2011 to 2015. This funding will be focused on helping the poorest people adapt to the effects of climate change, helping to encourage low carbon development, and protecting the world's forests and the livelihoods of the people who depend on them.

15.3.1 The International Climate Fund

The ICF is intended to demonstrate that building low carbon, climate resilient growth at scale is feasible and desirable. Additionally, it is intended to support climate negotiations, particularly through providing support for adaptation in poor countries and building an effective international architecture. The fund also aims to recognise that climate change offers real opportunities to drive innovation and new ideas for action, and create new partnerships with the private sector to support low carbon climate resilient growth.

The UK is investing £130 million in the Climate Public Private Partnership (CP3) from the ICF. CP3 will support projects delivering renewable and efficient energy, new technology and protect natural resources in emerging and developing countries including Africa and Asia. The funds will be run on a strict commercial basis by professional fund managers, demonstrating that developing country climate projects offer real investor opportunities. By investing in new renewable installations and technologies the initiative is expected to contribute to deploying approximately 7,000 Megawatts of clean, reliable energy and create up to 40,000 jobs. Across a range of investments CP3 is expected to contribute to GHG emission savings of at least 265 million tonnes of CO2 over the lifetime of the projects in which CP3 funds are invested.

Through the ICF, the UK is also providing £6m to help kick start solar energy projects in India. This funding will offset part of the financing cost of using ADB political and commercial risk guarantees on commercial loans for small-scale (2-25 MW) solar plants. These guarantees on private sector loans are available under ADB's Solar Power Generation Guarantee Facility. This will help India make the shift to a low carbon economy, and will reduce the risks for investors, generating an estimated £265m in private sector investment. This should lead to around 130 MW of solar power capacity, avoiding 4.9 million tonnes of carbon dioxide going into the atmosphere over the next 25 years.

The UK has also contributed £7m and technical support to the World Bank's Partnership for Market Readiness to help developing countries set up their own carbon trading systems to cut emissions. This will allow more investment in green technologies across the world and help stimulate private sector low carbon investment opportunities. The Partnership aims to increase the number of experts in 10-15 developing countries to design and implement market-based schemes, test and pilot schemes in at least 5 developing countries by 2015, and create a knowledge sharing forum.

Low carbon technology needs to be accessible to all and the UK will promote growth and prosperity by stimulating investment in clean energy, and increasing energy access for the poor. Through our ICF funding to the Scaling up Renewable Energy Program (SREP), we will help to support 3.4 million people in securing access to clean energy including in Ethiopia, Honduras, Kenya, Mali and Nepal. For example, in Kenya, SREP investment in increased renewable energy services will facilitate the construction of a geothermal plant and enable this to be connected to the grid to increase Kenya's renewable energy supply by 32%. In addition, by connecting this 200MW power plant to the grid by 2015, it will demonstrate a model for replication to enable a potential 5000MW to be generated by geothermal power in Kenya by 2030.

15.3.2 Knowledge transfer

Knowledge transfer can help accelerate the development and deployment of low-carbon and climate resilient 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, knowledge, technical assistance and capacity building 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 (CICs) in developing countries. These centres will provide a national focal point for innovation in climate-friendly technologies, providing business development support; R&D grants and links to local universities; links to local financiers; and market analysis

within that country. CICs will be linked to other CICs to encourage cross-border learning and knowledge sharing. The implementation of a centre has begun in Kenya, with India closely following. Scoping work is also underway in Ethiopia.

15.3.3 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.

International engagement is a significant part of the AVOIDing dangerous climate change (AVOID) programme and there have been a number of international activities to build links and explore understanding of the issues. The programme has investigated China's technology options for reducing CO_2 emissions from the energy sector in order to meet a national 2050 emissions target that is consistent with the international goal of limiting global temperature rise to below 2°C. The initial findings of the project were reviewed by Chinese researchers who subsequently provided input to the final report. The final report was followed by a workshop in Beijing involving UK and Chinese researcher and officials to share and compare thoughts on potential technology pathways for China. The AVOID programme is also currently considering options for working with Indian research institutes to conduct a similar analysis on India's technology options for meeting the 2°C target.

The UK has recently signed a Memorandum of Understanding (MoU) on energy research with the government of Bangladesh. Under the MoU, collaborative research projects on renewable energy as well as research related to energy technologies, systems, services and policies will be developed. It will involve UK universities and institutes partnering with colleagues in Bangladesh.

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, the next meeting of which will be held in London in April 2012 involving governments of both developed and developing nations. The UK is active in a number of multi-lateral organisations such as the Carbon Sequestration Leadership Forum (CSLF) which aim to promote the deployment of CCS worldwide and is 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.

15.3.4 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 is a signatory to the International Renewable Energy Agency (IRENA) which is an intergovernmental treaty organisation set up in 2009 to promote a rapid transition to the widespread and sustainable use of renewable energy technologies internationally. The UK has been playing an active part in IRENA by chairing its Policy and Strategy Committee to help develop the agency's work programme for 2012 (which includes activities on Policy Advisory Services and Capacity Building) and its mid-term strategy. Similarly, the UK (both DFID and DECC) continues to contribute to the Clean Technology Fund (CTF), one of the Climate Investment Funds; at the Durban COP in 2011, the UK announced a further contribution of £150m to the CTF, in addition to £385 already provided (2008-2011).

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 as a means of reducing carbon emissions, increasing energy security, and improving access to sustainable energy. It does so primarily through funding small scale capacity building projects, and to date it has funded 150 projects. 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.**

15.3.5 Capacity building projects on adapting to climate change

The UK Government is working to ensure that aid addresses both the causes and likely effects of climate change so that current and future progress in tackling poverty continues. The world's poorest people are hit hardest by the impacts of climate change with their crops lost to floods and drought, their homes damaged by floods and threatened by rising sea levels, and lives lost to extreme weather events. They are the most vulnerable and least able to adapt.

The UK is supporting developing countries to adapt to climate change through practical on-the-ground support, by building climate knowledge and capacity in vulnerable countries and by helping to ensure countries get access to sufficient finance.

Examples include:

- The UK announced at the Durban COP in 2011 a further £85m support from the Department for International Development (DFID) to the Pilot Programme for Climate Resilience (PPCR) in addition to the UK's earlier £225m contribution. This support is designed to deliver transformational outcomes in a small number of pilot countries through supporting the integration of climate resilience into development planning and budgeting.
- The UK also announced £10m support from DFID for the Adaptation Fund to support concrete adaptation activities that reduce vulnerability and increase adaptive capacity to respond to the impacts of climate change, including variability at local and national levels.

15.3.6 Energy Market Reforms – responding to energy market imperfections

Energy Market Reform (EMR) is the biggest change to the UK electricity market since privatisation. Although the current market has been effective, a number of unprecedented challenges require us to transform the UK's electricity sector. It is expected that a fifth of our current capacity is due to close over the next decade and the amount of intermittent and less flexible generation will increase. In addition, there are ambitious climate and renewable targets that we need to meet.

The UK Government's vision is for low-carbon generation to compete fairly on cost and EMR is a set of arrangements that will take the UK through this transition. We will continue to work with the existing market whilst maintaining a liberal approach to addressing the market failures.

In July 2011 the UK Government published the EMR White Paper ("*Planning our electric future: a White Paper for secure, affordable and low-carbon electricity*")[31] which set out a package of electricity market reforms:

- the form of the low-carbon contracts (Feed-in-Tariff with Contracts for Difference (FiT CfD)) to bring forward all forms of low-carbon electricity generation;
- how we will transition from the current Renewables Obligation to the FiT CfD;
- a Carbon Price Floor to put a fair price on carbon; and
- an Emissions Performance Standard to provide a regulatory backstop on the amount of emissions new fossil fuel plants can emit.

The White Paper marked the first stage of the market reform process and was followed by the publication of the Technical Update[32] to the White Paper in December 2011 which completed the strategic framework outlined in the White Paper.

[31] http://www.decc.gov.uk/en/content/cms/legislation/white_papers/emr_wp_2011/emr_wp_2011.aspx
[32] http://www.decc.gov.uk/en/content/cms/legislation/white_papers/emr_wp_2011/tech_update/tech_update.aspx

The Technical Update provides further details on the institutional framework for delivery of the reforms; the form of Capacity Mechanism we will legislate for to ensure security of supply; and the next steps in the EMR process. It sets out the Government's view that the System Operator – National Grid – is best placed to deliver both the FiT CfD and the Capacity Mechanism.

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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18 Acknowledgements

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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[33]	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[34]. Author of Annex 7
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. Co-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[35]	Author of all sections on Land Use Change and Forestry. Compilation of Sector 5 of the CRF.
Webb, Nicola	Author of Chapter 1 and 10, author of Annex 4 and 5 co-author of chapter 3 and Annex 3, End User inventory expert. Responsible for Executive Summary.
Contributors	
Champion, Helen[36]	Review of draft NIR and contributions regarding National Inventory System. Author of Chapter 15
Dore, Chris	Manager of Overseas Territories and Crown Dependencies inventory compilation
Gilhespy, Sarah	Contributions to agriculture inventory compilation and text
Goodwin, Justin	Contribution to text on QA/QC plan
Hallsworth, Stephen	Responsible for compiling the CRF for LULUCF
Hobson, Melanie	Compilation of rail emissions estimates and text for this sector
Manning, Alistair	Verification of the UK greenhouse gas inventory (Annex 10).
Martinez, Carlos	Author of Chapter 2 and Annex 9
Matthews, Robert	Contributions to LULUCF inventory
Misselbrook, Tom	Contributions to agriculture inventory compilation and text

[33] Rothamsted Research

[34] 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 a consortium led by AEA Technology.

[35] Centre for Ecology and Hydrology

[36] Climate, Energy, Science and Analysis, Department for Energy and Climate Change

Person	Technical work area and responsibility
Thomas, Jenny	Report Manager, responsible for bringing together contributions from sector experts
Walker, Charles	Sector expert for aviation in the NAEI.
Walker, Helen	Responsible for sections on shipping and inland waterways
Watterson, John	Knowledge leader responsible for the review of this report
Additional assistance	
Aston, Clare	Data acquisition
Misra, Anne	Assistance with QC of the time series consistency.
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
Mineral Products Association
UK Gas Distribution Networks
Tata Steel
DfT
NIEA
SEPA