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UK Greenhouse Gas Inventory, 1990 to 2012

Annual Report for Submission under the Framework Convention on Climate Change

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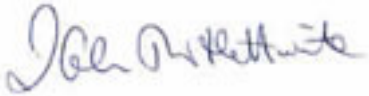
	Signature	
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Preface

This is the United Kingdom's National Inventory Report (NIR) submitted in April 2014 to the United Nations Framework Convention on Climate Change (UNFCCC). It contains national greenhouse gas emission estimates for the period 1990-2012, 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) Science Division, by Ricardo-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**.

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'.

IPCC categories

IPCC Category	Source Description
1	**Energy**
1A	**Fuel Combustion Activities**
1A1	**Energy Industries**
1A1a	Public Electricity and Heat Production
1A1b	Petroleum refining
1A1c	Manufacture of Solid Fuels and Other Energy Industries
1A2	**Manufacturing Industries and Construction**
1A2a	Iron and Steel
1A2b	Non-ferrous Metals
1A2c	Chemicals
1A2d	Pulp, Paper and Print
1A2e	Food Processing, Beverages and Tobacco
1A2fi	Stationary combustion in manufacturing and construction: Other
1A2fii	Mobile combustion in manufacturing industries and construction
1A3	**Transport**
1A3ai	International Aviation
1A3aii	Civil Aviation
1A3b	Road Transportation
1A3c	Railways
1A3di	International Navigation
1A3dii	National Navigation
1A3e	Other (to be specified)

IPCC Category	Source Description
1A4	**Other sectors**
1A4a	Commercial / Institutional Combustion
1A4b	Residential
1A4c	Agriculture / Forestry / Fishing
1A5	**Other (not elsewhere specified)**
1A5a	Other, Stationary (including Military)
1A5b	Other, Mobile (Including military)
1B	**Fugitive Emissions from Fuels**
1B1	**Fugitive Emissions from Solid Fuels**
1B1a	Coal Mining and Handling
1B1b	Solid fuel transformation
1B1c	Other (to be specified)
1B2	**Oil and natural gas**
1B2a	Oil
1B2b	Natural gas
1B2c	Venting and flaring
2A	**Mineral Products**
2A1	Cement Production
2A2	Lime Production
2A3	Limestone and Dolomite Use
2A4	Soda Ash Production and use
2A5	Asphalt Roofing
2A6	Road Paving with Asphalt
2A7	Other (to be specified)
2B	**Chemical Industry**
2B1	Ammonia Production
2B2	Nitric Acid Production
2B3	Adipic Acid Production
2B4	Carbide Production
2B5	Other (to be specified)
2C	**Metal Production**
2C1	Iron and steel production
2C2	Ferroalloys Production
2C3	Aluminium production
2C4	Aluminium and magnesium foundries
2C5	Other metal production
2D	**Other Production**
2D1	Pulp and Paper
2D2	Food and Drink
2E	**Production of Halocarbons and SF6**
2E1	Halocarbons production (by-product)
2E2	Halocarbons production (fugitive)
2F	**Halocarbons use**
2F1	Refrigeration and Air Conditioning Equipment
2F2	Foam Blowing
2F3	Fire Extinguishers
2F4	Aerosols
2F5	Solvents
2F9	Other (semiconductors electrical sporting goods)

IPCC Category	Source Description
2G	**Other (to be specified)**
3A	**Paint Application**
3A1	Decorative coating application
3A2	Industrial coating application
3A3	Other coating application (Please specify the sources included/excluded in the notes column to the right)
3B	Degreasing and Dry Cleaning
3B1	Degreasing
3B2	Dry cleaning
3C	Chemical Products, Manufacture and Processing
3D	Other (to be specified)
4	**Agriculture**
4A	Enteric Fermentation
4B	Manure Management
4C	Rice Cultivation
4D	Agricultural Soils
4E	Prescribed Burning of Savannas
4F	Field Burning of Agricultural Wastes
4G	Other
5	**Land use, land use change and forestry**
5A	Forest Land
5B	Cropland
5C	Grassland
5D	Wetlands
5E	Settlements
5F	Other Land
5G	Other (please specify)
6	**Waste**
6A	Solid Waste Disposal on Land
6B	Waste-water Handling
6C	Waste Incineration
6D	Other Waste
7A	**Other**

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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)

The Kyoto Protocol (KP) to the United Nations Framework Convention on Climate Change (UNFCCC) was esatblished in 1997 in response to the threat of dangerous climate change. Under this Protocol, the UK agreed to an emissions reduction target of -12.5% on 1990 levels, to be achieved during the first commitment period of the Protocol, which runs from 2008 to 2012.

The UK ***Climate Change Act,*** which became part of UK law in November 2008, subsequently introduced a new, more ambitious and legally binding target for the UK to reduce GHG emissions to 80% below base year levels by 2050. This will be done by way of legally binding five year *Carbon Budgets*. In May 2009, the UK Government set the levels of the first three five-year carbon budgets, covering the periods 2008-12, 2013-17 and 2018-22. 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*, which was published in July 2009. The *Annual statement of emissions,* published by 31st March each year, reports to the UK Parliament on progress towards these Carbon Budgets. The fifth *Annual Statement*, in relation to the 2012 reporting year, published in March 2014 showed that the UK has met the first Carbon Budget.

Further information on the UK's action to tackle climate change can be found at:
www.gov.uk/government/organisations/department-of-energy-climate-change
https://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs

ES.1.2 Background information on greenhouse gas inventories

The UK ratified the 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 2014. It contains GHG emissions estimates for the period 1990 to 2012, and describes the methodology on which the estimates are based. This report and the associated 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 Ricardo-AEA – the **Inventory Agency** - under contract to the UK Department of Energy and Climate Change (DECC). Ricardo-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). Ricardo-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 (OTs) and Crown Dependencies (CDs), 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 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;
- 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 deals with 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 IPCC Guidance and 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 KP 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 UNFCCC coverage: The KP commitment extends coverage to the UK's Crown Dependencies (Guernsey, Jersey and the Isle of Man) and Overseas Territories that have ratified the first commitment period of the Kyoto Protocol (the Cayman Islands, the Falkland Islands, Bermuda, Montserrat and Gibraltar).
3. The EUMM coverage: 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.

Emissions data for Coverage 1 are reported here for information and to facilitate comparison between different publications. Coverage 2 is used for the data in the CRF tables submitted to the UNFCCC. Coverage 3 is used for the data in the CRF tables submitted under the EUMM. **Table ES 2. 1** to **Table ES 3.** 1 show CO_2 and the direct greenhouse gases, disaggregated by gas and by sector for geographical Coverage 2. Table **ES 3. 2** and **Table ES 3.** 3 show emissions for the Kyoto basket based on Coverage 2 and 3, respectively.

Table ES 4. 1 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 KP 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 ES 2. 1 Emissions of GHGs in terms of carbon dioxide equivalent emissions including all estimated GHG emissions from the Crown Dependencies and relevant Overseas Territories, 1990-2012. (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	2011	2012	1990 - 2012
CO_2 (Inc. net LULUCF)	592.5	599.3	582.3	567.7	561.7	554.3	574.9	550.0	554.0	546.0	553.7	563.9	546.7	557.2	557.9	554.6	554.1	546.9	529.1	479.7	497.0	455.8	475.7	-20%
CO_2 (Exc. net LULUCF)	591.5	598.3	581.8	568.1	562.1	553.7	575.0	550.5	555.5	548.0	556.7	567.9	551.6	562.3	564.0	561.1	561.1	554.3	536.7	487.4	505.0	464.0	483.4	-18%
CH_4 (Inc. net LULUCF)	104.5	104.7	102.2	101.1	95.6	97.3	96.2	93.6	90.2	84.0	78.5	75.0	74.2	69.5	65.3	62.5	61.4	59.4	58.2	55.9	52.7	51.9	50.8	-51%
CH_4 (Exc. net LULUCF)	104.5	104.6	102.2	101.0	95.6	97.3	96.2	93.6	90.2	84.0	78.4	75.0	74.2	69.5	65.3	62.4	61.4	59.3	58.1	55.9	52.7	51.8	50.8	-51%
N_2O (Inc. net LULUCF)	69.9	70.1	65.3	60.7	61.2	59.6	59.6	60.0	59.8	49.3	48.3	45.7	43.8	43.3	43.9	43.0	40.8	40.1	39.1	36.9	37.8	36.4	36.1	-48%
N_2O (Exc. net LULUCF)	69.0	69.3	64.4	59.8	60.3	58.8	58.7	59.1	59.0	48.4	47.5	44.8	43.0	42.5	43.1	42.2	40.0	39.3	38.3	36.2	37.1	35.7	35.4	-49%
HFCs	11.4	11.9	12.3	13.0	13.9	15.3	16.6	19.0	16.7	9.9	8.9	9.7	10.1	11.2	10.4	11.3	11.9	12.2	12.8	13.2	13.6	13.8	14.0	23%
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	0.3	0.2	-85%
SF_6	1.0	1.0	1.1	1.1	1.2	1.2	1.2	1.2	1.3	1.4	1.8	1.4	1.4	1.3	1.0	1.0	0.7	0.7	0.6	0.6	0.6	0.6	0.5	-45%
Total (Inc. net LULUCF)	780.7	788.1	763.8	744.1	734.1	728.2	749.0	724.2	722.3	691.0	691.6	696.1	676.6	682.8	679.0	672.6	669.3	659.5	639.9	586.4	601.9	558.8	577.3	-26%
Total (Exc. net LULUCF)	778.8	786.3	762.5	743.6	733.5	726.8	748.2	723.8	723.0	692.2	693.7	699.2	680.6	687.0	684.2	678.3	675.5	666.1	646.7	593.4	609.1	566.3	584.3	-25%

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 first commitment period of the Kyoto Protocol. These are the Cayman Islands, Falkland Islands, Bermuda, Montserrat and Gibraltar.

Table ES 2. 1 presents the UK Greenhouse Gas Inventory totals by gas, including and excluding net emissions from LULUCF. The largest contribution to total emissions is CO_2, which contributed 83% to total net emissions in 2012. Methane emissions account for the next largest share (9%), 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 26%.

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 Afforestation, 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 KP reporting (this is only applicable for countries where there is a net LULUCF emission in 1990, which is the case for the UK).

Table ES 2. 2 details the emissions and removals from these activities which are included in the UK's emissions total for reporting under the KP.

Table ES 2. 2 KP-LULUCF activities (Mt CO_2e)

	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Article 3.3		0.2	0.2	0.1	0.0	-0.1	-0.2	-0.3	-0.3	-0.5	-0.5	-0.1
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	0.2											

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Article 3.3	-0.2	-0.3	-0.3	-0.5	-0.6	-0.9	-1.0	-1.1	-1.3	-1.5	-1.7	-1.8
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
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 ES 3. 1 details total net emissions of GHGs, aggregated by IPCC sector.

Table ES 3. 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**	**2011**	**2012**
1. Energy	611.7	621.1	604.9	589.3	575.8	568.0	587.2	561.6	564.3	554.7	561.9	573.0	556.3	564.8	565.6	561.1	560.9	552.4	535.1	489.7	506.3	465.4	485.5
2. Industrial Processes	54.2	52.4	47.0	43.7	46.3	46.4	48.3	50.4	48.6	31.8	31.2	29.9	27.9	29.7	30.0	30.2	29.6	31.3	30.4	25.0	26.5	25.4	25.0
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	0.0	0.0
4. Agriculture	65.5	65.3	65.1	64.4	64.8	64.4	64.9	65.4	64.9	64.1	61.7	58.4	58.1	57.5	57.6	57.0	55.4	54.0	53.2	52.3	53.1	52.7	52.1
5. LULUCF	1.9	1.8	1.3	0.5	0.5	1.5	0.8	0.4	-0.6	-1.1	-2.1	-3.1	-4.0	-4.2	-5.2	-5.7	-6.2	-6.5	-6.9	-6.9	-7.2	-7.5	-7.0
6. Waste	47.4	47.5	45.5	46.1	46.7	48.0	47.8	46.5	45.2	41.5	38.8	38.0	38.3	35.0	30.9	29.9	29.6	28.4	28.0	26.3	23.2	22.8	21.7
Total (net emissions)	**780.7**	**788.1**	**763.8**	**744.1**	**734.1**	**728.2**	**749.0**	**724.2**	**722.3**	**691.0**	**691.6**	**696.1**	**676.6**	**682.8**	**679.0**	**672.6**	**669.3**	**659.5**	**639.9**	**586.4**	**601.9**	**558.8**	**577.3**

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 first commitment period of the Kyoto Protocol. These are the Cayman Islands, Falkland Islands, Bermuda, Montserrat and Gibraltar.

The largest contribution to greenhouse gas emissions is from the energy sector. In 2012 this contributed 84% to the total emissions. 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 21%.

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 (largely related to lower livestock numbers) and from agricultural soils (largely related to changes in agricultural practices, and a decline in the use of synthetic fertiliser).

Industrial processes make up the third largest source of greenhouse gases in the UK, contributing just over 4% to the national total in 2012. 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 was a net sink in 2012. 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 2012 this contributed just under 4% 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 2012 were 54% below 1990 levels.

Total net emissions have decreased by 26% since 1990.

ES.3.2 KP Basket and KP-LULUCF Activities

Table ES 3. 2 provides the time series of the UK Kyoto basket of emissions (UNFCCC geographical coverage), and **Table 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 2012 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 against which the UK's progress towards its KP target will be judged.

Table ES 3. 2 Kyoto basket of emissions, and emissions associated with Articles 3.3, 3.4 and 3.7, 1990-2012 (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	2011	2012	1990-2012	Base Year - 2012
CO_2	591.5	591.5	598.3	581.8	568.1	562.1	553.7	575.0	550.5	555.5	548.0	556.7	567.9	551.6	562.3	564.0	561.1	561.1	554.3	536.7	487.4	505.0	464.0	483.4	-18%	-18%
CH_4	104.5	104.5	104.6	102.2	101.0	95.6	97.3	96.2	93.6	90.2	84.0	78.4	75.0	74.2	69.5	65.3	62.4	61.4	59.3	58.1	55.9	52.7	51.8	50.8	-51%	-51%
N_2O	69.0	69.0	69.3	64.4	59.8	60.3	58.8	58.7	59.1	59.0	48.4	47.5	44.8	43.0	42.5	43.1	42.2	40.0	39.3	38.3	36.2	37.1	35.7	35.4	-49%	-49%
HFCs	15.3	11.4	11.9	12.3	13.0	13.9	15.3	16.6	19.0	16.7	9.9	8.9	9.7	10.1	11.2	10.4	11.3	11.9	12.2	12.8	13.2	13.6	13.8	14.0	23%	-9%
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	0.3	0.2	-85%	-55%
SF_6	1.2	1.0	1.0	1.1	1.1	1.2	1.2	1.2	1.2	1.3	1.4	1.8	1.4	1.4	1.3	1.0	1.0	0.7	0.7	0.6	0.6	0.6	0.6	0.5	-45%	-55%
Grand Total	782.0	778.8	786.3	762.5	743.6	733.5	726.8	748.2	723.8	723.0	692.2	693.7	699.2	680.6	687.0	684.2	678.3	675.5	666.1	646.7	593.4	609.1	566.3	584.3	-25%	-25%
Article 3.3		0.2	0.2	0.1	0.0	-0.1	-0.2	-0.3	-0.3	-0.5	-0.5	-0.1	-0.2	-0.3	-0.3	-0.5	-0.6	-0.9	-1.0	-1.1	-1.3	-1.5	-1.7	-1.8		
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	-1.4	-1.4		
Article 3.7	0.2																									
Kyoto Protocol Total	782.2	777.6	785.1	761.1	742.2	732.0	725.2	746.5	722.1	721.1	690.2	692.2	697.6	678.9	685.3	682.3	676.3	673.2	663.7	644.2	590.7	606.2	563.2	581.1	-25%	-26%
Fixed Base Year	779.9																									-25%

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 during the first commitment period.

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 first commitment periodthe Kyoto Protocol. These are the Cayman Islands, Falkland Islands, Bermuda, Montserrat and Gibraltar.

Table ES 3. 3 Kyoto basket of emissions, and emissions associated with Articles 3.3, 3.4 and 3.7, 1990-2012 (in Mt CO_2 equivalent) – EUMM 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	2011	2012	1990-2012	Base Year - 2012
CO_2	588.8	588.8	595.6	579.1	565.4	559.3	550.9	572.1	547.5	552.3	545.0	553.7	565.1	548.7	559.5	561.1	558.1	558.1	551.0	533.7	484.4	502.0	461.1	480.5	-18%	-18%
CH_4	104.0	104.0	104.1	101.7	100.5	95.1	96.8	95.7	93.1	89.7	83.5	78.0	74.5	73.8	69.1	65.0	62.1	61.0	59.0	57.8	55.5	52.3	51.5	50.4	-51%	-51%
N_2O	68.9	68.9	69.1	64.3	59.7	60.2	58.6	58.6	59.0	58.8	48.3	47.4	44.7	42.9	42.4	43.0	42.1	39.9	39.2	38.2	36.0	36.9	35.6	35.3	-49%	-49%
HFCs	15.3	11.4	11.9	12.3	13.0	13.9	15.3	16.5	18.9	16.6	9.8	8.8	9.7	10.1	11.2	10.4	11.2	11.8	12.1	12.7	13.1	13.5	13.7	13.9	23%	-8%
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	0.3	0.2	-85%	-55%
SF_6	1.2	1.0	1.0	1.1	1.1	1.2	1.2	1.2	1.2	1.3	1.4	1.8	1.4	1.4	1.3	1.0	1.0	0.7	0.7	0.6	0.6	0.6	0.6	0.5	-45%	-55%
Grand Total	778.7	775.5	783.0	759.1	740.2	730.2	723.3	744.6	720.2	719.2	688.5	690.2	695.8	677.2	683.7	680.8	674.7	671.9	662.2	643.1	589.8	605.6	562.8	580.8	-25%	-25%
Article 3.3		0.2	0.2	0.1	0.0	-0.1	-0.2	-0.3	-0.3	-0.5	-0.5	-0.1	-0.2	-0.3	-0.3	-0.5	-0.6	-0.9	-1.0	-1.1	-1.3	-1.5	-1.7	-1.8		
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	-1.4	-1.4		
Article 3.7	0.2																									
Kyoto Protocol Total	778.9	774.3	781.7	757.8	738.8	728.7	721.7	743.0	718.4	717.3	686.6	688.6	694.2	675.5	682.0	678.9	672.7	669.6	659.8	640.6	587.1	602.7	559.7	577.6	-25%	-26%
Fixed Base Year	776.3																									-26%

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 ES 4. 1 Emissions of Indirect Greenhouse Gases in the UK, 1990-2012 (in kt).

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
NO_x	2,893	2,782	2,717	2,550	2,439	2,323	2,219	2,049	1,992	1,876	1,807
CO	9,125	9,314	8,899	8,535	8,049	7,546	7,593	7,075	6,782	6,424	5,650
NMVOC	2,702	2,637	2,557	2,439	2,358	2,181	2,105	2,003	1,849	1,664	1,527
SO_2	3,723	3,561	3,481	3,139	2,678	2,370	2,026	1,664	1,645	1,258	1,239

Gas	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
NO_x	1,768	1,725	1,671	1,618	1,596	1,544	1,480	1,327	1,157	1,123	1,049	1,068
CO	5,297	4,737	4,339	3,935	3,556	3,346	3,048	2,846	2,370	2,246	2,069	2,022
NMVOC	1,448	1,367	1,247	1,156	1,083	1,035	998	918	822	789	770	757
SO_2	1,139	1,019	997	838	713	671	593	494	400	418	390	429

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, 43% of emissions are from the solvents sector, with other significant contributions from both the energy and industrial processes sectors.

Contacts

This work is part of the Science Research Programme of the Department of 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.

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A copy of this report and related data may be found on the website maintained by Ricardo-AEA for DECC: http://ghgi.decc.gov.uk/

1 Introduction

This is the UK's 2014 National Inventory Report (NIR). From 2008 onwards, the NIR contains information required for reporting under the Kyoto Protocol as required by decision 15/CMP.1[4].

The National Inventory Report (NIR), as established by decision 18/CP.8[5], 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[6], 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, AND CLIMATE CHANGE

1.1.1 Background information on Climate Change

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 Climate Change Act[7] 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.

[4] 15/CMP.1 Guidelines for the preparation of the information required under Article 7 of the Kyoto Protocol. http://unfccc.int/resource/docs/2005/cmp1/eng/08a02.pdf#page=54

[5] 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. FCCC/CP/2002/7/Add.2 28 March 2003. http://unfccc.int/resource/docs/cop8/07a02.pdf

[6] Kyoto Protocol to the United Nations Framework Convention on Climate Change. http://unfccc.int/resource/docs/convkp/kpeng.pdf

[7] Climate Change Act 2008. http://www.legislation.gov.uk/ukpga/2008/27/contents

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

www.gov.uk/government/organisations/department-of-energy-climate-change
https://www.gov.uk/government/policies/adapting-to-climate-change

1.1.2 Background information on Greenhouse Gas Inventories

1.1.2.1 Reporting of the UK Greenhouse Gas Inventory

The UK ratified the 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 GHGs.

The UK's NIR is prepared in accordance with decision 18/CP.8 and follows the structure outlined in the document FCCC/SBSTA/2006/9[8]. In addition, the UK also reports GHG emissions by sources and removals by sinks in the 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 Ricardo-AEA – the **Inventory Agency** - under contract to the Science Division in DECC. Full details of the institutional arrangements for the preparation of the GHG inventory are explained in **Section 1.2.1**.

This report and corresponding CRF tables provide annual emission estimates submitted by the UK to the UNFCCC for the period 1990 to 2012. To fulfil both European Union Monitoring Mechanism (EUMM)[9] and UNFCCC reporting requirements the UK prepares two sets of CRF tables and officially reports 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 this report presents GHG emissions for the years 1990-2012, 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, include sections on the estimation of uncertainties and atmospheric verification of the inventory, and explain how the greenhouse gas inventory relates to the IPCC Guidelines and the National Atmospheric Emissions Inventory (NAEI). They contain mappings between IPCC, NAEI source categories and fuel types as well as emission factors and references to the technical literature. The IPCC Good Practice Guidance (IPCC, 2000) requires that

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

9 European Union mechanism for monitoring and reporting greenhouse gas emissions http://ec.europa.eu/clima/policies/g-gas/monitoring/index_en.htm

certain sets of activity data are reported as well as the 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 in 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

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 DECC through the publication of the Digest of UK Energy Statistics (DUKES) (see **Table 1.7**). The geographical coverage of DUKES is the United Kingdom (DECC, 2013). 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 territories associated with the UK, who have joined, or are likely to join, the UK's instruments of ratification to the UNFCCC and the first commitment period of the Kyoto Protocol. These include:

- **Crown Dependencies (CDs)**
  The Crown Dependencies are the Isle of Man and the Channel Islands (Jersey and Guernsey). 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 the Cayman Islands, Falkland Islands, Bermuda, Montserrat and Gibraltar. They 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.

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 estimates 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, 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/CP.3[10].

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

[10] 2/CP.3 Methodological issues related to the Kyoto Protocol http://unfccc.int/resource/docs/cop3/07a01.pdf

Gas	GWP
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 provides cross-references to appropriate parts of the report where more detailed information is provided.

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

Reporting element	Background information
	the standard electronic format (SEF) tables is provided in **Chapter 12**. SEF tables are reported alongside this report.
Changes in National Systems	The UK National System is managed and maintained by DECC, who is the Single National Entity. Changes to the national System are reported in **Chapter 13** of this report.
Changes in National Registry	The EU Member States who are also Parties to the Kyoto Protocol (25) plus Iceland, Liechtenstein and Norway have decided to operate their registries in a consolidated manner. The Consolidated System of EU registries was certified on 1 June 2012 and went to production on 20 June 2012. The UK National Registry is operated and maintained by the Environment Agency on behalf of DECC. The National Registry is represented on the National Inventory Steering Committee. All changes in the National Registry are reported in **Chapter 14**.
Minimisation of adverse impacts in accordance with Article 3, Paragraph 14	The UK has undertaken several assessments, reviews and analysis projects to better understand the impacts its policies could have on developing countries, and how 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 Ricardo-AEA – the **Inventory Agency** - under contract to the Science Division in DECC. Ricardo-AEA is 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). Ricardo-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 OTs and CDs, 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 Natural Environment Research Council's Centre for Ecology and Hydrology (CEH), under separate contract to the Science Division of 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 KP (Decision 20/CP.7[11]) 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[12] 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 on-going and is specifying the framework of data supply, such as data quality, format, timeliness and security to underpin the GHG inventory.

Figure 1.1 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 Key organisational structure of the UK National Inventory System

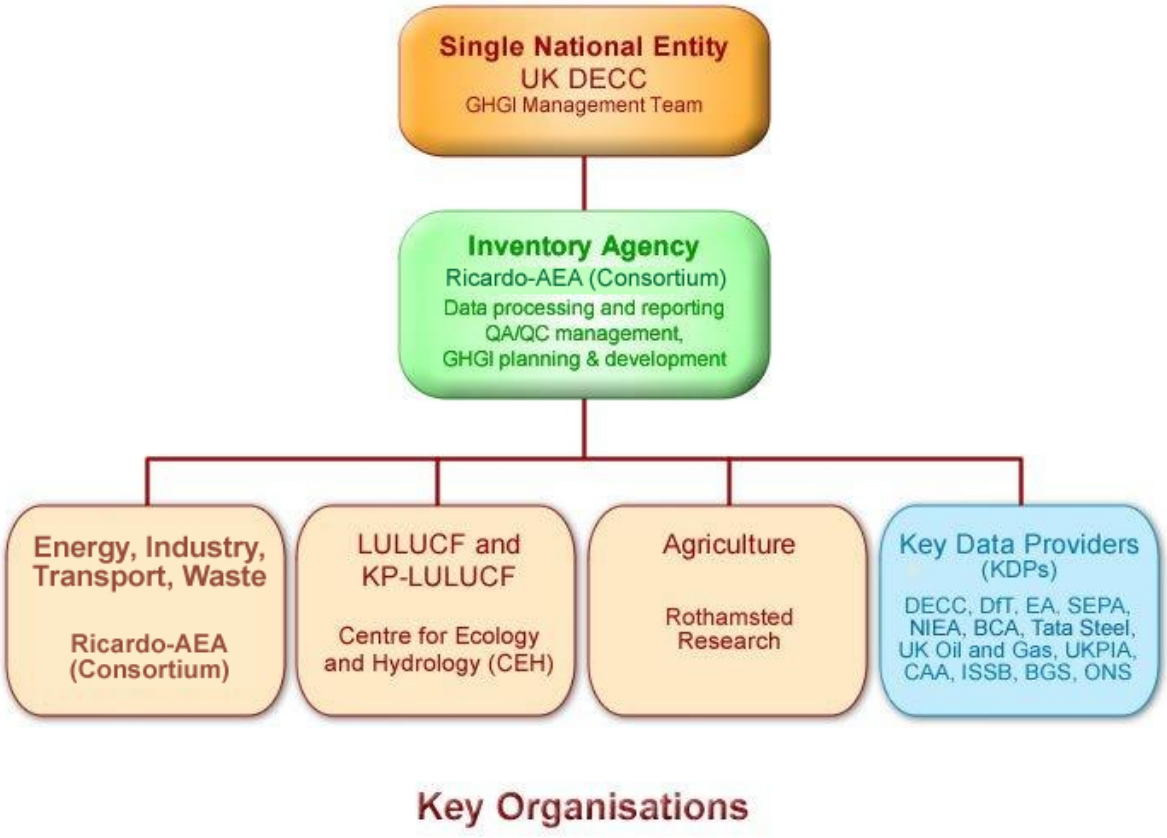


Figure 1.2 shows the main elements the UK National Inventory System, including provision of data to the European Union under the terms of the EU Monitoring Mechanism. DECC is the **Single National Entity** responsible for submitting the UK's GHGI to the UNFCCC. The

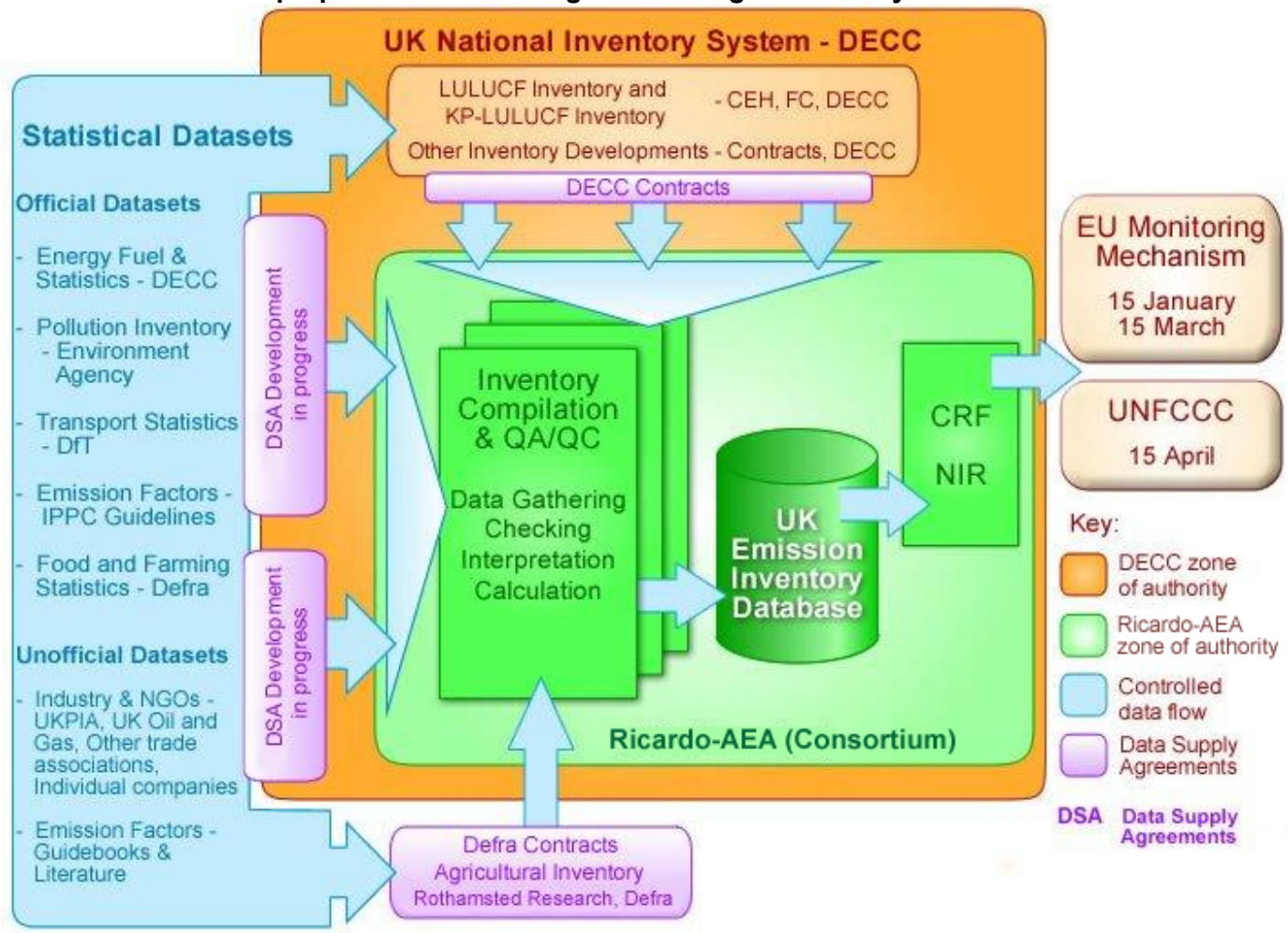
[11] 20/CP.7 Guidelines for national systems under Article 5, paragraph 1, of the Kyoto Protocol http://unfccc.int/resource/docs/cop7/13a03.pdf

[12] Decision No 280/2004/EC of the European Parliament and of the Council of 11 February 2004 concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:049:0001:0001:EN:PDF

Ricardo-AEA consortium compiles the GHGI on behalf of DECC, and produces disaggregated estimates for the Devolved Administrations within the UK.

Key Data Providers include other Government Departments such as Department for Environment, Food and Rural Affairs (Defra) and Department for Transport (DfT), Non-Departmental Public Bodies such as the Environment Agency for England and Wales (EA), Northern Ireland Environment Agency (NIEA) and the Scottish Environment Protection Agency (SEPA), private companies such as Tata Steel, BP Chemicals, and business organisations such as the UK Petroleum Industry Association (UKPIA) and the Mineral Products Association (MPA).

Figure 1.2 Main elements for the preparation of the UK greenhouse gas inventory



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 combination 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).

To meet the standards required under the KP, the UK introduced new legislation specifically for national inventory purposes which took effect from November 2005[13]. 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.

To ensure that the system works most effectively and to minimise the need for legislative action, DECC is establishing 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 on-going, through the National Inventory Steering Committee which is a forum of inventory stakeholders that DECC chairs (see **Section 1.2.2.4** below).

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, DECC has been the Single National Entity for the UK and this has been confirmed in writing to the UNFCCC 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 Science Division administers this responsibility. The Science Division coordinates expertise from across Government and manages research contracts to ensure

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

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 and planning

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

Development of legal and contractual infrastructure

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

The contact point for the single national entity is provided on the **Contacts** page of the NIR.

1.2.2.2 Inventory Agency – Ricardo-AEA Consortium

A new 3-year contract was established for the Inventory Agency in late 2011 following a competitive tendering exercise and a further 2-year extension of the contract (to 2016) has recently been agreed. Ricardo-AEA leads the consortium responsible for compiling the inventory, under contract to DECC. Ricardo-AEA is responsible for all aspects of national inventory preparation, reporting and quality management. The consortium consists of:

- Ricardo-AEA – lead contractor;
- Aether – responsible for estimates from railways and the Overseas Territories (OTs) and Crown Dependencies (CDs), and for improvements to the QA/QC plan;
- SKM Enviros – contribute to the F-gas inventory, in future inventory submissions;
- CEH[14] and AMEC – part of the consortium, but with no direct input to the GHG inventory.

Ricardo-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 KP.

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

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

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.

The inventory agency has formal systems in place to ensure that staff working on the inventory are well trained and able to carry out their duties effectively and efficiently. The technical competence of the staff is facilitated through a combination of the formal Ricardo-AEA and inventory-specific staff management and training systems. Roles and responsibilities for all inventory team members are clearly defined, and a comprehensive system of QA/QC is in place. **Section 1.6** sets out the QA/QC plan in detail. Ricardo-AEA systems ensure subcontractors are managed actively and deliver inputs to the inventory on time and to the specified quality.

The contact point for the inventory agency is provided on the **Contacts** page of the NIR.

The UK Natural Environment Research Council's 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. CEH provide finalised data to Ricardo-AEA for inclusion within the UK GHG inventory.

Rothamsted Research, 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 Ricardo-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 the appropriate format and in time for inventory compilation, allowing for completion of required QA/QC procedures;
- Assessment of their data acquisition, processing and reporting systems, having regard for QA/QC requirements;
- Identification of any required organisational or legal development and resources to meet more stringent NIS data requirements, notably the security of data provision in the future; and,
- Communication with DECC, Ricardo-AEA and their peers or members to help to disseminate information regarding the GHG inventory and National System.

Energy statistics required for compilation of the GHGI are obtained from DUKES, which is compiled and published annually by a team of energy statisticians within DECC.

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

- The Environment Agency's Pollution Inventory for England and Wales;
- The Scottish Environment Protection Agency's European Pollution Emissions Register;
- The Northern Ireland Environment Agency's Inventory of Statutory Releases; and
- EU Emissions Trading Scheme installations which report emissions to the Environment Agency.

Reporting to these UK inventories for the purposes of environmental regulation is a statutory requirement for industries covered by Integrated Pollution Prevention and Control (IPPC). The data from these inventory sources is also used to quality check data provided voluntarily by companies directly to Ricardo-AEA.

Rothamsted Research compiles the inventory for agricultural emissions using agricultural statistics from Defra.

The UK Natural Environment Research Council's 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, Devolved Administrations and from other sources.

1.2.2.4 The National Inventory Steering Committee, pre-Submission Review and Approval of the UK GHGI

To meet the detailed requirements of a National System and to ensure the UK efficiently and effectively works towards implementing best practices, in 2006 DECC 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. This pre-submission review is achieved at a NISC meeting prior to the finalisation of the inventory, and any recalculations to the inventory are presented and discussed at this meeting.

One of the main roles of the committee is to assist the DECC GHG inventory management team to manage and to prioritise the over-arching inventory QA and facilitate review and

improvement and better communication between inventory stakeholders across Government Departments and Agencies.

Special Advisors to the Steering Committee include the Inventory Agency team at Ricardo-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 NISC, 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 and invited experts.

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.

Following a UN Expert Review Team recommendation, a qualitative uncertainty analysis of the inventory is now being implemented by the inventory agency. This qualitative uncertainty analysis supports the Key Category Analysis and helps determine the highest priority emission sources in the UK where methodological improvements could be applied to improve the accuracy of emission estimates, or more detailed reporting used to improve transparency. This qualitative assessment is conducted by experts of the inventory team within the inventory cycle, including through a post-submission review of data sources, methods and feedback from the EUMM and UNFCCC ERTs.

In Spring 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.

Table 1.3 UK GHG National Inventory Steering Committee composition and responsibilities

Organisation	Role in relation to NISC	Key NISC responsibilities
DECC - Science Division	• 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 Carbon Budgets	• 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 – Science Division	• 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

Organisation	Role in relation to NISC	Key NISC responsibilities
Regulators: • Environment Agency for England • Natural Resources 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
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.

Organisation	Role in relation to NISC	Key NISC responsibilities
GHG inventory contractor (Ricardo-AEA)	• UK greenhouse gas inventory compilation and development	• Contractor responsible for the 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
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

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, international inventory experts etc.

1.2.2.5 UK Inventory Improvement Programme

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-EEA and the US EPA, or from specific research programmes sponsored by DECC and other UK Departments.

The UK NIS has a formal inventory improvement programme, managed by the NISC. 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.

The NISC helps prioritise improvements across the inventory. These improvements are designed to improve the transparency, accuracy, consistency, comparability, and completeness of the inventory. Small incremental improvements are made routinely to ensure the inventory uses the most accurate activity data and emission factors. A detailed and prioritised list of larger inventory improvement tasks is maintained by the inventory agency. The list is kept under review continually, and is formally reviewed annually at a NISC meeting. This list is prioritised by taking into account the Key Category Analysis (see **Section 1.5**), the quantitative uncertainty analysis, sector and pollutant expert judgements, and the future obligations of the inventory. The timing of the improvements and resourcing the work are important considerations for the NISC. The single national entity takes the final decision on timing and implementation of improvements to the inventory.

A table summarising the higher priority improvement items is being prepared and will be included with the UNFCCC submission of the NIR. The table will state the stakeholder leading the development work, and report the time frames and outputs of the improvements. A summary of work follows.

1.2.2.6 Integrated UK-DA GHGI improvement programme

During 2013-14, the integrated UK-DA GHGI improvement programme implemented a number of specific research projects to address inventory uncertainties and reporting requirements, including:

- Analysis of the accounting of fossil carbon that is stored in products and not released into the atmosphere. The results of this research have led to several changes to the UK GHGI for the 2014 submission, ranging from re-calculations of emission estimates, re-calculation of stored carbon estimates, and changes to the approach to reporting of the Reference Approach and the Sectoral Approach within the National Inventory Report. However, the research has also broadly confirmed the validity of the GHGI assumptions and methodology for most commodities (Ricardo-AEA, 2014b);
- Analysis of detailed iron and steel data to improve the transparency of the estimates of emissions from combustion and process emissions at integrated iron and steel plant (Ricardo-AEA, 2014)
- The inventory has incorporated recent data from local London airport inventories so that aircraft engine mixes; times in mode and thrust settings are consistent.
- In the agriculture sector the area of histosols has been kept consistent with areas reported in LULUCF.

- Updated digestibility of the feed for dairy cows as advised by the 2013 UNFCCC review from 75.0 to 74.5234142710097.
- Updated AWMS values as advised in the 2013 UNFCCC review : this implied reducing the amount allocated to daily spread and reallocation to solid storage. This one was renamed Deep litter and as a result the MCF value was changed from 1% (daily spread) to 39% for deep litter.
- Correction of an error in 2011 N excretion for dairy cows to link to milk yield.
- Following a recommendation from the 2013 UNFCCC review the UK estimates for landfill methane flaring and use in gas engines, used to update the 6A1 emission estimates in the 2014 submission, have been revised using new metered methane capture data from the Environment Agency;
- LULUCF improvement of methodology in estimating Forest Land emissions and removals by move to use of CARBINE model. The CARBINE model has improved estimates for forest areas timeseries, conifer and broadleaf areas and biomass densities. CARBINE includes a wider range of tree species and a more realistic estimate harvested wood products than was previously used.
- LULUCF inclusion of estimate for by-products from sugar production used as agricultural applications of lime to soil.
- LULUCF improvement in accuracy in land use and land-use change timeseries for Overseas Territories and Crown Dependencies for Grassland, Cropland, Settlement and Other Land areas.

The first NISC meeting of 2014 was held on the 10th April. **Table 1.5** contains details of the high priority improvements items for this inventory cycle and their expected timeline for implementation.

Table 1.5 High priority improvement programme items for 2014 cycle

Sector	Title & Project Detail	Reason for change	Expected timeline
Energy	**Fugitive emissions** - Review of completeness and nomenclature changes, also improvements to source data	Compliance with 2006 IPCC GL	Inclusion in 2015 inventory submission
Energy	**Fuel Use** - Incorporation of EU ETS Phase III data into the inventory and annual reconciliation of offshore fuel use CEFs between ETS data and National Statistics	Expansion of EU ETS scheme	Inclusion in 2015 inventory submission
Energy	**Road transport** - Estimate CO_2 emissions from Urea consumption	Compliance with 2006 IPCC GL	Inclusion in 2015 inventory submission
IPPU	**2006GL: new sources** – review of activity data for new sources in the IPPU inventory: Caprolactum, Glyoxal, Glyoxylic acid and Carbide production; Titanium Dioxide production; N_2O use in anaesthesia; Petrochemicals and carbon black; Soda ash production; Ferroalloy production; Lead & zinc production.	Compliance with 2006 IPCC GL	Inclusion in 2015 inventory submission
IPPU	**2006GL: updates to existing sources** – review of existing methods to ensure 2006GL compliance: Cement production; Lime production; Use of limestone and dolomite –	Compliance with 2006 IPCC GL	Inclusion in 2015 inventory submission

Sector	Title & Project Detail	Reason for change	Expected timeline
	glass, other process uses of carbonates; Chemicals industry (All); Lubricants and paraffin waxes; Asphalt and road paving.		
Agriculture	**Emissions Factors** – review of methane and nitrous oxide emissions factors as part of the ongoing GHG Platform Research project.	Compliance with 2006 IPCC GL and required updates	Inclusion in inventory submissions 2015 onwards as data becomes available
LULUCF	**Improved representation of land use change through data assimilation** – A new vector approach is currently being developed to allow for better representation of rotations between cropland and grassland.	Recommended in 2012 Annual Review Report	Inclusion in 2015 inventory submission
LULUCF	**Update to Wetlands Supplement (2013) methodology** - to determine how the methodology set out in the 'Drained Inland Organic Soils' and 'Rewetted Organic Soils' chapters of newly published Wetland Supplement (2013) can be used operationally in the UK LULUCF Greenhouse Gas Inventory.	Recommended in 2012 Annual Review Report	Inclusion if possible in 2016 inventory submission
Waste	**2006GL: new sources** – review of potential activity data required for 2006GL compliance: open dumps & unmanaged landfill; biological treatment of solid waste; uncollected wastewater.	Compliance with 2006 IPCC GL	Inclusion in 2015 inventory submission
Waste	**Landfill gas flaring data** – review of past operator returns to acquire further historical metered landfill flaring data.	UNFCCC 2013 Review	Inclusion in 2015 inventory submission
General	**Review and improve transparency of the National Inventory Report** for priority sectors	Identified by Single National Entity	Ongoing
General	**Emissions factors** – update of IPCC default emissions factors for 2006GL compliance	Compliance with 2006 IPCC GL	Inclusion in 2015 inventory submission
General	**Key Category Analysis & Uncertainties** – review of methodology to increase transparency	UNFCCC 2013 review & Compliance with 2006 IPCC GL	Inclusion in 2015 inventory submission
General	**Indirect sources of N_2O** – review of existing datasets for inclusion of this new source	Compliance with 2006 IPCC GL	Inclusion in 2015 inventory submission
General	**QA/QC** – Review and consider improvements needed to ensure 2006GL compliance, including new category specific comparisons	Compliance with 2006 IPCC GL	Inclusion in 2015 inventory submission
General	**Data Supply Agreements** (DSAs) - continue to explore further DSAs with key data suppliers	UNFCCC Review comment and internal priority	Ongoing

1.2.2.7 Agriculture inventory improvements

The UK GHG agricultural inventory is undergoing large improvements in order to quantify better 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 agriculture 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. This work will also to allow the inventory to reflect the effect of mitigation strategies[15].
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 N2O and CH4 emissions for the United Kingdom with an assessment of uncertainty (DEFRA project AC0114).
3. Measurements at field scale of CH4 emissions from enteric fermentation to develop Tier 2 methodology (DEFRA project AC0115).
4. Measurements at field scale of direct N2O 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 N2O losses are planned at three sites where drainage is collected and the N2O loss from leached/drained N is quantified (EF5).
5. Measurements at field scale of NH3 emissions from manure management systems (Agricultural GHG R&D Platfom – www.ghgplatform.org.uk).
6. Development of emission factors for N2O from animal manure management systems from existing data[16].
7. Assessment of the effect of mitigation strategies, specifically the use of nitrification inhibitors and optimising fertiliser timing on N2O emission from soils (DEFRA projects AC0116 and AC0213)

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 oil and gas installations and Gibraltar. The Environment Agency is a Government Agency.

Responsibilities of the Environment Agency include to:

- Manage 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;

[15] (DEFRA Agricultural GHG R&D Platfom – www.ghgplatform.org.uk)
[16] (Agricultural GHG R&D Platfom – www.ghgplatform.org.uk)

- Allow access for authorised users[17].
- Act on instructions from Competent Authorities to manage accounts;
- Assist registry users.

DECC is currently planning to implement a Data Supply Agreement with the Environment Agency to ensure that the specific responsibilities of the Agency are more formally agreed.

1.3 INVENTORY PREPARATION

1.3.1 GHG Inventory

The present UK GHG inventory for the period 1990-2012 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 and the Sector 5 LULUCF estimates are prepared by CEH.

1.3.2 Data collection, processing and storage

The data acquisition task provides the fundamental activity data from which the GHG inventory is constructed. The process starts in June with the annual requests for data. A database of contacts is used to track progress of the data acquired.

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

Method improvement

Improvements to calculation methods are implemented before the inventory is compiled. These improvements are in part based on recommendations of UNFCCC 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.

[17] Terms and Conditions at http://emissionsregistry.environment-agency.gov.uk/Default.aspx

Emissions reporting (including background data)
Estimates of emissions are prepared for the various reporting formats (e.g. IPCC, UNECE etc including differing geographical coverages).

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 via approved reporting routes, published in print and made available on publicly accessible 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.

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

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, Ricardo-AEA receives 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.

Ricardo-AEA has work programmes in place with CEH and Rothamsted to help harmonise the quality systems used with those Ricardo-AEA use in the core GHG inventory.

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

The QA/QC plan for the UK inventory is explained in **Section 1.6**. Additional details of QA/QC in the LULUCF and Agriculture sectors (see **Chapter 7**, **Section 7.10** and **Chapter 6**, **Section 6.9** respectively).

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.

Table 1.6 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 1.6 Summary of methods used to estimate emissions of the direct greenhouse gases

CRF sector	Comments on methods
1A	• Basic combustion module (see **Section 3.2.6.2.1**); and • Transport model (see **Section 3.2.8**).
1B	• Carbon Balance approach (See **Section 3.2.6.2**); • DECC EEMS inventory (See **Section 3.3.2.2**); and • Gas leakage data from network operators (See **Section 3.3.2.2**).
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 **Section 3.2.6.2**); 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, 3B, 3C, 3D	• (No direct GHGs emitted from these sectors)
4A	• Emissions calculated based on animal population data and appropriate EFs
4B	• Emissions calculated based on animal population data and appropriate EFs
4D	• Emissions calculated based on animal population data, fertilizer data and appropriate EFs
4F	• Emissions calculated based on IPCC methodologies and USEPA EFs
5	• Mathematical models used to estimate emissions and removals from Land-Use and Land Use Change • CARBINE model used to estimate emissions and removals from Forestry, provided by Forest Research.
6A	• The MethaneEmissions from Landfill model (MELmod)
6B	• IPCC default method and data from operator returns to the regulator
6C	• Country specific emission factors, partially based on Pollution Inventory data

The sources of data used are documented in the relevant sections of this NIR. Much of the activity data are taken from the key publications listed in **Table 1.7**. All sources are updated annually.

Table 1.7 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.
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 Statistics: Inventory of Statutory Releases, transport data (NI Department of the Environment, NI Department for Regional Development)	• Traffic count and vehicle km data for Northern Ireland; and • Information on regulated processes in NI.
Civil Aviation Authority	• Detailed domestic and international civil aviation aircraft km flown.
Pollution Inventory (Environment Agency)	• Information on emissions from regulated processes in England and Wales.
Scottish Pollutant Release Inventory (Scottish Environment Protection Agency)	• Information on regulated processes in Scotland.
United Kingdom Petroleum Industry Association	• Refinery emissions; • Lead and sulphur contents of fuels, benzene content of petrol, RVP of petrol.
Environmental Emissions Monitoring System (EEMS) (DECC Offshore Inspectorate)	• Detailed inventory of oil and gas emissions.

Source (and publisher)	**Relevant activity data contained in the source**
UK Iron and Steel Industry Annual Statistics (International 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.

1.5 DESCRIPTION OF KEY SOURCE CATEGORIES

1.5.1 GHG Inventory

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 1.8**, **Table 1.9, Table 1.10** and **Table 1.11** summarise the key source categories, for 2012 (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.

Following IPCC good practice, a qualitative analysis of the inventory has been made to identify key categories. Details of this analysis are given in **Annex 1**. Emissions from cement production (2A1) have been identified as a key category.

Table 1.8 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	DERV	CO_2	Level
1A3b	Gasoline/ LPG	CO_2	Level
2B5	Non-energy use of products	CO_2	Level, Trend
5A	5A LULUCF	CO_2	Level

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

Table 1.9 Key Source Categories for the base year (including LULUCF)

IPCC source category	Fuel/Activity	GHG	Reason (s)
1A	Coal	CO_2	Level
1A(stationary)	Oil	CO_2	Level
1A	Natural Gas	CO_2	Level
1A3b	Gasoline/ LPG	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
1B2	Oil & Natural Gas	CH_4	Level
4A	Enteric Fermentation	CH_4	Level
4B	Manure Management	CH_4	Level
6A	Solid Waste Disposal	CH_4	Level
1A1&1A2&1A4&1A5	Other Combustion	N_2O	Level
1A3b	Gasoline/ LPG	N_2O	Level
2B	Adipic Acid Production	N_2O	Level
2B	Nitric Acid Production	N_2O	Level

IPCC source category	Fuel/Activity	GHG	Reason (s)
4B	Manure Management	N_2O	Level
4D	Agricultural Soils	N_2O	Level
6B	Wastewater Handling	N_2O	Level
2	Industrial Processes	HFC	Level

Table 1.10 Key Source Categories for the latest reported year (excluding LULUCF)

IPCC source category	Fuel/Activity	GHG	Reason (s)
1A	Coal	CO_2	Level
1A(stationary)	Oil	CO_2	Level, Trend
1A	Natural Gas	CO_2	Level
1A3b	DERV	CO_2	Level
1A3b	Gasoline/ LPG	CO_2	Level
2B5	Non-energy use of products	CO_2	Level, Trend
4A	Enteric Fermentation	CH_4	Level
4B	Manure Management	CH_4	Level
6A	Solid Waste Disposal	CH_4	Level, Trend
1A1&1A2&1A4&1A5	Other Combustion	N_2O	Level, Trend
1A3b	DERV	N_2O	Level, Trend
1A3b	Gasoline/ LPG	N_2O	Trend
2B	Nitric Acid Production	N_2O	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 1.11 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
1A	Natural Gas	CO_2	Level
1A3b	Gasoline/ LPG	CO_2	Level
1B1	Mining & Solid Fuel Transformation	CH_4	Level
1B2	Oil & Natural Gas	CH_4	Level

IPCC source category	Fuel/Activity	GHG	Reason (s)
4A	Enteric Fermentation	CH_4	Level
4B	Manure Management	CH_4	Level
6A	Solid Waste Disposal	CH_4	Level
1A1&1A2&1A4&1A5	Other Combustion	N_2O	Level
1A3b	Gasoline/ LPG	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 analysis

A separate uncertainty analysis has been completed for the Key Categories for LULUFC activities under the KP. The full details of this analysis are given in Table NIR 3, reproduced in **Table A 1.2.1** 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 has been extended to include a range of on-going bespoke sector specific QA/QC activities to comply with Tier 2. Ricardo-AEA (the Inventory Agency is fully accredited to BS EN ISO 9001:2008 (see Box 1 below **Figure 1.3**). This accreditation provides additional institutional standards which the inventory agency has to apply to all projects and ensures that the wider company conforms to good practice in project management and quality assurance. The QA/QC plan sets out a timeline for QA/QC checks, designed to fit in with compilation and reporting requirements for all UK GHG and Air Pollutant reporting commitments.

1.6.1 Description of the current QA/QC system

The National Atmospheric Emissions Inventory and the UK Greenhouse Gas Inventory are compiled and maintained together by Ricardo-AEA (the Inventory Agency), on behalf of DECC and Defra). Ricardo-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). Much of the data received by Ricardo-AEA for the UK GHGI compilation come from other government departments, agencies, research

establishments or consultants working on behalf of UK government or for trade associations. Some of the organisations (e.g. DECC, the Office of National Statistics and British Geological Survey) qualify as the UK's National Statistical Agencies referred to in IPCC Guidance and abide by strict statistical QA/QC standards. Other organisations (e.g. CEH, providing the LULUCF estimates and the Environment Agency, providing regulated point source data) supply important datasets for the Inventory and have their own QA/QC systems. CEH is implementing a QA/QC system for LULUCF following the methodology of Ricardo-AEA (detailed below).

Whilst these organisations have their own QA/QC systems, Ricardo-AEA is responsible for co-ordinating inventory-wide QA/QC activities relating to the submitted datasets. In addition, Ricardo-AEA works with organisations supplying data to the GHG inventory 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 1.3** below. The QA/QC system includes three core components.

1. The QA/QC Plan is a document maintained by the GHGI's QA/QC manager (at Ricardo-AEA) and defines the specific Quality Objectives and QA/QC activities required in undertaking the compilation and reporting of GHG estimates. The plan also assigns roles, responsibilities and a timeline for completion of QA/QC activities.

   The scope of the QA/QC plan includes:

   a. Calculation of greenhouse gas estimates and reporting to UNFCCC and EUMM (including emissions and removals from all sources and gases).

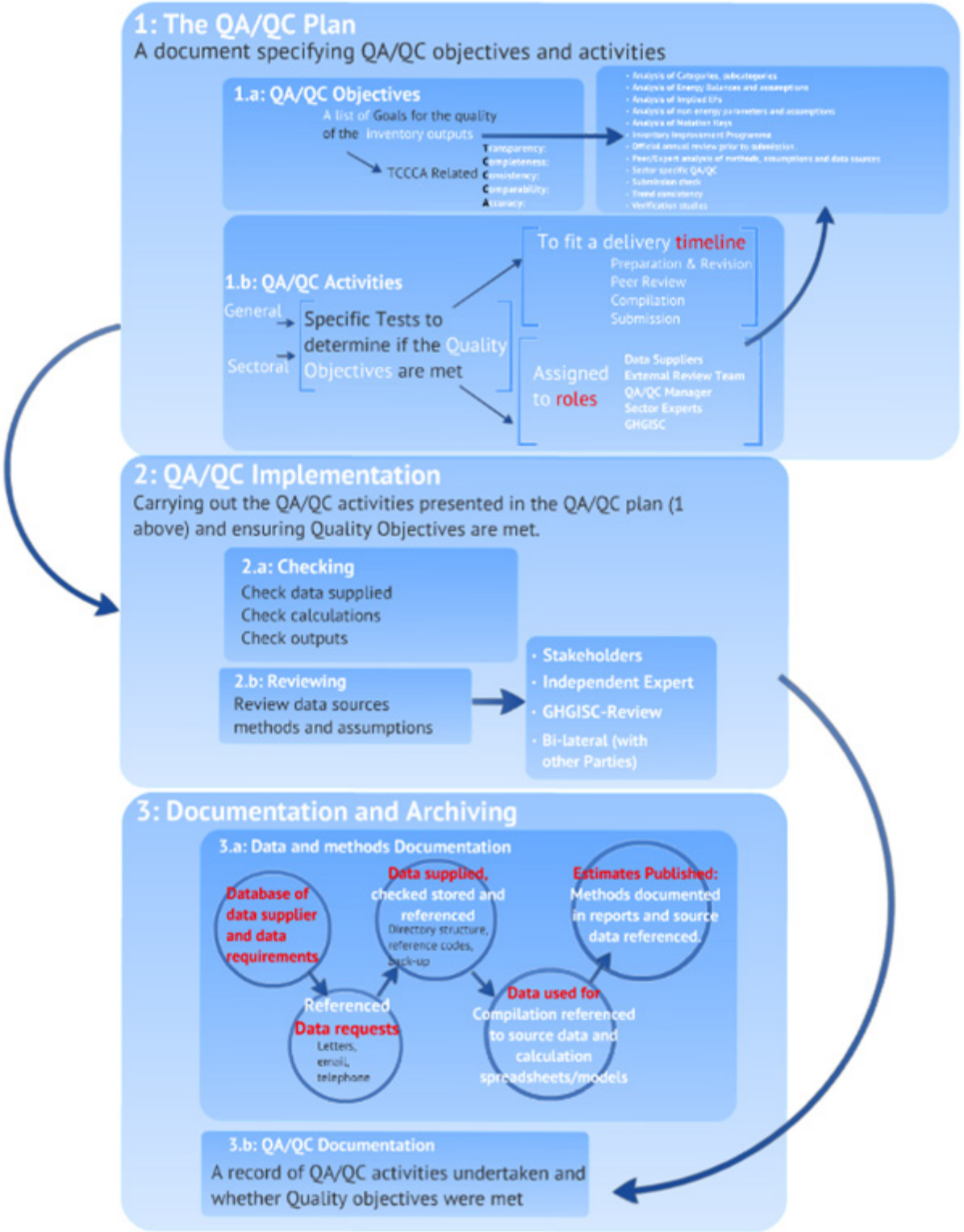
   b. Calculation of air pollutant estimates and reporting to UNECE (including emissions from all sources and pollutants).

   c. Calculation of estimates and reporting to UK National Statistics.

2. QA/QC implementation 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, and is agreed with DECC.

3. Documentation and Archiving. Documentation is embedded within the UK's compilation tools. The NIR transparently describes the data sources, methods, assumptions and QA/QC implementation used in producing the GHG inventory including records of activities undertaken, findings/issue logs, recommendations and any necessary actions taken or planned. Archiving ensures a complete backup and storage of all material used for the compilation of the estimates.

Figure 1.3 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 Ricardo-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 Ricardo-AEA internal QA auditors. The NAEI has been audited favourably by Lloyds on four 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. Ricardo-AEA is currently accredited to BS EN ISO 9001:2008. Lloyds Register Quality Assurance carried out a three yearly recertification audit of AEA (now Ricardo-AEA) in September and October 2011. Ricardo-AEA successfully passed the recertification, with no major non compliances, and a new certificate was issued. Ricardo-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 Quality Objectives

The key objectives of the QA/QC plan are to ensure that the estimates in the GHG and air pollutant inventories are of a suitably high quality and in achieving this the principles of Transparency, Completeness, Consistency, Comparability and Accuracy (TCCCA) are met and that the estimates of emissions are:

- Transparent in:
    - The description of methods, assumptions, data sources used to compile estimates in internal (spreadsheets and other calculation tools) and published material (e.g. the NIR) and on the inclusion of national and EU wide assumptions (e.g. source category detail and the split between EU ETS and non EU ETS 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 using internal checklists and summarised in relevant public material (e.g. NIR).
- Complete: and include all relevant (anthropogenic) emission/removal activities, using representative data for the national territory for socio-economic assumptions and policies and measures for all required years, categories, gases and scenarios.
- Consistent: across trends in emissions/removals for all years (especially where applicable between the historic and projected estimates) and that there is internal consistency in aggregation of emissions/removals.
- Comparable: with other reported emission/removal estimates through use of the latest reporting templates and nomenclature consistent with reporting requirements. Using the correct IPCC category level and consistent units for expressing mass of emissions/removals by gas., split between EU ETS and non EU ETS sources, scenarios, units for parameters and of input parameters with EU assumptions (e.g. energy prices, energy demand, carbon price, population etc).

- Accurate: ensuring the most accurate methods are used in the application of methods, minimising the uncertainty in assumptions and in use of data sources used for the estimates and inclusion of national and EU wide assumptions.

1.6.1.2 Roles and Responsibilities

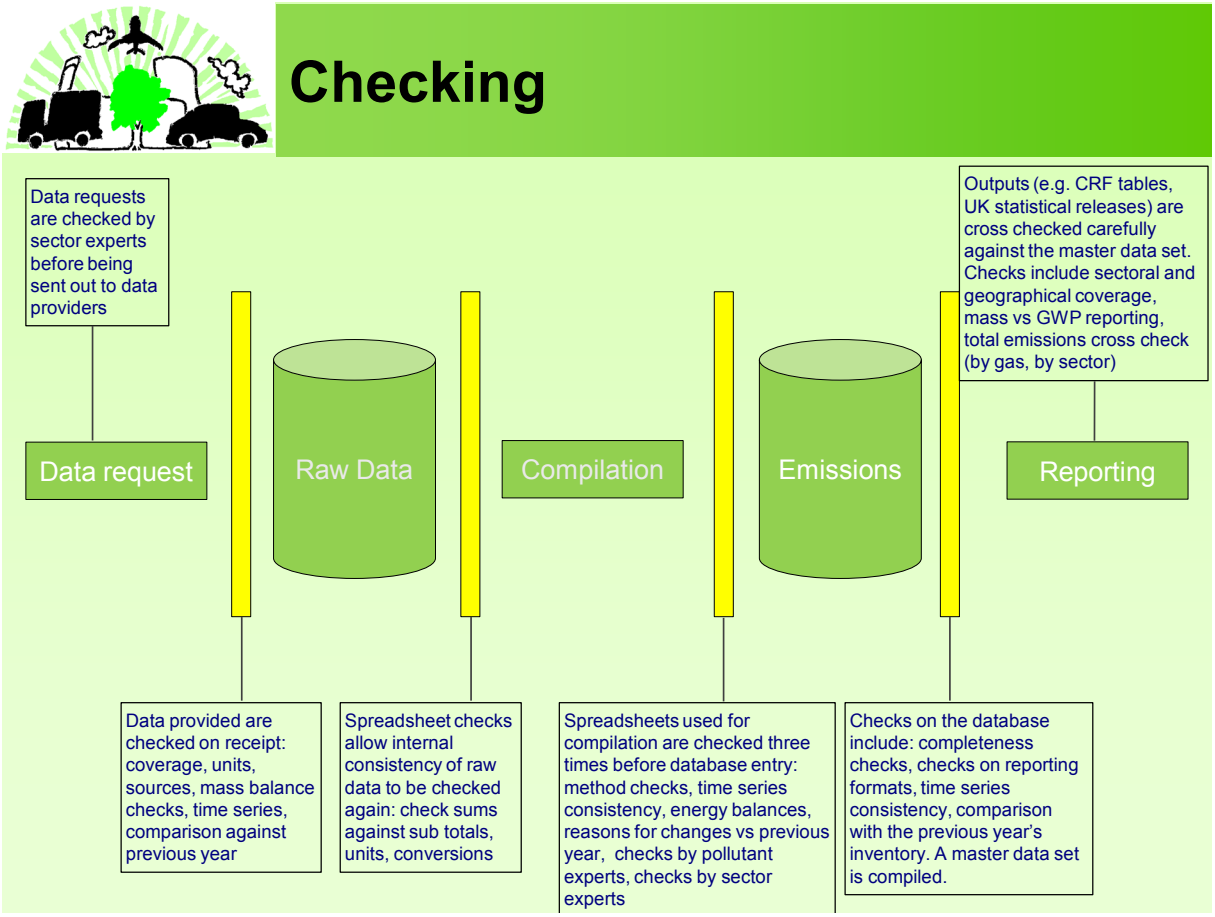
Specific responsibilities have been assigned to the different QA (review) and QC (checking) activities and to different roles within the compilation and reporting process. These are embedded within compilation and processing spreadsheets and databases. The following responsibilities are outlined in the QA/QC plan:

- QA/QC Manager: Coordinates all QA/QC activities and manages the contributions from data suppliers, sector experts and independent experts and undertakes cross cutting QA/QC activities. 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 review and checking activities and report to the QA/QC Manager. Sector Experts also liaise with Data suppliers and other key stakeholders to review estimates and check supplied material.
- Knowledge Leaders: Manage periodic review and perform final checking activities on data and report submissions. Knowledge Leaders have been selected for this role due to their recognised technical experience and authority in the subject area.
- External Review experts: Provide expert/peer review of projections for specific sectors and report to the QA/QC Manager.

1.6.1.3 Quality Control and Documentation

The UK's GHGI Quality Control (checking, documentation and archiving) occurs throughout the data gathering, compilation and reporting cycle. **Figure 1.4** illustrates the process of data checks used within the UK greenhouse gas inventory. The yellow vertical bars symbolise gates through which data does not pass until it meets the quality criteria and the appropriate checks have been performed.

Figure 1.4 Summary of the system of data checks used within the UK greenhouse gas inventory



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

- A database of contacts Containing uniquely referenced data on suppliers,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/removals 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.
- Individual data processing tools are used to prepare the majority of source data into suitable AD and EFs for UK emissions estimates. These data processing tools (spreadsheets and Database models) are uniquely identified and include QC procedures, summaries and source data referencing and documentation within them. QC procedures are embedded in the tools which provide sector specific checks (e.g. energy/mass balance) and implied emission factor checking for default and country specific emission factors. 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 activities that need to be performed, 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; records of authorship; version control and checking. All relevant cells in the data processing spreadsheets are colour coded for ease of reference indicating whether the cells are 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.

- A core database (NAEI database) of AD and EFs with embedded tier 1 QC routines and data source and data processing referencing. The database provides the quality assured data source of emission/removal 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 Activity Data and Emission Factor components for each estimate are held within the central database and include all sources, activities, gases/pollutants (GHGI and AQPI) and years. The majority of data in the database are imported directly from the individual data processing tools/spreadsheets (described above). For data transparency, all data points in the database carry a reference that pinpoints either the upstream data processing tools used to derive the data, the external data source and supplier or both. It 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 helps ensure that data are 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 are embedded within the database that support the annual QA activities defined in the QA/QC Plan and include:
    - 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.
    - Assessment of trends and time series consistency for selected key sources.
    - 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;
    - Other activity data checks (e.g. production and consumption with Official National Statistics).
    - Implied Emission Factor (IEF) checks (assessing trends in IEFs and comparisons with previous submissions).
    - A consistency check between IPCC output and CORINAIR formatted output.

- Data extraction checking routines and procedures: Data exported from the NAEI database and entered into reporting tools (e.g. the CRF Reporter tool) are checked against the direct database output totals to ensure that any inconsistencies are identified and rectified prior to submission. This includes interrogating the output xml from the CRF software and comparing this against a series of queries from the NAEI database to compare both emissions and activity data.
- 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, and from Expert and Peer Reviews. Any data presented in reports are checked against accompanying submission datasets and the NAEI database.
- 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 time series are frozen and archived on a central server. 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 referenced in the archive.

  The agriculture inventory (compiled by Rothamsted Research, North Wyke) is backed up on a daily basis on their network storage system. This system is mirrored with the Rothamsted Research Harpenden site, comprising an offsite backup.

  At CEH, all data and information relating to the LULUCF inventory is stored on a networked drive (accessible only by the project team) which is backed up daily by CEH computer support. There is a separate folder for each inventory year and at the end of an inventory cycle the final versions of all datasets remain unchanged for back reference if required. In addition to this the model code used within CEH for inventory compilation is stored in a subversion repository to ensure a clear record or all amendments and iterations.

1.6.1.4 Quality Assurance and Verification.

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

1.6.1.4.1 NISC annual Review

Annually and prior to submission the 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, including the Single National Entity (DECC) (see Institutional arrangements section) who have an understanding of the GHG estimates and input data sources.

1.6.1.4.2 Stakeholder Consultation with Key Data Providers

The GHGI team have an on-going 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 during the compilation of the 1990-2012 inventory include:

Department of Energy and Climate Change

- The inventory agency held a series of consultations with the DECC energy statistics team that produces DUKES and the regulators of the EU ETS data collection and reporting systems to determine sector-specific and fuel-specific quality parameters for the UK. Outcomes included checking and resolution of outlier data and inconsistencies between CITL data and source data from regulators; comparison of sector- and fuel-specific activity data published in UK energy statistics against the EU ETS data for the latest year.
- Following the in-country review in September 2012, the UK inventory agency prepared new estimates for emissions from petrochemical plant in the UK, to address identified gaps in the UK energy balance and use EU ETS data. These were included in the 2013 submission. Further consultation in 2013 with ethylene manufacturers, other chemical manufacturers, DECC energy statisticians and regulators in the UK has enabled improvements to be made in the estimates for these sources, to refine the time series and improve the data quality (completeness and accuracy) in the 2014 submission.
- As in previous years, data discrepancies between DUKES and EU ETS for the refinery sector were noted and resolved through consultation with the DECC DUKES team, EU ETS regulators and checked against data provided by the refinery sector trade association, UKPIA.
- Additional consultation with the DECC DUKES team, Iron and Steel Statistics Bureau and individual plant operators (notably Tata Steel) has clarified data management within the UK energy statistics compilation system and EU ETS for fuels used in integrated steelworks and coke ovens, as part of an inventory improvement programme task to improve the UK GHG inventory estimates for the iron and steel sector. This has enabled analysis of the data inputs from different data sources (iron and steel operators, independent coke oven operators, other industry consumers) to determine where emission factors for different fuels may be applicable at a greater level of resolution than the UK energy statistics provides, and to check activity data consistency. This process led to a number of instances where the GHGI deviates from DUKES data, mainly affecting emissions in 1A1c.
- 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 EU ETS and EEMS emission reporting systems. This has enabled the inventory agency to improve the accuracy of source allocation of emissions for the sector and to correct a number of errors in previous submissions where assumptions about source allocations or data completeness have been found to be incorrect in light of new data from operators.
- In order to obtain new source data and information to help improve the completeness of reporting of lime applications to land in the UK, CEH has consulted with DECC, Ricardo-AEA's Industrial Sector experts, the British Geological Survey and British Sugar.

Department for Transport

- Consultation with the Department for Transport (DfT) Traffic Statistics team to review and update use of DfT data within the inventory and address issues that have arisen due to staff changes at DfT, e.g. to re-visit the data reporting requirements agreed under the data supply agreement between DfT and DECC. There is an ongoing DfT project researching alternative data sources to estimate road traffic statistics, but no immediate outcomes from this work have become available for consideration in the 2014 submission.

Department for Environment, Food and Rural Affairs

- Consultation with the Environment Agency of England and Wales (EA) and Defra identified new data on landfill gas utilisation and flaring, which has led to a revision in 6A1 emission estimates in the 2014 submission.

Environmental Regulators

- Consultations, teleconferences and emails with sector experts and emission inventory analysts from the environmental regulatory agencies in the UK (EA, SEPA, NIEA) and plant operators 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 changes to plant design or scope of reporting. This has helped to address data reporting issues for manufacturers of fluorinated gases, and a number of chemical companies (including ammonia manufacturing sites).

Other data providers

- Consultation with natural gas distribution network operating companies to: (i) obtain new data on the estimated gas leakage from the transmission system to improve inventory transparency and to review the historic estimates for that source, (ii) a review of gas leakage data provided by some of the gas network operators during 2012 which was noted as outlier data compared to previous industry data, leading to small revisions to estimates in recent years, and (iii) to review the scope of the UK model used for estimating gas leakage from the gas transmission and distribution network, to compare the scope of the model against the reporting requirements of the 2006 IPCC Guidelines.
- Consultation with colliery operators and UK Coal, combined with review of annual reports on coal mine methane use in the UK have sought to build on progress in 2012 and to seek more data from smaller mine operators and test the veracity of UK inventory assumptions regarding emission factors from coal mining activities.
- Consultation with the water industry regulator (OFWAT), the Environment Agency for England and Wales and water and sewerage companies in the UK, to review the sector emission estimates of methane emissions from waste water treatment and sewage sludge treatment and disposal. The inventory agency met with Carbon Managers from most of the UK water companies via the UK Water Industry Research (UKWIR) forum and has procured activity and emissions data from more water companies to improve the completeness of estimates in the latest inventory.
- CEH consultation with Forest Research and R-AEA for move to use of CARBINE model for Forest Sector.
- CEH consultation with Forest Research and Department for Communities and Local Government to source and review wildfire activity data.

- CEH consultation with the British Geological Survey to review national activity timeseries data for limestone and dolomite production for agricultural use.
- CEH consultation with Department of Agriculture of the Government of Falklands to source activity data and understand agricultural practices.
- CEH consultation with the Environment Department of the States of Jersey to improve land area and land use calculations.

1.6.1.4.3 Reviews

The UK's programme of bilateral and external peer 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 in 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.

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).

In addition the UK participates in the annual UNFCCC review.

Review activities to date are summarised in the table below.

Table 1.12 Summary of Peer and Bilateral review activities

Review description	Summary
2006 - 2013: Annual UNFCCC review	Annual review by the UNFCCC expert review team. Reviews highlight reporting issues of transparency, completeness, consistency, comparability or accuracy that need to be resolved by the UK. A list of the current issues and their status are provided in Chapter 5.
2012: Peer review of all except Sector 5. Conducted by EC Technical Expert Review Team	The review focussed on non LULUCF sectors and provided a report for each Member State (including the UK) highlighting recommendations for improvements as well as documentation of any revised estimates as a result of the review. The UK made 3 minor (in total ~ 0.1%) revisions as recommended by this review for lime production and burning of biomass for energy to address underestimates, and for Dairy Cattle to address an over estimate. The review also presented another 20 recommendations for the UK to consider.
2011: Bilateral review of F-gases (2E, 2F) between Austrian, German and UK inventory teams	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, and some are now being implemented.

Review description	Summary
2010 and **2008**: Peer review of Refrigeration and air conditioning (2F1) with Industry experts; SKM Enviros	Assumptions about leakage rates and the mix of HFC fluids in each sub-sector were peer reviewed, by a workshop of experts in 2008. 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 was again peer reviewed by SKM Enviros in 2010, and has since been replaced by new research in 2011.
2009: Peer review of LULUCF (5). DECC funded peer review, CRH independent team	DECC funded an external peer review of the research programme that provides LULUCF emissions estimates to the Greenhouse Gas Inventory in 2009. In addition, 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.
2008: Bilateral review of Agriculture (4) with the French inventory team	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.
2005: Peer review of Adipic acid production (2B3) with Defra, Ricardo-AEA, plant operators, the Met Office	The review 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.
2002: Peer review of Fuel Combustion (1A) by Tim Simmons (UK energy statistician)	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.

1.6.1.4.4 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. Study tour by representatives of the Israeli Ministry of Environmental Protection and Central Bureau of Statistics, who compile the GHG inventory for Israel.
2. Knowledge sharing with Chinese energy statisticians on GHG emissions trading and statistics.

3. Capacity building activities in South Africa in the agricultural sector.
4. Knowledge sharing with the Romanian GHG inventory team during December 2011 to support the improvement of energy sector reporting.
5. Knowledge sharing with the Chinese Energy Research Institute regarding the UK experience of integrating facility-level data into the national inventory and outlining all of the QA procedures that govern energy and emissions data from facility to sector to national level within the UK, to support their efforts in developing a national system of data management to account for GHG emissions, working from provincial and facility-level data.
6. Capacity building in Spain – invited presentation of the UK agricultural inventory improvements and further conversations with Spanish government representatives.
7. Knowledge sharing with Russian and French inventory teams.
8. CEH participation in twice yearly knowledge sharing with European LULUCF inventory compilers at EU Joint Research Council LULUCF meetings.

1.6.2 Verification

DECC has a research programme that derives independent emission estimates for the UK using in-situ high-precision 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 Met Office inversion modelling system, InTEM (Inversion Technique for Emission Modelling), 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. The technique has been applied to 3 year rolling subsets of the data.

This work has been extended to three new sites across the UK, at Angus (north of Dundee), Talcolneston (Norfolk), and Ridge Hill (Herefordshire), to create the UK DECC (Deriving Emissions linked to Climate Change) Network. The data from these additional sites will result in significant increases in spatial and temporal resolution, improving UK estimates and enabling Devolved Administration emission estimates to be calculated from Atmospheric Observations. The uncertainties associated with the UK emission estimates are also expected to decrease.

The complete results of the verification using the atmospheric observations and a more detailed description of the modelling method used are given in Annex 10 of the full UK NIR and through the DECC funded website (www.metoffice.gov.uk/atmospheric-trends).

1.6.3 Treatment of Confidentiality

Much of the data necessary to compile the UK inventory are publicly available. The main exception relates to the reporting of emissions from PFCs and HFCs from some sources. For example, private companies that have provided data to estimate emissions of these gases from training shoes have provided data on condition that the data remains confidential, and it is therefore not possible to report emissions of PFC or HFC species from this source in

isolation. Therefore, a number of sources are reported in combination, and estimates of the total emissions in the main IPCC categories are provided.

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

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

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

1.7 GENERAL UNCERTAINTY EVALUATION

1.7.1 GHG Inventory

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

Approach 2 (Monte Carlo simulation) suggests that the uncertainty in the combined GWP weighted emissions of all the greenhouse gases is 6% in 1990 and 5% in 2012. The trend in the total GWP weighted emissions expressed as the fall between 1990 and 2012 is -26%, with 95% of the values found to lie within the range -24% to -29%. The source making the major contribution to the overall uncertainty is 4D – Agricultural soils.

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

1.8 GENERAL ASSESSMENT OF COMPLETENESS

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.

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

2 Trends in Greenhouse Gas Emissions

2.1 DESCRIPTION AND INTERPRETATION OF EMISSION TRENDS FOR AGGREGATED GREENHOUSE GAS EMISSIONS

Total emissions of direct greenhouse gases have decreased by 26. 0% between 1990 and 2012. This decline is driven predominantly by a decrease in emissions from the energy sector – particularly from power stations (IPCC category 1A1a). The following sections of this report provide an interpretation of this trend, focusing on the trends by gas, and by source sector.

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.

Table 2.1 UK Greenhouse Gas Emissions by Gas, 1990-2012 in Mt CO_2e

Emission Year	CO_2	CH_4	N_2O	HFCs	PFCs	SF6	**Total**
1990	592.51	104.52	69.87	11.38	1.40	0.99	780.68
1995	554.29	97.34	59.63	15.33	0.46	1.20	728.25
2000	553.68	78.46	48.35	8.86	0.46	1.79	691.60
2005	554.59	62.47	42.97	11.25	0.30	0.99	672.57
2008	529.09	58.16	39.06	12.78	0.20	0.58	639.88
2009	479.73	55.93	36.89	13.18	0.15	0.56	586.44
2010	497.01	52.70	37.76	13.56	0.22	0.65	601.90
2011	455.83	51.88	36.36	13.83	0.33	0.56	558.78
2012	475.71	50.82	36.05	13.99	0.21	0.54	577.33

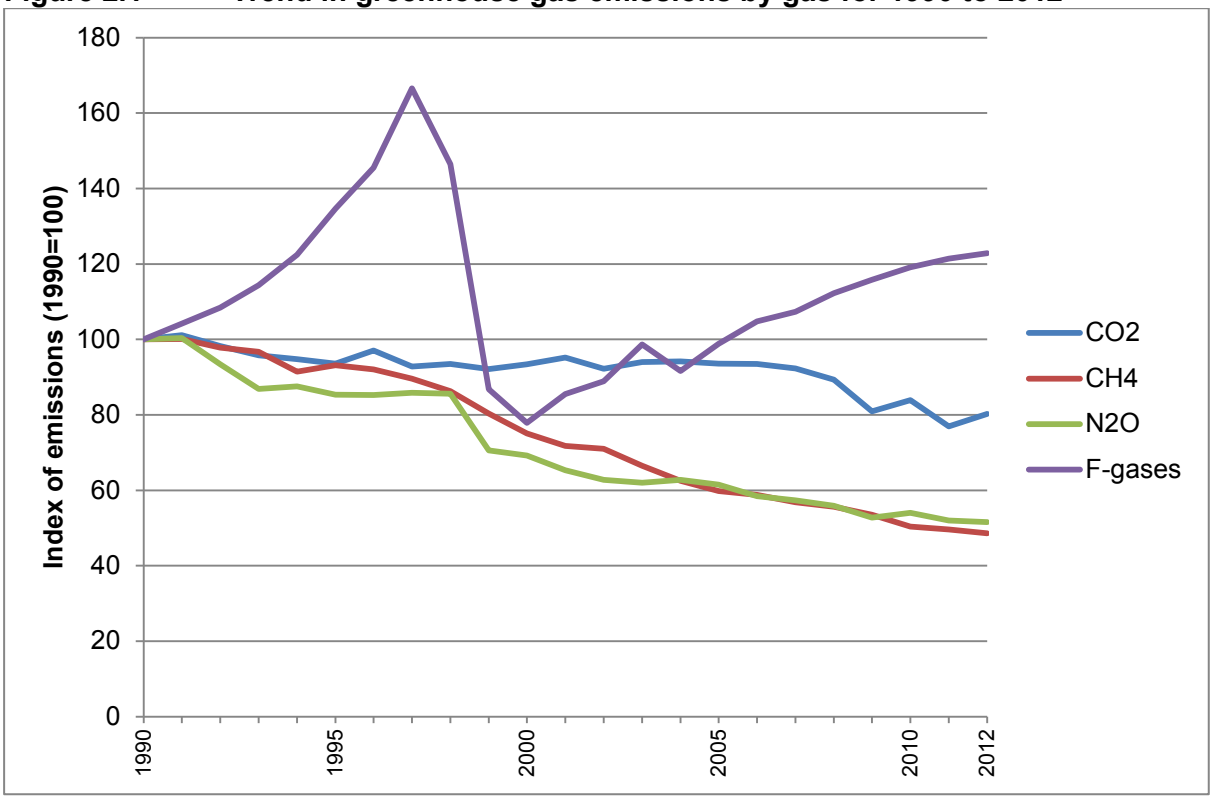
2.2 DESCRIPTION AND INTERPRETATION OF EMISSION TRENDS BY GAS

The largest contributor to global warming is CO_2 at 82.4% of the weighted emission in 2012 (see **Section 1.1.2** for information about weighted emissions). CH_4 contributes 8.8% and N_2O 6.2%. In spite of their high GWPs the contribution of halocarbons is small, estimated at around 2.6% of total GHG emissions. This is because their mass emissions are very small. Overall the total GWP weighted emission has fallen by 26.0% since 1990.

Table 2.2 UK Greenhouse Gas Emissions by Gas in 1990 and 2012

	CO_2	CH_4	N_2O	F-Gases	Total
Mt CO_2e					
1990	592.51	104.52	69.87	13.77	**780.68**
2012	475.71	50.82	36.05	14.74	**577.33**
% Share					
1990	75.90%	13.39%	8.95%	1.76%	**100.00%**
2012	82.40%	8.80%	6.24%	2.55%	**100.00%**

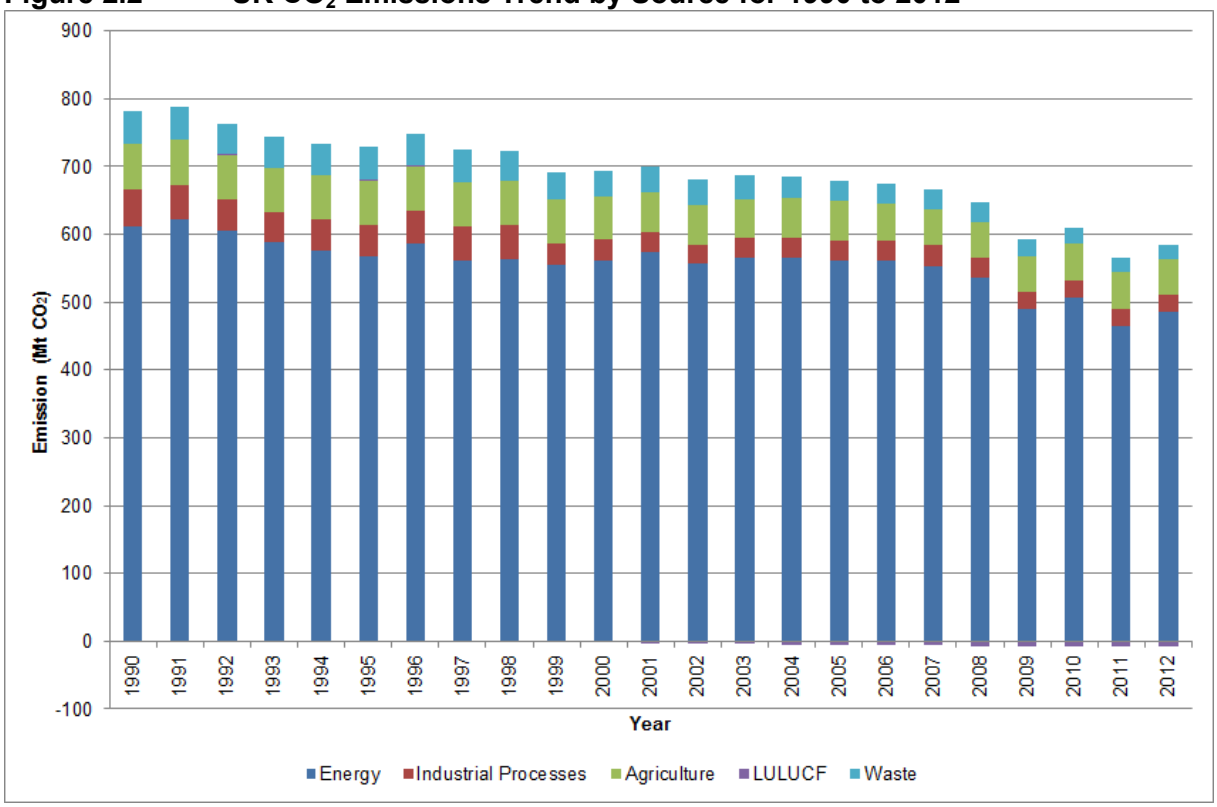
Figure 2.1 Trend in greenhouse gas emissions by gas for 1990 to 2012



2.2.1 Carbon Dioxide

In 2012, CO_2 emissions were 475.7 Mt CO_2 equivalent, 19.7% below the 1990 level. The trend in CO_2 emissions is illustrated in **Figure 2.2,** which shows that the total emissions are dominated by the energy sector, which is the main driver for the declining trend in emission, through fuel switching, structural change, and improvements in end-use efficiency.

Figure 2.2 UK CO_2 Emissions Trend by Source for 1990 to 2012



2.2.2 Methane

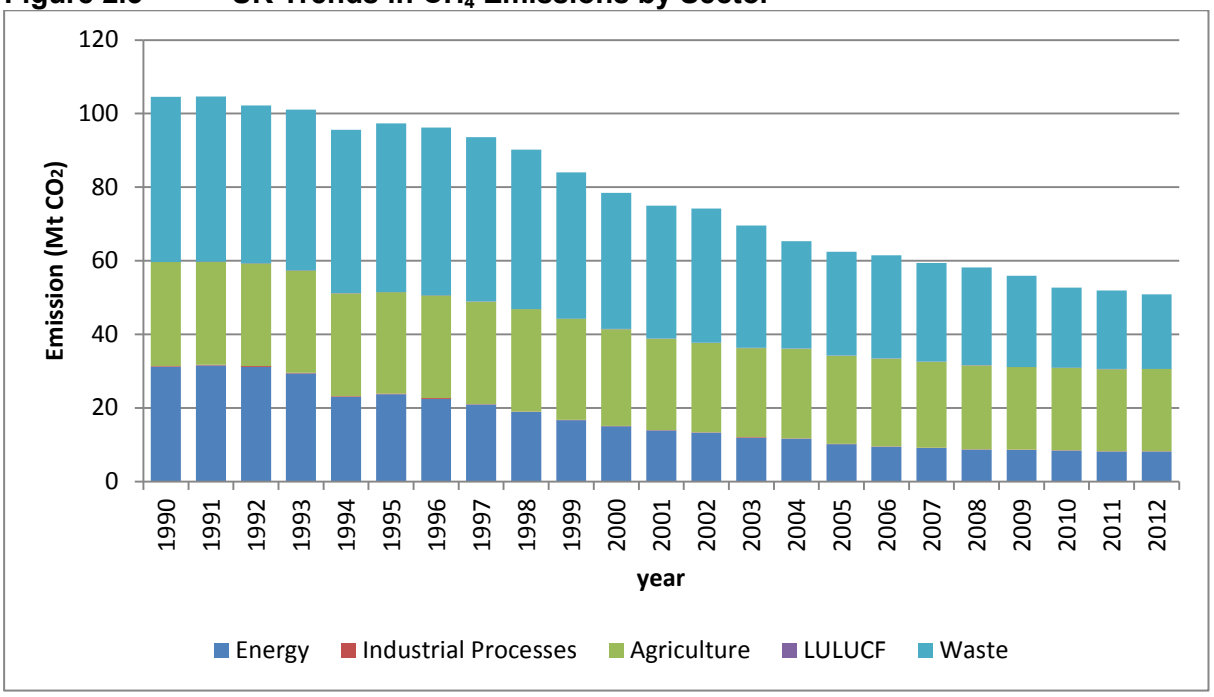
Figure 2.3 illustrates the trend in emissions of methane, broken down by source. Methane is the second most significant greenhouse gas in the UK after CO_2. In 2012, methane emissions were 50.8 Mt CO_2 equivalent.

The major sources of methane are agriculture, waste disposal, leakage from the gas distribution system and coal mining. Emissions from all these sources have declined since 1990, and the main reasons for these are:

- In the energy sector, reduced coal mining activity, and improvements to the gas distribution network have contributed to an overall decrease in emissions of 73.8% since 1990. Decreases in this sector have contributed 42.8% to the total decrease in methane emissions.
- Total emissions in the waste sector have decreased by 55.0% due to increased implementation of methane recovery systems at landfill sites. The reduction in emissions in this sector is responsible for 45.9% of the total decrease in methane emissions since 1990.
- Emissions from agriculture have decreased by 21.2% since 1990, following the trend of decreasing livestock numbers. This sector is responsible for 11.2% of total reductions in methane emissions.

Since 1990, emissions of methane have decreased by 51.4%. Emissions from LULUCF and Industrial Processes are not significant sources of methane in comparison to the other sectors.

Figure 2.3 UK Trends in CH_4 Emissions by Sector

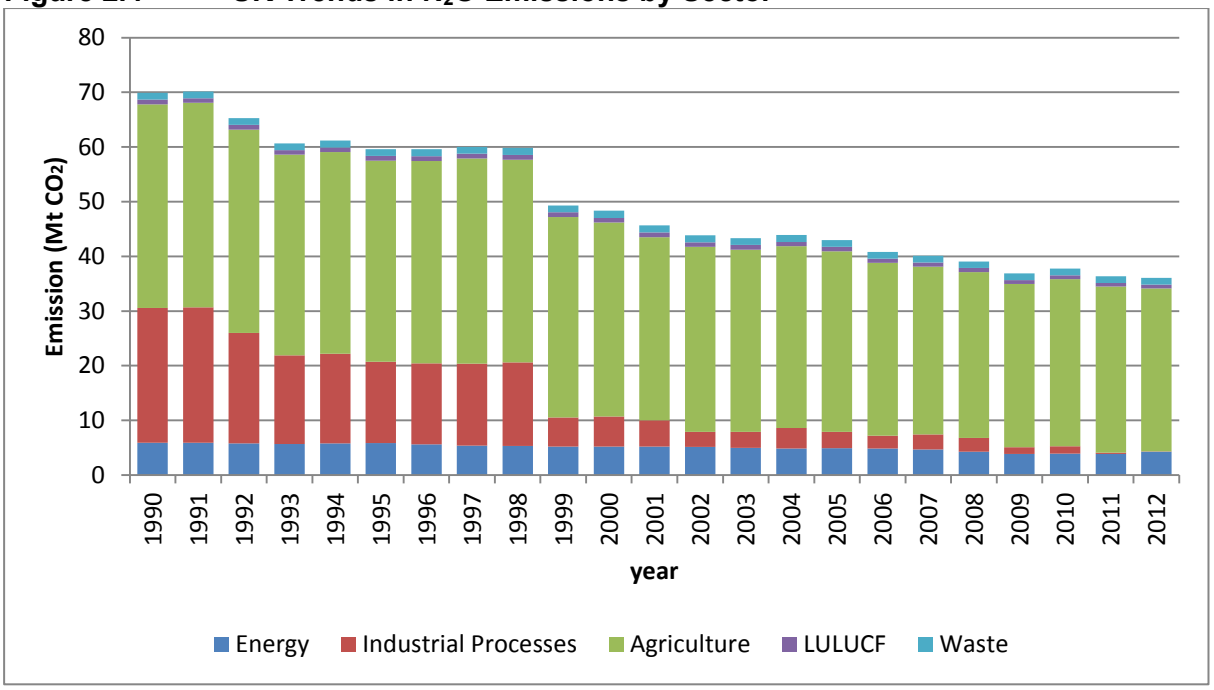


2.2.3 Nitrous Oxide

Figure 2.4 illustrates the trend in emissions of N_2O. The main anthropogenic sources are agriculture, transport, industrial processes, and coal combustion. In 2012, emissions of N_2O were 36.1 Mt CO_2 equivalent. Emissions have declined 48.4% since 1990, and the main reasons for this reduction are:

- The agriculture sector is a major source of N_2O emissions, contributing 82.8% to total emissions of N_2O. Emissions from this sector have decreased by 19.8% 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 35.3% to total N_2O emissions. In 2012, these sources accounted for only 0.2%. 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 2.4**). Emissions from Industrial Processes have decreased by 99.7% since 1990, contributing 72.7% 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 11.8% to total N_2O emissions in 2012. Emissions from this sector have decreased by 28.3% 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 1995 due to the increase in cars with 3-way catalysts in the fleet. From 1996 onwards, however, emissions from this source have started to decrease due to the improvements in catalyst technology in newer vehicles and a reduction in the sulphur content of fuel reducing the degradation of the catalysts. Emissions in 2012 are now 23.9% lower than emissions in 1990.

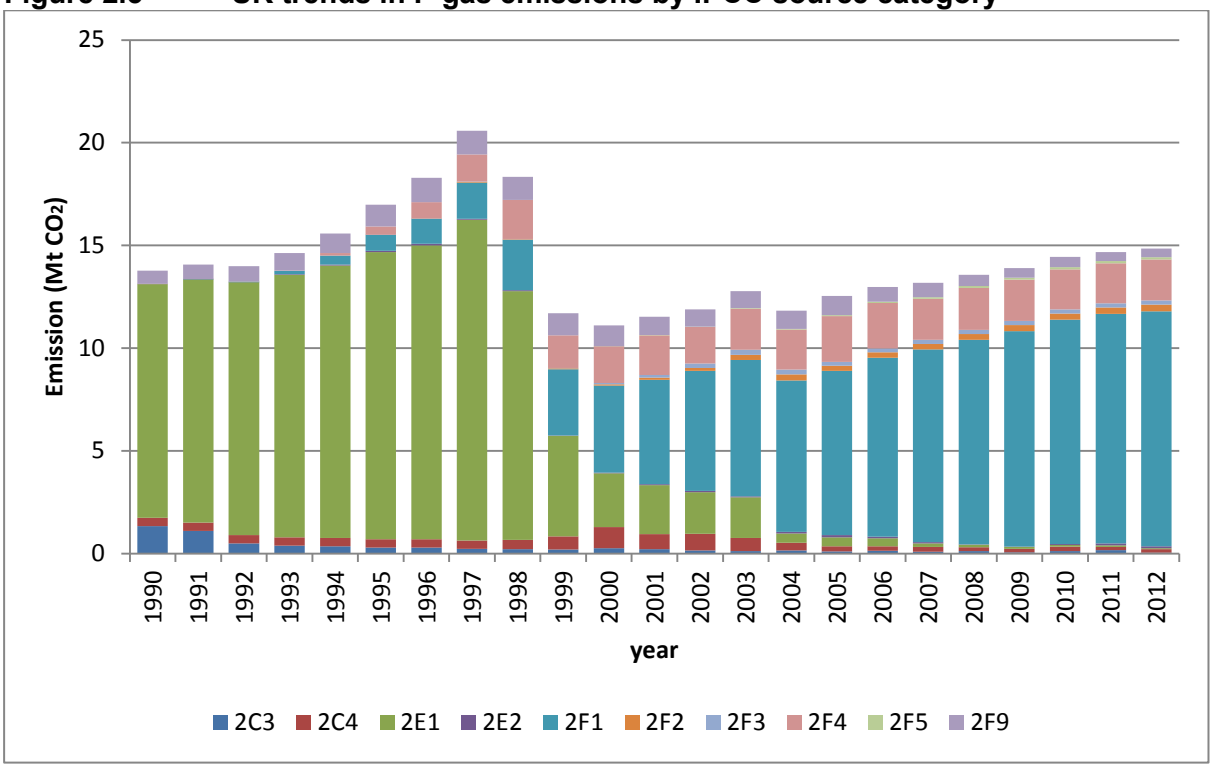
Figure 2.4 UK Trends in N_2O Emissions by Sector



2.2.4 Fluorinated-Gases

Emissions of the F-gases (HFCs, PFCs, and SF_6) totalled 14.7 Mt CO_2 equivalent in 2012. Since 1995 – the base year used for F-gases – the overall decrease in their emissions has been 13.2%, mainly driven by the fall in emissions from F-gas manufacture (sector 2E), due to the installation of abatement equipment at two of the three manufacturers. Emissions from certain end-use sectors, such as refrigeration, are continuing to grow.

Figure 2.5 UK trends in F-gas emissions by IPCC source category



The IPCC source categories referred to in **Figure 2.5** are:

2C3: Aluminium Production
2C4: Aluminium and Magnesium Foundries
2E1: Halocarbons production (by-product)
2E2: Halocarbons production (fugitive)
2F1: Refrigeration and Air Conditioning Equipment
2F2: Foam Blowing
2F3: Fire Extinguishers
2F4: Aerosols/Metered Dose Inhalers
2F5: Solvents
2F9: Other

2.3 DESCRIPTION AND INTERPRETATION OF EMISSION TRENDS BY CATEGORY

Table 2.3 below presents a summary of total GWP weighted emissions by sector. No direct GHGs are reported under Solvents and Other Product Use.

Table 2.3 Total GWP weighted emissions by sector (Mt CO_2e)

Year	Energy	Industrial Processes	Agriculture	LULUCF	Waste
1990	611.68	54.24	65.51	1.88	47.37
1995	567.98	46.43	64.38	1.49	47.97
2000	561.89	31.25	61.72	-2.09	38.84
2005	561.11	30.25	57.02	-5.68	29.88

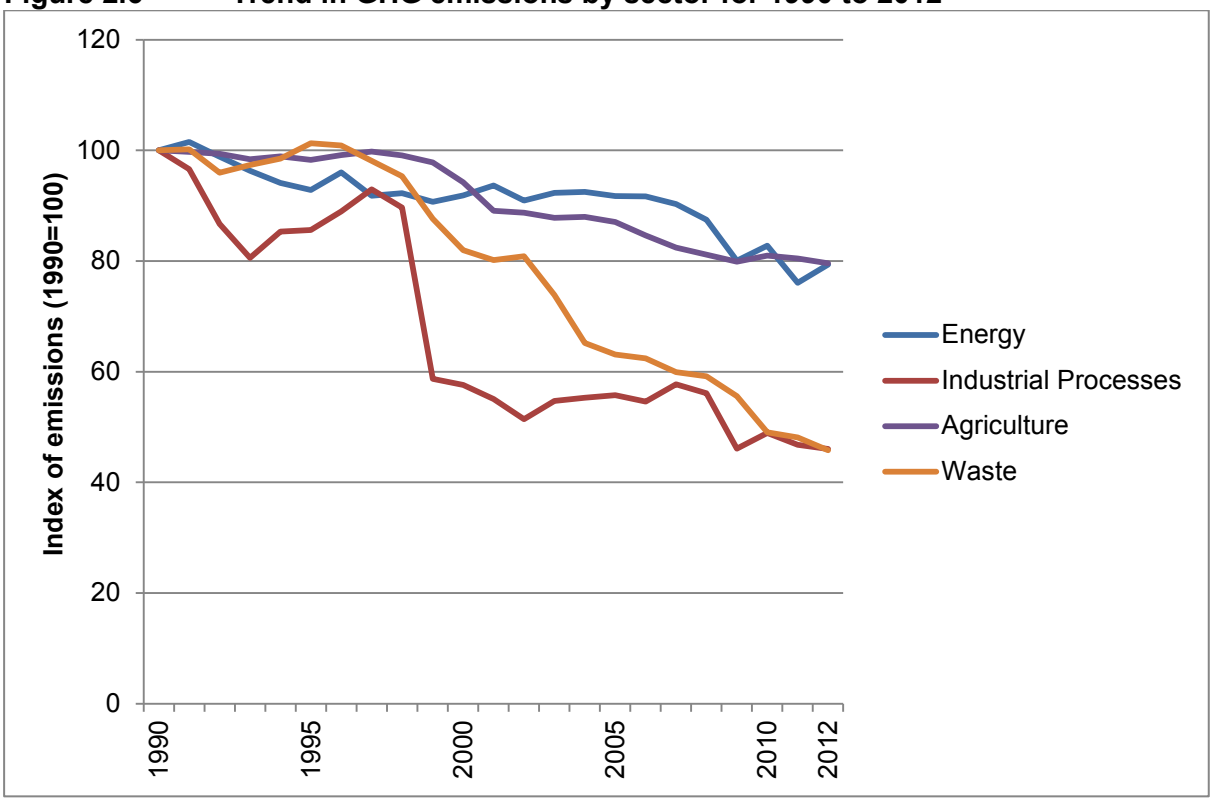
Year	Energy	Industrial Processes	Agriculture	LULUCF	Waste
2008	535.09	30.44	53.18	-6.86	28.01
2009	489.75	24.99	52.32	-6.94	26.32
2010	506.30	26.55	53.05	-7.25	23.25
2011	465.37	25.39	52.72	-7.49	22.79
2012	485.50	24.97	52.13	-6.98	21.70

Total emissions are dominated by the energy sector in both 1990 and 2012, contributing 78.4% to total net emissions in 1990 and 84.1% in 2012. Emissions from all sectors have declined between 1990 and 2012, with the largest decline in percentage terms from the LULUCF sector, which has gone from a net source to a net sink. In absolute terms, the largest overall decline is in the energy sector.

Table 2.4 Emissions by sector in 1990 and 2012, the emissions trend and share of the total

Sector	Emissions (Mt CO_2e)		Trend	Share	
	1990	2012	1990-2012	1990	2012
Energy	611.68	485.50	-21%	78%	84%
Industrial Processes	54.24	24.97	-54%	7%	4%
Solvent and Other Product Use	-	-	N/A	0%	0%
Agriculture	65.51	52.13	-20%	8%	9%
LULUCF	1.88	-6.98	-471%	0%	-1%
Waste	47.37	21.70	-54%	6%	4%
Grand Total	780.68	577.33	-26%	100%	100%

Figure 2.6 Trend in GHG emissions by sector for 1990 to 2012[18]



2.3.1 Energy

In 2012 emissions in the energy sector accounted for 84.1% of total net direct greenhouse gas emissions and have declined by 20.6% since 1990.

For CO_2; 99.4% of total net emissions came from this sector in 2012. Energy industries (category 1A1) were responsible for 40.1% of the sector's CO_2 emissions in 2012. There has been an overall decline in emissions from this sector of 19.4% since 1990. During the early 1990s, after the privatisation of the power industry in 1990, there was a strong move away from coal and oil generation towards use of gas. Compared to 2011, there was a notable reversal of this trend; this change in power sector fuel mix has contributed to the increase in sector emissons between 2011 and 2012.

Overall, between 1990 and 2012, there has been an 8.3% increase in the amount of electricity generated but a 22.0% decrease in CO_2 emissions from power stations (1A1a). There are several reasons; firstly the shift towards use of CCGT stations rather than conventional steam stations burning coal or oil – CCGT stations operate at a higher thermal efficiency, for example in 2012 they operated on average at 47.7% efficiency, whilst coal-fired stations operated on average at 36.0% efficiency. Secondly, the calorific value of natural gas per unit mass carbon is higher than that of coal and oil. Thirdly, there has been a slight increase in electricity generated from non-fossil fuel energy sources, due to increased use of wastes and renewable energy sources, which in 2012 including nuclear energy provided 30.9% of UK electricity generation.

[18] LULUCF is not included on this graph as it would make the other trends difficult to discern, see **Table 2.3** for the numeric trends

Emissions from category 1A2 – Manufacturing Industries and Construction contributed 13.7% to overall net CO_2 emissions in the UK in 2012. Since 1990, these emissions have declined by 38.3%, mainly as a result of a decline in the emissions from the Iron and steel industry. This sector has seen a significant decrease in coke, coal and fuel oil usage, with an increase occurring in the emissions from combustion of burning oil and waste.

Emissions of CO_2 from 1A3 (Transport) are dominated by road transport (1A3b), which in 2012 were responsible for 94.2% of the total emissions from transport. Emissions from road transport peaked in 2007 at 12.2% above 1990 levels. Carbon dioxide emissions from road transport have declined since 2007 partly due to improvements in average fuel efficiency of vehicles and the switch from petrol to diesel cars and from a reduction in traffic volumes. Total vehicle kilometres travelled are 3.5% less in 2012 than in 2007 with a larger drop in the kilometres travelled by HGVs, possibly due to the economic downturn. The increased displacement of fossil fuels by biofuels since 2002 has also had a significant impact on total CO2 emissions. The carbon emissions from the consumption of biofuels are not included in the UK totals. Emissions of CO_2 from domestic aviation increased by 65.4% between 1990 and 2005, but have since shown a decrease of 33.2% since 2005 despite an increase in the total number of km flown. This is because of a move to use more fuel efficient aeroplanes in 2006.

Emissions of CO_2 in the domestic sector (1A4b) account for 75.1% of CO_2 emissions in 1A4. These emissions have changed little over between 1990 and 2012 although the effect of annual temperatures can produce some large variations between any two years. Fuel consumption data since 1990 indicates a general trend in fuel switching in these sectors, away from more carbon-intensive fuels such as coal, coke, fuel oil and gas oil, towards natural gas. This shift has partly been driven by fuel prices but also through the growth of the UK gas supply network (most notably in Northern Ireland.

Methane emissions in the energy sector are mostly from fugitive emissions (1B). In 1990, 63.9% of these emissions came from the production of solid fuels; however these emissions have decreased by 89.2% and now make up just 27.6% of fugitive CH_4 emissions. Fugitive emissions from oil and gas operations have also decreased over this period, by 49.7%.

The energy sector accounted for 11.8% of total N_2O emissions in the UK during 2012. Of this, 38.7% arose from energy industries (1A1). Within this category, emissions from public electricity production have shown a 27.5% decrease, whilst emissions from petroleum refining have increased by 39.2%. Emissions from 1A1c (Manufacture of Solid Fuels and Other Energy Industries) have increased by 5.8% between 1990 and 2012. N_2O emissions from the energy sector have decreased overall by 28.3% since 1990. Over this period the use of coal has decreased and the use of natural gas increased.

The other major contribution towards N_2O emissions within the energy sector is the transport sector (1A3) (23.6%). Between 1990 and 1995, emissions increased by 23.0% due to the increasing numbers of petrol driven cars fitted with early generation three-way catalysts. These are used to reduce emissions of nitrogen oxides, carbon monoxide and non-methane volatile organic compounds however; nitrous oxide is produced as a by-product. Since then, emission factors have been declining with successive Euro standards, due to better catalyst formulations, as well as reductions in fuel sulphur content. The level of sulphur in fuel impacts upon the effectiveness and degredation rate of catalysts. The overall change in the N_2O emissions from the transport sector between 1990 and 2012 is 20.1%.

2.3.2 Industrial Processes

Emissions of direct Greenhouse gases within this sector have decreased by 54.0% since 1990. For 2012, 35.5% of emissions in this sector were of CO_2, although this made up only 2.1% of all CO_2 emissions. Only small quantities of CH_4 and N_2O come from this sector, whilst 100% of F-gases are assigned to industrial processes.

Between 1990 and 2012, emissions of N_2O from this sector declined by an estimated 99.7% due to reductions in emissions from adipic acid manufacture (a feedstock for nylon) and nitric acid production. N_2O emissions from nitric acid manufacture show a fall in 1999 due to the installation of an abatement system at one of the plants and another fall in 2011 due to installation of abatement in the remaining plants. Emissions from adipic acid manufacture were reduced significantly from 1998 onwards due to the retrofitting of an emissions abatement system to the only adipic acid plant in the UK, which subsequently closed in April 2009.

Since 1990, emissions of HFCs have increased by 22.6%. The largest contribution to this sector in 2012 arises from category 2F1 – refrigeration and air conditioning equipment. In 2012, these contributed 80.9% to the overall emissions of HFCs. Emissions from this category arise due to leakage from refrigeration and air conditioning equipment during its manufacture, lifetime and disposal. Emissions from aerosols contribute the next largest percentage (14.1%) to overall HFC emissions. In this category, it is assumed that all the fluid is emitted in the year of manufacture. This category contains mainly industrial aerosols and also metered dose inhalers (MDI). Emissions from manufacture of HFCs and HCFCs have decreased by 99.5% since 1990, due to plant closures and the installation of abatement equipment.

PFC emissions have declined by 85.2% since 1990. A significant source of PFC emissions is aluminium production. During the process of aluminium smelting, PFC is formed as a by-product. The emissions are caused by the anode effect, which occurs when alumina concentrations become too low in the smelter. This can cause very high electrical current and decomposition of the salt – fluorine bath. The fluorine released then reacts with the carbon anode to create CF_4 and C_2F_6. Since 1990, emissions arising from aluminium production have shown a 96.9% decrease due to significant improvements in process control and an increase in the rate of aluminium recycling.

The use of SF_6 in magnesium foundries contributed 29.7% towards total SF_6 emissions in 2012, and total emissions have decreased by 60.3%. Emissions from 2F9 – Other contributed 70.3% towards emissions, which includes emissions from electrical insulation. Emissions arise during the manufacture and filling of circuit breakers and from leakage and maintenance during the equipment lifetime. It also includes emissions from applications in the electronics industry and sports shoes.

2.3.3 Solvent and other product use

No direct GHG emissions are reported in this category.

2.3.4 Agriculture

Direct GHG emissions in 2012 consisted of 42.8% CH_4 and 57.2% N_2O and total direct GHG emissions decreased by 20.4% between 1990 and 2012. CH_4 emissions have declined by 21.2%, driven mostly by a decline in emissions from enteric fermentation from cattle due to

decreased cattle numbers. N_2O emissions have decreased by 19.8%, which has been driven by both a decline in animal numbers and a decrease in synthetic fertiliser application.

2.3.5 Land use, land use change and forestry

The UK has moved from being a net source of CO_2 from LULUCF activities in 1990 to a net sink for all years since 1998. As the LULUCF sector comprises both emissions and removals of greenhouse gases, expressing the change since 1990 on a percentage basis can be misleading. Total estimated emissions of direct greenhouse gases from the LULUCF sector fell from a source of 1.89 $MtCO_2e$ per year to a sink of 6.94 $MtCO_2e$ per year in 2012.The maximum size of the sink, 7.45 $MtCO_2e$, was reported in 2011. The land use categories which have the greatest effect on the net LULUCF emissions/removals are forest land and grassland (net sinks) and cropland (a net source). Forestland is currently a decreasing sink due to a lowering of the average age of trees as a consequence of historically low rates of afforestation during the 1990s. Emissions from cropland have decreased by 29.0% since 1990. Net removals from grassland have increased by 22.1% since 1990, although the size of the sink decreased by 6.9% since 2009.

Compared to CO_2, emissions of CH_4 and N_2O are relatively low in this sector. Methane emissions from the forestry, cropland, grassland and settlements categories have increased by 214% since 1990 over half of which (53.6%) since 2010. Emissions of nitrous oxide have decreased by 20.6% since 1990.

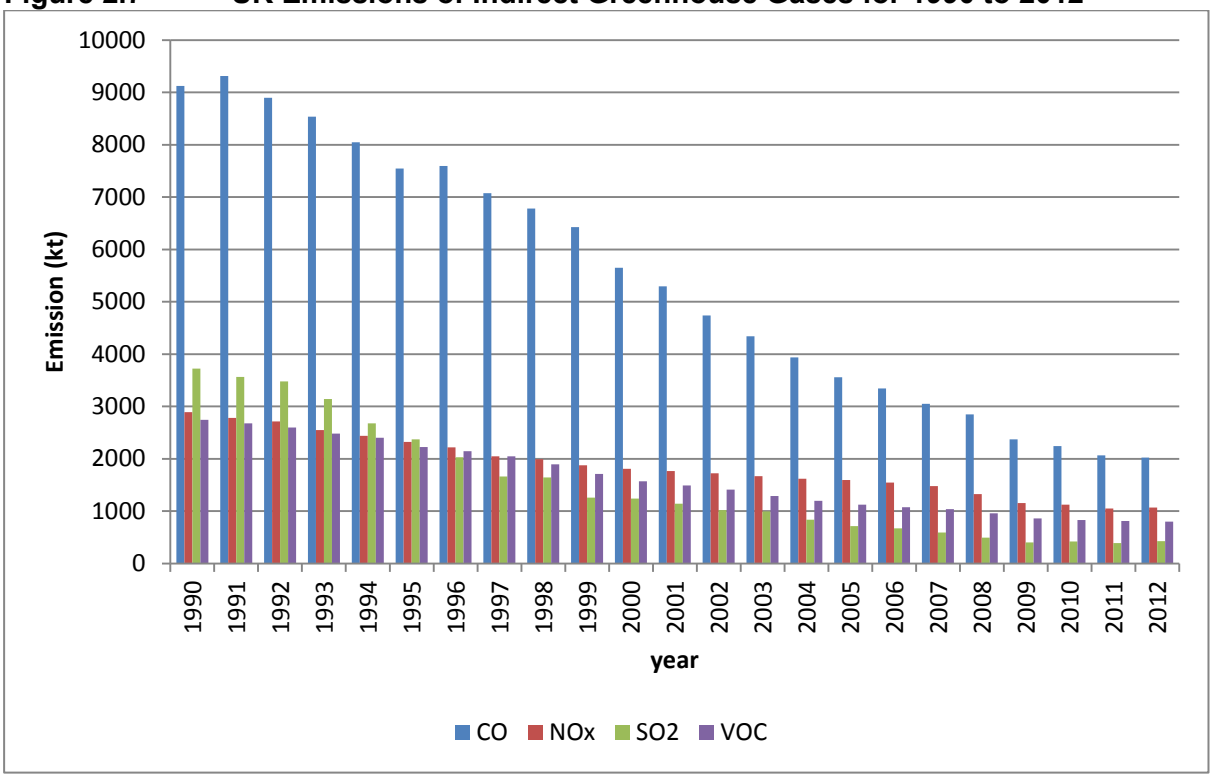
2.3.6 Waste

Total emissions from the waste sector have declined by 54.2% since 1990. 85.5% of this reduction is due to a decline in methane emissions from landfill. Emissions estimates from landfill are derived from the amount of biodegradable waste disposed of to landfill and are based on a model of the kinetics of anaerobic digestion involving four classifications of landfill site. The model also accounts for the effects of methane recovery, utilisation and flaring. Since 1990, methane emissions from landfill have declined by 56.9% due to the implementation of methane recovery systems. This trend is likely to continue as all new landfill sites are required to have these systems and many existing sites may have systems retrofitted.

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 **Table 2.4**.

Figure 2.7 UK Emissions of Indirect Greenhouse Gases for 1990 to 2012



2.4.1 Carbon Monoxide

In 2012, the total emissions of CO were 2,022 Gg, and since 1990, emissions have decreased by 77.8%.

Emissions of carbon monoxide from the energy sector contributed 91.7% to overall UK CO emissions in 2012, 37.4% of these emissions occur from transport (1A3). Since 1990, emissions from 1A3 have declined by 89.2%, which is mainly because of the increased use of three way catalysts, although a proportion is a consequence of fuel switching in moving from petrol to diesel cars.

Emissions from sector 1A2 contributed 31.5% to overall emissions of CO in 2012. Emissions from within this category mostly come biomass combustion and petrol use in off-road vehicles within the Manufacturing, industry and combustion sector.

2.4.2 Nitrogen Oxides

In 2012, total emissions of NO_x were 1,068 Gg, and since 1990, emissions have decreased by 63.1%.

Over 99.5% of NO_x emissions in the UK came from the energy sector in 2012. Since 1990 emissions from this sector have decreased by 62.9%, mostly as a result of abatement measures on power stations, three-way catalysts fitted to cars and stricter emission regulations on trucks. The main source of NO_x emissions is transport: in 2012, emissions from transport contributed 39.3% to the total emissions of NO_x in the UK, with 31.3% arising from road transport (1A3b). From 1970, emissions from transport increased (especially during the 1980s) and reached a peak in 1990. This reduction in emissions is due to the requirement since the early 1990s for new petrol cars to be fitted with three way catalysts

and the further tightening up of emission standards on these and all types of new diesel vehicles over the last decade.

Emissions from the energy industries (1A1) contributed 34.4% to total NO_x emissions in the UK during 2012. Between 1990 and 2012, emissions from this sector decreased by 57.7%, the main reason for this was a decrease in emissions from public electricity and heat production (1A1a) of 62.6%. Since 1998 the electricity generators adopted a programme of progressively fitting low NO_x burners to their 500 MWe coal fired units. Since 1990, further changes in the electricity supply industry such as the increased use of nuclear generation and the introduction of CCGT plant have resulted in additional reduction in NO_x emissions.

Emissions from Manufacturing, Industry and Construction (1A2) have fallen by 59.2% since 1990. In 2012, emissions from this sector contributed 15.6% to overall emissions of NO_x. Over this period, the industrial sector has seen a move away from the use of coal, coke and fuel oil towards natural gas and gas oil usage.

2.4.3 Sulphur Dioxide

In 2012, total emissions of SO_2 were 429 Gg, and since 1990, emissions have decreased by 88.5%.

97.9% of emissions of sulphur dioxide came from the energy sector in 2012, 67.5% of these emissions arose from energy industries (1A1). A majority of these emissions are from the public electricity and heat production category (1A1a). Since 1990, emissions from power stations have declined by 91.6%. This decline has been due to the increase in the proportion of electricity generated CCGT stations, other gas fired plants and as a result of the increase in the proportion of electricity generated in nuclear plants, as well as the application of Flue Gas Desulphurisation abatement equipment on several of the largest coal-fired power stations in the UK. CCGTs run on natural gas and are more efficient than conventional coal and oil stations and have negligible SO_2 emissions.

Emissions from Manufacturing, Industry and Construction (1A2) were responsible for 16.7% of UK emissions of SO_2 in 2012. Since 1990, emissions from this category have declined by 84.2%. This decline is due to the reduction in the use of coal and oil in favour of natural gas, and also some improvement in energy efficiency.

2.4.4 Non Methane Volatile Organic Compounds

In 2012, total emissions of NMVOCs were 757 Gg, and since 1990, overall emissions have decreased by 72.0%.

Emissions from the Solvents and Other Product Use sector contributed 45.0% to overall emissions of NMVOC in 2012, and since 1990 emissions have declined by 49.0%. The largest source of emissions within the solvents sector is category 3D (solvent and other product use: other), contributing 70.2% of NMVOC emissions in this sector.

34.9% of non-methane volatile organic compound emissions came from the energy sector in 2012. Of these, the largest contribution arises from the fugitive emissions of oil and natural gas (1B2), which contributed 20.0% towards the overall UK emissions of NMVOCs in 2012. This includes emissions from gas leakage, which comprise around 12.3% of the total for the energy sector. Remaining emissions arise from oil transportation, refining, storage and offshore.

Emissions from transport (1A3) contribute 6.7% to overall emissions of NMVOC in the UK in 2012. Since 1990, emissions from this sector have decreased by 94.7% due to the increased use of three way catalysts in petrol cars.

Emissions from the industrial processes sector contributed 14.6% to overall UK emissions of NMVOCs. The majority of emissions within this category come from the food and drink sector, emissions also arise from the chemical industry.

2.5 EMISSION TRENDS FROM KP LULUCF ACTIVITIES

The main driver of the emission and removal trends for KP-LULUCF before the application of the forest management cap is the degree of forest planting achieved between the 1950s and the 1980s, followed by a period of reduced planting rates. As these forest stands have reached maturity and are now being harvested, the net removal of carbon dioxide from forest management has started to fall. For Article 3.3 activities, new planting expansion of forest area at an average of 14.6 khaX ha per year since 1990 has produceds a net removal from afforestation and reforestation that is currently about three times the emission from deforestation. Deforestation emissions have however increased since 1990 due to [say why harvesting of mature trees.]. is reduced.

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 1993 onwards.

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

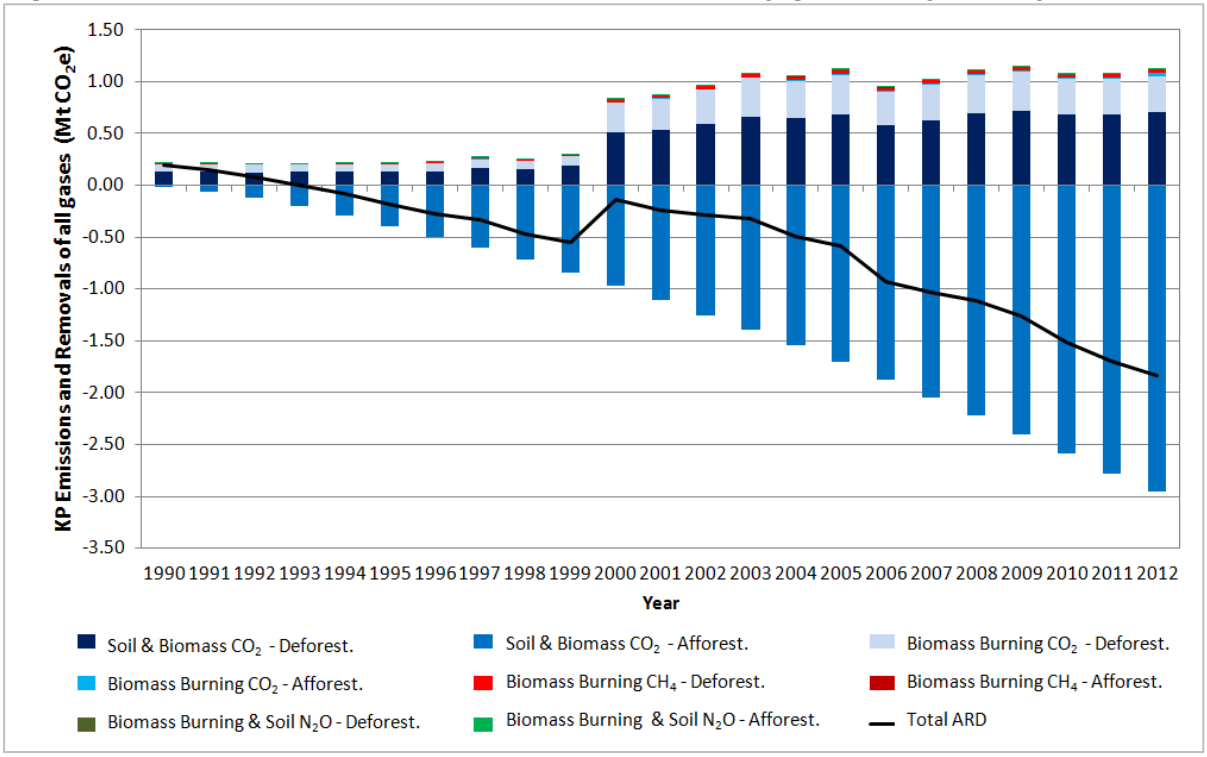
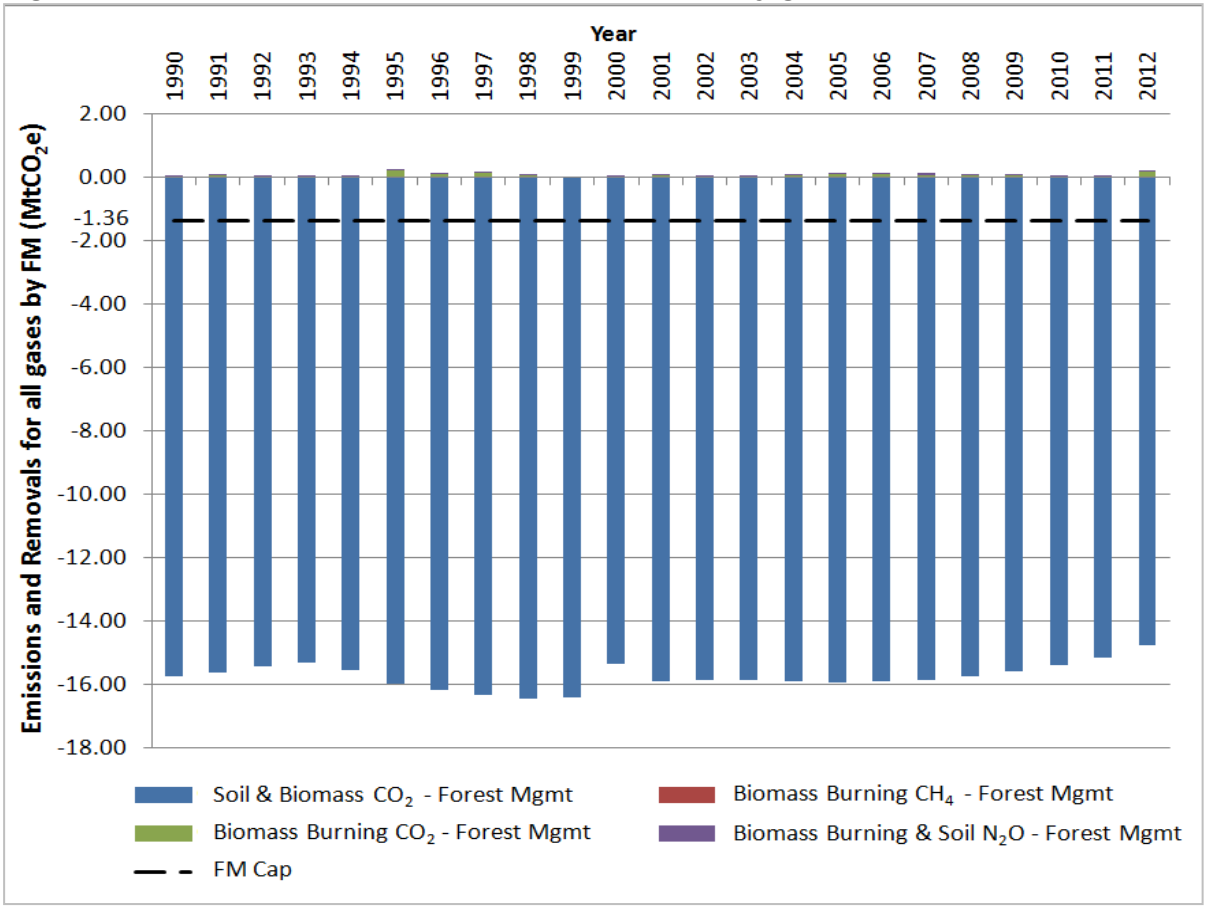


Figure 2.9 Article 3.4 Emissions and removals, by gas



3 Energy (CRF Sector 1)

3.1 OVERVIEW OF SECTOR

IPCC Categories Included	1A: Fuel Combustion 1B: Fugitive Emissions from Fuels
Gases Reported	CO_2, CH_4, N_2O, CO, NO_x, SO_2, VOC
Key Categories (Trends)	1A1, 1A2, 1A4, 1A5 Other Combustion, N_2O Stationary combustion-oil, CO_2 Mobile combustion-Road vehicles – DERV – N_2O Mobile combustion-Road vehicles – Gasoline/LPG – N_2O
Key Categories (Level)	1A1, 1A2, 1A4, 1A5 Other Combustion, N_2O Mobile combustion-Road vehicles - DERV, CO_2 (Latest yr only) Mobile combustion-Road vehicles - Gasoline/ LPG, CO_2 Mobile combustion-Road vehicles – DERV – N_2O (Latest yr only) Mobile combustion-Road vehicles - , Gasoline/ LPG, N_2O (Base yr only) Stationary combustion-coal, CO_2 Stationary combustion-gas, CO_2 Stationary combustion-oil, CO_2
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	All relevant UK Overseas Territories and Crown Dependencies emissions included within category totals within CRF submission – UK EFs used. Tables of total fuel use can be found in **Annex 3.8**.
Completeness	Only known omission is emissions from multilateral operations (a memo item) for which data are not available. A general assessment of completeness for the inventory is included in **Annex 5**
Major improvements since last submission	1A1c, 1A2a: Update of iron and steel energy source estimates through research to use EU ETS and other plant operator data within the UK carbon balance method. 1A2c: Re-allocation of emissions from chemical and petrochemical sites using process off-gases from 1A2f to 1A2c, and revision of time series of these estimates. 1A3: Revision to method for calculating CH_4 and N_2O emissions from road transport; now based on fuel sold.

In 2012 emissions in the energy sector accounted for 84.1% of total net direct greenhouse gas emissions. Within this category the largest contributions arise from 1A1 (energy industries), while 1A3 (transport), 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 20.6% since 1990, as shown in **Figure 3.2**, 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.

Figure 3.1 Breakdown of total GHG emissions in Energy sector in 2012

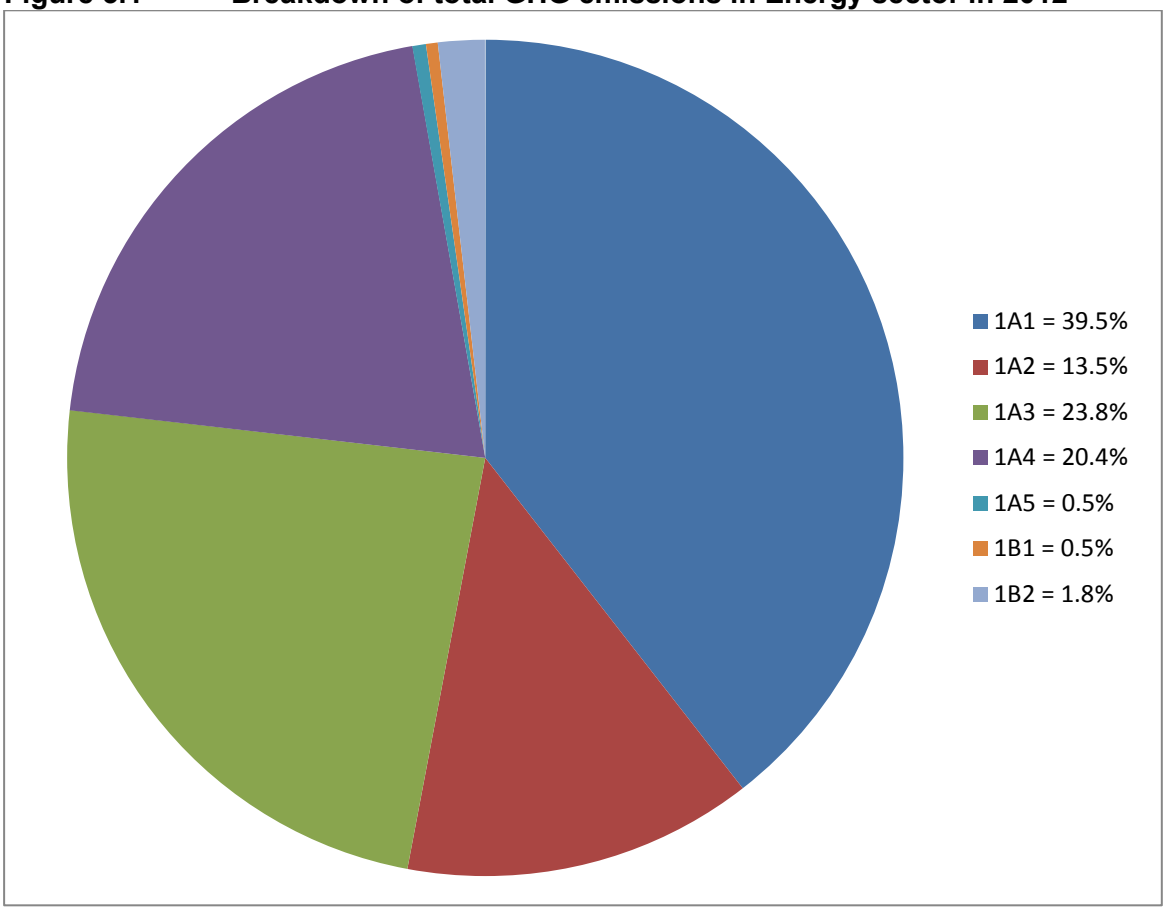
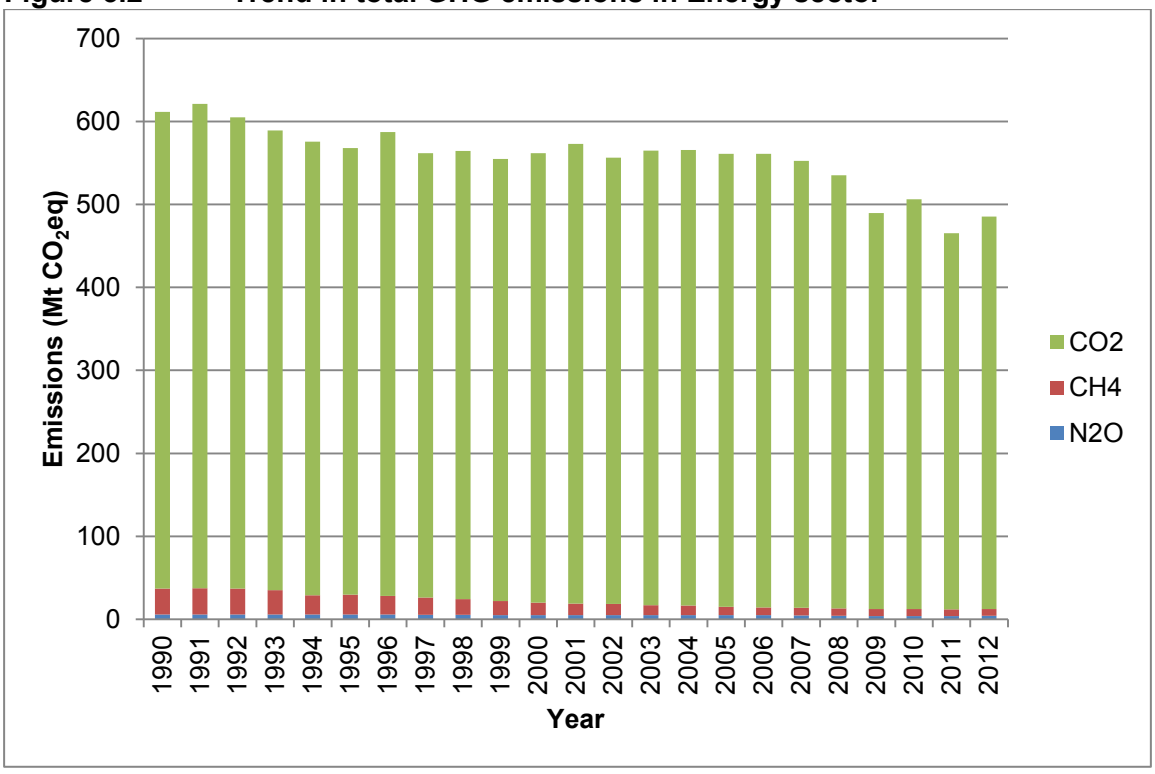


Figure 3.2 Trend in total GHG emissions in Energy sector



3.2 FUEL COMBUSTION (CRF 1.A)

3.2.1 Comparison of Sectoral and Reference approaches

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

Summary Table 7B of the IPCC Guidelines[19] 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. 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 statistical differences between production-side and demand-side fuel estimates within national energy statistics, and the more aggregated approach to applying emission factors to activity data across fuel types in the Reference Approach. Reasons for the differences between the two estimates are discussed in **Annex 4**.

Over the period (1990 to 2012), emissions estimated by the Reference Approach have fallen by 16.7% compared with 17.6% for the Sectoral Approach, and on average across the time series the Reference Approach emissions are 99.4% that of the Sectoral Approach.

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. In 2012, 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 **Section 3.2.8.2.1** and the revised Tier 2 method adopted for shipping described in **Section 3.2.8.2.4.**

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 inventory agency uses a bottom-up method based on vessel movements to estimate all marine activities that must be included in the domestic totals including coastal navigation, inland waterways, fuels and emissions associated with voyages from the UK to the Overseas Territories and fishing in waters outside UK waters. A consistent approach is used across the time-series as explained in **Section 3.2.8.2.4.** The balance of total fuel estimated for domestic navigation from these sources and the total fuel made available for consumption (as given in DUKES) is assigned to international marine

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

bunkers. This leads to a different 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 Feedstock and Non-Energy Use of Fuels

The UK inventory estimates for many source sectors include a component of emissions that are derived from fossil fuels that according the UK energy balance (DECC, 2013) are allocated to "non-energy use". Within each of the DUKES commodity balance tables, the energy statistics include sector-specific fuel use estimates, and also an annual estimate for fuels that are not directly used as an energy source. These estimates of non-energy use in DUKES are based on the annual returns to DECC from energy suppliers, supplemented by surveys of fuel users; the information provided to DECC typically indicates the allocation of fossil fuels to chemical and petrochemical companies (e.g. within refinery operator annual returns to DECC) for use as a production feedstock material.

In many cases the energy statistics allocate fuels to non-energy use that are used in chemical and petrochemical production processes where either:

- fossil carbon-containing off-gases are used for combustion in facility boilers; or
- products containing the "stored" carbon are subsequently used / partly combusted / disposed and degraded with some proportion of the "stored carbon" in products ultimately emitted to atmosphere.

In other instances, the allocation of fuels to "non-energy use" in the UK energy balance is contrary to other statistical evidence from industry or surveys that the inventory agency has access to in the compilation of the national inventory. For example, in the UK the allocation of petroleum coke to domestic and commercial combustion sources in the energy balance are missing for all years in the time series, whereas evidence from environmental reporting and research indicates that several industries use petroleum coke directly as a fuel or process input (e.g. cement kilns, power stations, domestic fuel manufacture).

Table 3.1 UK Energy Balance Allocations for Non Energy Use in 2012, Summary of Commodity-specific Non Energy Use Applications in the UK

Commodity[2]	2012 DUKES demand (kt)	2012 Non Energy Use allocation (kt), (% demand)[3]	Non Energy Use applications in UK
Liquid Fossil			
Ethane[1]	783	783 (100% NEU)	NEU data are based on annual reporting of Natural Gas Liquid deliveries from the UK Petroleum Products Reporting System. Ethane is supplied as a chemical feedstock to up to 7 petrochemical companies annually across the time series. These deliveries are dominated by three of the UK ethylene manufacturing plant which account for 80-100% of annual ethane consumption in recent years. In some years there are a number of supplies of very small quantities of ethane to other companies; this consumption is also assumed by DECC to be NEU.

Commodity[2]	2012 DUKES demand (kt)	2012 Non Energy Use allocation (kt), (% demand)[3]	Non Energy Use applications in UK
LPG (sum of propane and butane) [1]	2402	1304 (54% NEU)	NEU data are based on annual refinery operator returns, an annual LPG users survey and import data from HMRC. LPG supplies to a small number of petrochemical companies using LPG as a chemical feedstock typically account for 55-75% of total NEU. There are also a large number of other chemical companies buying LPG; this consumption is allocated to NEU. In total, deliveries are made to at least 120 companies annually.
OPG / RFG[1] (Other gases)	2655	116 (4.4% NEU)	OPG/RFG is supplied as a chemical feedstock to co-located chemical and petrochemical plant on integrated sites with refineries. These NEU data are based on annual refinery operator returns to DECC, and excludes estimates where the supply of OPG/RFG is used to fire boiler plant, which are recorded in DUKES as autogenerator use.
Naphtha[1]	1061	1061 (100% NEU)	Naphtha is supplied to up to 90 companies annually. NEU data are based on annual refinery operator returns and import data from HMRC. The annual data are dominated by two major petrochemical facilities using naphtha as feedstock, with one company accounting for roughly 70% of the 2012 total. A large number of smaller companies buy naphtha, including many chemical and pharmaceutical companies; this consumption is also assumed by DECC to be NEU.
White Spirit and SBP	219	219 (100% NEU)	These commodities are used primarily as solvents and cleaning agents; they are not used as fuels. The main use for white spirit and SBP solvents is as extraction, cleaning and degreasing solvent, where most users would recycle used product, and as a solvent in aerosols, paints, wood preservatives, lacquers, varnishes, and asphalt products (UKPIA, 2013).
Gas Oil[1]	4498	130 (2.9% NEU)	Middle Distillate Oil is used as a chemical feedstock at a small number of chemical production plants in the UK (e.g. 3 plant in 2012), based on refinery operator returns to DECC. The Health and Safety Executive have confirmed that there are no UK producers of explosives that use either gas oil or fuel oil as a raw material (HSE, 2013). (*The HSE regulates all UK sites that handle explosives*.)
Lubricants	412	412 (100% NEU)	No direct fuel use of lubricants is reported in the UK. This is based on data provided by refinery operators and HMRC for import / export data. The UK inventory agency makes assumptions regarding the ultimate fate of lubricants; the inventory includes emission estimates from

Commodity[2]	2012 DUKES demand (kt)	2012 Non Energy Use allocation (kt), (% demand)[3]	Non Energy Use applications in UK
			combustion of waste lubricants (a proportion of the whole UK demand) in source categories 1A1 and 6C.
Bitumen	1355	1355 (100% NEU)	No bitumen is used in combustion or otherwise emissive applications in the UK. This is based on information from the refinery operators, HMRC and from direct consultation with the Refined Bitumen Association (RBA, 2013). All bitumen in the UK is used in road surfacing, weather-proofing and other minor non-emissive applications.
Petroleum coke	2261	545 (24% NEU)	Petroleum coke is reported as used as a fuel within DUKES for the power sector and refinery sector only. The remaining data on UK consumption is allocated within the UK energy balance to NEU, based on reported data from refinery operators and HMRC import / export data. The UK inventory agency makes estimates for additional petcoke use in sectors such as the mineral processing sector, where its use is recorded within EU ETS and direct from the trade association (MPA, 2013). This accounts for a further 47 kt petcoke combustion in 2012. Another 150 kt of petcoke is estimated to have been used as a domestic sector fuel in 2012. The major NEU of petroleum coke in the UK is in the manufacture of specialty graphite electrodes used in the steel and aluminium industries, a high proportion of which is exported as product. The Humber refinery is the world's largest producer of specialty graphite cokes and the largest anode coke producer in Europe (UKPIA, 2013). The remaining NEU applications based on HMRC / refinery information include consumers in novel applications such as cathodic protection products. (DECC, 2013)
Miscellanous oil products	541	541 (100% NEU)	This category includes petroleum waxes. There are no energy uses of these products in the UK. This is based on information provided by refinery operators, the refinery trade association (UKPIA, 2013).
Solid Fossil			
Steam coal, coking coal, anthracite	n/a	0	*There is no reported NEU for any solid fossil fuels in DUKES. Where coking coal is converted to coke and subsequently used in industrial processes, the UK energy balance reports all of the coke use as an energy source. Within the UK GHGI, we follow this approach and report all coke use within the energy sector. In some cases the use of coke may be regarded as a process source and not an energy source, but in the UK*

Commodity[2]	2012 DUKES demand (kt)	2012 Non Energy Use allocation (kt), (% demand)[3]	Non Energy Use applications in UK
			inventory we do not report any coke use as NEU.
Gaseous Fossil			
Natural Gas	835,512 GWh	5,949 GWh (0.7% NEU)	In the UK, natural gas is used as a feedstock in production of ammonia, acetic acid and acetic anhydride. Until 2001 it was also used to manufacture methanol.

[1] In the UK GHG inventory, emission estimates are included from the combustion of process off-gases that are derived from feedstock materials. There is insufficient transparency in the available data (from operators and from EU ETS) to determine the precise source of the carbon in the process off-gases and residues. The primary feedstock commodities used in UK production for chemical and petrochemicals are: ethane, LPG, naphtha, gas oil and Refinery Fuel gas. In the UK inventory, therefore, we assume that a proportion of the reported NEU as feedstock for these commodities is the source of the process off-gas / residue combustion emissions.

[2]Note that this table excludes data for petroleum-based commodities that are reported in DUKES as 100% used as a fuel, including: aviation spirit, aviation turbine fuel, motor spirit, burning oil, DERV, and fuel oil.

[3] The "% NEU" data in the table above are the percentage share of the total reported UK demand for each commodity that DUKES reports as NEU.

The inventory agency generates annual estimates to account for all emission sources that are derived from NEU allocations of commodities, effectively re-allocating a share of the DUKES non-energy use to either combustion or process emission sources in the inventory. The evidence that the inventory agency uses to make these estimates includes:

- annual reporting by plant operators (e.g. EU ETS returns include data on the use of process off-gases in the chemical and petrochemical production sector);
- periodic surveys or research by trade associations / research organisations / environmental regulators, such as to assess the fate of coal tars and benzoles, petroleum coke or waste oils or the impact of regulations on solvents, waste, product design and use;
- information on the estimated split of stored:emitted carbon from feedstock chemicals in literature sources, including other country NIRs, where UK-specific information is not available.

During 2013, an extensive review of the information on non energy use of fuels was commissioned by DECC including a review of available data sources (such as EUETS) and consultation with industry, regulators, trade associations and statistical agencies to assess the best available data to inform UK inventory estimates. This study led to a number of revisions to the approach to reporting the UK GHG inventory, although the impact on the Sectoral Approach inventory totals was very low. The recalculations from this research are highlighted within the individual chapters of the NIR.

3.2.3.1 Inventory Compilation Methods for Feedstock / NEU of Fuels

The estimation methods are described within individual sections of the NIR, but are summarised here. The general approach adopted in the UK GHG inventory is to assume that emissions from all non-energy uses of fuels are zero (i.e. the carbon is assumed to be sequestered as products), except for cases where emission sources can be identified and emission estimates included in the inventory.

The UK inventory agency conducts periodic studies into the fate of fuels reported as non-energy use, in order to assess the levels of stored carbon and carbon emitted for different fuels over the time series. These detailed studies are supplemented through annual data gathering and consultation with stakeholders to maintain an accurate representation of the emitted and stored carbon in the inventory.

The assumptions and estimates for individual sources are based on a review conducted in 2013-14 (Ricardo-AEA, 2014b) which included research into UK-specific activities and data sources as well as a review of the National Inventory Reports (NIRs) of other countries.

The sections below outline the emission sources from feedstock and NEU of fuels that are included in the UK GHGI, the source data and estimation methods and a summary of the time series for each of the fuel types where there is a stored carbon component in the UK energy balance. The estimates are all presented in CRF Tables 1.Ab and 1.Ad.

Table 3.2 Summary of Emission Sources for UK Fuels Allocated as Non Energy Use in UK Energy Statistics

Fuel	IPCC	Source Category
Liquid Fossil		
Naphtha, LPG, , Refinery fuel gas / OPG, gas oil and Ethane	1A1a	Scrap tyre combustion in power stations (1994 to 2000 only). Fossil carbon in MSW combustion in energy from waste plant. *Emissions of carbon from chemical feedstock via combustion of products such as synthetic rubbers and plastics.*
	1A1b	Other petroleum gas use in refineries (2004 to 2012 only). *Re-allocated from non-energy use as EU ETS and trade association data indicates that DUKES data on OPG combustion are an under-report.*
	1A2c	Other petroleum gas use in petrochemical facility combustion. *Re-allocated from non-energy use as EU ETS and operator data indicates that DUKES data on OPG combustion are an under-report. These emissions were reported under 1A2f in the 2013 submission, but have now been re-allocated to 1A2c as these are entirely emissions from chemical and petrochemical production facilities.*
	1A2f	Carbon in energy recovery from waste solvent and mixed general waste containing fossil carbon, in cement kilns. Industrial combustion of waste solvents. Scrap tyre combustion in cement kilns. *Emissions of carbon from chemical feedstock via combustion of products such as synthetic rubbers and solvents.*
	2B5	Energy recovery from process gases in the chemical industry. Release of carbon from breakdown of chemical products such as soaps, detergents and pesticides after use. *Emissions of carbon from chemical feedstock via breakdown of products.*
	6C	Fossil carbon in chemical waste incineration. Fossil carbon in MSW incineration. Fossil carbon in clinical waste incineration. *Emissions of carbon from chemical feedstock via combustion of products such as synthetic rubbers and plastics.*
Lubricants	1A1a	Waste oil combustion in power stations.
	1A2f	Waste oil combustion in unclassified industry (including road-stone coating plant)

Fuel	IPCC	Source Category
		Waste oil combustion in cement kilns. Lubricant combustion in industrial engines.
	1A3a	Lubricant combustion in aircraft engines.
	1A3b	Lubricant combustion in road vehicle engines.
	1A3d	Lubricant combustion in marine shipping engines.
	1A4c	Lubricant combustion in agricultural engines.
	6C	Incineration of waste oil.
Bitumen	n/a	*No known UK applications that lead to GHG emissions.*
Petroleum coke	1A2f 1A4b 2C1 2C3	Based on reported energy use data by specific industries within datasets such as EU ETS and also from direct dialogue with industry representatives, the inventory agency re-allocates a small proportion of the reported "NEU" allocation from DUKES, and reports emissions within the UK GHG inventory. This re-allocation generates emissions for the mineral processing sector (1A2f) and for petcoke use in the domestic sector (1A4b). There are also non-combustion, emissive uses of petcoke in the UK through the use of petcoke-derived anodes in the metal processing industries. Emissions from these uses of petcoke are reported in 2C1 (electrode use in electric arc furnaces) and 2C3 (anode use in aluminium manufacture). *Note that DUKES already includes allocations of petcoke use as a fuel in combustion in power stations (1A1a) and refineries (1A1b), which are included in the UK GHG inventory.*
Other Oil	2B5	Carbon released from use of petroleum waxes. Uses of petroleum waxes includes candles, with carbon emitted during use.
Solid Fossil		
Coking coal (coal oils and tars)	n/a	*Unknown quantities of coal tar pitch are used in the manufacture of anodes for industrial processes. In the UK inventory the emissions from the use of these anodes are allocated only against petroleum coke (also used in anode production). This is a small mis-allocation of emissions between the two fuels since the carbon emitted is likely to arise from both petroleum coke and the coal tar pitch, but it is due to lack of detailed data, and does not affect the accuracy of UK inventory emissions.*
Gaseous Fossil		
Natural Gas	2B1	Ammonia production leading to either direct release of CO_2 or associated chemical production (of methanol) with subsequent release of carbon originating in the natural gas feedstock.

Naphtha, Ethane, Gas Oil, Refinery/Other Fuel Gas (RFG/OPG) Propane and Butane (LPG)

Ethane, LPG (given separately as propane & butane in the energy statistics), gas oil ("middle distillate oil" when used as a chemical feedstock), refinery / other fuel gas (RFG/OPG) and naphtha are all consumed in very significant quantities for non-energy uses, primarily as feedstock in chemical manufacturing. In the UK, several major petrochemical production facilities are supplied with Natural Gas Liquid (NGL) feedstock directly from upstream production pipelines, and then utilise NGL fractions such as ethane, propane and butane in their manufacturing processes. In addition, several integrated refinery / petrochemical complexes in the UK use a proportion of the refinery fuel gas as a feedstock in petrochemical production.

The NEU allocations presented in DUKES reflect the reported disposals of these commodities as feedstocks to chemical and petrochemical companies. There are several sources of GHG emissions from this stock of "NEU" feedstock carbon, although a high proportion of carbon is stored into products and not emitted.

One large emission source known to occur in the UK is the use of carbon-containing process off-gases as a fuel within the chemical facilities. Whilst the exact source of the carbon cannot be traced directly to a specific feedstock commodity within the UK sectoral approach, the available information from EU ETS and from consultation with operators enables the inventory agency to derive estimates of the GHG emissions across the time series from this emission source.

During the 2013 research study into NEU of fuels, the estimates of emissions and activity from this source were revised, leading to a number of small recalculations compared to the 2013 submission. Estimates for the ethylene manufacturing sites in the UK were improved through new information provided by the plant operators, whilst analysis of EU ETS data for a number of other chemical sites identified small additional emission sources that could be attributed to the combustion of process off-gases and residues derived from the chemical feedstock. As a result, the UK inventory emissions in 1A2c now include estimates of emissions from use of process off-gases and residues at 5 ethylene manufacturing sites and 4 other chemical manufacturing sites in the UK. The derivation of a time series of emission estimates from these sources is based as far as possible on reported data by plant operators within trading scheme data and other regulatory reporting mechanisms. For the early part of the time series, data on changes in plant capacity over time is used to derive the best estimates of activity and emissions by extrapolation back from later emission estimates, whilst for later years the completeness and transparency of operator reporting is greater. Therefore, whilst the uncertainty for the emission estimates in the early part of the time series is significantly greater than for those in recent years. The inventory agency has made best use of the available data to derive the time series estimates of emissions from "NEU" activity. Consultation with a sector trade association has also confirmed that there are no other sector estimates of this activity, or of production data across the time series, that could be used to further improve the time series (Personal communication: Chemical Industries Association, 2014).

Other emissions included within the UK GHG inventory (2B5) and derived from the NEU allocations as chemical feedstock include emission sources from the use or destruction of chemical products, e.g. when waste chemical products are incinerated. Although emissions from incineration and combustion of wastes are estimated, we cannot relate the carbon in these wastes back to individual feedstock, so it is not possible to generate reliable UK estimates of the proportion of carbon that is ultimately emitted from each individual fuel. 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.

Emissions can also occur from breakdown or combustion of products from the chemical industry that contain "stored carbon" from feedstock that in DUKES is allocated to non-energy use. 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.).

Other emission sources from the use or degradation of chemical products that contain carbon from ethane, naphtha, gas oil, RFG/OPG and LPG feedstocks are:

- 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. Emissions are reported under 2B5.

[Emissions in 2B5 from petroleum waxes are accounted for in the UK inventory under the fuel category "Other Oils" in CRF table 1Ad (see below).]

Emissions from products that contain fossil carbon that are oxidised in incinerators (MSW, chemical, clinical) are included in the GHG inventory and reported under 6C; where the use of such wastes as fuel includes power generation, the emissions are allocated in 1A1a. In the UK there have been short periods where scrap tyres have been used as a power station fuel. Tyres contain a mixture of natural and synthetic rubbers, however, and the emission estimates for combustion of scrap tyres in the UK inventory takes into account that only some of the carbon emitted is derived from fossil fuels.

In the reporting of the **Reference Approach** within the 2013 submission, the inventory agency had derived UK-specific carbon storage fractions using the available data on emissions (from the emission sources outlined above and reported in the Sectoral Approach) and the aggregated NEU allocations for ethane, LPG and naphtha. However, the 2013 research study engaged two UNFCCC Lead Reviewers to review the UK inventory compilation and reporting approach. The method used to calculate and report the Reference Approach was critically reviewed, compared against the approach taken by other Parties and the method overhauled for the 2014 submission. The UK inventory Reference Approach now follows the recommended approach from the 1996 IPCC Guidelines to apply default carbon storage fractions. In recent UNFCCC expert reviews, the inventory agency has received a range of advice on the most correct interpretation of the 1996 IPCC Guidelines. The two UNFCCC Lead Reviewers considered the available data and emission sources in the UK and determined that the best approach was to apply default carbon fractions to aid comparability against other reporting parties.

The UK energy balance for **gas oil** indicates a relatively high allocation of gas oil use in non-energy uses (130kt in 2012, which is around 2.9% of total UK supply) and these data are reflected in the UK GHG inventory, and the carbon stored is reported in CRF table 1A(d). Consultation with DECC energy statisticians in 2013 has confirmed that gas oil is delivered from UK refineries to petrochemical production facilities, and is used a a feedstock material, consistent with the NEU allocation in DUKES (DECC, 2013). Furthermore, consultation with the Health and Safety Executive, who regulate the UK explosives industry, has confirmed that no UK installations manufacture explosives using gas oil or fuel oil as a feedstock (HSE, 2013).

Lubricants

Lubricants are listed separately in the UK energy statistics and are used in vehicles and in machinery. The inventory includes 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.

UK GHG inventory estimates of the quantities of lubricants burnt are based on data from Recycling Advisory Unit, 1999; BLF/UKPIA/CORA, 1994; Oakdene Hollins Ltd, 2001 & ERM, 2008, as well as recent research to access information regarding the UK market for waste oils and the impact of European Directives to consolidate industrial emission regulations such as the Waste Incineration Directive (Oil Recycling Association, 2010). Estimates of waste oil combustion are derived for the following source categories:

- 1A1a Power stations
- 1A2f Cement kilns
- 1A2f Other (unclassified) industry

The estimated emissions for other industry assume that waste oils are used by two sectors: road-stone coating plant and garages. Other sectors may use waste oils as a fuel or as a reductant, but research to date provides no compelling evidence that there is a gap in the UK inventory for waste oil use by industrial operators.

The emission trends from power station use of waste lubricants reflect the fact that the Waste Incineration Directive (WID) had a profound impact on the market for waste oil, used as a fuel. It is assumed that no waste oil was burnt in power stations for the years 2006-2008. In 2009 a Quality Protocol[20] was introduced that allowed compliant fuel produced from waste oils to be burned as non-waste and this has encouraged a resumption in the consumption of waste oil-derived fuels from 2009 onwards.

Carbon dioxide emission estimates for the oxidation of lubricants within vehicle engines and machinery, and the use of waste oils for energy are all based on a single carbon emission factor derived from analysis of the elemental composition of a series of UK-sourced samples of waste oil (Passant, 2004). UK research into the fate (including combustion) of lubricating oils within engines has been conducted periodically, with one study providing an estimate of 16% of all lubricants burned in engines in 1989, and a 2005 study estimating the total to be 13% of all lubricant supply in 2004. The estimated percentage of total lubricant demand oxidised in engines for 1990-2003 is interpolated between the 1989 and 2004 values given in these studies, and the 2004 estimate is extrapolated forwards across all years to 2012.

This time series of the percentage of lubricant burnt in engines is then applied to the annual lubricant demand given in DUKES to give a time series of quantities burnt. The estimates of waste lubricants burnt are then further sub-divided into the different source categories (including road, rail, marine, off-road and air transport) using the more detailed source-specific analysis within the 2005 study.

Bitumen

In the UK, bitumen is used only for applications where the carbon is stored. By far the most important of these is the use of bitumen in road dressings. The inventory does assume that a very small proportion of the carbon in the bitumen itself is emitted as VOC during road-stone coating but does not include any estimates of direct carbon emissions from uses of bitumen. Industry consultation in 2013 (UK Petroleum Industries Association, 2013; Refined Bitumen Association, 2013) has confirmed that there are no emissive applications of bitumen in the UK. Around 85% of bitumen is used in road paving, with the remaining proportion used almost entirely in the manufacture of weather-proofing materials.

[20] http://www.environment-agency.gov.uk/business/topics/waste/116133.aspx

Coal Oils and Tars

Coal-tars and benzoles are by-products of coke ovens. Within the UK energy balance published by DECC (DECC, 2013), these fuels are reported as used in combustion applications. However, consultation with the operators of coal ovens (Tata, 2013) and also the UK company that refines and processes coal tars and benzoles (Koppers UK, 2013) has confirmed that all of these materials are collected, refined and processed into a range of products that are not used as fuels. The carbon within coal tars and oils are entirely used within chemical processes. In some cases, the carbon is processed into anodes used in the ferrous and non-ferrous metals industries and then used (in the UK and overseas) within emissive applcations. The UK inventory already includes estimates of emissions from UK consumption of carbon anodes within these industries, using methods based on UK metal production statistics.

Based on the evidence from process operators, the inventory agency deviates from the UK energy balance data and re-allocates all of the reported coal tars and oils to Non Energy Use, i.e. assuming that all carbon is stored and there are no GHG emissions from this source-activity.

In the reporting of the **Reference Approach** to the UK inventory, we assume the IPCC default assumption that 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).

Coal-tar pitch is used in the manufacture of electrodes, together with petroleum coke and a proportion of the carbon ultimately emitted, but details of input materials are scarce; emissions of carbon from these sources are included in the inventory attributed to petroleum coke. This may introduce a small mis-allocation of emissions between petroleum coke and coal oils and tars, but does not affect the UK inventory emissions total.

Natural Gas

Natural gas is used as a chemical feedstock for the manufacture of ammonia and methanol. Emissions either occur directly as a result of the manufacturing process or (in the case of methanol) are assumed to ultimately occur upon degradation of the chemical products. The emissions are reported under 2B1.

Most of the emissions from feedstock use of natural gas in ammonia production are at source, i.e. waste gases containing carbon are emitted directly from the ammonia plant. However, in keeping with IPCC guidance for the sector, the emissions also include carbon sequestered in methanol, which in the UK is produced as a by-product using the ammonia process CO_2 emissions. The methanol produced using carbon derived from natural gas feedstock will be used for various applications, including in consumer products such as antifreeze and screen-wash, as well as a raw material for petrochemical manufacture. Further CO_2 is captured and sold for use elsewhere, for example, in carbonated drinks. This CO_2 is also assumed all to be emitted in the UK.

In the reporting of the **Reference Approach**, the reported carbon stored fraction has been revised to 100%, following feedback in the 2013 UNFCCC centralised review of the UK inventory. The ERT highlighted that as the comparison of the Reference Approach and Sectoral Approach is intended as a verification step for sources in 1A only, that the reporting of gas activity in 2B1 should not be considered in deriving the carbon storage fraction.

Other Oil (industrial spirit, white spirit, petroleum wax, miscellaneous products)
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 only emissions from this group of petroleum feedstock that are included in the UK GHG inventory are the releases of carbon from petroleum waxes which are reported under 2B5. These are accounted for in the UK inventory under the fuel category "Other Oils" in CRF Table 1Ad.

Petroleum Coke
The evidence from industrial reporting of fuel use and from periodic surveys of fuel producers that use petroleum coke to produce domestic fuels (including smokeless fuels) indicates that the allocation of petroleum coke to combustion activities in the UK energy balance is an under-estimate across all years. Therefore, the inventory agency generates revised estimates for all combustion activities and effectively re-allocates some of the petroleum coke reported in DUKES as non-energy use to energy-related emission sources in the UK inventory.

Within the UK inventory, petroleum coke is included for the following energy and non-energy source categories:

- 1A1a: Power station use of petroleum coke, primarily within blends with coal at a small number of UK facilities;
- 1A1b: Refinery emissions from regeneration of catalysts;
- 1A2f: Cement industry use of petroleum coke as a fuel;
- 1A2f: Other industry use of petroleum coke as a fuel;
- 1A4b: Petroleum coke use within domestic fuels;
- 2C1: Carbon emissions from
- electrodes used in electric arc furnaces and ladle arc furnaces;
- 2C3: Carbon emissions from anode use in primary aluminium production.

The UK energy balance tables in DUKES contain data on the energy use in power stations (1A1a) and refineries (1A1b), although the former are only available for 2007 onwards, and both sets of data do not always agree with the available activity data from EU ETS. The remaining energy uses in other industrial combustion (1A2f) and the domestic sector (1A4b) are not included in DUKES. The UK inventory agency therefore makes independent estimates of the consumption of petroleum coke in all of these sectors.

Petroleum coke is burnt in **cement kilns** (1A2f) and in a handful of **power stations** (1A1a). A few other **large industrial sites** (also 1A2f) have also used the fuel. Good estimates of the consumption of petroleum coke by these large sites are available from the operators themselves, from trade associations and from EU ETS data (from 2005 onwards).

Fuel grade petroleum coke is also used as a **domestic fuel** (both smokeless and non-smokeless types, reported in 1A4b). The inventory agency uses data supplied by the UK fuel supply industry to estimate petroleum coke consumption for domestic fuels over the

period 1990 to 2012; these estimates are broadly consistent with fuel use data published in earlier editions of DUKES for a few years in the late 1990s.

Carbon deposits build up with time on catalysts used in **refinery** processes such as catalytic cracking. These deposits need to be burnt off to regenerate the surface area of the catalyst and ensure continued effectiveness of the catalyst; emissions from this process are reported within EU ETS since 2005, with the time series estimates provided by the trade association (UKPIA, 2013) and the catalyst regeneration is treated in the inventory as use of a fuel (since heat from the process is used) and are reported under 1A1b.

The remaining 'non-energy' consumption, following subtraction of these estimates from the DUKES UK supply total, is the best estimate for consumption of petroleum coke for non-energy uses, and these data are reported within the CRF table 1Ad.

Estimates of carbon released from electrodes and anodes during **metal processes** are estimated based on operator data and reported in 2C1 and 2C3. Petroleum coke content of these electrodes and anodes is estimated based on operator data and literature sources such as BREF notes. .

The consumption estimates for industrial users of petcoke as a fuel or in anode use are associated with low uncertainty as they are primarly based on operator reported data within the EU ETS or other regulatory reporting mechanisms. Whilst it is conceivable that other sectors may also use petroleum coke as a fuel, there is no evidence from resources such as EU ETS and Climate Change Agreement reporting that this is the case in the UK. The estimates of petroleum coke used to generate fuels for the domestic sector are associated with higher uncertainty as they are based on periodic consultation with fuel suppliers to that market, and expert judgement of stakeholders.

As well as the total UK supply figure from UK energy statistics, DUKES does give data on UK production, imports and exports of petroleum coke, which together provide more information on the nature of the UK consumption of petroleum coke. These data cover three distinct types of petroleum coke – catalyst coke, produced and consumed at refineries only (so no import/export or supply of fuel to other UK sectors), and then two products made in a refinery process known as coking: fuel grade (green) coke and anode-grade coke, with the former being used as a fuel, and the latter being a calcined version of the former, used in various non-energy processes. Consultation with the DECC energy statistics team and the only UK refinery with a coking process (DECC, 2013) has confirmed that the UK produces only anode-grade coke, and exports will also be anode-grade coke, whilst imports will be fuel grade coke for use as a cost-effective fuel source or raw material for production processes under NEU.

Carbon factors for petroleum coke use are derived from industry-specific data (including EU ETS fuel analysis) in the case of cement kilns (MPA, 2013), power stations and other industrial sites (EA, 2013; SEPA, 2013). The petroleum coke factor for refinery consumption is based on trade association analysis conducted as part of the 2004 Carbon Factors Review (UKPIA, 2004) while the factor for domestic consumption is based on compositional analysis of samples of petroleum coke sold as domestic fuels (Loader et al, 2008).

These factors do show quite a large variation from sector to sector: this is primarily a reflection of the different requirements of fuels for different sectors (higher quality, higher carbon for some, less so for others). The highest carbon factor is for 'petroleum coke' burnt in sector 1A1b, but this fuel is actually of a different nature from the fuel burnt as petroleum

coke in sectors 1A1a, 1A2f and 1A4b. In the case of 1A1b, the fuel is a build-up of carbon on catalysts used in various refinery process units, while in the other three cases, the petroleum coke is a solid by-product of a totally different refinery process (coking) which has different characteristics.

The total emissions and carbon stored from petroleum coke for selected years across the time series are presented below. Note that the data on stored carbon are consistent with those reported as "100% stored" in the CRF:

Table 3.3 Petroleum Coke Carbon Emissions and Carbon Stored across all UK Supply 1990-2012

	Units	1990	1995	2000	2005	2010	2011	2012
Petroleum coke emissions *(Sum of: 1A1a, 1A1b, 1A2f, 1A4b, 2C1, 2C3)*	kt Carbon	258	489	598	704	420	278	315
Petroleum coke – stored carbon	kt Carbon	350	344	58	43	288	170	220
Storage fraction across all UK supply of petroleum coke	%	58	41	9	6	41	38	41

3.2.3.2 Carbon Storage Fractions: Import-Export balance for Carbon-containing Materials

The analysis within the UK energy statistics or GHG inventory compilation system cannot accurately account for the variable (over time) import-export balance of carbon-containing materials in the UK economy. For example, where the inventory agency accounts for the carbon emissions from scrap tyres burned in cement kilns, power stations, incinerators and so on within the inventory estimates or from the degradation of plastics or released from detergents and other chemicals, there is no way of tracing the quantity that is derived from imported tyres/plastics/detergents.

The reported estimate of the fate of the reported NEU of fuels from the UK energy balance is based on an assumed "closed system", whereby we account for all emissions from carbon-containing products and fuel types that are allocated as NEU as if they are derived from the fuel statistics in the UK energy balance. The source of the carbon emitted from feedstock and NEU of fuels will partly be carbon from imported materials, with UK feedstock carbon also exported and emitted elsewhere.

3.2.4 Capture and Storage of CO2 from Flue Gases

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

3.2.5 Country specific issues

3.2.5.1 Fuel Use Statistics

The main source of energy consumption data used in the UK inventory is the Digest of UK Energy Statistics (DECC, 2013), hereafter referred to as DUKES. This annual publication gives detailed sectoral energy consumption broken down by fuel type, and covering the entire time period covered by the inventory. In many cases, these data are used directly in the inventory without modification. However, there are instances where the activity data used

in the inventory are not based directly on DUKES data, where alternative data sources provide supplementary data to inform energy use and emission estimates, including:

- Where a greater level of detail is required in the reporting of emissions than can be provided solely from DUKES data (e.g. to estimate fuel use and emissions for (i) mobile and (ii) stationary combustion sources separately in industrial, commercial and agricultural source categories);
- Where other data sources provide additional evidence that supports modifications to the DUKES data (for example, changes to the data for fuel oil usage in CRF category 1A1a).

The rationale for those modifications or deviations from DUKES data that are made, and the sources of alternate data are discussed in the sections detailing methodology for each CRF source category that follow **Section 3**. A summary of all of the modifications is given in **Annex 3, Section A 3.2**.

The modifications described above involve changes to the sector-level estimates of fuel use used in the UK inventory, when compared with the original source data from DUKES. As a general rule, the overall demand for each fuel in the UK inventory is kept consistent with the overall demand for that fuel in DUKES; the inventory agency approach is such that in almost all cases, any modifications to the sector allocation of DUKES data is matched by an equal and opposite allocation change in another sector, to ensure a zero net change in fuel demand relative to DUKES. **Annex 3, Section A 3.2** includes a series of tables that demonstrate this consistency between the UK inventory and DUKES.

There are some exceptions to the general rule of consistency with DUKES, for petroleum coke and for OPG, where other statistical evidence indicates that the energy balance data for fuel combustion sources is incorrect, and where re-allocations of fuel use from the "non-energy use" lines in DUKES are made by the inventory agency. These exceptions are shown in tabulated form in **Annex 3, Section A 3.2**.

Apart from DUKES, the main other data source used for fuel use estimates in the inventory is the installation-level data available for processes covered by the EU Emissions Trading System (DECC, 2013), which has been analysed and compared with the data from DUKES. Further details of the analysis of EU ETS and use of the data within the UK GHG inventory are given in **Annex 9**. Further fuel consumption data are taken from the EEMS data set (DECC Offshore Inspectorate, 2013) and from data supplied by the UK Mineral Products Association (MPA, 2013), and from the UK solid fuel supply sector (Roberts, 2013). These are used to modify fuel use and emission estimates for 1A1c, 1A2f, and 1A4b respectively, and are described more fully in the sections below that deal with those source categories.

Fuel use estimates for transport sources also rely upon data taken from DUKES, with some further detail provided from other sources. Details are given in **Section 3.2.8**.

3.2.5.2 Biomass

Combustion of biomass is included in the UK energy statistics and also in the UK inventory. The inventory considers the use of such fuels in all subsectors of CRF 1A, although biomass is currently only used in a limited number of sectors, including 1A1a, 1A2f, 1A4b and 1A4c. Greenhouse gas emissions including CO_2 are estimated for these fuels and presented in the relevant sections of the CRF. Emissions of N_2O and CH_4 from biomass combustion are included within the UK inventory totals. The CO_2 emissions from biomass are, however, not

added to the total UK emissions from fuel combustion and are instead recorded as a memo item.

3.2.5.3 Wastes and Waste-Derived Fuels

As with biomass, wastes used as fuels are included in both the UK energy statistics and in the UK inventory and emissions reported in the relevant sections of the CRF.

Small-scale use of wastes as fuels may not be reported completely within national statistics where wastes are disposed of in-situ by means of use as a fuel, and in these instances the UK GHG inventory data may be incomplete also. The inventory agency does make estimates for some known sources that are not reported in national statistics: for example, the use of process wastes as fuel by the petrochemical industry are included in estimates within source category 1A2c. These estimates are subject to high uncertainty for the earlier part of the time series due to a lack of source data, and there may be other sectors of industry that burn waste to raise heat for which no estimates are currently made in the UK inventory.

Other sources not currently estimated within the UK inventory include household use of domestic wastes for heating, for which there are no national statistics. The incidence of this activity is considered to be very low in the UK and therefore it is assumed that this would be a very insignificant source of GHG emissions. In addition, a high proportion of wastes burnt both in industry and in households is biomass-based, e.g. wood, paper, food waste, etc., and CO_2 emissions derived from biocarbon are excluded from the UK inventory totals.

For the first time in the 2014 inventory submission, the use of biogas derived from anaerobic digestion of food and agricultural wastes has been separated out from other biofuels use. This improvement in inventory detail and transparency also enables application of more appropriate emission factors for indirect GHG emissions for biomass and waste-derived fuel activities, and emission estimates for indirect gases are more accurate as a result.

3.2.5.4 Unoxidized Carbon

When fuels are combusted, a small proportion of the carbon in the fuel is not fully oxidized. For example, unburnt carbon can remain in the ash left after combustion of coal. Emission estimates for CO_2 need to take account of any carbon in fuels that remains long-term in this unoxidized form.

In the UK Inventory, it is assumed that unoxidized carbon is only significant for solid fuels. For gaseous and liquid fuels, although some carbon might not be oxidized fully during combustion (for example emitted as VOC or particulate matter), based on discussions with fuel suppliers, it is assumed than any indefinite storage of unoxidized carbon will be sufficiently trivial to be ignored. For solid fuels, UK-specific assumptions are employed, either based on expert judgements provided by UK industry, or based on EU ETS returns. **Table 3.4** summarises the assumptions used.

Table 3.4 Levels of unoxidized carbon assumed for the UK GHGI

Fuel Type	Fuel sub-type	Source Sector	Years	Assumed unoxidized carbon	
				UK GHGI[a]	IPCC default[c]
Gaseous	All fuels	All sectors	1990-2012	0%	0.5%
Liquid	All fuels (incl. petroleum coke)	All sectors	1990-2012	0%	1%
Solid	Coal	1A1a	1990-2004	2%	2%

Fuel Type	Fuel sub-type	Source Sector	Years	Assumed unoxidized carbon	
				UK GHGI[a]	IPCC default[c]
			2005	1.8%[b]	
			2006	3.9%[b]	
			2007	3.2%[b]	
			2008	3.8%[b]	
			2009	1.9%[b]	
			2010	1.9%[b]	
			2011	1.7%[b]	
			2012	1.7%[b]	
		1A2f (cement)	1990-2012	0%	
		1A4b	1990-2012	6%	
		All others	1990-2012	3%	
	Anthracite	1A4b	1990-2012	5.3%	
	Coke, solid smokeless fuel	1A4b	1990-2012	2%	
		All others	1990-2012	3%	

[a] Expert judgements provided by UK fuel producers and fuel users unless otherwise stated (see Baggott *et al, 2004*).
[b] Calculated from site-specific EU ETS returns for all UK coal-fired power stations. Over the period 2005-2012, the average unoxidized carbon from the EU ETS data is 2.5%.
[c] From the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories

3.2.6 Source Category 1A1 – Energy Industries

3.2.6.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	1A1a: Power stations	T1, T2	CS, D
	Misc industrial/commercial combustion (district heating)	T1, T2	CS, D
	1A1b: Refineries – combustion	T1, T2	CS, D
	1A1c: Coke production	T1, T2	CS, D
	Collieries – combustion	T1, T2	CS, D
	Gas production	T1, T2	CS, D
	Nuclear fuel production	T1, T2	CS, D
	Solid smokeless fuel production	T1, T2	CS, D
	Town gas manufacture	T1, T2	CS, D
	Oil production	T1, T2	CS, D
Gases Reported	CO_2, CH_4, N_2O, CO, NO_x, SO_2, VOC		
Key Categories (Trends)	1A1, 1A2, 1A4, 1A5 Other Combustion, N_2O Stationary combustion-oil, CO_2		
Key Categories (Level)	1A1, 1A2, 1A4, 1A5 Other Combustion, N_2O Stationary combustion-coal, CO_2 Stationary combustion-gas, CO_2 Stationary combustion-oil, CO_2		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Emissions from 1A1a included – no emissions observed in 1A1b or 1A1c. All relevant UK Overseas Territories and Crown Dependencies emissions included within category totals within CRF submission – UK EFs used.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	1A1c: Improved accuracy through use of EU ETS and installation-specific operator-reported data within the UK carbon balance approach for coke manufacture and iron and steel sources.		

[a]T1: Tier 1, T2: Tier 2, T3: Tier 3, CR: Corinair, CS: Country Specific, D: Default, OTH: Other

This source category includes: electricity generation, and the use of fossil fuels for petroleum refining, production of crude oil, natural gas, coal, coke and solid smokeless fuels. For most source estimates, the inventory method uses national energy statistics and applies country-specific factors for CO_2 (Tier 2), and default factors (typically from IPCC, US EPA, EMEP-EEA) for other gases (Tier 1). Coke manufacture emission estimates are derived from a carbon balance method applied across coke oven and iron and steel sector sources, using national statistics and installation-specific operator-reported data.

The main fossil fuels used by the UK electricity supply industry are bituminous coal and natural gas. Approximately 54 Mtonnes of coal were burnt at 16 power stations during 2012, while approximately 6,200 Mtherms of natural gas were consumed at 44 large power stations and 13 small (<50MWth) regional stations (mostly Combined-Cycle Gas Turbines, CCGTs). Heavy fuel oil was the main fuel at 2 large facilities, and gas oil or burning oil was used by 3 large and 9 small power stations, as well as being used as a secondary fuel at 9 nuclear power stations. Compared to 2011, there was a notable shift in the power sector fuel mix in the UK, with a large increase in coal use and large decrease in gas use; this change in power sector fuel mix has contributed to the increase in sector emissons between 2011 and 2012.

Bio-fuels are burnt at an increasing number of power generation sites (see **Table 3.5**) 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. A number of former coal-fired power station has been converted to operate as a dedicated biomass power station (from 2012 onwards). Electricity is also generated in a large number of engines running on biogas at landfill sites and sewage treatment works. 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 from biofuel use are estimated and included in the national inventory totals, in accordance with IPCC guidance on the treatment of biofuel-derived emissions.

Electricity is also generated at 26 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.

Table 3.5 gives estimates of the number of power stations by fuel type over the period covered by the inventory.

Table 3.5 Power stations in the UK by type

Year	Coal	Fuel oil	Gas oil	Gas	Waste	Biomass	Biogas	Nuclear Fission
1990	44	9	25	0	2	0	Unknown[a]	19
1995	23	8	25	5	4	0	Unknown[a]	16
2000	22	5	25	35	15	4	267	15
2005	17	5	25	47	20	5	461	12
2006	17	4	24	49	20	5	491	12
2007	17	4	22	49	20	6	518	10
2008	17	4	22	49	20	6	535	10
2009	17	4	22	51	22	6	545	10
2010	17	4	22	53	23	6	554	10
2011	17	3	22	55	26	6	563	10
2012	16	2	22	57	26	6	565	9

[a]Number of power stations for early years is unknown although emissions are reported, biogas consumption is obtained from DUKES.

The UK had 11 refineries at the start of 2012 and 10 at the end after closure of one site. Of the ten sites, 3 are small specialist refineries employing simple processes such as distillation to produce solvents or bitumens only. The remaining 7 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 2012, 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. **Table 3.6** shows how the numbers of refineries, coke ovens and other fuel processing works vary over the period covered by the inventory.

Table 3.6 Fuel processing sites in the UK by type

Year	Crude oil refineries	Specialist refineries	Coke ovens	Other solid fuel manufacturing
1990	11	4	9	6
1995	11	4	8	5
2000	9	3	8	3
2005	9	3	5	2
2006	9	3	5	2
2007	9	3	5	2
2008	9	3	5	2
2009	8	3	5	2
2010	8	3	5	2
2011	8	3	5	2
2012	7	3	5	2

Crude oil and natural gas are produced mainly from a large number of offshore installations located in the North Sea, together with a small number of production facilities in the Irish Sea or on land. Coal is extracted from a small number of deep mines, and a somewhat larger number of open-cast sites. In 2012, the UK produced 42 million tonnes of crude oil and about 1,630 PJ of natural gas, as well as 17.0 Mt of coal.

Nuclear fuel production is a very minor user of fuel in the UK.

3.2.6.2 Methodological Issues

Table 3.7 gives an overview of the estimation methodologies used for 1A1.

Table 3.7 Summary of Emission Estimation Methods for Source Categories in CRF Category 1A1

Source Category	Method	Activity Data	Emission Factors
Power stations	AD x EF	DECC energy statistics, EU ETS, operators	Carbon: EU ETS data, UK-specific factors (Fossil fuels from Baggott *et al*, 2004, MSW factors based on UK-specific waste composition data) CH_4, N_2O: IPCC, USEPA, UK-specific factors
Miscellaneous industrial/commercial combustion	AD x EF	DECC energy statistics,	Carbon: MSW factors based on UK-specific waste composition data. CH_4, N_2O: IPCC, USEPA, UK-specific factors
Refineries	AD x EF	DECC energy statistics, EU ETS	Carbon: EU ETS data, UK-specific factors (Baggott *et al,* 2004), UK refinery operators' data. CH_4, N_2O: IPCC, USEPA, UK-specific factors
Coke production	UK model, AD x EF	DECC energy statistics, ISSB	Carbon: carbon balance for fuel transformations in coke ovens and steelmaking processes (see CRF category 2C1), UK-specific factors for fuels used for energy (Baggott *et al*, 2004 CH_4, N_2O: IPCC, EMEP/EEA
Collieries – fuel combustion	AD x EF	DECC energy statistics	IPCC, EMEP/EEA, UK-specific factors
Gas production (downstream gas)	AD x EF	DECC energy statistics, EU ETS	IPCC, USEPA, UK-specific factors
Gas separation plant	AD x EF	DECC energy statistics, EU ETS	Carbon: IPCC, UK-specific factors CH_4, N_2O: EEMS
Upstream gas production	AD x EF	DECC energy statistics, EU ETS	EEMS and UK-specific factors
Nuclear fuel production	AD x EF	DECC energy statistics	Default factors (IPCC, UK-specific research)
Upstream oil production	AD x EF	DECC energy statistics, EU ETS	EEMS and UK-specific factors
Solid smokeless fuel production	AD x EF	DECC energy statistics, EU ETS	IPCC, UK-specific factors

The majority of emissions of direct greenhouse gases in the energy sector (1A1) are estimated from fuel consumption statistics using the standard approach detailed in the next section. This method involves the use of emission factors, applied to national activity data, and is applied to estimating emissions for direct greenhouse gases from power stations, refineries, and all of the sources included in 1A1c with the exception of coke production, where a carbon balance approach is used for the emissions related to the fuel transformations carried out in the ovens. Further details of the emission factors and activity data used for estimating emissions from 1A1 are given in the following sections.

Emissions data are usually available for individual sites from databases such as the Environment Agency's Pollution Inventory (PI), covering English and Welsh sites, and similar databases covering sites in Scotland and Northern Ireland. Hence the emissions of indirect gases for a particular sector can be calculated as the sum of the emissions from these point sources. That is:

Emission = Σ Point Source Emissions

However it is still necessary to make an estimate of the fuel consumption associated with these point sources, so that the emissions from non-point sources can be estimated from fuel consumption data without double counting. In general the point source approach is only applied to emissions of indirect greenhouse gases for sectors that consist solely or mainly of large sites (e.g. power stations, coke ovens, refineries). Indirect greenhouse gas emissions from a few energy sector sources consisting of smaller sites are estimated using emission factors (see **Table 3.9** for details of methods for indirect gases).

Emission factors for some secondary fuels such as coke, solid smokeless fuel, and coke oven gas are derived as part of a carbon balance model covering solid fuel manufacture and steelmaking.

3.2.6.2.1Basic Combustion Module

For all source categories in CRF sector 1A1, emissions result from the combustion of fuel. The activity statistics used to calculate the emission are fuel consumption statistics taken, mainly from DUKES (DECC, 2013), with supplementary data from other UK data sources such as EU ETS reporting and process operators' data. A file of the fuel combustion data used in the inventory is provided on a CD ROM attached to this report. Emissions are calculated according to the following equation:

$$E(p,s,f) = A(s,f) \times e(p,s,f)$$

where

E(p,s,f) = Emission of pollutant *p* from source s from fuel *f* (kg);
A(s,f) = Consumption of fuel *f* by source *s* (kg or kJ); and
e(p,s,f) = Emission factor of pollutant *p* from source s from fuel *f* (kg/kg or kg/kJ).

The pollutants estimated in this way are as follows:

- Carbon dioxide as carbon;
- Methane;
- Nitrous oxide;
- NO_x as nitrogen dioxide (some source/fuel combinations only);
- NMVOC;
- Carbon monoxide (some source/fuel combinations only); and
- Sulphur dioxide (some source/fuel combinations only).

The fuels covered are listed in **Annex 3, Section A 3.1**, though not all fuels occur in all sources.

3.2.6.2.2 Emission factors used

Table A 3.2.2 to **Table A 3.2.5** in Annex 3 list the emission factors used in this module, and a summary of the factors has already been given in **Table 3.7**. Emission factors are expressed in terms of kg pollutant/tonne for solid and liquid fuels, and g/TJ gross for gases. This differs from the IPCC approach, which expresses emission factors as tonnes pollutant/TJ based on the *net calorific value* of the fuel. For gases the NAEI factors are based on the *gross calorific value* of the fuel. This approach is used because the gas consumption data in DECC (2013) are reported in terms of energy content on a gross basis.

The tables are grouped into solid, liquid, gas and biomass/other based on the IPCC definitions of the fuels.

Factors are taken from the following data sources:

- UK-specific fuel-specific or sector-specific data (e.g. Baggott *et al*, 2004)
- UK-specific, site-specific data sets (EU ETS, EEMS, operators' data)
- IPCC guidance
- Other international guidance, emission factor compilations and literature sources (e.g. EMEP-EEA, US EPA)

UK sector-specific and/or fuel-specific emission factors for carbon 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. The results were published in Baggott *et al*, 2004, and the emission factors in this report still form much of the basis for the emission estimates for 1990-2003. The 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. Where carbon factors given in the review need to be updated annually, this is done either by collecting new data from industry so that the same methodology can be used to produce updated factors, or by scaling from the carbon factors for 2003, using the gross calorific values presented in the latest version of the Digest of UK Energy Statistics (DECC, 2013). The carbon content of a fuel is closely correlated with the calorific value and so using calorific value as a proxy provides a good estimate of the changing carbon contents.

The factors in Baggott *et al*, 2004 are supplemented by emission factors based on high quality site-specific emissions data available from the EU ETS data set, covering 2005-2012, and from the EEMS dataset (1997-2012). The use of EU ETS data is described in detail in **Annex 9.** EU ETS data are used for the most significant sources of carbon in 1A1. CO_2 emission factors for coal, fuel oil, petroleum coke, natural gas and sour gas use in power stations and fuel oil, petroleum coke, and refinery fuel gas (OPG) use in refineries are based on data reported to the EU Emissions Trading System (EU ETS) for the years 2005-2012. These data are of high quality, and available for all significant UK power plants and refineries - some very small power stations, e.g. on remote islands, do not report to EU ETS but their fuel use is negligible in the UK power sector context, and in any case will not include many of the fuels listed above (i.e. no coal, petroleum coke or gases). 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 earlier years must be calculated in a different way. The factors in Baggott *et al*, 2004 cover the period 1990-2003 and are considered the best available data for that period and so for many sources within 1A1, emission estimates for 1990-2003 are based on factors from Baggott *et al*, 2004, and emission estimates for 2005 onwards are based on factors derived from EU ETS data. Extrapolation back from the EU ETS data across the entire time series is not considered sufficiently reliable to replace the factors taken from the 2004 review. Emission factors for 2004 are predominantly assumed to be the same as in 2003.

Installation-specific, source-specific data are also available for upstream oil and gas exploration and production facilities via the EEMS reporting system and these are used for the estimates for several source categories within 1A1c. Unlike EU ETS, the EEMS dataset covers multiple pollutants and can be used to provide emission estimates for both direct and indirect greenhouse gases. EEMS data are available from 1997 onwards, although the quality and completeness of the data may differ across the time-series.

Where UK-specific factors and data are not available, international guidance and other literature sources have been used. IPCC guidance documents have provided many of the emission factors for methane and nitrous oxide, with other factors obtained from the EMEP-EEA Emission Inventory Guidebook (EMEP/EEA, 2013) or the US EPA's AP-42 publication (USEPA, 2013). Two reports by the Coal Research Establishment on emissions from coal-fired appliances (Brain *et al*, 1994 and Fynes & Sage, 1994) are also used.

As well as the annual data sets from EU ETS and EEMS, the following updates are routinely collected for use in deriving emission factors for the inventory:

1. The UK Petroleum Institute Association (UKPIA) advises whether the carbon emission factors supplied by them for the 2004 review continue to be valid. The UKPIA factors were based on fuel analyses and covered the following fuels:

    - Petrol;
    - Burning oil;
    - ATF;
    - Aviation spirit;
    - Diesel;
    - Fuel oil;
    - Gas oil;
    - Petroleum coke;
    - Naphtha;
    - OPG;
    - Propane; and
    - Butane.

2. Natural gas carbon factorsare provided annually by the UK gas distribution network operators and are derived from extensive measurements of the composition of natural gas fuel delivered to UK consumers.

A time series of UK-specific CO_2 emission factors for MSW is derived from waste composition data as used in the UK inventory landfill model. The approach relies on the assumption that the composition of waste in those areas of the UK which burn waste for energy is the same as the composition of waste in those areas that landfill it. The carbon intensity of different material types e.g. plastic film, dense plastics, textiles etc. within the waste is taken from a UK study (ERM, 2006) and the carbon content of each material type is assumed to remain constant across the time-series. The carbon contents calculated by the study are summarised in **Table 3.8** and emission factors are based on the fossil carbon content given in the table, assuming all carbon is oxidised.

Table 3.8 Biogenic and fossil carbon content of residual waste (time series)

Year	Biogenic carbon (kgC/T residual waste)	Fossil carbon (kgC/T residual waste)	Total carbon (kgC/T residual waste)	Proportion of carbon content which is fossil origin
1990	174	83	257	32.4%
1991	175	85	260	32.8%
1992	175	87	263	33.3%
1993	176	89	265	33.7%

Year	Biogenic carbon (kgC/T residual waste)	Fossil carbon (kgC/T residual waste)	Total carbon (kgC/T residual waste)	Proportion of carbon content which is fossil origin
1994	177	91	268	34.1%
1995	166	72	238	30.3%
1996	164	69	233	29.6%
1997	161	65	227	28.9%
1998	159	62	221	28.1%
1999	157	59	216	27.3%
2000	155	56	210	26.5%
2001	155	60	215	28.1%
2002	155	66	220	29.8%
2003	155	71	226	31.6%
2004	154	77	232	33.4%
2005	154	84	238	35.3%
2006	152	95	247	38.4%
2007	150	98	248	39.6%
2008	148	101	248	40.5%
2009	146	98	243	40.1%
2010	143	94	238	39.6%
2011	143	92	235	39.2%
2012	143	92	235	39.2%

The OPG burnt at oil and gas terminals is derived from the treatment of natural gas liquids and is predominantly ethane in composition (Personal communication: Clive Evans, DECC analyst, 2012). Therefore the IPCC default emission factor for ethane is used across the time-series for OPG combustion in this sector. Note that this factor is approximately 20% higher than the factor used for OPG in the refinery sector, which is based on EU ETS data and which reflects the different composition of OPG in that sector, which is derived from the treatment of crude oil.

EEMS emissions data are used for natural gas burnt by the upstream oil and gas industry, with emission factors back-calculated from the sectoral activity data used (described in the next section). These calculated emission factors are similar to what would be expected for natural gas. The EEMS data are used back to 1997 only, although data are also available for 1996. Emission factors calculated from these earliest EEMS data are outliers and so have been discarded, with emissions for 1990-1996 being calculated using the 1997 implied emission factor.

The implied emission factors (IEFs) presented in the UK CRF are generally aggregates of data at a more detailed level that is available in the UK inventory. This means the IEFs can vary across the time-series as both the activity data and the emission factors change for each set of detailed emission estimates. Updating carbon factors for the detailed sectors each year can cause large inter-annual changes in IEFs reported in the CRF. One approach to avoid this, which has been suggested by a UNFCCC Expert Review Team, is to use regression analysis and derive the CEFs from the best fit line. We have considered this approach and consulted with energy sector experts within DECC. For the moment, the UK continues to update CEFs on an annual basis because it considers that this approach provides the most accurate estimates of carbon emissions in a given year.

In general, we would not expect the UK-specific emission factors derived for the UK inventory to be significantly different from factors derived for other Member States of the European Union. However, there are some UK circumstances which may result in some differences with emission factors elsewhere. In particular, for sector 1A1a, the carbon factors for gas are higher in some years than might be expected because sour gas has been used in the UK ESI sector from 1992 onwards, and sour gas has a higher carbon factor than natural gas. The large increase in the CO_2 IEF between 1991 and 1992 is explained by the start-up of Peterhead power station in Scotland. This station burned large volumes of sour gas at that time, but after the mid-1990s, the quantities rapidly decreased again and the impact of sour gas on the UK IEF for gas should be small for the later part of the time-series.

Table 3.9 gives some basic information on the methods used to calculate emission estimates for indirect greenhouse gases.

Table 3.9 Methods used for deriving emission estimates for indirect greenhouse gases for CRF Source Category 1A1

Pollutant	CO	NOx	SO_2	NMVOC
Power Stations	R	R	R	R
Refineries	F/R	F/R	F/R	F
Coke ovens	F/R	F/R	R	F/R
SSF Manufacture	R	R	F	F
Collieries	F	F	F	F
Nuclear Fuels	F	F	F	F
Gas Production (distribution network)	F	F	F	F

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

There are no emissions observed in 1A1b or 1A1c for any overseas territories or crown dependencies. Fuel consumption data from 1A1a was provided by each territory. These data do not necessarily cover the entire time series so interpolation and extrapolation are applied to produce a complete time series. UK GHGI emission factors were applied to these activity data for all sources.

3.2.6.2.3 Activity data used

Activity data are predominantly taken from DECC (2013), but some alterations are made to the basic fuel consumption statistics available from this dataset (see **Annex 3.2** which includes activity data reconciliation tables for major UK fuels), to ensure consistency between the GHGI and fuel use data reported by certain process operators. Overall fuel consumption in 1A1 in the GHGI is, however, still consistent with DUKES, with the exception of certain petroleum fuels. For petroleum coke, fuel oil, gas oil and burning oil, statistics that are available through sources such as EU ETS returns indicate higher fuel use in the UK energy sector than is reported in the UK energy statistics. The data sources for petroleum coke use are described in each of the sectors where this fuel is used. For oils consumed in power stations DUKES reports less fuel burnt by power producers than is reported by operators either directly to the inventory agency 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, while maintaining consistency with the overall fuel consumption data in DUKES.

For OPG, analysis of EU ETS data from refineries has identified discrepancies in activity data between EU ETS and DUKES. Based on data from EU ETS and the refinery trade association, UKPIA, a systematic under-report was identified 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 EU ETS 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.

Furthermore, analysis of EU ETS data for chemical and petrochemical production sites has identified where feedstock-derived process gases and residues are used as a fuel on-site. The activity data for the feedstock is reported in DUKES as a non-energy use of the commodities (typically ethane, naphtha and LPG feedstock). In the inventory, therefore, these emissions are reported as combustion of Other Petroleum Gases. This constitutes another deviation from DUKES reported activity, re-allocating from a non-energy use to an energy use, albeit for secondary process gases rather than direct use of the commodities as a fuel.

Activity data for the combustion of petroleum coke also require amendment. Significant differences have been found between petroleum coke consumption derived from EU ETS data for 2005-2010, compared with the petroleum coke use given in DUKES. Therefore the emission estimates for those years are based on the EU ETS total, and the activity data for this fuel is then calculated based on the reported EU ETS emission and an emission factor provided by the refinery sector (UKPIA, 2013). For 1990-2004 and 2011-2012, DUKES data and the refinery sector emission factor are used to calculate emissions.

Further amendments are made to activity data for source categories in 1A1c, with revisions to OPG and natural gas activity data for the upstream oil and gas inventory, in consultation with the DECC DUKES team. Mismatches were identified between EEMS emissions and DECC DUKES data from PPRS, with gaps in DUKES:

- from 2003 onwards for LPG/OPG use in oil terminals, and
- prior to 2001, for upstream gas production facilities.

These gaps have been filled using EEMS and EU ETS activity data for these facilities.

EU ETS data also indicates that more natural gas is used by the downstream gas industry in gas compressor stations than is available in DUKES for the sector. So, for the year 2005 onwards, an amendment is made to the gas consumption data in the inventory with gas transferred from 1A2 to 1A1c to ensure that the inventory figure matches the figure given in EU ETS.

3.2.6.3 Uncertainties and Time-Series Consistency

The uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type. Uncertainty estimates for the activity data for fuel combustion sources are based on the statistical difference between supply and demand in DUKES, except for fuels where the total fuel use allocated in the inventory deviates from the national total in DUKES (OPG, petroleum coke). For these fuels, expert judgement has been applied to estimates for each of the categories where the fuels are used.

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. 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. EU ETS data have been used for the years 2008 to 2012, and EEMS activity data trends have been used to derive estimates for 2003 to 2007 for this activity. For more information about how EU ETS data are used, refer to **Annex 9**.

Emissions from petroleum coke consumption in refineries are based on DUKES data and an emission factor (UKPIA, 2013) from 1990 to 2004 and 2011-2012, and EU ETS emissions data from 2005 to 2010. As explained in **Section 3.2.3.1**, the EU ETS emissions data are not consistent with the data presented in DUKES for this sector for those years, but data for 2011 and 2012 are very similar, and the use of DUKES data retained. EU ETS data are not available for 1990-2004 and DUKES data are retained for those years.

For emission factors, the main issue regarding consistency is the use of factors taken from Bagott *et al*, 2004 for the years 1990-2003 and then the use of EU ETS-based emission factors from 2005 onwards for certain sectors, with interpolated values used for 2004. This is a change of methodology within the time series, but both sets of data represent the best available data for the years in question, and the values from both sources are similar, suggesting that the two methods give broadly consistent results. The two sets of data have therefore been combined without any amendments to either set of factors.

Table 3.10 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.

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 Statistics Authority's -*Official Statistics Code of Practice*- and as such is subject to a stringent QA process.

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 are 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 NIEA, with some routine checking procedures already in place. SEPA conducted a review of data quality during 2011 which has led to some updates to reported emissions data from facilities in Scotland within the Scottish Pollutant Release Inventory dataset.

The inventory also uses significant amounts of data from the EU ETS, for which there is a rigorous QA system in place. The EU ETS QA system governing data quality requires operators to submit monitoring plans to the regulators, and to submit annual returns to report source-specific fuel use and emissions which are independently verified by third parties that are accredited to perform EU ETS verification. The full details of EU ETS data are provided to the inventory agency, and the high level of detail and transparency enables the inventory agency to also perform quality checks on the data, for example to assess the time series consistency of the EU ETS reporting scope and emission estimation methods / tiers applied.

3.2.6.5 Source Specific Recalculations

Details of and justifications for recalculations to activity data are given in **Table 3.11** and emission factors in **Table 3.12** below. For information on the magnitude of recalculations to Source Category 1A1, see **Section 10**.

For the OTs and CDs there have been recalculations to these emission estimates since the previous submission, with estimates for Guernsey being the most substantially revised (70% increase of emissions in 2008 and 16% decrease in 2009 and 2010) due to the use of plant data reported in the national Electricity Annual reports for 2008-2010. CO_2 emissions from power generation in the Isle of Man increased by 15% in 2003 and decreased by 33% in 2004 due to the use of updated activity data. This recalculation improved the time series consistency of natural gas consumption data for the Isle of Man.

Table 3.11 1A1 Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
			1990	2011	1990	2011		
1A1a	Miscellaneous industrial/commercial combustion	MSW	0.217	0.144	0.217	0.146	Megatonne	Revision to DUKES
	Power stations	Fuel oil	6.172	0.553	6.120	0.424	Mt fuel consumed	Across time series, correction to fuel data for power stations in Cayman Islands. Using gas oil, rather than previously thought fuel oil. For later years, updates made to data received for Jersey.
		Gas oil	0.159	0.154	0.210	0.284	Mt fuel consumed	
		Natural gas	3.0	9445.4	3.0	9440.5	Mth fuel consumed	Revision to DUKES
		Liquid bio-fuels			0.000	0.017	Mt fuel consumed	New source added to the inventory
		Landfill gas	18	648	18	663	Mth fuel consumed	Revision to DUKES
		Sewage gas	41	98	41	99	Mth fuel consumed	Revision to DUKES
1A1b	Refineries	Fuel oil	2.10	0.66	2.10	0.48	Mt fuel consumed	Revision to DUKES
		Natural gas	9	200	9	217	Mt fuel consumed	Revision to DUKES
		OPG	1295	1682	1295	1774	Mth fuel consumed	Revisions to DUKES leading to recalculation of the OPG fuel use estimate
1A1c	Collieries - combustion	Colliery methane	23.0	22.1	23.0	23.3	Mth fuel consumed	Revision to DUKES
	Gas production	Natural gas	86	209	86	231	Mth fuel consumed	Revision to EU ETS-based estimate of fuel consumption
	Upstream oil production	Gas oil	0.349	0.489	0.349	0.494	Mt fuel consumed	Revision to DUKES
	Upstream gas production	Gas oil	0.0097	0.0376	0.0097	0.0384	Mt fuel consumed	Revision to DUKES

Table 3.12 1A1 Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	Pollutant	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
				1990	2011	1990	2011		
1A1a	Miscellaneous industrial/commercial combustion	Carbon	MSW	83.0	94.0	83.0	92.1	kt C / Mt	New MSW composition data received for 2011
	Power stations	Carbon	Coke	813	847	832	810	kt C / Mt	Changes to carbon balance input data and methodology, leading to revised EF for coke across the time series for all sources that are reported as burning coke oven coke.
		CH4	Liquid bio-fuels			0.0	1.2	kt / Mt	New source added to the inventory
		N2O	Liquid bio-fuels			0.0	0.2	kt / Mt	New source added to the inventory
		Carbon	MSW	83.0	94.0	83.0	92.1	kt C / Mt	New MSW composition data received for 2011.
		Carbon	OPG	1.495	1.468	1.491	1.453	kt C / Mth	Revisions to EU ETS-based emission factors
1A1b	Refineries - combustion	Carbon	Fuel oil	867	880	867	878	kt C / Mt	Revisions to EU ETS-based emission factors
		Carbon	OPG	1.495	1.468	1.491	1.453	kt C / Mth	Revisions to EU ETS-based emission factors
1A1c	Collieries - combustion	Carbon	Coke oven gas	1.165	1.169	1.153	1.100	kt C / Mth	Changes to carbon balance input data and methodology leading to revised EF for coke oven gas across the time series for all sources that are reported as burning coke oven gas.
		CH4	Coke oven gas	0.006	0.006	0.0001	0.0001	kt / Mth	Replacement of default emission factors from superseded version of the EMEP/EEA Emission Inventory Guidebook with factors from 2006 IPCC Guidelines
	Coke production	Carbon	Blast furnace gas	7.93	8.28	8.07	7.98	kt C/ Mth	Changes to carbon balance input data and methodology leading to revised EF for BF gas across the time series for all sources that are reported as burning BF gas.
		CH4		0.0118	0.0118	0.00011	0.00011	kt / Mth	Replacement of default emission factors from superseded version of the EMEP/EEA Emission Inventory Guidebook with factors from 2006 IPCC Guidelines
		N2O		0.0002	0.0002	0.00001	0.00001	kt / Mth	
	Coke production	Carbon	Coke oven Gas	1.17	1.17	1.15	1.10	kt C/ Mth	Changes to carbon balance input data and methodology leading to revised EF for coke oven gas across the time series for all sources that are reported as burning coke oven gas.
		CH4		0.006	0.006	0.0001	0.0001	kt / Mth	Replacement of default emission factors from superseded version of the EMEP/EEA Emission Inventory Guidebook with factors from

IPCC Category	Source Name	Pollutant	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
				1990	2011	1990	2011		
		N2O		0.0002	0.0002	0.00001	0.00001	kt / Mth	2006 IPCC Guidelines
	Solid smokeless fuel production	Carbon	Coke	813	847	832	810	kt C / Mt	Changes to carbon balance input data and methodology, leading to revised EF for coke across the time series for all sources that are reported as burning coke oven coke.
	Gas production	Carbon	OPG	1.495	1.468	1.491	1.453	kt C / Mth	Revisions to EU ETS-based emission factors

3.2.6.6 Source Specific Planned Improvements

Emission factors and activity data are kept under review and analysis of EU ETS data will continue.

3.2.7 Source Category 1A2 – Manufacturing Industries and Construction

3.2.7.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	1A2a: Iron and Steel (Combustion)	T1, T2	D, CS
	Iron and Steel (Sinter Plant)	T2	CS
	Iron and Steel (Blast Furnaces)	T1, T2	D, CS
	1A2b: Non-Ferrous Metals	T1, T2	D, CS
	1A2c: Chemicals Ammonia	T1, T2	D, CS
	(Combustion)	T1, T2	D, CS
	1A2d: Pulp, Paper and Print	T1, T2	D, CS
	1A2e: Food Processing, Beverages, Tobacco	T1, T2	D, CS
	1A2f: Other Industry (Combustion)	T1, T2	D, CS
	Cement (Fuel Combustion)	T1, T2	D, CS
	Cement (Non-decarbonising)	T2	CS
	Lime Production (Combustion)	T1, T2	D, CS
	Autogenerators	T1, T2	D, CS
	Other Industry (Mobile Combustion)	T3	D, CS
Gases Reported	CO_2, CH_4, N_2O, CO, NO_x, SO_2, VOC		
Key Categories (Trends)	1A1, 1A2, 1A4, 1A5 Other Combustion, N_2O Stationary combustion-oil, CO_2		
Key Categories (Level)	1A1, 1A2, 1A4, 1A5 Other Combustion, N_2O Stationary combustion-coal, CO_2 Stationary combustion-gas, CO_2 Stationary combustion-oil, CO_2		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Emissions from 1A2f included – no emissions observed in 1A2a-1A2e. All relevant UK Overseas Territories and Crown Dependencies emissions included within category totals within CRF submission.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	1A2a: Improved accuracy through use of EU ETS and installation-specific operator-reported data within the UK carbon balance approach for coke manufacture and iron and steel sources. 1A2c: Improved completeness of emission estimates for industrial use of OPG, and re-allocation of chemical and petrochemical industry use of OPG from 1A2f to 1A2c.		

This source category covers the use of fossil fuels for energy uses in industrial processes. The structure of the emissions data for this category reflects both the requirements for international reporting of emissions, but also the availability of data at a more detailed level for some industrial sectors. For most source estimates, the inventory method uses national energy statistics and applies country-specific factors for CO_2 (Tier 2), and default factors (typically from IPCC, US EPA, EMEP-EEA) for other gases (Tier 1). Iron and steel source emission estimates are derived from a carbon balance method applied across coke oven and iron and steel sector sources, using national statistics and installation-specific operator-reported data.

Iron and steel industry emissions are reported under 1A2a, these emissions being limited to those 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. Other iron and steel industry sources such as emissions from the addition of fuel oil or coke to blast furnaces, or 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. integrated steelworks data from ISSB, Tata Steel and SSI Steel), UK energy statistics and the EU ETS (where process emissions are reported separately from combustion emissions).

Sectoral emissions for the non-ferrous metal, chemical, paper, and food and drink industries are then reported under 1A2b to 1A2e. Chemical industry emissions, reported under 1A2c, are separated into those from gas use at ammonia production processes, and other emissions. This is due to the availability of detailed information on fuel use at ammonia plant.

All remaining industrial combustion plant is reported under 1A2f. Fuels used for cement production and for lime production are reported here but estimated separately since these data are available.

According to the IPCC 1996 Revised Guidelines, electricity generation by companies primarily for their own use is autogeneration, and the emissions produced should be reported under the industry concerned. However, most National Energy Statistics (including those of the UK) report fuels used by industry for electricity generation as a separate category. The UK statistics for autogeneration covers all industry sectors in a single figure for coal use, and another for natural gas. The UK inventory attempts to report this as far as possible according to the IPCC methodology by placing emission estimates in 1A2f.

The sectoral estimates reported under 1A2a to 1A2f include fuels reported in the national energy statistics for 'heat generation'. These are fuels that are used by sites that generate heat for other users e.g. many UK paper mills and chemical manufacturers are supplied with steam from a separate combustion plant run on a neighbouring site by a different operator. The re-allocation from the heat generation category to industry sectors is made on the basis of estimates provided by UK energy statisticians.

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 fuel combustion in industrial off-road machinery, such as generators and cement mixers, are also reported in 1A2f.

3.2.7.2 Methodological Issues

Table 3.13 gives a summary of the methodologies used to estimate emissions of direct gases from source categories within 1A2. For all of the source categories, the approach follows the principle of the basic combustion model – the use of emission factors applied to activity data – as described in **Section 3.2.6.2.1**.

Table 3.13 Summary of Emission Estimation Methods for Source Categories in CRF Category 1A1

Source Category	Method	Activity Data	Emission Factors
Blast furnaces	AD x EF	DECC energy statistics, ISSB and plant operator data	CO_2: UK-specific, including factors from coke and steelmaking carbon balance CH_4, N_2O: IPCC
Sinter plant	AD x EF	DECC energy statistics, ISSB and plant operator data	CO_2: UK-specific, from coke and steelmaking carbon balance CH_4, N_2O: UK-specific
Iron and steel - combustion plant	AD x EF	DECC energy statistics, ISSB and plant operator data	CO_2: UK-specific, including factors from coke and steelmaking carbon balance CH_4, N_2O: IPCC, USEPA, UK-specific
Non-ferrous metal (combustion)	AD x EF	DECC energy statistics	CO_2: UK-specific, including factors from coke carbon balance CH_4, N_2O: IPCC, UK-specific
Ammonia production - combustion	AD x EF	DECC energy statistics, operator data.	IPCC and UK-specific
Chemicals (combustion)	AD x EF	DECC energy statistics	CO_2: UK-specific CH_4, N_2O: IPCC, UK-specific
Pulp, paper & print (combustion)	AD x EF	DECC energy statistics	CO_2: UK-specific CH_4, N_2O: IPCC, UK-specific
Food & drink, tobacco (combustion)	AD x EF	DECC energy statistics	CO_2: UK-specific CH_4, N_2O: IPCC, UK-specific
Autogenerators	AD x EF	DECC energy statistics	CO_2: UK-specific CH_4, N_2O: IPCC, UK-specific
Cement production - combustion	AD x EF	Mineral Products Association (MPA) data, EU ETS	CO_2: UK-specific, including MPA data CH_4, N_2O: IPCC, UK-specific
Lime production - non decarbonising	AD x EF	EU ETS extrapolated across time-series using PI emissions and BGS production data.	CO_2: UK-specific, including EU ETS data and factors from coke carbon balance CH_4, N_2O: IPCC, UK-specific
Other industrial combustion	AD x EF	DECC energy statistics	CO_2: UK-specific, including EU ETS data and factors from coke carbon balance CH_4, N_2O: IPCC, USEPA, UK-specific
Industrial off-road mobile machinery	AD x EF	Inventory agency estimate of fuel use by different mobile units	CO_2: UK-specific CH_4, N_2O: UK-specific

3.2.7.2.1 Emission factors used

The emission factors used in the inventory are listed in **Annex 3**, **Tables A3.3.1**–**A3.3.4**.

Emission factors for carbon are almost exclusively derived from UK data. Site-specific data, (including both EU ETS data, and data provided by process operators directly or via industrial trade associations) is aggregated up to generate factors for a small number of sectors. Sector-wide factors are derived in other cases based usually on the methods described in Baggott *et al*, 2004. Emission factors for waste oils are based on the analysis of 8 samples of waste oils collected from UK sites in 2003. Finally, the factors for coke and other manufactured fuels are based on a carbon balance approach as described below.

Emissions of carbon from manufactured solid fuel plants, coke ovens and steelworks are calculated using a model where carbon inputs and outputs are estimated using energy and process statistics and making assumptions about the carbon content of selected inputs and/or outputs and then calculating the quantities of carbon emitted or output at other stages in the process in order to balance the overall inputs and outputs of carbon. The model for manufactured solid fuel plants is straightforward:

$$C_{coal} \rightarrow C_{SSF} + \text{carbon emission}$$

Where C_{coal} and C_{SSF} are the carbon estimated to be contained in the coal (anthracite) input to the fuel manufacturing process, and that in the solid smokeless fuel (SSF) output from the process. The activity data for the calculation is from DUKES (DECC, 2013). The mass of coal input is always larger than the SSF produced and we also assume a slightly lower carbon content for the SSF compared with the anthracite input, and so there is always an excess of carbon input in coal compared with carbon output in saleable SSF, this excess being treated in the inventory as an emission of carbon by the fuel manufacturing process.

The carbon balance for the combined coke ovens and integrated steelmaking processes is more complex, and is based on tracking the carbon through 4 successive stages – coke making, sintering, pig iron production, and basic oxygen steel production. At each stage carbon is input as fuels and/or feedstocks; carbon leaves in products; is emitted to air or removed as waste products. The scheme given below, listing the main inputs and outputs is a simplified version of the model:

coal → coke + coke oven gas + benzoles & tars + fugitive carbon emission
coke + limestone + iron ore → sinter + carbon emission
sinter + coke + other reducing agents → pig iron + blast furnace gas
pig iron + scrap + dolomite → steel + slag + basic oxygen furnace gas

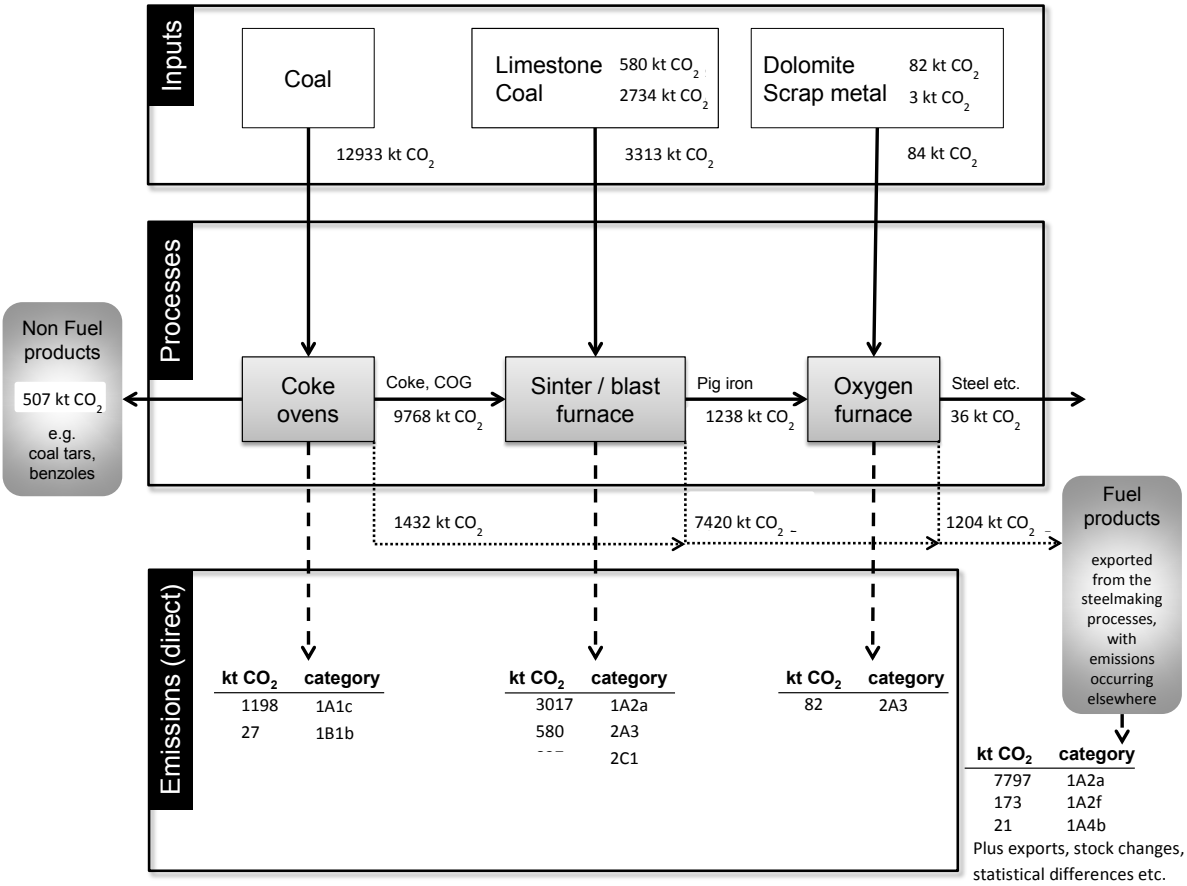
The outputs that are allowed to vary, and therefore used to ensure that the overall carbon balances, are coke, blast furnace gas and basic oxygen furnace gas.

For the latest submission the carbon balance methodology has been reviewed and improved with much use of detailed, site-specific, carbon factors and other data supplied by the operators, as part of their EU ETS reporting and provision of energy consumption data for use in Government statistics, as well as data supplied directly to the inventory agency. The improvements have reduced uncertainty in the estimates of carbon input in coking coal, which in turn has lowered the uncertainty in estimates of carbon outputs including emission estimates in the UK GHGI. The industry data has also led to relatively small changes in the allocation of carbon to each output and thus will have a small impact on the distribution of

emissions reporting across 1A1c, 1A2a and 2C1. Further details of the improvements made can be found within "*GHG Inventory Research: Use of EUETS Data - Iron & Steel Sector, Chemical Industry Feedstock Use*" (Ricardo-AEA, 2014).

The carbon balance model used is shown in a simplified form in **Figure 3.3**, with inputs and outputs of carbon (expressed as CO_2) given for the year 2012 as an example.

Figure 3.3 Carbon balance model for 2012



Methods used to calculate emission estimates for indirect gases are summarised in **Table 3.14**.

Table 3.14 Methods for calculation of indirect greenhouse gas emission from 1A2

Sector/pollutant	CO	NO_x	SO_2	NMVOC
Cement (fuel combustion)	*[Emissions reported under 'non-decarbonising' – see below]*			
Cement (non-decarbonising)	The inventory agency uses data reported by operators to environmental regulators directly within the inventory.			
Lime Manufacture	Emissions data from regulator.		AD x EF	
Autogenerators – coal	Emissions data from regulator.			AD x EF
Autogenerators - gas	AD x EF			
Other Industry	AD x EF[1.]			
Chemicals	AD x EF[1.]			
Non-ferrous metals	AD x EF[1.]			

Sector/pollutant	CO	NO_x	SO_2	NMVOC
Food & drink	AD x EF[1.]			
Paper & printing	AD x EF[1.]			
Sinter Plant	Emissions estimates for individual sites provided by process operators.			
Chemical industry (soda ash)	Data from regulator.	No emissions		

[1]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.

In almost all cases, the inventory contains fuel-specific emission estimates of indirect gases for each sector, so, for example, there are emission estimates for coal burnt in chemical plants, as well as estimates for emissions from gas burnt. The sole exception to this is for cement kilns. This is because each kiln burns a mixture of fuels (often a blend of coal and petroleum coke, plus waste-derived fuels) and while emissions of carbon from each fuel can still be calculated, it is more realistic to calculate overall emissions for indirect greenhouse gases. Estimates for the four indirect gases are based on emissions data reported by operators and are presented as overall emissions rather than broken down by fuel.

There are no emissions reported in 1A2a-1A2e for any overseas territories or crown dependencies. Fuel consumption data for 1A2f was provided by each territory. These data do not necessarily cover the entire time series so interpolation and extrapolation was applied to produce a complete time series. UK GHGI emission factors were applied to these activity data for all sources.

3.2.7.2.2 Activity data used

The DUKES publication is used to obtain the relevant activity statistics, but with some additional data collected from industry in order to provide further detail or to improve on the detailed allocation of fuels to industry sector. As with elsewhere in the UK inventory, the fuel data used are consistent with the overall demand figures given in the UK energy statistics. DUKES provide most of the data needed to derive separate estimates of fuel usages by industry sector, which are reported under the six source categories 1A2a – 1A2f. This full breakdown is available for coal, natural gas, fuel oil and gas oil as data are available within DUKES. Other fuels such as LPG, coke and burning oil are reported solely under 1A2f due to a lack of any data on sectoral use in DUKES. Details of the detailed activity data are given in Annex 3 (**Section A 3.2.1**).

Fuel consumption estimates from other data sources complement the DUKES data, and allow greater detail in the inventory. Fuel use in ammonia production (1A2c) and cement kilns (1A2f) are collected from process operators, directly in the case of ammonia, via the Mineral Products Association (MPA) in the case of cement kilns. These data are not complete for all of the earlier part of the time series, so some assumptions have to be made to fill these gaps. For example, MPA data are not available for 1991-1999, and so fuel usage for these years must be interpolated between the 1990 and 2000 data, taking also into account changes in cement clinker production in each year. For ammonia production sites, data on gas usage and ammonia production are quite limited prior to 1998, and the estimates for 1990-1997 are largely based on extrapolation back from later reported data. All of the sites in operation in 1990 were still in operation in the late 1990s when data are available, so the extrapolation back to 1990 can be done at site-level, and with a high level of confidence since the capacity of these plants across the time series is known.

Data for autogenerators are taken directly from DUKES and relate to fuels used for electricity generation by companies primarily for their own consumption. The inventory does not treat combined heat and power (CHP) differently to other installations. Hence CHP systems where all of the electricity is fed into the public supply are classified as power stations and CHP systems where electricity is used by the generator are classified as autogeneration. Emissions for autogenerators are reported under 1A2f.

For industrial and construction off-road machinery, emissions are reported under 1A2fii and 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 the Section on IPCC Categories 1A4, dealing with other off-road machinery, **Section 3.2.10**.

The reallocation of fuel activity data from UK energy statistics is required in some instances:

- to split out more detailed estimates for some industrial sectors such as ammonia, cement and lime. In these cases, the reallocation is merely between source categories that are reported under the same CRF category;
- to reconcile the inventory fuel data with other data for industrial users, such as fuel use estimates from cement kiln operators. In that case, the reallocation involves the transfer of fuel between categories within CRF 1A2f;
- to reconcile the inventory fuel data with other data for fuel users outside the industrial sector, for example data from EU ETS for gas distributors, and process operators in the case of power stations. In these cases, the reallocations involve the transfer of fuel between 1A2 and other source categories i.e. 1A1 for the two examples given.
- Gas oil is used in many types of mobile machinery as well as off-road vehicles, ships, boats, and trains. Reallocations are needed to reconcile the gas oil estimates in the inventory with other activity data for these mobile machinery and transport sectors, i.e. data on populations of mobile equipment, or train or ship movements etc. DUKES does not separate out fuels used in off-road vehicles or mobile machinery and so reallocations of gas oil are necessary in the inventory in order to both provide separate estimates for gas oil use in stationary sources and mobile sources, and also to reconcile the inventory estimates with other data sources. The approach developed for allocating gas oil between different source categories is described in **Section 3.2.9.2**

Reallocations of fuels are necessary for burning oil, fuel oil, gas oil, natural gas, OPG and petroleum coke.

In the case of petroleum coke, DUKES does not include estimates of petroleum coke use as an industrial fuel, instead treating it as being used for non-energy applications. However, other data from EU ETS and industrial operators indicates that a number of industrial sources do use petroleum coke as a fuel. The inventory estimates for petroleum coke use in 1A2f are therefore a reallocation of data from non-energy use in DUKES to 1A2. Therefore this re-allocation increases the overall reporting of petroleum coke as an emissive energy use, deviating from the DUKES commodity balance. A similar reallocation has to be made for petroleum coke from non-energy use to 1A4.

Analysis of information from EU ETS reporting has identified that a number of chemical and petrochemical manufacturers utilise carbon-containing process off-gases and residues as fuel sources. Consultation with industry and also with the DECC team of energy statisticians

has clarified that this is also an energy source that within DUKES is reported as non-energy use, across a number of petroleum commodities used as a chemical feedstock. The emission estimates from EU ETS are therefore used to derive inventory estimates to account for this use of feedstock-derived process gases, and the process gases are reported as "other petroleum gas" use within the inventory. The estimates within the 2014 submission have been updated following further research conducted by the inventory agency during 2013-2014 (Ricardo-AEA, 2014) and also have been re-allocated from 1A2f to 1A2c.

3.2.7.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type. The uncertainty in the activity data for fuel combustion sources is based on the statistical difference between supply and demand in DUKES, except for where the fuel total in the inventory deviates from the national total in DUKES (OPG, petroleum coke).

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

In general, emission factors are taken from a consistent source across the time series so few time series consistency issues arise. Some EU ETS data are used for coal-fired autogenerators and other large combustion plant such as lime kilns and the use of factors from Baggott *et al*, 2004 for the earlier part of the time series does result in a step change in the factors for the period 2003-2005. In the case of lime kilns, the EU ETS-based factors show considerable variation over the period 2005-2011 and so the step change between non-ETS data in 2003 and ETS data in 2005 is considered an acceptable trend using the best available data for the source. For coal-fired autogeneration, the earlier factors are typically 5 to 10% higher; this may indicate that the time series of emission factors are inaccurate, or it may indicate that the impact of EU ETS has led to switching of fuel sources by the plant operators.

Table 3.15 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 the time series and are predominantly 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

Details of and justifications for recalculations to activity data are given in **Table 3.16** and emission factors in **Table 3.17** below. For information on the magnitude of recalculations to Source Category 1A2, see **Section 10**.

For the OTs and CDs there have been recalculations to these emission estimates since the previous submission resulting in a 21% (14kt CO_2) decrease in emission estimates for Guernsey, due to a correction in the compilation spreadsheet.

Table 3.16 1A2 Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
			1990	2011	1990	2011		
1A2a	Iron and steel - combustion plant	Fuel oil	0.113	0.045	0.113	0.029	Mt fuel consumed	Revision to DUKES
		Natural gas	456.0	210.0	456.0	203.5	Mth fuel consumed	Revision to DUKES
		Coke oven gas	269.2	124.5	273.6	127.3	Mth fuel consumed	Revised estimates following comprehensive review of the available data from DECC , ISSB and plant operators, and revisions to the carbon balance approach used for coek manufacture and iron and steel sources.
1A2b	Non-ferrous metal (combustion)	Coal	0.079	0.040	0.079	0.039	Mt fuel consumed	Revision to DUKES
		Fuel oil	0.032	0.008	0.032	0.001	Mt fuel consumed	Revision to DUKES
		Natural gas	154	99	154	90	Mth fuel consumed	Revision to DUKES
1A2c	Chemicals (combustion)	Coal	1.13	0.36	1.13	0.45	Mt fuel consumed	Revision to DUKES
		Fuel oil	1.31	0.04	1.31	0.11	Mt fuel consumed	Revision to DUKES
		Gas oil	0.067	0.002	0.067	0.004	Mt fuel consumed	Revision to DUKES
		Natural gas	916	1159	916	976	Mth fuel consumed	Revision to DUKES
		OPG			531	574	Mth fuel consumed	Fuel re-allocated from 'other industrial combustion'(1A2f), and data across the time series also revised following consultation with plant operators and identification of more sites where process off-gases and residues are used as fuels.
1A2d	Pulp, Paper and Print (combustion)	Fuel oil	0.226	0.014	0.226	0.004	Mt fuel consumed	Revision to DUKES
		Gas oil	0.015	0.001	0.015	0.002	Mt fuel consumed	Revision to DUKES
		Natural gas	399	571	399	500	Mth fuel consumed	Revision to DUKES
1A2e	Food & drink, tobacco (combustion)	Fuel oil	0.791	0.025	0.791	0.140	Mt fuel consumed	Revisions to DUKES
		Gas oil	0.067	0.006	0.067	0.016	Mt fuel consumed	Revisions to DUKES

IPCC Category	Source Name	Activity Name	2013 submission 1990	2013 submission 2011	2014 submission 1990	2014 submission 2011	Units	Comment/Justification
		Natural gas	678	834	678	794	Mth fuel consumed	Revisions to DUKES
1A2f	Autogeneration – exported to grid	Coal	0.40	0.60	0.40	0.56	Mt fuel consumed	Revision to DUKES
	Autogeneration – exported to grid	Natural gas	36	490	36	457	Mth fuel consumed	Revision to DUKES
	Autogenerators	Coal	1.06	0.69	1.06	0.73	Mt fuel consumed	Revision to DUKES
	Autogenerators	Natural gas	96	571	96	598	Mth fuel consumed	Revision to DUKES
	Autogenerators	Biogas			0.00	40	Mth fuel consumed	Re-allocation of energy from 'other industrial combustion – biomass'
	Other industrial combustion	Biomass	0.00	2.18	0.00	1.41	Mt fuel consumed	Biomass used to generate biogas now reported separately
		Coal	1.60	0.70	1.60	0.89	Mt fuel consumed	Revision to DUKES and re-allocations of coal use between 1A1c and 1A2f based on plant operator data in some years, through inventory improvement programme research (Ricardo-AEA, 2014)
		Fuel oil	1.65	0.11	1.65	0.09	Mt fuel consumed	Revision to DUKES
		LPG	299	423	299	421	Mth fuel consumed	Revision to DUKES
		Natural gas	2346	1649	2473	1424	Mth fuel consumed	Changes due to revisions in the allocation of fuel between different industrial sectors and, for 2011, revisions to DUKES.
		OPG	536	575	24	0.00	Mth fuel consumed	Re-allocation of fuel use to the chemical industry (1A2c), where the OPG use is known to be within the chemical sector.
	Industrial off-road mobile machinery	Gas oil	2.03	1.39	2.03	1.14	Mt fuel consumed	Revisions to the sectoral-allocation of DERV and gas oil following a review of methodology for estimating these fuels.

Table 3.17 1A2 Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	Pollutant	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
				1990	2011	1990	2011		
1A2a	Iron and steel - combustion plant	Carbon	Coal	660	717	660	694	kt / Mt	Revised factor for 2011 due to revised GCV given in DUKES
	Iron and steel - combustion plant	Carbon	Coke	813	847	832	810	kt / Mt	Revision to carbon balance approach to use AD and EFS from ISSB/Tata in preference to DUKES stats and historic EF defaults.
	Iron and steel - combustion plant	Carbon	Blast furnace gas	7.9	8.3	8.1	8.0	kt / Mth	Revision to carbon balance approach to use AD and EFS from ISSB/Tata in preference to DUKES stats and historic EF defaults.
	Iron and steel - combustion plant	CH4	Blast furnace gas	0.01182	0.01182	0.00011	0.00011	kt / Mth	Blast furnace and coke oven gas factors changed to 2006 IPCC (not available in 1996 version) defaults from 1996 EMEP factor
	Iron and steel - combustion plant	N2O	Blast furnace gas	0.00021	0.00021	0.00001	0.00001	kt / Mth	Blast furnace and coke oven gas factors changed to 2006 IPCC (not available in 1996 version) defaults from 1996 EMEP factor
	Iron and steel - combustion plant	Carbon	Coke oven gas	1.17	1.17	1.15	1.10	kt / Mth	Revision to carbon balance approach to use AD and EFS from ISSB/Tata in preference to DUKES stats and historic EF defaults.
	Iron and steel - combustion plant	CH4	Coke oven gas	0.00604	0.00604	0.00012	0.00012	kt / Mth	Blast furnace and coke oven gas factors changed to 2006 IPCC (not available in 1996 version) defaults from 1996 EMEP factor

IPCC Category	Source Name	Pollutant	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
				1990	2011	1990	2011		
	Iron and steel - combustion plant	N2O	Coke oven gas	0.00021	0.00021	0.00001	0.00001	kt / Mth	Blast furnace and coke oven gas factors changed to 2006 IPCC (not available in 1996 version) defaults from 1996 EMEP factor
	Blast furnaces	Carbon	Blast furnace gas	7.9	8.3	8.1	8.0	kt / Mth	Revision to carbon balance approach to use AD and EFS from ISSB/Tata in preference to DUKES stats and historic EF defaults.
	Blast furnaces	CH4	Blast furnace gas	0.01182	0.01182	0.00011	0.00011	kt / Mth	Blast furnace and coke oven gas factors changed to 2006 IPCC (not available in 1996 version) defaults from 1996 EMEP factor
	Blast furnaces	N2O	Blast furnace gas	0.00021	0.00021	0.00001	0.00001	kt / Mth	Blast furnace and coke oven gas factors changed to 2006 IPCC (not available in 1996 version) defaults from 1996 EMEP factor
	Blast furnaces	Carbon	Coke oven gas	1.17	1.17	1.15	1.10	kt / Mth	Revision to carbon balance approach to use AD and EFS from ISSB/Tata in preference to DUKES stats and historic EF defaults.
	Blast furnaces	CH4	Coke oven gas	0.00604	0.00604	0.00012	0.00012	kt / Mth	Blast furnace and coke oven gas factors changed to 2006 IPCC (not available in 1996 version) defaults from 1996 EMEP factor
	Blast furnaces	N2O	Coke oven gas	0.00021	0.00021	0.00001	0.00001	kt / Mth	Blast furnace and coke oven gas factors changed to 2006 IPCC (not available in 1996 version) defaults from 1996 EMEP factor
	Sinter production	Carbon	Coke	813	847	832	810	kt / Mt	Revision to carbon balance approach to use AD and EFS from ISSB/Tata in preference to DUKES stats and historic EF defaults.
1A2f	Autogenerators	CH4	Biogas			0.00009	0.00009	kt / Mth	New source. Fuel re-allocated from other industrial combustion - biomass
	Autogenerators	N2O	Biogas			0.000009	0.000009	kt / Mth	New source. Fuel re-allocated from other industrial combustion - biomass

IPCC Category	Source Name	Pollutant	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
				1990	2011	1990	2011		
	Lime production - non decarbonising	Coke	Carbon	813	847	832	810	kt / Mt	Revision to carbon balance approach to use AD and EFS from ISSB/Tata in preference to DUKES stats and historic EF defaults.
	Other industrial combustion	Coke	Carbon	813	847	832	810	kt / Mt	Revision to carbon balance approach to use AD and EFS from ISSB/Tata in preference to DUKES stats and historic EF defaults.
	Other industrial combustion	Coke oven gas	Carbon	1.17	1.17	1.15	1.10	kt / Mth	Revision to carbon balance approach to use AD and EFS from ISSB/Tata in preference to DUKES stats and historic EF defaults.
	Other industrial combustion	Coke oven gas	CH4	0.00604	0.00604	0.00012	0.00012	kt / Mth	Blast furnace and coke oven gas factors changed to 2006 IPCC (not available in 1996 version) defaults from 1996 EMEP factor
	Other industrial combustion	Coke oven gas	N2O	0.00021	0.00021	0.00001	0.00001	kt / Mth	Blast furnace and coke oven gas factors changed to 2006 IPCC (not available in 1996 version) defaults from 1996 EMEP factor

3.2.7.6 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

Emissions sources	Sources included	Method	Emission Factors
	1A3a: Domestic Aviation 1A3b: Road Transport 1A3b: Railways (Freight) Railways (Intercity) Railways (Regional) 1A3d: National Navigation 1A3e: Aircraft Support	T3 T3 T2 T2 T2 T2, T3 T3	CS CS, CR CS, CR CS, CR CS, CR CS, CR CS
Gases Reported	CO_2, CH_4, N_2O, CO, NO_x, SO_2, VOC		
Key Categories (Trends)	Mobile combustion-Road vehicles – DERV – N_2O		
Key Categories (Level)	Mobile combustion-Road vehicles - DERV, CO_2 Mobile combustion-Road vehicles - Gasoline/ LPG, CO_2 Mobile combustion-Road vehicles – DERV – N_2O Mobile combustion-Road vehicles - , Gasoline/ LPG, N_2O		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Emissions from 1A3 included. All relevant UK Overseas Territories and Crown Dependencies emissions included within category totals within CRF submission – UK fuel based EFs used.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	Revision to method for calculating CH_4 and N_2O emissions from road transport; now based on fuel sold. This method revision was a result of an ERT adjustment to the UK inventory total following the review of the 2012 submission.		

Road transport is by far the largest contributor to transport emissions and estimations are made for a wide variety of vehicle types using petrol, diesel and LPG.

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 in DUKES 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.

Methane and nitrous oxide emissions from road transport are calculated on the basis of fuel sold. This is a significant methodological change from previous versions of the inventory where these emissions were calculated on the basis of traffic data and were not normalised to fuel sold. This methodological change is in response to a recommendation from the UNFCCC Expert Review Team from the in-country review during 2012, which led to an adjustment of the 2012 submission of the UK GHG inventory. Further details of the method change are given in **Section 3.2.8.2.1.3.**

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, inland waterways, and vessel movements between the UK and Overseas Territories and international marine.

Emissions from aircraft support vehicles in airports are reported in 1A3e. Note that emissions from fuel combustion to run UK pipelines (e.g. use of natural gas to operate compressors on pipelines) are not reported explicitly within DUKES and the emissions from this fuel use are included within other source categories in the inventory. The use of natural gas in compressor stations for the UK natural gas transmission and distribution pipeline network is included within an aggregated fuel allocation in DUKES for "Other" energy industry use, and the emissions are reported in 1A1c (Gas production – downstream). The UK also includes a number of chemical pipeline systems, including a network of pipes to transfer petrochemical products such as ethylene between different production centres in Scotland and England. The emissions from fuel use to operate these pipelines are either allocated within 1A2c Chemical industry combustion where natural gas is used or 1A1a Power generation where electricity is used to run compressors.

The UK does not include CH_4 or N_2O emissions from lubricants explicitly. 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 – and reported as IE in the CRF.

3.2.8.2 Methodological Issues

The following sections summarise and then provide greater detail in the methods used to estimate emissions for each transport category. The sections also describe the method used to estimate emissions from other mobile sources included in 1A4 (fishing) and 1A5 (military aviation and shipping) The method used to calculate emissions from aircraft support vehicles is described in the Section on IPCC Categories 1A4, dealing with other off-road machinery, **Section 3.2.9.**

3.2.8.2.1 Aviation (1A3a)

In accordance with the agreed guidelines, the UK inventory contains estimates for both domestic and international civil aviation. Emissions from international aviation are recorded as a memo item, and are not included in national totals. Emissions from both the Landing and Take-Off (LTO) phase and the Cruise phase are estimated. A summary of the more detailed approach used is given below, and a full description is given in

Watterson *et al.* (2004). The method used to estimate emissions from military aviation can be found towards the end of this section on aviation.

Emissions are estimated from the number of aircraft movements broken down by aircraft type at each UK airport, and so comply with the IPCC Tier 3 specification. Emissions of a range of pollutants are estimated in addition to the reported greenhouse gases. The method reflects differences between airports and the aircraft that use them. Emissions from additional sources (such as aircraft auxiliary power units) are also included.

A number of improvements have been made to the model over recent years, to include findings from UK specific research. These reports and model improvements are summarised below.

- The RASCO study (23 regional airports, with a 1999 case calculated from CAA movement data) carried out for the Department for Transport (DfT), and the published inventories for Heathrow, Gatwick and Stansted airports, commissioned by BAA and representative of the fleets at those airports. Emissions of NO_x and fuel use from the Heathrow inventory have been used to verify the results of this study.
- The Project for the Sustainable Development of Heathrow (PSDH) (DfT, 2006).
- For departures, this study made recommendations for revised thrust setting at take-off and climb-out as well as revised cut-back heights, and for arrivals, the PSDH made recommendations for revised reverse thrust setting and durations along with revised landing-roll times. Further recommendations related to: the effects of aircraft speed on take-off emissions; engine spool-up at take-off; the interpolation to intermediate thrust settings; hold times; taxiing thrust and times; engine deterioration and APU emission indices and running times.
- The outcomes of this study were incorporated into the 2009 inventory submission for Heathrow, and the 2010 inventory submission for all other airports.
- For the 2011 inventory submission, flights between the UK and overseas territories were included as domestic aviation. Previous inventories included flights from the UK to overseas territories as international aviation, recorded as a memo item. Flights from overseas territories to the UK were not included in previous inventories.
- For the 2012 inventory submission, all flights originating from the overseas territories, irrespective of destination, were included in the inventory as were return flights from oil rigs which had previously been omitted.
- The 2014 inventory submission has incorporated recent data from local London airport inventories (2008 onwards) so that aircraft engine mixes, times in mode and thrust settings are consistent. International flights with an intermediate stop at a domestic airport have been re-classified as having a domestic leg and an international leg, increasing the national inventory total for domestic flights and reducing the international component of aviation (which is reported as a memo item only).

3.2.8.2.1.1 Reporting of aviation in the GHG inventory

Following IPCC methodology guidelines and UNFCCC reporting guidelines, emissions from civil aviation are divided into domestic aviation and international aviation. Domestic aviation (including take-off and landing, and cruise) is reported in category 1A3a and is included in the national total. International aviation is reported as a memo item. Estimates are also made of emissions from military aviation; these are reported under category 1A5b.

The UK CAA has provided the aircraft movement data used to estimate emissions from civil aviation. The definitions the CAA use to categorise whether a movement is international or domestic are (CAA, *per. comm.*)

- **Domestic**:A flight is domestic if the initial point on the service is a domestic and the final point is a domestic airport; and
- **International**:A flight is international if either the initial point or the final point on the service is an international airport.

Take, for example, a flight (service) that travels the following route: **Glasgow** (within the UK) – **Birmingham** (within the UK) – **Paris** (outside the UK). The airport reporting the aircraft movement in this example is Glasgow, and the final airport on the service is Paris. The CAA categorises this flight as international, as the final point on the service is outside the UK.

The methodology in the 2014 UK GHGI submission classifies such flights as having a domestic leg (in our example **Glasgow** – **Birmingham**) and an international leg (in our example **Birmingham** –**Paris**). Following the IPCC Good Practice Guidance (IPCC, 2000), it is necessary to know whether passengers or freight are put down before deciding whether the whole journey is considered as an international flight or consisting of a (or several) domestic flight(s) and an international flight. The revised classification provides a conservative estimate of domestic emissions, which is approximately 1% higher than the estimate based on the CAA definition. A true estimate, based on IPCC definitions, will lie between these two bounds. However, the data are not readily available to identify which journeys should be classed as international flights and which as consisting of a (or several) domestic flight(s) and an international flight.

In order to ensure complete geographical coverage of the UK for the purposes of reporting to the UNFCCC, some reallocations are made to the CAA data. Flights between the UK and the CDs are considered to be within the UK in the CAA aircraft movement data, therefore no modifications are required for these flights, except for when calculating emissions for EUMM or UK only reporting.

Flights between the UK and the OTs are considered to be international in the CAA aircraft movement data, but have been reclassified as domestic aviation since the 2011 inventory submission. Flights between overseas territories (obtained from the DfT data) have been classed as domestic aviation. Other flights originating from the overseas territories have been classed as international.

Total modelled fuel use is normalised to the total in DUKES. The total in DUKES includes all flights originating from the UK and CDs, therefore flights from the OTs are additional to this total and are excluded from the normalisation.

3.2.8.2.1.2 Aircraft Movement Data (Activity Data)

The methods used to estimate emissions from aviation require the following activity data:

- **Aircraft movements and distances travelled**
  Detailed activity data has been provided by the UK Civil Aviation Authority (CAA). These data include aircraft movements broken down by: airport; aircraft type; whether the flight is international or domestic; and, the next/last POC (port of call) from which sector lengths (great circle) have been calculated. The data covered all Air transport Movements (ATMs) excluding air-taxi.

- Fights between the UK and overseas territories are considered to be international in the CAA aircraft movement data, but these have been reclassified as domestic aviation.
- International flights with an intermediate stop at a domestic airport are considered international in the CAA aircraft movement data. However these have been reclassified as having a domestic leg and an international leg in response to a recommendation from the UNFCCC centralised review in 2013.
- The CAA also compiles summary statistics at reporting airports, which include air-taxi and non-ATMs.
- The CAA data have been supplemented with data from overseas territories, supplied by DfT.
- A summary of aircraft movement data is given in **Table 3.18.** Flights between the UK and overseas territories are included in domestic.

- **Inland Deliveries of Aviation Turbine Fuel and Aviation Spirit**
  Total inland deliveries of aviation spirit and aviation turbine fuel to air transport are given in DUKES (DECC 2013). This is the best approximation of aviation bunker fuel consumption available and is assumed to cover international, domestic and military use.

- **Consumption of Aviation Turbine Fuel and Aviation Spirit by the Military**
  Historically, total consumption by military aviation has been given in ONS (1995) and Ministry of Defence (MOD) (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. These data also included estimates of aviation spirit and fuel classed as “Casual Uplift”, with the latter being drawn from commercial airfields world-wide and assumed not to be included in DUKES. In 2011 the MoD revised their methodology for calculating fuel consumption, which provided revised data for 2008/09 onwards (MoD 2011). These data no longer separately identified aviation spirit or fuel classed as “Casual Uplift”, so all fuel was assumed to be aviation turbine fuel and included in DUKES. In 2013 the MoD provided revised data for 2010/11 onwards that did separately identify aviation spirit. However, these data still did not identify “Casual Uplift”, so all fuel was assumed to be included in DUKES.

  Calendar year activity data are derived from the data sources described above.

Table 3.18 Aircraft Movement Data

	International LTOs (000s)	Domestic LTOs (000s)	International Aircraft, Gm flown	Domestic Aircraft, Gm flown
1990	460.47	376.96	652.00	116.36
1995	530.87	365.29	849.00	118.25
2000	704.29	407.15	1190.65	145.20
2005	800.49	488.19	1447.62	178.68
2008	840.42	471.95	1557.17	173.40
2009	773.30	420.55	1440.41	157.26
2010	733.97	393.88	1395.08	146.35
2011	769.22	381.18	1465.19	141.56

	International LTOs (000s)	Domestic LTOs (000s)	International Aircraft, Gm flown	Domestic Aircraft, Gm flown
2012	765.67	365.20	1444.63	137.51

Gm Giga metres, or 10^9 metres

Estimated emissions from aviation are based on data provided by the CAA and, for overseas territories, the DfT.

Gm flown calculated from total flight distances for departures from UK and overseas territories airports.

3.2.8.2.1.3 Emission factors used

The following emission factors were used to estimate emissions from aviation. The emissions of CO_2, SO_2 and metals depend on the carbon, sulphur and metal contents of the aviation fuels'. Emissions factors for CO_2, SO_2 and metals have been derived from the contents of carbon, sulphur and metals in aviation fuels. These contents are reviewed, and revised as necessary, each year. Full details of the emission factors used are given in Watterson *et al*. (2004).

Table 3.19 CO_2 and SO_2 Emission Factors for Civil and Military Aviation for 2012 (kg/t)

Fuel	CO_2	SO_2
Aviation Turbine Fuel	859	1.264
Aviation Spirit	853	1.264

Notes

Carbon and sulphur contents of fuels provided by UKPIA (2013)
Carbon emission factor as kg carbon/tonne
Military aviation only uses ATF

For the LTO-cycle calculations, emissions per LTO cycle are required for each of a number of representative aircraft types. Emission factors for the LTO cycle of aircraft operation have been calculated from the International Civil Aviation Organization (ICAO) database. The cruise emissions have been taken from CORINAIR data (which are themselves developed from the same original ICAO dataset).

Table 3.20 Average Non-CO_2 Emission Factors for Civil and Military Aviation - 2012

	Fuel	Units	CH_4	N_2O	NO_x	CO	NMVOC
Civil aviation							
Domestic LTO	AS	kt/Mt	0.76	0.10	4.48	60.86	6.20
Domestic Cruise	AS	kt/Mt	-	0.10	7.14	3.24	0.24
Domestic LTO	ATF	kt/Mt	0.17	0.10	12.66	8.61	1.61
Domestic Cruise	ATF	kt/Mt	-	0.10	14.24	2.42	0.50
International LTO	AS	kt/Mt	1.06	0.10	3.75	316.23	8.64
International Cruise	AS	kt/Mt	-	0.10	7.39	1.17	0.07
International LTO	ATF	kt/Mt	0.12	0.10	14.25	8.39	1.13
International Cruise	ATF	kt/Mt	-	0.10	14.11	1.16	0.52
Military aviation							
Military aviation	AS	kt/Mt	0.10	0.10	8.50	8.20	1.00
Military aviation	ATF	kt/Mt	0.10	0.10	8.50	8.20	1.00

AS – Aviation Spirit

ATF – Aviation Turbine Fuel

Use of all aviation spirit assigned to the LTO cycle

3.2.8.2.1.4 Method used to estimate emissions from the LTO cycle – civil aviation – domestic and international

The basic approach to estimating emissions from the LTO cycle is as follows. The contribution to aircraft exhaust emissions (in kg) arising from a given mode of aircraft operation (see list below) is given by the product of the duration (seconds) of the operation, the engine fuel flow rate at the appropriate thrust setting (kg fuel per second) and the emission factor for the pollutant of interest (kg pollutant per kg fuel).

The annual emissions total for each mode (kg per year) is obtained by summing contributions over all engines for all aircraft movements in the year. The time in each mode of operation for each type of airport and aircraft has been taken from individual airport studies. The time in mode is multiplied by an emission rate (the product of fuel flow rate and emission factor) at the appropriate engine thrust setting in order to estimate emissions for phase of the aircraft flight. The sum of the emissions from all the modes provides the total emissions for a particular aircraft journey. The modes considered are:

- Taxi-out;
- Hold;
- Take-off Roll (start of roll to wheels-off);
- Initial-climb (wheels-off to 450 m altitude);
- Climb-out (450 m to 1000 m altitude);
- Approach (from 1000 m altitude);
- Landing-roll;
- Taxi-in;
- APU use after arrival; and
- Auxiliary Power Unit (APU) use prior to departure.

Departure movements comprise the following LTO modes: taxi-out, hold, take-off roll, initial-climb, climb-out and APU use prior to departure.

Arrivals comprise: approach, landing-roll, taxi-in and APU use after arrival.

3.2.8.2.1.5 Method used to estimate emissions in the cruise – civil aviation – domestic and international

The approaches to estimating emissions in the cruise are summarised below. Cruise emissions are only calculated for aircraft departures from UK airports (emissions therefore associated with the departure airport), which gives a total fuel consumption compatible with recorded deliveries of aviation fuel to the UK. This procedure prevents double counting of emissions allocated to international aviation.

3.2.8.2.1.6 Estimating emissions of the indirect and non-greenhouse gases

The EMEP-EEA Emission Inventory Guidebook (EMEP-EEA, 1996) provides fuel consumption and emission factors for non-GHGs (NO_x, HC and CO) for a number of aircraft modes in the cruise. The data are given for a selection of generic aircraft type and for a number of standard flight distances.

The breakdown of the CAA movement by aircraft type contains a more detailed list of aircraft types than in the EMEP-EEA Emission Inventory Guidebook. Therefore, each specific aircraft type in the CAA data has been assigned to a generic type in the Guidebook. Details of this mapping are given in Watterson *et al*. (2004).

A linear regression has been applied to these data to give emissions (and fuel consumption) as a function of distance:

$$E_{Cruise_{d,g,p}} = m_{g,p} \times d + c_{g,p}$$

Where:

$E_{Cruise_{d,g,p}}$	is the emissions in cruise of pollutant p for generic aircraft type g and flight distance d (kg)
d	is the flight distance
g	is the generic aircraft type
p	is the pollutant (or fuel consumption)
$m_{g,p}$	is the slope of regression for generic aircraft type g and pollutant p (kg / km)
$c_{g,p}$	is the intercept of regression for generic aircraft type g and pollutant p (kg)

Emissions of SO_2 and metals are derived from estimates of fuels consumed in the cruise (see equation above) multiplied by the sulphur and metals contents of the aviation fuels for a given year.

3.2.8.2.1.7 Estimating emissions of the direct greenhouse gases

Estimates of CO_2 were derived from estimates of fuel consumed in the cruise (see equation above) and the carbon contents of the aviation fuels.

Methane emissions are believed to be negligible at cruise altitudes, and the emission factors listed in EMEP-EEA guidance are zero (EMEP-EEA, 1996); we have also assumed them to be zero. This was the assumption in the previous aviation calculation method also.

Estimates of N_2O have been derived from an emission factor recommended by the IPCC (IPCC, 1997) and the estimates of fuel consumed in the cruise (see equation above).

3.2.8.2.1.8 Overview of method to estimate emission from military aviation

LTO data are not available for military aircraft movements, so a simple approach is used to estimate emissions from military aviation. A first estimate of military emissions is made using military fuel consumption data and IPCC (1997) and EMEP-EEA (1999) cruise defaults shown in Table 1 of EMEP-EEA (1999) (see **Table 3.20)**. The EMEP-EEA (1999) factors used are appropriate for military aircraft. The military fuel data include fuel consumption by all military services in the UK. It also includes fuel shipped to overseas garrisons, casual uplift at civilian airports.

Emissions from military aircraft are reported under IPCC category 1A5 Other.

3.2.8.2.1.9 Fuel reconciliation

The estimates of aviation fuels consumed in the commodity balance table in the DECC publication DUKES are the national statistics on fuel consumption, and IPCC guidance states that national total emissions must be on the basis of fuel sales. Therefore, the estimates of emissions have been re-normalised based on the results of the comparison between the fuel consumption data in DUKES and the estimate of fuel consumed produced from the civil aviation emissions model, having first scaled up the emissions and fuel consumption to account for air-taxi and non-ATMs. The scaling is done separately for each airport to reflect the different fractions of air-taxi and non-ATMs at each airport and the different impacts on domestic and international emissions. The aviation fuel consumptions presented in DECC DUKES include the use of both civil and military fuel, and the military fuel use must be subtracted from the DUKES total to provide an estimate of the civil aviation consumption.

This estimate of civil aviation fuel consumption has been used in the fuel reconciliation. Emissions from flights originating from the overseas territories have been excluded from the fuel reconciliation process as the fuel associated with these flights is not included in DUKES. Emissions will be re-normalised each time the aircraft movement data are modified or data for another year added.

3.2.8.2.2 Road transport (1A3b)

The following is a summary of the methods used to develop the inventory for road transport and recalculations and methodological changes made in the 2014 submission of the inventory:

Summary of Methodology

A Tier 3 methodology is used for calculating exhaust emissions from passenger cars (1A3bi), light goods vehicles (1A3bii), and heavy duty vehicles including buses and coaches (1A3biii) and motorcycles (1A3biv). A Tier 2 methodology is used for calculating evaporative emissions (1A3bv) from petrol vehicles.

3.2.8.2.2.1 Summary of emission factors

There are a number of sources: COPERT 4, EMEP/EEA Emission Inventory Guidebook and UK specific emission factors as developed by Transport Research Laboratory (TRL) on behalf of the UK Department for Transport (DfT).

3.2.8.2.2.2 Summary of activity data

Traffic activity data in billion vehicle km by vehicle type are provided by DfT and total fuel sales for petrol and diesel are provided in the Digest of UK Energy Statistics (DUKES). Vehicle licensing statistics and on-road Automatic Number Plate Recognition data provided by DfT are used to further break down the vehicle km travelled by fuel type and vehicle year of first registration.

Details of methodology

Emissions of CO_2, CH_4, N_2O and SO_2 are calculated based on fuel sold. Emissions of other indirect GHGs and air pollutants are calculated on the basis of traffic activity. This is a significant methodological change in the estimation of CH_4 and N_2O emissions from previous inventory submissions, where these emissions were calculated on the basis of traffic data and were not normalised to fuel sold. This methodological change is in response to feedback from the UNFCCC Expert Review Team, who scrutinised the UK's inventory during 2013. The method for CH_4 and N_2O involved using traffic data and g/km emission factors to calculate implied fuel-based emission factors for individual vehicle types and combining these with normalised fuel consumption calculated for each vehicle type. Further details of this approach are provided later in this section on traffic-based emission estimations.

Fuel consumption by road transport

Data on petrol and diesel fuels consumed by road transport in the UK are taken from the Digest of UK Energy Statistics (DUKES) published by DECC and corrected for consumption by off-road vehicles and the very small amount of fuel consumed by the Crown Dependencies included in DUKES (emissions from the Crown Dependencies are calculated elsewhere). The figures on petrol and diesel consumption in DUKES were revised slightly in DUKES for the years 2005-2007. In particular, diesel consumption for 2007 is 1.8% higher than the previous years' figures for 2007.

In 2012, 13.23 Mtonnes of petrol and 21.54 Mtonnes of diesel fuel (DERV) were consumed in the UK. Petrol consumption has gone down while diesel consumption has increased as compared with 2011. It was estimated that of this, around 2.8% of petrol was consumed by inlands waterways and off-road vehicles and machinery and 0.5% used in the Crown Dependencies, leaving 12.80 Mtonnes of petrol consumed by road vehicles in the UK in 2012. Around 1.7% of road diesel is estimated to be used by inland waterways and off-road vehicles and machinery (the bulk of these use gas oil), and 0.2% used in the Crown Dependencies, leaving 21.13 Mtonnes of diesel consumed by road vehicles in the UK in 2012.

According to figures in DUKES (DECC, 2013), 0.093 Mtonnes of LPG were used for transport in 2012, a reduction from 0.098 Mtonnes the previous year.

Since 2005, there has been a rapid growth in consumption of biofuels in the UK. These are not included in the totals presented above for petrol and diesel which according to DECC refer only to mineral-based fuels (fossil fuels). According to statistics in DUKES and from HMRC (2013), 0.62 Mtonnes bioethanol and 0.56 Mtonnes biodiesel were consumed in the UK in 2012. On a volume basis, this represents about 4.1% of all petrol and 2.4% of all diesel sold in the UK, respectively. This is an increase in bioethanol, but a decrease in biodiesel consumption compared with 2011. On an energy basis it is estimated that consumption of bioethanol and biodiesel displaced around 0.369 Mtonnes of mineral-based petrol (about 2.8% of total petrol that would have been consumed) and 0.490 Mtonnes of mineral-based diesel (about 2.3% of total diesel that would have been consumed), respectively. The CO_2 emissions arising from consumption of these biofuels are not included in the national totals, but emissions of other pollutants are included from biofuel consumption.

To distribute fuel consumption, hence emissions, between different vehicle types, a combination of data sources and approaches were used making best use of all available information in the UK. The Tier 3 method makes use of g/km fuel consumption and emission factors combined with detailed traffic and fleet composition data described later in this Section and applied in the same way for all pollutant emissions.

Factors for calculating fuel consumption for petrol and diesel vehicles

Equations relating fuel consumption to average vehicle speed are based on the relationships for detailed categories of vehicles compiled by TRL on behalf of DfT. The factors themselves are available at http://www.dft.gov.uk/publications/road-vehicle-emission-factors-2009/ together with appropriate documentation from TRL on how the emission factors were derived (see for example the report by Boulter et al. (2009) at http://assets.dft.gov.uk/publications/road-vehicle-emission-factors-2009/report-3.pdf). The TRL equations were derived from their large database of emission measurements compiled from different sources covering different vehicle types and drive cycles. The measurements were made on dynamometer test facilities under simulated real-world drive cycles.

For cars, LGVs and motorcycles, the speed-related fuel consumption factors in g fuel/km were used in combination with average speed, fleet composition and vehicle km data for different road types as described below. The fleet-average fuel consumption factors calculated for these vehicle types, grouped into their respective Euro emission standards, are shown in **Table 3.21** for average speeds on urban, rural and motorway roads. The different emission standards are described in a later section.

Table 3.21 Fuel Consumption Factors for Light Vehicles (in g fuel/km)

g fuel /km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	66.4	62.8	69.1
	Euro 1	61.4	57.9	64.1
	Euro 2	58.8	55.3	61.5
	Euro 3	55.0	51.4	57.6
	Euro 4	50.8	47.2	53.4
	Euro 5	44.7	41.2	47.4
Diesel cars	Pre-Euro 1	60.3	55.0	61.2
	Euro 1	58.5	53.2	59.4
	Euro 2	54.9	49.6	55.8
	Euro 3	50.2	44.9	51.1
	Euro 4	47.7	42.4	48.7
	Euro 5	42.0	36.7	42.9
Petrol LGVs	Pre-Euro 1	68.7	64.1	70.0
	Euro 1	63.6	59.0	64.8
	Euro 2	60.9	56.3	62.1
	Euro 3	57.1	52.5	58.3
	Euro 4	52.3	47.7	53.6
	Euro 5	46.9	42.2	48.2
Diesel LGV	Pre-Euro 1	61.9	68.4	91.9
	Euro 1	76.7	84.4	110.1
	Euro 2	71.5	77.5	106.0
	Euro 3	63.2	69.8	104.0
	Euro 4	63.2	69.8	104.0
	Euro 5	63.2	69.8	104.0
Mopeds, <50cc, 2st	Pre-Euro 1	25.5		
	Euro 1	15.3		
	Euro 2	12.3		
	Euro 3	10.7		
Motorcycles, >50cc, 2st	Pre-Euro 1	27.5	30.2	
	Euro 1	25.3	27.8	
	Euro 2	25.3	27.8	
	Euro 3	25.3	27.8	
Motorcycles, >50cc, 4st	Pre-Euro 1	35.3	35.1	53.9
	Euro 1	33.5	33.2	46.9
	Euro 2	31.6	31.9	49.3
	Euro 3	31.6	31.9	49.3

For HGVs, the DfT provide statistics from a survey of haulage companies on the average miles per gallon (mpg) fuel efficiency of different sizes of lorries (DfT, 2011a). A time-series of mpg figures from 1989 to 2010 is provided by the Road Freight Statistics and these can be converted to g fuel per kilometre fuel consumption factors. The figures will reflect the operations of haulage companies in the UK in terms of vehicle load factor and typical driving cycles, e.g. distances travelled at different speeds on urban, rural and motorway roads. The shape of the DfT/TRL speed-related functions based on test cycle measurements of more limited samples of vehicles are then used to define the variation, relative to the averaged value, in fuel consumption factor with speed and hence road type. Figures for 2011 and 2012 from Road Freight Statistics were not available so overall HGV fuel efficiencies for 2010 were carried over to these years.

Table 3.22 presents the fleet-averaged fuel consumption factors for rigid and articulated HGVs from 1990-2012 calculated for urban, rural and motorway conditions based on the road freight statistics published in DfT (2011a) up to 2010.

Table 3.22 Average fuel consumption factors for HGVs (in g fuel/km) in the fleet based on DfT's road freight statistics

g fuel/km	Rigid HGVs			Artic HGVs		
	Urban	Rural	Motorway	Urban	Rural	Motorway
1990	272.4	217.7	231.5	438.8	337.1	343.6
1995	263.3	212.2	225.9	395.5	304.6	310.5
2000	247.8	204.8	219.2	370.2	287.7	293.2
2005	250.7	205.0	217.4	360.9	279.7	285.2
2008	279.6	226.0	238.5	379.8	293.5	299.3
2009	281.8	228.0	240.8	381.1	294.3	300.1
2010	285.3	229.9	242.5	384.9	296.9	302.7
2011	284.7	229.2	241.6	384.4	296.0	301.8
2012	284.6	228.9	241.3	384.6	295.9	301.8

For buses and coaches, the principal data source used was figures from DfT on the Bus Service Operators Grant system (BSOG). This is an audited subsidy, directly linked to the fuel consumed on local bus services. From BSOG financial figures, DfT were able to calculate the costs and hence quantity of fuel (in litres) used for local bus services going back to 1996 and using additional bus km data were able to derive implied fuel consumption factors for local service buses (DfT, 2013a). DfT believe this provides a relatively robust estimation of fuel consumption on local bus services and would be based on a larger evidence base than the DfT/TRL speed-related functions which are derived from a relatively small sample of buses and coaches tested. The BSOG data also take into account of fuel consumption on local bus services that were carried out on dead mileage, i.e. mileage to and from the start and end of a bus route. In terms of trend, the BSOG data imply a continual increase in the average fuel consumption factor for local buses from 1996 to 2009/10 (i.e. a reduction in fuel efficiency), but a slight improvement since then.

The BSOG data were used to define the fuel consumption factor for buses in the inventory over an urban cycle. However, the BSOG data do not cover rural bus services and coaches. For these, an approach similar to that used for HGVs was adopted by utilising the research-based, speed-related fuel consumption factors given by DfT/TRL in combination with the BSOG data. Using a combination of fleet composition data for different sizes of buses, the DfT/TRL functions were used to define how the fuel efficiency of the average bus and coach in the UK fleet varied with average speed and road type and year. The differences relative to the fuel efficiency factor for the average bus over an urban cycle were derived for the average bus on a rural cycle and the average coach on motorways. The relative differences were then applied to the BSOG-based urban bus factor to develop a series of internally consistent trends in bus and coach fuel consumption factor on urban, rural and motorway roads.

The BSOG data are provided on a financial year basis, the most recent being for 2012/13. The financial year figures were used to represent the factors for the earlier calendar year. Hence, the 2012/13 figures were used for the 2012 calendar year.

Table 3.23 presents the fleet-averaged fuel consumption factor for buses and coaches from 1990-2012 for urban, rural and motorway conditions based on this method. A small (1%) revision has been made to the figures for 2006.

Table 3.23 Average fuel consumption factors for buses and coaches (in g fuel/km) in the fleet based on DfT's BSOG data.

g fuel/km	Urban	Rural	Motorway
1990	268.9	167.8	190.9
1995	260.8	163.3	187.0
2000	277.0	176.7	206.4
2005	322.7	207.1	244.3
2008	338.2	216.2	255.4
2009	340.8	217.5	257.2
2010	337.5	215.1	254.5
2011	336.8	214.4	253.8
2012	326.3	207.4	245.7

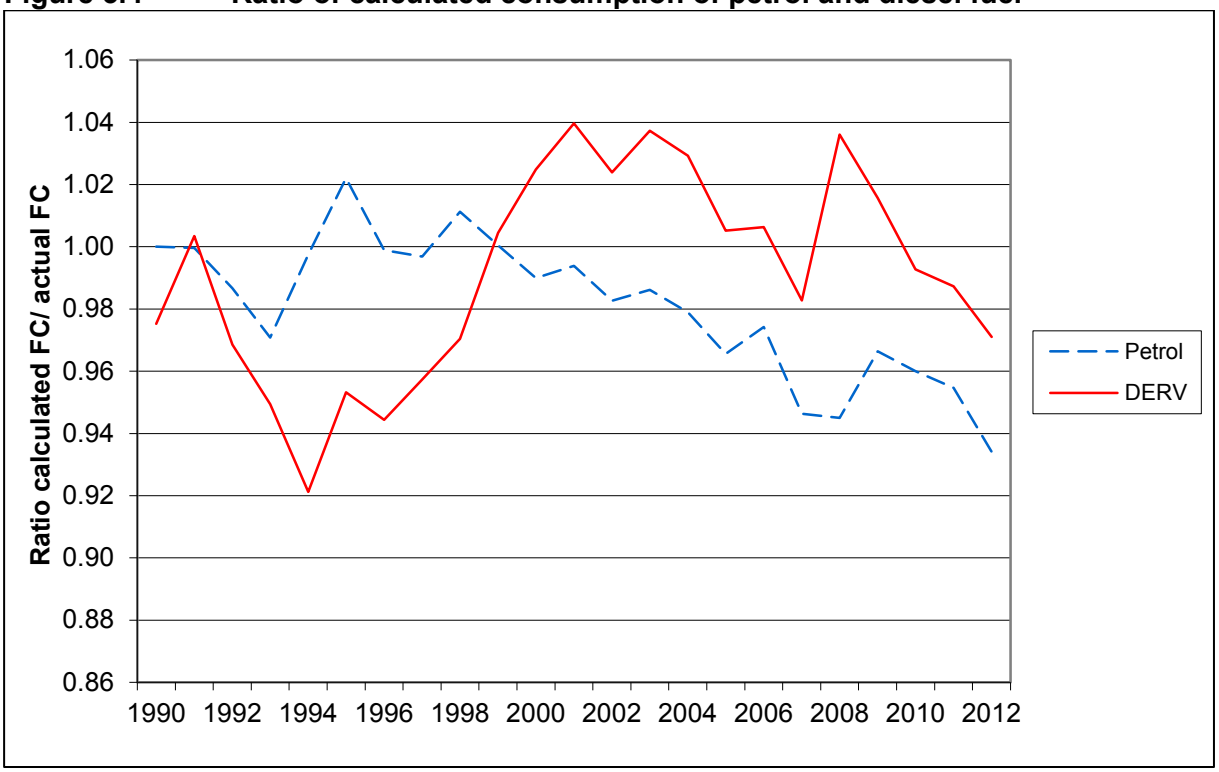
Fuel reconciliation and normalisation

A model is used to calculate total petrol and diesel consumption by combining these factors with relevant traffic data. The "bottom-up" calculated estimates of petrol and diesel consumption are then compared with DECC figures for total fuel consumption in the UK published in DUKES, adjusted for the small amount of consumption by inland waterways, off-road machinery and consumption in the Crown Dependencies.

The bottom-up estimated fuel consumption differs from the DUKES-based figures and so it is necessary to adjust the calculated estimates for individual vehicle types by using a normalisation process to ensure the total consumption of petrol and diesel equals the DUKES-based figures. This is to comply with the UNFCCC reporting system which requires emissions of CO_2 to be based on fuel sales.

Figure 3.4 shows the ratio of model calculated fuel consumption to the figures in DUKES based on total fuel sales of petrol and diesel in the UK, allowing for off-road consumption. For a valid comparison with DUKES, the amount of petrol and diesel displaced by biofuel consumption has been used to correct the calculated consumption of petrol and diesel. The ratio fluctuates just above and below the 1 line, but the difference is never higher than 8%. In 2012, the bottom-up method underestimates petrol and diesel consumption by 6.6% and 2.9% respectively. This is considered well within the uncertainty of the factors used to derive the bottom-up estimates.

Figure 3.4 Ratio of calculated consumption of petrol and diesel fuel



Note: Calculated petrol and diesel fuel consumption are based on traffic movement and fuel consumption factors summed for different vehicle types. DUKES figures for these fuels are based on fuel sales in the UK

The normalisation process introduces uncertainties into the fuel consumption estimates for individual vehicle classes even though the totals for road transport are known with high accuracy.

For petrol, the fuel consumption calculated for each vehicle type consuming petrol is scaled up or down by the same proportion to make the total petrol consumption align with DUKES. So for example, the fuel consumption estimated for petrol cars, LGVs and motorcycles are all increased by 6.6% to align with fuel sales in 2012. Cars consume the vast majority of this fuel, so the DUKES figures provide a relatively accurate description of the trends in fuel consumption by petrol cars. A small residual is consumed by petrol LGVs and motorcycles, so their estimates are susceptible to fairly high levels of uncertainty introduced by the normalisation process.

For diesel, a number of different vehicle classes (cars, LGVs, HGVs and buses) all consume similar amounts of fuel. Either the fuel consumption for all diesel vehicles can be scaled to align with DUKES, as carried out for petrol normalisation, or consumption for specific vehicle types can be adjusted to bring the total in line with DUKES. Because all vehicle types make a similar contribution to diesel consumption, adjusting the calculated figures for all vehicle types by scaling can lead to distorted trends in the figures for specific vehicle types over a time-series.

After discussions with officials at DfT, it was decided to retain the consumption for cars, LGVs and buses at the values calculated by the bottom-up approach and use HGVs to "carry the burden" of bringing the total diesel consumption in line with DUKES (DfT, 2009a). There were two main reasons for this. First, because HGVs are the largest overall consumer of diesel, this approach of correcting for the difference between calculated diesel consumption

and fuel sales figures from DUKES has a smaller effect on HGVs than other vehicle classes. A second reason is that a rationale can be given for HGVs leading to the overestimation of diesel consumption compared with sales since 1998 on the basis of "fuel tourism" effects. This is where vehicles consume fuel on UK roads that was purchased abroad. In this case, the fuel would not appear in the UK sales figures, but would be represented in consumption figures calculated from traffic movement data. Given the recent price differential between diesel sold in the UK and the rest of Europe and the amount of cross-border haulage operations, HGVs are believed to make a larger contribution to potential fuel tourism effects than any other class of vehicle. Furthermore, DfT were able to provide some data to back up this hypothesis. This included DfT estimates of the amount of fuel purchased abroad by UK vehicles and the kilometres travelled in the UK by foreign vehicles (DfT, 2009a). The 2009 figures suggested the total amount of fuel purchased abroad (and therefore not contributing to UK fuel sales in DUKES) by HGVs operating in the UK could be around 550 ktonnes compared with a gap of around 309 ktonnes in the estimate of total diesel consumption and the figures based on fuel sales in DUKES. This is at least consistent with a theory indicating HGV fuel tourism contributing to the gap and partial justification for adjusting the bottom-up estimated diesel consumption for HGVs to bring the total diesel consumption in line with DUKES. However, it is important to recognise that other factors including modelling uncertainty will also be playing a factor. Also, the increasing tendency to underestimate petrol and diesel consumption by the bottom-up method in the most recent years (**Figure 3.4**) may indicate increasing differences between real-world fuel efficiencies of modern vehicles compared with the factors used in the inventory.

LPG consumption

Emissions from vehicles running on LPG are estimated on the basis of national figures (from DUKES) on the consumption of this fuel by road transport. The CO_2 emissions from LPG consumption cannot be broken down by vehicle type because there are no reliable figures available on the total number of vehicles or types of vehicles running on this fuel. This is unlike vehicles running on petrol and diesel where the DfT has statistics on the numbers and types of vehicles registered as running on these fuels. It is believed that many vehicles running on LPG are cars and vans converted by their owners and that these conversions are not necessarily reported to vehicle licensing agencies. Figures from DUKES suggest that the consumption of LPG is around 0.3% of the total amount of petrol and diesel consumed by road transport and vehicle licensing data suggest around 0.4% of all light duty vehicles run on LPG in 2012.

Natural gas consumption

The UK inventory does not currently estimate emissions from vehicles running on natural gas. The number of such vehicles in the UK is extremely small, with most believed to be running in captive fleets on a trial basis in a few areas. Estimates are not made as there are no separate figures from DECC on the amount of natural gas used by road transport, nor are there useable data on the total numbers and types of vehicles equipped to run on natural gas 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.

Fuel-based emission factors

Emissions of CO_2, expressed as kg carbon per tonne of fuel, are based on the carbon content (by mass) of the fuel; emissions of SO_2 are based on the sulphur content of the fuel. Values of the fuel-based emission factors for CO_2 and SO_2 from consumption of petrol and diesel fuels are shown in **Table 3.24** based on information provided by UKPIA. UKPIA are contacted each year to confirm carbon factors for petrol and diesel and have not provided

any reason for changing values provided from the 2005 review. Values for SO_2 vary annually as the sulphur-content of fuels change, and are shown in **Table 3.24** for 2012 fuels.

Table 3.24 Fuel-Based Emission Factors for Road Transport (kg/tonne fuel)

Fuel	C[a]	SO_2[b]
Petrol	855	0.011
Diesel	863	0.015

a Emission factor in kg carbon/tonne, based on UKPIA (2005)

b 2012 emission factor calculated from UKPIA (2013b) – figures on the weighted average sulphur-content of fuels delivered in the UK in 2012

Emissions from LPG consumption are calculated from carbon factors for LPG fuel.

Implied emission factors for CH_4 and N_2O

Implied emission factors for CH_4 and N_2O are strongly influenced by the composition of the vehicle fleet which changes each year and the g/km factors for the different vehicle types, traffic activities and technologies used in the Tier 3 'bottom-up' calculation of emissions described later in this section. Implied emission factors for total petrol and diesel consumption for road transport activities in 2012 expressed in kg/TJ are shown in **Table 3.25**.

Table 3.25 Implied emission factors for CH_4 and N_2O from road transport in 2012.

kg/TJ	CH_4	N_2O
Petrol	3.06	1.00
Diesel	0.87	2.54

Time-series trends in the implied emission factors will be described later in this section following a description of the Tier 3 method used to estimate emissions from the vehicle activity data and g/km emission factors.

Emissions from LPG consumption are calculated from traffic-based emission factors for CH_4 and N_2O as described in following sections.

Traffic-based emission calculations: an overview

Emissions of the pollutants CH_4, N_2O, NMVOCs, NO_x, CO and other air pollutants from individual vehicle types are calculated from measured emission factors expressed in g/km and road traffic statistics from the Department for Transport. The emission factors are based on experimental measurements of emissions from in-service vehicles of different types driven under test cycles with different average speeds. The road traffic data used are vehicle kilometre estimates for the different vehicle types and different road classifications on the UK road network. These data have to be further broken down by composition of each vehicle fleet in terms of the fraction of diesel- and petrol-fuelled vehicles on the road and in terms of the fraction of vehicles on the road made to the different emission regulations which applied when the vehicle was first registered. These are related to the age profile of the vehicle fleet in each year.

Emissions from motor vehicles fall into several different categories, which are each calculated in a different manner. These are hot exhaust emissions, cold-start emissions and evaporative emissions of NMVOCs.

Hot exhaust emissions
Hot exhaust emissions are emissions from the vehicle exhaust when the engine has warmed up to its normal operating temperature. Emissions depend on the type of vehicle, the type of fuel, the driving style or traffic situation of the vehicle on a journey and the emission regulations which applied when the vehicle was first registered as this defines the type of technology the vehicle is equipped with that affects emissions.

For a particular vehicle, the driving style or traffic situation over a journey is the key factor that determines the amount of pollutant emitted over a given distance. Key parameters affecting emissions are the acceleration, deceleration, steady speed and idling characteristics of the journey, as well as other factors affecting load on the engine such as road gradient and vehicle weight. However, work has shown that for modelling vehicle emissions for an inventory covering a road network on a national scale, it is sufficient to calculate emissions from emission factors in g/km related to the average speed of the vehicle in the drive cycle (Zachariadis and Samaras, 1997). A similar conclusion was reached in the review of emission modelling methodology carried out by TRL on behalf of DfT (Barlow and Boulter, 2009, see http://assets.dft.gov.uk/publications/road-vehicle-emission-factors-2009/report-2.pdf). Emission factors for average speeds on the road network are then combined with the national road traffic data.

3.2.8.2.2.3 Vehicle and fuel type
Emissions are calculated for vehicles of the following types:

- Petrol cars;
- Diesel cars;
- Petrol Light Goods Vehicles (Gross Vehicle Weight (GVW) ≤ 3.5 tonnes);
- Diesel Light Goods Vehicles (Gross Vehicle Weight (GVW) ≤ 3.5 tonnes);
- Rigid-axle Heavy Goods Vehicles (GVW ≥ 3.5 tonnes);
- Articulated Heavy Goods Vehicles (GVW ≥ 3.5 tonnes);
- Buses and coaches; and
- Motorcycles.

Total emission rates (as well as fuel consumption) are calculated by multiplying emission factors in g/km with annual vehicle kilometre figures for each of these vehicle types on different types of roads. This procedure is followed to derive the initial bottom-up estimate of fuel consumption and implied fuel-based emission factors for CH_4 and N_2O by vehicle category before the normalisation to fuel sales is carried out.

3.2.8.2.2.4 Vehicle kilometres by road type
Hot exhaust emission factors are dependent on average vehicle speed and therefore the type of road the vehicle is travelling on. Average emission factors are combined with the number of vehicle kilometres travelled by each type of vehicle on rural roads and higher speed motorways/dual carriageways and many different types of urban roads with different average speeds. The emission results are combined to yield emissions on each of these main road types:

- Urban;
- Rural single carriageway; and
- Motorway/dual carriageway.

DfT estimates annual vehicle kilometres (vkm) for the road network in Great Britain by vehicle type on roads classified as trunk, principal and minor roads in built-up areas (urban) and non-built-up areas (rural) and motorways (DfT, 2013b). DfT provides a consistent time series of vehicle km data by vehicle and road types going back to 1993 for the 2012 inventory, taking into account any revisions to historic data. The vkm data are derived by DfT from analysis of national traffic census data involving automatic and manual traffic counts. Additional information discussed later was used to provide the breakdown in vkm for cars by fuel type.

Vehicle kilometre data for Northern Ireland by vehicle type and road class were provided by the Department for Regional Development (DRD), Northern Ireland, Road Services (DRDNI, 2013a). These provided a consistent time-series of vehicle km data for all years up to 2012. Data for 2011 has been revised slightly upward for buses and downward for LGVs and rigid HGVs. Motorcycle vehicle km data were not available from the DRDNI and so they were derived based on the ratio of motorcycles registered in Northern Ireland relative to the GB each year. The ratios were then applied to the motorcycle vehicle km activity data for the GB. Additional information is provided by DRDNI about the split between cars and LGVs and the petrol/diesel car split for cars and LGVs in the traffic flow based on further interrogation by DRDNI of licensing data (DRDNI, 2013b).

The Northern Ireland data have been combined with the DfT data for Great Britain to produce a time-series of total UK vehicle kilometres by vehicle and road type from 1970 to 2012 as shown in **Table 3.26**.

Table 3.26 UK vehicle km by road vehicles

Billion vkm		1990	1995	2000	2005	2010	2011	2012
Petrol cars	urban	142.2	137.9	135.1	119.9	99.5	96.7	93.4
	rural	141.1	134.1	134.2	127.3	109.1	105.0	100.0
	m-way	49.2	48.4	53.0	48.8	41.7	39.7	37.8
Diesel cars	urban	5.8	17.2	26.1	40.8	54.1	57.2	60.7
	rural	6.1	18.0	28.3	47.6	65.8	70.0	73.4
	m-way	2.8	8.5	14.6	25.1	33.5	36.6	39.2
Petrol LGVs	urban	11.1	7.5	4.2	1.9	1.3	1.2	1.1
	rural	11.4	8.3	5.0	2.3	1.6	1.5	1.4
	m-way	3.9	3.2	2.0	0.9	0.6	0.6	0.6
Diesel LGVs	urban	5.7	10.2	15.5	21.2	22.6	23.0	22.9
	rural	6.1	11.5	18.8	26.0	29.5	29.4	28.9
	m-way	2.0	4.4	7.4	10.5	11.4	11.9	12.5
Rigid HGVs	urban	4.5	3.7	3.9	4.0	3.2	3.1	3.0
	rural	7.1	6.8	7.2	7.5	6.6	6.3	6.1
	m-way	3.7	3.7	4.2	4.2	4.1	3.8	3.5
Artic HGVs	urban	1.1	1.1	1.1	1.0	0.8	0.8	0.8
	rural	4.3	4.7	5.1	5.3	5.0	5.0	4.9
	m-way	4.7	6.0	7.4	7.9	7.5	7.5	7.6

Billion vkm		1990	1995	2000	2005	2010	2011	2012
Buses	urban	2.4	2.9	3.0	3.2	3.1	2.9	2.7
	rural	1.7	1.5	1.7	1.5	1.6	1.4	1.3
	m-way	0.6	0.5	0.5	0.5	0.5	0.4	0.4
M/cycle	urban	3.3	1.9	2.3	2.9	2.5	2.4	2.3
	rural	2.0	1.6	2.0	2.2	1.8	2.0	2.0
	m-way	0.3	0.3	0.4	0.4	0.4	0.4	0.4
Total		**423.4**	**443.9**	**483.0**	**513.0**	**507.9**	**508.8**	**506.9**

3.2.8.2.2.5 Vehicle speeds by road type

Vehicle speed data are used to calculate emission factors from the emission factor-speed relationships available for different pollutants. Average speed data for traffic in a number of different areas were taken from the following main sources: Transport Statistics Great Britain (DfT, 2009b) provided averages of speeds in Central, Inner and Outer London surveyed at different times of day during 1990 to 2008. Speeds data from other DfT's publications such as 'Road Statistics 2006: Traffic, Speeds and Congestion' (DfT, 2007a) and 2008 national road traffic and speed forecasts (DfT, 2008a) were used to define speeds in other urban areas, rural roads and motorways. Where new information is not available, previous NAEI assumptions were maintained or road speed limits used for the vehicles expected to observe these on the type of road concerned. **Table 3.27** shows the speeds used in the inventory for light duty vehicles, HGVs and buses. DfT confirmed these data were still valid for 2012.

Table 3.27 Average Traffic Speeds in Great Britain

		Lights kph	Heavies kph	Buses kph
URBAN ROADS				
Central London	Major principal roads	16	16	16
	Major trunk roads	24	24	16
	Minor roads	16	16	16
Inner London	Major principal roads	21	21	24
	Major trunk roads	32	32	24
	Minor roads	20	20	20
Outer London	Major principal roads	31	31	32
	Major trunk roads	46	46	32
	Minor roads	29	29	29
	Motorways	108	87	87
Connurbation	Major principal roads	31	31	24
	Major trunk roads	38	37	24
	Minor roads	30	30	20
	Motorways	97	82	82
Urban	Major principal roads	36	36	32
	Major trunk roads	53	52	32
	Minor roads	35	34	29
	Motorways	97	82	82
RURAL ROADS				
Rural single carriageway	Major roads	77	72	71
	Minor roads	61	62	62
Rural dual carriageway		111	90	93
Rural motorway		113	90	95

3.2.8.2.2.6 Vehicle fleet composition: by age, size, technology and fuel type

Vehicle kilometre data based on traffic surveys do not distinguish between the type of fuels the vehicles are being run on (petrol and diesel) nor on their age. Prior to the 2010 inventory, the petrol car/diesel car mix on different road types was defined by the DfT Vehicle Licensing Statistics and data on the relative mileage done by petrol and diesel cars (DfT, 2008b, pers comm). The latter information, as originated from the National Travel Survey (DfT, 2007b), indicated that diesel cars do on average 60% more annual mileage than petrol cars. It was assumed that the additional mileage done by diesel cars is mainly done on motorways and rural roads. On this basis, it was previously assumed that the petrol car/diesel car mix on urban roads was to be indicated by the population mix according to vehicle licensing data (i.e. that there is no preferential use of diesel or petrol cars on urban roads) and the mix on rural and motorways adjusted to give an overall mileage pattern over all roads in the UK that leads to an average 60% higher annual mileage by diesel cars compared with petrol cars.

Since then, the inventory has made use of the Automatic Number Plate Recognition (ANPR) data provided by DfT (2012a, pers comm) for defining the UK's vehicle fleet composition on the road. The ANPR data has been collected annually (since 2007) at over 256 sites in the UK on different road types (urban and rural major/minor roads, and motorways) and regions.

Measurements are made at each site on one weekday (8am-2pm and 3pm-9pm) and one half weekend day (either 8am-2pm or 3pm-9pm) each year in June and are currently available for years 2007 to 2011. There are approximately 1.4-1.7 million observations recorded from all the sites each year, and they cover various vehicle and road characteristics such as fuel type, age of vehicle (which can be associated with its Euro standard), engine sizes, vehicle weight and road types.

Following a series of analysis and discussions with officials from DECC, Defra and DfT, it was concluded that the ANPR data should be best used to define the fleet composition on different road types for the whole of Great Britain (GB) while combining DA-country specific vehicle licensing data (hereafter referred as DVLA data) to define regional variation (DfT, 2010a). The ANPR data are used in two aspects to define:

- Petrol and diesel mix in the car fleet on different road types (urban, rural and motorway).
- Variations in age and Euro standard mix on different road types

As the ANPR data are only available between 2007 and 2011, it was necessary to estimate the road-type variations in the fleet for years before the ANPR became available otherwise a step-change would be introduced in the emission time-series. For the petrol/diesel mix of the GB car fleet as a whole, this was done by extrapolating the 2007 ANPR data back to 1990 based on the rate of change in the proportion of diesel vehicles as indicated by the DfT Vehicle Licensing Statistics. The result was then further adjusted by the DVLA data to define the variation of the petrol/diesel mix by the DA regions. The ANPR data confirmed that there is a preferential use of diesel cars on motorways, as was previously assumed in the inventory, but that preferential usage of diesel cars also extended to urban roads as well, although not to the extent as seen on motorways. For Northern Ireland, there were only two years of ANPR data (2010 and 2011) with reasonable number of observations being recorded. However, they did not show consistent trend or major difference in the proportion of diesel cars observed on different road types, and that the proportion was similar to that implied by the licensing data; as a result, it is assumed that there is no preferential use of diesel cars, and the petrol/diesel mix in car km should follow the proportion as indicated by the licensing statistics provided by DRDNI. This leads to the vehicle km data for petrol and diesel cars on different road types in the UK shown in **Table 3.26**.

The age of a vehicle determines the type of emission regulation that applied when it was first registered. These have successively entailed the introduction of tighter emission control technologies, for example three-way catalysts and better fuel injection and engine management systems.

Table 3.28 shows the regulations that have come into force up to 2012 for each vehicle type. The date into service is taken to be roughly the mid-point of the Directive's implementation dates for Type-Approval and New Registrations.

Table 3.28 Vehicles types and regulation classes

Vehicle Type	Fuel	Regulation	Approx. date into service in UK
Cars	Petrol	Pre-Euro 1	
		91/441/EEC (Euro 1)	1/7/1992
		94/12/EC (Euro 2)	1/1/1997
		98/69/EC (Euro 3)	1/1/2001
		98/69/EC (Euro 4)	1/1/2006
		EC 715/2007 (Euro 5)	1/7/2010
	Diesel	Pre-Euro 1	
		91/441/EEC (Euro 1)	1/1/1993
		94/12/EC (Euro 2)	1/1/1997
		98/69/EC (Euro 3)	1/1/2001
		98/69/EC (Euro 4)	1/1/2006
		EC 715/2007 (Euro 5)	1/7/2010
LGVs	Petrol	Pre-Euro 1	
		93/59/EEC (Euro 1)	1/7/1994
		96/69/EEC (Euro 2)	1/7/1997
		98/69/EC (Euro 3)	1/1/2001 (<1.3t) 1/1/2002 (>1.3t)
		98/69/EC (Euro 4)	1/1/2006
		EC 715/2007 (Euro 5)	1/7/2011
	Diesel	Pre-Euro 1	
		93/59/EEC (Euro 1)	1/7/1994
		96/69/EEC (Euro 2)	1/7/1997
		98/69/EC (Euro 3)	1/1/2001 (<1.3t) 1/1/2002 (>1.3t)
		98/69/EC (Euro 4)	1/1/2006
		EC 715/2007 (Euro 5)	1/7/2011
HGVs and buses	Diesel (All types)	Pre-1988	
		88/77/EEC (Pre-Euro I)	1/10/1988
		91/542/EEC (Euro I)	1/10/1993
		91/542/EEC (Euro II)	1/10/1996
		99/96/EC (Euro III)	1/10/2001
		99/96/EC (Euro IV)	1/10/2006
		99/96/EC (Euro V)	1/10/2008
Motorcycles	Petrol	Pre-2000: < 50cc, >50cc (2 st, 4st)	
		97/24/EC: all sizes (Euro 1)	1/1/2000
		2002/51/EC (Euro 2)	1/7/2004
		2002/51/EC (Euro 3)	1/1/2007

In previous years, the inventory was developed using licensing data to define the age mix of the national fleet and data from travel surveys that showed how annual mileage changes with vehicle age. This was used to split the vehicle km figures by age and Euro classification. The new ANPR data provided direct evidence on the age mix of vehicles on the road and how this varied on different road types and thus obviated the need to rely on licensing data and assumptions about changing mileage with age. The information tended to show that the diesel car, LGV and HGV fleet observed on the road was rather newer than inferred from the licensing records and mileage surveys. However, this information was only available for 2007-2011 and it was important to consider how the trends observed in these limited years of ANPR data availability could be rolled back to earlier years. This was done by developing a pollutant and vehicle specific factor for each road type reflecting the relative difference in the fleet mix on each road type defined by the ANPR data compared with the GB average between 2007 and 2011 and its impact on emissions. This factor is extrapolated to a value of 1 in 1990 because in this year all vehicles meet pre-Euro 1 standard, and hence differences in the age of the fleet on different road types or DA countries have no effect on emissions. This factor is then combined with a DA-specific “driver” derived from trends in licensing data to account for the relative differences in the fleet in each DA country compared

with the GB average. An overall year-, vehicle-, road-, DA- and pollutant-specific factor is then applied to GB average emission factors calculated in the fleet model.

As no ANPR data were available for 2012, the trends observed for 2011 marking the relative difference between the ANPR observations of vehicles on the road and the vehicle fleet according to registrations was applied to the registrations data for 2012. This ensured a smooth trend in the on-road fleet developed on a consistent basis across the time series up to 2012.

It should be noted that the application of the ANPR and DVLA data is dependent on the vehicle, pollutant and region combination. For instance, when calculating fuel consumption and CO_2 emissions, data on the average mpg fuel efficiency of different sizes of lorries from the Road Freight Statistics and the BSOG data for buses take precedence over the ANPR data, and they are continued to be used to define the fuel consumption/ CO_2 emissions for HGVs and buses respectively, without any adjustment to account for variations in the age of the HGV or bus fleets. For other pollutants where the mpg data from Road Freight Statistics are not used in the calculations of HGV emissions, the ANPR data are utilised. The ANPR or DVLA data have not been analysed or applied to the calculation of other pollutant emissions from buses/coaches, as there are likely to be variations in local bus fleets according to local authority measures to address air quality concerns that will not be reflected by licensing information alone, while coaches spend less time in the areas where they are registered. Similarly, neither the ANPR nor DVLA data have been analysed for motorcycles due to lack of data and their relative small contribution to the overall UK fleet.

The DfT/TRL emission factors cover three engine size ranges for cars: <1400cc, 1400-2000cc and >2000cc. The vehicle licensing statistics have shown that there has been a growing trend in the sales of bigger and smaller engine-sized cars in recent years, in particular for diesel cars at the expense of medium-sized cars. The inventory uses the proportion of cars by engine size varying each year from 2000 onwards based on the vehicle licensing data (DfT, 2013c). In addition, the relative mileage done by different size of vehicles was factored into the ratios; this is to take account of the fact that larger cars do more annual mileage than smaller cars (DfT, 2008b).

To utilise the DfT/TRL emission factors, additional investigation had to be made in terms of the vehicle sizes in the fleet as the emission factors cover three different weight classes of LGVs, eight different size classes of rigid HGVs, five different weight classes of artic HGVs, five different weight classes of buses and coaches and seven different engine types (2-stroke and 4-stroke) and size classes of mopeds and motorcycles. Information on the size fractions of these different vehicle types was obtained from vehicle licensing statistics and used to break down the vehicle km data. Some data were not available and assumptions were necessary in the case of buses, coaches and motorcycles.

DfT Road Freight Statistics (DfT, 2011a) provided a time series of vehicle km (2000-2010) travelled by different HGV weight classes based on the Continuing Survey of Road Goods Transport (CSRGT). The data show that there has been a gradual reduction in traffic activity for the rigid HGVs below 17 tonnes, while there has been an increase in traffic activity for rigid HGVs over 17 tonnes over the period 2000 to 2010. For artic HGVs, the dominant group continues to be those over 33 tonnes, and traffic activity from the below 33 tonnes category have been decreasing over time. This information has been used to allocate HGV vehicle km between different weight classes, although further assumption has to be made as the inventory uses a more detailed breakdown of weight classes than those defined in the Road Freight Statistics.

Only limited information on the sizes of buses and coaches by weight exists; based on analysis of local bus operator information, it was assumed that 72% of all bus and coach km on urban and rural roads are done by buses, the remaining 28% by coaches, while on motorways all the bus and coach km are actually done by coaches.

Assumptions on the split in vehicle km for buses outside London by vehicle weight class are based on licensing information and correlations between vehicle weight class and number of seats and whether it is single- or double-decker. It is assumed that 31% of buses are <15t and the remaining are 15-18t. For London buses, the split is defined by the fleet composition provided by Transport for London (TfL, 2012).

For motorcycle, the whole time series of vkm for 2-stroke and 4-stroke motorcycles by different engine sizes are based on a detailed review of motorcycle sales, population and lifetime by engine size. It was also assumed that mopeds (<50cc) operate only in urban areas, while the only motorcycles on motorways are the type more than 750cc, 4-stroke. Otherwise, the number of vehicle kilometres driven on each road type was disaggregated by motorcycle type according to the proportions estimated to be in the fleet. Research on the motorcycle fleet indicated that 2-stroke motorcycles are confined to the <150cc class.

3.2.8.2.2.7 Assumptions made about the proportion of failing catalysts in the petrol car fleet

A sensitive parameter in the emission calculations for petrol cars is the assumption made about the proportion of the fleet with catalyst systems that have failed, for example due to mechanical damage or failure of the lambda sensor. Following discussions with DfT, it is assumed that the failure rate is 5% per annum for all Euro standards and that up to 2008; only 20% of failed catalysts were rectified properly, but those that were rectified were done so within a year of failing. The revisions are based on evidence on fitting of replacement catalysts. According to DfT there is evidence that a high proportion of replacement catalysts were not Type Approved and do not restore the emission performance of the vehicle to its original level (DfT 2009c). This is being addressed through the Regulations Controlling Sale and Installation of Replacement Catalytic Converters and Particle Filters for Light Vehicles for Euro 3 (or above) LDVs after June 2009. Therefore a change in the repair rate is taken into account for Euro 3 and above petrol LDVs from mid-2009 assuming all failed vehicles are rectified properly.

3.2.8.2.2.8 Voluntary measures and retrofits to reduce emissions

The inventory takes account of the early introduction of certain emission standards and additional voluntary measures to reduce emissions from road vehicles in the UK fleet. The Euro 3 emission standards for passenger cars (98/69/EC) came into effect from January 2001 (new registrations). However, some makes of cars sold in the UK already met the Euro 3 standards prior to this (DfT, 2001). Figures from the Society of Motor Manufacturers and Traders suggested that 3.7% of new cars sold in 1998 met Euro 3 standards (SMMT, 1999). Figures were not available for 1999 and 2000, but it was assumed that 5% of new car sales met Euro 3 standards in 1999 increasing to 10% and 100% in 2000 and 2001 respectively.

Euro 4 cars are assumed to be introduced from year 2006 onwards as set by the Directive. This is in light of the study by King's College and AEA (Carslaw et al., 2011) on the basis of ANPR data and manufacturers' information.

Freight haulage operators have used incentives to upgrade the engines in their HGVs or retrofit them with particle traps. DETR estimated that around 4,000 HGVs and buses were

retrofitted with particulate traps in 2000, and this would rise to 14,000 vehicles by the end of 2005 (DETR, 2000). This was accounted for in the inventory for its effects on NO_x, CO and NMVOCs emissions.

3.2.8.2.2.9 Emissions from HGVs, buses, LGVs and black cabs (taxis) in London

The inventory pays particular attention to the unique features of the HGV and bus fleets in London. This is primarily so as to be able to account for measures taken to reduce emissions and improve air quality in London, but the measures can have an indirect effect on greenhouse gas emissions.

The effect of the Low Emission Zone (LEZ) on emissions from HGVs and buses from 2008 is taken into account by using a different Euro standard mix for HGVs within the LEZ area. To be compliant, vehicles must meet Euro III standards or above from 2008, but this is only in respect of PM emissions. With respect to other pollutant emissions, the London fleet of HGVs and buses (except TfL's buses) are assumed to be the same as the national fleet.

The specific features of the fleet of buses operated by Transport for London (TfL) in London were taken into account. Information from TfL on the Euro standard mix of their fleet of buses was used and was updated in the 2012 inventory. Based on information from DfT, it is assumed that approximately 78-87% of all bus km in London are done by TfL buses, the remainder being done by non-TfL buses having the composition of the national bus fleet, except from 2008 onwards where the fleet is modified to be compliant with the LEZ.

Information from TfL was also used to disaggregate the car vkm data between passenger cars and black cab taxis. This was important to take into account the high share of diesel powered light duty vehicles in areas of inner and central London where black cabs make up a high proportion of the traffic flow and the consequences this has on emissions. Emission factors for London black cabs were assumed to be the same as a diesel LGVs.

3.2.8.2.2.10 Fuel quality

In January 2000, European Council Directive 98/70/EC came into effect relating to the quality of petrol and diesel fuels. This introduced tighter standards on a number of fuel properties affecting emissions. The principal changes in UK market fuels were the sulphur content and density of diesel and the sulphur and benzene content of petrol. The volatility of summer blends of petrol was also reduced, affecting evaporative losses. During 2000-2004, virtually all the diesel sold in the UK was of ultra-low sulphur grade (<50 ppmS), even though this low level sulphur content was not required by the Directive until 2005. Similarly, ultra-low sulphur petrol (ULSP) became on-line in filling stations in 2000, with around one-third of sales being of ULSP quality during 2000, the remainder being of the quality specified by the Directive. In 2001-2004, virtually all unleaded petrol sold was of ULSP grade (UKPIA, 2004). These factors and their effect on emissions were taken into account in the inventory. It is assumed that prior to 2000, only buses had made a significant switch to ULSD, as this fuel was not widely available in UK filling stations.

The introduction of road fuels with sulphur content less than 10ppm from January 2009 is taken into account according to Directive 2009/30/EC.

3.2.8.2.2.11 Vehicle specific hot exhaust emission factors in g/km for N_2O and CH_4

The emission factors for N_2O for all vehicle types in g/km are based on the recommendation of the Emissions Inventory Guidebook (EMEP, 2010) derived from the COPERT 4 methodology "*Computer Programme to Calculate Emissions from Road Transport*". The

DfT/TRL review recommended these emission factors continue to be used for the UK inventory.

For N_2O emissions from petrol cars and LGVs, emission factors are provided for different Euro standards and driving conditions (urban, rural, highway) with adjustment factors that take into account the vehicle's accumulated mileage and the fuel sulphur content; both of these tend to increase emission factors. For diesel cars and LGVs, bulk emission factors are provided for different Euro standards and road types, with no fuel and mileage effects. The factors for motorcycles make no distinction between different Euro standards and road types. In the latest version of Emissions Inventory Guidebook (EMEP, 2010), the factors for HGVs and buses are provided for different Euro standards, weight classes and driving conditions.

Table 3.34 summarises the N_2O emission factor for all vehicle types and road conditions in mg/km; the factors for petrol cars and LGVs are shown for zero accumulated mileage, but the inventory takes account of the increase in emissions with mileage. For the latest Euro 3 and 4 cars, emission factors in urban areas increase by around 15% over 50,000km, while for rural and motorway conditions, emission factors increase by as much as 38% over this distance, though starting from a smaller base. The age-mileage functions provided by TRL are used to work out the accumulated mileage effects in the calculation of N_2O emission factors

Nitrous oxide emissions were a problem with early generation petrol cars fitted with three-way catalysts, being formed as a by-product on the catalyst surface during the NO_x reduction process. Emission factors have been declining with successive Euro standards since the first generation of catalysts for Euro 1, presumably due to better catalyst formulations as well as reductions in fuel sulphur content.

Road transport is a relatively unimportant emitter of CH_4, being only produced as a consequence of incomplete combustion, but largely controlled by catalysts on petrol vehicles. Emission factors are based on the speed-emission functions and road type factors from the 2009 DfT/TRL compilation. Full emission factor-speed relationships were available for cars and LGVs, whereas for HGVs, buses and motorcycles only single averaged factors for urban, rural and motorway roads were available.

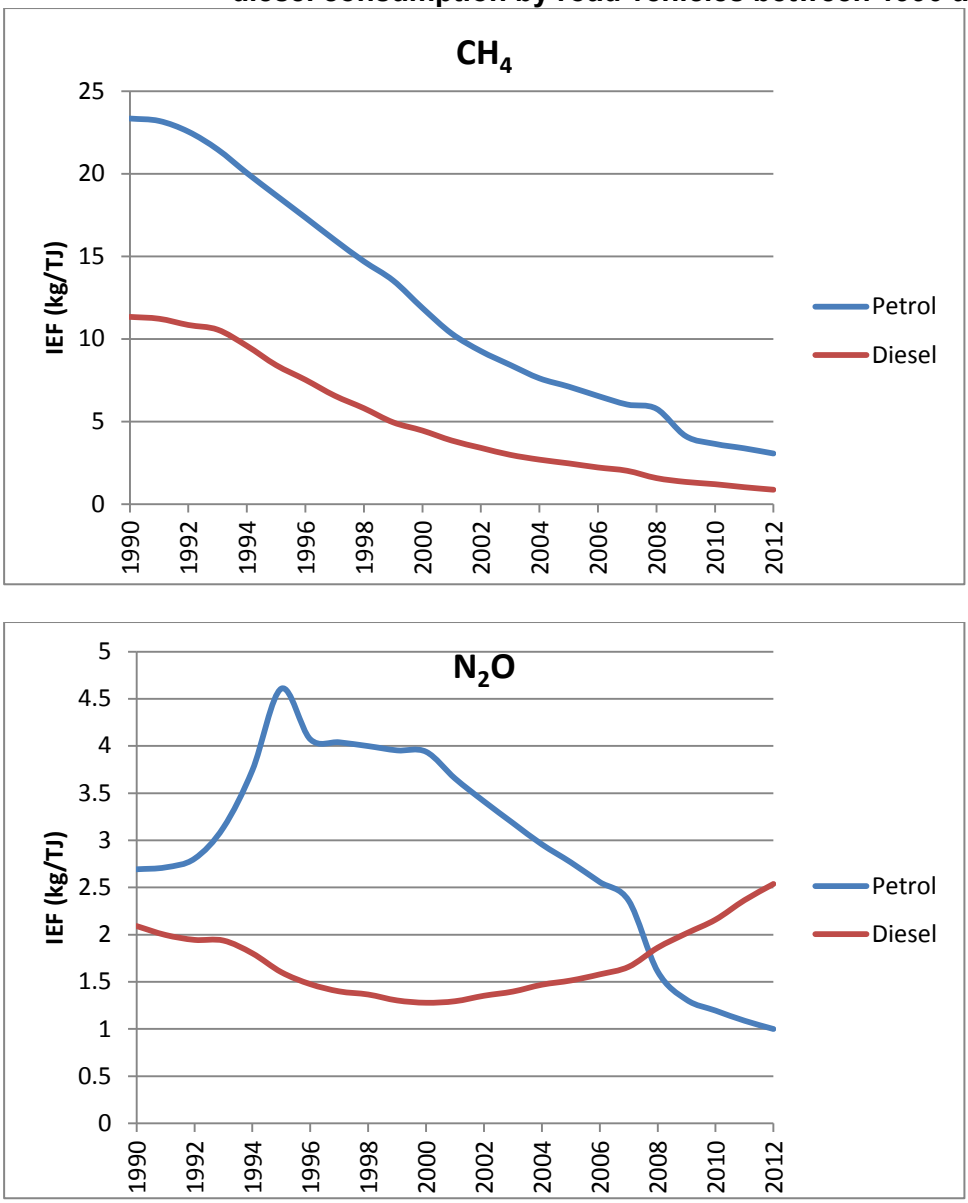
Table 3.35 summarises the CH_4 emission factor for all vehicle types and road conditions in mg/km.

3.2.8.2.2.12 Normalising N_2O and CH_4 emissions according to fuel sales and trends in implied emission factors

The Tier 3 traffic-based approach is used to calculate emissions and fuel consumption for each vehicle type. This allows the CH_4 and N_2O emissions to be normalised to fuel sales according to the method described earlier via the development of fuel-based implied emission factors for each vehicle category.

The time-series trends in implied emission factors for CH_4 and N_2O emissions from total petrol and diesel consumption for road transport activities are shown in **Figure 3.5** in kg/TJ. The time-series trend is a reflection of the evolution of the vehicle fleet over time and the different emission factors for different vehicle types and vintage.

Figure 3.5 Implied emission factors for CH_4 and N_2O emissions from petrol and diesel consumption by road vehicles between 1990 and 2012



The implied emission factors for CH_4 show a continuous downward trend. This is due to the fleet penetration of new vehicles meeting higher Euro standards. Although CH_4 emissions from vehicles are not regulated, the regulations and technologies used to limit total hydrocarbon emissions will also reduce CH_4 emissions. This is shown in **Table 3.35** where it can be seen how CH_4 emission for individual vehicle categories have been decreasing over the Euro standards.

The trends in implied emission factors (IEFs) for N_2O are more complex, but can be understood by reference to **Table 3.34**. For petrol, implied emission factors first increased in the 1990s with the introduction of Euro 1 cars and vans fitted with three-way catalysts to control pollutant emissions; this led to an unintended increase in N_2O emission factors. As mentioned earlier, emission factors have been declining with successive Euro standards since Euro 2 was introduced due to better catalyst and fuel formulations, with particularly marked improvements with the introduction of Euro 3 standards in 2000. This accelerated

the rate of decline in IEFs as these vehicles penetrated the fleet; the rate of decline was further enhanced with the introduction of lower sulphur fuels since 2005 and IEFs continue to decline as the fleet is further renewed and older, higher emitting Euro standards are removed from the fleet.

According to the Emissions Inventory Guidebook source of emission factors, factors for diesel light duty vehicles have been increasing with the introduction of successive Euro standards from pre-Euro 1 to Euro 3, but have stabilised since Euro 3 was introduced in 2000. For heavy duty diesel vehicles, emission factors first fell from pre-Euro I to Euro III standards, but have been further increasing since the introduction of Euro IV in 2005. This may be due to the introduction of Selective Catalytic Reduction (SCR) technology for controlling NO_x emissions from these vehicles, with increased N_2O emissions being an unintended consequence of the technology under real-world conditions.

The combined effect of increased penetration of higher Euro standards for diesel light and heavy duty vehicles since 2000 with higher emission factors explains the increase in IEFs for N_2O emissions from diesel consumption.

The uncertainties in the CH_4 and N_2O factors can be expected to be quite large. However, the relative differences between emission factors used for different technologies, Euro standards and fuels are likely to reflect realistic trends.

3.2.8.2.2.13 Emission factors for CH_4 and N_2O emissions from LPG consumption

Emissions of CH_4 and N_2O from consumption of LPG were calculated from vehicle km data and emission factors (expressed as g of pollutant per km) available from DfT/TRL covering all types of light duty vehicles (cars and LGVs). The problem was estimating the kilometres travelled by LPG vehicles. Consumption of LPG is relatively small in the UK (0.3% of all road fuels) and there are no reliable data on the number or types of vehicles running on LPG as some vehicles have been converted and conversions are not always logged with the vehicle licensing agency. It is estimated that around 0.4% of all light duty vehicles run on LPG in 2012. As information on the type of LPG vehicles travelling in the UK is not available, it has been assumed that all vehicles using LPG are LGVs and this assumption then allows the kilometres travelled by LPG LGVs to be calculated from fuel efficiency factors for vehicles using this fuel taken from DfT/TRL combined with the total LPG consumption given in DUKES. The LPG kilometres were then combined with the g/km emission factors for CH_4 and N_2O provided by TRL/DfT assuming the fleet composition of LPG vehicles in terms of the mix of Euro standards was the same as for diesel LGVs. Emissions were slightly revised in the 2012 inventory due to small revisions in the LGV fleet composition mix

Based on this approach, **Table 3.29** shows fleet-averaged emission factors for vehicles using LPG in the UK in 2012 for each main road type.

Table 3.29 Fleet-weighted emission factors for light duty vehicles running on LPG in 2012

g/km	Urban	Rural	Motorway
CH_4	0.0229	0.0130	0.0136
N_2O	0.0087	0.0034	0.0017

Although the method for calculating CH_4 and N_2O emissions from LPG consumption is based on g/km emission factors, the use of LPG fuel consumption to estimate km travelled means

the emissions are in effect based on LPG sales consistent with the method used for petrol and diesel consumption.

3.2.8.2.2.14 Emission of CH_4 and N_2O from lubricants

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 were tested. Hence, the emissions of CH_4 and N_2O (and other air pollutants) from lubricants are included implicitly in the hot exhaust emissions calculated for each vehicle and fuel type. Treating emissions of these pollutants separately would lead to a double count.

3.2.8.2.2.15 Vehicle specific hot exhaust emission factors in g/km for Indirect GHGs: NO_x, CO, NMVOCs

For NO_x, emission factors for Euro 5 diesel cars were updated in the 2012 inventory by adopting the latest factors in COPERT 4 v10, published in November 2012. The development of the COPERT 4 model is coordinated by the European Environment Agency and is used widely by other EU Member States to calculate emissions from road transport. The latest version of the COPERT model is available for download from http://www.emisia.com/copert/. The new Euro 5 factors are higher than previously assumed reflecting the real-world performance of these vehicles, to levels 23% higher than factors for Euro 4 vehicles. Although not adopted for diesel LGVs in COPERT 4 v10, a conservative assumption was made that Euro 5 factors for these vehicles are also 23% higher than their Euro 4 equivalent factors. Emission factors for all other vehicle types were not changed in COPERT 4 v10. For NO_x, COPERT 4 provides separate emission functions for Euro V HDVs equipped with Selective Catalytic Reduction (SCR) and Exhaust Gas Recirculation (EGR) systems for NOx control. According to European Automobile Manufacturers' association (ACEA), around 75% of Euro V HDVs sold in 2008 and 2009 are equipped with SCR systems, and this is recommended to be used if the country has no other information available (it is not expected that the UK situation will vary from this European average). The net result of adopting the COPERT 4 v10 factors is an increase in the estimates of diesel car and LGV NO_x emissions in this year's inventory from 2010.

Emission factors for total hydrocarbons (THC) have not been changed in the UK inventory as they remain unchanged in COPERT 4 v10.

The COPERT NO_x and THC emission factors are represented as equations relating emission factor in g/km to average speed. These baseline emission factors correspond to a fleet of average mileage in the range of 30,000 to 60,000 kilometres. For petrol cars and LGVs, COPERT provides additional correction factors (for NO_x and THC) to take account of degradation in emissions with accumulated mileage. The detailed methodology of emission degradation is provided in the 2009 EMEP/EEA Emissions Inventory Guidebook (EMEP, 2010).

The TRL/DfT (Boulter et al., 2009) emission factors for CO are continued to be used in the 2012 inventory, and are also represented as equations relating emission factor in g/km to average speed. The TRL/DfT emission factors are provided for an extensive range of vehicle types, sizes and Euro standards and are based on emission test data for in-service vehicles. The factors are presented as a series of emission factor-speed relationships for vehicles normalised to an accumulated mileage of 50,000 kilometres. Scaling factors are provided to take account of degradation in emissions with accumulated mileage – for some vehicle classes, emission factors actually improved with mileage, but most deteriorated. Scaling factors are also provided to take into account the effects of fuel quality since some of

the measurements would have been made during times when available fuels were of inferior quality than they are now, particularly in terms of sulphur content. These fuel scaling factors are also applied to the COPERT NO_x and THC emission factors.

Table 3.36 to **Table 3.38** summarise the baseline COPERT NO_x and THC emission factors (before any degradation corrections to the petrol LDVs factors and normalised to current fuels) and the TRL/DfT's CO emission factors (normalised to 50,000km accumulated mileage and current fuels) for all vehicle types under typical urban, rural and motorway road conditions in g/km. The factors have been averaged according to the proportion of different vehicle sizes in the UK fleet based on vehicle licensing statistics. Factors for NMVOCs are derived by subtracting the calculated g/km factors for CH_4 from the corresponding THC emission factors.

The speed-emission factor equations were used to calculate emission factor values for each vehicle type and Euro emission standard at each of the average speeds of the road and area types shown in **Table 3.27.** The calculated values were averaged to produce single emission factors for the three main road classes described earlier (urban, rural single carriageway and motorway/dual carriageway), weighted by the estimated vehicle kilometres on each of the detailed road types taken from DfT.

There is an important point to note from these tables of emission factors. The variation in emission factors with average speed differs with different vehicle types, Euro class and technology and the tables shown here are only meant as an illustration of how average emission factors vary across different road types with typical average speeds and Euro classes. Emission factors are especially sensitive to speed at the low urban speed end of the range. The urban emission factors shown in these tables refer to the average urban speed of 44 kph, but at lower, more congested road speeds the emission factors can be much higher and some pollutants show a different trend across the Euro standards at these low speeds. This is especially true for NO_x emission factors for diesel heavy duty vehicles where Euro V vehicles equipped with SCR can show higher factors for NO_x than the same vehicle of a Euro IV class at particularly low speeds reflecting the poor performance of SCR systems under real-world urban cycles. The Euro V factors for NO_x shown in these tables for HGVs and buses are for a higher urban speed and are a weighted average of different factors for vehicles equipped with SCR and EGR technology. For a detailed assessment of urban emissions, the reader is advised to use the original speed-emission factor relationships for different vehicle categories provided by the sources referenced above and derive their own emission factors.

The inventory uses the TRL fuel scaling factors to take into account the prevailing fuel quality in different years. Various other assumptions and adjustments were applied to the emission factors, as follows.

The emission factors used for NMVOCs, NO_x and CO are already adjusted to take account of improvements in fuel quality for conventional petrol and diesel, mainly due to reductions in the fuel sulphur content of refinery fuels. An additional correction was also made to take account of the presence of biofuels blended into conventional fossil fuel. Uptake rates of biofuels were based on the figures from HMRC (2013) and it was assumed that all fuels were consumed as weak (typically 5%) blends with fossil fuel. The effect of biofuel (bioethanol and biodiesel) on exhaust emissions was represented by a set of scaling factors given by Murrells and Li (2008). A combined scaling factor was applied to the emission factors according to both the emission effects of the biofuel and its uptake rates each year. The effects on these pollutants are generally rather small for these weak blends.

Account was taken of some heavy duty vehicles in the fleet being fitted with pollution abatement devices, perhaps to control particulate matter emissions (PM), or that otherwise lead to reductions in NO_x, CO and NMVOC emissions beyond that required by Directives. Emissions from buses were scaled down according to the proportion fitted with oxidation catalysts or diesel particulate filters (DPFs) and the effectiveness of these measures in reducing emissions from the vehicles. The effectiveness of these measures in reducing emissions from a Euro II bus varies for each pollutant and is shown in **Table 3.30**.

Table 3.30 Scale Factors for Emissions from a Euro II Bus Fitted with an Oxidation Catalyst or DPF

		NO_x	CO	NMVOCs
Oxidation catalyst	Urban	0.97	0.20	0.39
	Rural	0.95	0.22	0.55
DPF	Urban	0.90	0.17	0.19
	Rural	0.88	0.19	0.27

These scale factors based on data from LT Buses (1998).

Euro II HGVs equipped with DPFs have their emissions reduced by the amounts shown in **Table 3.31**.

Table 3.31 Scale Factors for Emissions from a Euro II HGV Fitted with a DPF

		NO_x	CO	NMVOCs
DPF	Urban	0.81	0.10	0.12
	Rural	0.85	0.10	0.12

3.2.8.2.2.16 Cold-Start Emissions

Cold start emissions are the excess emissions that occur when a vehicle is started with its engine below its normal operating temperature. The excess emissions occur from petrol and diesel vehicles because of the lower efficiency of the engine and the additional fuel used when it is cold, but more significantly for petrol cars, because the three-way catalyst does not function properly and reduce emissions from the tailpipe until it has reached its normal operating temperature.

Cold start emissions are calculated following the recommendations made by TRL in a review of alternative methodologies carried out on behalf of DfT (Boulter and Latham, 2009). Their main conclusion was that the inventory approach ought to take into account new data and modelling approaches developed in the ARTEMIS programme and COPERT 4 (EMEP, 2007). However, it was also acknowledged that such an update can only be undertaken once the ARTEMIS model and/or COPERT 4 have been finalised and that at the time of their study it was not possible to give definitive emission factors for all vehicle categories.

Boulter and Latham (2009) also stated that it is possible that the incorporation of emission factors from different sources would increase the overall complexity of the UK inventory model, as each set of emission factors relates to a specific methodology. It was therefore necessary to check on progress made on completing the ARTEMIS and COPERT 4 methodologies and assess their complexities and input data requirements for national scale modelling.

The conclusion from this assessment of alternative methodologies was that neither ARTEMIS nor a new COPERT 4 was sufficiently well-developed for national scale modelling and that COPERT 4 referred to in the EMEP/EEA Emissions Inventory Guidebooks still utilises the approach in COPERT III (EEA, 2000). COPERT III was developed in 2000 and is quite detailed in terms of vehicle classes and uses up-to-date information including scaling factors for more recent Euro standards reflecting the faster warm-up times of catalysts on petrol cars. COPERT III is a trip-based methodology which uses the proportion of distance travelled on each trip with the engine cold and a ratio of cold/hot emission factor. Both of these are dependent on ambient temperature. Different cold/hot emission factor ratios are used for different vehicle types, Euro standards, technologies and pollutants.

Cold start emissions are calculated from the formula:

$E_{cold} = \beta \cdot E_{hot} \cdot (e^{cold}/e^{hot} - 1)$

where

E_{hot} = hot exhaust emissions from the vehicle type
β = fraction of kilometres driven with cold engines
e^{cold}/e^{hot} = ratio of cold to hot emissions for the particular pollutant and vehicle type

The parameters β and e^{cold}/e^{hot} are both dependent on ambient temperature and β is also dependent on driving behaviour in particular the average trip length, as this determines the time available for the engine and catalyst to warm up. The equations relating e^{cold}/e^{hot} to ambient temperature for each pollutant and vehicle type were taken from COPERT III and were used with monthly average temperatures for central England based on historic trends in Met Office data.

The factor β is related to ambient temperature and average trip length by the following equation taken from COPERT III:

$\beta = 0.6474 - 0.02545 \cdot l_{trip} - (0.00974 - 0.000385 \cdot l_{trip}) \cdot t_a$

where

l_{trip} = average trip length
t_a = average temperature

The method is sensitive to the choice of average trip length in the calculation. A review of average trip lengths was made, including those from the National Travel Survey, which highlighted the variability in average trip lengths available (DfT, 2007b). A key issue seems to be what the definition of a trip is according to motorist surveys. The mid-point seems to be a value of 10 km given for the UK in the EMEP/EEA Emissions Inventory Guidebook, so this figure was adopted (EMEP, 2007).

The COPERT III method provides pollutant-specific reduction factors for β to take account of the effects of Euro 2 to Euro 4 technologies in reducing cold start emissions relative to Euro 1.

This methodology was used to estimate annual UK cold start emissions of NO_x, CO and NMVOCs from petrol and diesel cars and LGVs. Emissions were calculated separately for

each Euro standard of petrol cars. Cold start emissions data are not available for heavy-duty vehicles, but these are thought to be negligible (Boulter, 1996).

All the cold start emissions are assumed to apply to urban driving.

Cold start emissions of N_2O were estimated using a method provided by the COPERT 4 methodology for the Emissions Inventory Guidebook (EMEP, 2007). The method is simpler in the sense that it uses an mg/km emission factor to be used in combination with the distances travelled with the vehicle not fully warmed up, i.e. under "cold urban" conditions. For petrol cars and LGVs, a correction is made to the cold start factor that takes into account the vehicle's accumulated mileage and the fuel sulphur content, in the same way as for the hot exhaust emission. The cold start factors in mg/km for N_2O emissions from light duty vehicles are shown in **Table 3.32**. There are no cold start factors for HGVs and buses.

Table 3.32 Cold Start Emission Factors for N_2O (in mg/km)

mg/km	Petrol cars	Petrol LGVs	Comment
Pre-Euro 1	10.0	10.0	
Euro 1	34.0	43.4	
Euro 2	23.7	55.0	
Euro 3	11.6	20.9	
Euro 4	6.1	15.6	
Euro 5	6.1	15.6	Assume same as Euro 4

Data for estimating cold start effects on methane emissions are not available and are probably within the range of uncertainty in the hot exhaust emission factors. Cold start effects are mostly an issue during the warm up of three-way catalyst on petrol cars when the catalyst is not at its optimum efficiency in reducing hydrocarbon, NO_x and CO emissions, but without measured data, it would be difficult to estimate the effects on methane emissions. During this warm-up phase, one might expect higher methane emissions to occur, but as the catalyst is less effective in reducing methane emissions when fully warmed up compared with other more reactive hydrocarbons on the catalyst surface, the cold start effect and the excess emissions occurring during the catalyst warm up phase is probably smaller for methane emissions than it is for the NMVOCs. As petrol cars contribute less than 0.5% of all UK methane emissions across the time series, the effect of excluding potential and unquantifiable cold start emissions will be very small.

3.2.8.2.2.17 Evaporative Emission (1A3bv)

Evaporative emissions of petrol fuel vapour from the tank and fuel delivery system in vehicles constitute a significant fraction of total NMVOC emissions from road transport. The methodology for estimating evaporative emissions is based on the COPERT 4 simple approach from the EMEP/EEA Emissions Inventory Guidebook (EMEP, 2007). This is the preferred approach to use for national scale modelling of evaporative emissions for the UK inventory, as concluded from a review by Stewart et al. (2009) and recommendations of a review carried out by TRL under contract to DfT (Latham and Boulter 2009).

There are three different mechanisms by which gasoline fuel evaporates from vehicles:

i) Diurnal Loss

This arises from the increase in the volatility of the fuel and expansion of the vapour in the fuel tank due to the diurnal rise in ambient temperature. Evaporation through "tank

breathing" will occur each day for all vehicles with gasoline fuel in the tank, even when stationary.

ii) Hot Soak Loss

This represents evaporation from the fuel delivery system when a hot engine is turned off and the vehicle is stationary. It arises from transfer of heat from the engine and hot exhaust to the fuel system where fuel is no longer flowing. Carburettor float bowls contribute significantly to hot soak losses.

iii) Running Loss

These are evaporative losses that occur while the vehicle is in motion.

These emissions depend to varying degrees on ambient temperatures, volatility of the fuel, the size of vehicle, type of fuel system (carburettor or fuel injection and whether it uses a fuel return system) and whether the vehicle is equipped with a carbon canister for evaporative emission control. Since Euro 1 standards were introduced in the early 1990s, evaporative emissions from petrol cars and vans have been controlled by the fitting of carbon canisters to capture the fuel vapours which are then purged and returned to the engine manifold thus preventing their release to air. Evaporative emissions were particularly high from vehicles using carburettor fuel intake systems and these have been largely replaced by fuel injection systems on more modern vehicles which have further reduced evaporative losses.

COPERT 4 provides a method and emission factors for estimating evaporative emissions for more detailed vehicle categories and technologies than the previous method and also has the benefit of including factors for motorcycles. The vehicle classes are compatible with those available and currently used by the inventory in the calculation of exhaust emissions, although approximations and assumptions have been necessary to further divide vehicles into technology classes according to the type of fuel control systems used on cars (carburettor and fuel return systems) and carbon canisters fitted to motorcycles, given the absence of any statistics or other information available on these technologies relevant to the UK fleet. It has also not been possible to take into account the failure of VOC-control systems because of lack of data on failure rates and emission levels that occur on failure. The COPERT 4 method uses temperature and trip dependent emission factors, and it utilises look-up tables to assign emission factors according to summer/winter climate conditions and fuel vapour pressure.

The application of the method for the UK inventory required the following input data and assumptions.

The number of petrol cars in the small, medium and large engine size range was required and was taken from national licensing statistics. All Euro 1+ vehicles are assumed to be equipped with carbon canister controls. However, the method provides different emission factors for different sizes of canisters. The numbers of vehicles in the UK equipped with different sized canisters is not available, but the EMEP/EEA Emissions Inventory Guidebook provides a table that correlates size of carbon canister with Euro emission class. Hence an assignment of the appropriate COPERT 4 evaporative emission factor can be made to Euro class in the UK fleet.

The method also requires additional information on the number of cars with carburettor and/or fuel return systems. Both these systems lead to higher emissions, the latter because fuel vapour being returned to the fuel tank is warm and therefore heats the fuel in the tank. Data are not available in the UK on the number of cars running with either of these systems,

but it was assumed that all pre-Euro 1 cars would be with carburettor and that all Euro 1 onward cars would use fuel injection, but with fuel return systems, hence having high emission factors. The latter is a conservative assumption as some modern cars with fuel injection might be using returnless fuel systems and hence have lower emissions, but it was not possible to know this as there is no association with the car's Euro class.

COPERT 4 provides different emission factors for six classes of motorcycles associated with engine cc, whether the engine operated as 2-stroke or 4-stroke and for the largest motorcycles, whether they were or were not equipped with a carbon canister. A review of the motorcycle fleet had been undertaken to yield most of the required information, but it was necessary to make a conservative assumption that no motorcycles are currently fitted with carbon canisters.

Trip information was required to estimate hot soak and running loss evaporative emissions. The information required is the number of trips made per vehicle per day and the proportion of trips finishing with a hot engine. The same trip lengths as used in the calculation of cold start emissions were used.

The COPERT 4 methodology is based on knowledge of fuel vapour pressure (levels most appropriate for the region in the summer and winter seasons) and climatic conditions (ranges of ambient temperatures most applicable to the region in the summer and winter seasons). Based on the information on seasonal fuel volatility received annually from UKPIA (2013b), the COPERT 4 emission factors adopted for summer days were those associated with 70 kPa vapour pressure petrol and cooler summer temperature conditions and those adopted for winter days were those associated with 90 kPa vapour pressure petrol and milder winter temperature conditions characteristic of the UK climate.

The seasonal emission factors were applied based on the number of summer and winter days in each month. However as the COPERT 4 emission factors are also classified by fuel vapour pressure, the number of summer and winter days in each month has been defined by whether the fuel sold in that month is either a winter or summer blend or a mixture of both. The information from UKPIA indicates the average vapour pressure of fuels sold in the UK in the summer, winter and also the transitional spring and autumn months. This information allows identification of summer and winter months for the purpose of assigning COPERT 4 evaporative emission factor (winter months have an average vapour pressure of 90 kPa or more and summer months have a vapour pressure of 70 kPa or less). In the transitional months (September, May), the equivalent number of winter and summer days in the month were calculated from the average vapour pressure for the month assuming a winter fuel vapour pressure of 90 kPa and a summer blend vapour pressure of 70 kPa. From this, weighted average evaporative emission factors could be derived for the month.

Further details of the methodology and tables of emission factors are given in the EMEP/EEA Emission Inventory Guidebook (EMEP/EEA, 2007).

An implied emission factor based on the population, composition of the fleet and trips made in 2012 is shown for petrol cars and motorcycles in **Table 3.33**. The units are in g per vehicle per day.

Table 3.33 Fleet-average emission factor for evaporative emissions of NMVOCs in 2012

g/vehicle.day	2012
Petrol cars	0.64
Motorcycles	1.60

3.2.8.2.2.18 Overseas Territories and Crown Dependencies

Fuel consumption data for 1A3b were obtained from national statistics for all overseas territories and crown dependencies. Fleet composition data were available for some territories and used within the calculations. Detailed fleet data from the UK GHGI were used to break down the fuel consumption data in order to apply UK-specific emission factors.

Table 3.34 N_2O Emission Factors for Road Transport (in mg/km)

N_2O(mg/km)	Standard	Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	10.0	6.5	6.5
	Euro 1	21.3	13.8	6.9
	Euro 2	10.7	3.4	1.8
	Euro 3	1.4	0.6	0.5
	Euro 4	1.8	0.6	0.5
	Euro 5	1.8	0.6	0.5
Diesel cars	Pre-Euro 1	0.0	0.0	0.0
	Euro 1	2.0	4.0	4.0
	Euro 2	4.0	6.0	6.0
	Euro 3	9.0	4.0	4.0
	Euro 4	9.0	4.0	4.0
	Euro 5	9.0	4.0	4.0
Petrol LGVs	Pre-Euro 1	10.0	6.5	6.5
	Euro 1	22.0	13.8	6.9
	Euro 2	16.3	9.3	5.8
	Euro 3	10.5	4.6	4.6
	Euro 4	0.8	1.3	1.3
	Euro 5	0.8	1.3	1.3
Diesel LGV	Pre-Euro 1	0.0	0.0	0.0
	Euro 1	2.0	4.0	4.0
	Euro 2	4.0	6.0	6.0
	Euro 3	9.0	4.0	4.0
	Euro 4	9.0	4.0	4.0
	Euro 5	9.0	4.0	4.0
Rigid HGVs	Pre-Euro I	30.0	30.0	30.0
	Euro I	10.4	8.6	6.1
	Euro II	10.0	8.6	5.7
	Euro III	4.9	4.9	3.7
	Euro IV	10.6	12.9	10.6
	Euro V	27.6	37.1	31.3

N_2O(mg/km)	Standard	Urban	Rural	Motorway
Artic HGVs	Pre-Euro I	30.0	30.0	30.0
	Euro I	17.6	14.7	10.8
	Euro II	17.6	14.7	9.8
	Euro III	8.8	8.8	6.8
	Euro IV	18.6	22.9	18.8
	Euro V	47.9	65.1	54.5
Buses	Pre-Euro I	30.0	30.0	30.0
	Euro I	11.7	11.2	7.0
	Euro II	11.7	11.2	6.0
	Euro III	5.7	5.7	4.0
	Euro IV	12.4	13.1	11.4
	Euro V	32.2	35.2	33.6
Mopeds, <50cc, 2st	Pre-Euro 1	1.0		
	Euro 1	1.0		
	Euro 2	1.0		
	Euro 3	1.0		
Motorcycles, >50cc, 2st	Pre-Euro 1	2.0	2.0	
	Euro 1	2.0	2.0	
	Euro 2	2.0	2.0	
	Euro 3	2.0	2.0	
Motorcycles, >50cc, 4st	Pre-Euro 1	2.0	2.0	2.0
	Euro 1	2.0	2.0	2.0
	Euro 2	2.0	2.0	2.0
	Euro 3	2.0	2.0	2.0

Table 3.35 CH_4 Emission Factors for Road Transport (in mg/km)

mg CH4/km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	73.0	21.8	57.7
	Euro 1	15.0	5.2	20.9
	Euro 2	15.8	9.6	9.7
	Euro 3	5.0	4.1	7.2
	Euro 4	1.3	1.0	1.8
	Euro 5	1.3	1.0	1.8
Diesel cars	Pre-Euro 1	12.3	10.2	10.0
	Euro 1	6.1	6.3	6.2
	Euro 2	2.9	1.7	1.2
	Euro 3	1.4	1.1	1.1
	Euro 4	1.0	0.8	0.7
	Euro 5	1.0	0.8	0.7
Petrol LGVs	Pre-Euro 1	73.0	21.8	57.7
	Euro 1	15.0	5.2	20.9
	Euro 2	15.8	9.6	9.7
	Euro 3	5.0	4.1	7.2
	Euro 4	1.3	1.0	1.8
	Euro 5	1.3	1.0	1.8
Diesel LGV	Pre-Euro 1	11.8	4.0	22.0
	Euro 1	6.7	1.7	5.8

mg CH4/km		Urban	Rural	Motorway
	Euro 2	2.9	1.7	1.2
	Euro 3	2.2	0.6	1.0
	Euro 4	1.5	0.4	0.7
	Euro 5	1.5	0.4	0.7
Rigid HGVs	Pre-Euro I	185.5	50.2	43.6
	Euro I	85.0	23.0	20.0
	Euro II	54.4	20.0	18.6
	Euro III	47.6	21.4	18.2
	Euro IV	2.6	1.6	1.2
	Euro V	2.3	1.4	1.1
Artic HGVs	Pre-Euro I	381.8	174.5	152.7
	Euro I	175.0	80.0	70.0
	Euro II	112.0	69.6	65.1
	Euro III	98.0	74.4	63.7
	Euro IV	5.3	5.6	4.2
	Euro V	4.7	5.0	3.8
Buses & coaches	Pre-Euro I	381.8	174.5	152.7
	Euro I	175.0	80.0	70.0
	Euro II	113.8	52.0	45.5
	Euro III	103.3	47.2	41.3
	Euro IV	5.3	5.6	4.2
	Euro V	4.7	5.0	3.8
Mopeds, <50cc, 2st	Pre-Euro 1	219.0		
	Euro 1	43.8		
	Euro 2	24.1		
	Euro 3	19.7		
Motorcycles, >50cc, 2st	Pre-Euro 1	150.0	150.0	
	Euro 1	99.0	106.5	
	Euro 2	30.0	31.5	
	Euro 3	12.0	13.5	
Motorcycles, >50cc, 4st	Pre-Euro 1	200.0	200.0	200.0
	Euro 1	127.9	138.6	148.7
	Euro 2	126.7	93.1	107.1
	Euro 3	76.2	32.6	31.8

Table 3.36 NO_x Emission Factors for Road Transport (in g/km), before degradation correction for petrol cars and LGVs[21]

g NO_x (as NO_2 eq)/km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	2.11	2.66	3.58
	Euro 1	0.26	0.31	0.59
	Euro 2	0.14	0.16	0.19
	Euro 3	0.07	0.06	0.06
	Euro 4	0.05	0.03	0.02
	Euro 5	0.04	0.02	0.01
Diesel cars	Pre-Euro 1	0.57	0.53	0.74
	Euro 1	0.57	0.58	0.74

[21] The emission factors shown here are illustrative of magnitude and variability with vehicle and road type. The factors for urban roads refer to an average urban speed of 44 kph, but at lower, more congested road speeds the emission factors can be much higher and show a different trend across the Euro standards at these low speeds. For a detailed assessment of urban emissions, the reader is advised to use the original speed-emission factor relationships for different vehicle categories provided by the sources referenced above and derive their own emission factors. The Euro V factors for HDVs are a weighted average of factors vehicles equipped with SCR and EGR for NO_x control.

g NO_x (as NO_2 eq)/km		Urban	Rural	Motorway
	Euro 2	0.60	0.56	0.79
	Euro 3	0.69	0.67	0.86
	Euro 4	0.48	0.44	0.72
	Euro 5	0.59	0.54	0.89
Petrol LGVs	Pre-Euro 1	2.82	3.34	3.97
	Euro 1	0.41	0.42	0.61
	Euro 2	0.14	0.14	0.21
	Euro 3	0.09	0.09	0.13
	Euro 4	0.04	0.04	0.06
	Euro 5	0.03	0.03	0.04
Diesel LGV	Pre-Euro 1	1.29	0.81	2.08
	Euro 1	1.05	1.01	1.50
	Euro 2	1.05	1.01	1.50
	Euro 3	0.88	0.85	1.26
	Euro 4	0.71	0.68	1.02
	Euro 5	0.88	0.84	1.25
Rigid HGVs	Pre-Euro I	8.65	7.89	7.91
	Euro I	5.92	5.45	5.51
	Euro II	6.40	5.77	5.76
	Euro III	5.01	4.45	4.42
	Euro IV	3.47	3.19	2.86
	Euro V	2.77	1.34	0.81
Artic HGVs	Pre-Euro I	13.95	11.17	10.07
	Euro I	9.79	7.87	7.13
	Euro II	10.42	8.36	7.59
	Euro III	8.35	6.72	6.14
	Euro IV	5.74	4.81	3.59
	Euro V	3.83	1.94	1.27
Buses & coaches	Pre-Euro I	10.84	9.31	8.64
	Euro I	7.26	6.00	6.42
	Euro II	7.85	6.47	7.00
	Euro III	6.14	4.66	5.33
	Euro IV	4.21	3.35	3.85
	Euro V	3.35	2.16	1.91
Mopeds, <50cc, 2st	Pre-Euro 1	0.03		
	Euro 1	0.03		
	Euro 2	0.01		
	Euro 3	0.01		
Motorcycles, >50cc, 2st	Pre-Euro 1	0.03	0.04	
	Euro 1	0.04	0.05	
	Euro 2	0.05	0.06	
	Euro 3	0.02	0.04	
Motorcycles, >50cc, 4st	Pre-Euro 1	0.22	0.45	0.57
	Euro 1	0.23	0.44	0.57
	Euro 2	0.13	0.31	0.66
	Euro 3	0.07	0.16	0.34

Table 3.37 CO Emission Factors for Road Transport (in g/km) normalised to 50,000 km accumulated mileage (where applicable)

g CO/km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	9.77	6.85	5.53
	Euro 1	2.42	1.64	3.13
	Euro 2	0.53	0.69	1.82
	Euro 3	0.23	0.62	1.58
	Euro 4	0.42	0.71	1.56
	Euro 5	0.34	0.58	1.29
Diesel cars	Pre-Euro 1	0.58	0.43	0.36
	Euro 1	0.32	0.22	0.18

g CO/km		Urban	Rural	Motorway
	Euro 2	0.19	0.12	0.08
	Euro 3	0.06	0.04	0.02
	Euro 4	0.05	0.03	0.02
	Euro 5	0.04	0.02	0.01
Petrol LGVs	Pre-Euro 1	11.69	8.17	6.69
	Euro 1	3.10	3.25	4.81
	Euro 2	0.10	1.15	3.12
	Euro 3	0.41	0.77	2.22
	Euro 4	0.41	0.77	2.22
	Euro 5	0.33	0.63	1.82
Diesel LGV	Pre-Euro 1	0.71	0.77	0.95
	Euro 1	0.55	0.46	0.43
	Euro 2	0.59	0.62	0.76
	Euro 3	0.17	0.13	0.12
	Euro 4	0.14	0.10	0.09
	Euro 5	0.11	0.08	0.08
Rigid HGVs	Pre-Euro I	2.14	1.96	2.06
	Euro I	1.38	1.30	1.37
	Euro II	1.17	1.12	1.18
	Euro III	1.04	0.96	0.98
	Euro IV	0.57	0.50	0.55
	Euro V	0.08	0.07	0.07
Artic HGVs	Pre-Euro I	2.49	2.26	2.39
	Euro I	2.17	1.98	2.10
	Euro II	1.80	1.69	1.83
	Euro III	1.91	1.74	1.86
	Euro IV	0.34	0.31	0.34
	Euro V	0.13	0.12	0.13
Buses & coaches	Pre-Euro I	2.72	1.89	1.50
	Euro I	1.68	1.11	1.24
	Euro II	1.33	0.87	1.13
	Euro III	1.46	0.92	1.22
	Euro IV	0.13	0.08	0.09
	Euro V	0.13	0.09	0.09
Mopeds, <50cc, 2st	Pre-Euro 1	13.80		
	Euro 1	5.60		
	Euro 2	1.30		
	Euro 3	1.30		
Motorcycles, >50cc, 2st	Pre-Euro 1	16.08	23.67	
	Euro 1	10.61	15.62	
	Euro 2	8.39	12.35	
	Euro 3	4.63	6.82	
Motorcycles, >50cc, 4st	Pre-Euro 1	16.59	22.01	25.84
	Euro 1	10.08	17.56	15.74
	Euro 2	5.27	8.98	9.51
	Euro 3	2.91	4.96	5.25

Table 3.38 THC Emission Factors for Road Transport (in g/km)

g HC/km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	1.299	0.818	0.711
	Euro 1	0.154	0.115	0.119
	Euro 2	0.061	0.045	0.044
	Euro 3	0.014	0.017	0.033
	Euro 4	0.012	0.014	0.019
	Euro 5	0.012	0.014	0.019
Diesel cars	Pre-Euro 1	0.122	0.078	0.055
	Euro 1	0.052	0.032	0.029
	Euro 2	0.045	0.029	0.019
	Euro 3	0.020	0.012	0.010
	Euro 4	0.009	0.006	0.006
	Euro 5	0.009	0.006	0.006
Petrol LGVs	Pre-Euro 1	1.403	0.475	0.884
	Euro 1	0.175	0.082	0.099
	Euro 2	0.042	0.020	0.024
	Euro 3	0.025	0.011	0.014
	Euro 4	0.011	0.005	0.006
	Euro 5	0.011	0.005	0.006
Diesel LGV	Pre-Euro 1	0.120	0.101	0.118
	Euro 1	0.120	0.101	0.118
	Euro 2	0.120	0.101	0.118
	Euro 3	0.074	0.063	0.073
	Euro 4	0.028	0.023	0.027
	Euro 5	0.028	0.023	0.027
Rigid HGVs	Pre-Euro I	0.825	0.538	0.371
	Euro I	0.422	0.294	0.220
	Euro II	0.282	0.193	0.142
	Euro III	0.260	0.176	0.128
	Euro IV	0.037	0.029	0.027
	Euro V	0.023	0.018	0.015
Artic HGVs	Pre-Euro I	0.683	0.463	0.341
	Euro I	0.635	0.436	0.323
	Euro II	0.418	0.284	0.208
	Euro III	0.386	0.263	0.193
	Euro IV	0.059	0.044	0.039
	Euro V	0.036	0.027	0.023
Buses & coaches	Pre-Euro I	1.099	0.812	0.311
	Euro I	0.488	0.358	0.316
	Euro II	0.334	0.248	0.209
	Euro III	0.310	0.237	0.207
	Euro IV	0.047	0.038	0.033
	Euro V	0.028	0.024	0.021

g HC/km		Urban	Rural	Motorway
Mopeds, <50cc, 2st	Pre-Euro 1	13.910		
	Euro 1	2.730		
	Euro 2	1.560		
	Euro 3	1.200		
Motorcycles, >50cc, 2st	Pre-Euro 1	7.521	7.442	
	Euro 1	2.362	2.863	
	Euro 2	1.254	1.521	
	Euro 3	0.784	0.948	
Motorcycles, >50cc, 4st	Pre-Euro 1	1.595	1.302	1.726
	Euro 1	0.896	0.793	0.807
	Euro 2	0.394	0.432	0.577
	Euro 3	0.246	0.270	0.362

The table above shows the THC emission factors for road transport (in g/km), before degradation corrections for petrol cars and LGVs. Note that NMVOC emission factors are derived by subtracting methane factors from the THC factors.

3.2.8.2.3 Railways (1A3c)

The following is a summary of the methods used to develop the inventory for railways and recalculations and methodological changes made in the 2014 submission of the inventory:

Summary of Methodology
A Tier 2 methodology is used for calculating emissions from diesel trains as well coal-fired heritage trains.

Summary of emission factors
Factors for N_2O are from the 2009 EMEP / EEA Emissions Inventory Guidebook. UK specific emission factors in g/vehicle (train) km are used for other gases. These are taken from the Department for Transport's Rail Emissions Model (REM) for different rail engine classes based on factors provided by WS Atkins Rail. Data from UKPIA on carbon and sulphur content of gas oil are used.

Summary of activity data
Gas oil consumption data from Office of Rail Regulation for passenger and freight trains for 2005-2009 combined with trends in train km to estimate consumption for other years. Train km data from the REM are used to provide the breakdown between train classes.

3.2.8.2.3.1 Details of methodology

The UK inventory reports emissions from both stationary and mobile sources.

Railways (stationary)
The inventory source "*railways (stationary)*" comprises emissions from the combustion of burning oil, fuel oil and natural gas by the railway sector. The natural gas emission derives from generation plant used for the London Underground. These stationary emissions are

reported under 1A4a Commercial/Institutional in the IPCC reporting system (**Section 3.2.9**) and are based on fuel consumption data from DECC (2013).

Railways (mobile)

3.2.8.2.3.2 Activity data

Most of the electricity used by the railways for electric traction is supplied from the public distribution system, so the emissions arising from its generation are reported under 1A1a Public Electricity. In this sector, emissions are reported from the consumption of gas oil used to power diesel trains and from the consumption of coal used to power steam trains.

Coal consumption data has been obtained from DUKES. Estimates have been made across the time-series from 1990-2012 and are believed to be due to consumption by coal-fired heritage trains.

The UK inventory reports emissions from diesel trains that run on gas oil in three categories: freight, intercity and regional. These are reported under IPCC code 1A3c *Railways*. Emission estimates are based on vehicle / train kilometres travelled and emission factors in grams per vehicle / train kilometre.

Gas oil consumption by passenger trains was obtained from the Office of Rail Regulation's (ORR's) National Rail Trends Yearbook (NRTY) for the years 2005 to 2009. No data was available for the years 2010 to 2012 or prior to 2009 and therefore fuel consumption for these years was estimated on the basis of the trend in train kilometres. A small correction was made in the 2012 inventory to the fuel consumed by the railway sector in Northern Ireland in 2011 due to some data missing for Sunday rail services.

Gas oil consumption by freight trains was also obtained from ORR's NRTY for 2005-2009 (ORR, 2010). As with the passenger train estimates, no data from ORR was available for 2010 to 2012 or prior to 2005 and therefore fuel consumption for these years were estimated on the basis of the trend in tonne kilometres travelled.

Fuel consumption by both passenger and freight rail is estimated to have increased year on year alongside increases in train kilometres travelled and 2012 is no exception.

3.2.8.2.3.3 Emission factors

For diesel trains, CO_2, N_2O and SO_2 emissions are calculated using fuel-based emission factors and the total fuel consumed.

The factor for CO_2 is based on the carbon factor of gas oil according to UKPIA. The N_2O emission factor is based on the 2009 EMEP / EEA Guidebook factor for diesel trains.

The emission factor for SO_2 decreased from 0.76 kt/ Mt fuel in 2011 to 0.02 kt/ Mt fuel in 2012 in line with requirements introduced from the 1st January 2012 that limited the sulphur content of gasoil to 10ppm.

Emissions of CH_4, CO, NMVOCs and NO_x are based on the vehicle / train kilometre estimates and emission factors for different train types. The fuel consumption is distributed according to:

- For passenger trains: Vehicle train kilometre and emission factor data taken from the Department for Transport's Rail Emissions Model (DfT, 2012b) and extrapolations for the years 2010 to 2012. It has been assumed that the new trains introduced in 2012 are compliant with the European Non Road Mobile Machinery Stage IIIB regulations. This leads to a reduction in some emission factors.
- For freight trains: Train kilometre data taken from the NRTY and extrapolations for the period 2010 to 2012, with an assumed mix of locomotives and fuel consumption factors for different types of locomotive. As with passenger trains, it has been assumed that the new freight trains introduced in 2012 are compliant with the European Non Road Mobile Machinery Stage IIIB regulations. This leads to a reduction in some emission factors.

For coal-fired steam trains, US EPA emission factors for hand-stoked coal-fired boilers are used to estimate emissions. These are considered most appropriate for the type of coal-fired boilers on heritage trains.

The emission factors shown in **Table 3.39** are aggregate implied factors for trains running on gas oil and coal in 2012, so that all factors are reported on the common basis of fuel consumption.

Table 3.39 Railway Emission Factors for 2012 (kt/Mt fuel)

	Fuel	C[1]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Heritage	Coal	723	2.50	0.020	4.55	138	5.00	12.1
Freight	Gas oil	870	0.23	0.024	105.6	12.9	5.98	0.02
Intercity	Gas oil	870	0.12	0.024	38.9	8.4	3.03	0.02
Regional	Gas oil	870	0.08	0.024	39.7	9.7	2.23	0.02

1 Emission factors for CO_2 expressed as ktonnes carbon per Mtonne fuel

3.2.8.2.4 Navigation (1A3d)

The following is a summary of the methods used to develop the inventory for sources covered under navigation (1A3d). A description of the methodology used for fishing reported under 1A4ciii and military shipping reported under 1A5b is also included in this section.

The UK inventory provides emission estimates for domestic coastal shipping and inland waterways (1A3dii), fishing (1A4ciii), international marine bunkers (1A3di) and naval shipping (1A5b). International marine bunker emissions are reported as a Memo item and are not included in the UK national totals.

The method for estimating domestic coastal shipping is centred on a procedure developed by Entec (now AMEC) under contract to Defra for calculating fuel consumption and emissions from shipping activities around UK waters. The method uses a bottom-up procedure based on detailed shipping movement data for different vessel types, fuels and journeys (Entec, 2010). The approach represents a Tier 3 method for estimating emissions from domestic water-borne navigation in the IPCC Guidelines for national inventories.

Further Tier 3 approaches are used to estimate emissions from inland waterways, and other emissions away from UK waters for which the UK is responsible, including fishing activities and vessel movements between the UK and overseas territories. Emissions from military shipping are estimated from information provided by the MOD.

The balance in total marine fuel consumption is used to define emissions from international marine bunkers (1A3di) following a Tier 2 approach.

3.2.8.2.4.1 Overall Approach

Prior to the 2009 inventory (reported in 2011), emission estimates for coastal and international marine were based on total deliveries of fuel oil, marine diesel oil and gas oil to marine bunkers and for national navigation given in national energy statistics (DUKES). This led to very erratic time series trends in fuel consumption and emissions which bear little resemblance to other activity statistics associated with shipping such as port movement data. The total fuel delivery statistics given in DUKES (marine bunker plus national navigation) are believed to be an accurate representation of the total amount of fuel made available for marine consumption, but there is more uncertainty in the ultimate distribution and use of the fuels for domestic and international shipping consumption.

The shipping inventory developed by Entec (2010) provides estimates of shipping for journeys that can be classified as domestic, for journeys departing from or arriving at UK ports on international journeys and for journeys passing through UK shipping waters, but not stopping at UK ports, nor using UK fuels. The detailed study covered movements in only one year, 2007, but Entec used proxy data to back cast movements and fuel consumption to 1990 and forward cast to 2009. A methodology consistent with that described by Entec (2010) has been used to forward cast to 2012.

Emissions from domestic coastal shipping estimated by Entec are included in national inventory totals (1A3dii). Other methods are used to estimate emissions from other navigation sources not covered by Entec that must be included in the UK totals. These are emissions from military shipping, inland waterways, fishing in waters outside the Entec study area and emissions from vessel movements between the UK and overseas territories.

To retain consistency with the total fuel consumption for navigation in DUKES, the balance between DUKES and the amount of fuel calculated for domestic navigation and other sources included in UK totals is assigned to international navigation and reported as a Memo item.

A summary of the overall approach indicating the sources of activity data and emission factors is shown in the following table.

Table 3.40 Approaches of estimating activity and emission factors

		Source	IPCC	Activity data			Emission factors
				Source	Base year	Time-series	
DUKES total marine fuel consumption (A)	Domestic (B)	Domestic coastal	1A3dii	Entec (2010) based on detailed vessel movement data (LMIU and AIS)	2007	DfT port movement data to scale from 2007 to other years	Entec (2010), EMEP/EEA Guidebook, UKPIA (2013)
		Fishing in UK sea territories	1A4ciii	Entec (2010) based on detailed vessel movement data	2007	MMO fish landing statistics to scale from 2007 to other years	Entec (2010), EMEP/EEA Guidebook, UKPIA (2013)
		Fishing in non-UK sea territories	1A4ciii	MMO data on fish landings by sea territory from 1994-2012 and estimates of fish landed per trip			Entec (2010), EMEP/EEA Guidebook, UKPIA (2013)
		Naval	1A5b	MoD data on fuel consumption by naval vessels			Assumed same as international shipping vessels using gas oil
		Shipping between UK and OTs	1A3dii	DfT Maritime Statistics and OT port authorities: number of sailings between UK and OT	2000-2012	Trends for years before 2000 based on trends in fuel consumption derived by Entec for international shipping and trends in DfT data on number of cruise passengers	Assumed same as international shipping vessels using fuel oil
		Inland waterways	1A3dii	Based on estimates of vessel population and usage estimates using data from various sources.	2008	Statistics on expenditure on recreation (ONS), tourism (Visit England), port freight traffic (DfT), inland waterways goods lifted (DfT) used to scale from 2008	EMEP/EEA Guidebook, UKPIA (2013)
	Internati-onal (C)		1A3di	Fuel consumption difference between DUKES total marine fuel consumption and domestic navigation calculated above (C=A-B)			Implied emission factor for international shipping from Entec (2010)

Details in the approach for each of these parts of the inventory for navigation are given in the following sections, including the methodologies for inland waterways, naval shipping, fishing outside UK waters and shipping movements between the UK and Overseas Territories. Further details of the bottom-up methodology for estimating fuel consumption and emissions based on shipping vessel movements are given in the Entec (2010) report.

3.2.8.2.4.2 Domestic Navigation

Coastal shipping (1A3dii)

a) Activity data for 2007

Entec developed a gridded emissions inventory from ship movements within waters surrounding the UK including the North Sea, English Channel, Irish Sea and North East Atlantic. The study area was 200 nautical miles from the UK coastline and fuel consumption and emissions were resolved to a 5x5km grid and included emissions from vessels cruising at sea and manoeuvring and at berth in port.

The Entec inventory was based on individual vessel movements and characteristics data provided by Lloyd's Marine Intelligence Unit (LMIU) for the year 2007 supplemented by Automatic Identification System (AIS) data transmitted by vessels to shore with information about a ship's position and course. A major part of the Entec study was to consider vessel movements not captured in the LMIU database. These were known to include small vessels and those with multiple callings to the same port each day, such as cross-channel passenger ferries. To assess this, Entec carried out a detailed comparison between the LMIU data and DfT port statistics. The DfT port statistics (DfT, 2008c) are derived from primary LMIU data in combination with estimates from MDS-Transmodal for frequent sailings missing from the LMIU database. The DfT port data are reported as annual totals by port and ship type in Maritime Statistics and refer to movement of all sea-going vessels >100 Gross Tonnage (GT) involved in the movement of goods or passengers. In this comparison, special consideration was given to movements involving small vessels <500 tonnes, fishing vessels and movements from and to the same port. Missing from both data sources are movements by tugs, dredgers, research vessels and other vessels employed within the limit of the port or estuary as well as small pleasure craft.

The comparisons showed the extent by which the LMIU data underestimated port arrivals for each port most likely from missing vessels <300 GT with multiple callings each day. A more detailed analysis highlighted the particular movements underestimated in each port by the LMIU database and from this an estimate could be made as to the missing fuel consumption and emissions which needed to be incorporated into the final gridded inventory. The main outcome of the analysis was a series of scaling factors by which fuel consumption derived for the LMIU database (as described below) were uplifted for each vessel category involved in domestic and international movements.

The LMIU movement data included vessel type and speed. The vessel types were grouped into the following eight vessel categories:

- Bulk carrier
- Container ship
- General cargo
- Passenger
- Ro-Ro cargo

- Tanker
- Fishing
- Other

This categorisation marks the differences between engine and vessel operation between different vessel types and along with the vessel size gives an indication of the likely fuel used, whether fuel oil or marine diesel oil/gas oil (marine distillate).

Fuel consumption and emissions were calculated for each of these vessel categories for different operations. Vessel speeds were combined with distance travelled to determine the time spent at sea by each vessel. Entec undertook a detailed analysis of port callings where a significant proportion of emissions occur. The analysis considered time-in-mode for manoeuvring, hoteling in ports and loading and unloading operations.

The LMIU data were analysed to determine engine characteristics that influence fuel consumption and emissions for each vessel type. This included engine size, engine type and any installed abatement technology, together with fuel type, engine power and engine speed for both the main ship engine and auxiliary engines.

Fuel types were assigned depending on whether the vessel is travelling within or outside a Sulphur Emission Control Area (SECA). The area defined as a SECA was as defined in the Sulphur Content of Marine Fuels Directive (SCMFD) which came into force in July 2005 setting maximum permissible sulphur content of marine fuels of 1.5%. Around the UK coast, the SECA came into effect in August 2007 covering the North Sea and English Channel and sulphur limits also apply for passenger vessels between EU ports from August 2006. For the purposes of the inventory, it was assumed that the sulphur limit applied to all vessels in the SECA for the full 2007 calendar year and on this basis all shipping fuel used within a SECA was either marine diesel oil (MDO) or marine gas oil (MGO).

For vessel movements outside the SECA, vessels were assumed to be using either residual fuel oil (with higher sulphur content) or MGO or MDO. Entec made the allocation according to vessel type and whether the engine was the main ship engine or auxiliary engine. Details are given in Entec (2010).

The detailed Tier 3 approach used by Entec is able to distinguish fuel consumption and emissions between domestic movements from one UK port to another and UK international movements between a UK port and a port overseas. This enables the correct activities and emissions to be allocated to the IPCC category 1A3dii Domestic Water-borne Navigation.

The Entec inventory excluded emissions and fuel consumption from military vessel movements which are not captured in the LMIU and DfT database. Naval shipping emissions are reported separately using fuel consumption data supplied by the MoD. The Entec study did not cover small tugs and service craft used in estuaries, private leisure craft and vessels used in UK rivers, lakes and canals. These were captured in the estimates for inland waterways described below.

Fishing was one of the vessel categories treated by Entec, so this enables emissions from fishing vessels to be reported separately under the IPCC category 1A4ciii. However, Entec only covered emissions from fishing activities occurring within the UK waters study area extending 200 nautical miles from the UK coast. Emissions from UK fishing activities outside this area which must be included in the UK national totals were estimated by a different approach described later.

b) Time series trends in activity data

The LMIU data used by Entec only covered vessel movements during the 2007 calendar year. Applying the same approach to other years required considerable additional time and resources, so an alternative approach was used based on proxy data to develop a consistent time series in emissions back to 1990 and forward to 2012 from the 2007 base year emissions. The variables that were considered were:

- Trends in vessel movements over time affected by changes in the number of vessels and their size.
- Trends in fuel type in use over time reflecting the era before the introduction of SECAs which would have permitted higher sulphur content fuel to be used

The key consideration was the trend in vessel movements over time. For this, DfT's annual published Maritime Statistics were used as proxies for activity rate changes which were taken to be indicators of fuel consumed. A range of time-series trends back to 1990 from the DfT statistics are available and appropriate data were assigned to different vessel categories, differentiating between international and domestic movements. Details are given in the Entec (2010) report, but in brief:

- All ports traffic data based on tonnes cargo for domestic and international movements was assigned as an indicator for the bulk carrier, general cargo and tanker vessel categories. Trends were available from 1990-2012.
- All ports main unitised statistics reported as number of units for domestic and international movements was assigned as an indicator for the container ship and Ro-Ro cargo vessel categories. Trends were available from 1990-2012
- International and domestic sea passenger movements reported as number of passengers was assigned to the passenger vessel category

A time-series of tonnes fish landed in the UK provided in UK Sea Fisheries Statistics by the Marine Management Organisation was used for the domestic fishing vessels category (MMO, 2013).

The Entec (2010) report shows the trends in each of the relevant statistics relative to the 2007 base year level. Figure 13.1 in that report shows that before 2007, all statistics were showing a growth in the level of activity from 1990 with the exception of three. Since 2007, there has tended to be a downward trend in these activities that has continued to 2012.

It was assumed that 2007 heralded the introduction of marine gas oil and marine diesel oil consumption by vessels that had previously used residual fuel oil in the SECA around UK coasts. Thus in years between 1990-2006, all vessels except fishing and those in the 'other' category were assumed to be using fuel oil for their main engine. It was also assumed that passenger vessels outside the SECA started to use MDO in 2007 in order to comply with the SCMF Directive having previously been using fuel oil. Overall, this implies a large decrease in fuel oil consumption accompanied by a large increase in MDO/MGO consumption in 2007.

Entec made the following assumptions for each fuel based on current limits and data from IVL:

Table 3.41 Assumed sulphur content of fuel for 2007

	Sulphur content of fuel (2007)
Marine gas oil	0.2%
Marine diesel oil	1.5%
Residual fuel oil	2.7%

Such figures were based on assumptions from CONCAWE and Entec (2005).

As described in the revised MARPOL Annex VI, the maximum permitted sulphur content of marine fuels for vessels operating in a SECA became 1.5% in 2007, reducing to 1% from 1 July 2010. The average sulphur content of Marine Diesel Oil (MDO) and Marine Gas Oil (MGO) for domestic coastal shipping assumed by Entec was around 1% in 2007, i.e. below the 2010 limit for a SECA. Therefore the overall sulphur content and SO_2 factors for consumption of gas oil (the average of MDO and MGO) was held constant from 2007 onwards at 1% and assumed to apply to all domestic vessels operating around the UK.

Fishing vessels were assumed by Entec to be using MGO with a sulphur content of 0.2% in 2007 and 0.1% from 2008 onwards.

Other vessels outside the SECA were assumed to continue to be using fuel oil across the 1990-2012 time-series. Information from UKPIA and DECC shows that fuel oil is still used for marine consumption. UKPIA indicate that two types of bunker fuel oil are supplied for consumption with different sulphur contents for use inside and outside SECAs. For domestic consumption of fuel oil, it is assumed that fuel oil meeting the SECA limits is used which according to UKPIA had a sulphur content of 1.3% in 2008 falling to 0.9% in 2011. The higher sulphur content fuel oil is assumed to be used for international shipping only. According to UKPIA, these range from 2.2% in 2008 to 1.4% sulphur in 2011 and 1.6% in 2012. These are below the global MARPOL limit on sulphur content for marine fuels outside SECAs of 4.5% up to January 2012 and 3.5% since January 2012.

c) Emission factors

Entec calculated fuel consumption and emissions from g/kWh emission factors appropriate for the engine type and fuel type for operations “at sea” cruising, “at berth” when stationary in port and for “manoeuvring” while entering and leaving port. The 2007 emission factors and formulae used for calculating emissions are given in the Entec (2010) report. As well as the time spent cruising, in berth and manoeuvring, the formulae used the installed engine power and average load factor for the main ship engine and auxiliary engines.

The emission factors used by Entec come from amendments to an earlier set of emission factors compiled by Entec during a study for the European Commission (Entec, 2002, 2005). These largely originate from Lloyds Register Engineering Services and a study by IVL.

The Entec study considered only fuel consumption and CO_2 emissions and emissions of NO_x, SO_2, PM and NMVOCs, but did not cover other greenhouse gases, CH_4 and N_2O. The UK inventory uses fuel-based emission factors for CH_4 and N_2O taken from the EMEP/EEA guidebook and these are assumed to remain constant over the time-series.

Emission factors for SO_2 depend on the sulphur content of the fuel which changes annually, as discussed earlier.

For NO_x, the factors took into account limits on emissions from engines installed on ships constructed or converted after 1 January 2000, as required to meet the NO_x Technical Code of the MARPOL agreement. As the age of the engine is identified in the LMIU dataset, an average factor for engines in 2007 could be determined. For each year, an estimated engine replacement rate was used to estimate the proportion of pre- and post-2000 engines in the fleet and from this a weighted NO_x emission factor was derived. It was assumed that emission factors were constant in years before 2000.

Factors for NMVOCs are unchanged from those in Entec (2005).

d) Summary of fuel consumption trends and implied emission factors

A summary of fuel consumption trends for coastal shipping and implied emission factors for 2012 are provided at the end of this section in **Table 3.44** and **Table 3.45**.

3.2.8.2.4.3 Military shipping (1A5b)

Emissions from military shipping are reported separately under IPCC code 1A5b. Emissions are calculated using a time-series of naval fuel consumption data (naval diesel and marine gas oil) provided directly by the Sustainable Development and Continuity Division of the Defence Fuels Group of the MoD (MoD, 2013). Data are provided on a financial year basis and are amended to derive figures on a calendar year basis.

The time-series in fuel consumption from military shipping is included with that for coastal shipping shown at the end of this section in **Table 3.46**.

Implied emission factors derived for international shipping vessels running on marine distillate (MGO and MDO) from the Entec (2010) study were assumed to apply for military shipping vessels.

3.2.8.2.4.4 Emissions from Deep Sea Fishing in Sea Territories outside UK Waters (1A4ciii)

The Entec study covers only domestic emissions from fishing vessels that stay within UK waters (covering a sea area up to 200 nautical miles from the UK coast), leaving from and returning to UK ports. In response to comments from reviewers during the In-Country review of the UK's Greenhouse Gas Inventory in 2012, emissions have been estimated from commercial fishing activities occurring in waters outside the Entec study area. These emissions should be included in the UK national totals.

A Tier 2 approach was used to estimate emissions from deep sea trawlers heading out of the UK waters, fishing and then returning to the UK.

a) Activity data

The Marine Management Organisation (MMO) produces a report annually on the UK fishing industry[22] entitled "*UK Sea Fisheries Statistics*[23]". This is classed as a National Statistics Publication. This report gives the tonnes of fish landing into the UK and abroad by UK

[22] The MMO is an executive non-departmental public body (NDPB) incorporating the work of the Marine and Fisheries Agency (MFA) and marine-related powers and specific functions previously associated with DECC and the Department for Transport (DfT)

[23] http://www.marinemanagement.org.uk/fisheries/statistics/annual.htm#chapter3

vessels by **area of capture**. The areas of capture are listed in terms of the ICES[24] sea area classification system. The sea areas covered by Entec are broadly the ICES areas IV, V, VI and VII. The approach considered activities outside these areas. According to the MMO reports, the other areas where the UK actively fishes are listed below:

- Barents Sea/Murman Coast (I)
- Norwegian Coast (IIa)
- Bear Island & Spitzbergen (IIb)
- Bay of Biscay (VIII)
- East Coast of Greenland (XIV)
- North Azores (XII)
- Other Areas

The MMO reports give tonnes fish landed in the UK from each of these areas from 1994-2012 (see for example, Table 3.8 in the 2012 Fisheries statistics).

The approach involved calculating the fuel used by the fleet to reach and return from these "non-UK" sea areas and the fuel consumed whilst fishing in the areas.

To calculate the fuel used to reach and return from these non-UK ICES sea areas it is necessary to know:

- The number of vessel trips to non-UK ICES areas, based on average tonnes fish landed per trip
- The distance from a UK port to a point in the ICES sea area
- The average vessel speed in order to estimate the time taken to reach the sea area
- The typical engine power of the types of vessels used
- Time spent fishing in the sea areas

i) Number of vessel trips

According to the MMO Landings report, the fish catches in the non-UK ICES areas are mainly of pelagic fish such as mackerel and herring. These are also mainly caught by the largest vessels, over 24m.

A publication by Borges et al[25] on Dutch commercial fishing operations by pelagic trawlers indicated that a small number of very large-sized trawlers (factory trawlers) catch on average **155 tonnes** pelagic fish per vessel per trip based on data for 2005. These are vessels that are over 100m in length with an engine size close to 6,000kW making them similar in size to a bulk carrier ship.

The MMO Landings data for 2011 indicates that 39,500 tonnes fish were caught in the non-UK ICES areas in 2011. Assuming the UK vessels have the same trawling capacity as the Dutch fleet, then this would require **255 vessel trips** per year in 2011.

[24] ICES is the International Council for the Exploration of the Sea. See for example http://www.fao.org/docrep/009/a0210e/a0210e12.jpg

[25] L Borges et al, "What do pelagic freezer-trawlers discard?", ICES Journal of Marine Science, 65: 605–611(2008), http://icesjms.oxfordjournals.org/content/65/4/605.full.pdf

Although a very rough estimate, this is consistent with information on a Greenpeace website which states that there are 47 pelagic fishing vessels in the UK. If 255 vessel trips are made per year, this would imply each vessel does around 5-6 trips per year.

The Borges et al study stated that the Netherlands has some of the largest fishing vessels in the world. If the UK vessels are generally smaller then they will require more than the 255 trips to the non-UK ICES areas estimated above to make the total catch reported. However this will be offset by the fact that their engine sizes and hence fuel consumption rates would be lower.

According to Table 3 in the MMO Structure and Activity 2011 report, the average engine size of the >24m fleet of vessels in the UK was 1,206 kW which is considerably less than the engine size of the factory trawlers in the Dutch fleet. The largest vessels in the UK fleet are in Scotland (142 vessels >24m, with an average engine size of 1,350 kW). It is possible that very large vessels make up a sub-set of these figures.

For the purpose of these estimates, 255 vessel round-trips was assumed to the non-UK ICES areas in 2011 in conjunction with an assumed engine power for these vessels of 5,800kW. Fish landings for these non-UK ICES areas in other years from the MMO reports were used to calculate number of round-trips in other years.

For 2012, the landings of fish increased to 40,900 tonnes, which following the method applied above implies 264 round trips.

ii) Distances covered to/from the non-UK ICES sea areas

The MMO information was used to split the tonnes fish landings from the non-UK ICES areas between each area in each year. The tables in the 2011 MMO Landing reports indicate that the major areas of capture by UK fishing vessels in the non-UK ICES areas are the north Norwegian coast and 'other areas'. The MMO reports do not specify what 'other areas' refer to, but the MMO Landings report indicates that Spain and Morocco are major areas outside UK waters receiving landings of pelagic fish from UK vessels. It was therefore assumed that the landings to the UK from 'other areas' are from off the coast of Morocco which is known to be an important fishing area.

Further detailed landings data in the 2011 MMO Landings report indicate that 81% of landings of pelagic fish are to major ports in Scotland (Peterhead, Lerwick and Fraserburgh) with 11% to major ports in the south-west of England (mainly Plymouth, Newlyn and Brixham) and the rest to other ports.

It was assumed that all 11% of the landings to the south-west of England were captured in the 'other areas' (designated as Morocco). Peterhead and Lerwick were assumed to take the remaining percent of the landings captured from Morocco and all the landings captured off the coast of Norway and the other minor areas. The Peterhead/Lerwick split was taken to be 65%/35% for all the areas of capture based on MMO data.

This information on landings was used to split the total number of vessel trips from the UK (calculated above) to each of the non-UK ICES sea areas between the "representative" UK ports of Peterhead, Lerwick and Plymouth.

To calculate trip distances, certain central positions were allocated to each area of capture. Distances from the relevant UK port to these positions are shown below:

Table 3.42 Approximate distances to points in each sea area in km

	Peterhead	Lerwick	Plymouth
Barents Sea/Murman Coast (I)	1923	1730	
Norwegian Coast (IIa)	1000	750	
Bear Island & Spitzbergen (IIb)	2600	2300	
Bay of Biscay (VIII)	2000	1875	660
East Coast of Greenland (XIV)	1800	1700	
North Azores (XII)	3000	3000	
Other Areas [(a)]	2900	2900	1700

Using the return port-sea area distances and the number of return trips made, split between each combination of UK port-to-sea area, the total distances travelled per year by all UK fishing trips to the non-UK ICES areas were calculated for each year.

iii) Average vessel speed

An average cruise speed of 25 kph was used for the fishing vessels travelling between the UK port and area of fish capture. This is taken from the EMEP Inventory Guidebook section on marine navigation.

Using this speed with the trip distances calculated above, the total time taken to travel the distances calculated above was derived for each year.

iv) Rated engine power

A rated engine power of 5,800 kW was used for all vessels, consistent with the calculation of number of vessel trips above.

A weighted average engine load factor of 0.46 was used. This was based on an assumption that the vessel would be operating under different loads for different parts of a day. The assumptions were: 5 hrs/day at 80% load, 11 hrs day at 50% load, 8 hrs/day at 20% load.

v) Fuel consumption

A specific fuel consumption factor of 203 g/kWh was used to calculate total fuel consumption by UK vessels travelling to and returning from the non-UK ICES sea area in conjunction with rated engine power, load factor and total travel time. The fuel consumption factor was taken from Table 3-4 in the EMEP/EEA Emissions Inventory Guidebook 2009 for a medium- and high-speed diesel engine using MDO/MGO.

The fuel used whilst actively fishing in the non-UK areas was calculated by assuming each vessel spends 4 days actively fishing once it has reached its sea area. This was used in conjunction with the same engine power, load information and fuel consumption factor as above to calculate total fuel consumption for all UK vessels whilst actively fishing in these sea areas.

Note that using other information in the MMO reports on total fishing effort in combination with the vessel trip information and landings used here implies that the average time spent fishing is around 3-4 days, consistent with this assumption.

The total fuel consumption for fishing by UK vessels in non-UK ICES areas is the sum of the total fuel consumed during the fishing activity and the total fuel consumed travelling to and from the area of capture.

b) Emission factors

All the fuel used for deep sea fishing in non-UK waters is assumed to be gas oil sourced in the UK. The emission factors are those used by Entec for fishing vessels in UK waters supplemented by factors from the EMEP/EEA emissions inventory guidebook (2009) for marine engines.

Implied emission factors for 2012 derived for all fishing vessels are shown at the end of this section in **Table 3.47**.

3.2.8.2.4.5 Emissions from Vessel Movements Between the UK and Overseas Territories (1A3dii)

In response to comments from expert reviewers during the In-Country review of the UK's Greenhouse Gas Inventory in 2012, emissions have been estimated for vessel movements between the UK and Overseas Territories. These were not included in the Entec study, but need to be included in the UK national totals.

a) Activity data

There are no published data on the number and types of voyages between the UK and overseas territories (OTs). However, officials at the UK Department for Transport were able to interrogate their ports database which forms the basis of the less detailed information published in DfT's Maritime Statistics. This included information on freight shipping movements and passenger vessel movements. Additional information on passenger vessel movements were gathered from individual OT port authorities.

For freight shipping, the DfT were able to provide the number of trips made between a UK port and an OT port by each unique vessel recorded. The information provided the type of vessel and the departure and arrival port. Figures were provided for all years between 2000 and 2012.

The information on the type of vessel was used to define:

- The average cruise speed of the vessel
- The average main engine power (in kW), and
- The specific fuel consumption factor (g/kWh)

This information was taken from the EMEP Emissions Inventory Guidebook 2009[26].

Distances for each voyage were taken from http://www.portworld.com/map/. This has a tool to calculate route distance by specifying the departure and arrival ports.

Using the distance, average speed, engine power and fuel consumption factor it was possible to calculate the amount of fuel consumed for every voyage made.

[26] http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009

DfT were unable to provide the detailed port data for years before 2000. The individual OT port authorities also did not have this information. The trends in fuel consumption calculated by Entec for all UK international shipping from 1990 to 2000 (based on less detailed UK port statistics) were used to define the trend in fuel consumption between the UK and OTs over these years.

For passenger vessels, the information held by OT port authorities indicated the only movements were by cruise ships (i.e. not ferries). Detailed movement data were held by the port authority of Gibraltar listing all voyages departing to or arriving from the UK back to 2003[27]. The DfT also held information on the number of UK port arrivals by cruise ships from the OTs, but only between 1999 and 2004. This is unpublished information and was provided via direct communication with DfT officials.

Information held by the other OTs indicated that only Bermuda had any cruise ship sailings with the UK logged – one voyage in 2010[28]. The data held by DfT showed the majority of sailings were from Gibraltar and the data were consistent with the information provided by the Gibraltar port authority. However, the DfT data also showed a total of 8 arrivals from Bermuda and 3 arrivals from the Falkland Islands between 1999 and 2004.

This information was combined to show the total number of cruise ship movements between the UK and OTs from 1999 to 2012.

The same source of information as described above was used to define the distances travelled, cruise speed, engine power and fuel consumption factor to calculate total fuel consumption by cruise ships between the UK and each OT. The information for passenger ships was taken from the EMEP Guidebook.

No cruise ship information was available before 1999 from either DfT or the individual OT port authorities. Trends in the total number of passengers on cruises beginning or ending at UK ports between 1990 and 1999 published in DfT's Maritime Statistics (from Table 3.1(a) UK international short sea passenger movements, by port and port area: 1950 – 2009) were used to define the trend in fuel consumption by cruise ships between the UK and OTs over these years.

The total fuel consumed by vessels moving between the UK and each OT was calculated as the sum of all fuel consumed by freight and passenger vessels. This was calculated separately for movements from the UK to each OT and from each OT to the UK.

The time-series in fuel consumption from the UK to OTs is shown in **Table 3.46**.

b) Emission factors

All fuel used for voyages between the UK and OTs is assumed to be fuel oil. The emission factors used are average factors implied by Entec for all vessels involved in international voyages (see below) supplemented by factors from the EMEP/EEA emissions inventory guidebook (2009) for marine engines.

[27] http://www.gibraltarport.com/cruise/schedules

[28] http://www.gov.bm/portal/server.pt/gateway/PTARGS_0_2_998_282_551_43/http;/ptpublisher.gov.bm;7087/publishedcontent/publish/ministry_of_tourism_and_transport/marine_and_ports/dept___marine_and_ports___shipping_news/2010_cruiseship_schedule_3.pdf

Implied emission factors for 2012 derived for vessels using fuel oil for international voyages (including to/from the OTs) are shown in **Table 3.46**.

3.2.8.2.4.6 Emissions from Inland Waterways (1A3dii)

The category 1A3dii Waterborne Navigation must include emissions from fuel used for passenger vessels, ferries, recreational watercraft, other inland watercraft, and other gasoline-fuelled watercraft. These small vessels were not included in the Entec study.

The Guidelines recommend national energy statistics be used to calculate emissions, but if these are unavailable then emissions should be estimated from surveys of fuel suppliers, vessel movement data or equipment (engine) counts and passenger and cargo tonnage counts. The UK has no national fuel consumption statistics on the amount of fuel used by inland waterways in DUKES, but they are included in the overall marine fuel statistics. A Tier 3 bottom-up approach based on estimates of population and usage of different types of inland waterway vessels is used to estimate their emissions. In the UK, all emissions from inland waterways are included in domestic totals.

The methodology applied to derive emissions from the inland waterways sector uses the 2007 and 2009 EMEP/EEA Emissions Inventory Guidebooks (EMEP, 2009b). The inland waterways class is divided into four categories and sub-categories:

- Sailing Boats with auxiliary engines;
- Motorboats / Workboats (e.g. dredgers, canal, service, tourist, river boats);
    - recreational craft operating on inland waterways;
    - recreational craft operating on coastal waterways;
    - workboats;
- Personal watercraft i.e. jet ski; and
- Inland goods carrying vessels.

Details of the approach used are given in the report by Walker et al (2011).

a) Activity data for 2008

A bottom-up approach was used based on estimates of the population and usage of different types of craft and the amounts of different types of fuels consumed. Estimates of both population and usage were made for the baseline year of 2008 for each type of vessel used on canals, rivers and lakes and small commercial, service and recreational craft operating in estuaries / occasionally going to sea. For this, data were collected from stakeholders, including the British Waterways, DfT, Environment Agency, Maritime and Coastguard Agency (MCGA), and Waterways Ireland.

The methodology used to estimate the total amount of each fuel consumed by the inland waterways sector follows that described in the EMEP/EEA Emissions inventory guidebook (EMEP, 2009b) where emissions from individual vessel types are calculated using the following equation:

$$E = \sum_i N \times HRS \times HP \times LF \times EFi$$

where:
E = mass of emissions of pollutant i or fuel consumed during inventory period,
N = source population (units),
HRS = annual hours of use,

HP = average rated horsepower,
LF = typical load factor,
EFi = average emissions of pollutant i or fuel consumed per unit of use (e.g. g/kWh).

The method requires:

- a categorisation of the types of vessels and the fuel that they use (petrol, DERV or gas oil);
- numbers for each type of vessel, together with the number of hours that each type of vessel is used;
- data on the average rated engine power for each type of vessel, and the fraction of this (the load factor) that is used on average to propel the boat;
- g/kWh fuel consumption factors and fuel-based emission factors.

A key assumption made is that privately owned vessels with diesel engines used for recreational purposes use DERV while only commercial and service craft and canal boats use gas oil (Walker et al., 2011). Some smaller vessels also run on petrol engines. As a result, around 90 kt of DERV and 90 kt of petrol previously assigned to the road transport sector for 2009 in the 2009 inventory are now allocated to inland waterways.

Walker at al. (2011) and Murrells et al. (2011) draw attention to the potential overlap between the larger vessels using the inland waterways and the smaller vessels in the shipping sectors (namely tugboats and chartered and commercial fishing vessels), and the judgement and assumptions made to try to avoid such an overlap.

b) Time series trends in activity data

As it was only possible to estimate population and activities for one year (2008), proxy statistics were used to estimate activities for different groups of vessels for other years in the time series 1990 – 2012:

- Private leisure craft – ONS Social Trends 41: Expenditure, Table 1, Volume of household expenditure on "Recreation and culture"; http://www.ons.gov.uk/ons/rel/social-trends-rd/social-trends/social-trends-41/index.html. No data were available for this dataset after 2009, therefore a second dataset was used to estimate the activity in 2010-12: OECD.Stat data: http://stats.oecd.org/Index.aspx?QueryId=9189# - 'Final consumption expenditure of households, UK, 1990-2012', P31CP090: Recreation and culture);
- Commercial passenger/tourist craft – Visit England, Visitor Attraction Trends in England 2012, Full Report, http://www.visitengland.org/insight-statistics/major-tourism-surveys/attractions/Annual_Survey/, Page 13: "Total England Attractions"
- Service craft (tugs etc.) – DfT Maritime Statistics, Port traffic trends. Table PORT0104 - All UK port freight traffic, foreign, coastwise and one-port by direction; https://www.gov.uk/government/statistical-data-sets/port01-uk-ports-and-traffic; and
- Freight – DfT Waterborne Freight in the United Kingdom, Table DWF0101: Waterborne transport within the United Kingdom, 1990 – 2011; Goods lifted - UK inland waters traffic - Non-seagoing traffic – Internal https://www.gov.uk/government/statistical-data-sets/dwf01-waterborne-transport

One of these four proxy data sets was assigned to each of the detailed vessel types covered in the inventory and used to define the trends in their fuel consumption from the 2008 base year estimate.

Table 3.43 shows the trend in fuel consumption by inland waterways from 1990-2012 developed for the inventory this year. More detail regarding the vessels and their fuel type can be found in the report by Walker et al., 2011.

Table 3.43 Fuel consumption for inland waterways derived from inventory method

Year	Fuel Consumption (kt)					
	Gas Oil		Diesel		Petrol	
	Motorboats / workboats	Inland goods-carrying vessels	Sailing boats with auxiliary engines	Motorboats / workboats	Motorboats / workboats	Personal watercraft
1990	86.2	3.8	0.6	27.6	22.0	11.2
1995	94.3	4.2	0.9	39.8	28.5	16.1
2000	96.1	2.7	1.1	53.5	34.8	21.6
2005	100.2	2.2	1.6	72.9	45.2	29.5
2008	100.3	2.3	1.8	85.5	52.2	34.6
2009	94.6	2.1	1.9	89.6	54.8	36.3
2010	97.0	2.2	2.0	92.2	56.3	37.3
2011	99.0	2.2	2.0	92.4	56.8	37.4
2012	96.5	2.2	2.0	94.5	57.7	38.3

c) Emission factors

The fuel-based emission factors used for all inland waterway vessels were taken from the EMEP Emissions Inventory Guidebook and implied factors for 2012 are presented later in **Table 3.48**. The factors for SO_2 from vessels using gas oil took into account the introduction of the much tighter limits on the sulphur content of gas oil for use by inland waterway vessels, the limit reduced to 10ppm from January 2011.

3.2.8.2.4.7 International Navigation (1A3di)

Emissions from international marine bunkers are calculated, but reported as a Memo item and not included in the UK totals.

a) Activity data

The study by Entec provided a time-series in fuel consumption and emissions from vessels involved in international movements, i.e. those arriving at UK ports from overseas and those leaving UK ports to voyage overseas. However, when adding the estimates of fuel consumption from international movements to fuel consumed by domestic movements (UK port-to-UK port), the sum is different to the total fuel supplied to international marine bunkers and consumed by national navigation in DUKES. This is illustrated in **Table 3.44** which shows the total fuel consumed by domestic and international vessel movements in 2007 according to the Entec methodology compared with the total consumption statistics (national navigation plus marine bunkers) in DUKES for 2007 for fuel oil and gas oil, after deducting the amount of fuel used for military. Note that DUKES makes no separation between marine diesel oil and marine gas oil, so the figures here and in the inventory for gas oil refer to the combined amounts for both these types of fuel.

Table 3.44 Total consumption of marine fuels for domestic and international shipping calculated by the Entec method compared DUKES for 2007 (excludes military)

Mt fuel	Entec	DUKES
Gas oil	4.34	1.57
Fuel oil	1.00	2.04

The totals differ markedly. One reason for that is the Entec "international" category includes fuel consumed by vessels arriving at UK ports that purchased their fuel overseas and so would not be included in the DUKES marine bunkers supply. However, in reporting emissions from international shipping movements as a Memo item, the UK is only responsible for emissions from fuel supplied by the UK's bunker fuels market.

Another issue is the international bunker fuels market itself and how the figures in DUKES for marine bunkers relate to actual consumption by international shipping movements starting in the UK. International fuel bunkering may be affected by variations in international marine fuel prices such that it is conceivable that fuel tankering occurs to a greater or lesser extent each year. This may explain why the trend in total marine fuel consumption implied by DUKES since 1990 is more erratic than trends in shipping movements implied by port statistics.

All these factors can lead to potential differences in the total domestic plus international fuel consumption calculated from a method based on vessel movements from fuel statistics in DUKES. Moreover, DECC acknowledged that there is uncertainty with refineries who submit data to DUKES as to where the fuel ultimately gets used, i.e. whether for domestic shipping activities or for international marine fuel bunkers. So not only could the total fuel consumed be different, but these uncertainties could allocate the incorrect amounts of the DUKES marine fuels to domestic (national navigation) and international (marine bunkers) consumption.

Under IPCC guidelines, the UK is only responsible for emissions from the fuel it supplies, whatever it is used for, but an accurate estimate is required of the amount of fuel used for domestic shipping consumption because emissions arising from this are accounted for in the UK inventory totals. Therefore, to retain overall consistency with national energy statistics and the requirements of inventory reporting under IPCC Guidelines it was decided at a meeting with stakeholders (Defra, DECC, DfT and Entec) in July 2010 to adopt an approach for the inventory whereby the figures for domestic coastal shipping would be taken directly from the Entec study (described above), but the figures for international shipping would be based on the residual fuel consumption. This residual is the difference between the total fuel deliveries statistic in DUKES and the sum of the Entec figure for domestic coastal shipping plus other fuel used for domestic marine purposes sourced in the UK and included in the national totals. These include fuel used for military shipping, inland waterways, deep sea fishing in non-UK waters and fuel used to power vessels on trips from the UK to OTs, but not on the reverse trip.

Discussions with the DUKES team during a study on the allocation of gas oil across sectors (Murrells et al., 2011) revealed that it is likely that gas oil supplied for inland waterway vessels by marinas and filling points along rivers is included in the DUKES figures for national navigation.

Thus for fuel consumption across the time series:

International shipping fuel consumption = (total DUKES fuel consumption – Entec domestic shipping fuel consumption – naval fuel consumption – inland waterways fuel consumption – fishing vessels outside UK waters fuel consumption – shipping vessels travelling from the UK to overseas territories fuel consumption)

This approach was used to estimate international shipping fuel consumption and emissions for all years back to 1990.

This implies that the total marine fuel consumption by all marine activities covered in the inventory is considered a "closed" system, in other words, the sum of consumption across all the different marine activities (international shipping, domestic coastal shipping, fishing, naval and inland waterways, voyages to overseas territories, fishing outside UK waters) is consistent with the total amount of gas oil and fuel oil used for consumption as given in DUKES for marine bunkers and national navigation. The approach also implies a different domestic/international split to that implied by DUKES. The proportion of fuel consumption (hence emissions) allocated to domestic shipping is considerably smaller than that implied in DUKES as can be seen in **Table 3.45**.

Table 3.45 Consumption of marine fuels by domestic and international shipping

Mt fuel		NAEI	DUKES
Gas oil	Domestic	0.534	0.942
	International	1.035	0.627
	Total	1.569	1.569
	% domestic	34%	60%
Fuel oil	Domestic	0.122	0.569
	International	1.918	1.471
	Total	2.040	2.040
	% domestic	6%	28%

The table present consumption of marine fuels by domestic and international shipping calculated by the inventory approach on the basis of Entec figures for domestic coastal movements and inventory estimates of inland waterway, fishing in non-UK waters and voyages from UK to OTs activities compared with figures from DUKES for 2007

The DUKES figure for gas oil (international) has consumption by military vessels excluded.

A summary of fuel consumption trends for international navigation is provided at the end of this section in **Table 3.46**.

b) Emission factors

Emissions for international shipping (1A3di) were calculated by multiplying the residual fuel consumption calculated above with an implied emission factor for international vessel movements. The implied emission factors were derived from the Entec study by dividing the Entec emission estimates for international vessel movement by their associated fuel consumption for each fuel type. This effectively means the inventory does capture the types of vessels, engines, speeds and activities used for international movements in Entec's inventory even though the overall movements, fuel consumption and hence emissions are different. The same factors were used for voyages between the UK and OTs (see above).

Implied emission factors for international navigation in 2012 are shown in at the end of this section in **Table 3.47**.

3.2.8.2.4.8 Process for agreeing changes to shipping inventory approach and reasons behind deviation from DUKES

Following the results of the Entec report (published in 2010), the approach to deriving the estimates for the UK domestic and international shipping fuel use totals has been subject to periodic review through consultation across all stakeholders. These consultations and method developments have been necessary to analyse the data discrepancies between the "bottom-up" fuel use estimates derived from the Entec study, and the "top-down" estimates of fuel sales and ultimate fate by sector that are presented in the UK energy statistics, DUKES.

Periodic meetings are held to bring together the key parties: DECC, Defra, DfT, the UK Petroleum Industry Association (UKPIA), Entec and the inventory agency. The analysis of the different datasets has led to a revision in the derivation of the shipping fuel allocations, to use more data that are derived from the bottom-up data on vessel movements. The new method was then adopted for the 2009 version of the inventory published in early 2011 and was described in the UK's 2011 National Inventory Report methodology annex.

The inventory team now maintains regular contact with the DUKES team, and the outputs from DUKES and other data collection systems are considered in order to determine the best available estimates fo fuel use for domestic and international shipping.

3.2.8.2.4.9 Consistency with marine fuels data submitted to IEA/EUROSTAT

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 marine 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 shipping based on data from the Defence Fuels Group of the MoD; these emissions are included in national inventory estimates and not in the Memo Item (International bunkers) estimate.

Furthermore, the shipping methodology described above leads to a different domestic/international split in fuel use allocation for marine fuels compared with the allocations in the national energy statistics (DUKES) and submissions to IEA/EUROSTAT.

3.2.8.2.4.10 Summary of all Activity Data Trends and Emission Factors for Navigation

Trends in Fuel Consumption

Table 3.46 summarises the time-series in gas oil and fuel oil consumption for domestic coastal and military shipping, fishing, inland waterways and international shipping and voyages from the UK to the OTs since 1990. These all refer to fuel sourced in the UK, so the sum is consistent with total fuel consumption figures reported in DUKES. Fuel consumed in the OTs and for voyages from the OTs to the UK is not included in this table.

Table 3.46 Fuel consumption for UK marine derived from inventory method

	Gas oil (Mt)				Fuel oil (Mt)		
Year	Domestic coastal and military	Fishing	Inland waterways	International bunkers	Domestic coastal and military	Voyages from UK to OTs	International bunkers
1990	0.609	0.025	0.090	1.595	0.35	0.008	1.124
1995	0.535	0.026	0.098	1.358	0.37	0.009	1.187
2000	0.461	0.032	0.099	1.462	0.35	0.012	0.618
2005	0.443	0.029	0.102	1.235	0.36	0.009	1.155
2008	0.649	0.074	0.103	1.025	0.10	0.011	2.448
2009	0.629	0.049	0.097	1.046	0.09	0.009	2.260
2010	0.615	0.064	0.099	0.962	0.09	0.011	1.845
2011	0.592	0.037	0.101	0.990	0.09	0.011	2.139
2012	0.544	0.040	0.099	1.123	0.08	0.009	1.540

Emission Factors

Table 3.47 shows the implied emission factors for each main pollutant, for both domestic and international vessel movements and fishing in 2012. The units are in g/kg fuel and are from the EMEP/EEA emissions inventory guidebook, implied by the figures in the Entec study or based on fuel sulphur content.

Table 3.47 2012 Inventory Implied Emission Factors for Shipping

Fuel	Source	CH_4	N_2O	C[1]
		g/kg	g/kg	g/kg
Gas Oil	Domestic (excl. fishing)	0.05	0.08	870
	Fishing	0.05	0.08	870
	International	0.05	0.08	870
Fuel Oil	Domestic	0.05	0.08	879
	International	0.05	0.08	879

[1]Emission factors expressed as g carbon per kg fuel

Fuel	Source	NO_X	SO_2	VOC	CO
		g/kg	g/kg	g/kg	g/kg
Gas Oil	Domestic (excl. fishing)	64.44	20.00	2.82	7.40
	Fishing	57.97	2.02	2.04	7.40
	International	69.33	20.00	2.74	7.40
Fuel Oil	Domestic	70.57	17.60	3.52	7.40
	International	77.71	32.60	2.92	7.40

Table 3.48 provides emission factors for each main pollutant, assumed for all vessel types operating on the UK's inland waterways in 2012.

Table 3.48 2012 Inventory Emission Factors for Inland Waterway Vessels

Fuel	CH_4	N_2O	C[1]
	g/kg	g/kg	g/kg
DERV	0.05	0.08	863
Gas Oil	0.05	0.08	870
Petrol	1.7	0.08	855

[1]Emission factors expressed as g carbon per kg fuel

Fuel	NO_X	SO_2	VOC	CO
	g/kg	g/kg	g/kg	g/kg
DERV	42.5	0.0146	4.72	10.9
Gas Oil	42.5	0.02	4.72	10.9
Petrol	9.0	0.0114	50.0	300

3.2.8.3 Uncertainties and Time Series Consistency

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

Some of the core activity data for this source category are derived from DECC publication the Digest of UK Energy Statistics. **Section 3.5** provides further general information about the time series consistency of activity data in this publication, and provides more general comments on the approaches used to ensure time series consistency in source category 1A. The sector allocation of gas oil consumption given in the DECC publication was not considered suitable for the inventory, so the 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 the UK Department for Transport (DfT) who publishes a variety of road transport and maritime statistics used in the inventory for 1A3b and 1A3d, the Civil Aviation Authority (1A3a), Office of Rail Regulation (1A3c) and Ministry of Defence (Defence Fuels Group). Transport Statistics Great Britain is an established publication of the DfT and the compilers of the activity data in this and other published DfT transport statistics strive to use consistent methods to produce time-series consistency in the activity data. Various other national statistics were used to derive time-series consistency in the inventories for inland waterways, fishing and other off-road sectors.

In the current UK inventory there is a noticeable reduction in emissions from 2005 to 2006 despite a modest increase in aircraft movements and kilometres flown. This is attributable to the propagation of more modern aircraft into the fleet. From 2006 to 2007 there is a further reduction in emissions, which is attributable to both a modest decrease in aircraft movements and kilometres flown and the propagation of more modern aircraft into the fleet. Since 2007 there have been steady decreases in aircraft movements and kilometres flown, in line with the economic downturn. This, along with a propagation of more modern aircraft into the fleet, has resulted in a steady reduction in emissions.

Carbon dioxide emissions from road transport decreased slightly from 2011 to 2012 reflecting the overall reduction in fossil fuel petrol and diesel consumption indicated by DUKES. The shift from petrol to diesel consumption occurring in recent years continued. The reduction in overall fossil fuel consumption partly reflects a decrease in traffic activity in 2012 compared with 2011, as indicated by the vehicle km travelled, but may also reflect improvements in vehicle fuel efficiencies.

Within the time-series, emissions of N_2O from road transport are slightly higher in 2012 compared with 2011, this being due to the further penetration of Euro V HGVs and buses which have higher N_2O emission factors than earlier Euro standards. This may be a result of more effective catalytic exhaust after treatment systems aimed at reducing NO_x emissions leading to higher N_2O emissions as a by-product. This is slightly offset by a reduction in the emissions from petrol cars due to a reduction in petrol car activity (as these are displaced by diesel cars) combined with a reduction in the implied emission factor for petrol cars between 2011 and 2012 as older, higher emitting catalyst cars are displaced by newer cars.

Within the time-series, emissions of CH_4 from road transport are lower in 2012 compared with 2011. This is mostly due to a reduction in emissions from petrol cars which are the largest source of methane emissions from road transport. The decrease is due to a reduction in petrol car activity (as these are displaced by diesel cars) combined with a reduction in the implied emission factor for petrol cars between 2011 and 2012 as older,

higher emitting cars are displaced by newer cars. The emission factors for newer cars are smaller due to tighter regulations on exhaust emissions of total hydrocarbons.

Methane emission factors for diesel vehicles are also lower in 2012 compared to 2011 due to tighter regulations on exhaust emissions of total hydrocarbons. The high rate of change in implied emission factor for CH_4 from diesel used by road transport across the time series reflects the large decrease in emission factors for heavy duty vehicles. This is a consequence of the fleet penetration of new vehicles meeting the higher Euro standards with low g/km emission factors following the trends in total hydrocarbons. These factors show a 93-97% reduction in Euro IV emissions relative to Euro I.

The fluctuations in the time-series of emissions from navigation partly reflect the fluctuations in the total fuel consumption statistics for marine fuels given in DUKES. The time-series for national navigation is derived from trends in port activity statistics for different vessel types. Some of these show an increase in activities over time, others a decrease in activities over the time series. Further erratic behaviour in the time-series for bunker fuels results from the method used to introduce consistency with consumption data in DUKES. Further details in the methodology are given in the previous sections on navigation.

The break in the time-series in national navigation emissions for residual oil and gas oil from 2007 onwards is due to the imposition of the Sulphur Emission Control Area (SECA) around UK waters from this year. It is assumed that the imposition of fuel sulphur content limits resulted in increased use of lower sulphur distillate (gas oil) compared with high sulphur residual oil. It was also assumed that passenger vessels switched from using residual oil to gas oil outside of SECAs from 2007 onwards to comply with the Sulphur Content in Marine Fuel Directive. As a consequence, the sum in emissions and fuel consumption from both fuels does not show a break, but there is an increase in gas oil emissions and a decrease in residual oil emissions from 2007.

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

Details of and justifications for recalculations to activity data are given in **Table 3.49** and emission factors in **Table 3.50** below. For information on the magnitude of recalculations to Source Category 1A3, see **Section 10**.

3.2.8.5.1 Recalculations and methodology changes for Road Transport (1A3b)

The following recalculations and revisions to input data were made to the road transport inventory:

- Revised DUKES data for petrol and diesel sales (2005-2007), particularly for diesel sales in 2007 (2% higher compared to the value used in the 2011 inventory).
- The method for calculating emissions of CH_4 and N_2O has been changed by normalising the emissions to fuel sales. This has the effect of increasing the estimate of CH_4 emissions in 2011 by 0.11 ktonnes (3.7% of all road transport emissions) and N_2O emissions in 2011 by 0.05 ktonnes (1.8% of all road transport emissions) compared with the previous inventory submission where the inventory was based on traffic data and not normalised to fuel sales. The difference in emissions calculated by the revised and previous methods varies by year and in some years normalising to fuel sales leads to a smaller estimate in emissions.

- Minor revisions to the 2011 vehicle km activity data for Northern Ireland as provided by the Department for Regional Development.
- Updated information from Transport for London on the composition of the bus and black cab taxi fleet operating in London
- Small revisions to the LGV fleet using LPG fuel have a small effect on emissions of CH_4 and N_2O emissions from LPG consumption.
- There have been recalculations to OT and CD estimates in this sector since the 2013 submission. The most significant is the increase seen in CO_2 emissions for Jersey, averaging a 6% increase between 1990 and 1999. This increase was due to a cell reference correction in the compilation spreadsheet reassigning the activity data to the correct year.

3.2.8.5.2 Recalculations and methodology changes for Navigation (1A3d)

The recalculations made for navigation are due to very minor changes in activity data for some sources. A small decrease in one of the activity drivers for domestic navigation led to a 0.5% reduction in gas oil consumption in 2010 and 2011. This was slightly offset by a small increase in the drivers used for inland waterways affecting 2010 and 2011 gas oil consumption. There was an overall increase in total gas oil consumption for navigation in DUKES which, given the reductions in 2010 and 2011 consumption by domestic sources explained above, leads to a net increase in gas oil consumption for international marine bunkers.

Table 3.49 1A3 Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
			1990	2011	1990	2011		
1A3a	Aircraft - domestic cruise	Aviation turbine fuel	0.250	0.347	0.262	0.351	Mt fuel consumed	Reallocation between domestic and international aviation following UNFCCC review. Smaller changes also made due to incorporation of local airport inventory data.
	Aircraft - domestic take-off and landing	Aviation spirit	0.0210	0.0184	0.0210	0.0179	Mt fuel consumed	Reallocation between domestic and international aviation following UNFCCC review. Smaller changes also made due to incorporation of local airport inventory data.
		Aviation turbine fuel	0.1076	0.1145	0.1189	0.1184	Mt fuel consumed	Reallocation between domestic and international aviation following UNFCCC review. Smaller changes also made due to incorporation of local airport inventory data.
	Aircraft between UK and CDs - TOL	Aviation spirit	0.0017	0.0017	0.0017	0.0020	Mt fuel consumed	Reallocation between domestic and international aviation following UNFCCC review. Smaller changes also made due to incorporation of local airport inventory data.
		Aviation turbine fuel	0.014	0.017	0.015	0.018	Mt fuel consumed	Reallocation between domestic and international aviation following UNFCCC review. Smaller changes also made due to incorporation of local airport inventory data.
	Aircraft between UK and Gibraltar - Cruise	Aviation turbine fuel	0.0162	0.0167	0.0162	0.0174	Mt fuel consumed	Reallocation between domestic and international aviation following UNFCCC review. Smaller changes also made due to incorporation of local airport inventory data.
	Aircraft between UK and Gibraltar - TOL	Aviation turbine fuel	0.0018	0.0016	0.0019	0.0018	Mt fuel consumed	Reallocation between domestic and international aviation following UNFCCC review. Smaller changes also made due to incorporation of local airport inventory data.
	Aircraft between UK and other Ots (excl Gib.) - Cruise	Aviation turbine fuel	0.0529	0.0557	0.0528	0.0402	Mt fuel consumed	Reallocation between domestic and international aviation following UNFCCC review. Smaller changes also made due to incorporation of local airport inventory data.
	Aircraft between UK and other OTs (excl Gib.) - TOL	Aviation turbine fuel	0.0023	0.0025	0.0024	0.0021	Mt fuel consumed	Reallocation between domestic and international aviation following UNFCCC review. Smaller changes also made due to incorporation of local airport inventory data.
1A3b	Road transport - cars (Bermuda only)	DERV	0.006	0.006	0.006	0.005	Mt fuel consumed	Newly available activity data provided by Bermuda Government, affects time series from 2009 onwards.
	Road transport - HGV (Bermuda only)	DERV	0.003	0.001	0.003	0.004	Mt fuel consumed	Newly available activity data provided by Bermuda Government, affects time series from 2009 onwards.
	Road transport - LGVs (Bermuda only)	DERV	0.011	0.007	0.011	0.005	Mt fuel consumed	Newly available activity data provided by Bermuda Government, affects time series from 2009 onwards.
	Road transport - mopeds and motorbikes (Bermuda only)	Petrol	0.005	0.004	0.005	0.005	Mt fuel consumed	Newly available activity data provided by Bermuda Government, affects time series from 2009 onwards.

IPCC Category	Source Name	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
			1990	2011	1990	2011		
	Road transport - cars (Falkland Islands only)	DERV	0.000	0.001	0.000	0.000	Mt fuel consumed	Latest information provided by the Falklands Government updates all of petrol & DERV time series with minor revisions (data only ever provided from 2002 onwards)
	Road transport - HGV (Falkland Islands only)	DERV	0.001	0.001	0.001	0.002	Mt fuel consumed	Latest information provided by the Falklands Government updates all of petrol & DERV time series with minor revisions (data only ever provided from 2002 onwards)
1A3d	Inland goods-carrying vessels	Gas oil	0.0038	0.0019	0.0038	0.0022	Mt fuel consumed	Increase in DfT statistic on waterborne goods lifted on inland waterways used as the activity driver for fuel consumption for inland goods carrying vessels
	Motorboats / workboats (e.g. canal boats, dredgers, service boats, tourist boats, river boats)	DERV	0.028	0.093	0.028	0.092	Mt fuel consumed	Small decrease in activity driver used for leisure boats – ONS statistic on household expenditure on leisure and culture.
		Petrol	0.0220	0.0572	0.0220	0.0568	Mt fuel consumed	Small decrease in activity driver used for leisure boats – ONS statistic on household expenditure on leisure and culture.
	Personal watercraft e.g. jet ski	Petrol	0.011	0.038	0.011	0.037	Mt fuel consumed	Small decrease in activity driver used for leisure boats – ONS statistic on household expenditure on leisure and culture.

Table 3.50 1A3 Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	Pollutant	Activity Name	2013 submission 1990	2013 submission 2011	2014 submission 1990	2014 submission 2011	Units	Comment/Justification
1A3a	Aircraft - domestic take-off and landing	CH4	Aviation spirit	1.9677	1.5548	1.8777	0.7453	kt / Mt	Inclusion of local airport inventories
			Aviation turbine fuel	0.8018	0.1642	0.8421	0.1661	kt / Mt	Inclusion of local airport inventories
	Aircraft between UK and CDs - TOL	CH4	Aviation spirit	1.9398	1.6675	1.8698	0.8615	kt / Mt	Inclusion of local airport inventories
			Aviation turbine fuel	1.8103	0.2763	1.8664	0.2780	kt / Mt	Inclusion of local airport inventories
	Aircraft between UK and Gibraltar - TOL	CH4	Aviation turbine fuel	0.1123	0.1437	0.1126	0.1306	kt / Mt	Inclusion of local airport inventories
	Aircraft between UK and other OTs (excl Gib.) - TOL	CH4	Aviation turbine fuel	0.7754	0.2193	0.7418	0.0787	kt / Mt	Inclusion of local airport inventories
1A3b	Road transport - cars	CH4	Petrol	1.016	0.108	1.017	0.113	kt / Mt	Change in method to calculate emissions based on fuel sold in response to feedback from the Expert Review Team during 2013. Previous method based on km travelled. This has the effect of changing IEFs.
		N2O	Petrol	0.061	0.023	0.061	0.024	kt / Mt	Change in method to calculate emissions based on fuel sold in response to feedback from the Expert Review Team during 2013. Previous method based on km travelled. This has the effect of changing IEFs.
	Road transport - LGVs	CH4	Petrol	0.885	0.187	0.885	0.196	kt / Mt	Change in method to calculate emissions based on fuel sold in response to feedback from the Expert Review Team during 2013. Previous method based on km travelled. This has the effect of changing IEFs.

IPCC Category	Source Name	Pollutant	Activity Name	2013 submission 1990	2013 submission 2011	2014 submission 1990	2014 submission 2011	Units	Comment/Justification
		N2O	Petrol	0.053	0.054	0.053	0.057	kt / Mt	Change in method to calculate emissions based on fuel sold in response to feedback from the Expert Review Team during 2013. Previous method based on km travelled. This has the effect of changing IEFs.
	Road transport - HGV	CH4	DERV	0.438	0.061	0.454	0.063	kt / Mt	Change in method to calculate emissions based on fuel sold in response to feedback from the Expert Review Team during 2013. Previous method based on km travelled. This has the effect of changing IEFs.
		N2O	DERV	0.102	0.079	0.106	0.082	kt / Mt	Change in method to calculate emissions based on fuel sold in response to feedback from the Expert Review Team during 2013. Previous method based on km travelled. This has the effect of changing IEFs.
	Road transport - buses and coaches	N2O	DERV	0.135	0.055	0.135	0.056	kt / Mt	Update to data on London bus fleet composition and bus activity data in N Ireland
	Road transport - mopeds and motorbikes	CH4	Petrol	6.015	2.898	6.016	3.033	kt / Mt	Change in method to calculate emissions based on fuel sold in response to feedback from the Expert Review Team during 2013. Previous method based on km travelled. This has the effect of changing IEFs.
		N2O	Petrol	0.056	0.054	0.056	0.057	kt / Mt	Change in method to calculate emissions based on fuel sold in response to feedback from the Expert Review Team during 2013. Previous method based on km travelled. This has the effect of changing IEFs.
	Road transport - all vehicles LPG use	CH4	LPG		0.0006		0.0005	kt / Mth	Revisions to the composition of the LGV fleet used in the calculation of LPG emission factors
		N2O	LPG		0.0002		0.00014	kt / Mth	Revisions to the composition of the LGV fleet used in the calculation of LPG emission factors

3.2.8.6 Source Specific Planned Improvements

Emission factors, activity data and estimating methodology are continuously kept under review as new information emerges.

Most of the improvements in the transport sectors will depend on the availability of new or revised forms of activity data and emission factors and not all of these can be anticipated at this stage. Particularly for the road transport sector, the evidence to base changes in emission factors and new methods is a fast developing and changing area. A watching brief is kept on developments in emission factors and activity data for all modes of transport.

3.2.9 Source Category 1A4 – Other Sources

3.2.9.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	1A4a: Miscellaneous	T1	CS, D
	Public Sector Combustion	T1	CS, D
	Railways (Stationary Sources)	T1	CS, D
	1A4b: Domestic	T2	CS, D
	Domestic, House & Garden Machinery	T2, T3	CR, CS
	1A4c: Agricultural engines	T1	CS
	Agriculture – mobile machinery	T2, T3	CR, CS
	Agriculture – stationary combustion	T1	CS, D
	Fishing vessels	T2, T3	CR, CS
Gases Reported	CO_2, CH_4, N_2O, CO, NO_x, SO_2, VOC		
Key Categories (Trends)	1A1, 1A2, 1A4, 1A5 Other Combustion, N_2O Stationary combustion-oil, CO_2		
Key Categories (Level)	1A1, 1A2, 1A4, 1A5 Other Combustion, N_2O Stationary combustion-coal, CO_2 Stationary combustion-gas, CO_2 Stationary combustion-oil, CO_2		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	The activity data and emissions data in the CRF includes the components from the OTs and CDs for the relevant fuels.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major changes to inventory methods in these source categories.		

This source category covers emissions from fuel combustion by non-industrial sectors including commercial, agricultural and public sector use of fuels, as well as domestic sector energy use, and fuels used by fishing vessels. The estimates cover both fuels burnt in stationary plant, as well as gas oil and petrol used in mobile machinery, off-road vehicles and fishing vessels.

Most stationary plants are small-scale, apart from a few large installations providing energy for large commercial or public sector buildings. Emissions from railway sources are reported under 1A4a Commercial/Institutional where the fuel is used in stationary sources such as the combustion of burning oil and fuel oil to heat buildings, as well as natural gas combustion. This gas usage may include fuel used for electricity generation for own use by the railway sector. The sector 'miscellaneous' source covers energy use by sectors covered elsewhere, for example fuels used in the sewage and refuse disposal sector, and fuels used by television and radio broadcasters.

Activity data estimates for domestic sector use of fuels derived from petroleum coke are based on annual estimates provided by industry experts (CPL, 2013).

Carbon dioxide emissions from the burning of lubricants in agricultural engines are also reported under 1A4. Separate estimates of non-CO_2 emissions from lubricant use are not included, as the emission factors derived for gas oil and petrol use in mobile machinery includes consideration of all fuel inputs to those engines, and hence to include factors from lubricants would introduce a double-count.

Emissions from mobile machinery used in agriculture and domestic house and gardens are reported under 1A4cii and 1A4bii, respectively.

The category 1A4ciii includes emissions from fishing vessels, including estimates of emissions from UK fishing vessels operating outside UK waters, which was a source reported for the first time within the 2013 UK inventory submission.

The NAEI category public service includes emissions from stationary combustion at military installations, which should ideally be reported under 1A5a Stationary. However, we do not have separate data for the military fuel component.

3.2.9.2 Methodological Issues

Table 3.51 summarises the methodologies used for the 1A4 source categories .

Table 3.51 Summary of Emission Estimation Methods for Source Categories in CRF Category 1A4

Source Category	Method	Activity Data	Emission Factors
Miscellaneous industrial /commercial combustion	AD x EF	DECC energy statistics	Carbon: UK-specific, including factors from coke manufacture carbon balance) CH_4, N_2O: IPCC, UK-specific
Public sector combustion	AD x EF	DECC energy statistics	
Railways - stationary combustion	AD x EF	DECC energy statistics	
Domestic combustion	AD x EF	DECC energy statistics	Carbon: UK-specific, including factors from coke manufacture carbon balance), default (IPCC) factors CH_4, N_2O: IPCC, USEPA, UK-specific
House and garden machinery	AD x EF	DECC energy statistics	Carbon: UK-specific CH_4, N_2O: UK-specific
Agriculture - stationary	AD x EF	DECC energy	Carbon: UK-specific, including

Source Category	Method	Activity Data	Emission Factors
combustion		statistics	factors from coke manufacture carbon balance) CH_4, N_2O: IPCC, UK-specific
Agricultural engines	AD x EF	Inventory agency estimate of fuel use by different mobile units	Carbon: UK-specific
Agriculture - mobile machinery	AD x EF	Inventory agency estimate of fuel use by different mobile units	Carbon: UK-specific CH_4, N_2O: UK-specific
Fishing vessels	AD x EF	Inventory agency estimate of fuel use across different shipping types, based on Entec 2010 study and DECC energy statistics	Carbon: UK-specific CH_4, N_2O: EMEP/EEA

For most sources, the estimation procedure follows that of the basic combustion module described in **Section 3.2.6.2.1**, using DECC reported fuel use data and emission factors from **Table A 3.2.2** to **Table A 3.2.5**.

Emissions from 1A4b Residential and 1A4c Agriculture/Forestry/Fishing are disaggregated into those arising from stationary combustion and those from off-road vehicles and other machinery. Off-road machinery is a major user of gas oil and this section describes the method used to allocate gas oil consumption across a range of categories that are covered under other IPCC codes, including 1A2 and 1A3. These include sources that use gas oil for stationary combustion in the industrial, commercial and public sectors and for other mobile engines. However, the GHGI still maintains consistency with the total UK consumption of gas oil reported in DUKES.

The method for estimating emissions from fishing reported under 1A4ciii, including those from activities outside UK waters was described in **Section 3.2.8.2.4.**

The method used to estimate emissions from all other types of off-road machinery engines covered in 1A4, but also in 1A2 and 1A3 is also described in **Section 3.2.10**.

3.2.9.3 Treatment of Gas Oil in the inventory

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 the data resolution in DUKES does not distinguish between use of the fuel for stationary combustion and off-road machinery, a distinction which is necessary for the inventory.

The GHGI estimates consumption of gas oil and emissions for off-road machinery using a bottom-up method based on estimates of population and usage of different types of machinery. However, this has led to a situation where the total amount of gas oil

consumption across sectors exceeds that which is available as given in DUKES. Therefore consumption figures, mainly for stationary combustion in industry sectors, have had to be adjusted to obtain a total fuel balance.

The problem is extended when new sources of gas oil consumption are found. For example, the recent development of an inventory for the UK's inland waterways requires the allocation of gas oil to this sector (Walker et al, 2011). During the process of compiling the inland waterways inventory, it became clear that not all vessels with diesel engines use gas oil, but use road diesel and that this may also be the case for other off-road machinery sources, especially those that consume small amounts of fuel on an irregular basis, e.g. for private or recreational use rather than commercial use. There are also inconsistencies in terminology used to define types of fuel; it became apparent that the terms "gas oil", "red diesel" and "diesel" are used interchangeably by fuel suppliers and consumers and this confuses the situation when considering fuel allocations across different sectors.

In light of this, Task 5 of the 2011 UK GHG Inventory Improvement Programme aimed to address the allocation of gas oil and DERV in the GHGI (Murrells et al., 2011). The methodology outlined in Murrells et al. (2011) was used in the compilation of the 2011 inventory, and is summarised here. The same approach has been used in this inventory.

Several fuel suppliers and experts in the petroleum industry and at the Department for Transport were consulted to understand terminologies used, the physical differences between gas oil and DERV, and to gauge opinions on what determines where the fuels are mainly used where it is possible to use either gas oil or DERV. The study concluded that while the majority of agricultural and industrial machinery will be using low tax gas oil (red diesel), a small amount of DERV is likely to be used by private recreational boat users and by equipment with small engines used for private or small-scale commercial use on an irregular basis and the gas oil fuel supply infrastructure makes it more convenient to use DERV.

The study provided new estimates of the amount of DERV and petrol consumed by non-road transport sources with small internal combustion engines. This reduces the overestimation of gas oil consumption and relieves the pressure on how much gas oil consumption by other sources has to be adjusted to match the total amount available as given in DUKES.

The study also considered the allocation of gas oil given in DUKES to different industry and other sectors and how these can be mapped to inventory reporting categories. The detailed bottom-up method is used to estimate gas oil consumption by different off-road machinery and marine vessel types. Independent sources were used to estimate gas oil used by the rail sector while data provided by industrial sites reporting under emission trading schemes (EU ETS) were used to derive an allocation of gas oil consumption by stationary combustion sources in different industry, commercial and other sectors. Also, the UK energy statistics now include an allocation of gas oil for consumption by the oil and gas sector, but since only a partial time series was made available, the study included making estimates of gas oil for this category back to 1990.

A method of re-allocation was developed using an over-arching condition that the total sum of gas oil consumption across all sectors was consistent with the total consumption figures given in DUKES across all years. The method allowed the consumption estimates for industrial off-road machinery and stationary combustion by industry, commercial and public sector activities to vary in order to align the total consumption estimates with DUKES on the basis that the estimates for these sources are the most uncertain.

Details of the methodology were given in Murrells et al (2011). The report considers the uncertainties in the sector allocations and makes recommendations on how these can be improved based on current activities known to be taking place in the UK to understand the allocation of gas oil across some sectors. The method was first applied to the UK inventory reported in 2012 and the application of the method to define the allocation of gas oil consumption for all source categories across the time series from 1990-2010 was described in the 2012 UK National Inventory Report. The same allocation method has been applied across the current time series for this version of the inventory.

3.2.10 Estimation of Off-Road Machinery Sources (1A2fii, 1A4bii, 1A4cii, 1A3e)

The following is a summary of the methods used to develop the inventory for off-road machinery and recalculations and methodological changes made in the 2014 submission of the inventory:

Summary of Methodology
A Tier 3 methodology is used for calculating emissions from individual types of mobile machinery, including those covered under 1A2fii (industrial and construction) and 1A3e (aircraft support).

Summary of emission factors
Machinery or engine-specific fuel consumption and emission factors (g/kWh) are taken from EMEP-EEA Guidebook. Emission factors for more modern machinery based on engine or machinery-specific emission limits established in EU Non-Road Mobile Machinery Directive.

Summary of activity data
Bottom-up estimates from population and hours of use of equipment in 2004. Various proxy statistics used as activity drivers for different groups of machinery types to estimate fuel consumption in other years.

Summary of recalculations and methodology changes
There are no major recalculations or methodology changes since the 2013 submission.

3.2.10.1 Details of Methodology

Emissions are estimated for 77 different types of portable or mobile equipment powered by diesel or petrol driven engines. These range from machinery used in agriculture such as tractors and combine harvesters; industry such as portable generators, forklift trucks and air compressors; construction such as cranes, bulldozers and excavators; domestic lawn mowers; aircraft support equipment. In the inventory they are grouped into four main categories:

- domestic house & garden – reported under 1A4b
- agricultural power units (includes forestry) – reported under 1A4c
- industrial off-road (includes construction and quarrying) – reported under 1A2f
- aircraft support machinery – reported under 1A3e.

Emissions are calculated from a bottom-up approach using machinery- or engine-specific emission factors in g/kWh based on the power of the engine and estimates of the UK population and annual hours of use of each type of machinery.

The emission estimates are calculated using a modification of the methodology given in EMEP/ CORINAIR (1996). Emissions are calculated using the following equation for each machinery class:

$E_j = N_j \cdot H_j \cdot P_j \cdot L_j \cdot W_j \cdot (1 + Y_j \cdot a_j / 2) \cdot e_j$

where

E_j = Emission of pollutant from class j (kg/y)
N_j = Population of class j.
H_j = Annual usage of class j(hours/year)
P_j = Average power rating of class j(kW)
L_j = Load factor of class j(-)
Y_j = Lifetime of class j (years)
W_j = Engine design factor of class j(-)
a_j = Age factor of class j(y^{-1})
e_j = Emission factor of class j(kg/kWh)

For petrol-engined sources, evaporative NMVOC emissions are also estimated as:

$E_{vj} = N_j \cdot H_j \cdot e_{vj}$

where

E_{vj} = Evaporative emission from class jkg
evj = Evaporative emission factor for class jkg/h

The population, usage and lifetime of different types of off-road machinery were updated following a study carried out by the inventory agency on behalf of the Department for Transport (Netcen, 2004a). This study researched the current UK population, annual usage rates, lifetime and average engine power for a range of different types of diesel-powered non-road mobile machinery. Additional information including data for earlier years were based on research by Off Highway Research (2000) and market research polls amongst equipment suppliers and trade associations by Precision Research International on behalf of the former DoE (Department of the Environment) (PRI, 1995, 1998). Usage rates from data published by Samaras *et al* (1993, 1994) were also used.

The population and usage surveys and assessments were only able to provide estimates on activity of off-road machinery for years up to 2004. These are one-off studies requiring intensive resources and are not updated on an annual basis. There are no reliable national statistics on population and usage of off-road machinery nor figures from DECC on how these fuels, once they are delivered to fuel distribution centres around the country, are ultimately used. Therefore, other activity drivers were used to estimate activity rates for the four main off-road categories from 2005-2012.

For industrial and construction machinery, a set of four drivers is used. Each of the individual machinery types is mapped to one of these four drivers depending on the typical industry sector in which the machinery type is usually used. The four categories and drivers used are described in **Table 3.52**.

For domestic house and garden machinery, historic and projected trends in number of households are used (CLG, 2011), for airport machinery, statistics on number of terminal passengers at UK airports are used (CAA, 2013), and for agricultural off road machinery, the trends in gas oil allocated to agriculture in DUKES (DECC, 2013) are used.

Table 3.52 Activity drivers used for off-road machinery in the industry and construction sector.

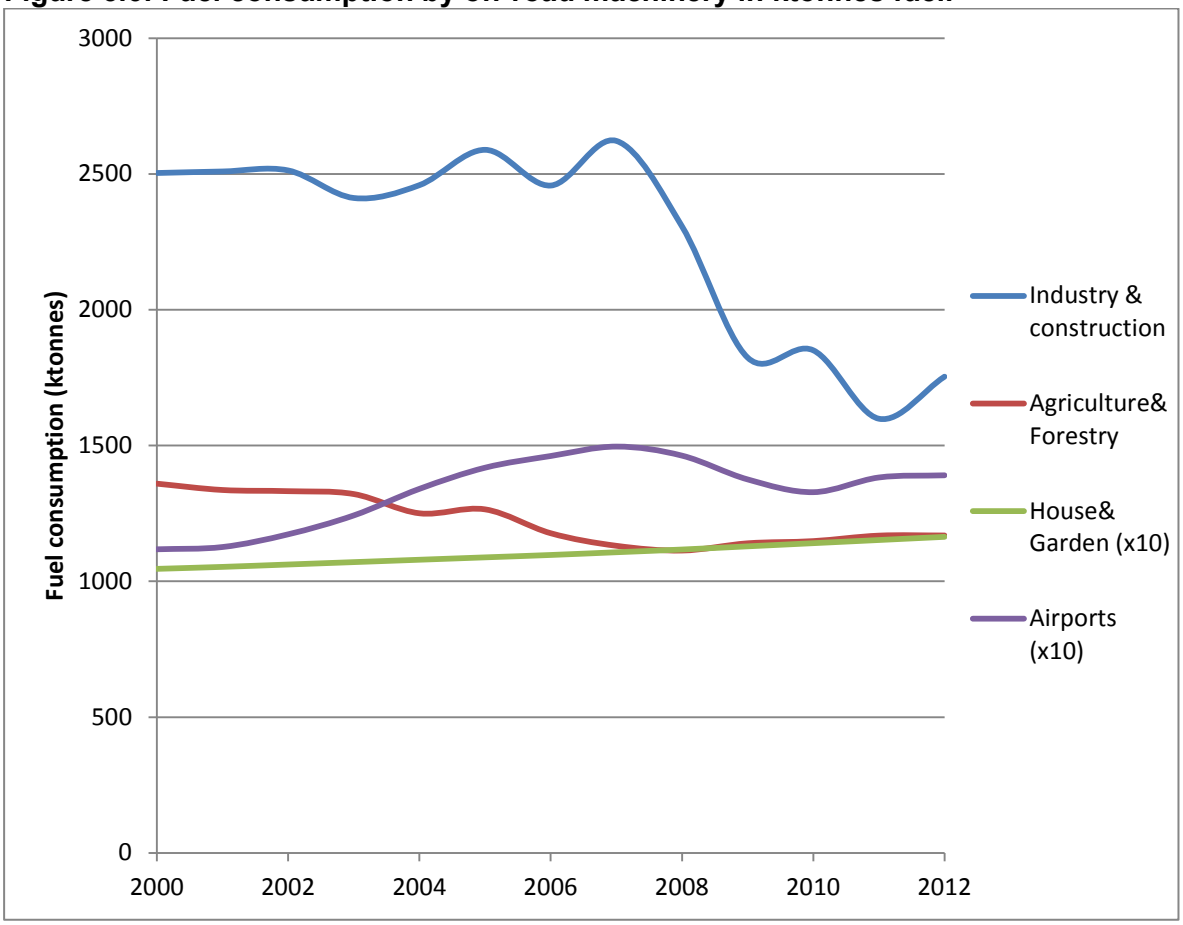
Category	Driver source	Machinery types
Construction	ONS construction statistics. "Output in the Construction Industry. Supplementary Tables July 2013", http://www.ons.gov.uk/ons/datasets-and-tables/index.html?pageSize=50&sortBy=none&sortDirection=none&newquery=Output+in+the+Construction+Industry&content-type=Reference+table&content-type=Dataset Table 3 – Value of construction output in Great Britain: non-seasonally adjusted. The value of all new work (i.e. excluding repair and maintenance work) at constant (2005) prices. The seasonally non-adjusted figures were used and scaled to ensure time series consistency.	generator sets <5 kW
		generator sets 5-100 kW
		asphalt pavers
		tampers /rammers
		plate compactors
		concrete pavers
		rollers
		scrapers
		paving equip
		surfacing equip
		trenchers
		concrete /industrial saws
		cement & mortar mixers
		cranes
		graders
		rough terrain forklifts
Quarrying	Data on UK production of minerals, taken from UK Minerals Yearbook data, BGS (2013).	bore/drill rigs
		off highway trucks*
		crushing/processing equip
Construction and Quarrying	Growth driver based on the combination of the quarrying and construction drivers detailed above.	excavators
		loaders with pneumatic tyres
		bulldozers
		tracked loaders
		tracked bulldozers
		tractors/loaders
		crawler tractors
		off highway tractors
		dumpers /tenders
General Industry	Based on an average of growth indices for all industrial sectors, taken from data supplied by DECC for use in energy and emissions projections.	generator sets 100-1000KW
		pumps
		air compressors
		gas compressors
		welding equip
		pressure washers
		aerial lifts
		forklifts*
		sweepers/ scrubbers
		other general industrial equip
		other material handling equip

Having calculated fuel consumption from a bottom-up method, the figures for diesel engine machinery were allocated between gas oil and road diesel. This was following a survey of fuelling practices of uses of off-road machinery where it was found that, particularly for small, non-commercial and domestic users who may only occasionally need to refuel, engines are filled with road diesel rather than gas oil. A further fuel reconciliation procedure was then followed for gas oil which took account of consumption from all sources, as described in

Section 3.2.9.2. If UK total consumption figures given in DUKES for gas oil exceeded that calculated for each source, the figure for gas oil consumption from industrial machinery was reduced to bring alignment with DUKES. The reason for making the reduction specifically to industrial and construction machinery use of gas oil rather than other sectors is because this source is considered to have the most uncertain estimates of activity due to the large and varied nature of machinery included.

Figure 3.6 shows the trend in total fuel consumption for the four main off-road categories since 2000. These include the combined consumption of gas oil, road diesel and petrol by each sector. The figures for airport machinery and house and garden machinery are multiplied by ten to put on the same scale as consumption by industry and construction machinery and agricultural machinery. The recent fall in consumption for the industry and construction machinery sector reflects the fuel reconciliation process used, but may also be explained by the recent economic downturn, particularly in the construction sector.

Figure 3.6: Fuel consumption by off-road machinery in ktonnes fuel.



A simple turnover model is used to characterise the population of each machinery type by age (year of manufacture/sale). For older units, the emission factors used came mostly from EMEP-EEA (1996) though a few of the more obscure classes were taken from Samaras & Zierock (1993). The load factors were taken from Samaras (1996). Emission factors for garden machinery, such as lawnmowers and chainsaws were updated following a review by Netcen (2004b). For equipment whose emissions are regulated by Directive 2002/88/EC or 2004/26/EC, the emission factors for a given unit were taken to be the maximum permitted by the directive at the year of manufacture. The emission regulations are quite complex in

terms of how they apply to different machinery types. Each of the 77 different machinery types was mapped to the relevant regulation in terms of implementation date and limit value.

The methodology follows the Tier 3 methodology described in the latest EMEP/EEA emission inventory guidebook (EMEP/EEA, 2009).

Aggregated emission factors for the four main off-road machinery categories in 2012 are shown in **Table 3.53** by fuel type.

The emission factors shown here for 2012 are generally the same as or lower than the factors for 2011. This is a consequence of the penetration of new machinery meeting the tighter emission regulations in the non-road mobile machinery fleet. The factors for SO_2 in 2012 reflect the sulphur content of fuels used, according to figures provided by UKPIA (2013).

Table 3.53 Aggregate Emission Factors for Off-Road Source Categories in 2012 (t/kt fuel)

Source	Fuel	C[1]	CH_4	N_2O	NO_x	CO	SO_2[2]	NMVOC
Domestic House&Garden	DERV	863	0.16	1.31	48.0	4.34	0.01	2.57
Domestic House&Garden	Petrol	855	0.69	0.03	3.27	668	0.01	31.7
Agricultural Power Units	Gas oil	870	0.16	1.32	19.9	16.8	0.02	3.76
Agricultural Power Units	Petrol	855	2.17	0.02	1.45	716	0.01	249
Industrial Off-road	DERV	863	0.13	1.27	29.2	15.5	0.02	5.84
Industrial Off-road	Gas oil	870	0.13	1.27	29.2	15.5	0.02	5.84
Industrial Off-road	Petrol	855	3.76	0.05	6.24	1035	0.01	39.3
Aircraft Support	Gas oil	870	0.14	1.34	21.9	12.52	0.02	4.08

[1] Emission factor as kg carbon/t, UKPIA (2004)
[2] Based on sulphur content of fuels in 2012 from UKPIA (2013).

3.2.10.2 Uncertainties and Time Series Consistency

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

Fuel consumption by these off-road machinery sources is not provided in DUKES so is estimated for each machinery type from a bottom-up Tier 3 approach to derive machinery population and usage rates. There are no centralised statistics on machinery population and usage so the uncertainties are considered quite high. An overall fuel balance taking account of consumption by other uses of gas oil, diesel and petrol ensures consistency with total consumption figures in DUKES. Various proxy data are used to establish a consistent time-series in activity rates, as explained in this section.

3.2.10.3 Source Specific QA/QC and Verification

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

3.2.10.4 Source Specific Recalculations

Details of and justifications for recalculations to activity data are given in **Table 3.54** and emission factors in **Table 3.55** below. For information on the magnitude of recalculations to Source Category 1A4, see **Section 10**.

For the OTs and CDs, there have been recalculations in this sector since the 2013 submission. There was an increase of approximately 55% in emissions from 1A4a for Jersey (2009, 2010 and 2011) due to the supply of new data for fuel oil consumption in 2012, which led to recalculations in years which had been based on an extrapolation of 2012. There was a decrease of approximately 90% across the time series for emissions from 1A4b from the Falkland Islands. This was due a correction in the conversion factor used for the fuel activity data and decreased emissions by 230kt CO_2 in 2011.

Table 3.54 1A4 Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
			1990	2011	1990	2011		
1A4a	Miscellaneous industrial/commercial combustion	Coal	0.314	0.015	0.314	0.014	Mt fuel consumed	Revision to DUKES
1A4a	Miscellaneous industrial/commercial combustion	Fuel oil	0.1738	0.0765	0.1738	0.0729	Mt fuel consumed	Revision to allocation of fuel oil to Crown dependencies
1A4a	Miscellaneous industrial/commercial combustion	Natural gas	1667	1590	1667	1674	Mth fuel consumed	Revision to DUKES
1A4a	Public sector combustion	Natural gas	1207	1208	1207	1690	Mth fuel consumed	Revision to DUKES
1A4b	Domestic combustion	Peat	0.351	0.035	0.351	0.037	Mt fuel consumed	Revised estimate of peat consumed as fuel in Scotland
1A4b	Domestic combustion	Petroleum coke	0.025	0.110	0.025	0.130	Mt fuel consumed	Updated estimate for petroleum coke use in domestic fuels
1A4c	Agriculture - stationary combustion	Natural gas	34.2	62.4	34.2	60.7	Mth fuel consumed	Revision to DUKES
1A4c	Agriculture - stationary combustion	Straw	0.191	0.496	0.191	0.480	Mt fuel consumed	Revision to DUKES
1A4a	Miscellaneous industrial/commercial combustion (Guersey only)	Fuel oil	0.005	0.005	0.005	0.004	Mt fuel consumed	Correction of error
1A4b	Domestic combustion (Guernsey only)	Burning oil	0.014	0.014	0.014	0.011	Mt fuel consumed	Correction of error
1A4a	Miscellaneous industrial/commercial combustion (Jersey only)	Fuel oil	0.005	0.000	0.005	0.005	Mt fuel consumed	New data received from Jersey Government
1A4a	Miscellaneous industrial/commercial combustion (Gibraltar only)	Natural gas	0.748	0.481	0.748	0.401	Mth fuel consumed	New data received from Gibraltar Government
1A4b	Domestic combustion (Falkland Islands only)	Natural gas	22.5	43.3	0.3	0.5	Mth fuel consumed	Correction of error

Table 3.55 1A4 Source specific recalculations to emission factors since previous submission

IPCC Category	Source Name	Pollutant	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
				1990	2011	1990	2011		
1A4a	Miscellaneous industrial/commercial combustion	Carbon	Coke	813.2	847.2	832.1	810.3	kt C / Mt	Revised time series of coke EFs from updated carbon balance for coke ovens
1A4a	Public sector combustion	Carbon	Coke	813.2	847.2	832.1	810.3	kt C / Mt	Revised time series of coke EFs from updated carbon balance for coke ovens
1A4a	Railways - stationary combustion	Carbon	Coke	813.2	847.2	832.1	810.3	kt C / Mt	Revised time series of coke EFs from updated carbon balance for coke ovens
1A4b	Domestic combustion	Carbon	Anthracite	813.4	816.1	813.4	837.9	kt C / Mt	Correction to 2011 emission factor based on GCV values in DUKES
1A4b	Domestic combustion	Carbon	Coke	813.2	847.2	832.1	810.3	kt C / Mt	Revised time series of coke EFs from updated carbon balance for coke ovens
1A4c	Agriculture - stationary combustion	Carbon	Coke	813.2	847.2	832.1	810.3	kt C / Mt	Revised time series of coke EFs from updated carbon balance for coke ovens

3.2.10.5 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**.

3.2.11 Source Category 1A5 – Other

3.2.11.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	1A5b: Aircraft Military Shipping Naval	T3 T2	CS, D CS, D
Gases Reported	CO_2, CH_4, N_2O, CO, NO_x, SO_2, VOC		
Key Categories (Trends)	1A1, 1A2, 1A4, 1A5 Other Combustion, N_2O		
Key Categories (Level)	1A1, 1A2, 1A4, 1A5 Other Combustion, N_2O		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	No emissions reported separately – all included within UK emission totals.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements.		

3.2.11.2 Methodological Issues

Emissions from military aircraft and naval vessels are reported under 1A5b Mobile. The method of estimation is discussed in the **Section 3.2.8.2.1** on aviation (1A3a) and **Section 3.2.8.2.4** on navigation (1A3d), respectively. Note that military stationary combustion is included under 1A4a Commercial and Institutional due to a lack of more detailed data.

3.2.11.3 Uncertainties and Time Series Consistency

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

3.2.11.4 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**.

3.2.11.5 Source Specific Recalculations

Details of and justifications for recalculations to activity data are given in **Table 3.56** below. For information on the magnitude of recalculations to Source Category 1A5, see **Section 10**.

3.2.11.6 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.

Table 3.56 1A5 Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
			1990	2011	1990	2011		
1A5b	Aircraft - military	Aviation spirit	0.0000	0.0000	0.0000	0.0001	Mt	Revised activity data received from the Ministry of Defence from 2010 onwards.

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

Emissions sources	Sources included	Method	Emission Factors
	1B1a: Deep-Mined Coal	T3	CS
	Coal Storage & Transport	T2	CS
	Open-Cast Coal	T2	CS
	1B1b: Charcoal Production	T1	D
	Coke Production (Fugitive)	T3	CS, OTH
	SSF Production (Fugitive)	T3	CS, OTH
	Iron & steel flaring (Coke Oven Gas)	T3	CS, OTH
	1B1c: Closed Coal Mines	T3	CS
Gases Reported	CO_2, CH_4, N_2O, CO, NO_x, SO_2, VOC		
Key Categories (Trends)	None identified		
Key Categories (Level)	Mining & Solid Fuel Transformation, CH_4 (Base yr only)		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Emissions from 1B1b – charcoal production, included for the Falkland Islands		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements since last submission.		

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 (SSF). Emissions also occur from the flaring of waste gases during coke and SSF manufacture.

In 2012 there were 13 deep-mining collieries operational, of which 4 have methane drainage and recovery systems used to collect and burn mines gas to raise power. A further 32 open cast coal mines were also operating in the UK in 2012. This is compared with 188 deep mining collieries and 126 open cast mines operating in 1990[29].

The reported emission trends for deep-mined coal in the UK reflect the decline in activity since the base year, with activity in 2012 (6.2 Mt coal) only 8.5% of that in 1990 (73 Mt coal). The decline in open-cast production is much less marked, with production in 2012 (10.1 Mt) 56% of that in 1990 (18.1 Mt).

[29] http://coal.decc.gov.uk/assets/coal/DyGgJafg_pdf_part.pdf

3.3.1.2 Methodological Issues

1B1a Coal Mining and Handling
1B1ai Underground mines, Mining Activities: Deep-mined coal.
1B1ai Underground mines, Post-Mining Activities: Coal storage and transport.
1B1aii Surface Mines, Mining Activities: Open-cast coal.

Emissions are calculated from saleable coal production statistics reported by DECC (2013). For all sources, UK-specific emission factors are applied, which in the early part of the time series are derived from periodic industry publications, and for later years (1998 onwards) are primarily derived from company-specific or mine-specific reporting of methane emissions by mine operators. Industry-wide colliery methane utilisation data are taken from DUKES (DECC, 2013).

From 1990-1995, a small number of "deep mines" operated in the UK were privately owned, shallower and smaller mines. These mines were licensed by the UK Government and in all years produced less than 3% of total UK deep-mined coal, whilst the majority of deep mines were Government-owned and operated. Research from 1995 indicated that these smaller licensed mines emitted less methane than the nationalised deeper mines, and therefore the aggregate emission factor for the early part of the time series is slightly lower. Activity data for production at licensed mines is taken from Barty (1995), with the activity data for non-licensed mines calculated by difference from the UK deep-mine coal production total in UK energy statistics.

Emission factors for methane from **deep-mined coal** production are taken from:

1990-1992 Bennet et al (1995) was a study on deep mines which produced estimates of emissions for the period 1990-93. This was a period over which significant numbers of mines were being closed, hence the range in emission factors from 10 to 13.1 kg CH_4 per tonne coal extracted.

1990-1995 The methane emission factor of 1.36 kg CH_4/tonne coal produced at licensed, shallow mines is from Williams (1993).

1993-1997 No time series of emissions data or industry research for deep-mined mines are available for 1993-97, and therefore the 1998 factor from operator reporting at deep mines (see below) is used. The combination of this 1998 factor for deep-mined coal and the lower factor for licensed, shallow mines operating to 1995 leads to a variable aggregate factor during 1993-1995.

1998-2012 The emission factors for UK mines in 1998-2012 are based on operator measurements of the methane extracted by the mine ventilation systems for all collieries operated by UK Coal (UK Coal, 2013) and for collieries owned by other operators that report methane utilisation and venting data (Coal Authority, 2013). Not all UK collieries provide data on methane utilisation and venting. The emission factor derived from the sites that provide data is applied across all UK production at deep mined sites. The proportion of UK production that is covered by the reporting collieries ranges from 77% in 1998 to 96% in 2004 and 2007, and is around 90% since 2008.

Methane extracted at deep mines is either emitted into the atmosphere or utilised for energy production; the gas is not flared for safety reasons. Data provided by colliery operators provides mine-specific annual data on the mass of methane:

- vented to atmosphere, fan drift (A)
- drainage to surface (B)
- utilisation of methane in electricity generation (C)

The total methane vented to atmosphere is therefore calculated as “A + B – C”.

The decline in methane emissions in recent years in the UK reflects both the decline in UK deep-mined coal production and the increase in uptake of technology to utilise coal mine methane to generate electricity.

The emission factor for methane from **coal storage and transport** factor of 1.16 kg CH_4 per tonne of coal produced is only applied to deep mined coal production and is taken from industry research, Bennet et al (1995).

The emission factor for methane emissions from **open cast coal production** of 0.34 kg CH_4 per tonne of coal production is taken from industry research, Williams (1993). The total emissions from open-cast mining are based on measurements of the total methane content of freshly sampled coal cores from open-cast sites from the three main producing regions in the UK (see **Annex A 3.2.4** for further details). These data are used to generate the total emission factor for all open-cast coal production, regardless of the stage at which this emission takes place. i.e. it is assumed in the UK GHGI estimation method that all of the measured methane content of the coal is released prior to combustion, and these emissions are all allocated within 1B1aii open-cast coal mining (Mining activities). This is consistent with the IPCC GLs method where country-specific data are used, in section 1.7.2.4, Equation 5 and the text on page 1.111: "In most cases, if the Tier 2 approach is used to estimate methane emissions from surface mines, post-mining emissions from surface-mined coals are assumed to be zero." As a result, the UK estimate for open-cast coal mining activities is likely to be an over-estimate, as some methane will be retained within the coal up to the point of combustion, especially for lump coal used in domestic grates, where desorption of the methane is much slower than for fine coal processed for use in other sources such as power stations. The basis for this open-cast coal production factor also explains why the EF on methane from coal storage and transport (see paragraph above) is only applied to the activity of deep-mined coal in the UK, rather than to the total UK coal production data; to apply it to open-cast production also would introduce a double-count.

The reported activity data in the CRF Table 1B1 for UK coal production used in the derivation of fugitive methane emission estimates comprises data for coal production at deep-mined and open-cast sites. In the UK energy balance, there is an additional line for coal production which is for “other” sources of coal into the UK economy, which are typically very small numbers (760 kt in 2012) and represent coal obtained from slurries, ponds and rivers. We therefore include the activity data for "other" sources of coal within the UK energy balance, as part of the overall supply of coal as reported in the CRF table 1.Ab, but we do not derive any estimates of fugitive emissions from this production source, as it is not coal that has been abstracted from open cast or deep mines. This leads to an apparent discrepancy in reported activity data between the CRF tables 1B1 and 1Ab. In 2012, the activity data in table 1B1 (excluding the coal from slurries / ponds) is 16.29 Mt, whereas the activity data in table 1Ab (including all UK coal sources) is 17.05 Mt. Similar reporting differences are evident across other years in the CRF.

1B1b Solid Fuel Transformation

Fugitive emissions from solid fuel transformation processes are reported in IPCC category 1B1b. The IPCC Revised 1996 Guidelines do not provide any methodology for such estimates, hence emissions are largely based on default emission factors.

Charcoal production.

Emissions from **charcoal production** were included in the UK GHG inventory for the first time in the 2013 submission. Emission estimates are based on UK activity data on charcoal production from FAOSTAT Forestry Production and Trade Statistics (FAO, 2013). These

data were available for the UK and the Falkland Islands but not for and other overseas territories or crown dependencies. The methane emission factor of 30 kt per Mt charcoal produced is derived from the default emission factors in table 1.14 of the IPCC 1996 Guidelines and an estimated NCV of charcoal of 30 MJ/kg from table 1.13 of the IPCC 1996 Guidelines.

Coke production.
Carbon emissions from coke ovens are based on a carbon balance approach (discussed in **Section 3.2.7**) with calculations arranged so that the total carbon emission, plus carbon in products and wastes, corresponds to the carbon content of the input raw materials. Emissions from the combustion of coke oven gas and blast furnace gas within the coke oven are based on this carbon balance approach, which allocates output carbon between the coke , coke oven gas, coal tars and benzoles that are produced in the coke oven, and is dependent on the country-specific carbon factor data applied for the coking coal input to the process.

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 A 3.2.9**.

The methane emission factor of 0.0802 kt per Mt coke produced is taken from the EIPPCB, Best Available Techniques Reference Document on the Production of Iron & Steel, March 2000 (EIPPCB, 2000).

Solid smokeless fuel production.
Emissions of carbon from **Solid Smokeless Fuel (SSF) production** are also based on a carbon balance approach, as discussed in **Section 3.2.7**. For other pollutants, estimates are either made based on a mass balance approach (for sulphur dioxide) or on SSF production data and emission factors as provided in **Table A 3.2.9**.

There are a number of SSF production processes used in the UK ranging from processes similar to coking which convert coal into smokeless fuels, to briquetting of anthracite dust and other naturally smokeless fuels. Given the range of processes in use, emission estimates will be very uncertain. It is possible that some emissions from SSF manufacture could arise from the combustion of off-gases produced during SSF manufacturing processes e.g. gases evolved from retorts used to manufacture some fuels, similar to the use of coke oven gas as a fuel in the coke manufacturing process. However, combustion of this type is not identified in the energy statistics and so emissions from SSF manufacture are treated as fugitive and reported under 1B1b.

In addition to coal, the manufacture of SSF involves the consumption of small quantities of coke oven coke in some years. This coke oven coke is treated as a fuel rather than a feedstock and the carbon within the coke is assumed emitted and reported under 1A1c.

Activity data for coal use in SSF manufacture are taken from UK energy statistics, DUKES (DECC, 2013), combining the sum of steam coal and anthracitic coal used in SSF manufacture. The emission factor is derived from the carbon balance approach which calculates total carbon lost (i.e. emitted) during the SSF manufacturing process, by subtracting the carbon retained in the SSF product from the sum of carbon inputs.

The methane emission factor of 0.0802 kt per Mt coke produced is taken from the EIPPCB, Best Available Techniques Reference Document on the Production of Iron & Steel, March 2000 (EIPPCB, 2000) and applied to the SSF production.

Iron and steel flaring of coke oven gas.
The activity data for **coke oven gas flaring in the iron and steel industry** is taken from the UK energy statistics, DUKES (DECC, 2013).

The carbon factor for coke oven gas is derived from the iron and steel integrated steelworks mass balance, as outlined in **Section 3.2.7**.

The methane emission factor of 0.0001 kt per Mth and the nitrous oxide emission factor of 0.00001 kt per Mth are taken from the factors presented for coke oven gas in the 2006 IPCC Guidelines. In previous years EMEP-EEA factors had been used; 2006 Guideline defaults are now used as no appropriate defaults are presented in either the 1996 Guidelines or the latest EMEP/EEA Guidebook.

1B1c Other Fugitive Emissions from Solid Fuels

Closed coal mines.

Methane emissions from **closed coal mines** are accounted for within Sector 1B1c of the UK inventory. Emission estimates are based on a recent study funded by DECC (WSP, 2011) which updated research from 2005 (White Young Green, 2005) to:

- reflect the UK trend in mine closures and re-openings driven by fluctuations in energy prices since the 2005 research; and
- improve the representation of methane recovery and utilisation at closed collieries (Colliery methane combustion emissions are reported in the energy sector, 1A).

The 2011 study derived estimates for historic methane emissions from closed coal mines and also generated projections to 2050, based on forecasts for UK coal mining activity. The 2012 emission estimates in this 2014 UK GHGI submission are therefore taken from the projections of emissions within the 2011 WSP report.

The UK model that was developed in 2005 and revised in 2011 generates both historic and projected methane emission estimates from closed UK coal mines, combining two separate sets of calculations to estimate emissions from:

- coal mines that were closed before 2005 and included in the 2005 update; and
- mines that were not included in the 2005 update, including mines closing or predicted to close between 2004 and 2028.

Methane emissions from closed mines reach the surface through many possible flow paths: vents, old mine entries, diffuse emission through fractured and permeable strata. Direct measurement of the total quantity of gas released from abandoned mines is not practical. The model uses a relationship between emissions and the quantity of the underlying methane gas within the abandoned mine workings, including site-specific considerations of the most appropriate decay model for the recently closed mines. The 2011 study used the same method, updating data for mine closures during 2005-2010. The research also includes benchmarking of UK specific estimates with other inventories to ensure that the method used remains appropriate for the UK.

The model calculates methane reserves for all UK coalfields that are not totally flooded from 1990 with projections to 2050. The gas reserves are calculated by totalling all the gas quantities in individual coal seams likely to have been disturbed by mining activity. To enable calculation of the reserves over time, the rise in water levels in the abandoned mines due to water inflow has been calculated based on industry consultation, with a date estimated for each of the mines to be fully flooded; as mine workings become flooded they cease to release significant amounts of methane to the surface.

The development of the model has drawn on industry monitoring to measure methane emission from vents and more diffuse sources, including measurement of the flow rate and methane concentrations of vented mine gases. The industry knowledge of these methane

sources has increased greatly in the UK over the last 10 years as the technology to capture and utilise the methane for power generation has developed alongside new economic incentives to utilise the mine methane in this way. Monitoring of more diffuse sources involves the collection of long-term gas samples to measure any increases in background atmospheric methane level in the locality.

Methane flows measured by both methods showed a general increase with the size of the underlying gas reserve. The data indicate an emission of 0.74% of the reserve per year as a suitable factor to apply to the methane reserve data in order to derive methane emission estimates for abandoned UK coalfields for 1990 to 2050, and this factor is applied within the model to derive the UK emission estimates.

Estimates have been made for both deep mined and open cast coal.

Table 3.57 Summary of data for closed coal mines (kt CH_4)

	1990	1995	2000	2005	2010	2011	2012
Cumulative Number of Mine Areas Closed	**121**	**132**	**138**	**144**	**148**	**148**	**148**
Deep Mine Methane Emissions Estimates	**52.8**	**97.7**	**70.0**	**49.9**	**48.9**	**45.4**	**43.6**
	±8.5	±16.1	±11.5	±7.4	±6.3	±5.8	±5.6
Open Cast Mine Methane Emissions Estimates	**3.1**	**2.8**	**2.3**	**1.8**	**1.6**	**1.6**	**1.6**
	±0.6	±0.6	±0.5	±0.4	±0.3	±0.3	±0.3
Total All Mines Methane Emissions Estimates	**55.9**	**100.4**	**72.3**	**51.7**	**50.5**	**47.0**	**45.2**
	±8.5	±16.1	±11.5	±7.4	±6.3	±5.8	±5.6
Methane Utilisation	**-4.7**	**-4.7**	**-14.1**	**-31.0**	**-33.0**	**-28.5**	**-27.1**
	±0.3	±0.3	±0.8	±1.6	±1.8	±1.5	±1.4
% Methane Utilised (deep mines, UK)	**9%**	**5%**	**20%**	**62%**	**68%**	**63%**	**62%**
Net Methane Emissions	**51.2**	**95.7**	**58.2**	**20.7**	**17.5**	**18.5**	**18.1**
	±8.5	±16.1	±11.5	±7.6	±6.5	±6.0	±5.8

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, with additional detail on coal mined in deep mines and open cast mines from the UK Coal Authority which has a statutory duty to regulate the industry and report on activities.

Section 3.5 provides further general information about the time series consistency of activity data in DUKES, and provides more general comments on the approaches used to ensure time series consistency in source category 1B.

The time series emission factors used in this source category are presented in **Annex 3, Section A 3.2.3.** The factors for coal mining are all based on UK industry research. Emission factors from coal storage and transport, licensed mines and from open cast mines do not

vary through the time series; in each case the same factor is applied to the UK activity in every year. For deep-mined coal emissions there is a variable emission factor across the time series, derived from operator reporting and reflecting the changing methane management practices within UK collieries, especially to increase methane capture and oxidation for power-raising in recent years, leading to a gradually declining methane emission factor per unit coal produced since the early 2000s. The variability in the factor also reflects the changes in production from different mines that have different methane management practices, as for some UK collieries the capture and use of methane has not proved cost-effective and therefore the technology is not uniformly implemented.

All of the non-CO_2 emission factors from sources in solid fuel transformation are from literature sources, with no variability across the time series. Emissions of CO_2 from these sources are based on a UK model that applies a carbon balance across all inputs and outputs in these fuel transformation sources.

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**. Activity data for coal production in deep-mined and open-cast mines in the UK are quality-checked through comparison of data reported within DUKES and data reported directly by the UK Coal Authority, which provides regional and UK totals of coal production. The information provided directly by colliery operators regarding their methane recovery systems are also checked against the data published by DECC on coal mine methane projects in the UK (which encompasses both operating and closed / abandoned mines with coal mine methane recovery systems).

3.3.1.5 Source Specific Recalculations

1B1b Smokeless Solid Fuel Production
An error in the calculations to derive the carbon emission factor for emissions from solid smokeless fuel production has been corrected, which affects the emission estimates from 2008 onwards. The method uses emission estimates and an activity that is derived from the sum of two types of coal. From 2008 onwards, whilst the sum of the two coal types has been reported as the activity in the inventory, the derivation of the emission factor was previously based on only one of the coal types, and therefore the derived emission factor was too high. The correction of this error has reduced the CO_2 emissions from this source in 2011 by 12.8kt.

1B1b Iron and Steel Flaring
Revisions have been made to the emission factors for carbon, methane and nitrous oxide from this source. The revision to the carbon factor is a result of an extensive overhaul of the UK carbon balance approach for integrated steelworks (Ricardo-AEA, 2014), which has led to revisions in the allocation of carbon emissions across 1A1c, 1A2a, 1B1b, 2C1. Consultation with Tata Steel and the Iron and Steel Statistics Bureau led to the provision of an extensive new dataset for fuel and other raw material carbon factors and other parameters (such as GCVs, typical moisture levels). The consequent revisions to the carbon balance data have led to slightly lower carbon emission factors for coke oven gas acros the time series, which in 2011 led to a reduction in emissions from flaring (under 1B1b) of 6.6 kt CO_2. In 1990, the emissions are now 1.4 kt CO_2 lower than in the 2013 submission.

In addition to the revisions to the carbon balance, the inventory agency has also reviewed the use of default factors for methane and nitrous oxide. The UK GHGI estimates of methane and nitrous oxide from coke oven gas flaring are now based on IPCC defaults from the 2006

IPCC Guidelines. This has led to a small reduction in GHG emissions from 1B1b across the time series; in 2011, compared to the 2013 submission, methane estimates are now 3.2 kt CO_2e lower, whilst nitrous oxide emissions are 1.6 kt CO_2e lower.

Details of and justifications for recalculations emission factors in **Table 3.58** below, there were no revisions to activity data for this source category. For information on the magnitude of recalculations to Source Category 1B1, see **Section 10**.

3.3.1.6 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**.

Table 3.58 1B1 Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	Pollutant	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
				1990	2011	1990	2011		
1B1b	Solid smokeless fuel production	Carbon	Coal	127.2	121.5	127.2	111.0	kt / Mt	Correction to method to derive the emission factor. From 2008 onwards the calculation of the emission factor (which is derived from an emissions total divided by coal activity) had not accounted for all activity, and hence the EF was too high.
	Iron and steel flaring	Carbon	Coke oven gas	1.165	1.169	1.153	1.100	Kt/Mth	Revision to carbon balance approach to use AD and EFs from ISSB/Tata in preference to DUKES stats and historic EF defaults.
	Iron and steel flaring	Methane	Coke oven gas	0.006	0.006	0.0001	0.0001	kt / Mth	Replacement of default emission factors from superseded version of the EMEP/EEA Emission Inventory Guidebook with factors from 2006 IPCC Guidelines.
	Iron and steel flaring	Nitrous oxide	Coke oven gas	0.0002	0.0002	0.00001	0.00001	kt / Mth	Replacement of default emission factors from superseded version of the EMEP/EEA Emission Inventory Guidebook with factors from 2006 IPCC Guidelines.

3.3.2 Source category 1B2 – Oil and Natural Gas

3.3.2.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	1B2a: Oil Production - well testing	T2	CS, PS
	Oil Production – process and fugitive emissions	T2	CS, PS
	Oil Production – offshore oil loading	T3	CS
	Oil Production – onshore oil loading	T3	CS
	Refineries (drainage)		
	Refineries (tankage)		
	Refineries (process)		
	Oil Production - oil terminal storage	T2	CS
	Petroleum processes		
	Petrol Stations (Petrol Delivery)		
	Petrol Stations (Vehicle Refuelling)		
	Petrol Stations (Storage Tanks)		
	Petrol Stations (Spillages)		
	Petrol Terminals (Storage)		
	Petrol Terminals (Tanker Loading)		
	Refineries (Road/Rail Loading)		
	1B2b: Gas production –well testing	T2	CS, PS
	Gas production – gas terminal storage	T2	CS, PS
	Gas production – process and fugitive emissions	T2	CS, PS
	Gasification processes		
	Gas transmission network leakage	T3	CS
	Gas distribution network leakage	T3	CS
	Gas leakage at point of use	T3	CS
	1B2c: Oil production – gas venting	T3	CS, PS
	Gas production – gas venting	T3	CS, PS
	Oil production – gas flaring	T3	CS, PS
	Refineries (Flares)		
	Gas production – gas flaring	T3	CS, PS
Gases Reported	CO_2, CH_4, N_2O, CO, NO_x, SO_2, VOC		
Key Categories (Trends)	None identified		
Key Categories (Level)	Oil & Natural Gas, CH_4 (Base yr only)		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	A general assessment of completeness for the inventory is included in **Annex 5**		
Major improvements since last submission	There have been no major methodological improvements since the last submission.		

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.

In the UK, 1B2 emissions occur from:

- oil and gas exploration and production facilities;
- gas and oil terminals;
- gas processing facilities;
- oil refineries;
- gas transmission networks;
- storage and distribution of petrol; and
- gas leaks at the point of use (i.e. leaks from residential and commercial gas appliances).

Emissions from fuel combustion at upstream oil and gas production facilities is reported within IPCC source category 1A1c Other Energy Industry; emissions reported in 1B2 comprise process, fugitive, venting and flaring emissions.

UK upstream oil and gas exploration and production is almost entirely offshore, with a very small number of onshore oil wells also evident; no onshore gas production occurs in the UK, although shale gas reserves have been identified and some preliminary research into prospective shale gas extraction is on-going within UK Government and industry.

Offshore oil and gas is transported to processing plants via pipelines and marine tankers; emissions of CH_4 and VOC occur during loading of oil into the ship's tanks (including from the onshore terminal when oil is transferred to tankers for export or transfer to UK refineries), and then subsequently at the unloading stage to onshore storage vessels, whilst emissions of VOC occur from storage tanks at oil terminals.

Fugitive emissions trends from the upstream oil and gas sector reflect the changes in UK production through the time series. Oil production in 2012 (1941 PJ) is 49% of that in 1990 (3981 PJ), whilst gas production peaked in the UK in 2000 (4083 PJ), and by 2012 production (1465 PJ) is much lower and now below that in 1990 (1709 PJ).

Note that the data reported on gas throughput in the CRF Table 1B2 for 2012 is 1465 PJ, and represents the upstream gas production throughput on a net energy basis. In the CRF Table 1.Ab, the UK gas production total for 2012 is presented as 452,806 GWh, which equates to 1630 PJ, but this figure includes the production of colliery methane that is generated in the UK and used directly on colliery sites to provide power and heat (and therefore there are no transmission and fugitive release estimates from this source).

Emissions of CO_2, CH_4, CO, N_2O, NO_x, SO_2, and VOC occur at refineries due to venting of gases from 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.

Distribution of petroleum products in the UK is typically via road and rail tankers from refineries to approximately 60 petrol/diesel terminals for storage prior to distribution to end users (primarily petrol stations), via road tankers. At petrol stations the oil products are stored

and then dispensed into the fuel tanks of road vehicles. Emissions of VOC occur from each storage stage and from each transfer stage.

3.3.2.2 Methodological Issues

An overview of the data sources and methods used to derive estimates for the 1B2 sources in the UK is presented in the table below. (Related 1A1 sources are included also, for reference and completeness):

Table 3.59 Summary of Data Sources and Estimation methods for 1B2 source categories in the UK GHG Inventory, 1990-2012

Type of facility / source	IPCC source categories	Data Sources and Methods
Offshore oil and gas platforms	[1A1c Other Energy industry: Upstream oil/ gas fuel use (diesel, own gas)]	Primarily based on DECC energy stats, however some gaps in data on gas use (1990-2001) and LPG/OPG use (2003-) are addressed using EU ETS and EEMS data.
	1B2aii, 1B2bii Oil, Gas Production: Upstream facility process and fugitive releases	1998-2012: sum of reported facility emissions for process and fugitive releases (EEMS). 1990-1997 data based on UKOOA 2005 study. Source allocation less certain for earlier years.
	1B2aiii Transport: Offshore loading of oil	1998-2012: sum of reported facility activity and emissions for offshore loading (EEMS). 1990-1997 emissions data based on UKOOA 2005 study. AD estimated assuming CH_4 IEF from 1998 is valid for earlier years.
	1B2ci,ii Venting at upstream oil, gas facilities	1998-2012: sum of reported facility emissions for venting releases (EEMS). 1990-1997 data based on UKOOA 2005 study. Source allocation less certain for earlier years.
	1B2ci,ii Flaring at upstream oil, gas facilities	1997-2012: sum of reported facility activity and emissions for flaring (EEMS). 1990-1996 emissions data based on UKOOA 2005 study, with mass-based AD estimated from the DECC volume time-series, assuming the same oil:gas split as in EEMS 1997, and aggregate oil and gas flaring volumes 1990-2012 (DECC 2013).
Offshore floating production and storage vessels, well testing rigs	[1A1c Other Energy industry: Upstream oil/ gas fuel use (diesel, own gas)]	[As above for oil and gas platforms]
	1B2ai, 1B2bi Oil, Gas Exploration: well testing	1998-2012: sum of reported facility activity and emissions for well testing (EEMS). 1990-1997 emissions data based on UKOOA 2005 study. AD estimated assuming CO_2 IEF from 1998 is valid for earlier years.

Type of facility / source	IPCC source categories	Data Sources and Methods
	1B2aii, 1B2bii Oil, Gas Production: Upstream facility process and fugitive releases	[As above for oil and gas platforms]
	1B2aiii Transport: Offshore loading of oil	[As above for oil and gas platforms]
	1B2ci,ii Venting at upstream oil, gas facilities	[As above for oil and gas platforms]
	1B2ci,ii Flaring at upstream oil, gas facilities	[As above for oil and gas platforms]
Onshore oil and gas terminals, onshore oil wells	[1A1c Other Energy industry: Upstream oil/ gas fuel use (diesel, own gas)]	As above for oil and gas platforms, except that where terminals do not report to EEMS (post-2009), the source estimates for own fuel use are based on EU ETS data (where available), with overall facility emissions aligned with IPPC/EPR-reported data (EA and SEPA, 2013).
	1B2aii, 1B2bii Oil, Gas Production: Upstream facility process and fugitive releases	As above for oil and gas platforms, but missing sites from EEMS are estimated based on IPPC/EPR-reported data (EA and SEPA, 2013). Source-specific estimates more uncertain for these sites where EEMS data missing.
	1B2avi Other: Onshore loading of oil	As above for the loading estimates for oil and gas platforms, but again – where EEMS data are absent the overall facility emissions are aligned with IPPC/EPR inventories and therefore source-specific estimates are uncertain.
	1B2ci,ii Venting at upstream oil, gas facilities	As above for venting estimates for oil and gas platforms, but where EEMS data are absent the overall facility emissions are aligned with IPPC/EPR inventories and therefore source-specific estimates are uncertain.
	1B2ci,ii Flaring at upstream oil, gas facilities	Flaring emissions estimated as above for offshore oil and gas platforms, except where terminals do not report to EEMS since 2010. EU ETS data on flaring are used if available. Where no EEMS or EU ETS data are available, an estimate of the total reported emissions in IPPC are allocated to flaring.

Type of facility / source	IPCC source categories	Data Sources and Methods
Refineries	[1B1b Petroleum refineries]	1990-2012 Combustion emissions estimated using UK energy statistics (DECC, 2013), augmented by trade association emissions data (UKPIA, 2013) and since 2005 the EU ETS dataset on fuel use and emissions (EA, SEPA and NIEA, 2013). Emission factors are taken from UKPIA compositional analysis, carbon factors review (2004) and EU ETS.
	1B2aiv Refining / Storage: Petroleum processes, Oil Terminal storage	1990-2012 Fugitive emissions from oil storage and refinery processes are derived from aggregate industry estimates provided by the refinery trade association (UKPIA, 2013).
UK oil distribution network	1B2av Distribution of Oil Products (no direct GHG emission sources)	Road and rail taker loading (UKPIA, 2013). Storage and loading at petrol terminals and petrol stations: method from Institute of Petroleum 2000 and CONCAWE (1986), input data from UKPIA (2013), DECC (2013), Met Office (2013).
UK gas transmission network	1B2biii Transmission: High pressure transmission network leakage	1990-2012 Gas network leakage data estimated directly by the gas network operators, using an industry leakage model and periodic surveys of the gas network (in 1992, 2002). Estimates include leakage from the transmission pipelines only. *Activity data in the CRF present the total gas delivery in the UK via the network, but these data are not directly used in the calculations to derive leakage estimates.*
UK gas distribution network and associated above ground installations, e.g. gas compressors	[1A1c Other energy industry: Gas combustion in gas network compressors]	1990-2012 Activity data from national energy statistics (DECC, 2013), augmented since 2005 by EU ETS data on gas use at gas compressor stations (EA, SEPA, NIEA 2013). Emission factors taken from gas compositional analysis from gas network operators (National Grid, Northern Gas Networks, Scotia gas, Wales and West, 2013).
	1B2biv Distribution: Low pressure distribution network leakage	1990-2012 Gas network leakage data estimated directly by the gas network operators, using an industry leakage model and periodic surveys of the gas network (in 1992, 2002). Estimates include leakage from the low pressure gas distribution pipelines and also from other sources such as Above Ground Installations on the grid. *Activity data in the CRF present the total gas delivery in the UK via the network, but these data are not directly used in the calculations to derive leakage estimates.*

Type of facility / source	IPCC source categories	Data Sources and Methods
Residential and commercial gas users	1B2dv Other Leakage: Gas leakage at point of use	1990-2012 Activity data on gas use in residential and commercial sectors, DUKES (DECC, 2013) Emission factors derived using assumptions of leakage rates of different types of appliance to derive an overall estimate of percentage total gas leaked.

Upstream Oil and Gas Emission Sources: Overview of Emissions Reporting

As noted in the table above, many of the 1B2 source estimates in the UK GHGI are derived from operator-reported activities and emissions from the upstream oil and gas facilities that are regulated by the DECC Offshore Inspectorate. Oil and gas operators submit annual source-specific emission estimates to DECC in the Environmental Emissions Reporting System (EEMS); reporting of emissions is mandatory for all offshore facilities, whilst onshore oil and gas terminals report on a voluntary basis as they are regulated under Integrated Pollution Prevention and Control (IPPC) Regulations by the onshore regulatory agencies, SEPA and the Environment Agency. Operator emissions reporting under IPPC is installation-wide (i.e. aggregated for each pollutant across all sources, not providing source-specific detail) and therefore the allocation of emissions across combustion, process and fugitive sources within the national inventory is more uncertain for onshore facilities such as terminals.

The EEMS Reporting System

Emissions from upstream oil and gas production facilities, including onshore terminals, are estimated based on operator reporting via EEMS, regulated by the DECC Offshore Inspectorate and developed in conjunction with the trade association Oil & Gas UK (formerly the UK Offshore Operators' Association, UKOOA). The EEMS data provides a detailed inventory of point source emissions estimates, based on operator returns for the years 1995-2012; the EEMS data for 1995 to 1997 inclusive are not complete, frequently exhibit duplicate entries with identical submissions by operators across years, nor are they consistent with data from 1998 onwards and hence the EEMS dataset is only used directly to inform national inventory estimates from 1998 onwards. 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.

The EEMS dataset are considered the primary dataset to inform UK GHG inventory estimates as they are source-specific, complete (cover all emission sources on each facility), transparent (activity data and emissions data reported for most sources) and have been reported by operators for around 15 years. The EU ETS data cover a smaller scope of installations and of sources within those installations[30], but the EU ETS data are verified by third parties and are therefore useful to use as a quality check for the combustion and flaring emissions source estimates within the national inventory.

[30] EU ETS data for upstream oil and gas facilities include combustion sources during 2005-7 (Phase 1 EU ETS) and combustion and flaring sources in 2008-12 (Phase II EU ETS). The EU ETS reporting scope excludes other GHG emission sources such as venting, process sources, fugitives, well testing emissions and methane from oil loading / unloading and oil storage.

Environmental reporting by oil and gas terminals in the UK includes:

- Annual reporting of emissions by pollutant aggregated across all emission sources under the IPPC/EPR reporting system to the Environment Agency, or to SEPA. These data are available from 1998 in England and Wales and for 2002 and 2004 onwards in Scotland and include emission estimates for a suite of GHG and air quality pollutants including CO_2, CH_4 and N_2O;
- For 1995 to 2009, all terminals also reported source-specific emission estimates to the EEMS system, but from 2010 this was determined to be on a voluntary basis only, and therefore from 2010 onwards the EEMS dataset is incomplete for terminals. For combustion and flaring sources, the EEMS dataset includes mass-based activity data, as well as emission estimates for a suite of GHG and air quality pollutants including CO_2, CH_4 and N_2O;
- From 2005 onwards, combustion CO_2 emissions at terminals have been reported under EU ETS, and from 2008 onwards combustion and flaring CO_2 emissions at terminals has been reported under EU ETS. The scope is not as comprehensive as EEMS or IPPC, but the data are useful to check carbon emission factors and to inform a de-minimis emission value for each site.

Therefore, for oil and gas terminals the EU ETS data provides useful additional detail, where facilities may not report to EEMS but do report facility-wide (i.e. aggregated across all sources) emission estimates under IPPC/EPR. The EU ETS data provides emission estimates that can be broken down by fuel and between combustion and flaring sources, to augment the IPPC emissions data.

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

- Gas flaring;
- Own 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 1998, 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.

UK Energy Statistics Data for Oil and Gas Activities

The Petroleum Processing Reporting System (PPRS) is the mechanism by which upstream oil and gas operators are required to report energy and other activity data to the DECC Energy Statistics team as part of the wider system of regulation of the oil & gas extraction

and production sector, and to inform upstream energy market trends. These data reported by oil and gas companies 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.

Inventory Compilation Approach: Quality Assurance of EEMS

The EEMS dataset quality system is managed by the regulatory agency (DECC) and developed in conjunction with the trade association (UK Oil & Gas). EEMS uses an online reporting system with controls over data entry, together with guidance notes provided to operators to provide estimation methodology options and emission factors for specific processes.

The inventory agency combines UK energy statistics, the EEMS data, EU ETS and IPPC data to derive the oil and gas sector estimates. The data reported from the EEMS system must be reconciled with the UK Energy Statistics and integrated into the NAEI without double-counting emissions. Where the EU ETS or IPPC data are inconsistent with the EEMS data, the inventory agency works with the DECC Offshore Inspectorate and facility operators to determine the best available data for each source. The inventory agency also conducts time-series consistency checks to identify missing sites or sources, and for those sources where the EEMS data includes emissions and activity data the inventory agency reviews the time series of implied emission factors to identify outliers. Any sites or sources where the quality checks identify gaps, outliers or inconsistent reporting between different regulatory systems are resolved in consultation with the DECC Offshore Inspectorate.

Reference Sources for Upstream Oil and Gas Emission Estimates, 1990-1997

The operator-reported emission estimates within EEMS area available from 1995 onwards, but as noted above are not comprehensive and consistent until 1998 onwards. The UK GHG inventory estimates for EEMS emission sources during 1990-1997 inclusive are based on industry estimates provided within periodic reports in the 1990s, with a comprehensive review and update by the trade association provided in 2005 (UKOOA, 2005). This 2005 update was based on a UKOOA report from 1998, updated to use latest emission factors and activity data from across the sector.

The 1998 UKOOA report presents data from detailed industry studies in 1991 and 1995 to derive emission estimates for 1990 from available operator estimates. Emission estimates for 1991-1994 were then calculated using production-weighted interpolations. Only limited data were available from operators in 1990-1994, and emission totals were only presented in broadly aggregated sectors of: drilling (offshore), production (offshore), loading (offshore) and total emissions onshore. Emission estimates for the more detailed oil & gas processing sources (well testing, fuel combustion, flaring, venting, process and fugitive, oil loading / unloading and oil storage) were then based on applying the fraction of total emissions derived from the 1997 data from EEMS.

In the 2014 submission, the source estimates from this 2005 update from UKOOA have been retained, with the exception of the fuel combustion emission estimates, due to the identified under-report in DUKES activity data for natural gas use from oil and gas terminals during 1990-2000 inclusive (DECC, 2012). In this instance, the inventory agency notes that the previous (i.e. UKOOA 2005) estimates were made based on incomplete activity data and therefore new estimates were derived and reported within source category 1A1c, for the first time within the 2013 submission. The data are unchanged in the current GHGI dataset.

Allocation to Upstream Oil and Upstream Gas Source Categories

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 enables the UK GHG inventory agency to report emissions separately between 1B2a and 1B2b source categories (whereas previously the gas production estimates were combined with the equivalent oil production source categories).

For the years 1990 to 1997 inclusive, the installation-specific EEMS data were not available (1990-1994) or are not regarded as a good quality dataset (1995-1997). 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.

Exploration: Well testing in Oil (1B2ai) and Gas (1B2bi)

The emissions from well testing are predominantly from the combustion of gases in on-site flares, with an industry assumption that the flares are 98% efficient. Therefore operators report a 2% non-combusted gas release, plus the flaring emissions. The emissions are allocated in 1B as they are a combination of flaring and fugitive releases and are associated with upstream oil and gas exploration and production.

Well testing is an activity that is not recorded within the Digest of UK Energy Statistics. Activity and emissions data for CO_2, SO_2, NO_x, CO, NMVOC, and CH_4 are taken from the EEMS dataset (DECC, 2013) for 1998 onwards, whilst emissions for 1990-1997 are taken from UKOOA estimates (UKOOA, 2005). The activity data for 1990-1997 has been estimated using the carbon factor from 1998, i.e. on the assumption that the carbon emission factor remains constant back to 1990. These calculations indicate possible inconsistencies in emissions data within the earlier years of the time-series, most notably for emissions of SO_2 during 1990-1997 and for N_2O during 1990-1994.

The activity data and implied emission factors are presented in Annex 3 in **Table A 3.2.20** and **Table A 3.2.21**.

Oil Loading Emissions: 1B2aiii Transport (offshore loading) and 1B2avi Other (onshore loading)

This emission source comprises CH_4 and NMVOC releases from tanker loading and unloading based on data from the EEMS dataset (DECC, 2013). Data from 1998-2012 are based on detailed operator returns, whilst 1990-1997 data are based on trade association estimates (UKOOA, 2005). In recent years, the methane and NMVOC data from operators appear to be incomplete in the EEMS dataset, most notably from ship loading emissions at BP sites (onshore terminals and offshore platforms). The inventory agency has added estimates in such instances, extrapolating emission estimates from earlier years. These emission totals for methane and NMVOCs are therefore subject to considerable uncertainty.

Activity data (tonnes oil loaded / unloaded) are available from the EEMS dataset for 1998 onwards, whilst the activity data for 1990-1997 are not available from industry reports and has therefore been estimated, based on the assumption that the methane emission factor remains constant back to 1990. This approach enables a transparent assessment of implied emission factors for 1998 onwards.

The activity data and implied emission factors are presented in Annex 3 in **Table A 3.2.22**.

Flaring: Oil (1B2ci) and Gas (1B2cii)

This emission source includes flaring of waste gases at offshore platforms and at onshore terminals. Flaring emission data for CO_2, SO_2, NO_x, CO, NMVOC, and CH_4 are taken from the EEMS dataset (DECC, 2013). Data from 1997-2012 are based primarily on detailed operator returns held within the EEMS dataset. In some cases, for onshore terminals, the allocation of emissions to "flaring" is uncertain, where source-specific reporting through EEMS is not available and estimates are made based on EU ETS and/or IPPC emissions totals.

Total flaring emissions estimates for the oil and gas sector for 1990-1996 data are taken from periodic reports by the trade association, UKOOA, with flaring emission estimates back to 1990 provided in 2005 (UKOOA, 2005). The allocation of flaring emissions to upstream oil and upstream gas sectors are derived using the 1997 split of oil:gas within the facility-specific EEMS data.

The activity data and implied emission factors are presented in Annex 3 in **Table A 3.3.52** and **Table A 3.3.53**. The implied emission factors for 1997-2012 are reported as kg pollutant per kg gas flared and are calculated from emissions and activity data reported annually by operators via the EEMS reporting system. The data for 1990-1996 are estimated based on reported emission totals (UKOOA, 2005) and extrapolated activity data. From 1990 onwards there is a full time series of gas flaring volumes for the oil and gas sector published by DECC (DECC, 2013), and this is used in conjunction with the EEMS data on mass of gas flared in 1997 to derive estimates of the mass of gas flared back to 1990.

Note that an estimate of NMVOC emissions from refinery flares is also reported in 1B2ci Venting and Flaring: Oil. This is based on estimates supplied by UKPIA (2013).

Other Upstream Oil and Gas Emission Sources

Other GHG emission sources from upstream oil and gas facilities that are estimated based on industry data and operator reporting, without underlying activity data include:

1B2aii Oil Production

- Fugitive emissions (CO_2, CH_4, NMVOC estimates only);
- Direct process emissions, such as acid gas stripping plant at terminals (CO_2, NO_X, SO_2, CO, CH_4, NMVOC);

1B2aiv Oil Refining / Storage

- Storage vessel emissions from the storage of crude oil at terminals (CH_4, NMVOC estimates only);

1B2bii Gas Production / Processing

- Fugitive emissions (CO_2, CH_4, NMVOC estimates only);
- Direct process emissions, such as acid gas stripping plant at terminals (CO_2, NO_X, SO_2, CO, CH_4, NMVOC);

1B2c Venting

- Gas Venting (CO_2, CH_4, NMVOC estimates only) at upstream oil facilities (1B2ci)
- Gas Venting (CO_2, CH_4, NMVOC estimates only) at upstream gas facilities (1B2cii)

Emissions data are taken from the EEMS dataset (DECC, 2013) and previous industry studies by the upstream oil and gas trade association (UKOOA, 2005). Data for 1998-2012 are based on detailed operator returns, whilst 1990-1997 data are based on the UKOOA submission in December 2005 which updated previous industry studies that calculated source emission estimates from extrapolation of total emissions data and the use of 1997 data splits between sources.

Note that there are no activity data for these activities available from DECC or UK Oil & Gas; UK GHGI estimates are the aggregated operator emissions reported via the EEMS system or from the UKOOA 2005 data submission. From 1998, the method is simply:

UK GHGI = ∑ facility emissions in EEMS (by source)

The inventory agency conducts annual quality checks to assess the completeness of reporting by facilities, and time series consistency checks. However, in the absence of any other industry activity data, there is a reliance on operators to use the available reporting guidance and EEMS templates to provide full and accurate emission estimates for use in the inventory.

Gaps in reported fugitive & storage tank emissions by certain operators and sites are evident in recent years, and where possible, data have been extrapolated from previous years to provide estimates to fill these gaps. There have also been some significant changes in activities at some sites that have led to notable emission reductions in recent years, including reduction of direct process emissions of SO_2 at the Elgin PUQ platform, due to a change to venting acid gases rather than flaring them.

1B2aiv Refining / Storage: Refinery and Petroleum Process Emissions

This source category includes estimates of NMVOC emissions from oil refineries due to venting of process plant for reasons of safety, from flaring of waste products, leakages from process plant, evaporation of organic contaminants in refinery wastewater, regeneration of catalysts by burning off carbon fouling, and storage of crude oil, intermediates, and products at refineries. In the UK inventory these emission sources are aggregated under:

- Refineries (drainage);
- Refineries (tankage); and
- Refineries (process).

All are based on UKPIA (2013) estimates for 1994-2012. The UKPIA data refer to the following UK refinery installations:

- Milford Haven (2 refineries);
- Pembroke;
- Coryton;
- Shell Haven;
- South Killingholme;
- Killingholme;
- Stanlow;
- North Tees;
- Fawley; and
- Grangemouth.

UKPIA also supply estimates for loading of petrol into road and rail tankers at refineries. Prior to 1994, process emissions are estimated by extrapolation from the 1994 figure on the basis of refinery throughput, whereas emissions from tankage, flares and drainage systems are assumed to be constant at the level repoted for 1994.

Also included under 1B2aiv Refining and Storage are NMVOC emissions from petroleum processes including:

- specialist refineries (Llandarcy, Eastham, Dundee, & Harwich)
- onshore oil production facilities
- miscellaneous petroleum processes not covered elsewhere in the inventory (e.g. Kimmeridge and Horndean well sites, oil and gas industry terminals not covered elsewhere such as Tranmere and Tetney Lock oil terminals)

Emissions are taken from the Pollution Inventory (Environment Agency, 2013). No emissions data have been found for the Dundee refinery.

Petrol Distribution, 1B2av

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 NMVOC occur from each storage stage and from each transfer stage.

The UK inventory includes emissions from the storage, distribution and sale of petrol in the following categories each of which is further divided into emissions of leaded and unleaded petrol:

- Refineries (Road/Rail Loading). Emissions during loading of petrol on to road and rail tankers at refineries;
- Petrol Terminals (Storage). Emissions from storage tanks at petrol distribution terminals;

- Petrol Terminals (Tanker Loading). Emissions during loading of petrol on to road and rail tankers at petrol terminals;
- Petrol Stations (Petrol Delivery). Emissions during loading of petrol from road tankers into storage tanks at petrol stations;
- Petrol Stations (Storage Tanks). Emissions from storage tanks at petrol stations;
- Petrol Stations (Vehicle Refuelling). Emissions due to displacement of vapour during the refuelling of motor vehicle at petrol stations; and
- Petrol Stations (Spillages). Emissions due to spillages during refuelling of motor vehicles at petrol stations.

Emissions also occur from storage tanks at refineries. This source is included together with emissions from the storage of crude oil and other volatile materials in the NAEI source category, refineries (tankage).

The emission estimates from road and rail tanker loading at refineries are supplied by UKPIA (2013). The remaining estimates are based on methodologies published by the Institute of Petroleum (2000) or, in the case of petrol terminal storage, based on methods given by CONCAWE (1986). The calculations require information on petrol density, given in DECC (2013), and petrol Reid Vapour Pressure (RVP), data for which have been obtained from a series of surveys carried out by Associated Octel between 1970 and 1994.

More recent, detailed RVP data are not available, but UKPIA have suggested values for 1999 onwards. Central England Temperature (CET) data (Met Office, 2013) are used for ambient UK temperatures. The methodology also includes assumptions regarding the level of vapour recovery in place at terminals and petrol stations. These assumptions draw upon annual account surveys carried out by the Petroleum Review (2000 onwards) that include questions on petrol station controls, and the timescales recommended in Secretary of State's Guidance for petrol terminals (PG 1/13 (97)). The activity data are the sales of leaded and unleaded petrol from DECC (2013).

Gasification Processes, 1B2bii

This source category includes NMVOC emissions from onshore gas production facilities, refining and odourisation of natural gas, natural gas storage facilities, and processes involving reforming of natural gas and other feedstock to produce carbon monoxide and hydrogen gases. Emissions are taken from the Pollution Inventory (Environment Agency, 2013) and Scottish Pollutant Release Inventory (SEPA, 2013). For the years prior to 1994, they are extrapolated based on gas throughput. Care is taken to avoid double counting with the upstream oil and gas exploration and production emissions.

Leakage from Natural Gas Transmission (1B2biii) and Distribution (1B2biv) Networks

The UK GHG inventory sources of natural gas leakage from the downstream gas supply system covers emissions of CH_4 and NMVOC from the UK gas transmission and distribution networks. Annual activity data and gas compositional analysis are provided by National Grid Gas, four companies (formed in 2005) that operate the low-pressure gas distribution networks within Great Britain, and also from Phoenix Gas in Northern Ireland. The leakage estimates are determined in three parts, reported in the CRF as follows:

1B2biii Transmission

- Losses from High Pressure Transmission Mains (National Grid Gas);

1B2biv Distribution

- Losses from Low Pressure Distribution Network (National Grid Gas, Scotia Gas, Northern Gas Networks, Wales & West, Phoenix Gas);
- Other losses, from medium pressure gas mains, Above Ground Installations (AGIs), AGI working losses and interference (National Grid Gas, Scotia Gas, Northern Gas Networks, Wales & West, Phoenix Gas).

The gas network operators provide annual gas leakage estimates on a mass basis, providing a breakdown of emissions across 14 regional gas networks:

National Grid Gas

- East of England
- East Midlands
- North London
- North West
- West Midlands

Northern Gas Networks

- North East
- Northern

Scotia Gas

- Scotland
- South East
- Southern

Wales and West Utilities

- South West
- Wales North
- Wales South

Phoenix Gas

- Northern Ireland

The UK GHG inventory estimates for 1B2biv are based on the aggregate of mass of gas leaked across all networks (low pressure mains and other losses), with the methane content of the natural gas based on compositional analysis from all of the gas network operators. The natural gas compositional data are summarised in **Annex 3**, presented within **Table A 3.2.19**.

The activity data reported in the CRF for these sources are the final UK annual gas demand data. These data are not used within the GHG inventory estimation method, but are presented to enable IEFs to be derived, to aid comparability of the UK estimates with those of other countries.

UK Gas Network Leakage Model

The UK gas network operators use a common industry leakage model to derive their annual estimates of gas leakage. The UK gas network leakage model was developed by British Gas and uses factors and assumptions on leakage rates for different types of gas mains and installations, based on measurements and surveys conducted in 1992 and 2002, with annual updates to maintain the representation of the UK gas network infrastructure (such as length

and type of pipelines and other units) and reflect the rolling programme of network replacement. Historic data for the leakage from the low-pressure distribution network and other losses is based on studies from British Gas in the early 1990s (British Gas, 1993; Williams, 1993).

Natural Gas Compositional Data
The methane, CO_2 and NMVOC content of natural gas is presented in **Annex 3**, in **Table A 3.2.19**. The methane and NMVOC data were provided by contacts within British Gas Research for 1990-1996 and by UK Transco from 1997 to 2005 (Personal Communication: Dave Lander, 2008), and from the gas network operators from 2006 onwards (National Grid Gas, Scotia Gas, Northern Gas Networks, Wales & West, 2013). NMVOC content for 2001-2003 has been estimated by interpolation due to a lack of data; CO_2 compositional data from 2004 onwards are derived from annual compositional analysis by gas network operators, whilst the 1990-2003 data have been extrapolated back from the 2004 figure. No gas composition data have been provided by Phoenix Gas and hence the UK average gas composition is assumed for Northern Ireland.

Each of the gas network operators obtain their compositional analysis from a central system of data logging from the automated sampling and analysis network that was operated previously under the Transco ownership, prior to the network being opened up to greater market competition. The inventory agency has direct contacts within the organisation (GL-Advantica) that manages the compositional data from across the UK gas network, and works directly with their gas analysis team to ensure that gas compositional data provided to the inventory agency by network operators is representative of the gas quality year-round, rather than a snap-shot from a limited number of analyses.

The calculation of the reported UK average gas composition is derived from the sum-product of the annual Local Distribution Zone (LDZ) compositional data and the estimated gas consumption through each of the LDZs, to provide an average gas composition for Great Britain which is then applied across the UK.

Northern Ireland Gas Network
The gas infrastructure in Northern Ireland is much newer than in the rest of the UK, as the gas pipeline (from Scotland) was only commissioned in 1999. Since then, the gas network has continued to develop across Northern Ireland. Annual estimates of gas leakage from 2005 onwards have been provided by the main gas operator (Phoenix Gas, 2013), and the data for 1999 to 2004 have been extrapolated back from the 2005 figure.

Other Gas leakage (1B2bv): Natural Gas Leakage at the Point of Use
During 2010, consultation with the gas network operators confirmed that the scope of the network leakage model did not include estimates of gas leakage downstream from the gas meter, i.e. at the point of use. Therefore, separate estimates are made in the UK GHGI 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 estimates are reported within 1B2bv, and in the CRF the activity data are presented for the total annual gas use by the domestic and commercial sectors from DUKES, in PJ, to aid comparability of the UK estimates with other country submissions.

Emissions from leakage at the point of use for gas boilers were included for the first time in the 2012 inventory submission; the UNFCCC ERT subsequently noted that pre-ignition losses for cooking and gas fires were not included. Despite the absence of an IPCC method for these sources, the UK inventory agency added emission estimates for gas leaks at the

point of use from domestic and commercial cooking appliances and from gas fires within the 1990-2011 UK GHG inventory.

The estimation method for natural gas leaks at point of use in the UK inventory includes:

Industrial Heating Boilers
Methane releases are assumed to be "**Not Occurring**" from these appliances, based on consultation with technical experts that advise the UK Government for the CHP QA scheme (Personal Communication: R Stewart, 2011). Larger boilers typically operate almost permanently once ignited (particularly if used for steam-raising) with little or no cycling from on to off states. Furthermore, releases of un-burnt natural gas are strictly controlled in industrial locations for safety reasons.

Domestic Heating and Water Heating Boilers
The emissions of methane from the domestic heating and water heating boilers are estimated based on:

- an assumed average boiler size in the UK of 30kW
- a burn chamber size, natural gas flow rate taken from a typical combination boiler
- an air flow rate based on 25% excess oxygen in the combustion chamber when compared to stoichiometric ratio
- an equation for a mixed reactor ($1-e^x$) that when integrated will provide an estimate of the concentration of un-burnt air/fuel mixture released
- differing assumptions relating to the boiler yearly operation and cycling frequency, between heating and water heating applications

Using this model the emissions of the un-burnt mixture can be estimated for both the boiler when cycling during heating and water heating operation. The assumptions for the two operations are detailed below.

Domestic Heating
It is assumed that on average in the UK domestic properties have heating systems operating for half of the year and on average the heating is on for 5 hours per day. It is also assumed that during each hour that the boiler providing heating cycles on and off 4 times.

Domestic Water Heating
It is assumed that all UK domestic properties have hot water heating systems also have gas heated hot water. We have assumed operation every day of the year and on average heating is on for 4 hours per day. It is also assumed that during each hour that the boiler is providing hot water heating the boiler cycles on and off 5 times. This assumption is very uncertain as it is thought to depend on the boiler type, boiler condition and hot water usage in the property, and is thought to derive a conservative estimate.

Time series estimates for domestic heating and water heating gas leakage
The number of boilers from 1990 to 2012 is thought to have increased due to the increasing use of gas central heating for space heating, and the increase in the number of houses. It is assumed that pre-ignition gas loss in boilers installed in houses in 1990 were greater than in the current boilers installed, as technology has improved. However, the stock of domestic boilers (ca. 22 million in 2008) is assumed to be greater than that in 1990.

The inventory agency does not have access to detailed UK data for i) the stock of boilers in use over the time series; ii) the leakage from the boilers, and how this leakage changes with

boiler technology. Therefore it has been assumed that the proportion of gas leaked (i.e. % of the total gas use) from domestic heating and water heating appliances per annum is steady across the time series, with the rationale that the sum of greater pre-ignition losses from fewer older-technology boilers in the early part of the time series will be roughly equivalent to the sum of lower pre ignition losses per unit from the greater number of newer-technology boilers in recent years.

Based on the model and assumptions outlined above, the emission of methane leaking from domestic boilers in the UK in 2008 has been estimated at 0.9 kt CH_4. Based on Energy Consumption in the UK (DECC, 2013) activity data for gas use in different appliance types, this equates to a factor of 0.078 tCH_4 per Mth total gas use in domestic boilers. This factor has been applied to the ECUK activity data for domestic boiler appliances across the time series; across all years, the estimated annual emission is in the range 0.75-1.0 kt CH_4.

Domestic Cooking Appliances (manual and automatic ignition) and Gas Fires
Methane emission from pre-ignition losses of gas appliances used in domestic cooking and domestic gas fires are based on activity data from ECUK (DECC, 2013) which provides the full time series of gas use for heating, water heating and cooking in the domestic sector. The method then applies a series of assumptions regarding the operational cycles and delays to ignition, to derive a simple percentage non-combusted estimate for each gas appliance type.

The assumptions applied in the estimation method are:

- Gas fires use an estimated 2.5% of total gas used for space heating in the domestic sector, with the remainder used in (automatic ignition) boilers. This assumption is based on inventory agency expert judgement;
- Gas use in cooking hobs is estimated to be 73.6% of the total domestic gas use in cooking, with the remainder in gas ovens. This is based on data of average annual gas oven fuel use in kWh/yr and average domestic gas hob fuel use in kWh/yr, combined with data on UK stock of gas ovens and hobs, taken from a series of 2011 European Commission Eco-design studies (Bio IS / ERA Technology, 2011);
- For manual ignition devices, a conservative estimate of the delay prior to ignition of 2 seconds has been assumed (expert judgement), whilst the average operational cycle times for different types of appliance have been estimated at 900 seconds for a domestic hob (expert judgement) and 5400 seconds for a gas fire (EC Eco-design Lot 20 Task 5, gas stove base case, 2011);
- For automatic ignition appliances, a conservative estimate of the delay prior to ignition of 0.25 seconds has been assumed (expert judgement), whilst the average operational cycle times of domestic ovens has been estimated at 900 seconds (expert judgement);

In 2012, these assumptions lead to an overall estimate of 0.50 Mth of natural gas leaking from domestic cooking appliances and domestic gas fires. Converting to a mass-basis and then applying the annual natural gas compositional analysis from gas network operators leads to an estimate of methane leakage of 0.83 kt CH_4 in the UK in 2012. Across the time-series, leakage estimates from domestic appliances are all within the range 0.79-1.0 kt CH_4.

Commercial Gas Appliances: Catering and other uses
Methane emission from pre-ignition losses of gas appliances used in commercial catering and other uses are based on activity data from ECUK (DECC, 2013) which provides the full time series of gas use for catering and other uses in the commercial sector. The method then

applies a series of assumptions regarding the operational cycles and delays to ignition, to derive a simple percentage non-combusted estimate for each gas appliance type.

The assumptions applied in the estimation method are:

- For commercial catering gas use, a conservative estimate of the delay prior to ignition of 0.5 seconds has been assumed (expert judgement, to reflect a mixture of hobs and oven use), whilst the average operational cycle has been estimated at 900 seconds (expert judgement);
- For other commercial gas appliances, assumed to be predominantly gas-fired boilers of automatic ignition design, a conservative estimate of the delay prior to ignition of 0.25 seconds has been assumed (expert judgement), whilst the average operational cycle time has been estimated at 1800 seconds (expert judgement);

In 2012, these assumptions lead to an overall estimate of 0.60 Mth of natural gas leaking from commercial gas appliances. Converting to a mass-basis and then applying the annual natural gas compositional analysis from gas network operators leads to an estimate of methane leakage of 1.0 kt CH_4 in the UK in 2012. Across the time-series the estimates are all within the range 0.8-1.2 kt CH_4 leaked from commercial gas appliances.

An overview of the time series of gas leak at point of use estimates in the UK, together with overall gas use by economic sector and appliance type is presented below.

Note that these emission estimates are very uncertain due to the lack of detailed activity data, lack of appliance-specific leakage information and therefore the range of assumptions that have been made within the method; an estimated uncertainty of +/-50% has therefore been assigned to this source within the UK inventory uncertainty analysis.

Table 3.60 Activity data and methane leakage estimates for Gas leakage at Point of Use, including cooking appliances, gas fires and boilers

Source / Appliance type	Units	1990	1995	2000	2005	2010	2011	2012
Annual Gas Use								
Domestic gas fires	ktoe	462	520	621	650	673	468	563
Domestic manual ignition hobs / cookers	ktoe	590	530	511	496	439	441	451
Domestic auto-ignition hobs / cookers	ktoe	211	190	183	177	157	158	161
Domestic auto-ignition space and water heating	ktoe	24,572	26,796	30,491	31,512	32,223	24,161	27,980
Service sector catering (ovens and hobs)	ktoe	506	647	655	657	605	521	615
Other service sector appliances (boilers)	ktoe	6737	8623	9935	9407	8430	7955	8374
Methane Leakage								
Domestic cooking and gas fires	$ktCH_4$	1.02	0.94	0.94	0.92	0.84	0.79	0.83
Domestic boilers and water heating	$ktCH_4$	0.76	0.83	0.94	0.98	1.00	0.75	0.87
Service sector (all sources)	$ktCH_4$	0.80	1.03	1.15	1.10	1.00	0.92	0.99
Total	**$ktCH_4$**	**2.58**	**2.80**	**3.03**	**3.00**	**2.83**	**2.46**	**2.69**

3.3.2.3 Uncertainties and Time Series Consistency

The 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 EEMS dataset for 1998-2012, whilst emission estimates for 1990-1997 are based on trade association data (UKOOA 2005) to update earlier industry studies (UKOOA 1998) that had used production data as a basis for generating sector-wide estimates from 1990. The EEMS dataset (DECC, 2013) provides a consistent time-series of emission estimates for many facilities and sources, but since 2010 the reporting by onshore terminals is voluntary and the completeness of the dataset is variable for recent years. Furthermore, whilst the EEMS data quality appears to be improving over recent years, the completeness of EEMS data for specific facilities and sources is still subject to uncertainty; reporting gaps appear to be systematic for some facilities, such as frequent non-reporting of oil loading / unloading emissions at some terminals. The Inventory Agency continues to work with the regulatory agency, DECC, in the continued development of emission estimates from this sector.

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 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.

As noted in the section above, the uncertainties for the estimates of gas leakage at point of use are high due to the lack of source data, an IPCC method and the need to use a series of assumptions and expert judgement to estimate the leakage from different gas appliance types. The inventory agency considers that the assumptions provide a conservative estimate of gas leakage at point of use across the time series.

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**. The DECC Offshore Inspectorate, in conjunction with 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.

There is a large volume of emissions and activity data reported by plant operators to the UK reporting systems including EEMS, PI/SPRI/NIPI and EU ETS. For all such data reporting mechanisms, the regulators provide source-specific guidance on emission estimation methods, reporting templates to engender a consistent, complete response from all plant operators, and there are QA systems in place by the regulators to govern the reported data quality.

In addition to these systems within data provider organisations, the inventory agency performs checks on data consistency for each installation where they report data to two or more reporting mechanisms in order to conduct quality checks (e.g. completeness, year to year consistency, EU ETS compared to EEMS compared to PI/SPRI). There is therefore a high level of sector-wide and source-specific data checking that is performed. This process

does reveal small data reporting disparities which can then be resolved through consultation with the operators and regulators, and there are some instances where the allocation of emissions to a specific source within an installation may not be completely transparent. Overall, however, the estimates are regarded as being associated with low uncertainty, due to the rigorous reporting systems and opportunities for data validation, cross-checking and correction of errors at source.

3.3.2.5 Source Specific Recalculations

Details of and justifications for recalculations to activity data are given in **Table 3.61** and emission factors in **Table 3.62** below. For information on the magnitude of recalculations to Source Category 1B2, see **Section 10**.

1B2aii Oil Production – Process and fugitive emissions
The inventory agency has reviewed the Pollution Inventory data for one onshore site in England and revised estimates for methane and VOC emissions upwards compared to the 2013 submission; the site reported abnormally high emissions in 2011, but these data have now been verified as correct, having previously been disregarded as an outlier. In addition, the previous analysis of process emissions from one offshore site have been reviewed in consultation with the regulator. The installation activities have declined in recent years and estimates of carbon dioxide and methane emissions provided for the 2011 data in the 2013 submission have now been revised downwards. The overall impact of these changes is a reduction of emissions in 2011 of 90 kt CO_2 and 11 kt CO_2e of methane.

1B2aiv Oil Production – Petroleum Processes
For 2011 and 2012, two new onshore oil processing sites have reported high methane emissions through the Environment Agency's Pollution Inventory. In the analysis for the 2013 submission, these data were reviewed and discarded as outliers. The inventory agency has now revised this assumption, in light of data for 2012 and discussion with the regulators. This has led to an increase in reported methane emissions for 2011 of 122 kt CO_2e.

Oil Loading Emissions: 1B2avi Transport (onshore loading)
Following review of the IPPC/EPR reporting for one oil terminal, the inventory agency identified that the oil storage tank farm where oil loading emissions occur is reported within the SPRI under a separate permit to the rest of the terminal, following changes to the regulatory system in recent years. Therefore additional information on emissions from this site have been identified and included in the UK GHG inventory. The impact on direct GHGs is minimal, with a very small increase in methane emissions in 2011 of less than 0.1 kt CO_2e, whilst the impact on NMVOCs emission estimates is higher.

Flaring: Oil (1B2ci) and Gas (1B2cii)
Minor revisions to flaring estimates have been made for two onshore gas terminals (Barrow, CATS) based on revised analysis of EU ETS data and the Pollution Inventory totals for the sites. In addition, there have been revisions to reported emissions of nitrous oxide from one terminal (Frigg) within the SPRI. These changes have led to a small increase in CO_2 emissions in 2011 of 5kt CO_2, and reductions in estimates of methane and nitrous oxide emissions in 2011 of 8.5 kt CO_2e and 15.6 kt CO_2e respectively.

1B2biv Distribution: Low pressure gas distribution network leakage.
The inventory agency reviewed data on gas leakage provided by gas network operators in 2012 and consulted with all operators during 2013 in order to compare the scope and detail of leakage data reporting against the 2006 IPCC Guidelines and to check recent data. As a result of this consultation, one of the UK gas network operators has revised the data

provided in 2012, and new estimates of leakage from their distribution network has been provided from 2007 onwards. As a result, the gas leakage estimates in 2011 are 53.6 kt CO_2e lower than in the 2013 submission.

Table 3.61 1B2 Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
			1990	2011	1990	2011		
1B2a	Upstream Oil Production - Onshore Oil Loading	Crude oil	204,683,559	29,014,248	204,683,559	48,376,624	t	Addition from 2007 onwards of new data on VOC emissions from an oil storage tank farm regulated under a separate permit to the main terminal installation, for one oil terminal in the UK. The emissions data are used in conjunction with EEMS data on activity and VOC emissions to derive new activity estimates for the site.
1B2b	Gas leakage	Natural Gas (leakage at point of use)	13,125	12,795	13,125	13,375	Mth	Revised gas activity data in DUKES (DECC, 2013)
1B2b	Gas leakage	Natural gas supply	438.3	220.9	438.3	217.8	Mth	Revised gas leakage estimates provided by one gas network operator from 2007 onwards, following inventory agency consultation to reconcile outlier data.
1B2cii	Upstream Gas Production - flaring	Non-fuel combustion	110,757	114,045	110,757	115,306	t	Minor revisions to flaring estimates for two onshore terminals (Barrow, CATS) based on revised analysis of EUETS data and the PI totals for the sites.

Table 3.62 1B2 Recalculations to Emission Factors since the previous submission

IPCC Category	Source Name	Pollutant	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
				1990	2011	1990	2011		
1B2a	Petroleum processes	Oil production	CH4	0.021	0.017	0.022	0.129	kt / Mt	Addition of emissions from onshore oil processing sites from the Pollution Inventory, leading to higher estimates for 2011 and 2012 compared to previous years, reflecting new installations and activities in the UK.
1B2a	Upstream Oil Production - process emissions	Non-fuel combustion	Carbon	30.7	64.0	30.7	39.3	kt (UK total emissions)	Revisions to installation emission estimates for a number of UK sites, including one increase due to revised PI data, and one decrease due to correction of an assumption in the 2013 submission data to reflect the down-turn in operation of one of the main osshore rig process emission sources.
1B2a	Upstream Oil Production - process emissions	Non-fuel combustion	CH4	10.30	7.30	10.30	6.77	kt (UK total emissions)	
1B2cii	Upstream Gas Production	Non-fuel combustion	CH4	9.15E-06	1.30E-05	9.15E-06	9.36E-06	kt / t	Minor revisions to flaring estimates have been made for two onshore gas terminals (Barrow, CATS) based on revised analysis of EUETS data and the Pollution Inventory totals for the sites. In

IPCC Category	Source Name	Pollutant	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
				1990	2011	1990	2011		
	- flaring								addition, there have been revisions to reported emissions of nitrous oxide from one terminal (Frigg) within the SPRI. These installation-specific revisions have a small knock-on effect to the overall emission factors for CH4 and N2O for the source.
1B2cii	Upstream Gas Production - flaring	Non-fuel combustion	N2O	4.52E-08	5.09E-07	4.52E-08	6.74E-08	kt / t	

3.3.2.6 Source Specific Planned Improvements

During 2013, the DECC Offshore Inspectorate conducted a review of the EEMS reporting system for upstream oil and gas facilities, and a number of revisions to the data reporting systems have been made, primarily aimed at improving the operator user-interface, but also facilitating completeness checks of the data. The inventory agency will work with the regulator to review the EEMS data available for 2013 emissions and assess whether any data improvements can be achieved for the UK GHG inventory.

Emission factors and activity data will be kept under review. The UK improvement programme is summarised in **Section 1.2.2.5.**

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 Statistics Authority's *Official Statistics Code of Practice (UKSA, 2009)* – and as such is subject to a stringent QA process.

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

3.4.2.1 Operator Reporting under Environmental Regulations

Since the early to mid-1990s, environmental regulations in the UK have established a system of annual reporting by plant operators, whereby source emissions to atmosphere (and water-courses, and to land) are reported as annual totals for a wide range of pollutants, including GHGs. The specific regulations in the UK have developed as EU-wide environmental reporting systems have developed, from Integrated Pollution Control (IPC) in the 1990s and early 2000s, to Integrated Pollution Prevention and Control (IPPC), Environmental Permitting Regulations (EPR), European Pollutant Release and Transfer Register (E-PRTR) and the

regulations are currently being evolved to meet the requirements of the Industrial Emissions Directive.

The reporting systems under these evolving environmental regulations, have led to the development of technical guidance (by sector or broad activity, e.g. “combustion”), emissions monitoring guidance (by pollutant, by technique, e.g. in the UK the MCERTs programme set out the quality requirements of Continuous Emission Monitoring Systems, CEMS), In addition, the regulators have set up data management and control systems to manage the data quality and reporting, including permit templates, electronic data reporting systems with built-in quality functions (step-by-step system of data approval by operators and regulators, completeness checks, consistency checks).

The Environment Agency regulate all industrial processes in England and Wales. 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 are subject to audit and review within the Agency’s QA procedures.

The operator emission estimates are initially checked and 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 environmental regulators in Scotland and Northern Ireland are SEPA and the NIEA. Scottish sites report annual emission returns to SEPA through the Scottish Pollutant Release Inventory (SPRI). Sites in Northern Ireland report annual emission returns to NIEA via the Northern Ireland Pollution Inventory (NIPI). Central teams of industry regulators in SEPA and NIEA conduct quality checks on the SPRI and NIPI data prior to data publication.

3.4.2.2 Operator Reporting under EU ETS

Plant operators of facilities that are within the EU ETS are regulated by the EA, SEPA, NIEA and Decc Offshore Inspectorate. Annual emission reports include source-specific data on estimation methods, fuel use data, emission factors, calorific values, oxidation factors, process emission sources, waste and biofuel emission sources. The data quality are governed by an EU-wide system of requirements in accordance with Monitoring and Reporting Guidelines and all operator data are checked and verified by independent third parties (who themselves must be an accredited authority to perform EU ETS data verification) prior to submission to the appropriate regulatory agency.

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

IPCC Categories Included	2A: Mineral Products 2B: Chemical Industry 2C: Metal Production 2D: Other Production 2E: Production of Halocarbons and SF_6 2F: Consumption of Halocarbons and SF_6
Gases Reported	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, NO_x, CO, NMVOC, SO_2
Key Categories (Trends)	2B2 Nitric Acid Production – N_2O 2B5 Non energy use of products – CO_2
Key Categories (Level)	2 Industrial Processes – HFCs 2B2 Nitric Acid Production – N_2O (Base yr only) 2B3 Adipic Acid Production – N_2O (Base yr only) 2B5 Non energy use of products – CO_2 (Latest yr only)
Key Categories (Qualitative)	2A1 Cement Production – CO_2
Overseas Territories and Crown Dependencies Reporting	2A-2E are reported as not occurring. Estimates for use of F-gases based on scaled UK estimates are reported in he relevant categories under 2F.
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	2A2: Inclusion of additional estimates for unconverted lime residues from sugar industry processes 2F: The NIR now includes information on the potential emissions of F-gases in the UK

The industrial processes sector (IPCC Sector 2) contributes 4.3% 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 54.0% decline in emissions, mostly due to changes in the emissions from the chemical production and halocarbon and SF_6 production industries. The step-change in emissions between 1998 and 1999 evident in **Figure 4.2** is due predominantly to the fitting of nitrous oxide abatement equipment at the UK's only adipic acid production plant (this plant has since closed).

Table 4.1 Number of industrial processes in the UK by type

Year	Cement	Lime – merchant[a]	Lime – captive[a]	Power stations with FGD[b]	Glass-Works[c]	Fletton brick works	Ammonia
1990	23[c]	11[c]	12	0	33[d]	8	4
1995	23	9	11	1	33[d]	5	4
2000	21	9	11	2	34	3	4

Year	Cement	Lime – merchant[a]	Lime – captive[a]	Power stations with FGD[b]	Glass-Works[c]	Fletton brick works	Ammonia
2005	16	9	8	5	32	3	4
2006	16	9	8	5	30	3	4
2007	15	9	8	5	28	3	4
2008	15	9	8	7	26	3	3
2009	13	9	6	8	25	3	3
2010	12	9	6	8	25	2	3
2011	12	9	6	8	25	1	3
2012	12	9	6	8	25	1	3
Year	Nitric acid	Adipic acid	Steel-works	Electric arc furnaces	Primary aluminium	Other non-ferrous[e]	
1990	8	1	4	20	4	5	
1995	6	1	4	20	4	4	
2000	6	1	4	19	4	3	
2005	4	1	3	12	3	2	
2006	4	1	3	11	3	2	
2007	4	1	3	10	3	2	
2008	4	1	3	8	3	2	
2009	2	1	3	7	3	2	
2010	2	0	2	7	2	2	
2011	2	0	2	7	2	2	
2012	2	0	3	7	1	2	

[a] merchant refers to site selling lime and emitting CO_2, captive refers to sites using lime and CO_2 in-situ so in theory no emissions result.

[b] Flue Gas Desulphurisation

[c] excludes very small glassworks producing lead crystal glass, frits etc.

[d] approximate figures only

[e] large-scale primary production or secondary refining operations only

The figures in **Table 4.1** show that the numbers of industrial processes in the UK have been declining since 1990. While this is partly due to the closure of some smaller sites, perhaps with growth in capacity at remaining sites, it is predominantly a reflection of decreasing production of many industrial materials in the UK. A large number of closures in the period 2007-2009 were due to decreased demand for many products as a result of the general economic situation in the UK and elsewhere, with falling demand for steel, cement, bricks and aluminium, for example, leading to plant closures.

The UK reports both actual and potential emissions of fluorinated gases within IPCC source category 2F, Consumption of Halocarbons and SF_6.

- Actual emissions are estimates of the emission of a gas to atmosphere in a given year.
- Potential emissions are estimated as the apparent consumption of fluid in a given year (IPCC, 1997). Apparent consumption is based on data on annual production, imports, exports and destruction of fluid. Hence, it is assumed that the entire emission occurs in the year of use rather than presenting estimates that reflect fluid leakage over the lifetime of a piece of equipment.

In this chapter, only actual emissions are discussed. Potential emissions provide a convenient benchmark to compare emissions between countries and are simpler to estimate. Potential F-gas emissions are not reported for other Industrial Processes, such as from metal

processes (2C) or halocarbon production (2E). For further details of the UK inventory estimates of potential emissions of F-gases, please see **Annex 3.3**.

Figure 4.1 Breakdown of total GHG emissions in Industrial Processes sector

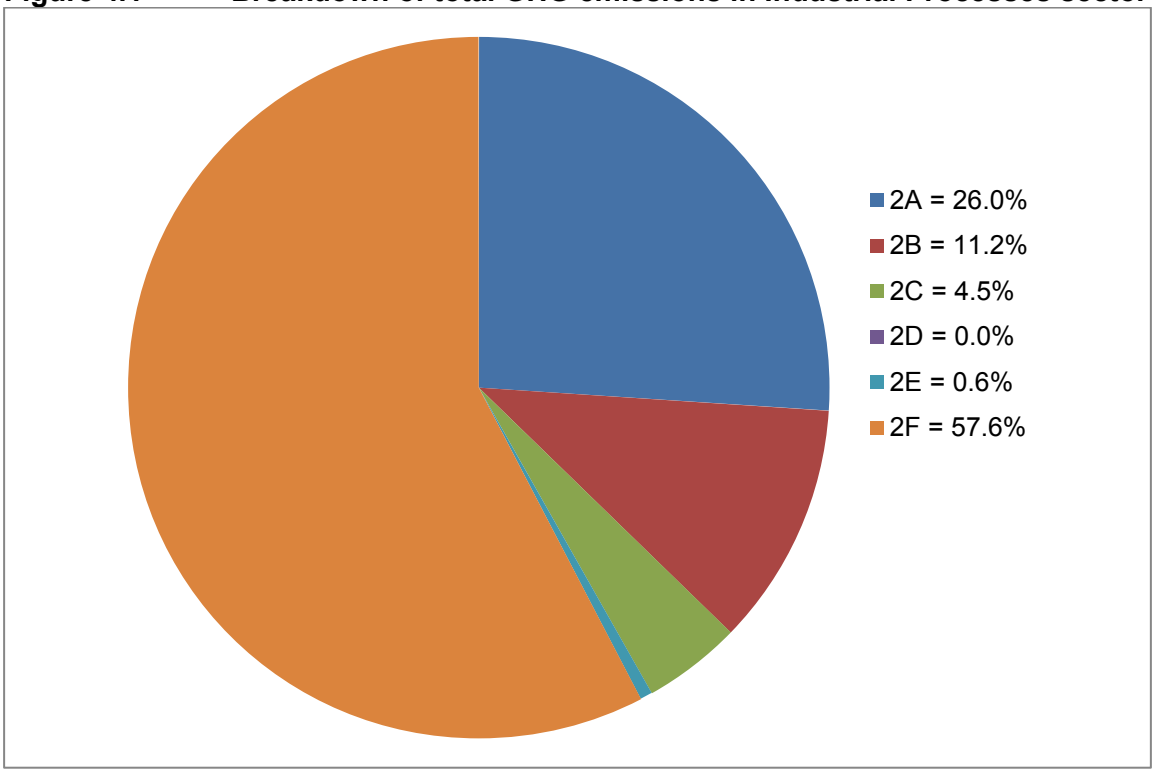
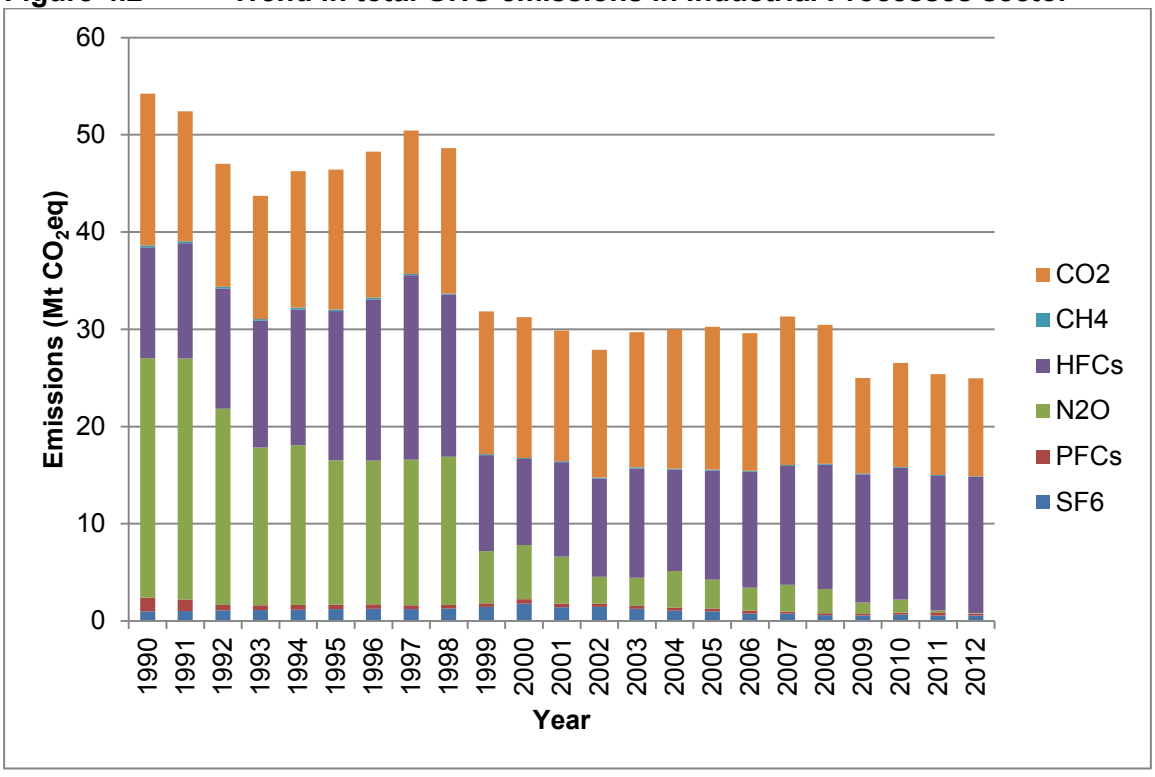


Figure 4.2 Trend in total GHG emissions in Industrial Processes sector



4.2 SOURCE CATEGORY 2A1 – CEMENT PRODUCTION

4.2.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2A1: Cement (Decarbonising)	T2	CS
Gases Reported	CO_2		
Key Categories (Trends)	None identified		
Key Categories (Level)	None identified		
Key Categories (Qualitative)	2A1 Cement Production – CO_2		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements		

Emissions of CO_2 from fuel combustion in cement kilns are reported under CRF source category 1A2f, whilst emissions from calcination of non-fuel feedstock to cement kilns 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 2012, although production at one site was very low during 2012.

4.2.2 Methodological Issues

Emissions for 2005-2012 are estimated from the annual UK production of clinker and emission factors provided by the Mineral Products Association (MPA), formerly the British Cement Association (BCA). This 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 2012 only, and so the emission factor value for 2005 has been applied to earlier years as well.

The methodology used for estimating CO_2 from calcination is summarised in **Table 4.2**.

Table 4.2 Methods used to estimate emissions of CO_2 from this category

Period	Activity data	Emission factor, kt C / kt carbonate	Emission
1990-2000	British Geological Survey – UK Minerals Yearbook, figure for UK	Use of 2005 factor from BCA	AD x EF
2001	British Geological Survey – UK Minerals Yearbook, figure for Great Britain only	Use of 2005 factor from BCA	AD x EF
2002-2004	British Cement Association, clinker production data for UK	Use of 2005 factor from BCA	AD x EF
2005-2012	Mineral Products Association, clinker production data for UK	Factor derived from annual, site-specific data compiled from EU ETS data by Mineral Products Association	AD x EF

4.2.3 Uncertainties and Time Series Consistency

The time-series consistency of the MPA (formerly called BCA) data is very good due to its continuity.

An 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). This initial large drop and a less pronounced downward trend in production over the period 1994-2007 may, in part, also be due to increased use of slag cement, the production of which is likely to have risen sharply over the same period – we estimate that capacity for slag cement production increased from 0.75 Mtonnes at the start of 1990 to 1.5 Mtonnes by 2004, with a further increase to 2 Mtonnes by 2007. A sharp decrease in clinker 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, and none of these have subsequently been re-opened. Although clinker production figures for the UK as a whole are confidential, figures for Great Britain (i.e. excluding a single plant in Northern Ireland) are published (Department for Business, Innovation & Skills, Monthly Statistics of Building Materials and Components, February 2014) and illustrate recent trends in the cement sector, with clinker production falling from 10,227 tonnes in 2007, to 63% of that level (6,421 tonnes) in 2009, with only small changes in production since.

The country-specific emission factors for cement clinker production for the period 2005-2012 are relatively constant, with only small year on year changes. The trend in emissions therefore largely 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**. Emissions reported to the inventory agency by the Mineral Products Association are cross checked with plant specific data reported in the EU ETS to ensure complete coverage of all emissions.

4.2.5 Source Specific Recalculations

No recalculations have been made in this category.

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

Emissions sources	Sources included	Method	Emission Factors
	2A2: Lime Production (Decarbonising)	T2	D
Gases Reported	CO_2		
Key Categories (Trends)	None identified		
Key Categories (Level)	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	Inclusion of additional estimates for unconverted lime residues from sugar industry processes		

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. However, for the inventory it is necessary to distinguish between merchant lime processes where the purpose is to produce lime for use off-site and where carbon dioxide is an unwanted by-product emitted to atmosphere, and those captive lime processes where lime is produced so that both the carbon dioxide and lime can be used on-site in the process. In these latter processes, which include sugar refining and the production of sodium carbonate using the Solvay process, none of the carbon dioxide is emitted to atmosphere, apart from the exception listed in the next section.

Lime was produced at 15 UK sites during 2012. 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 method uses EU ETS data to determine emissions from 2005 onwards, Pollution Inventory (PI) data from 1994 to 2004 and British Geological Survey (BGS) data from 1990 to 1993. The EU ETS data consist of CO_2 emission estimates and activity data. The activity data takes various forms e.g. feedstock or product, depending upon site, and so the emissions data have been adopted, with the lime activity data then being back-calculated using a default emission factor of 121.5 t carbon/ kt limestone or dolomite. This emission

factor is derived by assuming that 85% of UK lime production is from limestone and the remaining 15% is from dolomite (based on a recommendation from the EU's UNFCCC review). For limestone, an emission factor of 120 t carbon/kt limestone is then assumed, based on the stoichiometry of the chemical reaction, and for dolomite, the corresponding emission factor of 130 t carbon/kt dolomite is used.

Prior to 2005 there are no EU ETS data, and data are also missing for 2005-2006 for some lime kilns because of UK exemptions from the EU ETS for some sites in those years. Therefore, between 1994 and 2004, CO_2 emission estimates for lime production are based on emissions data published for each site in the Pollution Inventory (PI). The PI data are mostly for total CO_2 i.e. include emissions from both decarbonisation and fuel combustion on a site, but estimates of the CO_2 from decarbonisation only are made using EU ETS data and PI data for 2006-2008, both of which give fuel combustion emissions separately from decarbonisation. For the period 1994-1997, there is less reporting of CO_2 in the PI and so site-specific CO_2 emissions are estimated based on other site-specific data such as emissions data for particulate matter from those sites in the relevant years. We have no PI data for the period 1990-1993 so BGS activity data are the only data available to calculate emissions. As emissions estimates based on BGS data are consistently lower than emissions from PI and EU ETS sources for the period from 1994 onwards, we have assumed that BGS data for 1990-1993 would also underestimate emissions and have therefore applied a 'correction' factor of 1.08 to the BGS data for those years. The methods used for each part of the time series are summarised below.

Table 4.3 Methods used to estimate emissions from this category for merchant lime plants

Period	Activity data	Emission factor, kt C / kt carbonate	Emission
1990-1993	BGS x 1.08	121.5	AD x EF
1994-1997	(back-calculated)	121.5	PI CO_2 + estimates extrapolated from later PI data on basis of other data such as emissions data for other pollutants
1998-2004	(back-calculated)	121.5	PI CO_2
2005-2006	(back-calculated)	121.5	EU ETS & PI CO_2
2007-2011	(back-calculated)	121.5	EU ETS

The calculated emissions and activity data exclude carbonates calcined in the chemical industry since this is all used in the Solvay process, which does not release CO_2. The calcination of limestone in the sugar industry has previously been excluded for the same reason. However, the UNFCCC centralised review of the 2013 submission of the UK GHG Inventory recommended that CO_2 emission estimates were needed for lime production associated with sugar production. Based on consultation with the UK sugar industry, the UK inventory estimates have previously assumed that all of the lime used in the carbonatation process (whereby lime and carbon dioxide are used to remove impurities in sugar solutions) was converted to calcium carbonate, meaning no net emission in CO_2. The ERT recommended instead that this conversion was assumed not to be complete and that instead some unreacted lime was present in waste sludges at the end of the carbonatation process. Emission estimates have therefore been included for the 2014 submission, using a default

percentage of unreacted lime as advised by the ERT, This ERT default is based on data from other countries since UK-specific data are not available and EU ETS returns from UK sugar producers do not include any emissions associated with unreacted lime. Due to the confidentiality of the lime production data at the sugar production sites, further details of the methodology cannot be given here.

The calcium carbonate produced by the sugar industry is marketed as a soil liming agent and is assumed to be wholly used by UK agriculture. Emissions associated with this usage are included in the estimates for LULUCF as described in Chapter 7.

Emission factors for indirect gases from the production of lime are calculated from emissions reported in the PI in the case of CO and NO_x, and for VOC based on literature factors**.**

4.3.3 Uncertainties and Time Series Consistency

Uncertainty in the emission estimates for merchant lime plants is low for recent years but higher for earlier years in the time series. EU ETS data provides a comprehensive dataset for UK facilities from 2008 onwards, and the uncertainties associated with these verified data are low; the EUETS data from 2005 provide partial coverage of the sector and are used in conjunction with other data sources to derive inventory estimates, and hence the data for 2005-2007 are also regarded to be associated with low uncertainty. Uncertainty is higher for the estimates before 2005, because of the need for assumptions to be made in deriving the estimates (for example, assumptions regarding the split between combustion and process emissions in the PI data used between 1994 and 2004).

The estimates for facilities producing sugar are regarded as highly uncertain since EU ETS data for those sites do not provide any evidence that any CO_2 is emitted at those sites from this source. In addition, a study for the European Commission on EU ETS emission allowances for the lime sector (Ecofys, 2009) states that it can be assumed that “there are no process-dependent CO_2 emissions released from the limestone that is used”.The UK producer has also indicated that they consider the conversion of lime back to calcium carbonate as being complete (Personal Communication: British Sugar, 2013).

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**. Cross comparison of the BGS data with the EU ETS data as a means of verification has indicated a potential under report in the BGS data. This has led to a change in the methodology to ensure completeness of the inventory reporting.

4.3.5 Source Specific Recalculations

Details of and justifications for recalculations to activity data are given in **Table 4.4** below. For information on the magnitude of recalculations to Source Category 2A2, see **Section 10**.

Table 4.4 2A2 Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
			1990	2011	1990	2011		
2A2	Lime production - decarbonising	Limestone	C	C	C	C	Mt	Activity data revised to take account of estimated emissions associated with carbonatation process in sugar refining.

[C = Commercially confidential data]

4.3.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review. EU ETS Phase III data will be reviewed to seek any new information on sources of emissions from lime-related process sources that may be added to the scope of EU ETS from 2013 data onwards.

4.4 SOURCE CATEGORY 2A3 – LIMESTONE & DOLOMITE USE

4.4.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2A3: Basic oxygen furnaces Sinter production Power Stations (FGD)	T2 T2 T2	CS CS D
Gases Reported	CO_2		
Key Categories (Trends)	None identified		
Key Categories (Level)	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements		

Limestone and dolomite are used in steelmaking, typically being added to sinter where they are calcined, releasing CO_2 which is emitted to atmosphere, while the other products subsequently act as slag formers in blast furnaces. In practice, some of the limestone or dolomite used may be added directly to blast furnaces without being sintered first, which would mean that the CO_2 released would be emitted from the blast furnace stage of steelmaking rather than the sintering stage. However, this distinction is not important for GHG reporting and the practice is ignored for the GHGI with all additions and, therefore, emissions being reported as from sintering. Dolomite is also an important addition as a fluxing agent in basic oxygen furnaces and CO_2 evolved from the dolomite is reported as a separate category under 2A3. Limestone and dolomite are also used as sources of CaO and MgO in the manufacture of soda-lime glasses and for the liming of soils by the agricultural sector. Glass industry emissions are discussed in **Section 4.8,** while agricultural use is covered in **Chapter 6** of this report.

Limestone is also used in flue-gas desulphurisation (FGD) plant which are 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.

4.4.2 Methodological Issues

Data on the usage of limestone and dolomite for steel production are available from the Iron & Steel Statistics Bureau (2013). Previously, Corus UK Ltd (now Tata Steel) had provided analytical data for the carbon content of limestone and dolomite used at their steelworks (Corus, 2005), and these were used to generate default emission factors of 111 t carbon/kt limestone and 123 t carbon/kt dolomite for sintering and basic oxygen furnaces. For the latest submission, these factors have been replaced with values based on EU ETS data (Tata Steel, 2013). Separate values are available for the years 2007-2012. These data show close consistency across the EU ETS reported time series and therefore the 2007 value has been extrapolated back across the time series as the best estimate for the limestone and dolomite quality back to 1990.

Emissions from Flue Gas Desulphurisation (FGD) are calculated using an emission factor of 69 t carbon/kt gypsum produced. This factor is based on the stoichiometric relationship between gypsum and carbon dioxide formed in the FGD plant. Data on gypsum produced in FGD plant has previously been taken from the British Geological Survey (2012), but these data are not always consistent with site-specific emissions data available from EU ETS, and so now a composite series of activity data is used with BGS data for 1994-2004, and EU ETS data for 2005-2012. BGS data for 2005 are in very good agreement with EU ETS data for that year, and so it has been assumed that BGS data for 1994-2004 are also comparable with the later EU ETS data.

4.4.3 Uncertainties and Time Series Consistency

The 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 Iron & Steel Statistics Bureau. In the case of FGD plant, there is a change in methodology between 2004 and 2005 however, BGS and EU ETS-based emission estimates for 2005 are very close, and for 2006-2012 are within 8% of each other.

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

Details of and justifications for recalculations to emission factors are given in **Table 4.5** below. For information on the magnitude of recalculations to Source Category 2A3, see **Section 10**.

Table 4.5 2A3 Source specific recalculations to emission factors since previous submission

IPCC Category	Source Name	Pollutant	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
				1990	2011	1990	2011		
2A3	Basic oxygen furnaces	Carbon	Dolomite	123.0	123.0	128.5	128.5	kt C / Mt	Improved emission factors from industry sources, through accessing a much larger dataset of installation-specific analysis for emission sources used by plant operators to underpin EUETS data returns. (Tata Steel, 2013)
2A3	Sinter production	Carbon	Limestone	111.0	111.0	118.0	120.1	kt C / Mt	
2A3	Sinter production	Carbon	Dolomite	123.0	123.0	128.5	128.5	kt C / Mt	

4.4.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.5 SOURCE CATEGORY 2A4 – SODA ASH PRODUCTION & USE

Soda ash has been produced at two sites in the UK, both operating over the entire time period covered by the inventory. Emissions from fuels used at these sites are included in data reported under 1A2c. Emissions are assumed not to occur from the process itself since the soda ash is manufactured using the Solvay process and not from Trona, and all carbon dioxide formed from calcination of the limestone used in the UK processes is assumed to be sequestered in the soda ash product.

Emissions from soda ash (sodium carbonate, Na_2CO_3) used in the manufacture of soda-lime glasses is reported under source category 2A7.

4.6 SOURCE CATEGORY 2A5 – ASPHALT ROOFING

Emissions of CO_2 are not estimated from this source as there is no methodology available.

4.7 SOURCE CATEGORY 2A6 – ROAD PAVING WITH ASPHALT

4.7.1 Source Category Description

Emissions sources	2A6: Road Construction
Gases Reported	NMVOC
Key Categories (Trends)	None identified
Key Categories (Level)	None identified
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Not occurring
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	No major improvements made

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 being used to reduce the viscosity of the road dressing. The kerosene partially evaporates once the road dressing is laid and is emitted to atmosphere. Emissions of NMVOC 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, 2013).

4.7.3 Uncertainties and Time Series Consistency

The estimates of NMVOC from road paving are quite uncertain, particularly due to the long-term extrapolation of a single set of consumption data. Emissions occur only from 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. An uncertainty analysis for indirect GHGs is not included in this report.

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 in this category.

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 sources	Sources included	Method	Emission Factors
	2A7: Glass Production	T2	CS, D
	Brick Manufacture (Fletton)	T2	CS, D
	Glass (continuous filament glass fibre)	T2	CS, D
	Glass (glass wool)	T2	CS, D
Gases Reported	CO_2, CH_4, CO, NO_x, SO_2, NMVOC		
Key Categories (Trends)	None identified		

Key Categories (Level)	None identified
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Not occurring
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	No major improvements

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 and other glasses.

Fletton bricks are manufactured in Southern England using the Lower Oxford Clay. This clay contains a high level of carbonaceous material which acts as a fuel during firing, leading to emissions of carbon dioxide, carbon monoxide, methane, and NMVOC. The clay also contains sulphurous material, which results in SO_2 emissions as well.

The UK had 22 large sites making glass at the end of 2012, for the production of container glass (12 sites), flat glass (5 sites), continuous filament glass fibre (1 site), or glass wool (4 sites). There are also 3 small sites producing stone wool. Special and domestic glasses are no longer manufactured on a large scale in the UK, and production of lead glass, frits and ceramic fibres are only on a very small scale. It is assumed that limestone and dolomite are used in the production of container, flat, and special glass, and in glass wool.

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 VOCemissions from the use of coating materials for glass fibres. Both continuous filament glass fibre and glass/stone wool manufacture involve the attenuation of molten product into fine fibres, which are then cooled and coated with organic materials.

Coated roadstone is produced at numerous sites. The stone is quarried, crushed and then coated with bitumen. Emissions of NMVOC from these processes are reported in 2A7.

Process emissions of N_2O are not estimated for production of glass, Fletton bricks and asphalt because suitable methods or data have not been found. Operators of UK plant regulated under the Industrial Emissions Directive do not report any emissions data to the regulators and so any releases of N_2O from each of these sites must be below the reporting threshold of 10 tonnes and therefore any emissions will be very low for the UK as a whole.

4.8.2 Methodological Issues

Methodologies for direct greenhouse gases are summarised in **Table 4.6**.

Table 4.6 Summary of Emission Estimation Methods for Source Categories in CRF Category 2A7

Source Category	Method	Activity Data	Emission Factors
Fletton bricks	UK model	Inventory Agency estimates, based on Government statistics on brick production	CO_2, CH_4: based on total site emissions reported by operator, after subtraction of an estimate of emissions from fuel combustion N_2O: Not estimated
Glass Production	AD x EF	Inventory Agency estimates, based on industry data	CO_2: based on carbon content of carbonates CH_4, N_2O: Not estimated

Emission estimates are also made for indirect gases from Fletton brickmaking (SO_2, CO, NMVOC) using the same UK model as for CO_2. Emissions data for Fletton brickworks during recent years are available from the Pollution Inventory (Environment Agency, 2013). 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 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. One site that closed in 2008 burnt coal, whereas the other two sites (that are still in operation in recent years) 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).

Table 4.7 gives a timeline for the Fletton brick sector, summarising the sites operating and the data available for emission estimates over the time series.

Table 4.7 Timeline for Fletton Brick sector

Period	Number of sites and fuels	Availability of data
1990-1997	Estimated eight works in operation in 1990; only 5 still in operation by 1993. Those in 1993 burnt coal, or a mixture of coal and natural gas.	No emissions data available, annual production (numbers) of all bricks available and Fletton brick production estimated from this. Emission factors based on (1998) emissions data.
1998-2008	Two of the 5 works in operation since 1993 close in 1998/1999. Both used coal only as a fuel so by the end of 1999, 3 works remain: one burns coal, the other two, both in the same area in England, now burn natural gas only.	Annual emissions of CO_2 and methane available in the Pollution Inventory for each site until 2004, when emissions for the two gas-burning sites, which are located about 1.5 km apart start to be reported as combined totals. Reported emissions have to be split between energy-related and process-related emission. Annual production (numbers) of all bricks available, so Fletton brick production has to be estimated.

Period	Number of sites and fuels	Availability of data
2009-2012	Closure of coal-burning site at end of 2008, leaving only the 2 gas-burning works remaining.	Annual emission of CO_2 and methane available in the Pollution Inventory for the combined works. Emission factors and activity data derived as in previous years. EU ETS reported data shows close agreement with in-house estimates of fuel use (within 1% for 2008-2012).

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 approach used 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 provided by the glass industry (British Glass, 2001). Glass production data are available on an annual basis for container glass only (British Glass, 2013), and production of other types of glass is therefore estimated based on available data covering specific years (e.g. British Glass, 2001; EIPPCB, 2000), which are then 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, since other glass sectors use different glass formulations such as borosilicate glass, and the emission factor used is applicable to soda-lime glasses only.

Table 4.8 gives summary details for the UK glass industry and the scope of estimates for CO_2 emissions from carbonate use.

Table 4.8 Background Information on the Estimation of Emissions from Carbonate Use in Glassmaking and Related Industries

Glass Sector	1990 production, kt	2012 production, kt	Estimates included for emissions from use of:		
			Limestone	Dolomite	Soda Ash
Container	-[a]	-[a]	Yes	Yes	Yes
Flat	-[a]	-[a]	Yes	Yes	Yes
Special	226	0	Yes	Yes	No
Domestic, including lead	76	<1	Yes	Yes	Yes
Continuous filament glass fibre	82	37	Yes	Yes	No
Glass wool	104	278	Yes	Yes	No
Stone wool	83	97	No	No	No
Ceramic fibres	14	14	No	No	No
Frits	13	7	No	No	No

[a] confidential

Emissions of NMVOC in recent years from glass fibre and glass wool processes located in England are available from the Pollution Inventory. These data are used to calculate emission factors, based on estimates of glass production at these sites, and emissions can then be calculated both to include all processes throughout the UK and, by extrapolation, to include other years.

Emissions of NMVOC during manufacture of coated roadstone are estimated using production data from TSO (2013) and an emission factor of 8.73 g/t coated roadstone, which is the average of emission factors given by US EPA (2013) for various types of batch roadstone coating plant.

4.8.3 Uncertainties and Time Series Consistency

The 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 derived from UK industry information.

The emission factor is based on the stoichiometry of the chemical reaction undergone by the soda ash and is accurate.

Estimates for Fletton bricks, carbon in particular, are sensitive to the assumptions made about supplementary fuel use, however the estimates cannot be improved without fuel consumption data, which are not available.The time-series involves some extrapolation of data using brick production estimates and this will introduce 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

No recalculations have been made in this category.

4.8.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.9 SOURCE CATEGORY 2B1 – AMMONIA PRODUCTION

4.9.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2B1: Ammonia Feedstock	T2	CS
Gases Reported	CO_2		
Key Categories (Trends)	None identified		
Key Categories (Level)	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	The activity data reported under 2B1 is now limited to the gas use as feedstock for ammonia production. In previous submissions, the inventory agency had reported activity data for gas use in all NEU applications under 2B1 in error.		

Ammonia is typically 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 to form ammonia.

$N_2 + 3H_2 \Leftrightarrow 2NH_3$

If the by-products CO and CO_2 are not captured and used, then these are emitted to atmosphere. Ammonia plants can be integrated with methanol manufacture for greater efficiency, since the carbon oxides can be used to manufacture methanol:

$CO + 2H_2 \Leftrightarrow CH_3OH$
$CO_2 + 3H_2 \Leftrightarrow CH_3OH + H_2O$

Over the time period covered by the UK greenhouse gas inventory, ammonia has been manufactured at four locations in the UK. CO_2 emissions are reported from three of those sites: at the remaining site (Hull), the ammonia is produced with hydrogen supplied as a by-product from another chemical process operated on a neighbouring site. That other process reforms natural gas to produce CO_2 used in the manufacture of chemical feedstocks, and so the CO_2 is assumed stored. At one of the remaining three sites where CO_2 is reported, some carbon from the steam reformer was, until 2001, exported for use in the manufacture of methanol. That carbon was still reported as emitted in line with IPCC Guidelines for ammonia production processes.

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.

Methane emissions from the steam reforming processes and the associated ammonia production facilities are reported under 2B5, together with methane emissions from other types of chemical manufacturing sites. Nitrous oxide emissions are not estimated: manufacturers do not report any emissions of this pollutant and they are therefore assumed to be negligible.

4.9.2 Methodological Issues

IPCC source category 2B1 is reserved for emissions of GHGs from natural gas used as a feedstock in the ammonia process. Where emissions are derived from the combustion of natural gas to produce heat required by the steam reforming stage of the ammonia process, emissions are reported under IPCC source category 1A2c because this is an energy use of the natural gas.

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 chemicals manufacture does not need to be included since there are no process emissions of CO_2.

Table 4.9 summarises the details of the UK ammonia plants and **Table 4.10** gives details of production and emissions etc. by the sector.

Table 4.9 Details of UK ammonia plants

Plant	Feedstock	Carbon emissions	Notes
Billingham	Natural gas	Yes	Some production of methanol using by-product carbon until 2001
Severnside	Natural gas	Yes	Closed in 2007
Ince	Natural gas	Yes	
Hull	Hydrogen	No	

Table 4.10 UK ammonia production and emission factors

Year	Ammonia production, ktonnes		Gas for feedstock, TJ	CO_2 emitted, ktonnes	CO_2 emission factor		
	Total	Excluding Hull	Ammonia plant		t / TJ	t / t NH_3 *(all UK production plant)**	t / t NH_3 *(excluding Hull plant production)*
1990	1328	1128	28413	1431	50.37	1.08	1.27
1995	1388	1145	28741	1462	50.88	1.05	1.28
2000	1213	986	26956	1382	51.28	1.14	1.40
2005	1172	945	23360	1200	51.38	1.02	1.27
2006	949	722	17534	901	51.36	0.95	1.25
2007	1251	1024	24050	1235	51.34	0.99	1.21
2008	1082	855	19885	1019	51.24	0.94	1.19
2009	889	662	14980	767	51.22	0.86	1.16
2010	1084	857	18950	969	51.15	0.89	1.13
2011	687	573	12592	643	51.03	0.93	1.12
2012	1017	806	18575	948	51.06	0.93	1.18

*As reported within the CRF table 2(I).A-Gs1

CRF table 2(I).A-Gs1 presents the ammonia production data for all UK sites (including Hull where there are no CO_2 emissions). In order to aid transparency and comparability of the country-specific IEFs for this source, in the table above we also provide the time series of CO_2 emission factors on an energy basis (t/TJ) which shows close consistency across all years, and also an emission factor per tonne of ammonia production for the three sites where there are CO_2 emissions (the right hand column) which is a higher IEF than the UK aggregate including the Hull plant production that is presented in the CRF.

The operator of the Ince and Billingham UK ammonia plants has provided information on reasons underlying the year on year variation in emission factors. Firstly, plants are typically shut down for routine maintenance every two years, and start-up and shut-down procedures increase the emission factors overall. Secondly plant production rates are varied by the operator during times of high gas prices or low demand, which reduce efficiency and increase emission factors.

In addition to these operational variables, each plant will have a different intrinsic efficiency, which will in part reflect the age of the plant and the technology used. The IPCC 2006 Good Practice Guidance suggests a Tier 1 default emission factor of 1.694 tonnes CO_2 / tonne NH_3 for 'modern' European plant, but a higher Tier 1 default of 2.104 tonnes CO_2 / tonne NH_3 for a 'typical' plant i.e. based on a mix of modern and old plant. These IPCC emission factors are for emissions from all natural gas used i.e. including the gas burnt to generate heat for the ammonia process, so should not be compared with the current UK factors given in the above table, since these exclude the gas used for energy. UK factors on a comparable basis to those given in the 2006 Guidelines show an average 1.873 tonnes CO_2 / tonne NH_3 for production across 1990-2012, and would only be outside the range suggested by the two IPCC defaults for one year: in 2011, when production was very low, the emission factor was 2.123 tonnes CO_2 / tonne NH_3. All of the UK plant have been in operation since before 1990;the fact that the average UK factor lies between the 2006 IPCC Guideline defaults for

modern plant and mixed modern/old plant indicates that the performance of the UK ammonia plant are broadly typical of European plant.

4.9.3 Uncertainties and Time Series Consistency

The uncertainty analysis in Annex 7 provides estimates of uncertainty according to IPCC source category and fuel type. The uncertainty associated with this source is low, since the carbon content of natural gas is well known and plant specific data are received from the operators annually.

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.

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

Details of and justifications for recalculations to activity data are given in **Table 4.11** and emission factors in **Table 4.12** below. Through consultation with plant operators, the total UK ammonia production in 2011 has been revised in the 2014 submission; production at one site in the UK was reported too high, in error, in the 2013 submission. This revision is reflected in a lower overall ammonia production figure reported for 2011 in CRF table 2(I).AGs-1. For information on the magnitude of recalculations to Source Category 2B1, see **Section 10**.

Table 4.11 2B1 Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
			1990	2011	1990	2011		
2B1	Ammonia production - feedstock use of gas	Natural gas	470.35	203.26	269.30	119.35	Mth fuel consumed	Correction to quoted activity data to exclude natural gas used as a feedstock in production of chemicals other than ammonia. In previous submissions, activity data included gas used as feedstock in manufacture of acetic acid and acetic anhydride in error. Emission estimates from gas use as feedstock in ammonia production are unchanged.

Table 4.12 2B1 Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	Pollutant	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
				1990	2011	1990	2011		
2B1	Ammonia production - feedstock use of gas	Carbon	Natural gas	0.830	0.862	1.449	1.468	kt C / Mth	Impact of correction to activity data. Emission estimates are unchanged.

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

Emissions sources	Sources included	Method	Emission Factors
	2B2: Nitric Acid Production	CS	CS
Gases Reported	N_2O, NO_x		
Key Categories (Trends)	Nitric Acid Production – N_2O		
Key Categories (Level)	Nitric Acid Production – N_2O (Base yr only)		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements		

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 2012 nitric acid was being manufactured at 2 UK sites with a total of 4 production plants. At one site, the nitric acid production plant has had NO_x/N_2O abatement fitted to all units since commissioning (pre-1990), whilst at the other UK production site, all three production lines have had nitrous oxide abatement retrospectively fitted during 2011 Quarter 1. This has led to a notable reduction in the UK IEF for nitrous oxide emissions from nitric acid production in the UK between 2010 and 2011 (see **Table 4.15** below).

4.10.2 Methodological Issues

Across the 1990-2012 time-series the availability of emissions and production data for UK nitric acid plant is inconsistent, and hence a range of methodologies have had to be used to

provide estimates and derive emission factors for this sector. Where possible, emission estimates are based on site-specific data provided by process operators.

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 three sites operating between 1990 and 1993, 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 nitric acid site using one of the following:

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, Scotland, 1990-1993). This default factor is the average of the range quoted in IPCC Guidelines (IPCC, 1997) for medium pressure plant

Table 4.13 and **Table 4.14** give a summary of the approaches used across the time series to estimate production and N_2O emissions.

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. Emissions between 1990 and 1993 are estimated by interpolating between the 1994 emission based on plant-specific data, and an estimate for emissions in 1988 based on nitric acid production data (CIS, 1991) and a default NO_x emission factor of 3.98 tonne NO_x / kt of 100% acid produced.

This default NO_X emission factor is a weighted aggregate of CORINAIR (1989) emission factors for the different types of nitric acid processes ranging from 3-12 t/kt of 100% acid produced. The weighting is based on data on the types of UK manufacturing plant in the year 1985, provided by the Nitric Acid Association (Munday, 1990).

Some nitric acid capacity is co-located 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 4.11**) but emissions from 1994 onwards are reported separately. This causes some inconsistency in between reporting categories, although total emissions are not affected.

Table 4.13 Methods used to estimate emissions from this category

Period	Site specific production data		Site Specific emissions data, kt N_2O		
	Estimated	Operator data	As reported by operator	Estimated using site-specific EF	Estimated using IPCC default EF
1990-1993	7 sites	1 site		5 sites	3 sites
1994	5 sites	1 site		6 sites	
1995-1997	4 sites	2 sites		6 sites	
1998-1999		6 sites	5 sites	1 site	
2000	1 site	5 sites	5 sites	1 site	
2001		5 sites	4 sites	1 site	
2002-2008		4 sites	4 sites		
2009-2012		2 sites	2 sites		

Table 4.14 Methods used by operators to quantify site emissions

Period	Site emissions based on:	
	Emission Factors	Monitoring
1998-2000	4 sites	1 site
2001-2004	3 sites	1 site
2005	2 sites	2 sites
2006-2007	1 site	3 sites
2008	2 sites[a]	2 sites
2009	1 site	2 sites
2009-2012	None	2 sites

[a] One site closed at end of January 2008 which submitted emissions data for that month based on emission factors having used monitoring to quantify emissions the previous year.

Table 4.15 Summary of Nitric Acid Production in the UK, 1990-2012

Year	No of sites	Production (Mt 100% Nitric Acid)	Aggregate EF (kt N_2O / Mt Acid)	Aggregate EF (kt NO_X / Mt Acid)
1990	8	2.41	5.23	3.36
1994	6	2.49	3.89	1.93
1995	6	2.40	3.82	0.808
1996	6	2.44	3.83	0.743
1997	6	2.35	3.78	0.902
1998	6	2.61	3.99	0.732
1999	6	2.44	6.29	0.913
2000	6	2.03	6.94	0.992
2001	5	1.65	6.62	0.662
2002	4	1.64	4.20	0.392
2003	4	1.71	4.38	0.431
2004	4	1.71	5.00	0.438
2005	4	1.71	3.80	0.379
2006	4	1.47	3.87	0.424
2007	4	1.61	3.54	0.380
2008	4	1.29	3.89	0.234
2009	2	0.93	3.89	0.270
2010	2	1.21	3.51	0.221
2011	2	1.08	0.616	0.118
2012	2	1.13	0.173	0.127

The larger of the two remaining UK plants fitted control equipment to reduce N_2O emissions in early 2011, and this will also have decreased NOx emissions from that plant as well, leading to the large decreases in the aggregate EFs for both pollutants in 2011 compared with the previous year.

4.10.3 Uncertainties and Time Series Consistency

The 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, which is a reflection of nitric acid production patterns across UK sites that utilise different process conditions. Successive closures have changed the average N_2O EF, as plants with generally above-average emission rates cease production. Abatement of N_2O at two plants has also played a part in reducing the UK emission factors over time. The changes in EF may also partially reflectthe lack of availability of a consistent time-series of emissions data.

The nitric acid plant emissions data reported by operators since 1998 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 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 to this category for the 2012 submission.

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

Emissions sources	Sources included	Method	Emission Factors
	2B3: Adipic Acid Production	CS	CS
Gases Reported	N_2O		
Key Categories (Trends)	None identified		
Key Categories (Level)	2B3 Adipic Acid Production – N_2O (Base yr only)		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements		

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.

4.11.2 Methodological issues

There was only one company manufacturing adipic acid in the UK, but this closed in early 2009. Production data are not provided in the NIR because of commercial confidentiality concerns.

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 was a thermal oxidation unit and was reported by the operators to be 99.99% efficient at N_2O destruction. The abatement unit was not available 100% of the time, and typically achieved 90-95% availability during adipic acid production.

A small nitric acid plant was associated with the adipic acid plant, and this also emitted N_2O. From 1994 until the plant's closure in 2009, the emission from the nitric acid production is reported under 2B2, but prior to 1994 it is included under adipic acid production because separate emissions data for the different processes on that site were not available for those years. This discrepancy in reporting will cause a variation in the reported effective emission factor for these years for 2B2 and 2B3 but overall emission estimates are not affected.

4.11.3 Uncertainties and Time Series Consistency

The 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 known, but the data are considered to be reliable as they are subject to QA/QC checks by the operator, by the Environment Agency (before being reported in the Pollution Inventory) and by the regulators of the UK Emission Trading Scheme (DEFRA NCCP). A higher uncertainty is assumed for 1990 than for later years. Emissions no longer occur from this source since the plant has now closed.

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. 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 to this category for the 2012 submission.

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

Emissions sources	Sources included	Method	Emission Factors
	2B5: Energy Recovery From Wastes	CS	CS
	Carbon in pesticides	CS	OTH
	Carbon in consumer products	CS	OTH
	Petroleum waxes	CS	OTH
	Sulphuric Acid Production	CS	CS, OTH
	Chemical Industry	CS	CS, OTH
	Chemical Industry (Carbon Black)	CS	CS, OTH
	Chemical Industry (Ethylene)	CS	CS, OTH
	Chemical Industry (Methanol)	CS	CS, OTH
	Chemical Industry (Nitric Acid Use)	CS	CS, OTH
	Chemical Industry (Pigment Manufacture)	CS	CS, OTH
	Chemical Industry (Reforming)	CS	CS
	Chemical Industry (Soda ash)	CS	CS, OTH
	Chemical Industry (Sulphuric Acid Use)	CS	CS, OTH
	Coal, tar and bitumen processes	CS	CS, OTH
	Solvent and Oil recovery	CS	CS, OTH
	Ship purging	CS	CS, OTH
Gases Reported	CO_2, CH_4, CO, NO_x, SO_2, VOC		
Key Categories (Trends)	2B5 Non energy use of products – CO_2		
Key Categories (Level)	2B5 Non energy use of products – CO_2 (Latest yr only)		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements		

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. Many chemical processes report CO_2 emissions in the Environment Agency Pollution Inventory and similar data sets, but these emissions are most likely to be due to combustion processes operated as part of those chemical processes (e.g. for steam raising) and so cannot be used as evidence of process-related emissions. Chemical processes can result in indirect 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 in 1A2c.

Emissions can also occur from products from the chemical industry. Sources of emissions include burning of waste products and final products (e.g. flaring, burning of candles, firelighters and other products, use of explosives and pyrotechnics 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 consumer products (soaps, shampoos, detergents etc.); and
- Carbon in 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 2012 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 a third, general, source category (named ‘chemical industry’ in the inventory).

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 2012. 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 methodology for estimating carbon released from consumer products is based upon that used by the US and reported in Annex 2 of their NIR[31]. The basic approach is to assume that all carbon in consumer products is fossil-derived, and that all of this carbon is ultimately biodegraded and emitted – in other words, the estimates are conservative. The UK also considers a slightly wider scope of consumer products than in the U.S. inventory in that all

[31] http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2014-Annex-2-Emissions-Fossil-Fuel-Combustion.pdf

non-aerosol consumer products are included in the estimates, rather than just soaps, shampoos and detergents. In practice, we expect this increased scope for the UK estimates will have a very small impact on the emission estimates.

For cosmetics, toiletries and household products, activity data are based on detailed consumption data for 1994, extrapolated to other years in the time-series using sales value data in the case of cosmetics and toiletries, and population or household numbers in the case of household products (population in the case of household products such as dishwashing and laundry detergents, household numbers in the case of household cleaning products such as polishes and surface cleaners). For automotive care products such as anti-freeze and automotive cleaning products, UK consumption data have not been found and so UK consumption is estimated using per capita usage rates from the United States.

The carbon content of these consumer products is then estimated using a factor given in the US NIR of 22% carbon. The organic solvents that are present in certain consumer products such as polishes, screenwash etc. are then subtracted from this carbon figure since those solvents are reported as NMVOC emissions in CRF 3D. The remaining carbon is assumed to be biodegraded in the environment and emitted, with these emissions reported in 2B5.

A similar approach is used for pesticides, except that in this case, a proportion of the carbon is assumed to be in the form of persistent chemicals and therefore treated as stored. Data on UK consumption of pesticide active ingredients were used as the activity data and a carbon emission factor of 40% of the carbon content was taken from the US GHG inventory. This carbon factor was derived using data published in the 2005 US NIR (where carbon emitted from pesticides was reported as 0.2 Tg CO_2 eq. while carbon stored was 0.3 Tg CO_2 eq.) and has been kept unchanged since. Due to a lack of information on the chemical composition of UK pesticides, the active ingredients have been treated as 100% carbon and so the carbon emission factor used in the UK inventory is also 40% of the total mass of active ingredient.

The quantity of waste recovered for use as a fuel was previously 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. However, 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, and it was possible that some of the wastes might be already covered elsewhere in the GHG inventory, for example the estimates made for ethylene crackers and other petrochemical process use of waste-gases.

Through an inventory improvement research project in 2013-14 (Ricardo-AEA, 2014b), a review was conducted of available data on industrial use of process off-gases and waste residues as fuels, including consultation with operators of several of the installations that were known to use process off-gases as a fuel. The research included a review of data within the EU ETS (for 2005 to 2012) where the reported fuel name and available data on fuel quality indicated that residues or gases derived from chemical feedstock materials were being used as a fuel. In addition, installation-specific (but anonymised) data from the chemical industry Climate Change Agreement (CCA) data reported for 2008 and 2010 were also reviewed. The use of the CCA data was primarily to quality check the number of sites in the chemicals sector that reported the use of waste-derived fuels, and this dataset confirmed that there were a very small number of sites reporting waste-derived fuel use. The research has led to a revision of the estimates presented as fuel combustion in IPCC source category 1A2c, Chemical Combustion; it is not possible with the current data available to distinguish

between feedstock-derived off-gases that are used directly as a fuel and those used in other process-related activities that result in emissions, such as flaring, and therefore the total emissions reported for those sites are allocated to 1A2c. Furthermore, the research identified where there were potential overlaps between reported data in 1A2c and the previous method for 2B5 as outlined in the paragraph above. As a result, a revised estimate has been made for this version of the inventory, removing double-counts for a number of sites and slightly reducing the overall reported emissions across 1A2c and 2B5.

In the case of other pollutants, site-specific emissions data for chemical processes located in England and Wales are available in the Pollution Inventory (Environment Agency, 2013). Reporting generally started in 1994 or 1995, and few data exist for the years prior to 1994. Site specific emissions data for ethylene production processes in Scotland and additional data for some of the other methane-emitting processes in England and Wales have been obtained from process operators and from the Scottish Pollutant Release Inventory (SEPA, 2013). 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 NIEA (2013). The inventory time-series for methane from ethylene production is based on a full set of operator-reported emissions data, most of which will be estimates based on, for example, production data and emission factors, rather than being based on measurements. The time-series for other methane-emitting chemical processes require more extrapolation to address gaps in the operator-reported data: again, where operator-reported data are available, these generally are based on estimation methods rather than measurement.

The National Sulphuric Acid Association (NSAA, 2003) has 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 available, butemission factors are estimated using the best available 'surrogate' activity data that are available across the time series; this approach then enables estimates of emissions to be made for the years prior to operator-reported emission estimates (typically pre-1994). For most commodities, the extrapolation is 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 (2013). In a few cases, such as the figures for methane from ethylene production and SO_2 from sulphuric acid production, emissions data are available from operators across the whole time-series, or can be estimated for individual plant based on plant capacities rather than using index of output data to extrapolate emissions.

The operator-reported emissions data from regulatory inventories (PI, SPRI, NIPI) are not complete for all years, and the inventory agency uses IPCC good practice guidance methods of interpolation or the use of proxy data (e.g. other reported pollutants) to generate complete emission estimates in those circumstances. For example, emissions from a given process may be reported for some years but not others, even though the process is known to have been operating throughout. Most of the gaps occur in the earlier years of the Pollution Inventory, and therefore the estimates for the earlier years of the time series are associated with higher uncertainty than data for more recent years.

4.13.3 Uncertainties and Time Series Consistency

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

Non-energy use of products (2B5) has been identified as a key category for the first time in the 2014 submission. This results from revisions made to the uncertainty analysis for this category. Currently, emissions are estimated using a country-specific method that relies upon default factors and extrapolation of limited activity data. The estimates for 2B5 are therefore uncertain but they are also likely to be conservative for a number of reasons:

- All carbon in consumer products is assumed to be emitted to atmosphere in some form.
- The US methodology has been extended in the UK inventory to additional types of consumer products for which the methodology may not be as appropriate.
- Pesticides are assumed to be 100% carbon because of a lack of data on actual composition.

Both the activity data and the emission factors for this sector are subject to high uncertainty. The activity time series relies upon extrapolation of data for 1994 and so research to collect more up-to-date consumption data would be perhaps the area of uncertainty that could most easily be addressed.

For estimates of CO_2, uncertainties for emissions from the breakdown of consumer products and pesticides are high, since the assumptions are not UK-specific. For the use of waste residues and process off-gases as fuel in the chemical industry, the emissions estimates are also somewhat uncertain as the completeness of the data are very hard to verify; the recent inventory improvement study, however, has confirmed that there are no remaining high-emitting sites in the UK that are reporting the use of process wastes as a fuel, and therefore the overall uncertainty on the UK inventory estimates is not regarded as significant. Energy and environmental experts within the UK trade association for the chemical sector, the Chemical Industries Association, also confirmed that they were not aware of any other sites in the UK that used process off-gases, over and above the sites identified included in the UK GHGI (Personal communication, Chemical Industries Association, 2014), which are dominated by the 4 ethylene production sites and a handful of other sites producing organic chemicals, typically co-located with refineries.

For estimates of other pollutant emissions, those for 1994 onwards are mostly based on data reported by process operators through the regulatory agency data management and checking systems that govern UK industrial emissions data within the PI, SPRI and NIPI. The dataset is evidently incomplete in some years, due to the variations through time in the reporting thresholds for different pollutants. The inventory agency has used good practice techniques to address these reporting inconsistencies, and therefore the completeness of the data is good through the time series.

Unfortunately the availability of production data for many chemicals and other products from the sites reported under 2B5 is very limited in the UK, and this inhibits the inventory agency's ability to conduct data validation tests on the reported emissions data, against a reliable time-series of production estimates. This approach is deployed in other sections of the UK inventory (e.g. within the iron and steel sector where the ISSB produces good quality, detailed production statistics) but the ONS statistical outputs for many other manufacturing

sectors is limited due to the suppression of data that are deemed commercial in confidence. As a result, some of the data extrapolation has to be conducted using ONS data that are aggregated across several related manufacturing sectors, and this adds to the level of uncertainty, especially for earlier years where operator-reprted data are more scarce.

Emission estimates for NMVOC in the early part of the time series are more uncertain than the estimates for other pollutants due to inconsistencies in operator reporting to the Pollution Inventory until the late 1990s. For the first few years of the Pollutuion Inventory, operators reported NMVOCs using a range of different approaches (e.g. “as toluene”, “as carbon”, reporting several individual compounds and then also a total NMVOC figure – but not sufficiently transparent to unambiguously identify double-counts). As a result, the data have to be interpreted using expert judgement in order to derive as consistent a time series as possible.

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 uncertainty of some emission estimates from 2002 onwards is higher for 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, and a greater need to extrapolate data to fill reporting gaps.

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**. Emissions data taken from the Pollution Inventory are subject to additional QA/QC by the Environment Agency before being used in the inventory.

4.13.5 Source Specific Recalculations

Details of and justifications for recalculations to emission factors and activity data are given in **Table 4.16** and **Table 4.17** below, now recalculations have been made to activity data. For information on the magnitude of recalculations to Source Category 2B5, see **Section 10**.

Table 4.16 2B5 Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
			1990	2011	1990	2011		
2B5	Chemical industry - general	Chemicals and manmade fibres	62.3	95.7	62.3	96.5	Unitless	Revision to index of manufacturing output for the chemicals sector

Table 4.17 2B5 Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	Pollutant	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
				1990	2011	1990	2011		
2B5	Non-aerosol products - household products	Carbon	Carbon in detergents	314.0	415.5	314.0	416.1	kt (total UK emissions)	Review of NEU information performed during 2013. Note that the "EF" here is effectively the best estimate of total UK emissions, and the revision is due to a small change in estimates of soap and detergent use in the UK. The underlying assumption of what proportion of carbon in detergents are ultimately emitted is unchanged.
2B5	Non-aerosol products - household products	Carbon	Petroleum waxes	19.9	11.3	19.9	12.7	kt (total UK emissions)	Review of NEU information performed during 2013. Note that the "EF" here is effectively the best estimate of total UK emissions, and the revision is due to a small change in estimates of petroleum wax use in the UK, revised in DUKES for 2010 and 2011. The underlying assumption of what proportion of carbon in petroleum waxes are ultimately emitted is unchanged.
2B5	Other industrial combustion	Carbon	Energy recovery - chemical industry	81.7	85.5	23.8	23.8	kt (total UK emissions)	Review of NEU information performed during 2013. Review of the EU ETS and CCA data identified a number of sites where the estimates derived for 2B5 were double-counting emissions that are now reported under combustion of "OPG" within 1A2c.

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 inventory agency will continue to review the available operator-reported data and seek to derive a consistent time series of emissions. The scope of reporting of EU ETS has been extended to cover other sources including flaring in the chemical industry, from 2013 data onwards, and therefore there may well be additional information arising from the EU ETS that could help to clarify and improve the resolution of data reporting in future submissions.

4.14 SOURCE CATEGORY 2C1 – IRON AND STEEL PRODUCTION

4.14.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2C1: Iron & steel flaring (BFG) Electric arc furnaces Ladle arc furnaces Following for indirect gases only: Blast furnaces Basic oxygen furnaces Iron and Steel (other) Rolling Mills (Hot & Cold Rolling)	T1, T2 T1, T2 T2 T2 T2 T2 T2	D, CS D, CS CS CS CS CS CS
Gases Reported	CO_2, CH_4, CO, NO_x, SO_2, VOC		
Key Categories (Trends)	None identified		
Key Categories (Level)	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	2C1: Improved accuracy through use of EU ETS and installation-specific operator-reported data within the UK carbon balance approach for coke manufacture and iron and steel sources.		

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 integrated steelwork are reported under 1A1c, 1B1b, 1A2a,

2A3 and 2C1, depending upon the emission source. Only carbon emissions from flared blast furnace gas and basic oxygen furnace gas are reported under 2C1.

Carbon emissions from electric arc furnaces and ladle arc furnaces are calculated using emission factors provided by Corus (2005). 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. **Table 4.18** summarises the methods used for direct gas emissions reported under 2C1.

Table 4.18 Summary of Emission Estimation Methods for Source Categories in CRF Category 2C1

Source Category	Method	Activity Data	Emission Factors
Iron & steel - flaring	AD x EF	DECC energy statistics	Carbon: UK-specific factor from carbon balance CH_4, N_2O: IPCC (2006)
Electric arc furnaces	AD x EF	ISSB	Carbon: UK-specific factor CH_4, N_2O:EMEP/EEA
Ladle arc furnaces	AD x EF	ISSB	Carbon: UK-specific factors

Emissions of indirect gases are generally based on emissions data reported by process operators either directly to the inventory agency, or via the Environment Agency Pollution Inventory. In a few instances where emissions data are not available, literature factors are used.

4.14.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type. The sectoral Monte Carlo analysis indicates an overall uncertainty of 5.8% for emissions in this category.

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**.

The carbon balance model has been improved for this version of the GHG Inventory by the greater use of EU ETS and other industry data, rather than defaults for carbon emission factors. In the process of updating the model, the consistency between the GHG Inventory and EU ETS/industry data has been examined in detail, and consistency between the two improved.

4.14.5 Source Specific Recalculations

Details of and justifications for recalculations to emission factors are given in **Table 4.19** below. No significant recalculations have been made to activity data for 2C. For information on the magnitude of recalculations to Source Category 2C1, see **Section 10**.

Table 4.19 2C1 Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	Pollutant	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
				1990	2011	1990	2011		
2C1	Iron and steel - flaring	Carbon	Blast furnace gas	7.93	8.28	8.07	7.98	kt C / Mth	Revised as a result of changes to the steelmaking carbon balance model, with use of improved industry data on carbon contents of fuels, products and other materials
2C1	Iron and steel - flaring	CH4	Blast furnace gas	0.0118	0.0118	0.0001	0.0001	kt / Mth	Now using the IPCC default value from 2006 GL as there is no default in 1996 GL. Previously the EMEP-EEA default was used which has been removed from the latest version of the Guidebook.
2C1	Iron and steel - flaring	N2O	Blast furnace gas	0.0002	0.0002	0.00001	0.00001	kt / Mth	Now using the IPCC default value from 2006 GL as there is no default in 1996 GL. Previously the EMEP-EEA default was used which has been removed from the latest version of the Guidebook.

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

Ferroalloys do not seem to have been produced in the UK in significant quantities at any point over the 1990-2012 timescale of the inventory – no national activity data have been found. However, it is possible that some small-scale production may have occurred at some point. Any emissions are likely to have been both small and in the case of emissions due to use of coke oven coke would in any case be already reported in 1A2. We therefore do not make any estimates of emissions for 2C2 and report emissions as being included in 1A2.

4.16 SOURCE CATEGORY 2C3 – ALUMINIUM PRODUCTION

4.16.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2C3: Non-Ferrous Metals (Aluminium Production)	T2, CS	CS, PS
Gases Reported	CO_2, PFCs, CO, NO_x, SO_2, VOC		
Key Categories (Trends)	None identified		
Key Categories (Level)	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements		

Aluminium was produced by the electrolytic reduction of alumina at two sites in the UK at the end of 2011, although the larger of these two sites subsequently closed in early 2012, leaving just one small smelter operating in the UK. A third site had closed during 2009, and a fourth process closed in mid-2000. The operational site and the recently-closed processes all use or used 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 are estimated using statistics on the production of aluminium by each type of process and suitable emission factors. The carbon emission factors reflect current practice, and higher emission factors were used for earlier years, due to the production of some aluminium using the Soderberg process.

During the 1990s, there were two aluminium smelting operators in the UK, operating at four sites. One of these sites closed in 2000, another in 2009, and a third in 2012 leaving just one small site now open. All emissions of PFCs (CF_4 and C_2F_6) occur during the aluminium smelting process during anode effects. The estimates were based on estimates of emissions provided by the plant operators. These estimates were derived from records of the number and duration of anode effects.

Both operators use 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 for three of the plants, and for VSS (Vertical Stud Soderberg) for the plant which closed in 2000. One of the operators used North West American Calculation assuming 3lbs PFC for every minute the cell was on anode effect, for the early part of the time series. The time series does not show any discontinuity as a result of the change in method.

Parameters for the calculation of emissions for the two operating plant in 2012 are set out below.

Table 4.20 Parameters for calculation of PFC emissions from Aluminium production in 2012

	Units	Plant 1	Plant 2
CF4 Produced (IPAI)	kgs	1267	565
C2F6 Produced (IPAI)	kgs	163	73

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 time series 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.

For other pollutants, emissions data are available from regulators (i.e. the Environment Agency's Pollution Inventory for the two largest processes in England & Wales, and the

Scottish Pollutant Release Inventory, produced by the Scottish Environment Protection Agency, for the Scottish sites) and also, more recently, direct from plant operators.

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.

Methodologies used for direct gases from 2C3 are summarised in **Table 4.21**.

Table 4.21 Summary of Emission Estimation Methods for Source Categories in CRF Category 2C3

Source Category	Method	Activity Data	Emission Factors
Primary aluminium	AD x EF	BGS, operators	Carbon: UK-specific factors (defaults for Soderberg and pre-bake processes) PFC: Operator reported data, based on IPCC T2 method

Emissions of indirect gases are based on emissions data reported by process operators either directly to the inventory agency, or via the Environment Agency Pollution Inventory or the Scottish Pollutant Release Inventory.

The time series of emission factors and activity data used are reported in **Table 4.22** below.

Table 4.22 Time series of activity data and emission factors for aluminium production

Year	Activity data	Emission factors - kt/Mt					
	Mt Al Produced	Carbon	C2F6	CF4	CO	NOx	SO2
1990	0.29	423.8	0.075	0.60	72.43	2.81	13.53
1995	0.24	423.2	0.019	0.16	72.43	2.81	13.53
2000	0.31	420.0	0.014	0.11	79.12	0.76	14.60
2005	0.37	420.0	0.004	0.04	77.17	0.77	15.25
2008	0.33	420.0	0.006	0.05	95.89	0.90	14.81
2009	0.25	420.0	0.004	0.03	94.84	0.84	8.73
2010	0.19	420.0	0.010	0.08	96.07	1.08	12.84
2011	0.21	420.0	0.013	0.10	99.25	1.08	15.87
2012	0.06	420.0	0.012	0.09	102.87	0.30	16.68

4.16.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type. The overall uncertainty for this sector is estimated at 7%.

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%).

A large increase in emissions of PFCs between 2010 and 2011 was observed for one of the operating plants, this has been discussed with the plant operator. The increase in emissions can be explained by the pot restart programme, which is further elaborated below:

1. PFC emissions are influenced by the number of pots re-started in a given period. Stopping and starting electrolytic cells is a normal process activity, however the rate of increase in operating pots did have an effect on the emissions (62 during 2011). To restart pots requires power outages and liquid (bath and aluminium) to be transferred from 'donor' pots. The electrolysis process benefits from stability and this is impossible during a restart programme with frequent power interruptions and liquid level changes.
2. Significant effort has been put into the metal flow process from the potrooms to the casting plant to smooth out the liquid level changes and improve stability; however this was an ongoing challenge during 2011.
3. The drive to improve energy efficiency through pot voltage reduction and increased amperage minimises the functional operating window of the pot and puts more emphasis on the definitive control of liquid levels. When increasing amperage the process becomes much more sensitive to change and the acceptable operating window much smaller. Low anode effect rates can be achieved, however much more attention to detail is required and the pot liquid levels (metal and bath) need to be well controlled. Whilst the operator's efforts to improve energy efficiency for every tonne of aluminium produced have been successful, an increase in instability on the potlines could be attributable to these efforts. A point to note is that the energy efficiency improvements have reduced carbon dioxide emissions which will offset some of the increased PFC emission.
4. Unavoidable rectiformer maintenance work throughout 2011 resulted in power interruptions contributing to the potline instability.

There was a large decline in emissions in 2012 as aluminium smelting activities came to an end in March 2012 at one of the plants.

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**. Emissions data taken from the Pollution Inventory are subject to additional QA/QC from the inventory agency.

4.16.5 Source Specific Recalculations

No recalculations have been made to this category for the 2012 submission.

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

Since 2004, one of the main industry users has implemented a cover gas system using HFC 134a in place of SF_6 for most of its production capacity. Actual emissions of SF_6 for this sector are therefore reported 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, and it was considered best to report all emissions relating to this category together.

4.18 SOURCE CATEGORY 2C5 – OTHER METAL PRODUCTION

4.18.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2C4: SF_6 Cover Gas	T2	CS, PS
	2C5: HFC Cover Gas	T2	CS, PS
	2C5: Non-Ferrous Metals (other non-ferrous metals)	T2	CS, PS
	Non-Ferrous Metals (primary lead/zinc)	T2	CS, PS
	Non-Ferrous Metals (secondary Copper)	T2	CS, PS
	Non-Ferrous Metals (secondary lead)	T2	CS, PS
Gases Reported	HFCs, SF_6, CO, SO_2		
Key Categories (Trends)	None identified		
Key Categories (Level)	Industrial Processes - HFCs		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	A review of the data sources and methodology used to estimate emissions from F-gases used as cover gases in magnesium foundaries was carried out in 2013.		

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.

SF_6 is used in the magnesium alloy and casting industry as a cover gas, to prevent molten magnesium oxidising when exposed to air. It is estimated that 95% of SF_6 (Gluckman, 2013) 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. Since 2006, EU magnesium producers have looked for alternatives to SF_6 in response to bans in the EU F-Gas regulation. Some die casters have gone back to using SO_2. Others have used HFC 134a and a fluoro-ketone (FK 5-1-12) with the trade name Novec 612.

The UK magnesium casting industry is very small. There are three significant manufacturers (one alloy producer, one die-caster and one sand-caster) plus two very small operations (both sand-casters). 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 HFC 134a, are currently considered not suitable.

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. Emissions of carbon from use of this coke are included with estimates for other industrial combustion (see **Section 3.2.7**). 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, while emissions of carbon from the butane are reported under 1A2.

4.18.2 Methodological Issues

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

A review of the data sources and methodology used to estimate emissions from F-gases used as cover gases in magnesium foundries was carried out in 2013 (Gluckman, 2013). Each of the UK magnesium producers was contacted to obtain updated estimates for their uses of SF_6 and HFC 134a. Extra questions were asked about ability to switch to alternatives (including HFC 134a, FK 5-1-12 and SO_2) and how emissions can be estimated (i.e. from consumption data or from actual emissions measurements). In all cases UK magnesium companies are able to report consumption, but have no actual measured data on emissions. The assumptions about the fraction of SF_6 and HFCs that are emitted from the consumption of these F-gases has been reviewed through discussion with industry experts

and in some cases amended. It is estimated that 95% of SF_6 consumption is emitted but that only 20% of HFC 134a consumption is emitted (as a much greater proportion reacts with the magnesium). These figures are based on expert estimates by Gluckman (2013). The revised estimates of emissions in the 2014 submission are similar to those reported in the previous inventory until approximately 2005. From 2006, the revised emission estimates are higher than those in the previous inventory because of more accurate data obtained on SF_6 consumption by the UK magnesium producers.

For magnesium alloy production, SF_6 emissions from 1998 onwards are estimated based on the data reported to the Environment Agency Pollution Inventory (EA, 2013), whilst emissions prior to 1998 are estimated based on consultations with the plant operators.

From 2004, one of the main industry users of SF_6 as a cover gas has implemented a cover gas system using HFC134a 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 (80%) thus reducing the fraction of gas emitted as a fugitive emission.

From 2008, emissions of HFCs have been reported in the Pollution Inventory, and therefore the reported data are used directly.

As part of a recent study to update the F-gas inventory (Gluckman, 2013), 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.

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

Other
Emission estimates for these processes are derived from emissions data available from the Pollution Inventory (Environment Agency, 2013). 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 uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type.

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 1998-2012, the uncertainty of the time-series emissions is estimated to be significantly lower (+/- 10%). Data received from the main magnesium alloy producer and

the other 4 casting operations are associated with low uncertainty and show good consistency across the time series.

SF_6 emissions from UK magnesium producers peaked in 2000 at approximately 1,000 kt CO_2 equivalent. The use has fallen steadily, particularly from 2006 onwards, being approximately 130 kt CO_2 equivalent in 2012. HFC 134a emissions were zero until 2008 and are approximately 2 kt CO_2 equivalent by 2012.

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**, 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, where 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. The recommendation to review the amount of HFC134a emitted from magnesium production has been implemented.

4.18.5 Source Specific Recalculations

Details of and justifications for recalculations to activity data are given in **Table 4.23** below. For information on the magnitude of recalculations to Source Category 2F9, see **Section 10**.

Table 4.23 2C5 – Other Metal Production - Source specific recalculations since previous submission

IPCC Category	Source Name	Activity Name	2013 submission 1990	2013 submission 2011	2014 submission 1990	2014 submission 2011	Units	Comment/Justification
2C4 (2C5)	Other Metal Production	HFCs	C	C	C	C		A review of the data sources and methodology used to estimate emissions from F-gases used as cover gases in magnesium foundaries was carried out in 2013.
2C4 (2C5)	Other Metal Production	SF_6	0.426	0.074	0.406	0.161	Mt CO_2 equivalent	A review of the data sources and methodology used to estimate emissions from F-gases used as cover gases in magnesium foundaries was carried out in 2013.

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

Emissions sources	2D1: Wood Products Manufacture
Gases Reported	NMVOC
Overseas Territories and Crown Dependencies Reporting	Not occurring
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	No major improvements

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 1A2d. 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 of NMVOC from wood product manufacture 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 (2013). 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 direct greenhouse gases are reported in this section and no major methodological changes have been made this year

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

Emissions sources	2D2: Brewing (barley malting, fermentation, wort boiling) Bread Baking Cider Manufacture Other Food (animal feed; cakes, biscuits, cereals; coffee, malting, margarine and other solid fats; meat, fish and poultry; sugar) Spirit Manufacture (barley malting, casking distillation, fermentation, maturation, spent grain drying) Wine Manufacture
Gases Reported	NMVOC
Overseas Territories and Crown Dependencies Reporting	Not occurring
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	No major improvements

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 5 large grain distilleries and approximately 90 smaller malt distilleries at the end of 2012. 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 (2013), 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.

NMVOC emission factors for food and drink are shown below.

Table 4.24 NMVOC Emission Factors for Food and Drink Processing, 2012

Food/Drink	Process	Emission Factor	Units
Beer	Barley Malting Wort Boiling Fermentation	0.6[c] 0.0048[c] 0.02[c]	g/L beer
Cider	Fermentation	0.02[c]	g/L cider
Wine	Fermentation	0.2[c]	kg/m^3
Spirits	Fermentation Distillation Casking Spent grain drying Barley Malting Maturation	1.58[d] 0.79[g] 0.40[h] 1.31[i] 4.8[c] 15.78[d]	g/ L alcohol g/ L alcohol g/ L whiskey kg/ t grain kg/ t grain g/ L alcohol
Bread Baking		1[a]	kg/tonne
Meat, Fish & Poultry		0.3[f]	kg/tonne
Sugar		0.020[b]	kg/tonne
Margarine and solid cooking fat		10[f]	kg/tonne

Food/Drink	Process	Emission Factor	Units
Cakes, biscuits, breakfast cereal, animal feed		1[f]	kg/tonne
Malt production (exports)		4.8[c]	kg/ t grain
Coffee Roasting		0.55[f]	kg/tonne

a Federation of Bakers (2000)
b Environment Agency (2013)
c Gibson *et al* (1995)
d Passant *et al* (1993)
e Assumes 0.1% loss of alcohol based on advice from distiller
f EMEP/EEA, 2013
g Unpublished figure provided by industry
h Based on loss rate allowed by HMCE during casking operations
i US EPA, 2007

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 direct greenhouse gases are reported in this section and no major methodological changes have been made this year

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 sources	Sources included	Method	Emission Factors
	2E1 and 2E2: Halocarbons Production (By-Product and Fugitive)	T2	PS
Gases Reported	HFCs, PFCs		
Key Categories (Trends)	None identified		
Key Categories (Level)	Industrial Processes - HFCs		

Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Not occurring
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	No major improvements

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.

There is no UK production of SF_6.

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 are not available. Two of the three manufacturers were members of the UK greenhouse gas Emissions Trading Scheme. As a requirement of participation in the scheme, their reported emissions were verified annually via external and independent auditors. For PFC production, emissions are now reported to the Environment Agency's Pollution Inventory, and these emissions are directly used within the GHG inventory. The operator of the HFC and (now closed) HCFC 22 plant provides speciated emissions data directly to the inventory agency, based on vent analysis and flowmeter readings, or on weighbridge differences. The other HCFC 22 plant, which closed in 2008, also reported to the Pollution Inventory and these emissions were used within the GHG inventory.

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 and activity data are not reported, to protect commercially confidential information.

4.21.3 Uncertainties and Time-Series Consistency

The uncertainty analysis in **Annex 7**, shown in **Section A 7.6**, provides estimates of uncertainty according to IPCC source category and fuel type. The uncertainty estimate for emissions from HFC manufacture has been revised for this submission, based on information from the plant operator. The uncertainty is now estimated at 10%.

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 HCFC 22 plant and

HFC manufacturing plant (run by the same operator) are treated using the same thermal oxidiser unit. Emissions also decrease in 2004, reflecting the installation of a thermal oxidiser at the second of the UK's HCFC 22 manufacturing sites. This was installed in late 2003, and became fully operational in 2004. HFC 23 emissions decreased in 2009 and 2010 following the closure of both HCFC 22 manufacturing sites. A small emission of HFC 23 remains, which arises from the production of HFC 125, most likely due to impurities in the feedstock.

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 2007-2009, before increasing again in 2010 and 2011 and then declining again.

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. Data reported via the Pollution Inventory are also further checked by the Environment Agency.

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, where 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

No recalculations have been made to emissions from this sector.

4.21.6 Source Specific Planned Improvements

There are currently no planned improvements for this sector, however data sources will be kept under review.

4.22 SOURCE CATEGORY 2F1 – REFRIGERATION AND AIR CONDITIONING EQUIPMENT

4.22.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2F1: Commercial Refrigeration Domestic Refrigeration	T3 T3	CS CS

	Industrial Refrigeration Mobile Air Conditioning Refrigerated Transport Stationary Air Conditioning	T3 T3 T3 T3	CS CS CS CS
Gases Reported	HFCs		
Key Categories (Trends)	None identified		
Key Categories (Level)	Industrial Processes - HFCs		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	All emissions from OTs and CDs are included within the UK totals for this sector. Emissions are calculated by scaling emissions from the UK model using a suitable scaling factor (population, GDP etc).		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	Inclusion of estimate for OTs and CDs within this category; update of estimate for OTs and CDs to be in line with latest inventory.		

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 4.25 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.

Revised Model End-Use		Description
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 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 2012 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 4.26 Summary of 2012 Input Assumptions by End-Use

Application		2012 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	41,161,015	2,903,417	15	0.10	HFC-134a, HCs	0.6%	0.3%	34%*
Commercial Refrigeration	Small Hermetic Stand-Alone Refrigeration Units	2,546,160	275,806	10	0.5	HFC-134a, R-404A, R-407C, HCs	1%	1.4%	39%*
	Condensing Units	618,135	50,502	14*	5*	HFC-134a, R-404A, R-407A, R-407F,R-410A, R-507, HCs	2%	10%	15%
	Centralised Supermarket Refrigeration Systems	10,752,987 (m^2)	811,536 (m^2)	18*	0.26 (kg/m^2)	HFC-134a, R-404A, R-407A, HCs, R-717, R-744	2%	16%	8%
Transport Refrigeration	Land Transport Refrigeration	90,733	13,680	7	3.8	HFC-134a, R-404A	0.2%	14.5%	19%
	Marine Transport Refrigeration	527	32	25*	1,500*	R-404A, R-407C, R-717	1%	39%	29%
Industrial Refrigeration	Industrial Systems	20,808	915	25*	65	HFC-134a, R-404A, R-407C, R-410A, R-507, HCs, R-717, R-744	1%	8%	14%
Stationary Air-Conditioning	Small Stationary Air Conditioning	5,157,551	460,823	13	1.5	R-407C, R-410A	0.5%	3%	29%
	Medium Stationary Air Conditioning	661,894	55,500	15	15	R-407C, R-410A	1%	5.9%*	29%
	Large Stationary Air Conditioning (Chillers)	41,616	2,693	18	180	HFC-134a, R-407C, R-410A, R-717	0.5%	3%	19%
	Heat Pumps	31,672	6,385	15	3	HFC-134a, R-404A, R-407C, R-410A	1%	6%*	32%*
Mobile Air-Conditioning	Light Duty Mobile Air Conditioning	28,588,787	1,785,065	15	0.718	HFC-134a	0.5%	10%	29%
	Other Mobile Air Conditioning	512,231	85,380	10	4*	HFC-134a, R-407C	0.5%	10%	29%

[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.

Speciated emissions are now reported for the OTs and CDs under 2F1. Emission estimates from the UK GHGI were scaled by a territory-specific indicator. Relevant indicators include territory population, GDP and number of cars. The indicators for each activity were chosen based on expert judgement and were dependent on the information available for each territory.

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). The 2010 uncertainty estimates have been applied to 2012 in the Monte Carlo analysis for the GHG inventory.

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

Details of and justifications for recalculations to activity data are given in **Table 4.27** below. For information on the magnitude of recalculations to Source Category 2F, see **Section 10**.

There has been a change in methodology in this sector for OTs and CDs, which allows the OTs and CDs to be based on the latest UK GHGI data. There have been updates to some of the indicators used. All other recalculations are a reflection of those made to the UK inventory.

There was a decrease of 21kt CO_2e in emission estimates for the Cayman Islands for 2011 and similar reductions across the time series. This was due to an update in the methodology used to estimate emissions from the Cayman Islands to make it compatible with the methodology used to estimate emissionsfrom the other OTs and CDs, and reduce the requirement for interpolation/extrapolation. All other recalculations arise as a consequence of improvements made to the UK inventory.

Table 4.27 2F1 Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2013 submission 1990	2013 submission 2011	2014 submission 1990	2014 submission 2011	Units	Comment/Justification
2F1	Commercial Refrigeration	HFCs	0.000	3.217	0.000	3.193	Mt CO_2 equivalent	Due to revisions in emissions factors used to estimate emissions from the OTs and CDs
2F1	Refrigerated Transport	HFCs	0.000	0.925	0.000	0.919	Mt CO_2 equivalent	Due to revisions in emissions factors used to estimate emissions from the OTs and CDs
2F1	Stationary Air Conditioning	HFCs	0.000	1.988	0.000	1.975	Mt CO_2 equivalent	Due to revisions in emissions factors used to estimate emissions from the OTs and CDs

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 will be considered if resources are available.

4.23 SOURCE CATEGORY 2F2 – FOAM BLOWING

4.23.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2F2: Foams	T3	CS
Gases Reported	HFCs		
Key Categories (Trends)	None identified		
Key Categories (Level)	Industrial Processes - HFCs		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	All relevant emissions from OTs and CDs are included within the UK totals for this sector. Emissions are calculated by scaling emissions from the UK model using GDP.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements		

Emissions of HFCs from foams can occur as follows:

- During the manufacturing process;
- Over the lifetime of the foam; rigid foams are closed cell foams and the blowing agent is designed to remain in the foam and contributes to its performance. Loss of HFCs is undesirable as it may affect the performance of the foam but is estimated to occur, albeit at a low rate; and
- At disposal of the foam.

Emissions at each point vary according to the type of foam. Typically, of the HFC used in the production process, less than 10% is emitted during manufacture (although emissions may be as high as 40 to 45 % for some types of foam), less than 1% per year over the useful lifetime of the product and the remainder on disposal.

4.23.2 Methodological Issues

The methodology used to estimates emissions corresponds to the IPCC Tier 2 'bottom-up' approach. The emission factors from the sector have been summarised below.

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 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 below.

Table 4.28 Species according to application for foam blowing

Application	HFC-245fa	HFC-365mfc	HFC-227ea	HFC-134a	HFC-152a
PU Boardstock	25%	67.5%	7.5%		
PU Cont. Panel		90%	10%		
PU Disc. Panel		90%	10%		
PU Spray	100%				
PU P-i-P		90%	10%		
PU Block - Slab		90%	10%		
PU Block - Pipe		90%	10%		
XPS				65%	35%
PF Boardstock		90%	10%		
PF Disc. Panel		90%	10%		
PF Block - Slab		90%	10%		
PF Block - Pipe		90%	10%		
PU - Appliance	50%	45%	5%		
PU - Reefer	50%	45%	5%		

Table 4.29 sets out the bank size and emissions of HFCs by species and by foam type for 2012. No emissions are occurring for this source in 1990 or in 1995. The bank also includes HFC species not currently reported in the UK GHG inventory, since no GWP was available in the IPCC Second Assessment Report (HFC-365mfc, HFC-245fa).

Table 4.29 Bank size and emissions for foams for 2012

Foam type		PU Boardstock	PU Cont. Panel	PU Disc. Panel	PU Spray	Other PU	XPS Board	Phenolic Foam
Size of Bank (tonnes HFC)		3003	3648	497.5	242.8	264.8	6829	1644
Emissions (tonnes)	0.00	0.00	0.00	0.00	0.00	201.8	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	108.6	0.00	0.00

Foam type		PU Boardstock	PU Cont. Panel	PU Disc. Panel	PU Spray	Other PU	XPS Board	Phenolic Foam
	5.92	2.67	0.92	0.00	1.52	0.00	4.11	4.08

Speciated emissions for the OTs and CDs are now reported under 2F2. Emission estimates from the UK GHGI were scaled using the GDP of each territory.

4.23.3 Uncertainties and Time-Series Consistency

The 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, where 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 has been a change in methodology in this sector for OTs and CDs, which allows the OTs and CDs to be based on the latest UK GHGI data. There have been updates to some of the indicators used.

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

Emissions sources	Sources included	Method	Emission Factors
	2F3: Fire Fighting	T3	CS
Gases Reported	HFCs, PFCs		
Key Categories (Trends)	None identified		
Key Categories (Level)	Industrial Processes - HFCs		
Key Categories (Qualitative)	None identified		

Overseas Territories and Crown Dependencies Reporting	All relevant emissions from OTs and CDs are included within the UK totals for this sector. Emissions are calculated by scaling emissions from the UK model using GDP.
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	No major improvements

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. 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.

As well as HFCs being used to replace Halon-based systems in the mid-1990s, a small quantity of PFC (mainly C_4F_{10}) was imported by a US company into the EU to be used as an alternative fluid in fire fighting fixed systems. The main application of these PFC-based fixed systems is for fire protection of flooding closed rooms (e.g. control rooms). Imports for new systems stopped in 1999, as this application of PFCs was not regarded as an essential use. The F gas Regulation banned the sale of new PFC-based systems in 2007. For purposes of recharge, PFCs are still supplied. By 2010 it is assumed there are no fixed systems using PFCs in the EU.

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 **Table 4.30** below.

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) and no updates were introduced.

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

Table 4.30 Key assumptions used to estimate HFC emissions from fire extinguishers

	Parameter	1990	1995	2012
Activity data	HFC species and ratio HFC 227ea : HFC 23	97.5 : 2.5	97.5 : 2.5	97.5 : 2.5
	Size of bank (t)	0	20	2560
	Used for manufacture	0	20	91
	Equipment lifetime (yrs)	0	20	n/a
Emission factors	% released through fire	1.5	1.5	1.5
	% released through servicing	3.4	3.4	1.0
	% released during recovery	0.1	0.1	0.1
	PM %	0	0	0
	PL %	4.9	4.9	2.5
	D %	0.1	0.1	0.1

PL% = % released through fire + % released through servicing
D% = % released during recovery
Speciated emissions for the OTs and CDs are now reported under 2F3. Emission estimates from the UK GHGI were scaled by the GDP of each territory.

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, where 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 has been a change in methodology in this sector for OTs and CDs, which allows the OTs and CDs to be based on the latest UK GHGI data. There have been updates to some of the indicators used.

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

Emissions sources	Sources included	Method	Emission Factors
	2F4: Metered Dose Inhalers Aerosols (Halocarbons)	T3	CS
Gases Reported	HFCs		
Key Categories (Trends)	None identified		
Key Categories (Level)	Industrial Processes - HFCs		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	All relevant emissions from OTs and CDs are included within the UK totals for this sector. Emissions are calculated by scaling emissions from the UK model using population data.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	During 2013, a review of the data sources and methodology used to estimate emissions from MDIs was carried out and as a result, changes to activity data and methodology have occurred.		

Most aerosols use hydrocarbon propellants, with a relatively small proportion of the market favouring dimethyl ether (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.

4.25.2 Methodological Issues

Aerosols
The methodology used to estimates emissions corresponds to an IPCC Tier 2 method. Aerosol HFC emission estimates have been derived on the basis of fluid consumption data provided by the British Aerosol Manufacturers' Association (BAMA). 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. 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 estimate emissions corresponds to an IPCC Tier 2 method. During 2013, a review of the data sources and methodology used to estimate emissions from MDIs was carried out and as a result, changes to activity data and methodology have occurred. The current approach is essentially a "UK consumption model". The number of MDIs used each year in the UK is derived from the UK National Health Service (NHS) prescription data. HFC emissions have been calculated with revised estimates of the species and volumes of HFCs used as MDI propellants. Detailed data from the UK NHS are used for estimates between 1998 to 2012. Estimates for 1990-1997 are based on extrapolated data from 1998. This method ensures time series consistency. The NHS data are available for England, Wales, Scotland and Northern Ireland, allowing an accurate split to be made of the UK totals.

The NHS data gives good estimates of the number of MDIs of each drug type that have been prescribed. However, the data gives no information about the amount of HFC propellant per MDI prescribed. The estimates assume an average figure of 12g/MDI (Gluckman, 2013).

Aerosols

Table 4.31 Key assumptions used to estimate HFC134a emissions from aerosols

	Parameter	1990	1995	2012
Activity data	Used for UK manufacture (tonnes)	8.7	339.6	582.1
	Exported (tonnes)	0.87	33.96	36.6
	Imported (tonnes)	0	0	303.0
	Product lifetime (yrs)	1	1	1
Emission factors	PM %	1	1	1
	PL %	97	97	97
	D%	2	2	2

Table 4.32 Key assumptions used to estimate HFC152a emissions from aerosols

	Parameter	1990	1995	2012
Activity data	Used for UK Manufacture (tonnes)	0.267	10.39	46.6
	Exported (tonnes)	0.0267	1.039	25.0
	Imported (tonnes)	0	0	0.0
	Product lifetime (yrs)	1	1	1

	Parameter	1990	1995	2012
Emission factors	PM %	1	1	1
	PL %	97	97	97
	D %	2	2	2

Metered Dose Inhalers (MDIs)

The table below shows the way in which emissions are estimated from NHS data on total number of MDIs used in the UK each year. The majority of MDIs use HFC 134a. A small number (4%) have been formulated using HFC 227ae.

Table 4.33 Key assumptions used to estimate HCF emissions from MDIs

			kt CO_2e
Year	**MDI Number (thousands)**	**Average Propellant (g per MDI)**	**GWP basis**
2006	40,146	14	767
2007	41,874	13	743
2008	45,353	12	742
2009	48,413	12	792
2010	50,190	12	822
2011	50,644	12	829
2012	52,009	12	851
			GWP AR 2
	96% HFC 134a + 4% HFC 227ae		1,364

Speciated emissions for the OTs and CDs are now reported under 2F4. Emission estimates from the UK GHGI were scaled by the population of each territory.

4.25.3 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. From this work, 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 used is +/- 30-40%. This is now considered a slightly conservative estimate, and the latest methodology used is likely to generate estimates of emissions with uncertainties of perhaps +-25% to 30%. The factor introducing the greatest component of uncertainty is the amount of propellant per MDI and work continues to refine the methodology and reduce this uncertainty.

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, where 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

Details of and justifications for recalculations to activity data are given in **Table 4.34** below. For information on the magnitude of recalculations to Source Category 2F4, see **Section 10**.

There has been a change in methodology in this sector for OTs and CDs, which allows the OTs and CDs to be based on the latest UK GHGI data. There have been updates to some of the indicators used..

Table 4.34 2F4 Source specific recalculations since previous submission

IPCC Category	Source Name	Activity Name	2013 submission 1990	2013 submission 2011	2014 submission 1990	2014 submission 2011	Units	Comment/Justification
2F4	Metered dose inhalers	HFCs	0.002	1.608	0.000	0.834	Mt CO_2 equaivalant	Change due to revision to methodology used to calculate emissions from MDIs in the UK. Also due to small changes to estimate of emissions in OTs and CDs.

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

Emissions sources	Sources included	Method	Emission Factors
	2F5: Precision Cleaning	T3	CS
Gases Reported	HFCs		
Key Categories (Trends)	None identified		
Key Categories (Level)	Industrial Processes - HFCs		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements		

HFCs can be used as solvents in a range of applications such as precision cleaning to replace CFCs, HCFCs or 1,1,1-trichloroethane. HFCs have been developed that are used for precision cleaning in sectors such as aerospace and electronics.

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 review of available data for this source is part of the current improvement programme

Table 4.35 Key assumptions used to estimate emissions from the use of solvents

	Parameter	1990	2005	2012
Activity data	EU Estimate (tonnes of HFC released)	0	0	600
	UK Estimate (tonnes of HFC released)	0	0	82.5
	Product lifetime (yrs)	n/a	n/a	n/a
Emission factors	PM %	n/a	n/a	n/a
	PL %	n/a	n/a	n/a
	D %	n/a	n/a	n/a

4.26.3 Uncertainties and Time Series Consistency

The 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, where 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 to emissions from this sector..

4.26.6 Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

4.27 SOURCE CATEGORY 2F7 – SEMICONDUCTOR MANUFACTURE

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 4.29**.

4.28 SOURCE CATEGORY 2F8 – ELECTRICAL EQUIPMENT

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 4.29**.

4.29 SOURCE CATEGORY 2F9 – OTHER

4.29.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2F7: Semiconductor Manufacture 2F8: Electrical Insulation 2F9: Training Shoes One Component Foams	OTH, T1, T2, T3	CS, OTH
Gases Reported	HFCs, PFCs, SF_6		
Key Categories (Trends)	None identified		
Key Categories (Level)	Industrial Processes - HFCs		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	All relevant emissions from OTs and CDs are included within the UK totals for this sector. Emissions are calculated by scaling emissions from the UK model using a suitable scaling factor (population, GDP etc.).		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	A review of the data sources and methodology used to estimate emissions from electrical switchgear was carried out in 2013. Being based on reported consumption and emission data, this methodology is a considerable improvement on previous estimates.		

In the CRF, emissions in 2F9 are presented in two separate categories. One Component Foams, and Semiconductors, Electrical and Production of Trainers. Emissions from Semiconductors, Electrical and Production of Trainers have been combined in order to preserve the confidentiality of estimates of emissions of SF_6 and PFCs used in training shoes.

One Component Foams:
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. 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.

Semiconductor manufacture:
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%.

Electrical Equipment:
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. Currently, there are no alternative fluids that have the same properties as SF_6.

Production of Trainers:
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. SF6 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 SF6 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.

Use of SF_6 as a tracer in scientific research:
The UK has reviewed the completeness of the F-gas inventory and has identified the use of SF_6 as a tracer in scientific research.

4.29.2 Methodological Issues

One Component Foams:
The method of calculation is an IPCC Tier 2 method.

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)

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. 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. Research indicated that Germany accounted for 77% of the total EU emission, and that 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 (AEA, 2008).

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. Therefore no emissions occur from 2009 onwards.

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

Estimates of PFC and SF_6 emissions from electronics in 2001 are based on data supplied by UK MEAC – the UK Microelectronics Environmental Advisory Committee (in conjunction with the former UK 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. 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. 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. These assumption were 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 (AEA, 2008).

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 (AEA, 2008).

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.

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 and SF_6 from semiconductor manufacturing are combined with emissions from training shoes and electrical insulation in source category 2F9 for reasons of commercial confidentiality.

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

Table 4.36 Key assumptions used to estimate emissions from semiconductor manufacture

	1990-1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2009	2010	2012
Annual growth in UK semiconductor production	15%	15%	15%	15%	16%	-39%	0%	0%	0%	5%	10%	10%	10%
Annual rate of change of usage per unit consumption													
CF_4	3%	2%	1%	0%	-1%	-1%	-2%	-2%	-2%	-8%	-8%	-8%	-1%
C_2F_6	3%	2%	1%	0%	-1%	-1%	-2%	-2%	-2%	-8%	-8%	-8%	-1%
C_3F_8	0%	0%	0%	0%	1%	1%	1%	1%	1%	1%	1%	1%	-1%
C_4F_8	0%	0%	0%	0%	1%	1%	1%	1%	1%	1%	1%	1%	-1%
CHF_3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
SF_6	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
NF_3	0%	0%	0%	0%	0%	2%	3%	5%	5%	5%	5%	5%	0%
Consumption, kg*													
CF_4		3640	4269	4959	5752	3,474	3404	3336	3270	3158	3313	3352	3976
C_2F_6		14882	17456	20275	23519	14,203	13919	13641	13368	12914	13545	13707	16256
C_3F_8		582	669	770	893	550	556	561	567	601	925	1027	1218
C_4F_8		37	43	49	57	35	35	36	36	38	59	65	78
CHF_3		2166	2491	2865	3324	2,027	2027	2027	2027	2129	3117	3428	4148
SF_6		1379	1586	1824	2116	1,291	1291	1291	1291	1355	1984	2183	2641
NF_3		2459	2828	3252	3772	2,301	2301	2301	2301	2416	3313	3891	4709
Fraction fed to abatement													
CF_4	0%	0%	0%	0%	0%	0%	0%	0%	10%	15%	35%	40%	50%
C_2F_6	0%	0%	0%	0%	0%	0%	0%	0%	10%	15%	35%	40%	50%
C_3F_8	0%	0%	0%	0%	0%	0%	0%	0%	10%	15%	35%	40%	50%
C_4F_8	0%	0%	0%	0%	0%	0%	0%	0%	10%	15%	35%	40%	50%
CHF_3	0%	0%	0%	0%	0%	0%	0%	0%	10%	15%	35%	40%	50%
SF_6	0%	0%	0%	0%	0%	0%	0%	0%	10%	15%	35%	40%	50%
NF_3	90%	90%	90%	90%	90%	90%	90%	90%	95%	100%	100%	100%	100%

*Derived from 2001 data, working backwards or forwards from 2001 consumption using annual growth rate and rate of change of consumption per unit production for appropriate year.

Electrical Equipment:
A review of the data sources and methodology used to estimate emissions from electrical switchgear was carried out in 2013. Data was collected from all the key UK users of Gas Insulated Switchgear (GIS), including National Grid and the UK electricity distribution companies. Data was also obtained from ENA (Electrical Networks Association) and from the electricity industry Regulator, Ofgem. Since the introduction of the EU F-Gas Regulation in 2006, the UK electricity industry has made significant efforts to monitor and reduce consumption of SF_6. The Regulator collects annual data from each electricity company. These data were used to estimate the size of the SF_6 bank in GIS and emissions for 2008-2012. Emissions from earlier years were estimated by extrapolating the data backwards, using the previously reported bank size in 1995 and 2000 and previously reported leakage rates. This approach ensured time series consistency, whilst making best use of good quality available data. Being based on reported consumption and emission data, this methodology is a considerable improvement on previous estimates.

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

A full description of the emissions and associated methodology used is contained in AEA (2004) and AEA (2008).

Use of SF_6 as a tracer in scientific research:
SF_6 is used as a tracer gas in UK studies of greenhouse gas emissions from ruminant livestock. It is currently the only viable way to measure emissions of methane from ruminant livestock individuals at pasture (Defra, *per. comm*.).

Emissions for this source, which are very small, are now included under 2F9 from 2011 onwards.

A small charge of SF_6 is stored in a permeation tube, which is then introduced to the rumen of the animal. The gas emissions are vacuum sampled from eructation via a tube near the animal's muzzle connected to an evacuated flask. The total CH_4 emissions are inferred from the differential concentrations of SF_6 and CH_4 between the flask and atmosphere.

The total amounts of SF_6 used are given in the table below:

Table 4.37 Quantities of SF_6 used in scientific research

Year	kg SF_6	kg CO_2e*
2011	1.224	29,254
2012	1.433	34,249
2013	0.270	6,453
2014	0.273	6,525
Total	**3.200**	**76,481**

*Assuming a GWP of 23,900

More details of the work can be found at www.ghgplatform.org.uk .

Speciated emissions for OTs and CDs are now reported under 2F9. Emission estimates from the UK GHGI were scaled by the GDP or population of each territory.

4.29.3 Uncertainties and Time-Series Consistency

Estimates of emissions in some categories of this sector are based on very limited and uncertain data, and are therefore uncertain.

One Component Foams:
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. 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**.

2F9 – Semiconductors, Electrical and Production of Trainers:
For electrical switchgear, emissions from earlier years were estimated by extrapolating the data backwards, using the previously reported bank size in 1995 and 2000 and previously reported leakage rates. This approach ensured time series consistency, whilst making best use of good quality available data. Being based on reported consumption and emission data, this methodology is a considerable improvement on previous estimates. The uncertainty associated with electrical transmission and distribution is conservatively estimated at +/- 20%.

For the other sources in this group, estimates of the uncertainties associated with time-series data for this sector were made in AEA (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%.

These uncertainty data 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, where 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

Details of and justifications for recalculations to activity data are given in **Table 4.38** below. For information on the magnitude of recalculations to Source Category 2F9, see **Section 10**.

There has been a change in methodology in this sector for OTs and CDs, which allows the OTs and CDs to be based on the latest UK GHGI data. There have been updates to some of the indicators used. All other recalculations are a reflection of those made to the UK inventory.

Table 4.38 2F9 - Other use of F-gases - Source specific recalculations since previous submission

IPCC Category	Source Name	Activity Name	2013 submission 1990	2013 submission 2011	2014 submission 1990	2014 submission 2011	Units	Comment/Justification
2F9	Semiconductors, electrical, sporting goods, and SF_6 used as a tracer gas	SF_6	0.604	0.533	0.582	0.398	Mt CO_2 equivalent	This change is due to the revision to estimates for electrical insulation and the inclusion of SF_6 as a tracer gas for the first time.

4.29.6 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

IPCC Categories Included	3A Paint Application 3B Degreasing & Dry Cleaning 3C Chemical Products, Manufacture & Processing 3D Other
Gases Reported	NMVOC
Overseas Territories and Crown Dependencies Reporting	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.
Completeness	Emissions of CO_2 for this sector are currently not estimated although emissions from this source are considered to be very small. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	No major improvements

5.2 SOURCE CATEGORY 3A – PAINT APPLICATION

5.2.1 Source Category Description

Emissions sources	3A: Decorative paint (retail decorative) Decorative paint (trade decorative) Industrial Coatings (automotive) Industrial Coatings (agriculture & construction) Industrial Coatings (aircraft) Industrial Coatings (Drum) Industrial Coatings (coil coating) Industrial Coatings (commercial vehicles) Industrial Coatings (high performance) Industrial Coatings (marine) Industrial Coatings (metal and plastic) Industrial Coatings (metal packaging) Industrial Coatings (vehicle refinishing) Industrial Coatings (wood)
Gases Reported	NMVOC
Overseas Territories and Crown Dependencies	Emissions from the Overseas Territories and Crown Dependencies are included within the CRF submission under

Reporting	3D5 other non-specified and are scaled, based on UK emissions.
Completeness	Emissions of CO_2 for this sector are currently not estimated although emissions from this source are considered to be very small. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	No major improvements

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

Table 5.1 Paints and their applications in the UK

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

5.2.2 Methodological Issues

Emission estimates for most types of coatings are based on annual consumption data and emission factors provided by the British Coatings Federation (BCF, 2013). Emission estimates for drum coatings, metal packaging coatings and OEM coatings are estimated instead using a combination of solvent consumption data and emission 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 while these data are regarded as consistent over the time series in terms of sectoral definitions, they do not cover all sectors for all years and also do not necessarily cover all UK manufacturers. Instead, the data are for BCF members and an allowance must be made to take account of coatings produced by non-members. The BCF have provided periodic estimates of the coverage of their data and these are used to scale-up the annual BCF statistics. BCF data no longer cover certain sectors like car coating where these are no longer represented by the organisation, so alternative data sources have been found.

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

No direct greenhouse gases are reported in this section and no major methodological changes have been made this year

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

Emissions sources	3B: Dry Cleaning Surface Cleaning Leather Degreasing
Gases Reported	NMVOC
Overseas Territories and Crown Dependencies Reporting	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.
Completeness	Emissions of CO_2 for this sector are currently not estimated although emissions from this source are considered to be very

	small. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	No major improvements

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, 2013), although this is not expected to introduce significant uncertainty into the estimates. Emission factors assume that all hydrocarbon and oxygenated solvent is emitted, while emission factors for chlorinated solvents are lower, reflecting the fact that some solvent is sent for disposal rather than emitted.

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

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

5.3.3 Uncertainties and Time-Series Consistency

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

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

5.3.4 Source Specific QA/QC and Verification

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

5.3.5 Source Specific Recalculations

No direct greenhouse gases are reported in this section and no major methodological changes have been made this year

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

Emissions sources	3C: Coating Manufacture (paint) Coating Manufacture (ink) Coating Manufacture (glue) Film Coating Leather coating Other Rubber Products Tyre Manufacture Textile Coating
Gases Reported	NMVOC
Overseas Territories and Crown Dependencies Reporting	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.
Completeness	Emissions of CO_2 for this sector are currently not estimated although emissions from this source are considered to be very small. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	No major improvements

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 direct greenhouse gases are reported in this section and no major methodological changes have been made this year

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

Emissions sources	3D: Aerosols (Car care, Cosmetics & toiletries, household products) Agrochemicals Use Industrial Adhesives Paper Coating Printing Other Solvent Use Non Aerosol Products (household, automotive, cosmetics & toiletries, domestic adhesives, paint thinner) Seed Oil Extraction Wood Impregnation
Gases Reported	NMVOC
Overseas Territories and Crown Dependencies Reporting	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.
Completeness	Emissions of CO_2 for this sector are currently not estimated although emissions from this source are considered to be very small. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	No major improvements

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).

All overseas territories and crown dependencies emissions arising from Solvents are reported under 3D5. Emission estimates from the UK GHGI were scaled by a territory-specific indicator. Relevant indicators include territory population, GDP, number of cars and number of households. The indicators for each activity were chosen using expert judgement and were dependent on the information available for each territory.

5.5.3 Uncertainties and time-series consistency

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

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

5.5.4 Source-specific QA/QC and verification

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

5.5.5 Source-specific recalculations

No direct greenhouse gases are reported in this section and no major methodological changes have been made this year

There has been a change in methodology in this sector for OTs and CDs, which allows the OTs and CDs to be based on the latest UK GHGI data. There have been updates to some of the indicators used. All other recalculations are a reflection of those made to the UK inventory.

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

IPCC Categories Included	4A: Enteric Fermentation 4B: Manure Management 4D: Agricultural Soils 4F: Field Burning of Agricultural Residues 4G: Other
Gases Reported	CH_4, N_2O, NO_x, CO, NMVOC, SO_2
Key Categories (Trends)	Agricultural Soils – N_2O Manure Management – N_2O
Key Categories (Level)	Agricultural Soils – N_2O Manure Management – CH_4 Manure Management – N_2O Enteric Fermentation in Domestic Livestock – CH_4
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Emissions for OTs and CDs are included for enteric fermentation animal wastes and agricultural soils.
Completeness	No emissions are reported for categories 4D3 and 4D4 because no emissions have been identified. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	Revision to distribution of manure in different management systems with update on MCF

The agriculture sector has the second largest contribution to total GHG emissions in the UK, after the energy sector. It contributes approximately 9.0% to the total emissions. The emissions from this sector have shown an overall decrease of 20.4% since 1990, reflecting trends in livestock numbers and emissions from fertiliser application.

Figure 6.1 Breakdown of total GHG emissions in the Agriculture sector in 2012

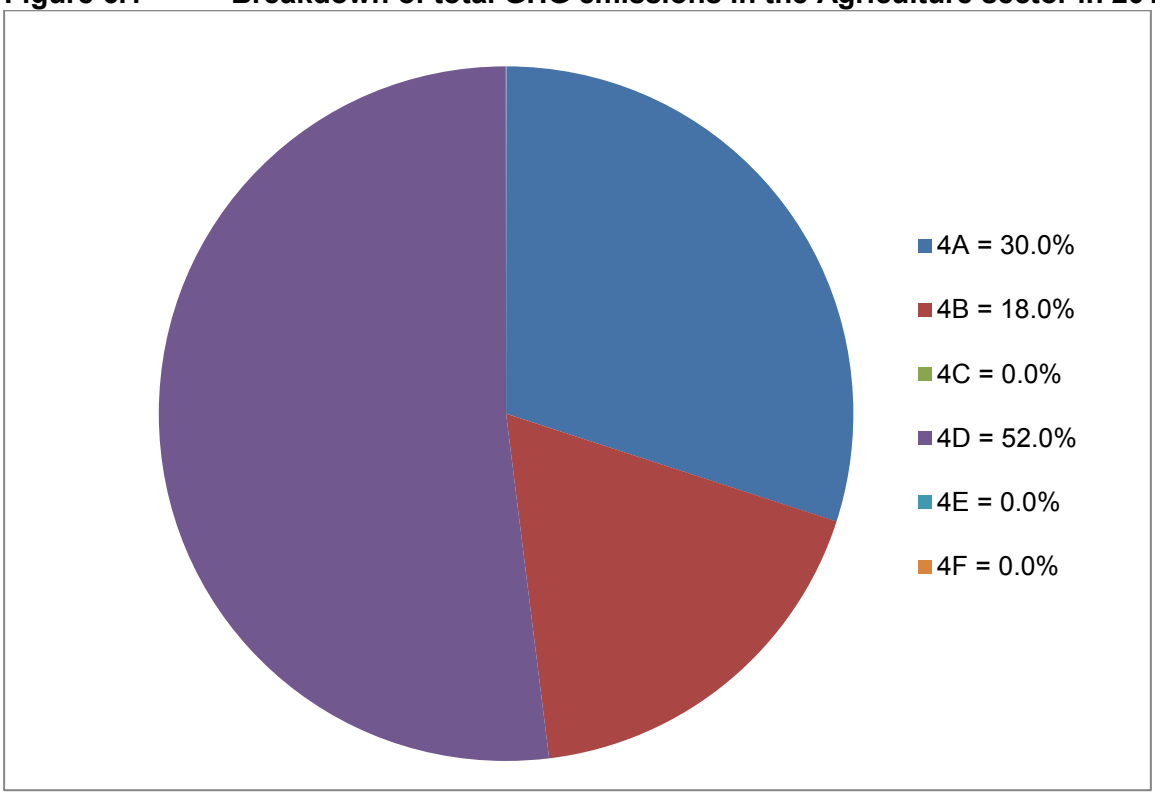
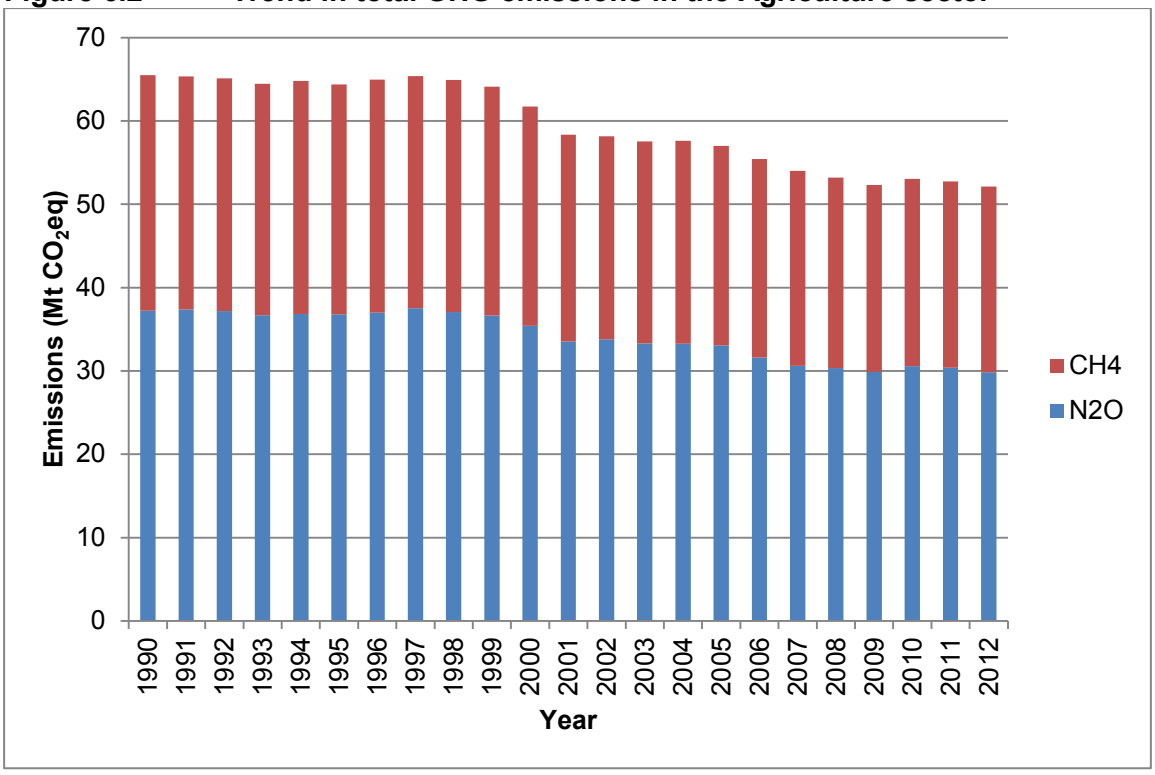


Figure 6.2 Trend in total GHG emissions in the Agriculture sector



6.2 SOURCE CATEGORY 4A – ENTERIC FERMENTATION

6.2.1 Source category description

Emissions sources	Source included	Method	Emission Factors
	4A1: Dairy Cattle Enteric Other Cattle Enteric 4A3: Sheep Enteric 4A4: Goats Enteric 4A6: Horses Enteric 4A8: Pigs Enteric 4A10: Deer Enteric	T2 T2 T1 T1 T1 T1 T1	D D CS D D D CS
Gases Reported	CH_4		
Key Categories (Trends)	None identified		
Key Categories (Level)	Enteric Fermentation in Domestic Livestock – CH_4		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	A separate category for all OTs and CDs livestock is used in the CRF (4A10). IPCC default EFs are applied to animal numbers. Tables of animal numbers used in calculations can be found in **Annex 3.9.**		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	Revision to feed digestibility for cattle.		

Methane is produced in herbivores 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

Detailed information on activity data and emissions factors can be found in **Annex 3**, **Section A 3.5.1**.

Emissions from enteric fermentation are calculated from detailed animal livestock population data collected in the June Agricultural Census and the appropriate emission factors (see **Table A 3.5.3** in **Annex 3**). Livestock population data are reported annually as statistical outputs of the four Devolved Administrations of the UK (i.e. England, Wales, Scotland and Northern Ireland), based on the annual June Agricultural Survey for each country[32]. These

[32] **England:** https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june
Scotland: http://www.scotland.gov.uk/Publications/2012/09/1148/downloads
Wales: http://wales.gov.uk/statistics-and-research/survey-agricultural-horticulture/?lang=en and John Bleasdale, Welsh

data are summed to provide UK population data for the livestock categories and subcategories as used in the inventory compilation (See **Tables A3.6.1** and **A3.6.2** in **Annex 3**). Data for earlier years are often revised so information was taken from the England and the Devolved Administrations' agricultural statistics databases.

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.

6.2.2.1 Dairy cows

The dairy cattle emission factors (for dairy cows only) are estimated following the IPCC Tier 2 procedure (IPCC, 2000), using country-specific data for dairy cow live weight, milk yield, milk fat content, feed digestibility and activity (proportion of the year spent grazing) and vary from year to year (see **Tables A3.6.4** and **A3.6.5** in **Annex 3**). 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. Dairy cows live weights are derived from slaughter weight data, provided by Defra[33], based on a slaughter weight to live weight ratio of 0.48. There has been a linear increase in reported slaughter weights since 1990, with the exception of the period 1997 to 2005 during which period one of the measures introduced by the EU commission to control the exposure of humans to BSE (the 'Over 30 Month scheme') produced anomalies in the data series. Dairy cow live weights for this period were therefore derived by interpolation using the linear regression fitted to the periods before and after these dates; see **Tables A3.6.3**, **A3.6.4** and **A3.6.5** in **Annex 3.** Details of the method used to estimate live weight from slaughter weights can be found below. Milk yield is obtained from the Defra website[34].

A country-specific value for the digestibility of feed (DE), expressed as a percentage of the gross energy, for dairy cows is used. As recommended by the Review Team, the value was adjusted from the 75% used last year to include all decimals to 74.5234142710097%. This value is considerably higher than the IPCC (1997) default value for Western Europe of 60%, but is based on typical diets for cows over the lactating and non-lactating period, combining forage and concentrates, with energy values for the various feeds according to MAFF (1990). The calculations used by national experts to derive a UK specific DE value are provided in Appendix A3 tables A3.5.5 and A3.5.6. Details of the methodology are provided below:

The UK uses an energy balance approach to estimate the metabolisable energy (ME) requirement for a dairy cow for a year including the lactating and non-lactating period. This accounts for the ME required for maintenance for the entire year, the ME required for milk production during the lactating period and the ME required for pregnancy. The UK has survey data on average concentrate feed use by dairy cows and use this data to derive the amount of energy supplied by concentrates over the entire year. The value of typical concentrate use (not the required or recommended use) for a 7,000 litre yielding cow of 0.29 kg concentrates per litre of milk (Nix, 2009) is derived from such survey data. This does not represent the amount of concentrate feed required to meet the whole energy demand for milk production, but is the typical concentrate use on UK dairy farms for that level of milk yield. The digestibility (DE as % of GE) value for concentrate feed (c. 82%) is derived from the typical mix of protein and energy feed ingredients. Using this value, the annual ME requirement that has to be met from forage can then be derived. The relative proportions of

Government
Northern Ireland: http://www.dardni.gov.uk/june-agricultural-census-final-results and Paul Caskie, DARDNI

[33] http://www.defra.gov.uk/statistics/foodfarm/food/slaughter/

[34] https://www.gov.uk/government/publications/agriculture-in-the-united-kingdom-2012, (Chapter 8 – Livestock, Table 8.5 Milk).

concentrate to forage DM intake per year estimated in this way are 29% concentrate and 61% forage.

The UK do not have detailed survey data on amounts of different forages consumed by dairy cows, so the proportional annual breakdown (40% as fresh grass, 50% as grass silage, 10% as maize silage) is based on expert opinion (Bruce Cottrill, ADAS) taking into account the proportion of time spent at grazing by dairy cows and the amount of maize grown in the UK. The UK benefits from a relatively warm and wet maritime climate that is particularly suited to grassland production, as such grazing periods in the UK may be longer than those in other European countries. The UK is currently considering options to improve activity data on typical forage diets for a range of livestock production systems. The digestibility values for the different forage components are taken from MAFF 1990 (UK Tables of Nutritive Value and Chemical Composition of Feedingstuffs, 1990, Rowett Research Services Ltd). For grazed grass, the value used is not an average of all DE estimates for grass in this database, but is the value specifically given by MAFF 1990 for 'Fresh grass (grazed) – all species', which is taken to be representative of the annual average DE for grazed grass (compiled from a total of 244 samples taken throughout the grazing period, and includes grasses with ME values ranging from 7.2 to 14.1, across a range of species including hybrid rye grasses, perennial rye grasses and Tall Fescue). While some farms may specifically feed in-calf heifers and dry cows a poorer quality of forage, this is not considered typical for most dairy farms, where the animals will be receiving forage of the same quality. The details of the calculations are in the Appendix A3 tables **A3.5.5** and **A3.5.6**.

6.2.2.2 Beef cows

A Tier 2 methodology is used for the calculation of the enteric emissions from beef cows, but a time series of cattle weights is not available, and so a constant weight of 500 kg has been assumed (expert opinion, Defra). The main parameters involved in the calculation of the emissions factors for beef are shown in **Table A 3.5.6** (**Annex 3**). The digestibility value for beef cows used by the UK is 65% for annual average feed composition. This value is based on expert opinion (Bruce Cottrill, ADAS), reflecting the poorer quality diet that beef cows will generally receive in comparison with dairy cows. From the MAFF (1990) source cited above, the DE/GE of fresh grass in the category 8-10 ME is 0.63. For big bale silage - also widely used for beef cattle - in the categories 8-10 and 10-12 ME, the DE/GE ratios are 0.61 and 0.67. And diets of cattle reared predominantly on maize silage will have DE/GE values close to 0.65. NB: for comparison, Ireland and New Zealand report digestibility values of 75 and 71.4%, respectively, for non-dairy cattle in their 2011 inventory.

6.2.2.3 Other cattle

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 (**Table A 3.5.6** in **Annex 3**). 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.

6.2.2.4 Sheep

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 at 40% of that of an adult sheep (Sneath et al. 1997) together with a reduction factor reflecting the reduced lifespan of lambs. The average lifespan of lambs is estimated by Wheeler et al. (2012) as 8.1 months. The animals under category 'other sheep' are largely barren ewes that will be slaughtered at some time during the year. These are therefore assumed to be alive for 6 months of the year, which is reflected in the emission calculation rather than the emission factor. These emission factors are assumed constant over the entire time series.

6.2.2.5 Deer

The UK emission factors for deer are country-specific and are based on Sneath et al. (1997). The resulting emission factor for stags and hinds is larger (10.4 kg CH_4/head/yr) than for calves (5.2 kg CH_4/head/yr).

6.2.2.6 Overseas Territories and Crown Dependencies

Emission estimates were compiled by Aether using animal numbers were sourced from the territories directly or from the FAO and can be found in **Annex 3.9**. IPCC default emission factors were applied to these data.

6.2.3 Uncertainties and time-series consistency

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.4.1**, 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 Agricultural Census, published annually by the devolved administrations (i.e. England, Wales, Scotland and Northern Ireland). These are long running publications 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

Details of and justifications for recalculations to activity data and to emission factors are given in **Table 6.1** and **Table 6.2**, respectively. For information on the magnitude of recalculations to Source Category 4A, see **Section 10**.

Dairy cow feed digestibility was corrected from 75% to 74.5234142710097%, according to information from Bruce Cottrill (ADAS, pers. comm.). All decimals were included as recommended by the ERT. This was applied to the entire time series.

The 2011 N excretion rate for dairy cows was linked to milk yield (this was previously not the case for 2011). The link was present for all other years therefore this change only affected

the results from 2011. In addition the milk yield data for 2011 was provisional in last year's submission and has subsequently been updated (from 7533 to 7528 l/yr).

Activity data for horses has been revised to include both agricultural and non-agricultural horses for the whole time series.

The only significant change in OT and CD emissions can be seen in estimates for cattle in the Cayman Islands in 1993 where livestock data have been recalculated to improve time series consistency.

Table 6.1 4A Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	2013 submission 1990	2013 submission 2011	2014 submission 1990	2014 submission 2011	Units	Comment/Justification
4.A.1	Enteric Fermentation – Cattle	647.49	552.07	649.54	553.66	kt	Updated feed digestibility from 75.0 to 74.5234142710097. Entered cow milk yield for 2012 and updated provisional data for 2011 (from 7533 to 7528 l/yr).
4.A.6	Enteric Fermentation – Horses	3.64	5.63	10.26	18.43	kt	Entered new 1990-2012 time series data for horses to include both agricultural and non-agricultural horses.

Table 6.2 4A Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	2013 submission 1990	2013 submission 2011	2014 submission 1990	2014 submission 2011	Units	Comment/Justification
4.A.1	Enteric Fermentation – Cattle (dairy cows)	86.8	111.0	87.5	111.9	kg CH_4 $head^{-1}$ yr^{-1}	Updated feed digestibility from 75.0 to 74.5234142710097. Entered cow milk yield for 2012 and updated provisional data for 2011 (from 7533 to 7528 l/yr).

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, pigs and sheep) and calculations included when activity data are available.

6.3 SOURCE CATEGORY 4B – MANURE MANAGEMENT

6.3.1 Source category description

Emissions sources	Source included	Method	Emission Factors
	4B1: Dairy Cattle Wastes	T2	CS, D
	Other Cattle Wastes	T2	CS, D
	4B3: Sheep Wastes	T2	CS, D
	4B4: Goats Wastes	T2	CS, D
	4B6: Horses Wastes	T2	CS, D
	4B8: Pigs Wastes	T2	CS, D
	4B9: Broilers Wastes	T2	CS, D
	Laying Hens Wastes	T2	CS, D
	Other Poultry Wastes	T2	CS, D
	4B10: Deer Wastes	T2	CS, D
Gases Reported	CH_4, N_2O		
Key Categories (Trends)	Manure Management – N_2O		
Key Categories (Level)	Manure Management – CH_4 Manure Management – N_2O		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	It was not possible to introduce a new category in which to put emissions of N_2O from manure from the OTs and CDs into Sector 4B. A separate category was therefore included in Sector 4G - Other. A time series of UK EFs are applied to animal numbers.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	Revision to feed digestibility for cattle. Activity data for horses has been revised to include both agricultural and non-agricultural horses. Allocation of excreta to management systems has been revised and MCF changed accordingly.		

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

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 livestock population data provided by the devolved administrations as described in **Section 6.2.2**. The emission factors are listed in **Table A 3.5.3**. **Table A 3.5.7** shows the methane conversion factors assumed for the different systems.

The emission factors for manure management are calculated following IPCC Tier 2 methodology using default IPCC data for 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 (IPCC 2000, Equation 4.16) is used to determine VS, and deer where no IPCC data are available), country-specific data for the proportion of manure from each livestock type managed according to the different animal waste management systems (AWMS) and IPCC default methane conversion factors for the different AWMS (IPCC 2000, Equation 4.17). The emission factors are listed in **Table A 3.5.3 (Annex 3)**. **Table A 3.5.7 (Annex 3)** shows the methane conversion factors assumed for the different systems.

Emission factors and underlying data for dairy cows, beef cows and other cattle are given in **Tables A 3.6.3** to **A 3.6.6 in Annex 3**.

Country-specific data on the proportion of manure managed in the different AWMS data derive from a number of sources, including published ad-hoc surveys (e.g. Smith et al., 2000a, 2001b, 2001c; Sheppard 1998, 2002; Webb et al., 2001) and, more recently, relevant data from the Farm Practices Surveys for England and a time series is included to reflect changes in practice over time (data for 2011 are given in **Table A 3.5.9** in **Annex 3**).

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. Calculation follows IPCC (1997) (equation 2, p 4.98) for each livestock category and subcategory, using country-specific data for nitrogen excretion by the different livestock types and for the proportion of manure managed according to the different AWMS, and default IPCC emission factors for the different AWMS (IPCC, 2000). Country-specific values for nitrogen excretion per head for the different livestock types were derived from the report of Defra project WT0715NVZ (Defra, 2006) with interpretation by Cottrill and Smith (ADAS) (**Table A 3.5.8 in Annex 3**).

The conversion of excreted N into N_2O emissions is determined by the type of manure management system used. The distribution of waste management systems for each animal type ($AWMS_{(T)}$) is given in **Table A 3.5.9** in **Annex 3**. Emissions from poultry are calculated following IPCC (2000) where manure is allocated to poultry with or without bedding, but reported as AWMS 'Other'.
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)
- Deep litter (previously solid storage and dry lot).
- Other systems (poultry manure without bedding and poultry manure with bedding (poultry litter); IPCC (2000)

According to IPCC (1997) guidelines and IPCC GPG (2000), the following AWMS are reported in the Agricultural Soils category:

- All animal manures and slurries applied to soils
- 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 (tonnage of poultry litter incinerated obtained directly from EPR (Teresa Wachter Fuel Operations Manager, Energy Power Resources Limited, a total of 462,000 tonnes for 2012).

Table A 3.5.10 gives the N_2O emission factor for each animal waste management system ($EF3_{(AWMS)}$). These are expressed as the emission of N_2O-N per mass of excreted N processed by the waste management system.

6.3.2.3 Emissions in the Overseas Territories and Crown Dependencies

Animal numbers are sourced from the territories directly or from the FAO and can be found in **Annex 3.9**. Estimates for CH_4 emissions from manure management are calculated using IPCC default emission factors. N_2O estimates are calculated using UK GHGI emission factors. Emission estimates were compiled by Aether and Ricardo-AEA.

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 livestock population data and appropriate emission factors. The livestock population data are collected in the June Agricultural Census, published annually by the devolved administrations (i.e. England, Wales, Scotland and Northern Ireland). These are long running publications 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

Details of and justifications for recalculations to activity data and to emission factors are given in **Table 6.3** and **Table 6.4** respectively. For information on the magnitude of recalculations to Source Category 4B, see **Section 10**.

Dairy cow feed digestibility was corrected from 75% to 74.5234142710097%, according to information from Bruce Cottrill (ADAS, pers. comm.). All decimals were included as recommended by the ERT. This was applied to the entire time series.

In the UK, 58% of the land is subject to Nitrate Vulnerable Zones (NVZ). In these zones, manure application is not allowed at certain times of the year. Furthermore manure application on snow is not allowed[35]. As a consequence and in response to ERT comments in the 2013 review, the UK has updated its AWMS values by reducing the allocation of manure to daily spread, affecting cattle, pigs & poultry. The difference was attributed to Deep litter as a response to the review, the allocation of manure to solid storage and dry lot was changed to deep litter.

In consequence, the methane conversion factor (MCF) was updated from 1% to 39% for deep litter (previously solid storage and dry lot) in response to ERT 2013.

The 2011 N excretion rate for dairy cows was updated, it is now linked to milk yield (this was previously not the case for 2011). The link was present for all other years therefore this change only affected the results from 2011. Activity data for horses has been revised to include both agricultural and non-agricultural horses for the whole time series.

There have been changes to the livestock numbers for the OTs and CDs since the previous submission due to improved calculations to ensure the consistency of the time series. The only significant change can be seen in estimates for cattle in the Cayman Islands in 1993 where livestock data have been recalculated to improve time series consistency. Bermuda has seen a large increase in emissions for N2O emissions from manure management. This is due to an improvement in methodology (as estimates were previously based on extrapolation of N2O emissions data from 2000). The method now uses country-specific livestock data and UK N2O emission factors – as is used for all other regions.

[35] https://www.gov.uk/managing-sewage-sludge-slurry-and-silage

Table 6.3 4B Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	2013 submission 1990	2013 submission 2011	2014 submission 1990	2014 submission 2011	Units	Comment/Justification
4.B.1	Methane Emissions from Manure Management – Cattle	78.57	79.38	239.01	200.84	kt	Updated AWMS values in response to ERT 2013. Updated MCF value from 1% to 39% for deep litter (previously solid storage and dry lot) in response to ERT 2013. Updated feed digestibility from 75.0 to 74.5234142710097. Entered cow milk yield for 2012 and updated provisional data for 2011 (from 7533 to 7528 l/yr).
4.B.3	Methane Emissions from Manure Management – Sheep	5.16	3.68	13.45	9.59	kt	Updated MCF value from 1% to 39% for deep litter (previously solid storage and dry lot) in response to ERT 2013.
4.B.4	Methane Emissions from Manure Management – Goats	0.01	0.01	0.05	0.05	kt	Updated MCF value from 1% to 39% for deep litter (previously solid storage and dry lot) in response to ERT 2013.
4.B.6	Methane Emissions from Manure Management – Horses	0.28	0.43	0.79	1.42	kt	Entered new 1990-2012 time series data for horses to include both agricultural and non-agricultural horses.
4.B.8	Methane Emissions from Manure Management – Swine	71.25	24.39	158.17	84.40	kt	Updated AWMS values in response to ERT 2013. Updated MCF value from 1% to 39% for deep litter (previously solid storage and dry lot) in response to ERT 2013.
4.B.9	Methane Emissions from Manure Management – Poultry	8.02	12.18	14.99	18.93	kt	Updated AWMS values in response to ERT 2013.
4.B.12-14	Nitrous Oxide Emissions from Manure Management - AWMS	6.32	5.31	10.79	8.64	kt	Updated AWMS values in response to ERT 2013. Updated 2011 N excretion value for dairy cows to link to milk yield. Entered cow milk yield for 2012 and updated provisional data for 2011 (from 7533 to 7528 l/yr).

Table 6.4 4B Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	2013 submission 1990	2013 submission 2011	2014 submission 1990	2014 submission 2011	Units	Comment/Justification
4.B.1	Methane Emissions from Manure Management (Cattle)					kg CH_4 $head^{-1}$ yr^{-1}	Updated AWMS values in response to ERT 2013.
	- Dairy cows	20.0	31.8	33.9	42.6		Updated MCF value from 1% to 39% for deep litter (previously solid storage and dry lot) in response to ERT 2013.
	- Beef cows	2.5	2.5	13.0	13.0		
	- Dairy heifers	4.7	7.7	22.1	21.7		
	- Beef heifers	3.3	3.3	17.3	17.3		
	- Dairy replacements >1 year	4.7	7.7	22.1	21.7		Updated feed digestibility from 75.0 to 74.5234142710097.
	- Beef all others > 1 year	3.3	3.3	17.3	17.3		
	- Dairy calves < 1 year	0.7	0.7	15.6	15.6		Entered cow milk yield for 2012 and updated provisional data for 2011 (from 7533 to 7528 l/yr).
	- Beef calves < 1 year	0.5	0.5	11.0	11.0		
4.B.3	Methane Emissions from Manure Management (Sheep)					kg CH_4 $head^{-1}$ yr^{-1}	Updated MCF value from 1% to 39% for deep litter (previously solid storage and dry lot) in response to ERT 2013.
	- Breeding sheep	0.19	0.19	0.48	0.48		
	- Other sheep	0.19	0.19	0.48	0.48		
	- Lambs	0.05	0.05	0.13	0.13		
4.B.4	Methane Emissions from Manure Management – Goats	0.12	0.12	0.48	0.48	kg CH_4 $head^{-1}$ yr^{-1}	Updated MCF value from 1% to 39% for deep litter (previously solid storage and dry lot) in response to ERT 2013.
4.B.8	Methane Emissions from Manure Management (Swine)					kg CH_4 $head^{-1}$ yr^{-1}	Updated AWMS values in response to ERT 2013.
	- Sows	5.9	4.0	17.3	12.7		Updated MCF value from 1% to 39% for deep litter (previously solid storage and dry lot) in response to ERT 2013.
	- Gilts	5.9	4.0	17.3	12.7		
	- Boars	5.9	4.0	17.3	12.7		
	- Fattening & other pigs 80 - > 100 kg	8.0	5.6	21.5	21.0		
	- Fattening & other pigs 50-80 kg	8.0	5.6	21.5	21.0		
	- Other pigs 20-50 kg	8.0	5.6	21.5	21.0		
	- Pigs < 20 kg	14.2	5.9	21.5	17.1		

IPCC Category	Source Name	2013 submission 1990	2013 submission 2011	2014 submission 1990	2014 submission 2011	Units	Comment/Justification
4.B.9	Methane Emissions from Manure Management (Poultry)					kg CH_4 $head^{-1}$ yr^{-1}	Updated AWMS values in response to ERT 2013.
	- Growing pullets	0.063	0.063	0.117	0.117		
	- Laying fowls	0.063	0.064	0.117	0.114		
	- Breeding flock	0.063	0.063	0.117	0.117		
	- Table chicken	0.063	0.082	0.117	0.117		
	- Turkeys	0.063	0.063	0.117	0.116		
	- Total other poultry	0.063	0.063	0.117	0.117		

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

Emissions sources	Source included	Method	Emission Factors
	4D1: Agricultural Soils: Direct Soil Emissions	T1, T1a	D
	4D2: Agricultural Soils: Animal Emissions	T2	CS
	4D4: Agricultural Soils: Indirect Emissions	T1	D
Gases Reported	N_2O		
Key Categories (Trends)	Agricultural Soils – N_2O		
Key Categories (Level)	Agricultural Soils – N_2O		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Emissions included under 4D4 'other' within the CRF. These estimates use tier 1 methodology.		
Completeness	No emissions are reported for categories 4D3 and 4D4 because no emissions have been identified. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	Updated Scottish crop production time series for 2008 to 2011 due to improved data sources. Some crop production values were also updated for E&W (from 2006). Inclusion of emissions from OTs and CDs following UNFCCC review recommendations.		

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:

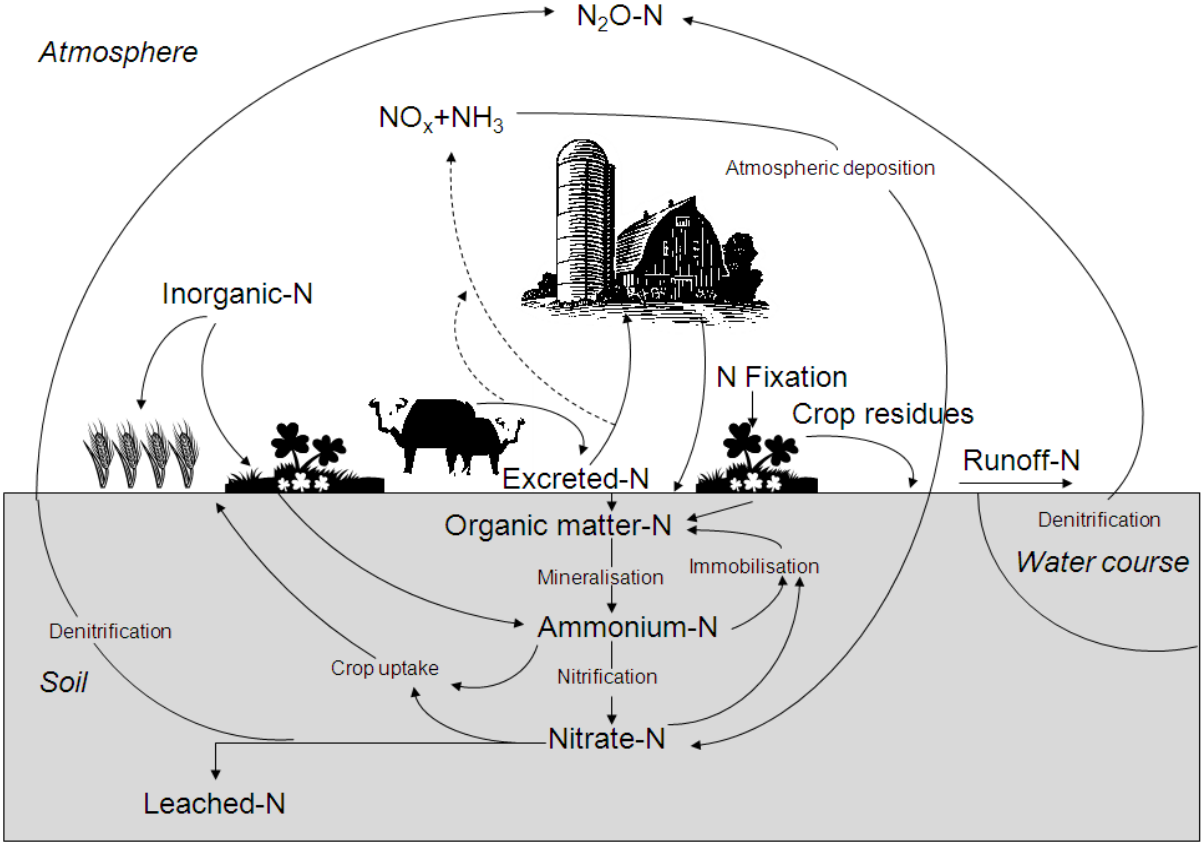
(i) The use of inorganic fertilizer
(ii) Biological fixation of nitrogen by crops
(iii) Crop residues returned to soils
(iv) Cultivation of histosols (organic soils)

(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 6.3**).

Figure 6.3 Simplified nitrogen cycle highlighting the steps involved in the production of N_2O from agriculture.



6.5.2 Methodological issues

6.5.2.1 Inorganic Fertiliser

Emissions from the application of inorganic fertilizer are calculated using the IPCC (2000) Tier 1 methodology (equation 4.20) and IPCC default emission factors.

Annual consumption of synthetic fertilizer is estimated based on crop areas from the Devolved Administrations[36] and the British Survey of Fertiliser Practice (plus country-specific

[36] **England:** https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june

data for Northern Ireland provided by Paul Caskie, DARDNI) as shown in **Table A 3.5.11** (**Annex 3**). **Table A 3.5.12** shows the trend in areas and fertiliser N application rates for the major crop categories over the period 1990-2011.

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 (2000) methodology (equation 4.20) 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 were provided by Tom Johnson, DEFRA (England & Wales), Helen McAfee, The Scottish Government and Conor McCormack, DARDNI. The fraction of dry mass for the crops considered is given in **Table A 3.5.13 (Annex 3)**.

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 using equation 4.29 of the IPCC GPG (2000).

Helen McAfee (Scottish Government) also supplied an updated time series for 2008 to 2011 due to improved data sources. Some crop production values were updated for E&W (from 2006) from data supplied by Lindsay Holmes, DEFRA. Production data of crops are provided by Tom Johnson, DEFRA (England & Wales), Helen McAfee, The Scottish Government and Conor McCormack, DARDNI and are shown in **Table A 3.5.14**. The dry mass fraction of crops and residue fraction are given in **Table A 3.5.13**. 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), and 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 estimated at 1500 km^2 (as in **Section A 3.5.7**).

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 the IPCC default emission factors for pasture range and paddock and country specific data for the fraction of livestock N excreted and deposited onto soil during grazing. The latter UK specific value is much larger than the IPCC default value (0.23), as cattle in particular spend more time grazing at pasture in the UK than is the case in many other countries (**Section A 3.5.2.1 Table A 3.5.5**).

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 using IPCC default emission factors and country-specific data for the amount of manure nitrogen applied to the land.

Scotland: http://www.scotland.gov.uk/Publications/2012/09/1148/downloads
Wales: http://wales.gov.uk/statistics-and-research/survey-agricultural-horticulture/?lang=en and John Bleasdale, Welsh Government
Northern Ireland: http://www.dardni.gov.uk/june-agricultural-census-final-results and Paul Caskie, DARDNI

The summation is for all animal types and manure previously stored in categories defined as a) liquid, b) deep litter and c) other (poultry manure without bedding and poultry manure with bedding (litter)).

The UK follows the IPCC (2000) 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. For daily spreading of manure and application of previously stored manures to land, the emission is given by equations 4.20 and 4.23 of IPCC GPG (2000). The summation is for all animal types and manure that is daily spread or previously stored in categories defined as a) liquid, b) deep litter and c) other (poultry manure without bedding or poultry manure with bedding (litter)). The fraction of livestock N excretion in excrements burned for fuel is expressed as a fraction of all livestock groups N.

6.5.2.7 Application of sewage sludge to land

Following the IPCC 2000 GPG methodology, 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 (see **Table A 3.5.15**). Data sources for the annual production of sewage sludge (as dry matter) are described in Waste sector, see **Section 8.3**.
The UK follows the IPCC (2000) methodology (equation 4.20). 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 country specific 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 (2000). 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 contribution from synthetic fertilisers is given by equations 4.30, 4.31 of the IPCC GPG (2000).

The method used corrects for the N content of manures used as fuel (poultry litter incineration).

6.5.2.10 Leaching and runoff

Indirect emissions of N_2O from leaching and runoff are estimated according the IPCC using equations 4.34, 4.35, 4.36 from IPCC GPG (2000). 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 (poultry litter incineration).

6.5.2.11 Overseas Territories and Crown Dependencies

The Tier 1 methodology from the IPCC Guidelines was applied to calculate emissions from agricultural soils for the OTs and CDs. Livestock data were provided from each of the OTs/ CDs or sourced from FAO. The quantity of synthetic fertiliser applied and crop production data were obtained from FAO and Defra; these data can be found in **Annex Section A 3.8**. Emission factors taken from the IPCC guidelines and Western European emission factors were applied to all CDs (Isle of Man, Guernsey and Jersey) whilst Latin American emission factors were applied to all OTs (Cayman Islands, Falkland Islands, Montserrat and Bermuda). This decision was based on both geographical location, and the understanding of farming practices. Emission estimates were compiled by Aether and Ricardo-AEA.

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 **Section A 3.5.3**). 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 the Devolved Administrations) 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

Details of and justifications for recalculations to activity data are given in **Table 6.5**. For information on the magnitude of recalculations to Source Category 4D, see **Section 10**.

Some of the Scottish crop production data was updated for 2008 to 2011 due to improved data sources. Some crop production values were also updated for E&W (from 2006) from improved data supplied by Defra.
The time series data on amounts of sewage sludge produced was updated with data provided by Ricardo-AEA in agreement with the Waste sector.

There have been recalculations in this sector for OTs and CDs since the previous submission. Estimates have decreased by approximately 40% across the entire time series for all OTs and CDs due to a correction in the compilation spreadsheet. The inclusion of land area time series data has changed estimates for some regions by approximately 3% and increased the consistency between the Agriculture and LULUCF sectors. The correction of an error that excluded emissions from animal manure as fertilizer has resulted in a significant increase in estimates for Montserrat across the time series. Emissions have increased by a factor of 400 resulting in approximately a 2kt CO_2e increase.

Table 6.5 4D Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	2013 submission 1990	2013 submission 2011	2014 submission 1990	2014 submission 2011	Units	Comment/Justification
4.D.1.2	Direct Soil Emissions – Spreading Animal Manures on Land	8.36	6.41	8.36	6.47	kt	Updated AWMS values in response to ERT 2013. Updated 2011 N excretion value for dairy cows to link to milk yield. Entered cow milk yield for 2012 and updated provisional data for 2011 (from 7533 to 7528 l/yr)from AUK 2013
4.D.1.3	Direct Soil Emission – N Fixing Crops	0.85	0.49	0.85	0.49	kt	Entered crop production data for E, W, S, and NI 2012 along with updated time series for 2008 to 2011 due to improved data sources. Some crop production values also updated for E&W (from 2006).
4.D.1.4	Direct Soil Emission – Crop Residue	7.06	9.14	7.06	9.10	kt	Entered crop production data for E, W, S, and NI 2012 along with updated time series for 2008 to 2011 due to improved data sources. Some crop production values also updated for E&W (from 2006).
4.D.2	Pasture, Range and Paddock Manure	21.20	17.60	21.78	18.77	kt	Updated AWMS values in response to ERT 2013. Updated 2011 N excretion value for dairy cows to link to milk yield. Entered cow milk yield for 2012 and updated provisional data for 2011 (from 7533 to 7528 l/yr). Entered new 1990-2012 time series data for horses to include both agricultural and non-agricultural horses.
4.D.3.1	Indirect Emissions – Atmospheric Deposition	6.35	4.96	6.41	5.11	kt	Updated AWMS values in response to ERT 2013. Updated 2011 N excretion value for dairy cows to link to milk yield. Entered cow milk yield for 2012 and updated provisional data for 2011 (from 7533 to 7528 l/yr).

					Entered new 1990-2012 time series data for horses to include both agricultural and non-agricultural horses. Entered 2012 sewage sludge data provided by Ricardo-AEA (and updated time series).
4.D.3.2	Indirect Emissions – Nitrogen Leaching and Runoff	33.17 25.29	33.39 25.85	kt	Updated AWMS values in response to ERT 2013. Updated 2011 N excretion value for dairy cows to link to milk yield. Entered cow milk yield for 2012 and updated provisional data for 2011 (from 7533 to 7528 l/yr)from AUK 2013 Entered new 1990-2012 time series data for horses to include both agricultural and non-agricultural horses. Entered 2012 sewage sludge data provided by Ricardo-AEA (and updated time series).
4.D.4	Other – Municipal Sewage Sludge Applied to Fields	0.28 0.66	0.28 0.76	kt	Entered 2012 sewage sludge data provided by Ricardo-AEA (and updated time series).

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

Emissions sources	Source included	Method	Emission Factors
	4F1: Barley Residue Wheat Residue Oats Residue 4F5: Linseed Residue	T1 T1 T1 T1	D D D D
Gases Reported	CH_4, N_2O, NO_x, CO, NMVOC, SO_2		
Key Categories (Trends)	None identified		
Key Categories (Level)	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	No data available for this source. No emissions reported		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements		

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) shown in **Table A 3.5.16**.

The estimates of the masses of residue burnt of barley, oats, wheat and linseed are based on crop production data (Tom Johnson, DEFRA (England & Wales), Gregor Berry, The Scottish Government and Conor McCormack, DARDNI) and data on the fraction of crop residues burnt (MAFF, 1995; ADAS, 1995). 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 A7.4.1**, 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

For oats, barley and linseed replaced N-C ratio value of 0.012 (value for wheat) with the correct default value of 0.015 (IPCC 1997). For information on the magnitude of recalculations to Source Category 4F, see **Section 10**.

6.7.6 Source-specific planned improvements

No improvements are planned.

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 is supplied annually from the June census[37], which follow documented QA procedures. Activity data on mineral fertiliser are calculated using application rates from Defra's annual British Survey of Fertiliser Practice (BSFP) multiplied by crop areas from the June Census. Data from the June Census, in the form of *.PDF files, can be downloaded from the Devolved Administrations websites 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 data for livestock numbers and crop areas are supplemented by data provided by the Centre for Ecology and Hydrology (U. Dragotsis) for England, Scotland and Northern Ireland but not Wales. The livestock and crop area data are also used to generate the NH_3 inventory.

[37] **England:** https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june
Scotland: http://www.scotland.gov.uk/Publications/2012/09/1148/downloads
Wales: http://wales.gov.uk/statistics-and-research/survey-agricultural-horticulture/?lang=en and John Bleasdale, Welsh Government
Northern Ireland: http://www.dardni.gov.uk/june-agricultural-census-final-results and Paul Caskie, DARDNI

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

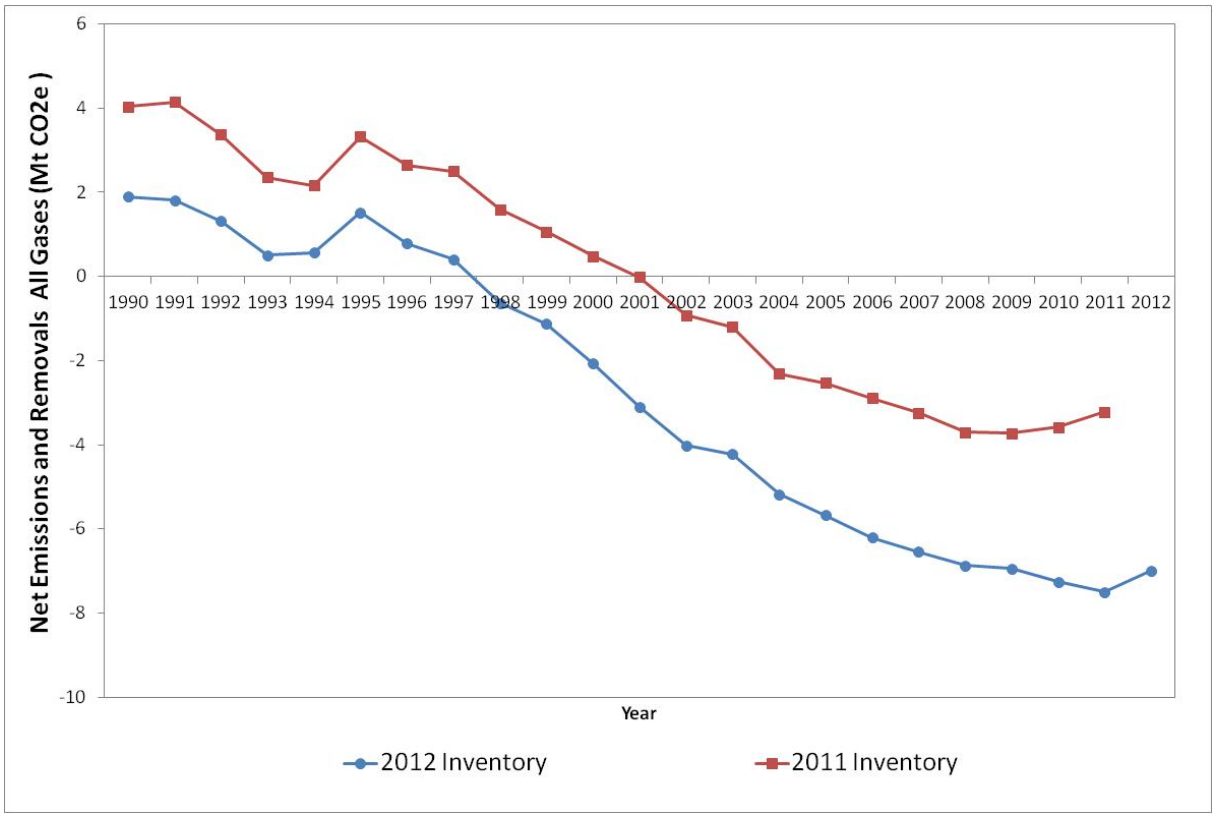
7.1 OVERVIEW OF SECTOR

IPCC Categories Included	5A: Forest Land 5B: Cropland 5C: Grassland 5D: Wetlands 5E: Settlements 5G: Other (Harvested wood products)
Gases Reported	CO_2, CH_4, N_2O, NO_x, CO
Key Categories (Trends)	5E LULUCF – CO_2
Key Categories (Level)	5A LULUCF – CO_2 5B LULUCF – CO_2 5C LULUCF – CO_2 5E LULUCF – CO_2
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Reported under the relevant Sector 5 sub-categories at Tier 1
Completeness	No known omissions- areas are reported for land uses with no associated emissions. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	Change to CARBINE model for 5A Forest Land and 5G Harvested Wood Products. Inclusion of emissions from all forests older than 20 years, including those planted prior to 1921 which were previously assumed to be in carbon equilibrium. Update to the deforestation areas from 2000 onwards. Inclusion of by-products from sugar production for soil liming in 5B Cropland and 5C Grassland. Recalculation of timeseries for the Overseas Territories and Crown Dependencies, affecting 5B, 5C and 5E Settlements.

CRF Sector 5 includes carbon stock changes, emissions of greenhouse gases (CO_2, CH_4, N_2O, NO_x and CO) by sources and removals of CO_2 by sinks from land use, land use change and forestry. Removals of carbon dioxide are conventionally presented as negative quantities. In the 1990-2011 inventory, the sector reported hving been a net sink since 2001, with a net removal in 2011 of -3.22 Mt CO_2 equivalent (**Figure 7.1**), or -3.31 Mt CO_2 equivalent including the Overseas Territories and Crown Dependencies (OTs and CDs). The overall trend for 1990-2012 inventory (excluding OTs/CDs) is similar to the 1990-2011

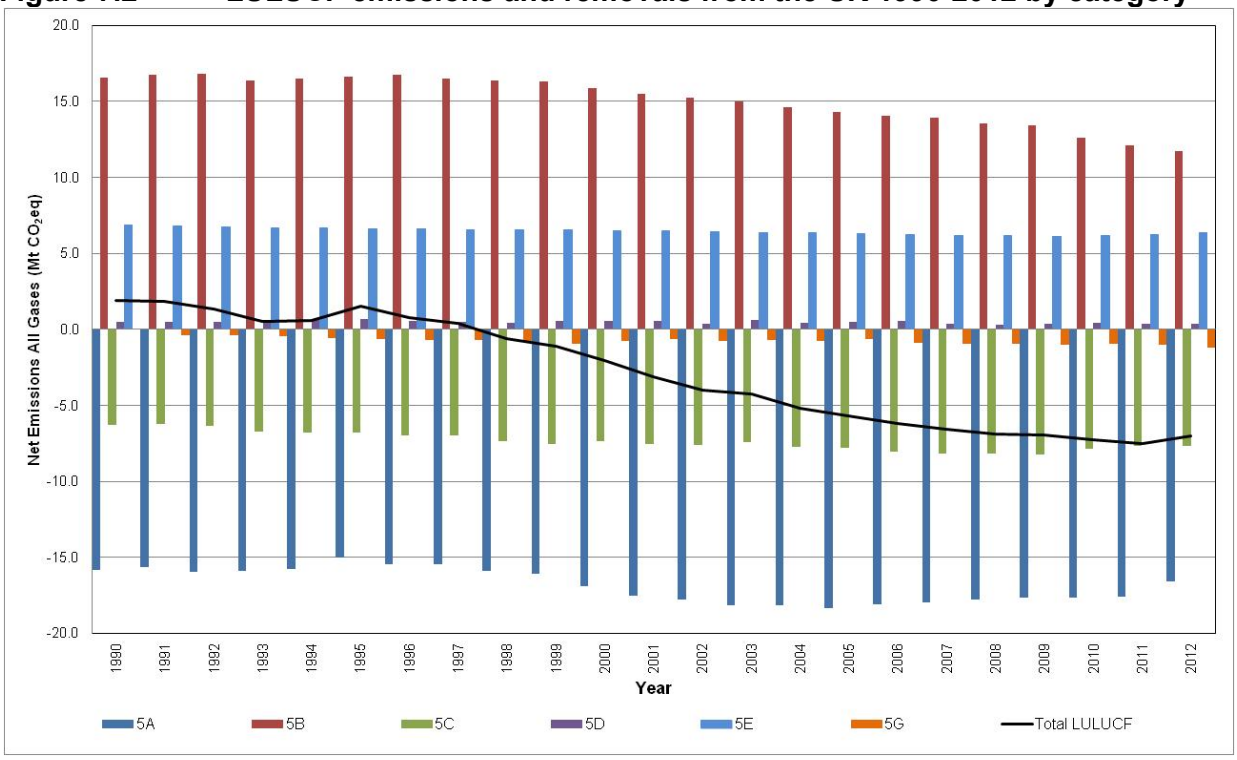
inventory, although Sector 5 now reports a larger sink compared with the 1990-2011 inventory (the smallest annual difference is -5.18 Mt CO_2 equivalent compared with the previous submission of -2.32 Mt CO_2 equivalent for 2004, the largest annual difference is -7.50 Mt CO_2 equivalent compared with the previous submission of -3.25 Mt CO_2 equivalent for 2011). The 1990-2012 inventory shows the Sector becoming a sink from 1998, three years earlier than in the 1990-2011 inventory (**Figure 7.1**). In the 1990-2012 inventory, the sector has a net removal in 2012 of -6.99 Mt CO_2 equivalent, or -6.98 Mt CO_2 equivalent when the Overseas Territories and Crown Dependencies (OTs/CDs) are included (**Figure 7.1**). Summary analysis of the trends in greenhouse emissions from the LULUCF sector is provided in **Section 2.3.5**. The methodological differences between the 2011 and 2012 inventories are explained in tis chapter, with summary information provided in the table at the start of this chapter (*Major improvements since last submission*).

Figure 7.1 LULUCF change in net emissions for all gases between the 2011 and 2012 inventories.



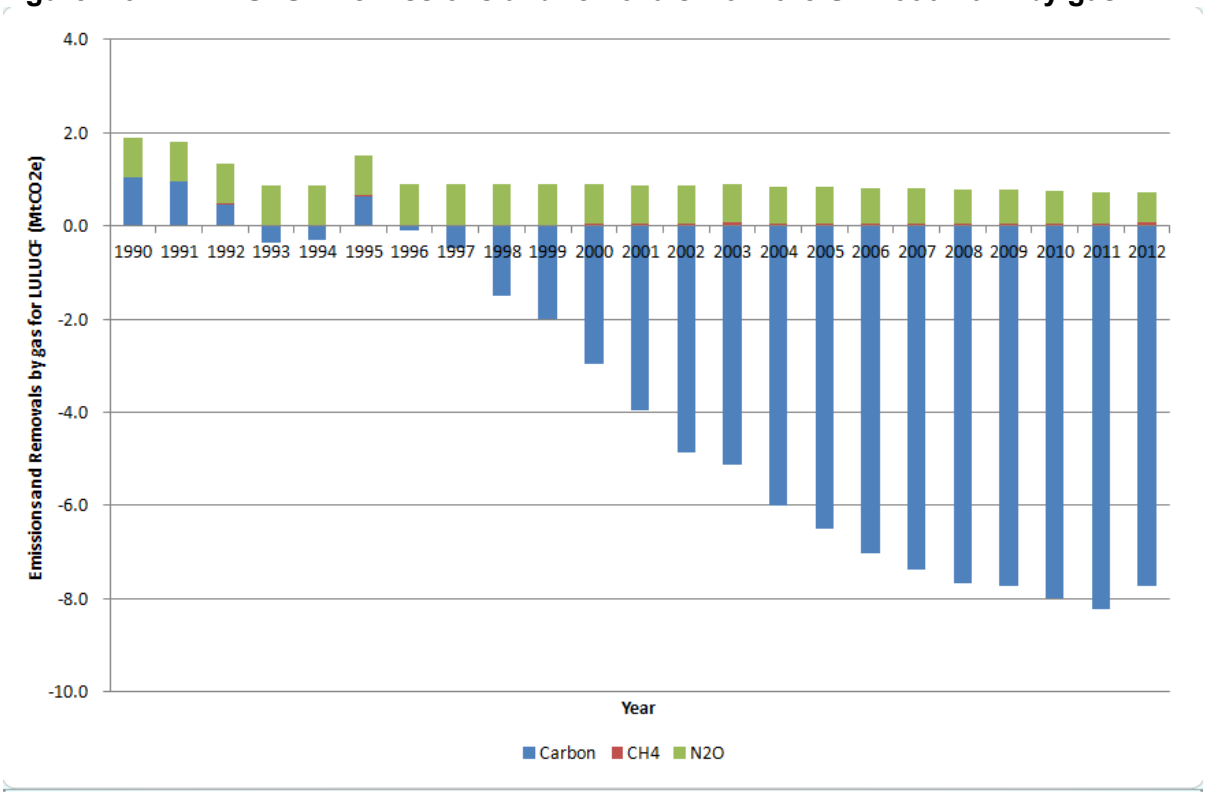
The LULUCF Sector covers emissions and removals of direct and indirect greenhouse gases under six categories: 5A: Forest Land, 5B: Cropland, 5C: Grassland, 5D: Wetlands, 5E: Settlements, 5G: Other - Harvested wood products. 5A: Forest Land, 5C: Grassland and 5G: Other - Harvested wood products are net sinks. 5B: Cropland, 5D: Wetlands and 5E: Settlements are net sources (**Figure 7.2**).

Figure 7.2 LULUCF emissions and removals from the UK 1990-2012 by category



The LULUCF Sector is the only Sector within the inventory to report net removals. The net carbon sink reported since 1998 is provided by carbon gains in above and below ground biomass, soil carbon sequestration and HWP. The Sector is a source of methane and nitrous oxide, but these are lower than the net carbon removals since 1998 (**Figure 7.3**).

Figure 7.3 LULUCF emissions and removals from the UK 1990-2012 by gas



The inclusion of new activities and the revisions to the methodology and to activity data are described in this chapter and **Annex 3.7** on methods used to estimate emissions and removals. 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/.

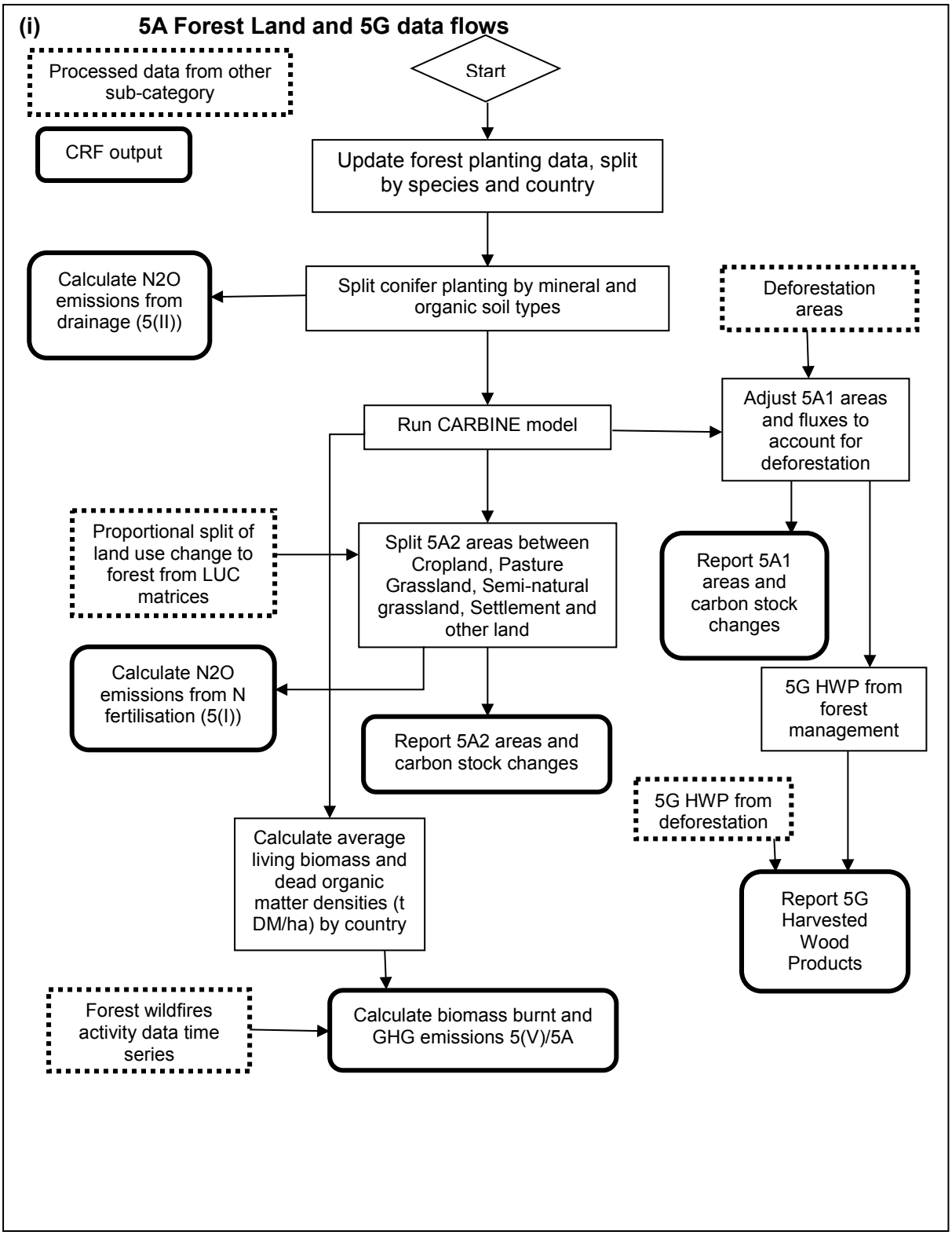
Greenhouse gas emissions and removals from the UK CDs and OTs are reported under the relevant categories of CRF Sector 5. The data, assumptions and methodologies are explained in section 7.9. The availability of data for the different OTs and CDs is very variable, so that emission estimates can only be made for the CDs of Jersey, Guernsey and the Isle of Man and the OT 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. Lack of suitable data for the Caribbean territories (as discussed in the 1990-2006 NIR http://naei.defra.gov.uk/reports/reports?report_id=507) makes it impossible to create inventories for them at the present time.

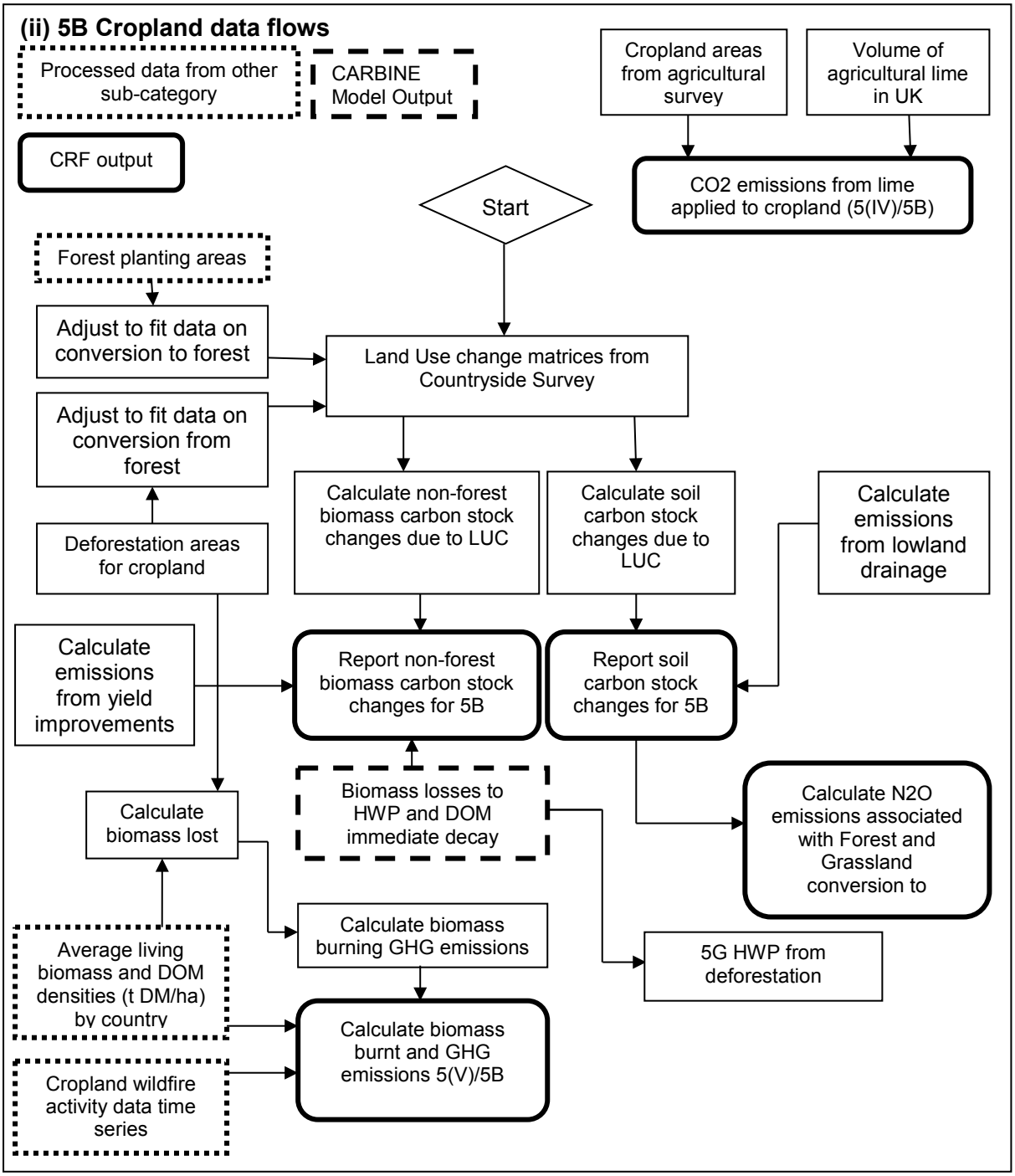
7.1.1 The land use transition matrix

Reporting in CRF Sector 5 is based on broad land categories: Forest Land, Cropland, Grassland, Wetlands, Settlements and Other Land. According to the IPCC Guidelines for Agriculture, Forestry and Other Land Use (2006), 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.

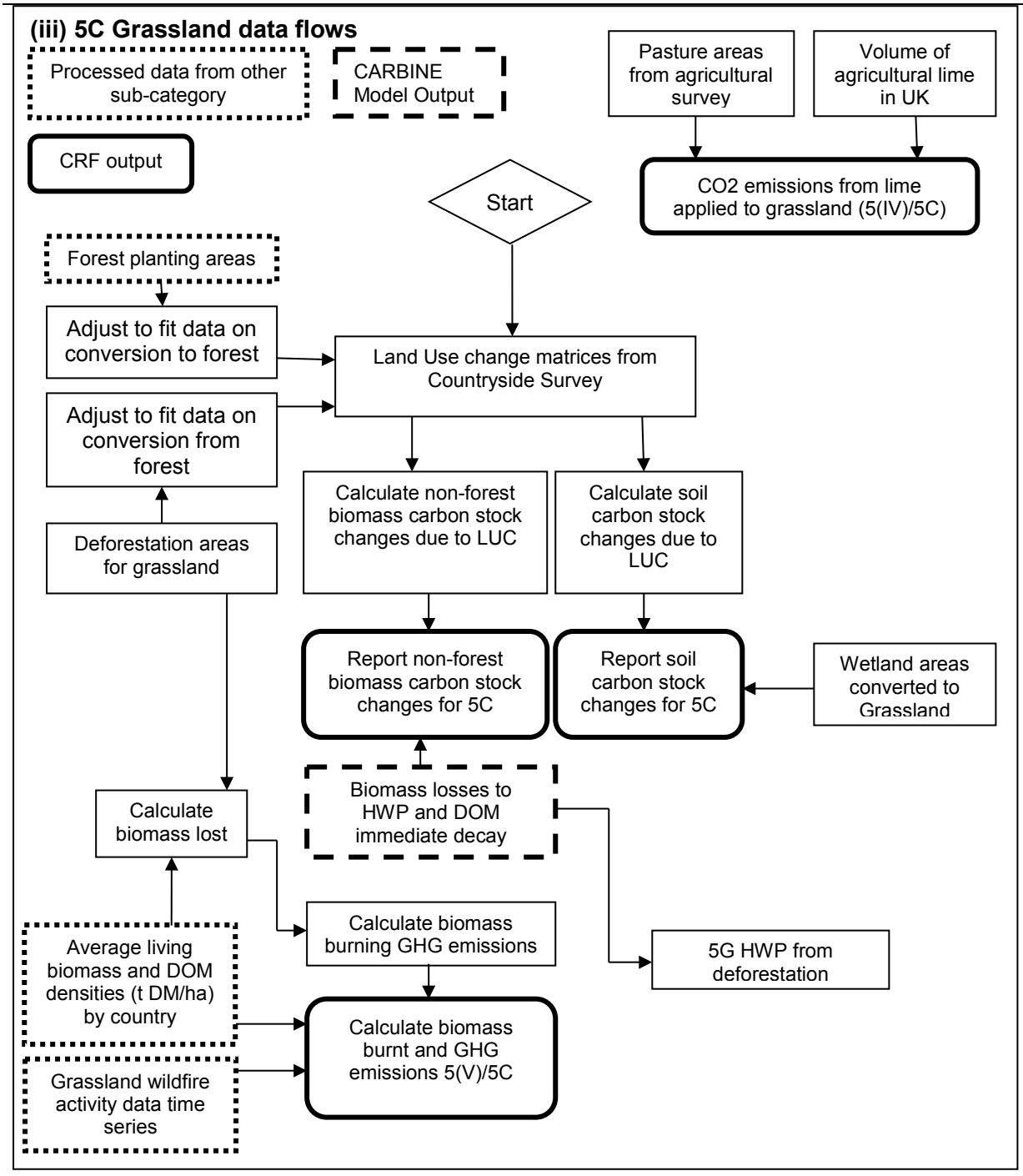
Areas of forest land come from statistics published by the Forestry Commission. Areas of Cropland, Grassland and Settlements in 1990, 1998 and 2007 come from the Broad Habitat areas reported for each country (England, Scotland, Wales and Northern Ireland) in the Countryside Surveys (available from http://www.countrysidesurvey.org.uk). The area reported in the Wetlands category is the area undergoing active commercial peat extraction or that has only ceased extraction since 1990 (see **section 7.5** for further information) and the area of inland water. Other Land includes the area of land not identified within the other categories. Areas of land use change to forest (afforestation) in GB since 1920 come from planting data provided by the Forestry Commission and areas pre 1920 come from modelling the age class structure of existing forests given by the National Inventory of Woodlands and Trees. Areas of land use change to forest in Northern Ireland come from planting statistics since 1900 supplied by the Northern Ireland Forest Service. 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 and expert knowledge from representatives of the devolved administrations. Other land use change data comes from the changes between the three Countryside Surveys (1990, 1998 and 2007), rolled forward to 2011. A flow chart has been developed to show the hierarchy between different data sources (**Figure 7.4**)

Figure 7.4 **Data flow diagrams for each land use sub-category, showing cross-linkages between sectors: (i) 5A and 5G, (ii) 5B, (iii) 5C, (iv) 5D and (v) 5E**

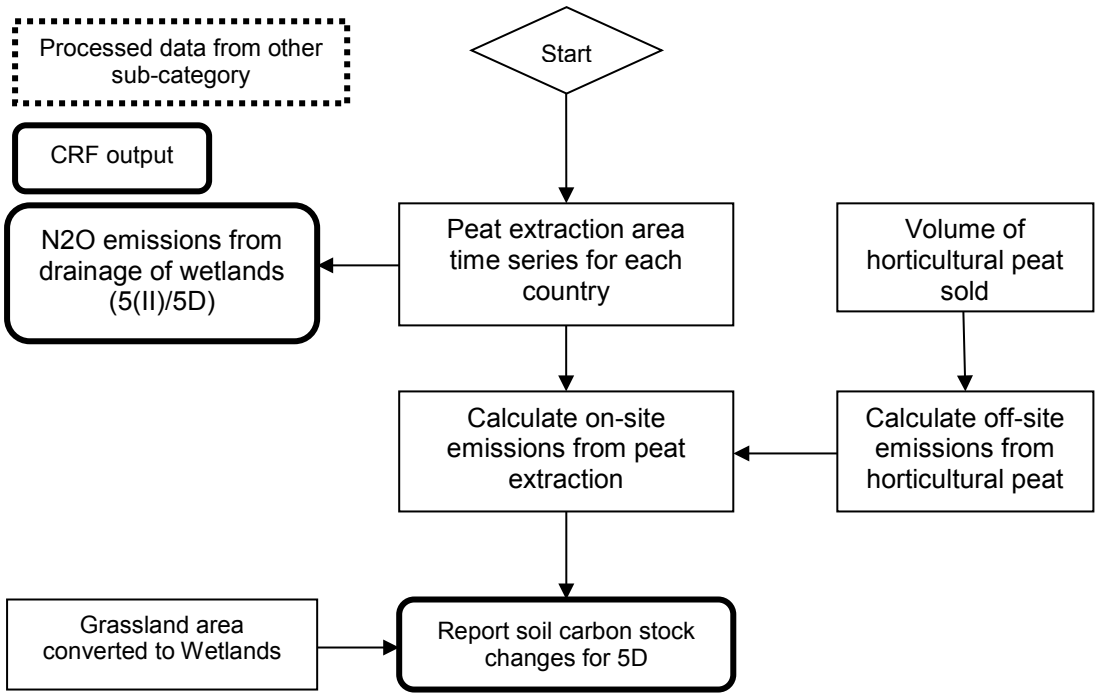



(ii) 5B Cropland data flows
Processed data from other sub-category
CARBINE Model Output
Cropland areas from agricultural survey
Volume of agricultural lime in UK
CRF output
Start
CO2 emissions from lime applied to cropland (5(IV)/5B)
Forest planting areas
Adjust to fit data on conversion to forest
Land Use change matrices from Countryside Survey
Adjust to fit data on conversion from forest
Calculate non-forest biomass carbon stock changes due to LUC
Calculate soil carbon stock changes due to LUC
Calculate emissions from lowland drainage
Deforestation areas for cropland
Calculate emissions from yield improvements
Report non-forest biomass carbon stock changes for 5B
Report soil carbon stock changes for 5B
Biomass losses to HWP and DOM immediate decay
Calculate N2O emissions associated with Forest and Grassland conversion to
Calculate biomass lost
Calculate biomass burning GHG emissions
5G HWP from deforestation
Average living biomass and DOM densities (t DM/ha) by country
Calculate biomass burnt and GHG emissions 5(V)/5B
Cropland wildfire activity data time series

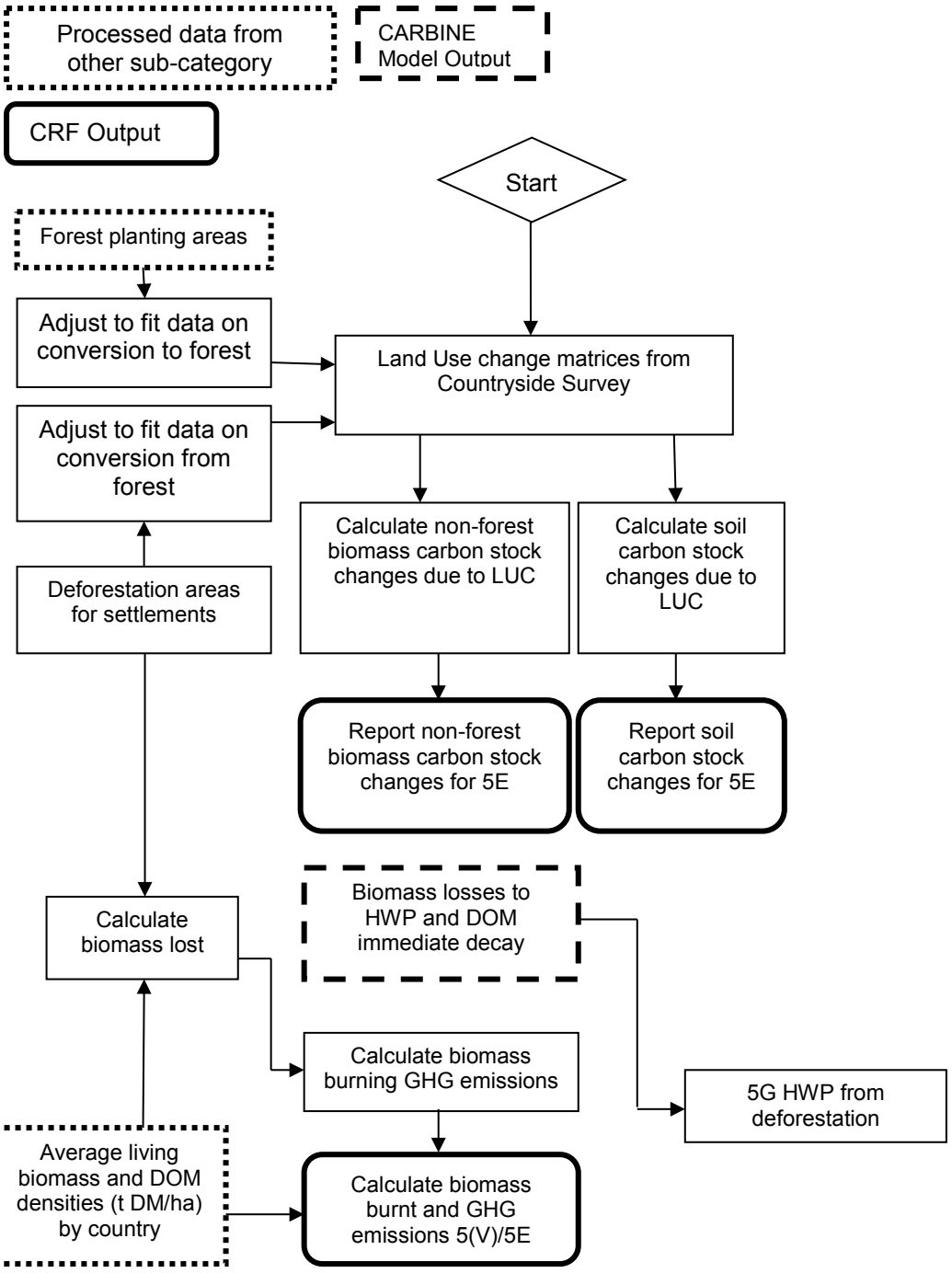
(iii) 5C Grassland data flows



(iv) 5D Wetlands data flows



(v) 5E Settlements data flows



The 2011 ERT recommended the inclusion of the full set of annual land use change matrices in the NIR (**Table 7.1**). 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.

Table 7.1 Annual land use change (in kha) matrices 1990-2012

1990 to 1991

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2359	2	19	0	1	0	2380
Cropland	0	6022	96	0	1	0	6119
Grassland	0	83	13670	0	5	0	13759
Wetland	0	0	0	177	0	0	177
Settlement	1	2	13	0	1711	0	1728
Other Land	0	0	0	0	0	253	253
Total	2360	6110	13798	177	1718	253	24415

1991 to 1992

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2379	2	17	0	1	0	2399
Cropland	0	6031	96	0	1	0	6128
Grassland	0	83	13633	0	5	0	13721
Wetland	0	0	0	177	0	0	177
Settlement	1	2	13	0	1720	0	1737
Other Land	0	0	0	0	0	253	253
Total	2380	6119	13760	177	1727	253	24415

1992 to 1993

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2398	2	16	0	1	0	2416
Cropland	0	6040	96	0	1	0	6137
Grassland	0	83	13598	0	5	0	13687
Wetland	0	0	0	176	0	0	176
Settlement	1	2	13	0	1729	0	1746
Other Land	0	0	0	0	0	253	253
Total	2399	6128	13723	177	1736	253	24415

1993 to 1994

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2416	2	16	0	1	0	2435
Cropland	0	6049	96	0	1	0	6146
Grassland	0	83	13562	0	5	0	13651
Wetland	0	0	0	176	0	0	176
Settlement	1	2	13	0	1738	0	1755
Other Land	0	0	0	0	0	253	253
Total	2416	6137	13688	176	1745	253	24415

1994 to 1995

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2434	2	15	0	1	0	2452
Cropland	0	6058	96	0	1	0	6155
Grassland	0	83	13527	0	5	0	13615
Wetland	0	0	0	176	0	0	176
Settlement	1	2	13	0	1747	0	1764
Other Land	0	0	0	0	0	253	253
Total	2435	6146	13651	176	1754	253	24415

1995 to 1996

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2452	2	17	0	1	0	2472
Cropland	0	6067	96	0	1	0	6164
Grassland	0	83	13490	0	5	0	13578
Wetland	0	0	0	175	0	0	175
Settlement	1	2	13	0	1757	0	1773
Other Land	0	0	0	0	0	252	252
Total	2453	6155	13616	176	1763	253	24415

1996 to 1997

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2471	2	14	0	1	0	2488
Cropland	0	6076	96	0	1	0	6173
Grassland	0	83	13456	0	5	0	13545
Wetland	0	0	0	175	0	0	175
Settlement	1	2	13	0	1765	0	1782
Other Land	0	0	0	0	0	252	252
Total	2472	6164	13580	175	1772	252	24415

1997 to 1998

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2487	2	15	0	1	0	2504
Cropland	0	6085	96	0	1	0	6182
Grassland	0	83	13422	0	5	0	13511
Wetland	0	0	0	175	0	0	175
Settlement	1	2	13	0	1774	0	1791
Other Land	0	0	0	0	0	252	252
Total	2488	6173	13546	175	1781	252	24415

1998 to 1999

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2504	2	14	0	1	0	2520
Cropland	0	6094	96	0	1	0	6191
Grassland	0	83	13389	0	5	0	13477
Wetland	0	0	0	174	0	0	174
Settlement	1	2	13	0	1783	0	1800
Other Land	0	0	0	0	0	252	252
Total	2505	6182	13512	175	1790	252	24415

1999 to 2000

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2520	2	14	0	1	0	2536
Cropland	0	6103	96	0	1	0	6200
Grassland	0	83	13356	0	5	0	13445
Wetland	0	0	0	174	0	0	174
Settlement	1	2	13	0	1791	0	1808
Other Land	0	0	0	0	0	252	252
Total	2521	6191	13479	174	1798	252	24415

2000 to 2001

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2536	2	13	0	2	0	2553
Cropland	0	6093	52	0	0	0	6145
Grassland	2	99	13367	0	8	0	13476
Wetland	0	0	0	174	0	0	174
Settlement	1	5	10	0	1799	0	1815
Other Land	0	0	0	0	0	252	252
Total	2539	6199	13442	174	1809	252	24415

2001 to 2002

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2550	2	14	0	2	0	2569
Cropland	0	6038	52	0	0	0	6090
Grassland	2	99	13400	0	8	0	13509
Wetland	0	0	0	173	0	0	173
Settlement	1	5	10	0	1806	0	1822
Other Land	0	0	0	0	0	252	252
Total	2554	6144	13476	174	1816	252	24415

2002 to 2003

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2566	2	11	0	2	0	2580
Cropland	0	5984	52	0	0	0	6036
Grassland	3	99	13436	0	8	0	13546
Wetland	0	0	0	173	0	0	173
Settlement	1	5	10	0	1813	0	1829
Other Land	0	0	0	0	0	251	251
Total	2570	6090	13509	173	1822	252	24415

2003 to 2004

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2577	2	10	0	1	0	2590
Cropland	0	5930	52	0	0	0	5982
Grassland	3	99	13473	0	8	0	13583
Wetland	0	0	0	173	0	0	173
Settlement	1	5	10	0	1820	0	1836
Other Land	0	0	0	0	0	251	251
Total	2581	6036	13545	173	1829	251	24415

2004 to 2005

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2587	1	9	0	1	0	2599
Cropland	0	5876	52	0	0	0	5928
Grassland	3	99	13512	0	8	0	13622
Wetland	0	0	0	173	0	0	173
Settlement	1	5	10	0	1827	0	1843
Other Land	0	0	0	0	0	251	251
Total	2590	5981	13583	173	1836	251	24415

2005 to 2006

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2595	1	8	0	1	0	2607
Cropland	0	5822	52	0	0	0	5874
Grassland	3	99	13550	0	8	0	13660
Wetland	0	0	0	172	0	0	172
Settlement	1	5	10	0	1835	0	1851
Other Land	0	0	0	0	0	251	251
Total	2599	5927	13621	173	1844	251	24415

2006 to 2007

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2603	1	6	0	1	0	2612
Cropland	0	5769	52	0	0	0	5821
Grassland	2	99	13591	0	8	0	13700
Wetland	0	0	0	172	0	0	172
Settlement	1	5	10	0	1843	0	1859
Other Land	0	0	0	0	0	251	251
Total	2607	5874	13660	172	1852	251	24415

2007 to 2008

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2609	1	8	0	1	0	2619
Cropland	0	5716	52	0	0	0	5768
Grassland	3	99	13629	0	8	0	13739
Wetland	0	0	0	172	0	0	172
Settlement	1	5	10	0	1850	0	1866
Other Land	0	0	0	0	0	251	251
Total	2612	5821	13700	172	1859	251	24415

2008 to 2009

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2617	1	5	0	1	0	2624
Cropland	0	5663	52	0	0	0	5715
Grassland	3	99	13670	0	8	0	13780
Wetland	0	0	0	172	0	0	172
Settlement	1	5	10	0	1858	0	1874
Other Land	0	0	0	0	0	250	250
Total	2620	5768	13738	172	1867	250	24415

2009 to 2010

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2621	1	5	0	1	0	2627
Cropland	0	5610	52	0	0	0	5662
Grassland	3	99	13713	0	8	0	13823
Wetland	0	0	0	172	0	0	172
Settlement	1	5	10	0	1865	0	1881
Other Land	0	0	0	0	0	250	250
Total	2624	5715	13780	172	1874	250	24415

2010 to 2011

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2623	1	4	0	1	0	2628
Cropland	0	5661	6	0	0	0	5666
Grassland	3	0	13797	0	0	0	13800
Wetland	0	0	0	172	0	0	172
Settlement	1	0	17	0	1881	0	1899
Other Land	0	0	0	0	0	250	250
Total	2627	5661	13823	172	1882	250	24415

2011 to 2012

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2625	1	6	0	1	0	2633
Cropland	0	5666	6	0	0	0	5672
Grassland	3	0	13769	0	0	0	13771
Wetland	0	0	0	172	0	0	172
Settlement	1	0	17	0	1899	0	1916
Other Land	0	0	0	0	0	250	250
Total	2628	5667	13797	172	1900	250	24415

2012 to 2013

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2628	1	12	0	2	0	2643
Cropland	0	5672	6	0	0	0	5678
Grassland	2	0	13736	0	0	0	13738
Wetland	0	0	0	172	0	0	172
Settlement	1	0	17	0	1916	0	1934
Other Land	0	0	0	0	0	250	250
Total	2631	5673	13770	172	1918	250	24415

Work is being undertaken to improve the representation of land use change. We have developed a new approach to assimilate multiple land use data sets. This is summarised below and is due to be included in the next submission. It entails vector representation of land use history, and derivation of the most probable set of land use vectors which represent the set of characteristic land use histories giving rise to the observed change in land use at national scale. This should give better representation of cycles or reversals in land use change which are especially important when considering long time horizons.

The starting point is given by the satellite-derived Corine land cover maps from 1990, 2000 and 2007, which cover the UK at 100-m resolution. Overlain on this are the CEH Countryside Survey data and the Forestry Commission National Forest Estate and Woodlands ground-based data. These data are together used to produce a set of 100-m resolution maps, where each pixel has an associated vector of land use over time. The maps are aggregated into the set of distinct representative vectors with their corresponding areas. The vector areas are then calibrated to match the observed time series of the areas of forest, urban, arable, and grassland reported in national statistics. The calibration uses a Bayesian Markov Chain Monte Carlo (MCMC) approach. The method has been developed to sample from the Dirichlet distribution which ensures that the total land use area is conserved. Current work is focussing on balancing the goodness-of-fit achieved with the time series data against the need to for parsimonious representation (i.e. vectors with more changes are less likely). Getting this balance right involves adding appropriate constraints in the calibration. Further data on agricultural land use will be available in the near future, from the land parcel information arising from the Integrated Administration and Control System (IACS) data, and will be included in the data assimilation.

The areas of land in the different land use categories in the OTs and CDs are shown in **Table 7.2**. Insufficient data exist to construct full land use change matrices.

Table 7.2 Areas of land by category in the Crown Dependencies and Overseas Territories 1990-2012, kha

Land category	Sub-category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Forest remaining Forest		2.4	2.5	2.6	2.8	2.9	3.0	3.1	3.3	3.4	3.5	3.7
Land converted to forest		2.1	2.0	1.9	1.7	1.6	1.5	1.3	1.2	1.1	0.9	0.8
Cropland remaining Cropland		12.0	11.9	11.8	11.8	11.5	11.0	11.0	10.7	11.0	10.5	10.0
Land converted to Cropland	Grassland converted to Cropland	0.1	0.1	0.1	0.2	0.2	0.1	0.5	0.8	0.9	0.9	1.0
Grassland remaining Grassland		1263.7	1263.8	1263.8	1263.7	1263.5	1263.5	1263.2	1263.0	1262.2	1262.3	1262.3
Land converted to Grassland	Cropland converted to Grassland	1.4	1.4	1.5	1.6	1.9	2.4	2.4	2.4	2.7	2.9	3.2
Land converted to Grassland	Settlement converted to Grassland	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.6	0.7
Settlements remaining Settlements		9.7	9.8	9.8	9.7	10.0	10.0	10.0	10.1	10.2	10.3	10.4
Land converted to Settlement	Grassland converted to Settlements	1.0	1.0	0.9	1.0	1.0	0.9	0.9	0.9	1.0	1.1	1.1
Other Land remaining Other Land		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Land converted to Other Land		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total area		*1292.7*	*1292.8*	*1292.9*	*1292.9*	*1293.0*	*1293.1*	*1293.1*	*1293.2*	*1293.2*	*1293.3*	*1293.4*

Land category	Sub-category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Forest remaining Forest		3.8	3.8	3.9	4.0	4.1	4.2	4.2	4.3	4.4	4.5	4.5	4.5
Land converted to forest		0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.3	0.4	0.4
Cropland remaining Cropland		9.5	9.3	9.0	8.6	8.6	8.5	8.4	8.4	8.4	7.8	7.5	7.4
Land converted to Cropland	Grassland converted to Cropland	1.0	1.1	1.1	1.3	1.5	1.7	2.0	2.3	2.3	2.4	2.4	2.5
Grassland remaining Grassland		1262.0	1262.0	1261.9	1262.1	1261.9	1257.3	1256.8	1256.7	1256.2	1257.2	1256.8	1258.1
Land converted to Grassland	Cropland converted to Grassland	3.8	3.7	3.9	3.8	3.7	3.5	3.4	3.3	3.9	3.5	3.9	3.7
Land converted to Grassland	Settlement converted to Grassland	0.7	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.1	1.1	1.0	1.1
Settlements remaining Settlements		10.4	10.5	10.6	10.6	10.7	10.7	10.7	10.8	10.8	10.8	10.9	10.9
Land converted to Settlement	Grassland converted to Settlements	1.2	1.3	1.4	1.5	1.5	1.6	1.7	1.7	1.7	1.8	1.7	1.7
Other Land remaining Other Land		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Land converted to Other Land		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Total area		*1293.4*	*1293.5*	*1293.5*	*1293.6*	*1293.6*	*1289.2*	*1289.0*	*1289.2*	*1289.5*	*1289.6*	*1289.3*	*1290.5*

Total land areas for reported OTs and CDs: Isle of Man = 57.20 kha, Guernsey = 6.30 kha, Jersey = 11.96 kha, Falkland Islands = 1217.30 kha. The Caribbean Overseas Territories are not included in these areas: Bermuda = 5.5 kha, Cayman Islands = 26.6 kha, Montserrat = 10.2 kha

7.2 CATEGORY 5A – FOREST LAND

7.2.1 Description

Emissions sources	5A Forest Land: carbon stock change 5A Forest Land: 5(I) Direct N_2O emissions from N fertilisation of Forest Land 5A Forest Land:5(II) Non-CO_2 emissions from drainage of soils 5A Forest Land: 5(V) Biomass burning
Gases Reported	CO_2, CH_4, N_2O
Methods	T3 for carbon stock changes, T1 for other emissions
Emission Factors	Country-specific for T3 methods
Key Categories (Trends)	None identified
Key Categories (Level)	5A (CO_2)
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Reported under the relevant Sector 5 sub-categories at Tier 3
Completeness	No known omissions
Major improvements since last submission	Use of the CARBINE carbon accounting model for carbon stock change modelling. Inclusion of emissions from all forests older than 20 years in the Forest remaining Forest Land category – instead of just from post-1921 forests as was reported in previous submissions.

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

Forest Land includes carbon stock gains and losses and GHG emissions from forest management and overall is the biggest net sink in the UK. All UK forests are 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. Forest surveys have been intermittent in the UK and there is no network of permanent sample plots. Consequentially, estimates of carbon stock gains and losses for biomass and soils are modelled based on planting history and yield classes. The area of forest reported in 5.A.1 now includes all forest older than 20 years. In previous inventories only carbon stock changes from forests planted since 1921 were reported (when the first national survey of forests was undertaken), and all older forest was assumed to be in equilibrium. With the move to the more detailed CARBINE model (see below, and **Annex Section A 3.6.1**) the planting year of all pre-1921 forest has been estimated and hence carbon stock change from all forests is modelled. The forest area and carbon stock changes in 5.A.1 take account of losses of forest land converted to other categories and the associated carbon stock changes and emissions and removals are then estimated and reported under the category concerned, with data on mineral and organic soils reported separately.

In the UK nitrogen fertilisers 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 fertilisation is assumed for areas of Settlements converted to Forest Land and Grassland converted to Forest Land on organic soils. N_2O emissions from this fertilisation are reported under 5.A.2 in Table 5(I). Nitrogen fertilisers are not generally applied to native woodlands, mature forests or re-planted forests in the UK, so emissions of N_2O from N fertilisation of forests (Table 5(I)) for 5.A.1 are reported as Not Occurring.

Drainage of forest land occurs in UK forests planted on certain soils types. Emissions of non-CO_2 emissions from forest drainage are reported in Table 5(II).

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

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

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

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

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 to the LULUCF sector compilers. 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 Forestry Statistics publication.

The National Inventory of Woodland and Trees (NIWT) 1995-99 http://www.forestry.gov.uk/inventory provides 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 is 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. An initial digital woodland map was published in spring 2011. 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 field survey started in 2010 and should be completed in 2014. The core field survey sample has been reduced to around 0.5% of area. Interim results were used to produce reports estimating standing and 25 year production forecasts for softwood, and a preliminary report for hardwood. 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.

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

The definition of forest 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 downward 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 estimated 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 with the current definition. 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 area identified as woodland in both surveys 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 forestland used in LULUCF reporting is taken from the statistics published by the Forestry Commission (see also **Figure 7.4**).

7.2.4 Methodological Issues

In this inventory submission the carbon uptake by UK forests is calculated by a carbon accounting model, CARBINE (which has replaced the C-Flow model used in previous submissions).The overall carbon uptake is calculated 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 model is able to represent all of the introduced and native plantation and naturally-occurring species relevant to the UK, the different growth rates of forests and four broad classes of forest management (clear-fell with thinnings, clear-fell without thinnings, thinned but not clear-felled and no timber production). The forest carbon sub-model is further compartmentalised to represent fractions due to tree stems, branches, foliage, and roots. The method can be described as Tier 3, as defined in the Good Practice Guidance for LULUCF (IPCC 2006). The CARBINE 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 3.6** for biomass, dead organic matter and soil.

Other greenhouse gas emissions, including forest fertilisation, wildfires and estimates of N2O emissions from forest drainage, are estimated using Tier 1 or Tier 2 approaches, and are described in **Annex 3.6**.

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 3.6.13**). 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 (which was assumed to continue up to 2011 and is 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. Although this analysis was done for the C-Flow model, the functioning of CARBINE is a broadly similar model we assume that the results of an uncertainty analysis of these parameters would give broadly similar results. The main difference due to the switch to the CARBINE model is that there is a greater range of species, growth rates and possible management regimes giving a more

realistic representation of forestry in the UK. Future uncertainty analyses will include the CARBINE functioning and the revised forestry datasets.

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 inventory of trees pre-1920 is based on the National Woodland Inventory of Trees, which will have uncertainties inherent to assigning age to forest and sub-sampling of the population.

The new National Forest Inventory (NFI) field survey will provide better information on the errors due to sub-sampling of the population, but the results of a full cycle of measurement from this are not yet available.

Based on expert judgement, the wildfire activity data are estimated to have an uncertainty of 50% for 1990-2004 and 2010-2012 and 100% for 2005-2009, as these have been extrapolated. The IPCC default of 70% uncertainty is used for the emission factors.

In terms of time series consistency:

- For forest carbon stock changes, N fertilization of forests and non-CO_2 emissions from drainage, 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. From 1990 – 2004 all data originate from the state forestry agencies so there is good time series consistency during this period. Data have been extrapolated for 2005-2009. A newer and more complete data source is used from 2010 onwards, but this is consistent with the previous data sources.

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 7.10**. 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). Further work has been undertaken comparing the inventory as predicted by CARBINE to the inventory as predicted by C-Flow. A separate document will be produced confirming that the results of C-Flow and CARBINE for the same input data are very similar, and detailing the changes in assumptions that drive the changes in the inventory (CEH, 2014).

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, 2011), 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. For the specific purposes of this inventory the CARBINE soil model was parameterised to give similar results to the C-Flow soil model.

7.2.7 Category-Specific Recalculations

The reported overall net GHG sink in category 5A has increased by 11-42% (with an average of 21% over the 1990-2011 time series) from the 2011 inventory (**Figure 7.5**). This is due to the inclusion of carbon stock changes from pre-1921 forest and more detailed representation of the tree species, growth rates and management practices used in the UK, which all arise from the move to using the CARBINE model. In addition, the emissions from wildfires on Forest Land are now calculated using the data on biomass and dead organic matter carbon stocks calculated by CARBINE. Details of the magnitude of the changes and the justifications for each emissions source are given in **Table 7.3**.

Figure 7.5 5A Forest Land changes in net emissions between 2011 and 2012 inventories

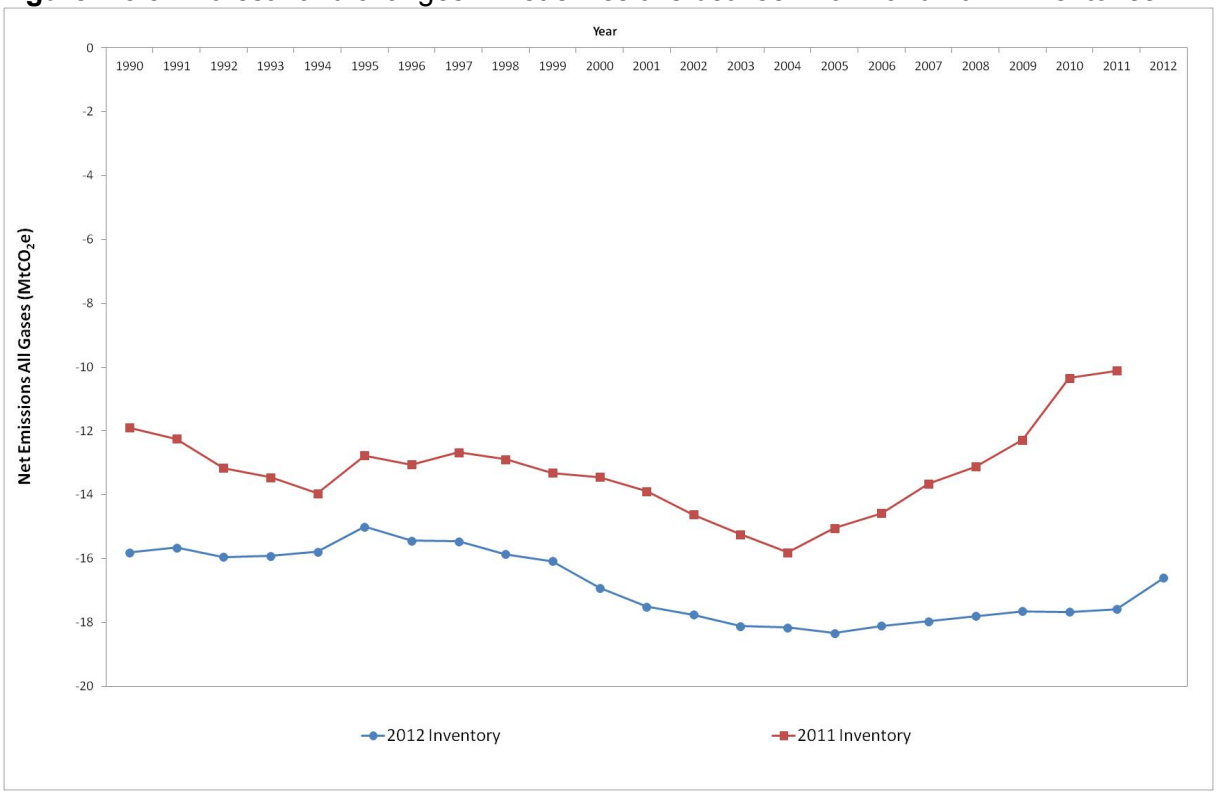


Table 7.3 5A Category specific recalculations to activity data since previous submission

IPCC Category	Source Name	2013 Submission 1990	2013 Submission 2011	2014 Submission 1990	2014 Submission 2011	Units	Comment/Justification
5A1	Carbon stock change in living biomass - gains	5667.09	9655.58	3433.48	5247.28	Gg C	Change to using the CARBINE carbon accounting model for forest modelling. Emissions are now estimated from all Forest remaining Forest Areas (not just post-1920 forest).
5A1	Carbon stock change in living biomass - losses	-4854.07	-8944.09	-1596.23	-2674.92	Gg C	Change to using the CARBINE carbon accounting model for forest modelling. Emissions are now estimated from all Forest remaining Forest Areas (not just post-1920 forest).
5A1	Net carbon stock change in dead organic matter	349.47	604.63	32.45	456.78	Gg C	Change to using the CARBINE carbon accounting model for forest modelling. Emissions are now estimated from all Forest remaining Forest Areas (not just post-1920 forest).
5A1	Net carbon stock change in mineral soils	500.85	632.70	880.85	780.62	Gg C	Change to using the CARBINE carbon accounting model for forest modelling. Emissions are now estimated from all Forest remaining Forest Areas (not just post-1920 forest).
5A1	Net carbon stock change in organic soils	69.95	127.11	262.41	436.80	Gg C	Change to using the CARBINE carbon accounting model for forest modelling. Emissions are now estimated from all Forest remaining Forest Areas (not just post-1920 forest).
5A1/5(II)	Non-CO2 emissions from drainage of soils	0.16	0.18	0.15	0.18	Gg N_2O	Total Forest remaining Forest area changed due to move to CARBINE model.
5A1/5(V)	Biomass burning - wildfires	227.35	364.82	156.74	198.57	Gg CO_2	Change to using the CARBINE carbon accounting model for forest modelling leading to updated biomass densities.
5A1/5(V)	Biomass burning - wildfires	0.20	0.33	0.15	0.19	Gg CH_4	Change to using the CARBINE carbon accounting model for forest modelling leading to updated biomass densities.
5A1/5(V)	Biomass burning - wildfires	0.01	0.02	0.01	0.01	Gg N_2O	Change to using the CARBINE carbon accounting model for forest modelling leading to updated biomass densities.
5A2	Carbon stock change in living biomass - gains	3396.62	1600.36	624.03	263.99	Gg C	Change to using the CARBINE carbon accounting model for forest modelling and Land to Forest areas changed slightly due to update of new planting data with the move to the CARBINE model.

IPCC Category	Source Name	2013 Submission 1990	2013 Submission 2011	2014 Submission 1990	2014 Submission 2011	Units	Comment/Justification
5A2	Carbon stock change in living biomass - losses	-1724.83	-894.54	-19.76	-5.32	Gg C	Change to using the CARBINE carbon accounting model for forest modelling and Land to Forest areas changed slightly due to update of new planting data with the move to the CARBINE model.
5A2	Net carbon stock change in dead organic matter	73.74	26.37	26.61	9.68	Gg C	Change to using the CARBINE carbon accounting model for forest modelling and Land to Forest areas changed slightly due to update of new planting data with the move to the CARBINE model.
5A2	Net carbon stock change in mineral soils	-109.83	56.60	415.76	290.53	Gg C	Change to using the CARBINE carbon accounting model for forest modelling and Land to Forest areas changed slightly due to update of new planting data with the move to the CARBINE model.
5A2	Net carbon stock change in organic soils	-43.82	11.78	309.67	59.05	Gg C	Change to using the CARBINE carbon accounting model for forest modelling and Land to Forest areas changed slightly due to update of new planting data with the move to the CARBINE model.
5A2/5(I)	Direct N2O emissions from N fertilization of Forest Land	0.02	0.00*	0.02	0.00*	Gg N_2O	Land to Forest areas changed slightly due to update of new planting data with the move to the CARBINE model.

* Due to the number of decimal places presented in this table, these values appear as zero rather than their true value which would require reporting with a much greater degree of accuracy.

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.

7.3 CATEGORY 5B – CROPLAND

7.3.1 Description

Emissions sources	5B Cropland: carbon stock change 5B Cropland:5(III) N_2O emissions from disturbance associated with LUC to Cropland 5B Cropland:5(IV) CO_2 emissions from agricultural lime application 5B Cropland:5(V) Biomass burning
Gases Reported	CO_2, CH_4, N_2O
Methods	T3 for carbon stock changes, T1 for other emissions
Emission Factors	Country-specific for T3 methods
Key Categories (Trends)	None identified
Key Categories (Level)	5B (CO_2)
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Reported under the relevant Sector 5 sub-categories at Tier 1
Completeness	No known omissions- areas are reported for land uses with no associated emissions.
Major improvements since last submission	Inclusion of by-products from sugar production for soil liming in 5B Cropland. Recalculation of timeseries for the Overseas Territories and Crown Dependencies.

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.

Ongoing 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 Cropland remaining Cropland, along with (i) biomass carbon stock changes from yield improvements and (ii) organic soil carbon emissions from fenland drainage.

Carbon stock change from yield improvements is the annual increase in the biomass of cropland vegetation in the UK due to yield improvements (from improved species strains or management, rather than fertilization or nitrogen deposition). The annual increase is assumed to remain constant and is the average annual increase in yield between 1980 and 2000 (Sylvester-Bradley *et al*. 2002).

Carbon stock changes from fenland drainage arise because fenland areas of England were drained many decades ago for agriculture which allowed oxygen into previously water logged soils. As a result, soil carbon in these areas continues to oxidise and be released as CO_2, resuting in 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 Land converted to Cropland (biomass burning emissions occur in the same

year as the land use conversion, while loss of soil carbon occurs over a longer period). 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 soil 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 carbonate in limestone, chalk, dolomite and Limex applied 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. In the 1990-2012 inventory, data on the application of LimeX, a lime based by-product of sugar refining, was added following the 2012 UNFCCC Review. Full details of the LimeX method and activity data are given in **Annex 3.6.6.**

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. Emissions from wildfires on Cropland are included in the inventory although cropland wildfires are infrequent and emissions are small. Full details of the method and activity data are given in **Annex 3-6.**

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) and results are combined to give UK totals. The approaches used for representing land use areas in the inventory are described in **Section 7.1.1.**

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; an assessment of fenland drainage in England, and data on wildfires on agricultural land from Fire and Rescue service and satellite data.

The areas of Cropland receiving lime are estimated from the cropland (tillage + bare fallow) area[38] reported in the annual June Agricultural Census and the proportions of arable areas receiving lime reported in the British Survey of Fertiliser Practice (2012).

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

[38] This does not include uncropped arable land such as set-aside or agricultural land which is not in agricultural production (Good Agricultural and Environmental Condition (GAEC) Class 12).

From 2010 areas of wildfire on Cropland are taken from Fire and Rescue service data. Between 2001 and 2009 the area of wildfire on Cropland is calculated by using satellite data on the total area of wildfires in the UK which are apportioned to land use using the same ratios as found in the Fire and Rescue service data. Cropland wildfire areas prior to 2001 are extrapolated (see **Annex Section 3.6.5** for details).

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 Agriculture, Forestry and Other Land Use Guidance (IPCC 2006). 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 Forest land category instead: this will be rectified in future submissions, but is estimated to have a minor impact given the area of orchards in comparison to either the Cropland or Forestland categories. Post-1980, cropland is the sum of the Arable and Horticulture Broad Habitat types in the Countryside Survey. These have now been re-assigned to a single Broad Habitat class "Arable and horticulture" (Haines-Young *et al*. 2000, Appendix A), defined as:

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

7.3.4 Methodological Issues

Changes in biomass and soil carbon due to land use change are estimated using a land use matrix approach. A summary of data flows associated with the land use matrix is given in **Section 7.1.1**. 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. Detailed descriptions of the methods and emission factors used for the activities in this Category can be found in **Annex 3.6.2**.

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. In the model soil carbon stock changes follow an exponential path between initial and final land uses with the most rapid change in the early years after land use change. The carbon stocks for each land use category are calculated as averages for Scotland, England, Northern Ireland and Wales using 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 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. 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 administrations in the UK. The mean soil carbon flux for each region resulting from these imposed random choices is 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. Ongoing 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 3.6.2**.

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 up to 2012) (slightly higher than the previous assessment of 50%).

The uncertainty analysis (see **Annex 3.6.13**) 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 planned, which should constrain the high uncertainties associated with this.

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 activity 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) as the effects of drainage are highly uncertain.

Expert judgement estimates that the wildfire activity data have an uncertainty of 50% for 2010-2012 and 100% for 1990-2009, as these years have been extrapolated. The IPCC default of 70% uncertainty is used for the emission factors.

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 controlled 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.

- For emissions from wildfires, a new activity dataset became available for 2010 onwards. Burnt areas have been extrapolated back to 2001 based on remote sensing data, but between 1990 and 2001 there are no appropriate data to use for extrapolation.

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 7.10**.

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). A more recent study using Countryside Survey data (Reynolds *et al.* 2013) also found a decrease in soil carbon stocks under Cropland between 1978 and 2007. However neither study includes data on the full previous land use and management at a given site, and therefore it is not possible to establish whether these trends are being driven by carbon loss following land use change to Cropland, changes in land management or is a response to environmental change.

7.3.7 Category-Specific Recalculations

The main change between the 1990-2011 inventory and the 1990-2012 inventory is the inclusion of emissions from liming using Limex, which has given a small increase in emissions (**Figure 7.6**). Other small changes in emissions are described in**Table 7.4**.

Figure 7.6 5B Cropland change in net emissions between the 1990-2011 and 1990-2012 inventories

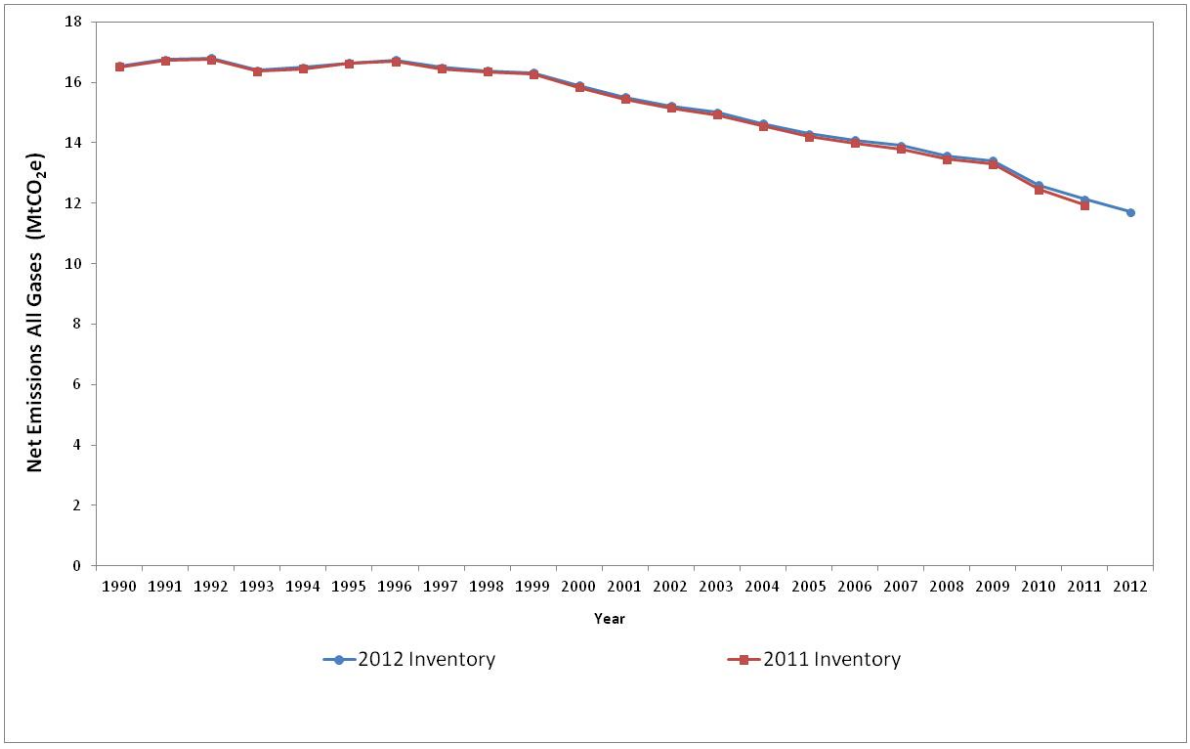


Table 7.4 5B Category specific recalculations to activity data since previous submission

IPCC Category	Source Name	2013 Submission 1990	2013 Submission 2011	2014 Submission 1990	2014 Submission 2011	Units	Comment/Justification
5B1	Net carbon stock change in organic soils	-0.73	-0.20	-0.73	-0.31	Gg C	Improved methodology for estimating Grassland and Other land areas for Jersey, the Isle of Man and the Falklands Islands, affecting conversions to and from these land uses from 2005 onwards.
5B1/5(IV)	CO2 emissions from agricultural lime application	831.72	483.16	863.16	590.19	Gg C	Inclusion of LimeX data (limestone by-products from sugar refinery applied to soils). Minor amendment to the volume of limestone sold for liming. Update to the Jersey 2011 cropland area.
5B1/5(V)	Biomass burning - wildfires	0.00*	0.00*	0.00*	0.00*	Gg CH_4	Update to IRS activity data for 2010 onwards, affects hindcasting of wildfire areas from 1990-2009.
5B1/5(V)	Biomass burning - wildfires	0.00*	0.00*	0.00*	0.00*	Gg N_2O	Update to IRS activity data for 2010 onwards, affects hindcasting of wildfire areas from 1990-2009.
5B2.1	Carbon stock change in living biomass - losses	-0.43	-1.04	-0.30	-0.89	Gg C	Change to using the CARBINE carbon accounting model for forest modelling.
5B2.1	Net carbon stock change in dead organic matter	-0.05	-0.14	-0.06	-0.18	Gg C	Change to using the CARBINE carbon accounting model for forest modelling.
5B2.2	Carbon stock change in living biomass - losses	-0.04	-1.22	-0.04	-1.18	Gg C	Improved methodology for estimating Grassland and Other land areas for Jersey, the Isle of Man and the Falklands Islands, affecting conversions to and from these land uses from 2005 onwards.
5B2.2	Net carbon stock change in mineral soils	-0.19	-6.08	-0.19	-6.13	Gg C	Improved methodology for estimating Grassland and Other land areas for Jersey, the Isle of Man and the Falklands Islands, affecting conversions to and from these land uses from 2005 onwards.
5B2.2/5(III)	N2O emissions from disturbance associated with land-use conversion to cropland	2.48	1.67	2.48	1.93	Gg N_2O	Improved methodology for estimating Grassland and Other land areas for Jersey, the Isle of Man and the Falklands Islands, affecting conversions to and from these land uses from 2005 onwards. Improved accuracy at the calculation stage.
5B2.1/5(V)	Biomass burning - controlled burning	1.07	2.60	0.80	2.36	Gg C	Change to using the CARBINE carbon accounting model for forest modelling leading to updated biomass densities.

IPCC Category	Source Name	2013 Submission 1990	2013 Submission 2011	2014 Submission 1990	2014 Submission 2011	Units	Comment/Justification
5B2.1/5(V)	Biomass burning - controlled burning	0.00*	0.01	0.00*	0.01	Gg CH_4	Change to using the CARBINE carbon accounting model for forest modelling leading to updated biomass densities.
5B2.1/5(V)	Biomass burning - controlled burning	0.00*	0.00*	0.00*	0.00*	Gg N_2O	Change to using the CARBINE carbon accounting model for forest modelling leading to updated biomass densities.

* Due to the number of decimal places presented in this table, these values appear as zero rather than their true value which would require reporting with a much greater degree of accuracy.

7.3.8 Category-Specific Planned Improvements

An inventory development project (SP1113), with a focus on soil carbon the impacts of cropland and grassland management on soil carbon, has been funded by the UK's Department of Environment, Food and Rural Affairs. The key objectives of the project are:

- The development of an operational framework for reporting soil carbon stock changes from agricultural Cropland and Grassland management;
- The compilation of appropriate activity data for reporting at Tier 1 and/or Tier 2 levels;
- The integration of research on the impacts of land management on soil carbon stock change into a comprehensive "database" that will allow the elucidation of country-specific emission factors for the key land management activities in the UK; and
- The extension of estimates of soil carbon stock change into the future, in order to investigate the impact of policies, both for mitigation and other ambitions, such as energy/food security and the maintenance of biodiversity.

The methodologies will be compatible with the current LULUCF inventory reporting system, and will be integrated into annual inventory reporting after the project completion (May 2014). A range of Business As Usual and mitigation scenarios will be developed to investigate the potential for climate change mitigation from cropland and grassland management to 2020 and 2050. These will be applied using the methodology already developed for the 1990-2010 reporting and by Tier 3 ensemble modelling, and the results will be assessed for the mitigation potential and interacting impacts in different regions of the UK.

The project will also use European Commission Integrated Administration and Control System (IACS) data to provide a more accurate assessment of Grassland/Cropland rotation lengths for each UK administration.

The results of the project will be used to improve the LULUCF inventory reporting and projections. This will better reflect the impacts of land management on GHG emissions and removals, enabling the analysis of the impact of specific policies in this area and progress in achieving climate change mitigation targets.

A planned follow-up to this project will investigate the effect of management practices on above and below biomass carbon stocks in Cropland and Grassland. While inventory reporting guidance excludes carbon stores in annual crops, carbon stocks in perennial crops such as orchards and soft fruit will be examined as well as perennial biomass crops such as short rotation coppice and miscanthus.

7.4 CATEGORY 5C – GRASSLAND

7.4.1 Description

Emissions sources	5C Grassland: carbon stock change 5C Grassland: CO_2 emissions from agricultural lime application 5C Grassland: 5(V) Biomass burning
Gases Reported	CO_2, CH_4, N_2O
Methods	T3 for carbon stock changes, T1 for other emissions
Emission Factors	Country-specific for T3 methods
Key Categories (Trends)	None identified
Key Categories (Level)	5C (CO_2)
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Reported under the relevant Sector 5 sub-categories at Tier 1
Completeness	No known omissions- areas are reported for land uses with no associated emissions.
Major improvements since last submission	Inclusion of by-products from sugar production for soil liming in 5C Grassland. Recalculation of timeseries for the Overseas Territories and Crown Dependencies. Increase in the Forest to Grassland areas from 2000 onwards.

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.

Ongoing 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 Grassland remaining Grassland. The area of undisturbed grassland (8,561.48 kha in 2011) 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 and biomass burning emissions due to the conversion of other land categories to Grassland in the 20 years before the inventory reporting year are reported under 5.C.2 Land converted to Grassland (biomass burning 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 carbon dioxide from carbonate in limestone, chalk, dolomite and LimeX applied 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. In the 1990-2012 inventory, data on the application of LimeX, a lime based by-product of sugar refining, was added following 2012 UNFCCC Review. Full details of the LimeX method and activity data are given in **Annex 3.6.6.**

Emissions of CO_2, CH_4 and N_2O from the burning of forest biomass when Forest Land is converted to Grassland and emissions from wildfires on Grassland are reported under Table 5(V). Full details of the methods and activity data are given in **Annex 3.6.4** and **Annex 3.6.5**.

The data reported for the UK in Sectoral Table 5 in the Information item "Grassland 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 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) and results are combined to give UK totals. The approaches used for representing land use areas in the inventory are described in **Section 7.1.1.**

Data sources that contain area information for reporting carbon stock changes and/or emissions from Grassland are habitat/landscape surveys; Forestry Commission data on unconditional felling licences; published statistics on agricultural lime and land use; and data on wildfires on agricultural land from Fire and Rescue service and satellite data.

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 are available). Details are given in **Annex 3.6.4**.

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 (2012). It is assumed that no lime is applied to unimproved rough grazing.

From 2010 areas of wildfire on Grassland are taken from Fire and Rescue service data. Between 2001 and 2009 the area of wildfire on Grassland is calculated by using satellite data on the total area of wildfires in the UK which are apportioned to land use using the same ratios as found in the Fire and Rescue service data. Grassland wildfire areas prior to 2001 are extrapolated.

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 Agriculture, Forestry and Other Land Uses guidance (IPCC 2006). 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

Changes in biomass and soil carbon due to land use change are estimated using a land use matrix approach. A summary of data flows associated with the land use matrix is given in **Section 7.1.1**. 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 3.6.2**.

The dynamic model of soil carbon stock change is described in **Section 7.3.4**.

7.4.5 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. 5C Grassland was estimated to have an uncertainty of 52% for net emissions in 1990 and 2009 (assumed to continue to 2012) (slightly lower than the previous assessment of 55%).

The uncertainty analysis (see **Annex 3.6.13**) 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 planned, which should constrain the high uncertainties associated with this.

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. This also follows for the new inclusion of by-products from sugar production for soil liming.

The wildfire activity data are estimated to have an uncertainty of 50% for 2010-2012 and 100% for 1990-2009, as these years have been extrapolated. The IPCC default of 70% uncertainty is used for the emission factors.

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 controlled 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
- For emissions from wildfires, a new activity dataset became available for 2010 onwards. Burnt areas have been extrapolated back to 2001 based on remote sensing data, but between 1990 and 2001 there are no appropriate data to use for extrapolation.

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 7.10**.

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). A more recent study using Countryside Survey (CS) data (Reynolds *et al.* 2013) also found no significant change in soil carbon stocks under most Grassland habitat types between 1978 and 2007, although soil carbon stocks under bracken increased. The reason for the different results obtained by NSI and CS is not clear, although there are methodological differences between the two surveys.

7.4.7 Category-Specific Recalculations

The Grassland sink estimates for the years 2000 – 2011 is lower in the 1990-2012 inventory compared than in the 1990-2011 inventory because of updated areas of land deforested to Grassland during this period. Inclusion of emissions from use of Limex in all inventory years has also reduced the net sink from Grassland for all years. These increases in estimated emissions have been partly offset by increased reported removals due improved assessment of the Grassland area in some OTs and CDs and by improved modelling of biomass and dead organic matter carbon stocks of land which is deforested to Grassland from the CARBINE model. Full details of changes leading to recalculations are given in **Table 7.6**.

Figure 7.7 5C Grassland change in net emissions between the 1990-2011 and 1990-2012 inventories.

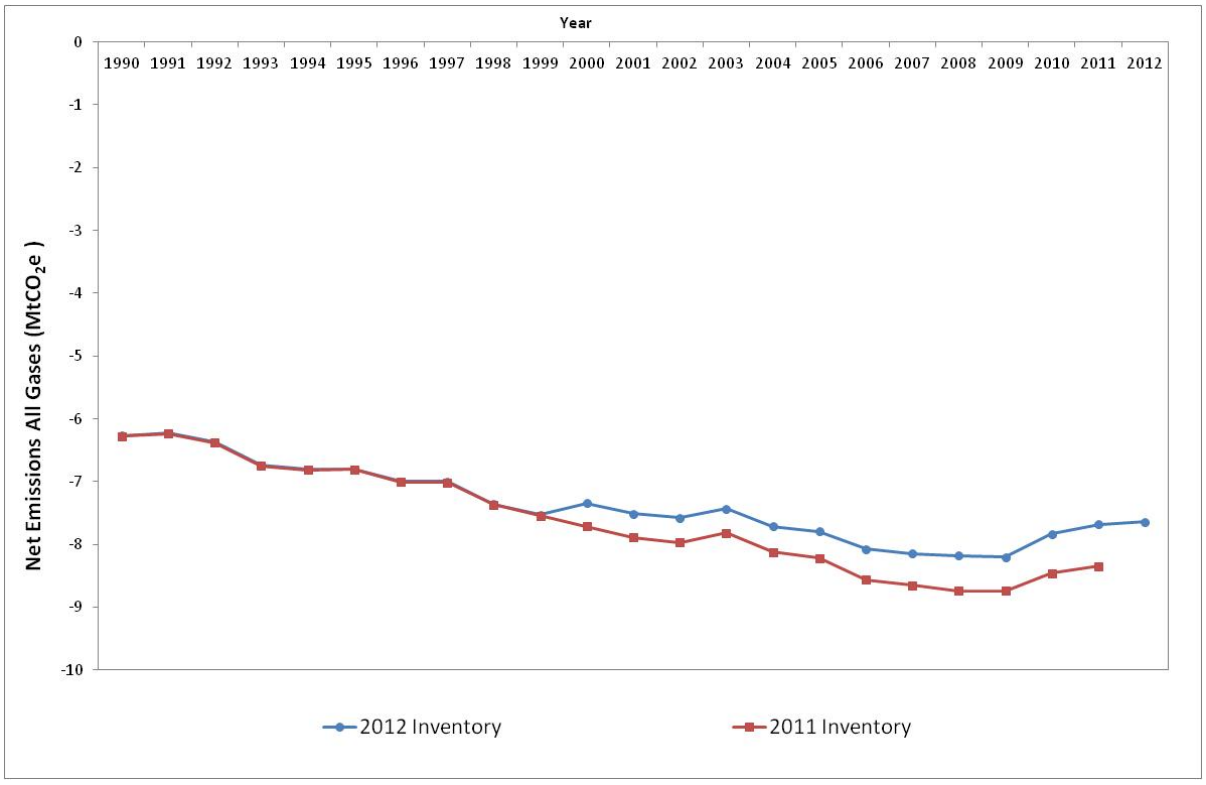


Table 7.6 5C Category specific recalculations to activity data since previous submission

IPCC Category	Source Name	2013 Submission 1990	2013 Submission 2011	2014 Submission 1990	2014 Submission 2011	Units	Comment/Justification
5C1/5(IV)	CO2 emissions from agricultural lime application	686.08	323.72	714.93	443.04	Gg C	Inclusion of LimeX data (limestone by-products from sugar refinery applied to soils). Minor amendment to the volume of limestone and dolomite sold for liming.
5C1/5(V)	Biomass burning - wildfires	0.50	0.33	0.50	0.37	Gg CH_4	Amendment of grassland / heathland split.
5C1/5(V)	Biomass burning - wildfires	0.05	0.03	0.05	0.03	Gg N_2O	Amendment of grassland / heathland split.
5C2.1	Carbon stock change in living biomass - losses	-11.20	-31.20	-7.79	-107.15	Gg C	Change to using the CARBINE carbon accounting model for forest modelling. Update to the deforestation to grassland areas (2000-2011 only).
5C2.1	Net carbon stock change in dead organic matter	-1.24	-4.00	-1.43	-17.22	Gg C	Change to using the CARBINE carbon accounting model for forest modelling. Update to the deforestation to grassland areas (2000-2011 only).
5C2.2	Carbon stock change in living biomass - losses	-0.85	-8.02	-0.72	-1.96	Gg C	Improved methodology for estimating Grassland and Other land areas for Jersey, the Isle of Man and the Falklands Islands, affecting conversions to and from these land uses.
5C2.2	Net carbon stock change in mineral soils	4.41	40.37	3.77	9.60	Gg C	Improved methodology for estimating Grassland and Other land areas for Jersey, the Isle of Man and the Falklands Islands, affecting conversions to and from these land uses.
5C2.2	Net carbon stock change in organic soils	NO	-0.13	NO	-0.06	Gg C	Improved methodology for estimating Grassland and Other land areas for the Falklands islands affecting conversions from these land uses from 2009 onwards.
5C2.1/5(V)	Biomass burning - controlled burning	27.35	77.44	20.29	273.60	Gg C	Change to using the CARBINE carbon accounting model for forest modelling leading to updated biomass densities. Update to the deforestation to grassland areas (2000-2011 only).
5C2.1/5(V)	Biomass burning - controlled	0.12	0.34	0.09	1.19	Gg CH_4	Change to using the CARBINE carbon accounting

IPCC Category	Source Name	2013 Submission 1990	2013 Submission 2011	2014 Submission 1990	2014 Submission 2011	Units	Comment/Justification
	burning						model for forest modelling leading to updated biomass densities. Update to the deforestation to grassland areas (2000-2011 only).
5C2.1/5(V)	Biomass burning - controlled burning	0.00*	0.00*	0.00*	0.01	Gg N2O	Change to using the CARBINE carbon accounting model for forest modelling leading to updated biomass densities. Update to the deforestation to grassland areas (2000-2011 only).

* Due to the number of decimal places presented in this table, these values appear as zero rather than their true value which would require reporting with a much greater degree of accuracy.

7.4.8 Category-Specific Planned Improvements

An inventory development project (SP1113), with a focus on soil carbon the impacts of cropland and grassland management on soil carbon, has been funded by the UK's Department of Environment, Food and Rural Affairs. The key objectives and details of the project are described in **Section 7.3.8**.

The project will also use IACS data to provide a more accurate assessment of Grassland/Cropland churn for each UK administration.

An extension to the project will investigate the effect of management practices on above and below biomass carbon stocks in Cropland and Grassland including dwarf shrub heath such as heather moorland

Further adjustments to the deforestation activity dataset will be made once finalised estimates of Forest 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. This may affect the grassland estimates as the majority of land use change arising from deforestation is conversion of forestland to grassland.

The IPCC Wetlands Supplement (2013) gives more detailed guidance than was previously available on how emissions from Wetlands should be considered in national inventories. The UK will be commissioning research to ensure that reporting in the LULUCF inventory reflects this new guidance. This may mean that some activity on peatland which is currently reported under Grassland is transferred to the Wetland section of the inventory in future.

7.5 CATEGORY 5D – WETLANDS

7.5.1 Description

Emissions sources	5D Wetlands: Carbon stock change 5D Wetlands: 5(II) Non-CO_2 emissions from drainage of soils
Gases Reported	CO_2, N_2O
Methods	Tier 1
Emission Factors	Country specific and default EFs
Key Categories (Trends)	None identified
Key Categories (Level)	None identified
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Not occurring
Completeness	No known omissions- areas are reported for land uses with no associated emissions.
Major improvements since last submission	None

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. The IPCC 2006 Guidelines define 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). The coverage of the 2013 Wetlands Supplement updates emission factors and includes inland organic soils and wetlands on mineral soils, coastal wetlands including mangrove forests, tidal marshes and seagrass meadows, and constructed wetlands for wastewater treatment.

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. A small area of grassland converted to Wetland is included under 5.D.2 Land converted to Wetlands, with the associated soil emissions estimated using the Tier 1 methodology. 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. There is no known commercial peat extraction data available for the Overseas Territories or Crown Dependencies.

The area of inland water (164.05 kha) is reported in this category but no anthropogenic 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

For Wetlands, the approach differs from that used for other land use categories, because 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) supplied the set of Great Britain peat extraction site records from the Directory of Mines and Quarries (Cameron et al. 2013 data - personal communication): 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. For the 1990-2012 inventory the Google imagery was checked for updates against the 2013 data supplied by BGS. The Google imagery for extraction sites reporting changes since 2010 was found to be from approximately 2010, the same age as at previous assessment.
- 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 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 extraction are clearly visible on aerial/satellite imagery (**Figure 7.8**). It appears 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 (as some areas may not actually be undergoing extraction, or the photographs may not be up-to-date).

Figure 7.8 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 or satellite photographs or by field visits. Peat extraction for domestic use occurs in Northern Ireland and Scotland. 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 not so far for Scotland.

The area of inland water is taken from the "UK Standard Area Measurements" (Office for National Statistics 2011). 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 using the Tier 1 methodology, which does not distinguish between peat extraction production phases (i.e. it includes conversion and vegetation clearing). On-site emissions associated with peat extraction are reported under 5.D.1 Wetlands remaining Wetlands. All carbon in horticultural peat is assumed to be emitted 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 3.6.10**.

The site records show that the area under active peat extraction diminished between 1990 and 2002 for Great Britain and 1991 and 2007 for Northern Ireland. Some areas show no change on the Google Earth imagery, and are assumed to be abandoned extraction sites that are still producing emissions (reported under 5D1). Sites in Northern Ireland and sites in Great Britain where extraction is no longer visible on the Google Earth imagery are assumed to have been converted to Grassland. Changes in biomass carbon and organic soil carbon from this land use change are reported using the Tier 1 approach from the IPCC 2006 Guidelines.

A small area of land conversion to Wetlands occurs between 2003 and 2005, which is assumed to be all from Grassland (based on the examination of Google Earth imagery). This area and the associated on-site emissions are reported under 5D.2 Land converted to Wetlands, using the 5 year transition period recommended by the IPCC 2006 Guidelines.

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.

Time series consistency for activity data is affected by uncertainty in survey dates.

7.5.6 Category-Specific QA/QC and Verification

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

There has been no change in the overall net GHG source in category 5D between 1990 and 2010 (**Figure 7.9**). The activity data for 2010-2011 was updated with the latest published information on peat volume sales (Office for National Statistics 2013a). Volumes for 2012

were assumed to be equal to those in 2011. The changes in emissions are shown in **Table 7.7**.

Figure 7.9 5D Wetlands change in net emissions between 2011 and 2012 inventory

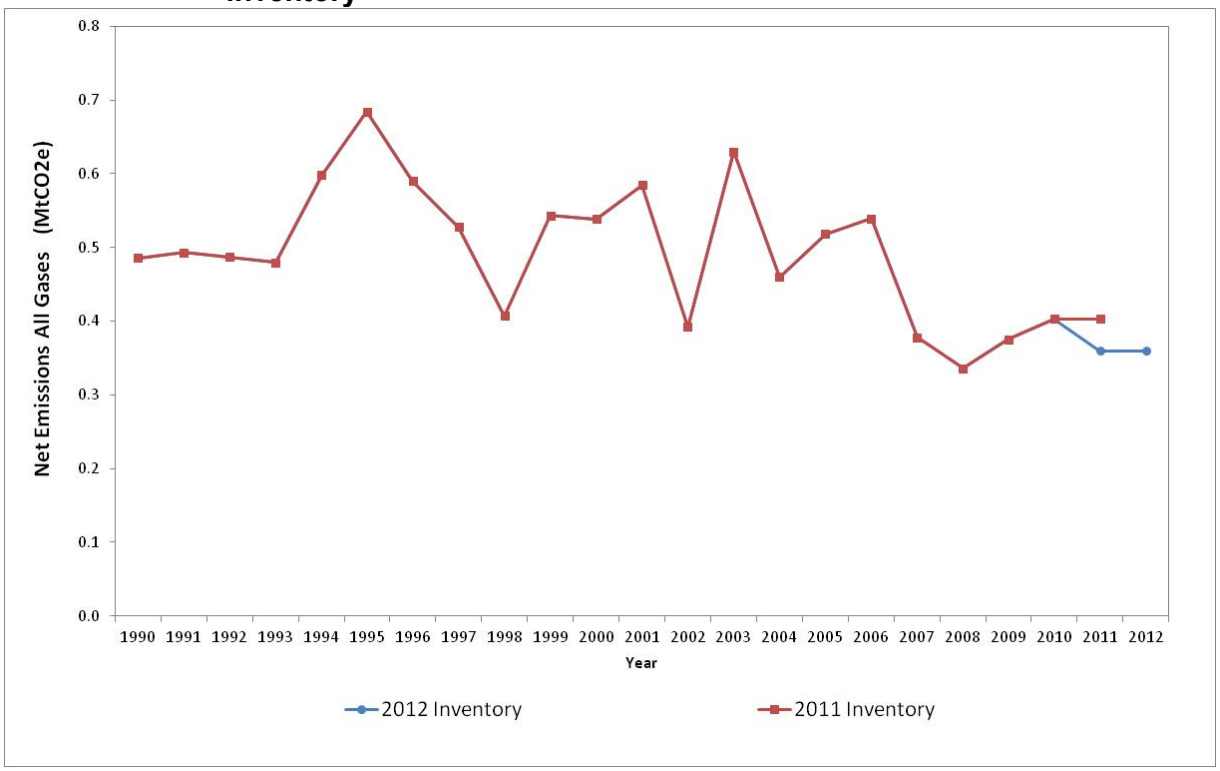


Table 7.7 5D Category specific recalculations to activity data since previous submission

IPCC Category	Source Name	2013 Submission 1990	2013 Submission 2011	2014 Submission 1990	2014 Submission 2011	Units	Comment/Justification
5D1	Net carbon stock change in soils	-90.39	-63.01	-90.39	-51.15	Gg C	Correct 2011 activity data for horticultural peat extraction now available.

7.5.1 Category-specific planned improvements

None planned, but this category will be re-examined for the 1990-2013 inventory in line with the 2013 IPCC Wetlands Supplement.

7.6 CATEGORY 5E – SETTLEMENTS

7.6.1 Description

Emissions sources	5E Settlements: Carbon stock change 5E Settlements: 5(V) Biomass burning
Gases Reported	CO_2, CH_4, N_2O
Methods	T3 for carbon stock changes, T1 for other emissions
Emission Factors	Country-specific for T3 methods
Key Categories (Trends)	5E (CO_2)
Key Categories (Level)	5E (CO_2)
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Reported under the relevant Sector 5 sub-categories at Tier 1
Completeness	No known omissions- areas are reported for land uses with no associated emissions.
Major improvements since last submission	Recalculation of timeseries for the Overseas Territories and Crown Dependencies. New activity data for wildfires.

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.

Ongoing 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 Settlement remaining Settlement. 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 (biomass burning 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 7.1.1.**

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). This information is obtained 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 3.6**.

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 Agriculture, Forestry and Other Land Use Guidance (IPCC 2006). For pre-1980 land use matrices Settlement land is the sum of the Built-up, Urban open, Transport, Mineral workings and Derelict land cover types in the Monitoring Landscape Change project (MLC 1986). Post-1980, Settlement land corresponds to the "Built-up and Gardens" and "Boundary and linear features" Broad Habitat types in the Countryside Survey (Haines-Young *et al*. 2000, Appendix A), defined as:

Built-up and Gardens: "Covers urban and rural settlements, farm buildings, caravan parks and other man-made built structures such as industrial estates, retail parks, waste and derelict ground, urban parkland and urban transport infrastructure. It also includes domestic gardens and allotments."

Boundary and linear features: "a diverse range of linearly arranged landscape features such as hedgerows, walls, stone and earth banks, grass strips and dry ditches. This habitat type also includes some of the built components of the rural landscape including roads, tracks and railways and their associated narrow verges of semi-natural habitat."

Some components of the "Boundary and linear features" Broad Habitat type could fall under the definition of Cropland or Grassland. It is not possible to disaggregate this Broad Habitat further and the assignment to a single land use category avoids double-counting. In the latest 2007 Countryside Survey the "Boundary and linear features" Broad Habitat type covered 2% of the UK land area.

7.6.4 Methodological Issues

A summary of the land use matrix approach used to estimate changes in biomass and soil carbon due to land use change is given in **Section 7.3.4**.

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 3.6.2**.

7.6.5 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. 5E Settlement was estimated to have an uncertainty of 52% for net emissions in 1990 and 2009 (assumed to continue to 2012) (slightly higher than the previous assessment of 50%).

The uncertainty analysis (see **Annex 3.6.13**) 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, which should constrain the high uncertainties associated with area, is ongoing and once verified, will be included in the 2015 submission.

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 7.10**. Research described in **Section 7.1.1** is also relevant to this section.

7.6.7 Category-Specific Recalculations

There has been a 1% increase in the size of the overall net GHG source in category 5E between the 2011 and the 2012 inventories (**Figure 7.10**). These arise in part from revised emissions estimates from land converted to Settlement from Forest land due to the change to use of CARBINE methodology. Other changes are due to improved methodology for the Overseas Territories and Crown Dependencies as described in **Section 7.9**. Changes in emissions are described in **Table 7.8**.

Figure 7.10 5E Settlements change in net emissions between 2011 and 2012 inventory

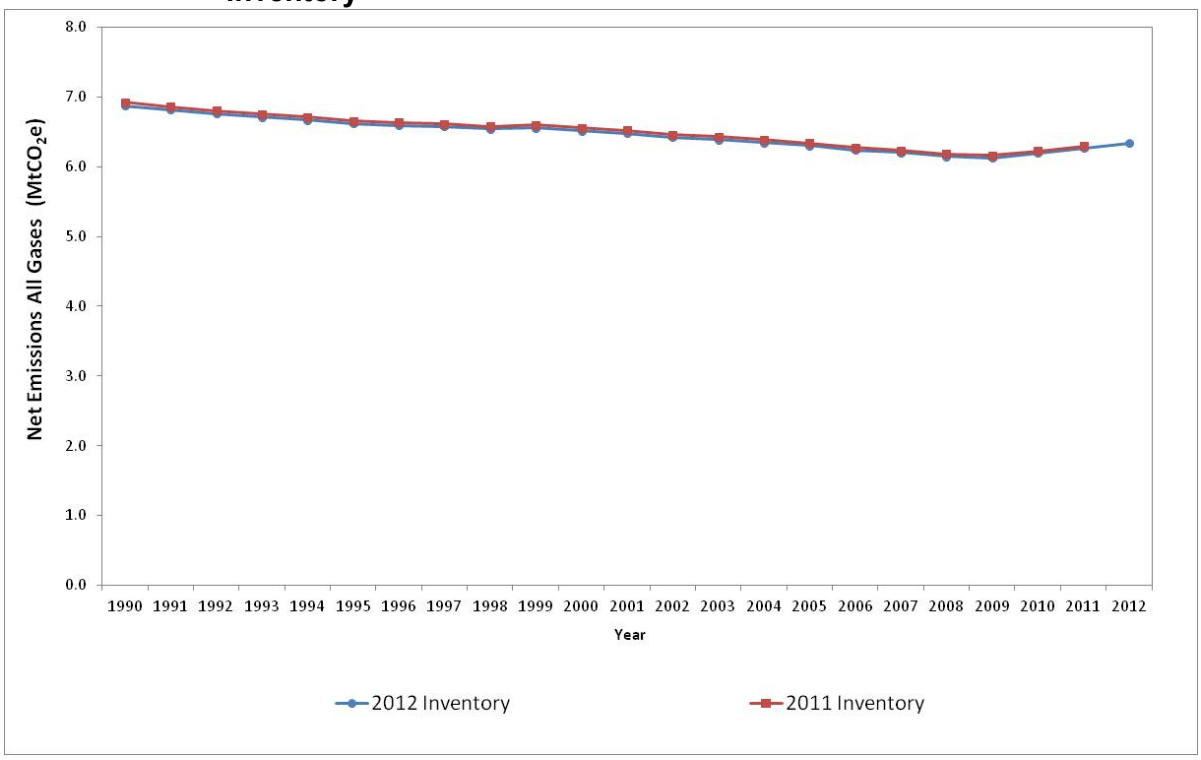


Table 7.8 5E Category specific recalculations to activity data since previous submission

IPCC Category	Source Name	2013 Submission 1990	2013 Submission 2011	2014 Submission 1990	2014 Submission 2011	Units	Comment/Justification
5E2.1	Carbon stock change in living biomass - losses	-29.61	-31.50	-20.57	-26.35	Gg C	Change to using the CARBINE carbon accounting model for forest modelling.
5E2.1	Net carbon stock change in dead organic matter	-3.34	-3.93	-3.96	-4.30	Gg C	Change to using the CARBINE carbon accounting model for forest modelling.
5E2.3	Carbon stock change in living biomass - losses	-0.80	-1.17	-0.80	-1.37	Gg C	Improved methodology for estimating Grassland and Other land areas for Jersey affecting conversions from these land uses. Removal of step change by linear interpolation for Grassland converted to Settlement in Jersey previously occurring in 2007-2008.
5E2.3	Net carbon stock change in soils	-6.66	-7.88	-6.66	-11.42	Gg C	Improved methodology for estimating Grassland and Other land areas for Jersey affecting conversions from these land uses. Removal of step change by linear interpolation for Grassland converted to Settlement in Jersey previously occurring in 2007-2008.
5E2.1/5(V)	Biomass burning - controlled burning	72.50	77.95	53.97	67.43	Gg C	Change to using the CARBINE carbon accounting model for forest modelling leading to updated biomass densities.
5E2.1/5(V)	Biomass burning - controlled burning	0.32	0.34	0.24	0.29	Gg CH_4	Change to using the CARBINE carbon accounting model for forest modelling leading to updated biomass densities.
5E2.1/5(V)	Biomass burning - controlled burning	0.00*	0.00*	0.00*	0.00*	Gg N_2O	Change to using the CARBINE carbon accounting model for forest modelling leading to updated biomass densities.

* Due to the number of decimal places presented in this table, these values appear as zero rather than their true value which would require reporting with a much greater degree of accuracy.

7.6.8 Category-Specific Planned Improvements

Further adjustments to the deforestation activity dataset including land converted from forest to settlement will be made once finalised estimates of Forest 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.

7.7 CATEGORY 5F – OTHER LAND

7.7.1 Description

Emissions sources	None
Gases Reported	None
Methods	N/A
Emission Factors	N/A
Key Categories (Trends)	None identified
Key Categories (Level)	None identified
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Areas reported under the relevant Sector 5 sub-categories at Tier 1
Completeness	No known omissions- areas are reported for land uses with no associated emissions.
Major improvements since last submission	Recalculation of timeseries for the Overseas Territories and Crown Dependencies.

No emissions or removals are reported in this category. It is assumed that there are very few areas of land of other types that become bare rock or water bodies, which make up the majority of this type. Therefore Table 5.F. (Other Land) is completed with 'NO' (Not Occurring).

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

The approaches used for representing land use areas in the inventory are described in **Section 7.1.1**.

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 7.9**). 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 7.9 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

Emissions sources	5G Other (Harvested Wood Products)
Gases Reported	CO_2
Methods	Tier 3
Emission Factors	Country-specific
Key Categories (Trends)	None identified
Key Categories (Level)	None identified
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Reported under the relevant Sector 5 sub-categories at Tier 3
Completeness	No known omissions
Major improvements since last submission	Use of the CARBINE carbon accounting model to calculate net changes in stocks of carbon in HWP. Inclusion of Harvested Wood Products from all forests older than 20 years – instead of just from post-1921 forests as was reported in previous submissions. Update to the deforestation areas from 2000 onwards.

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 3.6.11**. The carbon accounting model (CARBINE) 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, Cropland or Settlement) are estimated using CARBINE and all products are assumed to decay in the year of deforestation.

7.8.3 Uncertainties and Time-Series Consistency

The uncertainty analysis in the Annexes (**A 3.6.16**) 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 which is in line with the continued use of the 30% estimate. Although this analysis was based on the previously used CFlow model it is likely to apply to the CARBINE model as well.

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. The pre-1920 planting data was estimated from the age class structure from the National Inventory of Woodlands and Trees, which was used to estimate the forest statistics on total woodland area used in previous inventories.

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 7.10**. In conjunction with the switch to CARBINE, the timber production predicted has been compared to the national timber production statistics produced by the Forestry Commission based on data from sawmills.

7.8.5 Category-Specific Recalculations

The move to using the CARBINE model for estimating emissions from Harvested Wood Products has changed significantly the HWP time series, mainly because CARBINE can model a wide range of forest management cycles, take account of national timber production statistics and model four different end-use wood products. The previously-used CFlow model assumed a standard rotation for all conifer and broadleaf species and used only one decay curve to represent all end-uses. In addition, the fact that all forest (not just post-1921) is now modelled, and the deforestation time series has been updated for 2000 onwards, mean that the volume of biomass entering the HWP pool is changed. The combined effect of these changes on the time series can be seen in **Figure 7.11** and **Table 7.10**.

Figure 7.11 5G Other (Harvested Wood products) change in net emissions between 2011 and 2012 inventory

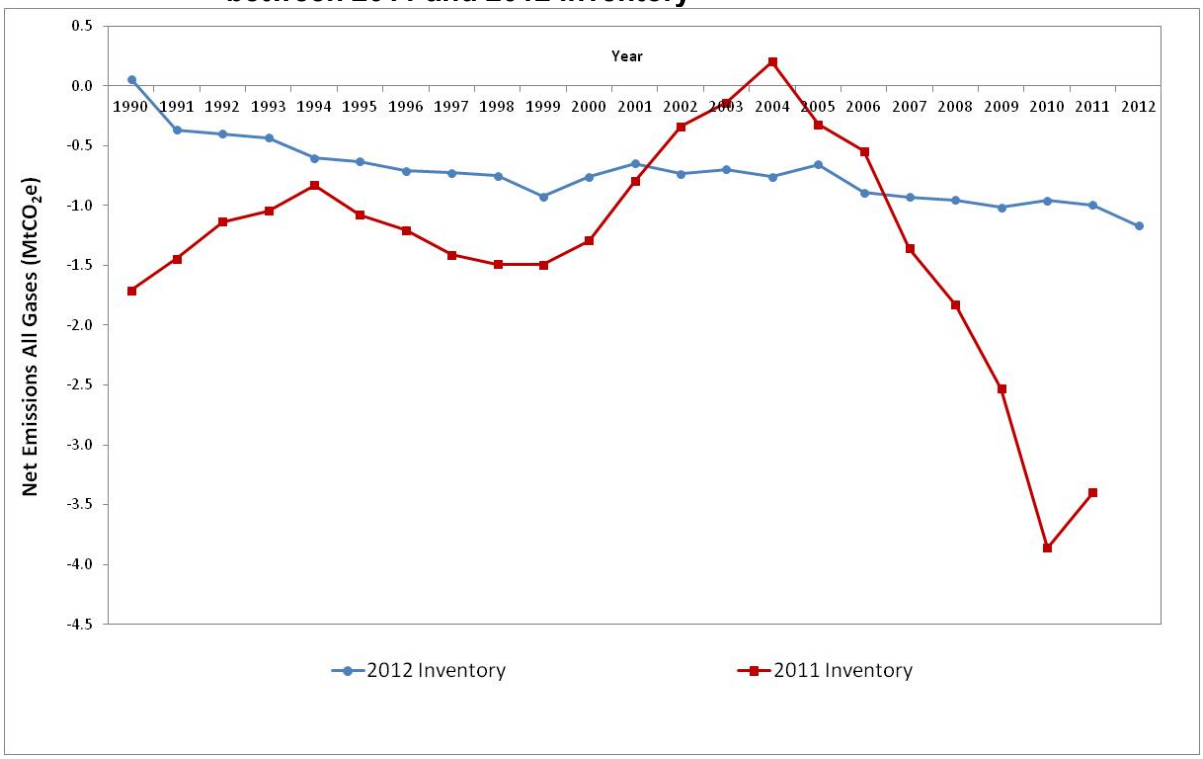


Table 7.10 5G Category specific recalculations to activity data since previous submission

IPCC Category	Source Name	2013 Submission 1990	2013 Submission 2011	2014 Submission 1990	2014 Submission 2011	Units	Comment/Justification
5G	Harvested Wood Products	-1710.68	-3401.78	59.16308	-997.119	Gg C	Change to using the CARBINE carbon accounting model for forest modelling including the modelling of Harvested Wood Products.

7.8.6 Category-Specific Planned Improvements

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.

In the next inventory the estimates and growth rates of trees in private sector forest will be improved based on information from the National Forest Inventory, rather than assumed to be the same as the public forest estate. The distribution of ages of forest will also be improved by using this information.

7.9 LULUCF EMISSIONS AND REMOVALS IN THE OVERSEAS TERRITORIES AND CROWN DEPENDENCIES

The UK includes direct GHG emissions in its GHG Inventory from UK CDs and OTs which have joined, or are likely to join, the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol. Currently, these are: Guernsey, Jersey, the Isle of Man, the Falkland Islands, the Cayman Islands, Bermuda, Montserrat and Gibraltar. The OTs and CDs were contacted for any updates in datasets in 2013 and a web search of statistical publications was undertaken. This work builds on an MSc project to calculate LULUCF net emissions/removals for the OTs and CDs (Ruddock 2007). Net emissions and removals from the OTs and CDs are reported under the relevant sub-categories of Sector 5. The estimates have high uncertainty and may not capture all relevant activities. **Annex 3.6.12** provides detailed descriptions of the methods and emission factors used.

Crown Dependencies

Emissions and removals have mostly been calculated at Tier 1, with a Tier 3 method for forestry in the Isle of Man and Guernsey.

Similar climate and land management parameters are assumed as for the UK. Land areas have been interpolated between land area surveys in some cases. More detailed activity data allowed a Tier 3 method to be applied for forestry in the Isle of Man and Guernsey.

There has been methodological improvement to the 1990-2012 inventory for Jersey and Isle of Man since the 1990-2011 inventory by using Grassland as a buffer. This is in line with UNFCCC Review recommendations applied in the 1990-2011 inventory to rest of the UK. In previous submissions, any land not categorised was reported as Other Land with no emissions occurring. According to the IPCC Guidelines (2006), Other Land should only contain bare rock or water bodies. Uncategorised land for the OTs and CDs is more probably rough grassland or scrub and should be classified as Grassland under the IPCC Guidelines (2006). Categorising this land as Other Land produced a decreasing trend of emissions, which was not representative of real trends. This issue was not present in the Guernsey timeseries, as data are based on decadal habitat survey data of the entire island. Trends for the other Crown Dependencies, now follow the same trend as Guernsey, a steady increase in emissions due primarily to land conversion to Settlement.

For Jersey, net emissions of GHGs from LULUCF now use updated activity data, and the Tier 1 methodology has been applied consistently. This results in a change in the emissions trend so that Jersey becomes a steadily increasing source to 0.014 Mt CO_2e in 2008 decreasing to 0.013 Mt CO_2e in 2012, due to conversion from Grassland to Settlement. **Annex 3.6.12** provides more details.

For the Isle of Man, net emissions of GHGs from LULUCF were updated using activity data rolled over from 1990-2011, because insufficient funding was available for an agricultural census in 2012. Tier 1 methodology (for non-forest land use) was applied consistently. Consequently there is a change in the emissions trend. In the 1990-2012 inventory the Isle of Man in 1995 becomes a steadily increasing source to 0.03 Mt CO_2e in 2008 decreasing to 0.02Mt CO_2e in 2012, due to conversion from Grassland to Settlement. **Annex 3.6.12** has additional details.

For Guernsey, net emissions of GHGs from LULUCF were updated for the 1990-2012 inventory, using activity data rolled over from the 2010 Habitat Survey, and ensuring the Tier 1 methodology was applied consistently. Carbon stock changes due to afforestation were also modelled using the Tier 3 CFlow model. The LULUCF sector in Guernsey is a small source, increasing from close to 0.0002 Mt CO_2e in 1999 to 0.006 Mt CO_2e in 2012, due to

conversion to Settlement and conversion to and liming of Cropland **Annex 3.6** has more details.

Overseas territories

Data were only available to estimate emissions from the Falklands.

Net emissions of GHGs from LULUCF were updated for the 1990 to 2012 inventory, using updated activity data from the Falkland Islands. The Tier 1 methodology was applied consistently. Overall there is very little land use change on the islands (93% of their area is natural Grassland), but there is some land conversion on organic soils and consequently the Falkland Islands are a small source.

There has been a methodological improvement to the 1990-2012 inventory for the Falklands since 1990-2011 inventory from using Other Land as a buffer to using Grassland as a buffer. This is in line with UNFCCC Review recommendations applied in the 1990-2011 inventory to rest of the UK. In previous submissions, any land not categorised that year was reported as Other Land with no emissions occurring. According to the IPCC Guidelines (2006), Other Land should only contain bare rock or water bodies. Uncategorised land for the OTs and CDs is more probably rough grassland or scrub and should be classified as Grassland under the IPCC Guidelines (2006). In the Falklands, this was further complicated by the agricultural census categorising non-farmed agricultural land as “Other Land”. These issues have led to a decreasing trend of emissions, which was not representative of real trends. Trends for the Falklands, now show a steady increase in emissions due primarily to land conversion to Settlement. This results in a change in the emissions trend from 1997, from 1990-2011 of 0.005 Mt CO2e in 2012 to 1990-2012 to 0.002 Mt CO_2e for 2012 (**Annex 3.6.12**).

7.10 GENERAL COMMENTS ON QA/QC

The Centre for Ecology and Hydrology (CEH) 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. CEH is currently in the process of applying for ISO9001, the internationally recognised standard for the quality management of businesses.

Forest Research 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.

A Microsoft Access 2007 database is now used to compile all the LULUCF inventory numbers and associated data. This database is used to produce consistent outputs for the CRF and other national and international reporting requirements, and for archiving purposes. The project maintains a publicly available website, http://ecosystemghg.ceh.ac.uk/ where the inventory reports and tables are made available. This website is currently undergoing redevelopment. The inventory data are 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.

In collaboration with Ricardo-AEA, CEH has been developing a new QA/QC plan to standardise and structure the way checks are carried out within the LULUCF sector. The majority of this plan is now implemented and will be fully implemented in the next submission. The QA/QC Plan will be embedded into all planning, preparation and management activities of the Inventory. The QA/QC plan will assign QA/QC priorities and to all stakeholders involved with the compilation and dissemination of data from the Inventory. Appropriate QA/QC responsibilities will be applied to data suppliers, where possible and appropriate through Data Supply Agreements; to subcontractors undertaking components of the inventory activities, as part of contractual arrangements and key performance indicators; and to all members of the project team at CEH, through its project key performance indicators, team and staff objectives and management activities.

The QA/QC plan will set out the key Data Quality Objectives (DQOs), covering all principles of Transparency, Consistency, Completeness, Comparability and Accuracy.

8 Waste (CRF Sector 6)

8.1 OVERVIEW OF SECTOR

IPCC Categories Included	6A: Solid Waste Disposal on Land 6B: Wastewater Handling 6C: Waste Incineration
Gases Reported	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
Key Categories (Trends)	Solid Waste Disposal – CH_4 Wastewater Handling – N_2O
Key Categories (Level)	Solid Waste Disposal – CH_4 Wastewater Handling – N_2O
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Emissions for 6A and 6B are included as a separate category within 6A and 6B respectively. Emissions from 6C are included within UK MSW incineration and the same EFs are applied.
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	

Emissions from the waste sector contributed 3.8% to greenhouse gas emission in 2012. 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 54.2% 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.

Figure 8.1 Breakdown of total GHG emissions from the Waste sector in 2012

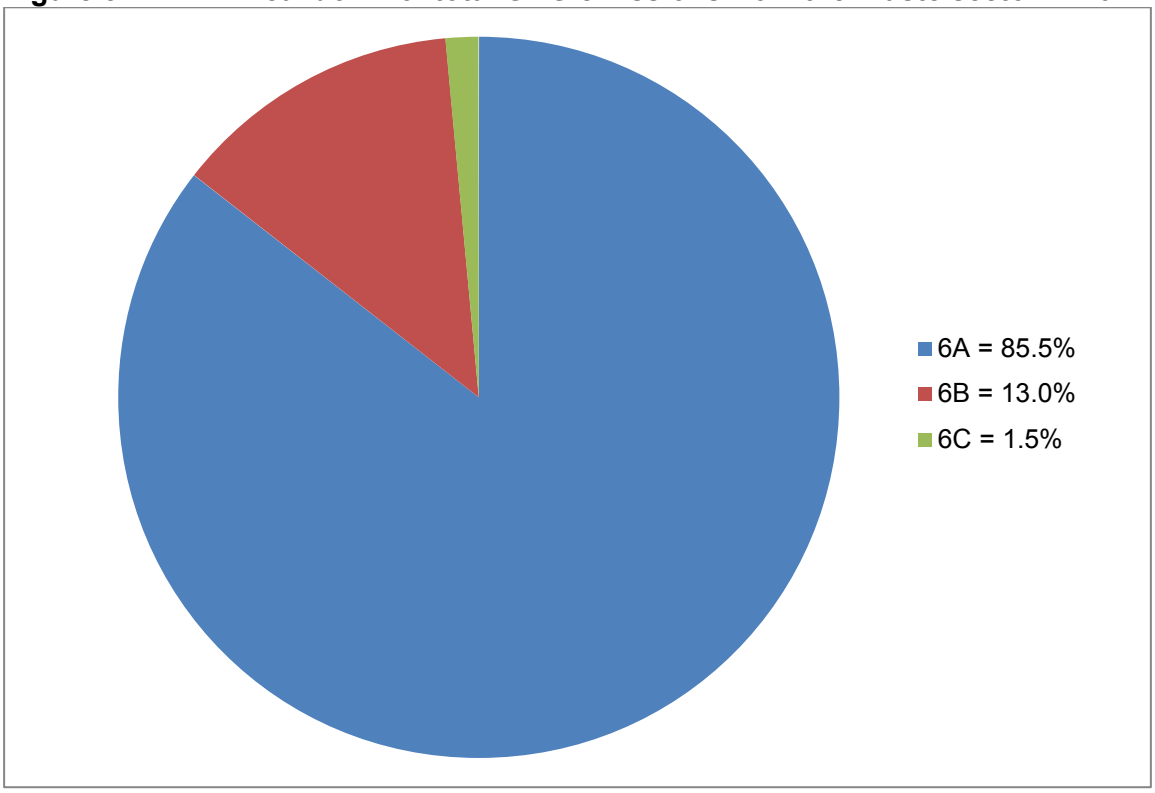
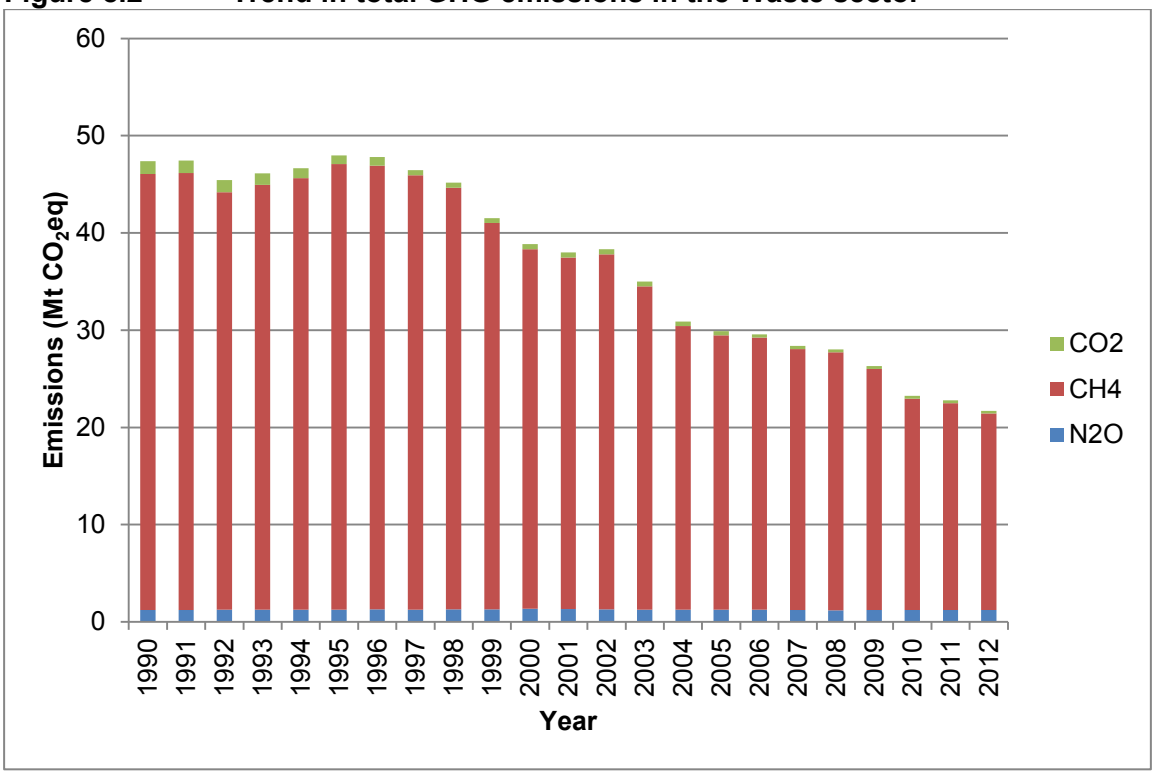


Figure 8.2 Trend in total GHG emissions in the Waste sector



8.2 SOURCE CATEGORY 6A – SOLID WASTE DISPOSAL ON LAND

8.2.1 Source category description

Emissions sources	Sources included	Method	Emission Factors
	6A: Landfill	OTH, T2	CS
Gases Reported	CH_4, NMVOC		
Key Categories (Trends)	Solid Waste Disposal – CH_4		
Key Categories (Level)	Solid Waste Disposal – CH_4		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Emissions for 6A are included as a separate category within 6A.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	None		

The NAEI category "Landfill" maps directly on to IPCC category 6A1 Landfills (managed waste disposal on land) for methane emissions. Emissions are reported from landfills that started receiving waste in 1980, when legislative changes took effect to improve management of landfill sites,and old unmanaged waste disposal sites that closed prior to 1980.

Estimated emissions from this sector in 2012 were 18.6 Mt CO_2e. Emissions have been on a downward trend since 1995.

In addition to CH_4, anaerobic decomposition also produces an approximately equivalent amount of carbon dioxide and further CO_2 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, and so emissions of fossil-derived CO_2 from Solid Waste Disposal Sites (SWDS) are not considered further. Emissions of CO_2 from landfills are reported as "Not Estimated" (NE) as they are considered to be entirely biogenic in origin and therefore not counted towards the national total.

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 CH_4 emitted. An emission factor of 0.01[39] has been used, which is equivalent to 5.65g NMVOC /m^3 landfill gas (Passant, 1993).

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

Nitrous oxide emissions from landfill are believed to be negligible and are not further considered here.

The amount of methane emitted from landfills depends primarily on the amount of carbon in biodegradable waste landfilled and how the sites are operated to reduce the escape of the methane produced from such wastes. Policy measures to reduce methane emissions from landfills have focused on both these aspects. Diverting biodegradable waste away from landfill avoids the future formation of methane, but of course landfills continue to produce CH_4 for many years from waste that has already been deposited. Improving the efficiency of gas capture from landfills results in an immediate reduction in emissions, but is by nature an "end of pipe" solution, which does not itself prevent the formation of methane. 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 which have reduced the emissions of methane from UK landfills derive from the 1999 Landfill Directive[40]. 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, further revoked by the Environmental Permitting (England and Wales) Regulations 2010 SI 675. The regulations were further amended in 2013.. In Scotland, the Landfill 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 require reduction of the amount of biodegradable waste landfilled to specific targets and improved landfill design, operation and management in order to reduce release of methane.

The revised EU Waste Framework Directive 2008/98/EC provides the legislative framework for collection, transport, recovery and disposal of waste. The Directive mandates management of waste according to the waste hierarchy – with the first and preferred method being prevention, followed by reuse, recycling, recovery, and lastly disposal. This mandates the movement away from landfilling of waste.

8.2.2 Methodological issues

The UK approach to calculating emissions of methane from landfills uses a "Tier 2" methodology based on 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 (Revised 1996 IPCC Guidelines[41] p6.10 – 6.11). The IPCC FOD methodology is based on the premise that Dissimilable Degradable Organic Carbon compounds (DDOC)[42] decay under the airless conditions in landfills to form methane, carbon dioxide and a variety of stable decomposition products that remain in the

[40] 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

[41] IPCC, "*Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual,*" 1997

[42] 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.

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.

The Revised 1996 IPCC Guidelines (IPCC, 1997) and Good Practice Guide (IPCC 2000) define the overall approach for calculating methane emissions 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 5.2 of the Good Practice Guide (IPCC 2000).[43]

In the UK model, the various waste types are allocated to three pools (p) of dissimilable degradable organic carbon (DDOC) that decompose according to their characteristic first order rate constant, k_p, defines the proportion of material decomposing per year in each year following disposal. The three pools are described as Rapidly, Moderately, and Slowly Decomposing Organics (RDO, MDO and SDO, respectively). Allocation of DDOC in waste materials to these pools was described in a report produced by Eunomia Consulting and Research (2011), and is summarised in **Table A 3.7.1.1**.

The characteristic decay rates for these three pools are: 0.046 $year^{-1}$ (SDO), 0.076 $year^{-1}$ (MDO) and 0.116 $year^{-1}$ (RDO). These are within the range of 0.030 to 0.200 $year^{-1}$ quoted in IPCC, 2006. Fats, sugars and proteins are assigned to the rapidly degrading pool (RDO), lignin to the slowly degrading pool (SDO) and cellulose, hemicelluloses and remaining compounds are allocated to the moderately degrading pool (MDO).

Methane generation is calculated by equation (1), adapted from IPCC 2000 Equation 5.1:

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

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 (1) is based on the methodology described in the 2000 Good Practice Guidance (IPCC, 2000) which uses the approach developed for the 1996 Guidelines (IPCC, 1997) with the inclusion of 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 as follows, adapted from notes to IPCC 2000 Equation 5.1:

(2) $$L_{x,t,p} = MCF \,.\, F. \;\; DDOC_{x,t,p} \,.\, 16/12$$

Where

[43] IPCC, "*IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories,*" 2000

$DDOC_{x,t,p}$ 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) 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 (x), all three decomposition pools (p) and all years in which the waste is landfilled (t), adapted from IPCC 2000 Equation 5.1:

(3) $$\text{Total } CH_4 \text{ generated}_T = \Sigma (W_{x,t,p} \,.\, Q_{x,T,t,p})$$

Where

$W_{x,t,p}$ is the quantity of waste of type x landfilled in year t (dimensions mass) in pool p; and
$Q_{x,T,t,p}$ is the amount of methane generated in year T from a unit of waste type x, landfilled in year t, allocated to pool p

The Revised 1996 IPCC Guidelines (IPCC, 1997) define 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 proportion of waste decays aerobically and does not produce methane. For modern landfills, the MCF term is given the value of 1 (IPCC 1997 Table 6-2), but the Guidelines allow use of a smaller figure for unmanaged dumpsites. All solid waste disposal sites in the UK that have received biodegradable wastes since 1980 have been required to adhere to a number of regulations are classed as landfills and assigned a MCF value of 1. MCF has been assigned a value of 0.6 for old closed landfills that operated up to 1980 (IPCC 1997 Table 6-2).

The remaining term in equation 2 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.

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 clarity 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 data (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.

Activity data for 2012 were taken from the following published data sources:

- England: "Local authority collected waste for England - quarterly estimates." published by Defra (https://www.gov.uk/government/publications/local-authority-collected-waste-for-england-quarterly-estimates)
- Scotland: Household Waste Interrogator (http://www.environment.scotland.gov.uk/get_interactive/data_visualisation/household_waste.aspx)
- Wales: StatsWales "Tonnes of waste generated by type and year" (Ref. Envi0006) (https://statswales.wales.gov.uk/Catalogue/Environment-and-Countryside/Waste-Management/Local-Authority-Municipal-Waste/Annual/TonnesOfWasteGenerated-by-Type-Year)
- Northern Ireland: "*Municipal waste sent for recycling and composting, KPI(e), and landfill, KPI(f), for Northern Ireland 2011-12*" (www.doeni.gov.uk/lac_municipal_waste_2011-12_appendix.xls)

8.2.2.1 Methane recovery from modern landfills

Landfill operators are required under their permit conditions to control the release of landfill gas. For large landfills containing biodegradable wastes, this requires the use of impermeable liners and cover material, and gas extraction systems. These typically consist of a system of gas wells (perforated pipes sunk into the waste) connected to a network of gas collection pipes. Suction is applied to the gas wells, resulting in a slight negative pressure sufficient to draw out the landfill gas but not enough to draw excessive air into the waste. Air ingress is avoided, as it can result in aerobic decomposition of the waste, which produces considerable heat, and may lead to the waste catching fire, as well as shutting off methane formation. The landfill gas collected is normally used to generate electricity on a commercial basis. Where this is not practicable, gas collected can be burnt in flares. In either case, the net effect of the combustion process is to convert the methane to carbon dioxide. The carbon dioxide so produced is not taken into further consideration for inventory purposes as it is considered to be entirely biogenic in origin.

The key factors in determining methane emissions are estimates of the quantity of methane generated, and information on the amount of methane collected, either for utilisation or flaring. Data on utilisation is available and of good quality, but data on flaring for years prior to 2009 is available but not easily accessible. The current inventory is based on the quantities of gas recorded at modern landfills as being collected and burnt in landfill gas engines and flares. No gas collection is assumed to be carried out at old pre-1980 closed sites

Current estimates for methane recovered are given in **Annex Table A 3.7.1.2**.

Regulatory guidance[44] for landfill operators refers to a target of collecting at least 85% of the methane formed in landfills receiving biodegradable waste. A high standard of gas collection and combustion efficiency is achieved by compliance with the Landfill Directive requirements for gas collection, and by implementing national guidance on landfill gas collection. This is enforced via the landfill permitting and regulatory processes. Large-scale passive venting of landfill gas is no longer accepted under permitting conditions and impermeable barriers are required as best practice to prevent the migration of landfill gas off-site.

[44] See "Guidance on the management of landfill gas" Landfill Technical Guidance Note TGN(03) The Environment Agency and Scottish Environment Protection Agency 2004.

8.2.2.2 Gas Utilisation

Power generation is currently the dominant use for landfill gas in the UK and good data are available on this from official sources. The method for calculating methane combusted in landfill gas engines is as reported in the 2013 UK NIR.

Current data on the amount of methane used for power generation in England, Scotland, Wales and Northern Ireland, calculated from the electricity generated from landfill gas as reported in the Digest of UK Energy Statistics (DECC, 2013), is given in **Annex Table A 3.7.1.2**.

8.2.2.3 Flaring

Since 2009, operators of landfills permitted under the Integrated Pollution Prevention and Control (IPPC) Directive have been required to report the annual quantity of methane flared at the regulated sites under the terms of their operating permits. Because it has been obtained under the terms of IPPC operating permits, this data has documentation and quality control built in via the permitting procedures and operator obligations at an individual site level. The use of this dataset is therefore considered by the UK to be a robust and appropriate basis on which to evaluate the quantities of methane flared by operators.

The data on landfill gas volumes flared were obtained via a range of methods appropriate to the circumstances of the site.

- Sites equipped with flares but with no engines for gas utilisation typically meter the flow of gas either periodically or continuously with recording of data typically on an hourly basis, and record the flare operating hours continuously. Continuous data are sense checked against the plant size and running conditions. Total gas combustion volume in a year is calculated by multiplying the metered flow by the relevant operating period. Sites in this category account for 26% of landfill gas flared in 2009; 19% in 2010; 21% in 2011; and 10% in 2012.

- Sites equipped with a relatively large number of engines frequently use a low throughput flare (30 – 50 m^3/hour) as a buffer to accommodate minor fluctuations in the quantity of landfill gas produced at the site. The volume of landfill gas flared at such sites is typically estimated from the flare capacity and operator estimates of its typical usage. Sites in this category account for up to 6% of landfill gas reported as flared in 2009, 5% in 2010, 7% in 2011 and 8% in 2012.

- Sites using gas engines are equipped with flares to operate as back-up when gas engines are not operational. At some sites, continuous data are available for gas flow to flare. If this is available, it is used to calculate the volume of landfill gas flared as described above. If continuous data are not available, the quantity of gas flared at such sites is typically calculated from the metered throughput to landfill gas engines multiplied by the number of hours of down time – i.e. on the basis that that the flare runs at the same rate as the engines when the engines are off. These estimates are typically modified following discussion with the local field team. Sites in this category account for the balance of gas flared at landfill sites.

This calculation method is considered by the UK to be a robust basis for estimation of the quantity of methane flared at UK landfill sites.

Operator flaring data was evaluated as follows.

1. A database was assembled of operator data on the volumes of landfill gas combusted in flares and engines during 2009, 2010, 2011 and 2012 at landfill sites with up-to-date permit conditions.

2. The methane content of landfill gas flared at operational sites was estimated to be 44%, with lower values used for older sites based on the experience of the Environment Agency. This is supported by publications such as a study for the Irish EPA of the applicability of flaring at sites with low levels of landfill gas.[45] The UK-specific methane content values are lower than the IPCC default, leading to lower estimates of methane mitigated at flares and conservative estimates of methane emissions.

3. Methane emissions from closed but still permitted sites were estimated using the operational site database. The numbers of closed sites with engines and flares and with flares only were multiplied by the average landfill gas volumes flared per site for each year.

4. Methane emissions from local authority controlled sites make a small contribution to landfill gas flaring, which was estimated in liaison with the Environment Agency's landfill gas evidence specialists. The proportions of these sites equipped with flares were estimated, together with a conservative evaluation of the operational time of these flares.

5. The quantities of methane flared in each year from these three categories of landfill were added to give a total quantity of methane flared at landfill sites in England and Wales in 2009, 2010, 2011 and 2012. These values were scaled on the basis of population data to give a total quantity of methane flared in the United Kingdom.

Integration of these methane flaring quantities into the UK methane inventory for the period 1990 to 2008 was carried out as follows.

1. Landfill gas flare capacity in the UK in 1990 was evaluated in a study carried out for the UK Government by LQM in 2003.[46] It was considered that this data provided a reasonable robust basis for calculating the volume of landfill gas flared in 1990.

2. The quantity of methane combusted in gas engines in 1990 was obtained from data reported in Digest of UK Energy Statistics (DECC, 2013) as described previously. Combining this with the estimated quantity of methane flared in 1990 indicated that 12% of collected methane was combusted in engines in 1990, and 90% of methane was flared. A similar assessment was carried out using the data for 2009 described above. This indicated that 81% of collected methane was combusted in engines in 2009, and 19% of methane was flared.

3. For the years between 1991 and 2008 inclusive, the proportion of collected methane combusted in flares was assumed to decrease linearly between these two values. Based on the known quantity of methane burnt in landfill gas engines, the quantity combusted in flares was calculated for each year.

[45] Environmental Protection Agency for Ireland, "*Management of Low Levels of Landfill Gas*," Report prepared by Golder Associates Ireland Ltd, 2011

[46] LQM, "Methane emissions from landfill sites in the UK," Final report to Defra, Ref. 443/1 EPG1/1/145, January 2003

4. The calculations of methane flaring prior to 2009 were further checked using data from modern and old permitted landfill sites for which landfill gas flare metering data are available, and on which Environment Agency expert advice was based. Landfill gas flaring was occurring at all sites investigated. Analysis of the data from these sites supported the methodological assumption that the proportion of flaring increases through the time-series back to the 1990 estimate.

The uncertainties in these calculation methods are addressed in **Section 8.2.3**.

The estimates shown in **Table A 3.7.1.2** are based on the estimate of methane used for power generation added to the estimated quantity of methane flared. The minor proportion of landfill gas used for non-electricity generation purposes such as direct use and as a vehicle fuel, mentioned above was neglected in these calculations and assumed to be emitted to the atmosphere as a conservative assumption.

8.2.2.4 Overseas Territories and Crown Dependencies

Data on the annual tonnage of MSW landfilled has been obtained from some, but not all, territories. Where possible these have been used and then historic UK emission estimates used where this has not been possible in order to calculate a consistent time series. A number of territories were assumed to have no emissions arising from this sector: Bermuda (ceased in 1995), Jersey, Falkland Islands and the Isle of Man (ceased in 2004).

8.2.3 Uncertainties and time-series consistency

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.5.1** to **Table A7.5.4**, 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 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 quantity of methane combusted in engines and flares, and the oxidation factor. An ongoing programme of work is being carried out to address these uncertainties. The uncertainty estimates in **Annex 7** are intended to reflect the current uncertainties in 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 the quantity of methane collected is believed to be a major source of uncertainty in overall emission of landfill methane. Uncertainties in the key components of this calculation are as follows.

- Current and historical combustion of methane in landfill gas engines: Reliable data on methane collected for power generation are available, based on national statistics for energy generated from landfill gas engines (DUKES 2013). The methane to carbon

dioxide ratio of gas burnt in landfill gas engines is assumed to be 50:50, following the IPCC default approach. Gas engine efficiency is assumed to be 30% on average. Operator reports on metered gas volumes combusted in gas engines at operational sites in 2009, 2010, 2011 and 2012 were scaled up to provide an estimate of methane combustion at all sites in England and Wales. The methane quantities derived from operator reports agreed with the quantities derived from DUKES data to within 2%.

- Combustion of methane in flares in 2009, 2010, 2011 and 2012. The calculated values for methane combustion in flares for these years are based principally on data obtained from site operators at operational sites through the permitting processes. These data are subject to the quality control inherent in the permitting process. To the extent possible, permit holders are under a legal obligation to provide accurate and reliable responses to requests for data and annual reports made under the terms of their permit.

- A series of sensitivity tests was carried out, which indicated that inputs to the methane inventory could vary by up to ±12% with reasonable variations in input parameters. The most significant uncertainty was associated with the assumed efficiency of landfill gas engines.

In view of these sensitivities, the data for methane combustion in flares for 2009, 2010, 2011 and 2012 are considered to be sufficiently robust for use in this Inventory, particularly in the context of uncertainties inherent in the Tier 2 methodology for calculating landfill methane emissions.

- Combustion of methane in flares prior to 2009. The calculated values for methane combustion in flares in 1990 is based on an assessment of flare sales carried out in 1990, combined with an independent review of landfill gas flaring completed in 2003. It was assumed that the proportion of landfill gas collected and not combusted in engines which was flared decreased linearly between 1990 and 2009. This assumption was used to calculate the quantity of methane combusted in the period 1991 to 2008. This approach provides a realistic and conservative profile of methane flaring at landfill sites, and is consistent with calculations based on landfill gas flaring records for a small number of sites during this period. The profile of methane flaring follows a similar pattern to that identified by LQM (2003) on the basis of flare sales,[46] with a maximum in the quantity of methane flared in 2002 – 2004. However, the estimated quantity of methane flared in 2002, 2003 and 2004 is about half that estimated by LQM on the basis of flare sales. This provides confidence that the approach set out here provides a conservative assessment of methane capture and flaring (i.e. erring on the side of underestimating methane capture).

Landfill permit conditions are designed to deliver a high standard of gas collection and combustion efficiency. Requirements to design and operate landfills to minimise gas escape have strengthened considerably since the 1990s. In this context, the calculated collection efficiency of 59% derived in this analysis appears reasonable and likely to be conservative. As noted in previous NIRs, further measurements and operator/regulatory input 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. In the absence of better data, the IPCC oxidation default factor of 10% is applied to the estimated quantity of gas released as a fugitive emission. A recent pilot

survey carried out on behalf of the UK Government and Environment Agency included measurements of surface methane oxidation. This study did not support a move away from the IPCC default position. 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.

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 were set out in the previous NIR.

8.2.5 Source-specific recalculations

The UK inventory of methane emissions from this sector has been recalculated, as set out in **Table A 3.7.1.2**. Previously, emissions were calculated by assuming that a specific proportion of methane generated at UK landfill sites was captured. The balance was assumed to be emitted to the atmosphere, with a proportion (10%) oxidised via the landfill surface. This approach has been improved as explained above, such that the quantity of methane combusted in engines and flares in each year is subtracted from the quantity of methane generated at UK landfill sites. Again, it is assumed that the balance is emitted to the atmosphere with a proportion (10%) oxidised via the landfill surface. **Table A 3.7.1.2** shows the quantity of methane generated; the quantity of methane combusted in engines and flares; the quantity of methane oxidised by the landfill surface; and the quantity of methane emitted to the atmosphere.

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 have carried out a small pilot study to measure methane emissions from a selection of landfills, and a programme of research on closed landfills is currently under way (www.environment-agency.gov.uk/acumen). Consequently, emissions estimates are expected to continue to improve in the future.

8.3 SOURCE CATEGORY 6B – WASTEWATER HANDLING

8.3.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	6B1: Industrial Waste Water Treatment 6B2: Sewage Sludge Disposal (CH_4) 6B2: Sewage Sludge Disposal (N_2O) 6B3: OT and CD Sewage Treatment (all)	T1 CS, OTH T1 OTH	D CS, OTH D OTH
Gases Reported	CH_4, N_2O		
Key Categories (Trends)	Wastewater Handling – N_2O		
Key Categories (Level)	Wastewater Handling – N_2O		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Emissions from wastewater handling within OTs and CDs are included as a separate category, reported under 6B3.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements.		

Emissions reported in 6B1a arise from wastewater handling in a number of industry sectors in the UK where organic content of effluent is high. No data are currently available on sludge removal so all water treatment, sludge treatment and disposal emissions are reported as aggregated under 6B1a.

Emissions reported in 6B2b arise from wastewater handling, sludge treatment and disposal in the UK's municipal waste water treatment system which encompasses the treatment of effluent and sludge from residential and commercial sectors as well as trade waste from many industrial sites in the UK.

Methane is released from handling of wastewater and its residual solid by-products (i.e. sludge) under anaerobic conditions, due to the decomposition of organic matter by bacteria. Nitrous oxide is released from human sewage during waste water handling due to the release of nitrogenous material from proteins.

8.3.2 Methodological Issues

The emissions from 6B1 and 6B2 are estimated for the following sources in the UK:

- ***6B1 Industrial Waste Water Treatment (CH_4).*** Default IPCC methodology applied to UK waste water estimates of organic load from the food and drink and chemical industries.
- ***6B2 Domestic and Commercial Waste Water (CH_4).*** UK-specific method, using activity data for the municipal waste water treatment volumes, organic content and

sludge treatment and disposal routes. Emission factors are derived from water company reported data for recent years, extrapolated back to 1990.

- ***6B2 Domestic and Commercial Waste Water (N_2O).*** Default IPCC methodology applied to UK time series of population and protein intake estimates from food surveys.
- ***6B3 OT and CD Sewage Treatment (All).*** For the majority of overseas territories and crown dependencies, wastewater emissions are estimated using UK data and scaled by population. Emissions from Montserrat are estimated using IPCC Tier 1 methodology based on population data. Data specific to Bermuda were provided by the territory and used within the time series, interpolating and extrapolating where necessary.

8.3.2.1 6B1 Industrial Waste Water Treatment

In the UK, a high proportion of industry trade waste water is disposed to the municipal sewer system and treated by water companies together with the sewage and effluent from domestic and commercial sectors. In the data reported by the water companies and used to generate methane emission estimates in 6B2 (see below), the annual reporting to water regulators includes explicit data on the BOD from "trade waste" and the total BOD treated (i.e. including domestic and commercial effluent) in the municipal systems. The share of total BOD that is attributable to the industry sector (i.e. "trade waste", managed via contracts between water companies and industry operators) is variable across the UK and across years. In 2008 (before the economic down-turn) the trade waste share of total BOD treated in the municipal waste water systems (i.e. emissions from which are reported in 6B2) was 13.2%, but from 2009-2012 the figure has been in the range 10.8-11.7%.

In addition to the emissions reported in 6B2 due to trade waste disposed to municipal sewers, where large industrial sites that have on-site waste water treatment plant are regulated under IPPC/EPR, then the annual IPPC/EPR reporting to regulator inventories (PI/SPRI/NIPI) includes the requirement to report any methane emissions from the waste water effluent plant. The PI/SPRI/NIPI data on methane emissions are used within the UK GHGI, and included within many IPCC source categories, but the lack of source-specific detail in the PI/SPRI/NIPI reporting does not enable the waste water treatment emission estimates from these industrial facilities to be split out and reported separately in the CRF.

In practice it is not straightforward to ascertain the extent to which emissions from waste water treatment are consistently included in operator estimates across different industry sectors, as the IPPC/EPR data are not presented "by source", but rather "by installation". Within sector-specific guidance to plant operators on pollution inventory data preparation, emissions of methane from wastewater treatment are not highlighted as a common source to be considered, whilst in guidance for several industrial sectors, wastewater treatment is singled out as a potentially significant source of ammonia and nitrous oxide emissions.

Therefore, some industrial waste water treatment methane emissions are already reported within a range of IPCC source categories, but cannot be quantified explicitly due to the lack of transparency of available source data from UK environmental regulatory reporting systems.

At the 2012 in-country review, the lack of transparency and level of emissions reported in 6B2 led the expert review team to recommend that the UK introduces new separate estimates of emissions of methane from industrial waste water treatment. Therefore in the 2013 submission the inventory agency added a new time series estimates using the IPCC

default methodology and available UK activity data from high-BOD-emitting UK industry sources, primarily in the food and drink and chemical production sectors. The UK inventory agency considers that this introduces a double count to the inventory, but is a conservative estimate to ensure completeness. The method is retained within the 2014 submission, as no further evidence has been obtained by the inventory agency.

Summary of Estimation method for UK 6B1 Estimates
In developing industrial waste water methane emission estimates, the following UK industries have been considered, as they are high-BOD-emitting waste water source sectors in the UK economy:

- Organic Chemicals
- Food and Drink, including:
  - milk-processing
  - manufacture of fruit and vegetable products
  - potato processing
  - meat processing
  - production of alcohol and alcoholic beverages
  - breweries
  - manufacture of animal feed from plant products
  - malt houses
  - fish processing

The estimation methodology is based on the following data and assumptions:

- Default values for Chemical Oxygen Demand (COD) and amount of wastewater generated used for organic chemical production from the IPCC 2000 GPG;
- PRODCOM data (supplied by the Office of National Statistics) used for organic chemical production (2009) and scaled using Office of National Statistics Index of Production (IOP) for other years (1997 is earliest year for IOP so 1990-1996 estimates use the 1997 value).
- Total organic load obtained for food and drink industry sub-sectors in a 2002 paper by Defra47, scaled across the time series using Office of National Statistics Index of Production data (as above, 1997 data are used for 1990-1996 also).

[The UK activity data are summarised for selected years across the time series in Annex 3, ***Section A 3.7.2****]*

The inventory agency considers that these new emission estimates are very conservative, and likely to be over-estimates, noting that:

- There is no information currently available on how much wastewater for the chemical and food and drinks industries are treated on site and how much is included in emissions of wastewater sent to sewers. We have therefore used IPCC default values for the amount of wastewater consumed per tonne of output and amount of COD in the wastewater, and assumed all wastewater is treated on site rather than any of it disposed to municipal sewers.
- There is no information currently available on how much sewage sludge is removed and sent to landfill or applied to agricultural land. Although it is likely that this activity

[47] http://www.defra.gov.uk/publications/files/pb6655-uk-sewage-treatment-020424.pdf

does take place, due to the absence of information, the default value of zero has been used.
- There is no information on the amount of methane recovered, so the default value of zero has been used, although it is likely that this activity also takes place. There is some evidence from the EU ETS dataset that several UK food and industry facilities collect methane from anaerobic digestion systems and use the gas as a fuel source.
- There is no UK specific information on the split of aerobic and anaerobic industrial wastewater treatment and therefore the IPCC default estimate has been used. It is likely that aerobic treatment systems will be used in many UK facilities.

8.3.2.2 6B2 Domestic and Commercial Waste Water (CH_4)

The UK estimates for methane from domestic and commercial waste water and sewage sludge treatment and disposal are derived from a time series of activity data for (i) total mass of sewage sludge disposed, and (ii) population equivalent of effluent treated in the municipal water treatment systems. These data cover all of the UK water company activity since 1990, and reflect the shifts in UK water sector regulation and management, dominated by a step-change in activity due to the impact of the Urban Waste Water Treatment Directive. This banned dumping of sewage sludge to sea, which ceased in the UK in 2000, and the activity data exhibit an increase in sewage sludge treatment and disposal by other methods between 2000-2001 as the UK industry responded to the new regulations. UK water companies provide emissions data and activity data on amount of sludge disposed, but there are no data on population equivalents of waste water treated prior to 2002 and hence the estimates for digestion are uncertain from 1990-2001. As a result, all CH_4 emissions for 6.B.2.1-Domestic and Commercial Wastewater are currently reported in the UK inventory under 6B2b Sludge.

Waste Water Treatment and Sludge Disposal Activity Data
Activity data are available at an aggregated level (across countries: England and Wales, Scotland, Northern Ireland, and with less detail on sludge fate) for the early part of the time series within EPSIM data published by UK Government (Defra, 2004). More detailed activity data (from each of 12 UK water companies, with details on sludge treatment and fate) are available for recent years.

In recent years, each of the UK's 12 water and sewerage companies report annual activity data on water treatment, sewage sludge arisings and the ultimate fate of sewage sludge, to UK industry regulators. The activity data reported by each company includes data that are used to estimate company GHG emissions:

- Total volume of sludge disposed (kt dry solids)
- Trade effluent load (BOD/yr)
- Total annual load (BOD/yr)
- Population Equivalent Served ('000)

In addition, each company provides a detailed split of sewage sludge disposal routes, including data (kt dry solids per year) for the following activities:

- Incineration
- Composted
- Landfill
- Land reclamation
- Farmland
- Disposal at sea (up to the year 2000, when this activity was banned)

- Other

From 1997 to 2008, each of the 10 water companies in **England and Wales** reported sludge disposal activity 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 is limited to the total activity for all sludge treated and disposed, with no detailed breakdown of ultimate disposal fate; for each water company in England and Wales, therefore, the 2008 breakdown across the eight disposal routes has been used to estimate the detailed activity from 2009 onwards, except where water companies have provided activity data directly to the inventory agency.

For years prior to 1997, the EPSIM data present a breakdown of sewage sludge disposal data across five options: farmland, incineration, landfill, sea disposal and other. No additional information is available, such as the BOD loading of the municipal sewerage system, nor the population equivalents treated by UK water companies.

In **Scotland** the same level of detailed activity data as outlined above for companies in England and Wales have been available since 2002 and continue to be published to 2012, from the Water Commissioner for Scotland; EPSIM data are used for 1990-2001.

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. EPSIM data are used for 1990-2003.

Emission Estimation: Use of UK-specific Factors

The UK GHG inventory follows a UK water industry GHG emission estimation methodology developed by UKWIR and used by all UK water companies to generate their annual emission estimates from all sources / activities:

- Methane emission estimates from sludge **digestion** are calculated using the activity estimates for Population Equivalents. *Activity data prior to 2002 are not available, and therefore the 2002 data are used for all years from 1990-2001*;
- Methane emission estimates from **water and sludge treatment** use the activity data for total mass of sewage sludge arisings in the year, *which are available for all years*;
- Residual methane releases from secondary treatment and disposal options use the mass for sludge disposed to those routes, for: **farmland / land reclamation**, **composting**. *Activity data for composting is reported as zero from all companies in England and Wales over 1997-1999, and there are no activity data for earlier years; hence composting activity is assumed to be zero from 1990-1999 inclusive*. *Activity data for sludge disposed to farmland / land reclamation are available for all years until 2008; estimates for 2009-12 are estimated based on the share of total sludge disposed to agriculture in 2008, except in a few cases where water companies have provided activity data directly to the inventory agency.*

Methane emissions from sewage sludge disposed to landfill and incineration are accounted for in 6A and 6C, and hence no estimates are included in 6B2 to avoid a double-count. No estimates are made for sewage sludge disposed to sea or to “other” disposal routes; in the 12 years since disposal to sea has ceased, the disposal to “other” sources has averaged 4.0% of total sludge disposals, with known fates to forestry and used for topsoil. Whilst the initial methane emissions from water and sludge treatment (to generate this mass of sludge

then disposed to “other”) are included in the UK GHGI, there are no emissions data pertaining to the disposal to “other” sources from the UK water companies and hence it is assumed that there are no additional methane emissions from these disposal routes.

UK-specific emission factors are applied to the activities outlined above. These factors are derived from UK water industry emissions data reported to the inventory agency, through use of the UKWIR estimation spreadsheet tool that all UK water companies utilise. The UKWIR tool provides emission factors for sub-processes within the industry, enabling water companies to calculate their methane emissions based on their stock of water treatment equipment and effluent inputs to individual water treatment works. From the aggregated industry reported emissions and activity data, implied emission factors for digestion, water and sludge treatment, composting, disposal to farmland and land reclamation are derived and applied across the time series.

Water company reporting of emissions to the inventory agency is not comprehensive; emissions data are only available from 2009 onwards, and only from up to 9 of the 12 UK water companies in any one year; for example in 2009, emission reporting by water companies was estimated to cover around 53% of total UK water treatment, sludge treatment and disposal activity, whilst the data for 2012 covers a larger proportion of the UK industry at around 65% of all source activities. . The inventory agency note that there is a limited dataset from which to derive UK-specific emission factors, although ongoing engagement with water companies and UKWIR is providing a solution that will enable more comprehensive and consistent data collection.

During 2013 the inventory agency met with all UK water company carbon managers and the authors of the UKWIR reporting tool that all companies use under a voluntary mechanism for GHG emissions reporting. Through this consultation, 9 out of 12 water companies provided 2012 emissions data, covering around 65% of UK water company activities. In addition, a reporting template has been drafted for inclusion within the UKWIR tool, which from 2013 data onwards should provide a more consistent, complete dataset on activities and emissions from the industry.

Despite limitations to data collection in previous years, there is good consistency across the emission factors derived from the different water companies and the data are based on UK-specific water treatment facilities, effluent inputs and treatment / disposal activities, and therefore are regarded as the best available data upon which to derive inventory estimates.

For further details of emission factors see **Annex 3, section A 3.7.3.**

Reporting of Methane Recovery from Sewage Treatment

The inventory compilation method uses industry-wide data on emissions. Calculations are not conducted at a technology level; no specific consideration of the use of anaerobic digestion or use of sewage gas in power generation is included in the estimation method and these factors do not affect the veracity of the emission estimation method. To derive the estimates of methane recovery from sewage treatment that are reported within the CRF Table 6.Bs1, the inventory agency uses national statistics on electricity generated through sewage sludge digestion and back-calculates an estimate of methane recovered.

Data on the annual amount of electricity generated using sewage gas are provided in DUKES (DECC, 2013), and consultation with the energy statistics team has clarified that they assume a 35% energy efficiency factor for these systems. The inventory agency therefore uses the 35% conversion assumption to back-calculate the national annual sewage

gas energy input to these power plant, and then uses the sewage gas calorific value (published in DUKES, DECC 2013) to derive the mass of methane recovered to report in the CRF. The emission calculation is not affected by these assumptions.

8.3.2.3 6B2 Domestic and Commercial Waste Water (N_2O)

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, 2012); see **Table 8.1**. For the purposes of the 2012 estimates within the inventory, the Expenditure and Food Survey 2013 was not available in time, and therefore the data for 2011 has been used as a best estimate.

In previous years, the protein consumptions used to estimate emissions were "household intakes". However, 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 is applied. The sum of the "household intakes" and "eating out intakes" then provides the total protein consumption per year per person.

Table 8.1 Per capita protein consumption in the UK (kg/person/yr), 1990-2012

Year	Protein consumption (kg/person/yr)
1990	27.9
1995	28.6
2000	29.9
2005	29.8
2010	28.7
2011	28.2
2012*	28.2

*2011 data used, as 2012 are data not published in time for inventory compilation.

The nitrous oxide emissions are calculated by multiplying the total protein consumption per year per person by the fraction of nitrogen in protein (0.16 kg N/kg protein based on the IPCC rev 1996 Guidelines) by the emission factor (0.01 kg sewage-N produced based on the IPCC rev 1996 Guidelines).

This derives a total for the UK nitrous oxide emissions from sewage sludge, but not all of those emissions are allocated to 6B2. The nitrous oxide emissions from sludge spread on agricultural land are reported under IPCC source category 4D Agricultural Soils. Therefore to avoid a double-count in the UK GHG inventory, the emissions reported in 6B2 are the difference between the UK total from the IPCC default method, and the estimates included in 4D. **Table 8.2** below summarises the data reported in the CRF, across 4Dand 6B. The table also includes the time series of estimates of emissions from waste water treatment and sewage sludge treatment and disposal in the Overseas Territories and Crown Dependencies, which are reported in the CRF under 6B3 Other, and include estimates for: Bermuda, Cayman Islands, Guernsey, Isle of Man, Jersey and Montserrat.

Table 8.2 Nitrous Oxide Emissions in the UK Inventory: Allocation to Waste and Agriculture Source Categories, 1990-2012

CRF	Source	Units	1990	1995	2000	2005	2010	2011	2012
n/a	Total UK emissions using IPCC method (Excluding OTs and CDs)	kt N_2O	4.02	4.16	4.41	4.52	4.49	4.45	4.51
4D	Direct soil N_2O emissions from sewage sludge	kt N_2O	0.28	0.31	0.33	0.69	0.75	0.76	0.73
6B2	Reported UK waste water sector N_2O emissions	kt N_2O	3.74	3.85	4.09	3.83	3.74	3.69	3.79
6B3	Waste Water N_2O emissions, OTs and CDs	kt N_2O	0.02	0.02	0.02	0.02	0.03	0.03	0.03

Note that data shown above are rounded to two decimal places, based on data calculated at full precision.

Use of UK-Specific Protein Consumption Data instead of FAO Data

The FAO estimate of per capita protein consumption is based on supply balance sheets for all commodity items. For each commodity supply balance sheet, factors are applied to the estimate of supply for human consumption to derive total protein consumption and a per capita figure is obtained by dividing by population statistics. These are summed across the supply balance sheets to derive a total protein consumption estimate for a country.

The FAO estimate is therefore an aggregate calculation based on aggregate commodity supply data. It uses common conversion factors (not specific to any country) to derive food, protein and fat per capita consumption estimates. It also relates to quantities available for consumption and will not be net of any losses (including e.g. fat trimmed from meat) beyond the farm-gate through to retail. These methodological limitations of the FAO estimates are more significant for developed countries such as the UK where a greater proportion of consumption is in the form of processed products.

The UK GHGI estimate of protein consumption is derived from the Expenditure and Food Survey (Defra, 2012). This is a sample household survey in which households record the actual purchases of food they make. UK-specific conversion factors are then applied to these individual food items to estimate consumption of protein and other nutrients. The UK-specific conversion factors are based on a detailed analysis of the individual types of food purchased and contrasts to the more broad-brush factors used by the FAO. The Expenditure and Food Survey estimate is also net of any losses through the food chain through to retail as it is based on actual purchases. The only limitation to the Expenditure and Food Survey is that it may have an element of under-recording due to purchases of some food items not being included in the diary of survey participants, but the inventory agency considers that it is more representative of UK protein consumption per capita than the FAO estimate.

8.3.3 Uncertainties and Time-Series Consistency

As outlined in **Section 8.3.2**, the method for deriving methane emission estimates for 6B2 uses activity data from across the time series, and applies emission factors that are derived from reported emissions data from 2009 onwards. The method uses a published national set of activity statistics that reflect the changing fate of sewage sludge treatment and disposal; 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 and the sludge disposal trends are consistent with this regulatory change.

Not all UK water companies report their emission estimates in all years since 2009, and the available dataset for deriving country-specific factors is limited in some cases to only around 50% coverage of UK water treatment and sludge treatment / disposal activity. The inventory agency has continued to develop working relationships with the 12 UK water companies and in 2013 obtained activity and emissions data from 9 out of 12 water companies. A new template for UK water company reporting has been drafted and will be integrated within the UKWIR carbon accounting tool that all UK water companies use annually to report to voluntary industry mechanisms. Therefore, in future (for data for 2013 onwards), we anticipate a much more complete, consistent set of activity and emissions data to be reported from across the UK; this will help to further develop the UK-specific dataset from which estimates can be derived, improving accuracy through accessing more complete, representative data which will reflect the range of waste water quality and the design / stock of waste water treatment facilities across the UK.

The reported emissions and activity by UK water companies since 2009 has been used to derive country-specific emission factors for water treatment, sludge treatment and disposal, and these factors are applied to the activity dataset back to 1990. We are therefore using the best available data to estimate the emissions back to 1990, although the limited UK water company reporting used to derive the factors adds to the uncertainty of the inventory estimates.

Furthermore, the limited activity data time series for 6B2 due to changes in data reporting across the time series limits the accuracy of the estimates for the early part of the time series; for example, no comprehensive UK data for Population Equivalents (PE) of waste water treatment are available prior to 2002, and hence the estimates of methane emissions from digestion for 1990-2001 are somewhat uncertain, as they are based on the 2002 activity data. Note, however, that the aggregate UK PE data is in the range 73,000 ± 200 during 2002-2006, and therefore the variability in the data are quite low; furthermore, the use of data on digestion activity from after the ban on disposal of sewage to sea (in 2000) is very likely to introduce a conservative estimate for those earlier years in the time series, rather than an under-report.

See **Annex A 3.7.3** for further method details, and **Section 8.3.6** below for an insight into the planned improvements for this source method.

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

Details of and justifications for recalculations to activity data are given in **Table 8.3** and emission factors in **Table 8.4** below. For information on the magnitude of recalculations to Source Category 6B, see **Section 10**.

The emission estimates from industrial waste water treatment (6B1) have been revised for 2011 based on updated information on the Index of Production from the Office of National Statistics. The new data for 2011 has led to updates in the waste water activity estimates for

the chemical and food & drink industries, increasing emissions by around 6% compared to the 2013 submission.

The inventory agency has reviewed the activity data from water companies and corrected the emission estimates for nitrous oxide from domestic and commercial waste water and sludge disposal (6B2), to update the 2011 data to use actual protein consumption data for that year rather than to extrapolate protein data from 2010, as within the 2013 submission. There have also been some revisions to the estimates for nitrous oxide emitted from sewage sludge disposal to agricultural soils (in 4D) and therefore this has a knock-on effect on the nitrous oxide emission estimate in 6B.

Table 8.3 6B Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
			1990	2011	1990	2011		
6B1	Industrial Waste Water Treatment	Non-fuel combustion	374.5	345.2	374.5	367.0	Gg COD	Updated Index of Production data available to inform estimates in 2011 (and 2012).

Table 8.4 6B Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	Pollutant	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
				1990	2011	1990	2011		
6B2	Domestic andCommercial Waste Water	N_2O	Non-fuel combustion	0.065	0.062	0.064	0.059	kt / million people	Emission factor revised to reflectrevisions in the estimates of nitrous oxide emissions from sewage sludge disposal to agriculture (in 4D), and also to update the 2011 protein consumption data.

8.3.6 Source Specific Planned improvements

Consultation with water industry contacts and regulators will be continued during 2014, with the following aims.

i) To finalise the scope of a new reporting template that has been drafted to be incorporated within the UKWIR carbon accounting tool, which all UK water companies already use annually in voluntary industry reporting systems. Completion of this template by UK water companies will enable the inventory agency to obtain more complete, consistent reporting of activity data and emission estimates for 2013 data onwards;

ii) Continue to build relationships with representatives of all of the UK water companies and the developers of the UKWIR tool, to seek more complete reporting of emissions data and activity data, to improve on the nine out of 12 companies that reported emissions data in 2013. The UK inventory agency recognises the need to develop/increase the water company reporting dataset to reduce uncertainties in the country-specific factors used in the current 6B2 methane estimation method, and to seek more data to help development of a more accurate method for nitrous oxide emission estimates;

iii) Review the emission estimates from earlier in the time series and the current approach of back-extrapolation of emission factors from more recent research which introduces additional uncertainty for estimates in the early part of the time series;

iv) Review data available from environmental regulators pertaining to industrial waste water treatment emissions, volumes, characteristics (e.g. organic load), and to seek any further information from industry contacts in the chemical and food & drink sectors. Recent engagement with the Chemical Industries Association (Personal communication, CIA, 2014) indicates that there is work ongoing to develop a new BREF note for the chemicals sector which may help to identify relevant data for the inventory method, although the outputs from this work stream are not yet available.

The inventory agency will continue to review available data on disposals of sewage sludge to “other” (i.e. non-specified) disposal routes and consider options for deriving methane estimates for this activity.

8.4 SOURCE CATEGORY 6C – WASTE INCINERATION

8.4.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	6C: Incineration: MSW Incineration: Sewage Sludge Incineration: Clinical Incineration: Chemical Accidental fires - vehicles	T2 T2 T2 T2 T2	CS, D CR, D CS, CR, D CS, D CS
Gases Reported	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2		
Key Categories (Trends)	None identified		
Key Categories (Level)	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Included in the CRF with the UK MSW incineration, since the same emission factors are applied.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements have been made since the last submission.		

This source category covers the incineration of wastes, excluding waste-to-energy facilities. In the UK, all MSW incineration plants have recovered energy since 1997, and so emissions are reported under CRF source category 1A1a. For the years 1990-1996, at least some MSW was incinerated at plants with no energy recovery, so emissions are split between 1A1a and 6C for those years, in proportion to the waste burnt with and without energy recovery respectively. All incineration of chemical wastes, clinical wastes, sewage sludge and animal carcasses is reported under 6C. In-situ burning of agricultural waste e.g. crop residue burning is reported under category 4F.

There are approximately 70 plants 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.

8.4.2 Methodological Issues

Emissions of CO_2, 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, 2013). 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. The emissions of N_2O from chemical waste incinerators are the default factor given in the IPCC guidelines (2006).

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-EEA 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 CO_2, 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 CO_2 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-EEA 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 (2013).

Emissions from MSW incineration for the period 1990-1996 are reported split between 1A1a and 6C, in proportion to the tonnages of waste burnt with and without waste recovery respectively. The same methodology is used to estimate emissions for both types however, and details and CO2 factors are given in **Section 3.2.6**.

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.

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.

The tonnage of MSW burnt in incinerators is provided by the Cayman Islands, Bermuda and the Falklands. UK GHGI EFs were then applied to these activity data to estimate emissions from this sector. Waste incineration in Jersey and the Isle of Man is reported under 1A1a. It is assumed that this source is not occurring in the remaining territories.

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

Details of and justifications for recalculations to activity data are given in **Table 8.5** and emission factors in **Table 8.6** below. For information on the magnitude of recalculations to Source Category 6C, see **Section 10**.

Table 8.5 6C Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
			1990	2011	1990	2011		
6C	Accidental fires - vehicles	Mass burnt	12.81	8.97	12.81	7.18	kt	Updated fire statistics now received for 2011 where previously had been extrapolated.
	Incineration - clinical waste	Clinical waste	0.350	0.112	0.350	0.113	Mt	Updated and corrected data from the Environment Agency from 2009 onward.
	Incineration (Bermuda)	MSW	0.000	0.062	0.000	0.054	Mt	Waste to incineration data obtained so this has been applied instead of the estimates made previously.
	Incineration (Falkland Islands)	MSW	0.00014	0.00014	0.00014	0.00001	Mt	MSW incineration activity revised based on new data (zero MSW incineration in 2012).

Table 8.6 6C Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	Pollutant	Activity Name	2013 submission		2014 submission		Units	Comment/Justification
				1990	2011	1990	2011		
6C	Incineration	Carbon	MSW	83.0	94.0	83.0	92.1	kt / Mt	Updated waste compostion data for 2011 used to calculate CEF. Only affects OTs as no waste without energy recovery in the UK.

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. Should data on methane flaring become available within the pollution inventory for chemical waste incineration this data will be included in the inventory. No evidence has been found for any chemical waste incineration processes carried out in Scotland or Northern Ireland, and so emissions in these regions are assumed to be zero. The need to deal with significant gaps in the reported data means that estimates are quite uncertain. Emission estimates for clinical waste, animal carcass and sewage sludge incineration are also quite uncertain and ideally would be improved. However, all incineration processes are relatively minor sources of greenhouse gases and further development of the methodology is not a priority.

9 Other (CRF Sector 7)

9.1 OVERVIEW OF SECTOR

No emissions are reported in Sector 7.

10 Recalculations and Improvements

This section of the report summarises the recalculations and improvements made to the UK GHG inventory since the 2013 NIR (2011 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. The CRF was resubmitted in October 2013 following a UNFCCC review, recalculations checks within the CRF documents will show recalculations between October 2013 and this submission so will not necessarily be consistent with the NIR.

Each year, the UK greenhouse inventory is *updated*, *extended* and may be *expanded*.

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 2011; this report gives emission estimates for 2011, and includes estimates for the year 2012 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 2013 NIR (2011 inventory) was issued. The changes in emissions are net changes (the sum of any increases and decreases) in the source category, for the year 2011 (**Table 10.1**) and the base year (**Table 10.2**). **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.

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 (2012 inventory; 2014 NIR); and

PS = Previous Submission (2011 inventory, 2013 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 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 10.1.1**). 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 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 in the 2012 submission 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 EU ETS 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.

10.1.1 GHG Inventory

Table 10.1 Re-Calculations of direct GHG emissions for the year 2011 in the UK 2014 NIR (2012 inventory) – including KP-LULUCF inventory.

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2012 inventory minus emissions in 2011 inventory)	Change in emissions (%) (Percentage change relative to the 2011 inventory)	Brief description of reasons for Re-Calculation
1A1			
CO_2	-55.7	0.0%	The largest change in this sector is a revision made to national energy statistics for refineries. Changes to the carbon balance approach have caused changes to Carbon EF for solid fuels. Revisions have been made to data received for carbon content of MSW. Reduction in emissions of CH_4 and N_2O from combustion of coke oven gas and blast furnace gas due to use of 2006 Guideline EFs to replace EMEP-EEA defaults. Other smaller revisions to the national energy statistics have also been made. See **Section 3.2.6** for more details.
CH_4	-20.8	-8.7%	
N_2O	-1.8	-0.1%	
1A2			
CO_2	-3165.3	-4.7%	The use of OPG has been reallocated from 1A2f to 1A2c to improve transparency although only small overall revisions have been made for OPG combustion. Reduction in emissions of CH_4 and N_2O from combustion of coke oven gas and blast furnace gas due to use of 2006 Guideline EFs to replace EMEP-EEA defaults. Revisions to the national energy statistics have also been made. See **Section 3.2.6** for more details.
CH_4	-105.6	-45.9%	
N_2O	-122.8	-12.8%	
1A3			
CO_2	-18.8	0.0%	Main methodological revisions are to the emission normalisation . N_2O and CH_4 emissions are now normalised with respect to fuel consumption in response to feedback from the Expert Review Team (ERT) during 2013, previously it was based on km travelled. Reallocations have also bee made between domestic and international aviation following the UNFCCC review. Revisions also made to national energy statistics. See **Section 3.2.8** for more details.
CH_4	1.8	2.6%	
N_2O	14.8	1.6%	
1A4			

Source category	Change in emissions	Change in emissions	Brief description of reasons for Re-Calculation
CO_2	2961.4	3.5%	No major methodological changes have been made for this sector. Emission factors for solid fuels have been updated following development of the new carbon balance approach. Revisions have been made to national energy statistics and data received from OTs and CDs. See **Section 3.2.93.2.8** for more details.
CH_4	4.3	0.8%	
N_2O	1.4	0.2%	
1A5			
CO_2	0.2	0.0%	Revisions of activity data provided by the MOD. See **Section 3.2.113.2.8** for more details.
CH_4	0.0	0.0%	
N_2O	0.0	0.0%	
1B1			
CO_2	-19.3	-7.5%	Changes made following update of carbon balance approach and new research with DECC and the iron and steel industry. Reduction in emissions of CH_4 and N_2O from combustion of coke oven gas and blast furnace gas due to use of 2006 Guideline EFs to replace EMEP-EEA defaults. See **Section 3.3.13.2.8** for more details
CH_4	-3.2	-0.2%	
N_2O	-1.6	-94.4%	
1B2			
CO_2	-85.6	-2.1%	Additional information received from onshore oil processing sites and revisions to installation emission estimates for a number of sites. See **Section 3.3.23.2.8** for more details
CH_4	51.5	1.0%	
N_2O	-15.6	-25.7%	
2A			
CO_2	58.7	0.9%	The main recalculation has been to activity data to take account of estimated emissions associated with carbonatation process in sugar refining; this was added in response to feedback from the ERT in 2013. See **Section 3.2.9 3.2.8** for more details.
2B			
CO_2	-219.3	-8.6%	Changes result from review of non-energy use of fuels. See **Section 4.13** for more details.
CH_4	1.1	1.6%	
2C			
CO_2	-36.4	-2.6%	Improvements have been made to the steelmaking carbon balance model due to improved industry data on carbon contents of fuels, products and other materials. Blast furnace and coke oven gas emission factors changed to 2006 IPCC (not available in 1996 version) defaults from 1996 EMEP factor. HFC emissions data received from industry revised. See **Section 4.14** for more details.
CH_4	-8.3	-93.2%	
N_2O	-2.1	-34.3%	
HFCs	-10.5	-80.0%	
2F			
HFCs	-817.8	-5.6%	These changes are mainly due to the revision to methodology used to calculate emissions from MDIs in the UK, small changes

Source category	Change in emissions	Change in emissions	Brief description of reasons for Re-Calculation
PFCs	0.0	0.1%	also to estimates for electrical insulation and the inclusion of SF_6 as a tracer gas for the first time. See **Section 4.22 to 4.29** for more detail.
4A			
CH_4	302.1	2.0%	The main methodological revision is to the feed digestibility for cattle. See **Section 6.2** for more details.
4B			
CH_4	4098.3	160.1%	Main methodological revisions are to the feed digestibility for cattle, the inclusion of activity data for both agricultural and non-agricultural horses, and the allocation of excreta to management systems. See **Section 6.3** for more details.
N_2O	1033.4	60.0%	
4D			
N_2O	613.4	2.3%	Main methodological revisions are improved Scottish crop production data, and the inclusion of emissions from OTs and CDs in response to UNFCCC review reccomendations. See **Section 6.3** for more details.
5A			
CO_2	-7456.9	73.0%	Main methodological revisions are the use of the CARBINE carbon accounting model for carbon stock change modelling and the inclusion of emissions from all forests older than 20 years in the Forest remaining Forest Land category – instead of just from post-1921 forests as was reported in previous submissions. See **Section 7.2** for more details.
CH_4	-3.1	-44.4%	
N_2O	-4.8	-7.6%	
5B			
CO_2	106.4	0.9%	The main methodological revision is the inclusion of by-products from sugar production for soil liming. There have also been recalculations in the time series for the OTs and CDs. See **Section 7.2** for more details.
CH_4	0.0	-7.8%	
N_2O	82.4	15.9%	
5C			
CO_2	732.7	-8.6%	The main methodological revision is the inclusion of by-products from sugar production for soil liming. There have also been recalculations in the time series for the OTs and CDs and revised estimates to forest and grassland areas. See **Section 7.4** for more details.
CH_4	18.8	133.9%	
N_2O	2.9	29.1%	
5D			
CO_2	-43.5	-10.8%	Revisions made to national statistics. See **Section 7.53.2.8** for more details.
5E			
CO_2	-14.4	-0.2%	The main methodological revision is the use of the new activity data for wildfires. There have also been recalculations in the time series for the OTs and CDs.
CH_4	-1.0	-13.5%	

Source category	Change in emissions	Change in emissions	Brief description of reasons for Re-Calculation
N_2O	-0.1	-13.5%	See **Section 7.67.4** for more details.
5G			
CO_2	2404.7	-70.7%	Main methodological revisions are the use of the CARBINE carbon accounting model for carbon stock change modelling and the inclusion of emissions from all forests older than 20 years in the Forest remaining Forest Land category – instead of just from post-1921 forests as was reported in previous submissions. The deforestation areas have additionally been updated. See **Section 7.8** for more details.
6A			
CH_4	5404.6	38.1%	Recalculations have been made to the method for estimating methane capture at landfill sites. See **Section 8.2** for more details.
6B			
CH_4	80.1	4.9%	Small revisions to activity data for industrial wastewater treatment. Also improved consistency with the agriculture sector to ensure sewage sludge applied to agricultural soils is the same for both sectors. See **Section 8.3** for more details.
N_2O	-54.3	-4.5%	
6C			
CO_2	-2.2	-0.8%	Most significant change is due to receiving updated waste composition data for MSW incineration. This only affects the OTs and CDs. See **Section 1.1** for more details.
CH_4	-0.6	-10.5%	
N_2O	-0.1	-0.2%	

Table 10.2 Re-Calculations of direct GHG emissions for the base year in the UK 2014 NIR (2012 inventory).

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2012 inventory minus emissions in 2011 inventory)	Change in emissions (%) (Percentage change relative to the 2011 inventory)	Brief description of reasons for Re-Calculation
1A1			

Source category	Change in emissions	Change in emissions	Brief description of reasons for Re-Calculation
CO_2	-5.3	0.0%	Reduction in emissions of CH_4 and N_2O from combustion of coke oven gas and blast furnace gas due to use of 2006 Guideline EFs to replace EMEP-EEA defaults. Small change to carbon data as a correction to EU ETS data has caused a change to OPG CEF for all years. See **Section 3.2.6** for more details.
CH_4	-35.5	-17.5%	
N_2O	-14.4	-0.7%	
1A2			
CO_2	1215.8	1.2%	The use of OPG has been reallocated from 1A2f to 1A2c to improve transparency although only small overall revisions have been made for OPG combustion. Reduction in emissions of CH_4 and N_2O from combustion of coke oven gas and blast furnace gas due to use of 2006 Guideline EFs to replace EMEP-EEA defaults. See **Section 3.2.6** for more details.
CH_4	-178.2	-53.9%	
N_2O	-55.3	-3.4%	
1A3			
CO_2	74.4	0.1%	Main methodological revisions are to the emission normalisation . N_2O and CH_4 emissions are now normalised with respect to fuel consumption in response to feedback from the Expert Review Team (ERT) during 2013, previously it was based on km travelled. Reallocations have also bee made between domestic and international aviation following the UNFCCC review. See **Section 3.2.8** for more details.
CH_4	2.8	0.4%	
N_2O	9.3	0.7%	
1A4			
CO_2	-78.8	-0.1%	No major methodological changes have been made for this sector. Emission factors for solid fuels have been updated following development of the new carbon balance approach. See **Section 3.2.93.2.8** for more details.
CH_4	-0.2	0.0%	
N_2O	-0.1	0.0%	
1B1			
CO_2	-1.4	-0.2%	Changes made following update of carbon balance approach and new research with DECC and the iron and steel industry. Reduction in emissions of CH_4 and N_2O from combustion of coke oven gas and blast furnace gas due to use of 2006 Guideline EFs to replace EMEP-EEA defaults. See **Section 3.3.13.2.8** for more details
CH_4	-4.0	0.0%	
N_2O	-2.0	-94.4%	
1B2			
CO_2	0.0	0.0%	Additional information received from onshore oil processing sites and revisions to installation emission estimates for a number of sites. See **Section 3.3.23.2.8** for more details
CH_4	0.7	0.0%	
2A			
CO_2	91.7	0.9%	The main recalculation has been to activity data to take account of estimated emissions associated with carbonatation process in sugar refining, this was added in response to feedback from the ERT in 2013. See **Section 3.2.9 3.2.8** for more details.
2B			

Source category	Change in emissions	Change in emissions	Brief description of reasons for Re-Calculation
CO_2	-212.4	-7.1%	Changes result from review of non-energy use of fuels. See **Section 4.13** for more details.
2C			
CO_2	31.4	1.4%	Improvements have been made to the steelmaking carbon balance model due to improved industry data on carbon contents of fuels, products and other materials. Blast furnace and coke oven gas emission factors changed to 2006 IPCC (not available in 1996 version) defaults from 1996 EMEP factor. HFC emissions data received from industry revised. See **Section 4.14** for more details.
CH_4	-15.3	-93.3%	
N_2O	-3.9	-34.7%	
2F			
HFCs	-1.6	-13.2%	These changes are mainly due to the revision to methodology used to calculate emissions from MDIs in the UK. See **Section 4.22 to 4.29** for more detail.
PFCs	0.0	0.0%	
4A			
CH_4	182.0	1.0%	The main methodological revision is to the feed digestibility for cattle. See **Section 6.2** for more details.
4B			
CH_4	5526.6	159.0%	Main methodological revisions are to the feed digestibility for cattle, the inclusion of activity data for both agricultural and non-agricultural horses, and the allocation of excreta to management systems. See **Section 6.3** for more details.
N_2O	1389.0	67.9%	
4D			
N_2O	259.1	0.8%	Main methodological revisions are improved Scottish crop production data, and the inclusion of emissions from OTs and CDs in response to UNFCCC review reccomendations. See **Section 6.3** for more details.
5A			
CO_2	-3899.5	32.5%	Main methodological revisions are the use of the CARBINE carbon accounting model for carbon stock change modelling and the inclusion of emissions from all forests older than 20 years in the Forest remaining Forest Land category – instead of just from post-1921 forests as was reported in previous submissions. See **Section 7.2** for more details.
CH_4	-1.2	-27.3%	
N_2O	-3.1	-5.3%	
5B			
CO_2	30.7	0.2%	The main methodological revision is the inclusion of by-products from sugar production for soil liming. There has also been recalculations in the time series for the OTs and CDs. See **Section 7.2** for more details.
CH_4	-0.1	-35.1%	
N_2O	0.0	0.0%	
5C			

Source category	Change in emissions	Change in emissions	Brief description of reasons for Re-Calculation
CO_2	11.9	-0.2%	The main methodological revision is the inclusion of by-products from sugar production for soil liming. There has also been recalculations in the time series for the OTs and CDs and revised estimates to forest and grassland areas. See **Section 7.4** for more details.
CH_4	-0.6	-4.9%	
N_2O	0.0	-0.3%	
5E			
CO_2	-49.4	-0.7%	The main methodological revision is the use of the new activity data for wildfires. There has also been recalculations in the time series for the OTs and CDs. See **Section 7.67.4** for more details.
CH_4	-1.7	-25.6%	
N_2O	-0.2	-25.6%	
5G			
CO_2	1769.8	-103.5%	Main methodological revisions are the use of the CARBINE carbon accounting model for carbon stock change modelling and the inclusion of emissions from all forests older than 20 years in the Forest remaining Forest Land category – instead of just from post-1921 forests as was reported in previous submissions. The deforestation areas have additionally been updated. See **Section 7.8** for more details.
6A			
CH_4	-110.4	-0.3%	Recalculations have been made to the method for estimating methane capture at landfill sites. See **Section 8.2** for more details.

Table 10.3 Changes in Methodological Descriptions

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)			
1. Energy			Chapter 3
A. Fuel Combustion (Sectoral Approach)			
1. Energy Industries	√	√	
2. Manufacturing Industries and Construction	√	√	
3. Transport	√	√	
4. Other Sectors	√	√	
5. Other	√	√	
B. Fugitive Emissions from Fuels			
1. Solid Fuels	√	√	
2. Oil and Natural Gas	√	√	
2. Industrial Processes			Chapter 4
A. Mineral Products	√	√	
B. Chemical Industry	√	√	
C. Metal Production	√	√	
D. Other Production	√	√	
E. Production of Halocarbons and SF6	√	√	
F. Consumption of Halocarbons and SF6	√	√	
G. Other			
3. Solvent and Other Product Use			
4. Agriculture			Chapter r 6
A. Enteric Fermentation	√	√	
B. Manure Management	√	√	
C. Rice Cultivation	√	√	
D. Agricultural Soils	√	√	
E. Prescribed Burning of Savannahs			
F. Field Burning of Agricultural Residues			

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)			
G. Other			
5. Land Use, Land-Use Change and Forestry			Chapter 7
A. Forest Land	√	√	
B. Cropland	√	√	
C. Grassland	√	√	
D. Wetlands	√	√	
E. Settlements	√	√	
F. Other Land	√	√	
G. Other	√	√	
6. Waste			Chapter 8
A. Solid Waste Disposal on Land	√	√	
B. Waste-water Handling			
C. Waste Incineration			
D. Other			
7. Other (as specified in Summary 1.A)			
Memo Items:			
International Bunkers			
Aviation		√	
Marine			
Multilateral Operations			
CO2 Emissions from Biomass			

10.1.2 KP-LULUCF Activities

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.

10.2 IMPLICATIONS FOR EMISSION LEVELS

10.2.1 GHG Inventory

Information at sector level is summarised in **Table 10.1** and **Table 10.2** above. The overall impact of all recalculations is an increase in emissions of 5,878 Gg CO_2 equivalent in the base year, and 5,635 Gg CO_2 equivalent in 2011.

An overview chart showing the sector level changes is set out below.

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.

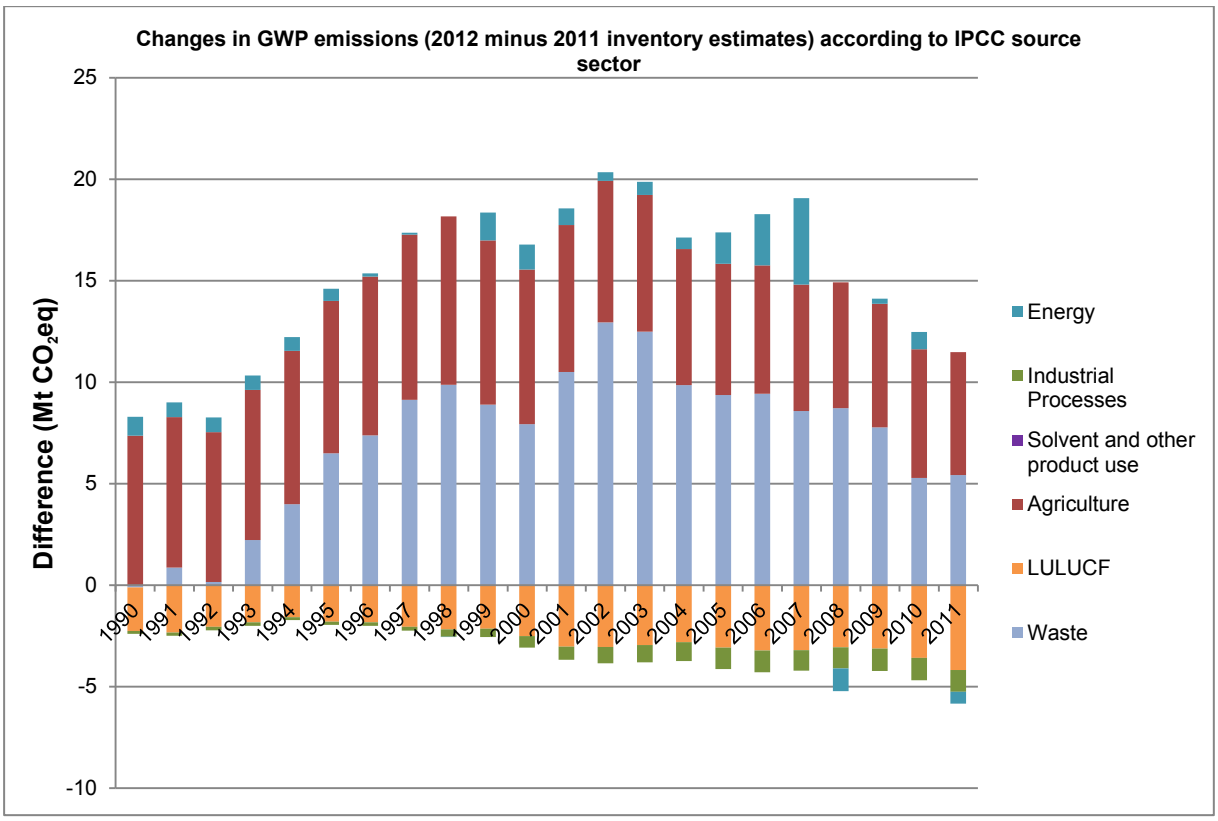
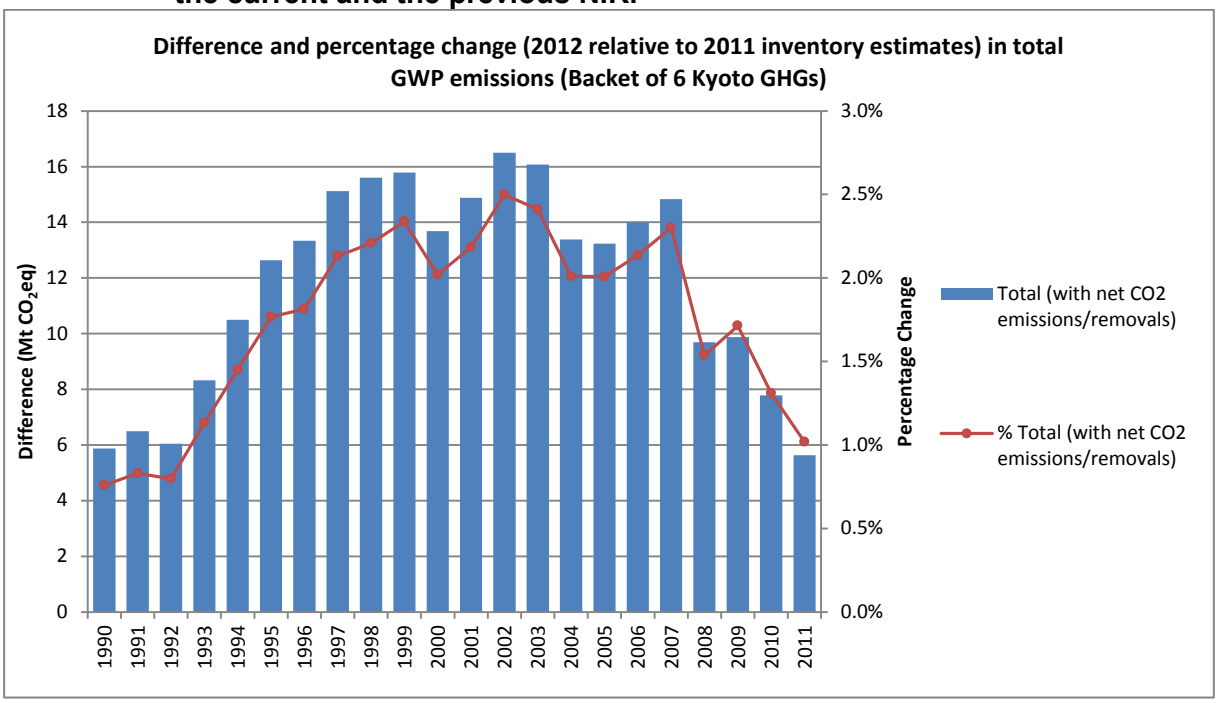


Figure 10.2 shows the net impact of all recalculations in absolute and percentage terms.

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.



10.2.2 KP-LULUCF Activities

Information on the reasons for recalculations is included in **Section 10.1.2** and **Section 11.3.1.4**. The net impact of these changes is a decrease of 2,143 Gg CO_2e in the base year, and a decrease of 4,176 Gg CO_2e in 2011.

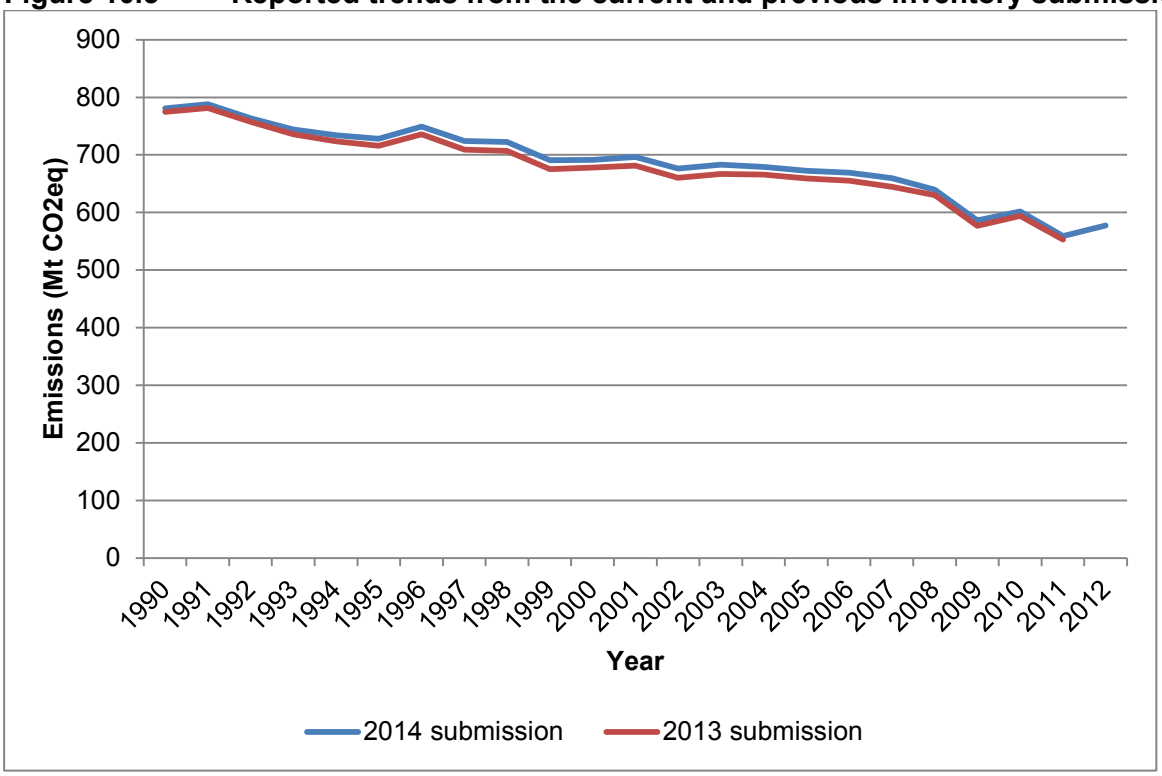
10.3 MPLICATIONS FOR EMISSION TRENDS, INCLUDING TIME SERIES CONSISTENCY

10.3.1 GHG Inventory

There has been little change in the reported trend in emissions. The reported trend from 1990 to 2011 in the 2013 inventory submission was a decrease of 28.6%. The recalculated trend from 1990 to 2011, as presented in the 2014 submission is a decrease of 28.4%.

The chart below displays the trend from both the 2013 and 2014 submissions.

Figure 10.3 Reported trends from the current and previous inventory submissions



10.3.2 KP-LULUCF Activities

Information on the reasons for recalculations is included in **Section 10.1.2** and **Section 11.3.1.4**. As the KP-LULUCF Inventory contains both emissions and removals of GHGs, expressing the change in trend from the base year to 2011 as a percentage difference is inappropriate.

10.4 RECALCULATIONS, INCLUDING IN RESPONSE TO THE REVIEW PROCESS, AND PLANNED IMPROVEMENTS TO THE INVENTORY

All recalculations to the inventory, including those made in response to the review process and other recalculations e.g. due to data revisions are described in detail within chapters 3-8, and are summarised in **Table 10.1** and **Table 10.2**. This section of the report summarises all recommendations from the review process, including where these have led to:

- recalculations
- changes in reporting in the NIR
- changes in reporting in the CRF
- planned improvements for future submissions

The UNFCCC conducted a Centralised Review of the 2013 GHGI submission (2013 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 (2013) submission. The review took place during September 2013. A review report has not yet been received; however, improvements have been implemented based on comments provided during the review week and also raised in the Potential Issues of Implementation Saturday Paper.

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 and EU Expert Review Teams.

10.4.1 GHG Inventory

Table 10.4 Brief Details of Improvements to the NIR and the Inventory in response to UNFCCC Reviews in response to the 2013 reviews.

Expert Review Team Comment	Expert Review Team Recommendation	UK GHGI Actions
Recommendations from the centralised review: September 2013		
1A3a Civil aviation In explaining how the UK distinguishes between domestic and international flights, the NIR describes an example concerning a flight that travels from Glasgow-Birmingham-Paris. The UK considers this an international flight, as the final destination is outside the UK. However, it would only be international if there were no passengers of freight loaded/unloaded at the intermediate, domestic stop. The ERT finds this improbable and at least part of the emissions from this type of flight must be included in the national total.	The ERT recommends that the party collect the necessary data to distinguish which intermediate, domestic stops involve loading/unloading passengers and/or freight, calculate the amount of fuel used in the domestic part of these flights, document methodology implemented and include the associated emissions under civil aviation in the energy sector. If detailed data are not available, the ERT recommends the Party consider the approach provided by the UK in response to the ERT.	For the 2014 submission, international flights with an intermediate stop at a domestic airport have been reclassified as having a domestic leg and an international leg. This assumes that all such flights include the on or offloading of passengers and/or freight and is therefore likely a small overestimation.
1A3b Road Transportation As identified in the 2012 annual review report, the UK uses the COPERT IV model to calculate GHG emissions from road transportation. To calculate the CO_2 emissions, the UK scales the AD for fuel consumption to the quantity of fuel sold in the country in accordance with the revised 1996 IPCC Guidelines. However, for CH_4 and N_2O the Party does not scale the AD for fuel consumption to the national total, therefore leading to an underestimate of CH_4 and N_2O emissions. In 2013 the UK did not change the methodology. The ERT concludes that an underestimation still exists and recommends that the UK apply the scaling of fuel consumption for CH_4 and N_2O.	The ERT recommends that the UK apply the scaling of fuel consumption for CH_4 and N_2O.	Emissions of N_2O and CH_4 from transport have been normalised based on fuel sold, following the same approach as used to calculate CO_2. These data are included in the 2014 submission.

Expert Review Team Comment	Expert Review Team Recommendation	UK GHGI Actions
2A2 Lime Production The UK did not include CO_2 emissions from the fraction of CaO remaining in the sugar refinery waste products. Recommend estimating and including the CO_2 emissions related to the remaining CaO; include the amount of limestone of the sugar refinery waste in CRF table 5(V)	ERT recommends that the Party: • Estimate the amount of lime produced or limestone consumed in sugar refineries • Estimate the amount of CaO remaining • Estimate the CO_2 emissions attributable to this amount of CaO • Include the estimated CO_2 emissions under lime production • Include description of methodology behind the emissions estimates under lime production in the NIR	Emission estimates have been revised in the 2014 submission. It is now assumed that the conversion of lime to calcium carbonate is not a complete reaction and that some unreacted lime is present in waste sludges at the end of the carbonatation process.
3D1 The use of N_2O for Anaesthesia Which efforts are planned to estimate the current reported as NE emissions of N_2O from this sector?		The UK does not have any data at the moment on N_2O emissions from the use of N_2O for anaesthesia, and it is assumed to be small. However, the UK has begun dialogue with Royal College of Anaesthetists who is attempting to gather data on N_2O use for anaesthetics, and if this is successful then the UK may be able to provide estimates for this sector. The UK plans to have an estimate ready for the 2015 submission to be consistent with the 2006 Guidelines.

Expert Review Team Comment	Expert Review Team Recommendation	UK GHGI Actions
4A1 Enteric fermentation When estimating the CH_4 emissions from enteric fermentation from cattle, the United Kingdom uses a tier 2 method from the IPCC good practice guidance. For the 2013 annual submission the United Kingdom recalculated the emission estimates for the entire time series due to updated information on the digestibility (DE) rates of the feed. In the recalculation, the United Kingdom increased the DE from 73.8 per cent to 75 per cent. The ERT is of the opinion that there is a lack of transparency in the emission estimates and therefore is unable to conclude if there is an underestimate of CH4 emissions from enteric fermentation from all cattle sub categories.	The ERT recommends that the UK submit documentation and reasoning for the selected feeding components which are used to estimate average feeding plans.	The UK provided information to justify the methodology used to estimate digestibility (DE) based on best available evidence and expert judgement, in accordance with IPCC good practice. The UK responded to the 7 specific points raised by the ERT and trusted that it clarified the UK method, committed to improve transparency of this in the 2014 NIR. The ERT was satisfied with the response. As a result the UK revised the DE value to include decimals as suggested by the ERT to 74.5234143.

Expert Review Team Comment	Expert Review Team Recommendation	UK GHGI Actions
4B(a) Manure Management The use of a an overestimated digestibility (DE) rate of the feed in combination with the tier 2 methodology from the IPCC good practice guidance yields a low amount of excreted manure. If the United Kingdom cannot provide documentation for the currently applied DE rates for all cattle subcategories identified by the ERT, a recalculation of the amount of volatile substance (VS) in the manure is needed in order to avoid an underestimation of the CH_4 emissions from manure management. The ERT has not received further clarification from the United Kingdom on these issues in response to questions raised by the ERT during the review week. Therefore the ERT considers that there is a lack of transparency in the emission estimates and it is unable to conclude if there is an underestimate in the CH_4 emissions from manure management for the cattle subcategories.	The ERT recommends that the UK submit documentation and reasoning for the selected feeding components which are used to estimate average feeding plans including the share of grass from grazing for each cattle category used in the UK inventory. If the UK cannot provide documentation for the currently applied DE rates for all cattle subcategories as identified by the ERT, a recalculation of the amount of volatile substance (VS) in the manure is needed in order to avoid an underestimation of the CH_4 emissions from manure management.	The UK provided information to justify the methodology used to estimate digestibility (DE) based on best available evidence and expert judgement, in accordance with IPCC good practice. The UK responded to the 7 specific points raised by the ERT to clarify the UK method and the transparency of the UK approach has been improved in the 2014 NIR. The ERT was satisfied with the response. As a result the UK revised the DE value to include decimals as suggested by the ERT to 74.5234143.
4B(a) Manure Management The United Kingdom has not supplied the ERT with transparent information on how animal manure is handled today. The ERT concludes that the information provided does not support the assumption that up to 40 per cent of the amount of produced manure is applied to the fields on a daily basis is normal practise today. The ERT therefore considers that a major part of the amount of manure, which in the inventory is currently assumed to be applied on a daily basis, is an overestimate. As a consequence, the amount of stored manure is underestimated, leading to an	The United Kingdom is recommended to provide documentation on current practice for how daily spread of animal manure is taking place today. The documentation should take into account the different climatic conditions for the entire United Kingdom territory, especially for winter conditions. If daily spread is not occurring in winter, documentation for the fractions applied in summer and winter respectively should be included. The documentation should also include if and where this practise (daily spread) is legal according to UK environmental regulations.	The UK provided the following response to the ERT, which was accepted. The UK has re-evaluated the criteria it was using for categorising manure management as ‘Daily spread’ and the proportions of excreta currently assigned to this management category for the different livestock types. The UK does have country-specific information, based on a number of surveys that have been conducted and therefore feels justified in applying country-specific AWMS breakdown rather than using IPCC default values. Survey response data

Expert Review Team Comment	Expert Review Team Recommendation	UK GHGI Actions
underestimation of the CH_4 emissions from stored manure.	If such documentation cannot be given, the ERT recommends that the United Kingdom submit revised CH_4 emissions estimates from manure management for the entire time series with the default assumption for daily spread in tables B-3, B-4 and B-6 of the Revised 1996 IPCC Guidelines (i.e. dairy cattle–20 per cent daily spread, non-dairy cattle–0 per cent and swine–0 per cent).	are analysed, taking into account the number of a given livestock type on each respondent holding such that the results are expressed as proportions of manure generated rather than as proportion of farmers/respondents. Cattle: Previously, survey responses for slurry and deep litter management indicating 'little or no storage' were assumed to be equivalent to 'Daily spread' systems. However, this has been revised such that only slurry systems reporting 'little or no storage' are classified as 'Daily spread'. Deep litter manure will often remain in the house following removal of the animals for a period of weeks or months and may be spread directly to the land with no further storage, or removed from the building and stored on a concrete pad or in a field heap. Previously, that estimated to be spread 'with no further storage' was mistakenly equated with the 'Daily spread' manure management category. Revised estimates for the proportion of slurry that is 'Daily spread' are given in the Table below for each Devolved Administration. There is no differentiation between cattle type, so these values are applied to all cattle. Pigs: The UK agrees that there is no basis for a

Expert Review Team Comment	Expert Review Team Recommendation	UK GHGI Actions
		'Daily spread' system associated with UK pig production systems, so the value for 'Daily spread' for pigs has been revised to 0%. Poultry: Previously used values were based on survey responses indicating 'no storage', but it is now understood that these mostly refer to export of manure from the poultry farm, which will almost certainly then be stored elsewhere. The UK agrees that there is no basis for a 'Daily spread' system associated with UK poultry production systems, so the value for 'Daily spread' for poultry manure has been revised to 0%.
4B(a) Manure Management The United Kingdom has assumed that all "solid manure" is stored as "solid storage" (Table 4.10 in the IPCC good practice guidance). The methane conversion factor (MCF) used is 1 per cent. If the animals are confined and the manure is only removed once or twice per year then the storage systems should be characterized as "deep litter"	As the United Kingdom has acknowledged that the dominant way of handling solid manure is in deep litter systems, the ERT recommends that the United Kingdom submit revised CH_4 emissions estimates for all cattle and sheep categories for the entire time series. The IPCC good practice guidance does not provide any advice on the distribution between solid manure and deep litter systems. Therefore the ERT recommends that the United Kingdom make a split between the two manure management types and document this rationale in a transparent way.	The UK has accepted this recommendation to submit revised CH4 emissions estimates for all cattle and sheep categories for the entire time series and proposes to do so based on the following approach. The UK has no data on the relative proportions of straw-bedded manure that is managed either as 'Solid storage' or as 'Deep litter' and will therefore take the conservative approach of assuming all straw-bedded systems for cattle and pigs are 'Deep litter' and will revise the entire time series accordingly.
4B(b) Manure Management Documentation for the manure application practise for daily spread should be given, explaining the	The United Kingdom is recommended to provide data and documentation for how the daily spread of animal manure is estimated (see Attachment A-6). If	The UK has accepted this recommendation to review the amounts of manure applied as daily spread and proposes to submit a

Expert Review Team Comment	Expert Review Team Recommendation	UK GHGI Actions
percentage of manure that is daily spread. If it is not possible to document the practice of daily spread, the amount of stored manure is underestimated and the associated N_2O emissions from stored manure are also underestimated	the amount of daily spread is revised, the associated change in the amount of manure stored shall be reflected in the N_2O emissions estimated in the inventory. If sufficient documentation cannot be given, the ERT recommends that the United Kingdom submit revised estimates of its N_2O emissions from manure management for the entire time series with the default assumption for daily spread in tables B-3, B-4 and B-6 of the Revised 1996 IPCC Guidelines (i.e. dairy cattle–20 per cent daily spread, non-dairy cattle–0 per cent and swine–0 per cent).	revised Tier 2 time-series, based on the following approach. The UK has re-evaluated the criteria it was using for categorising manure management as 'Daily spread' and the proportions of excreta currently assigned to this management category for the different livestock types. The UK does have country-specific information, based on a number of surveys that have been conducted and therefore feels justified in applying country-specific AWMS breakdown rather than using IPCC default values. Survey response data are analysed, taking into account the number of a given livestock type on each respondent holding such that the results are expressed as proportions of manure generated rather than as proportion of farmers/respondents. Cattle: Previously, survey responses for slurry and deep litter management indicating 'little or no storage' were assumed to be equivalent to 'Daily spread' systems. However, this has been revised such that only slurry systems reporting 'little or no storage' are classified as 'Daily spread'. Deep litter manure will often remain in the house following removal of the animals for a period of weeks or months and may be spread directly to the land with no further storage, or removed from the building and stored on a concrete

Expert Review Team Comment	Expert Review Team Recommendation	UK GHGI Actions
		pad or in a field heap. Previously, that estimated to be spread 'with no further storage' was mistakenly equated with the 'Daily spread' manure management category. Revised estimates for the proportion of slurry that is 'Daily spread' are given in the Table below for each Devolved Administration. There is no differentiation between cattle type, so these values are applied to all cattle. Pigs: The UK agrees that there is no basis for a 'Daily spread' system associated with UK pig production systems, so the value for 'Daily spread' for pigs has been revised to 0%. Poultry: Previously used values were based on survey responses indicating 'no storage', but it is now understood that these mostly refer to export of manure from the poultry farm, which will almost certainly then be stored elsewhere. The UK agrees that there is no basis for a 'Daily spread' system associated with UK poultry production systems, so the value for 'Daily spread' for poultry manure has been revised to 0%.

Expert Review Team Comment	Expert Review Team Recommendation	UK GHGI Actions
4B(a) Manure Management In the current inventory the nitrogen excretion rates (Nex) from dairy cows have been estimated to be 121 kg/dairy cow/year in 2011. In the reporting to EMEP/EEA under the EU National Emission Ceiling a Nex of 123.5 kg/dairy cow/year is reported. In response to questions raised by the ERT during the review to provide a rationale for the difference in reporting to these two organizations, the United Kingdom inventory team acknowledged that there is an error in the current GHG inventory reporting for 2011 in the 2013 annual submission. The Party did not provide a revised Nex in response to the questions raised. Based on the information provided, the ERT concludes that there is a potential underestimation of N_2O emissions.	The ERT recommends that the United Kingdom apply the revised Nex of 123.5 kg/dairy cow/year reported to EMEP/EEA to the estimates for the annual GHG inventory submission and submit revised emissions estimates for 2011.	The UK accepted this recommendation to submit revised Nex estimates for 2011 based on the following approach. The UK applied the revised Nex value of 123.5 kg/dairy cow/year for 2011 and submited a revised emission estimate.
4.D.1.2. Animal manure applied to soil In the current inventory the nitrogen excretion rates (Nex) from dairy cows have been estimated to be 121 kg/dairy cow/year in 2011. In the reporting to EMEP/EEA under the EU National Emission Ceiling a Nex of 123.5 kg/dairy cow/year is reported.	The ERT recommends that the United Kingdom apply the revised Nex of 123.5 kg/dairy cow/year reported to EMEP/EEA to the estimates for the annual GHG inventory submission and submit revised emissions estimates for 2011.	Response as above
4.D.2, Pasture range and paddock In the current inventory the nitrogen excretion rates (Nex) from dairy cows have been estimated to be 121 kg/dairy cow/year in 2011. In the reporting to EMEP/EEA under the EU National Emission Ceiling a Nex of 123.5 kg/dairy cow/year is reported.	The ERT recommends that the United Kingdom apply the revised Nex of 123.5 kg/dairy cow/year reported to EMEP/EEA to the estimates for the annual GHG inventory submission and submit revised emissions estimates for 2011.	Response as above

Expert Review Team Comment	Expert Review Team Recommendation	UK GHGI Actions
4.D.3.1. Indirect emissions from atmospheric deposition In the current inventory the nitrogen excretion rates (Nex) from dairy cows have been estimated to be 121 kg/dairy cow/year in 2011. In the reporting to EMEP/EEA under the EU National Emission Ceiling a Nex of 123.5 kg/dairy cow/year is reported.	The ERT recommends that the United Kingdom apply the revised Nex of 123.5 kg/dairy cow/year reported to EMEP/EEA to the estimates for the annual GHG inventory submission and submit revised emissions estimates for 2011.	Response as above
4.D.3.2. Indirect emissions from leaching and run-off In the current inventory the nitrogen excretion rates (Nex) from dairy cows have been estimated to be 121 kg/dairy cow/year in 2011. In the reporting to EMEP/EEA under the EU National Emission Ceiling a Nex of 123.5 kg/dairy cow/year is reported.	The ERT recommends that the United Kingdom apply the revised Nex of 123.5 kg/dairy cow/year reported to EMEP/EEA to the estimates for the annual GHG inventory submission and submit revised emissions estimates for 2011.	Response as above

Expert Review Team Comment	Expert Review Team Recommendation	UK GHGI Actions
6A Solid waste disposal on land The UK reported that CH_4 capture was estimated based on gas collection efficiency averaged over modern and closed landfill with the recovery rate of 75% which is an expert judgment agreed with peer reviewers in the UK. The assumed collection efficiency of 75% is the highest among Parties. The IPCC good practice guidance indicates that 'Reporting based on metering of all gas recovered for energy utilisation and flaring is consistent with good practice. The use of undocumented estimates of landfill gas recovery potential is not appropriate; as such estimates tend to over-estimate the amount of recovery. The ERT considers that CH_4 recovery of UK assumed for the flared amounts is not based on metering of gas recovery and the subtraction of this amount from CH_4 generated is therefore not in line with IPCC good practice guidance.	The ERT recommends UK to revise the calculation of methane emission from SWDS for the whole time series by using gas recovery data from monitored sources only. Unless well documented monitoring data on flared methane is available, only methane recovery for power generation should be taken into account, and the amount of CH_4 recovery flared should be considered as zero	The UK has revised the calculation of methane emission from SWDS for the whole time series by using gas recovery data supplied by the Environment Agency.

Expert Review Team Comment	UK GHGI Actions	Time frame
Final recommendations from 2012 UNFCCC Review (ARR Report : May 2013)		
General		
Inventory planning: Make better use of the coordination mechanism provided by the National Inventory Steering Committee to ensure that all the agencies/organisations/experts involved in the inventory preparation process better understand the roles of and relationships between all of the agencies and data providers	The UK has continued to build on the relationships within the National Inventory Steering Committee and has introduced clearer governance arrangements for the inventory. For the 2014 submission, NISC representatives are responsible for reviewing and commenting on methodology updates and documentation.	2014 submission.
Inventory planning: Provide additional information on the inventory improvement programme (e.g. regarding priority setting) in the NIR	The UK's Inventory Improvement Programme 2014 is included in **Section 1.2.2.6** of the NIR, with a table of high priority items presented in **Table 1.5**.	2014 submission

Expert Review Team Comment	UK GHGI Actions	Time frame
Inventory planning: Provide a comprehensive improvement plan in the NIR	See above.	2014 submission
Key Category Analysis: Include in the NIR a further brief explanation of what is covered in the qualitative approach	We have improved reporting in the NIR to clarify how the qualitative analysis is conducted and the outcomes from it. A qualitative analysis is conducted annually to ensure significant categories are identified. No additional key categories were identified.	2013 submission
Key Category Analysis: Improve the presentation of the key category assessment information	An improved description of the KCA was included in the 2013 submission. No further feedback was received during the 2013 review.	2013 submission
Recalculations: Include clearer explanations of the recalculations in the NIR	Clearer descriptions of recalculations were included in the 2013 submission. No further feedback was received during the 2013 review.	2013 submission
Time series consistency: Improve time-series consistency or where full consistency is not possible, provide further explanations	Any areas where there are inconsistent time series are explained within the NIR.	2013 submission
QA/QC: Apply the QC procedures consistently to the whole inventory preparation and reporting process	The QA/QC plan has been updated to improve consistency. Ricardo-AEA team members now work alongside CEH and Rothamsted to ensure that similar approaches are used.	2014 submission
Transparency: Focus on the presentation and streamlining of the information provided in the NIR and continue to improve the transparency of the NIR	The UK reviewed and updated the NIR for the 2013 submission to improve transparency. We will continue to work on improving transparency.	Ongoing
Transparency: Undertake a review of the notation keys to ensure the correct ones are being applied	The UK reviewed and updated the notation keys for the 2013 submission. Where changes are made to methodologies, notation keys will continue to be reviewed and updated where appropriate.	2013 submission – and ongoing.
Transparency: Ensure that use of the notation key “IE” is fully transparent by providing adequate explanations of where the corresponding emissions have been included	The UK continues to ensure comments are present wherever IE is used in the CRF.	
Inventory management: Briefly describe in the NIR the roles of Rothamsted Research and CEH (the UK Centre for Ecology and Hydrology) with respect to archiving	A section has been added to the 2014 NIR submission which outlines the roles of Rothamsted Research and CEH with respect to archiving (see **Section 1.6.1.3**)	2014 submission

Expert Review Team Comment	UK GHGI Actions	Time frame
Previous review reports: Provide a table in the NIR that contains all of the recommendations contained in table 8 of the 2012 annual review report together with a short explanation and/or reference to the appropriate section of the NIR in which the recommendation is addressed, including in the inventory improvement plan, as appropriate.	Table included in chapter 10 of NIR (Chapter 5 of short NIR). We will continue to develop the content of this table in order to ensure transparency of responses to previous ERT comments.	Each year.
Previous review reports: Include explicit information in the NIR whenever adjustments have been applied to the inventory, explaining how the UK has responded to the adjustments in subsequent inventories	Adjustments and any subsequent revisions to UK inventory estimates are described where appropriate within the NIR. The one adjustment to the UK GHGI from the 2012 submission was for CH_4 and N_2O emissions from road transport sources, where the method was revised to align the emission totals with fuel sold. This method is retained by the inventory agency and is reported in **Section 3.2.8**.	2013 submission
Energy		
Activity data: Make efforts to incorporate all additional and/or updated information in DUKES, in order to ensure the consistency of all AD in the energy sector	Efforts have been made to incorporate all additional and/or updated information in DUKES. A table was included within the 2013 NIR to explain any deviations from DUKES activity data and to show completeness and consistency of the energy sector.	2013 submission
Activity data: Improve the quality of the AD through DECC and ensure that all major energy-producing companies, outside of the electricity and heat production and refinery activities are included in DUKES	The DECC DUKES team have representatives at the NISC. There is a programme of continuous improvement to ensure completeness.	Ongoing
Activity Data: Improve the use of EU ETS data within the GHG inventory estimates by ensuring that aggregated AD by fuel and category for EU ETS installations are included in the energy balance in DUKES and can be reconciled with the energy statistics, in order to provide more complete and accurate energy use allocation for use in the GHG inventory across the time series	The inventory improvement programme 2013-14 included a task to increase the use of EUETS data in the GHGI for the iron and steel sector and for feedstock use of fuels. The improvement programme for 2014-15 includes a high priority task to continue to use EUETS data, including from the first year of Phase III reporting (i.e. data for 2013), in the GHGI.	2014 submission. Ongoing.
ADs and EFs: Use comparable units for the carbon EFs and PJ for consumption of gaseous fuels	Comparable units are used within the CRF and a new 'additional information' spreadsheet is submitted alongside the UNFCCC submission showing all emission factors in energy terms.	2013 submission

Expert Review Team Comment	UK GHGI Actions	Time frame
QA/QC: Implement its planned efforts on QA/QC procedures during the last step of compilation of the inventory	The QA/QC plan has been updated to ensure better procedures. This is an ongoing programme of improvement.	Ongoing
AD: Improve the consistency of the information reported in the different sectors	A table was included within the 2013 NIR to explain any deviations from DUKES activity data and to show completeness and consistency of the energy sector.	2013 submission
Reference approach: Investigate the reasons for the differences and improve the QC procedures performed prior to the submission of the CRF tables	A review of the reference approach has been conducted for the 2014 submission.	2014 submission
Reference approach: Reconsider the use of the notation key "NA" and closely follow the definitions of the notational keys	A review of the reference approach has been conducted for the 2014 submission.	2014 submission
Feedstocks and non-energy use of fuels: Provide additional information on the categories where feedstocks are used and provide references for the storage fractions	Additional information has been provided in the 2014 NIR to improve the transparency of feedstock and NEU allocations within the UK GHGI, in **Section 3.2.3**. Research into NEU of fuels during 2013-14 led to a revised method for several commodities and a revision to the use of carbon storage fractions. **Annex 4** provides further information.	2014 submission
Stationary combustion: liquid fuels – CO_2, CH_4 and N_2O. Review, through DECC, the allocation of fuels to non-energy uses within DUKES, in order to identify any other misallocations of fuels to non-energy use that may lead to underestimates of emissions in the GHG inventory	See above. The research into NEU of fuels during 2013-14 included the DECC DUKES team, and additional information has been provided on NEU allocations in **Section 3.2.3**. Improvements were made to the completeness of emission estimates from use of feedstock-derived off-gases, reported in 1A2c. We will continue to keep the NEU allocations under review as part of the inventory improvement programme.	2014 submission. Ongoing.
Fugitive emissions from solid fuels –CH_4: Report CH_4 emissions from closed coal mines under the category other, in order to improve the transparency and comparability of the inventory for this category	Emissions from closed coal mines are now reported under a separate category, 1B1c Other.	2013 submission
Industrial processes and solvent and other product use		
Transparency: Improve transparency of the NIR by using tables and figures and providing summarised information on the number of facilities, the changes in production capacities and the abatement measures introduced over the entire time series in relation to complex categories such as I&S production and nitric acid production.	Some additional tables have been included in the 2013 submission. Additional suggestions were put forward during the 2013 centralized review and these will be included where possible in the 2014 UNFCCC submission.	2013 and 2014 submissions

Expert Review Team Comment	UK GHGI Actions	Time frame
AD: Implement the planned category-specific improvements in order to ensure the consistency of the AD and methodologies used	Implemented.	2013 submission
Nitric acid production – N_2O: Improve transparency in the NIR; collection information on the methods used by the plant operators to estimate N2O emissions and ensure the consistency of the data reported across the entire time series	Implemented.	2013 submission
Consumption of halocarbons and SF_6 – HFCs: Report a correct and realistic estimate of the potential and actual emissions ration for the unspecified mix of HFCs for the UK as a whole	FGases have been speciated within the CRF and NIR.	2013 submission
Ammonia production – CO_2: Report on the amount of natural gas used for ammonia production and provide clear explanations of the distribution of natural gas consumption for non-energy use by ammonia production plants	Implemented.	2013 submission
Other (chemical industry(all)) – CH_4: Include additional information in the NIR explaining additional plants/sites were included in the estimates and that the data reported in the regulator's inventories are the best available data for this category for the UK	Additional tables were included in the 2013 submission. Further text to clarify the scope of sources in the UK, the data sources and methods, have been added to the NIR to improve transparency for this source. See **Section 4.13**.	2013 and 2014 submissions
Agriculture		
Recalculations: Revise and improve the descriptions of the recalculations	Implemented.	2014 submission.
Institutional Arrangements: Provide information on any changes in the division or responsibilities regarding the preparation and development of the inventory for the agriculture sector for the Devolved Administrations	No changes planned.	
Transparency: Revise the use of the notation keys applying the correct notation keys consistently across the NIR and the CRF tables	Notation keys have been revised	2014 submission.

Expert Review Team Comment	UK GHGI Actions	Time frame
Enteric Fermentation – CH_4: Incorporate background information on the calculations for the country-specific parameters and a proposal for the correction of anomalies in the time series of live weights for dairy cattle.	Anomalies in dairy cows weight are described in **Section 6.2.2.1** of the 1990-2011 NIR. More details in CS parameters were also included.	2014 submission.
Enteric Fermentation – CH_4: Revise the emission estimates for enteric fermentation for sheep based on the results of the programme of work to improve the methodology for calculating the emissions from this category	Emissions from sheep were revised according to results from ADAS report (More Robust Evidence on the Average Age of UK Lambs at Slaughter, 2012)	2014 submission.
Agricultural soils – N_2O: Develop a country-specific estimate of the area of cultivated histosols as soon as possible and report it in future annual submissions	Country specific value included, consistent with that used in LULUCF.	2014 submission.
LULUCF		
Time series consistency: Prioritise the implementation of the data assimilation process to build the time series of land-use changes and other activities as listed in the improvement plan for the LULUCF sector.	This is included as a priority task on the 2014 improvement programme and is expected to be included in the 2015 submission.	2015 submission
Transparency: Improve the transparency of the information reported in the NIR.	Implemented.	2013 submission
Transparency: Include a full set of annual land-use transition matrices.	Implemented.	2013 submission
Forest land – CO_2: Meet the planned deadline for reporting the carbon stock change estimates using the FC CARBINE model for inclusion in the 2014 annual submission	Implemented.	2014 submission
Forest land – CO_2: meet the planned deadline for reporting the carbon stock change estimates for pre-1920 forest land in the 2014 annual submission	Implemented.	2014 submission
Cropland and grassland-CO_2: Differentiate between mineral and organic soils in the cropland and grassland categories and report the carbon stock changes in mineral and organic soils separately	Changes in grassland and cropland on organic soils are now reported as IE (was previously NO), with the data included in the mineral soil value. The pro rata approach to divide the emissions based upon the total land areas of mineral and organic soil will be investigated for future submissions. This is included in the 2014-15 improvement programme.	2015 submission

Expert Review Team Comment	UK GHGI Actions	Time frame
Land converted to cropland – CO_2: Build a consistent time series of emissions for the OTs and CDs from 1990 onwards.	Implemented.	2014 submission
Waste		
Transparency: Provide information related to the emission estimates for the OTs and CDs in the NIR and CRF tables and improve the description of relevant data in the NIR.	Implemented.	2013 submission
QA/QC: Improve QA/QC procedures in order to ensure consistency throughout the CRF tables and the NIR	The QA/QC plan has been updated to ensure better procedures. This is an ongoing programme of improvement.	Ongoing
Solid waste disposal on land – CH_4: Improve transparency of the explanations of the recalculations performed	Implemented. Clearer descriptions of recalculations were included in the 2013 submission.	2013 submission
Solid waste disposal on land – CH_4:Improve the estimates of the CH_4 collection rate in order to provide better evidence to support the estimates of landfilled waste emissions in the UK	Estimates have been revised in the 2014 submission following a recommendation from the 2013 review.	2014 submission
Wastewater handling – N_2O: Improve the description of the data used and include the explanations provided to the ERT during the review	Implemented.	2013 submission
Wastewater handling – N_2O: Provide in the waste chapter of the NIR, information on the exact location where the N_2O emissions from industrial wastewater reported as IE are included in the CRF tables and on the methodology used for their calculation	Industrial wastewater estimates were included separately for the 2013 submission following the in country review.	2013 submission
Wastewater handling – CH_4: Ensure the accuracy of the data used for the estimates, including the description of and references for the data used and ensure that the applied EFs and fully representative of the activity and emissions for the whole UK	Implemented.	2013 submission
Wastewater handling – CH_4: Provide in the NIR a list of the industries included in the estimate for this category and ensure that the calculation of the CH_4 emission estimates is more transparent	Implemented.	2013 submission
Other		

Expert Review Team Comment	UK GHGI Actions	Time frame
Calculation of the commitment period reserve: Correctly calculate the commitment period reserve in accordance with paragraph 6 of the annex to decision 11/CMP.1	Implemented.	2014 submission. Ongoing.
Article 3, Paragraph 14 of the Kyoto Protocol: Include information on changes in the reporting compared with previous annual submission in accordance with the annex to decision 15/CMP.1 and continue to update such information with the aim of increasing transparency.	Details of all changes to KP reporting methodology since the previous inventory submission are explained fully in the KP-LULUCF chapter of the NIR.	2014 submission. Ongoing.

10.4.2 KP-LULUCF Estimates

Table 10.5 Improvements to KP-LULUCF estimates in response to FCCC Reviews

KP-LULUCF		
Transparency: Report the required information on units of land subject to activities under Article 3, Paragraph 3 of the Kyoto Protocol which would otherwise be included in land subject to elected activities under Article 3, paragraph 4 of the KP in CRF table 5(KP-I)A.1.3	Table 5(KP-I)A.1.3 has not been updated with the individual country areas in the 2013 submission. This will be considered for the next submission.	2015 submission
Include information in **Section 11.2.1** of the NIR describing the spatial assessment unit used and, in accordance with the annex to decision 16/CMP.1, on how it corresponds to the minimum land area and width requirements defined by the United Kingdom's forest definition, and hence the detection of land-use change at the scale consistent with the United Kingdom's forest definition (reiteration of recommendation in the previous review report)	The data sources and methodology can detect a land use change at a resolution consistent with the forest definition in Section 11.1.1 (0.1 ha). ARD and FM are reported at the level of the four countries of the UK: England, Scotland, Wales and Northern Ireland, and the combined area of the Overseas Territories and Crown Dependencies (GPG LULUCF Reporting Method 1). There is sufficiently detailed data to allow UK 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.	2014 submission
Afforestation and reforestation – CO_2: Meet the planned deadline in order to report carbon stock changes estimates using the FC CARBINE model in the 2014 submission.	Implemented.	2014 submission
Deforestation –CO_2: Differentiate between soil organic matter carbon stock changes for mineral and organic soils and estimate the emissions associated with the drainage of organic soils if this practice occurs Use country specific values to estimate the carbon stocks contained in each pool prior to deforestation or provide justification for using a unique biomass factor	Completed as part of CARBINE modelling. Note that soil organic matter carbon stock changes have not yet been separated into organic and mineral soils. Drainage is estimated from both soil types (started for 2013 submission). Country specific values for carbon stocks prior to deforestation are used (started for 2013 submission).	2014 submission
Forest management – CO_2: Meet the planned deadline in order to report the carbon stock change estimates using the FC CARBINE model in the 2014 submission	Implemented.	2014 submission

11 KP-LULUCF

11.1 GENERAL INFORMATION

Emissions sources	Forest Management Afforestation Forest Land
Gases Reported	CO_2, CH_4, N_2O
Methods	NA
Emission Factors	NA
Key Categories (Trends)	See section 1.6.1
Key Categories (Level)	See section 1.6.1
Key Categories (Qualitative)	Not undertaken
Overseas Territories and Crown Dependencies Reporting	OTs and CDs are included at Tier 1 level
Completeness	
Major improvements since last submission	Use of the CARBINE carbon accounting model for carbon stock change modelling. Inclusion of emissions from all pre-1989 forest in the Forest Management category – instead of just from post-1921 forests as was reported in previous submissions. Update to the deforestation areas from 2000 onwards.

11.1.1 Definition of Forest

The UK uses the following definition of forest which has been agreed with the Forestry Commission:

- minimum area of 0.1 hectares
- minimum width of 20 metres
- tree crown cover of at least 20 per cent, or the potential to achieve it
- minimum height of 2 metres, or the potential to achieve it.

This definition includes felled areas awaiting restocking and integral open spaces 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 minimum area of 0.5 hectares and an integral open space

threshold of 0.5 ha. These different thresholds will require adjustment to areas before NFI data can be used for GHGI purposes. Currently 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 were not used for this inventory submission, but will be used once woodland loss estimates are confirmed, which should be in time for the next inventory submission.

11.1.2 Elected activities under Article 3, paragraph 4 of the Kyoto Protocol

The UK has elected 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 MtCO2) per year, or 6.78 MtCO2 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.

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. The Forestry Commission reports new planting by financial year, which runs from 1st April to 31st March. To be compatible with the requirement to demonstrate that activities under Article 3.3 began on or after 1st January 1990, it is therefore necessary to adjust the planting figures. 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 latest reported year. The numbers reported elsewhere in the UNFCCC GHGI are not adjusted (**Figure 11.2**): in 2012 the area of forest established since 1990 was 335,344 ha in the UNFCCC GHGI and 327,387 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 total are of forest in UNFCCC Sector 5A Forest Land**

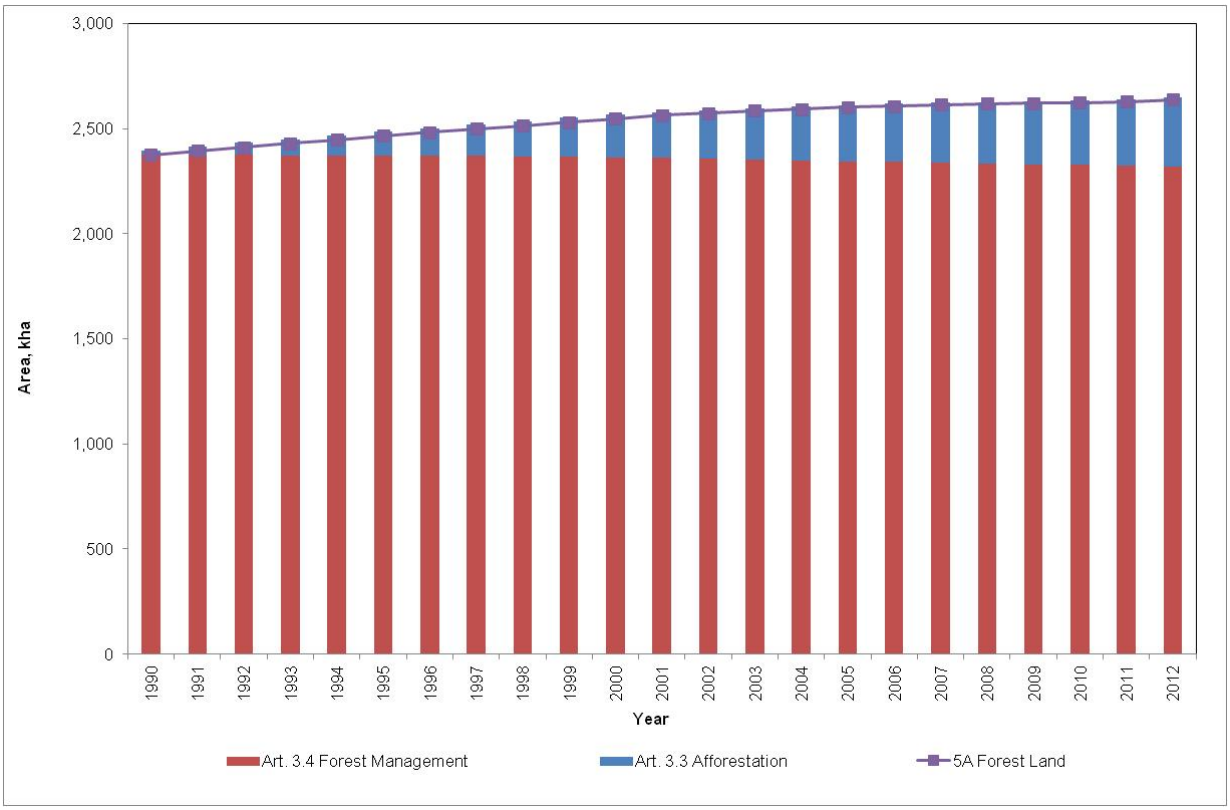
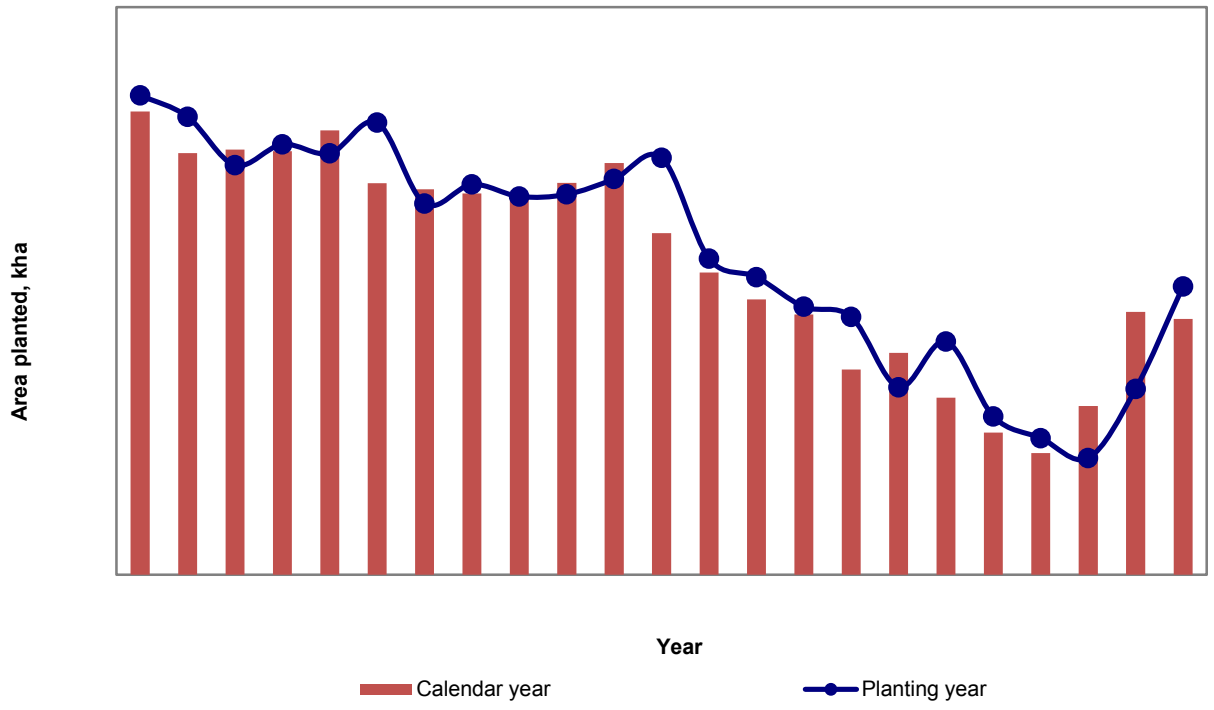


Figure 11.2 **UK afforestation since 1990 in the UNFCCC GHGI (by planting year) and in Article 3.3 (adjusted by calendar year)**



Deforestation since 1990 is 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 1990-2012 matches the area reported under Article 3.3 Deforestation (53.53 kha).

New estimates of woodland loss from the NFI have yet to be fully reconciled with inventory reporting. 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. 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 is expected to increase significantly once smaller areas of loss are examined. Deforestation rates from 2000 onwards have increased using expert knowledge from representatives of the devolved administrations in the Forestry Commission and Natural Resources Wales. The NFI statistics used in previous submissions were deemed to underestimate deforestation.

The Forest Management area is the area established before the end of 1989 adjusted to reflect losses from deforestation. In the UNFCCC GHGI the deforestation area is deducted from the 5A1 Forest remaining Forest Land area, and carbon stock changes are adjusted accordingly. The area of Forest Management and the area of 5A1 Forest remaining Forest are comparable in 2010 at 2325 and 2335 kha, respectively. as the area of 5A1 in 2010 will include all forest planting up until 1990.

Afforestation and reforestation are considered together using datasets 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, although this may be 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 reducing stocking density from its previous level). 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 and expert opinion 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

This is 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, as described in 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 the information is 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** (0.1ha).

ARD and FM are reported at the level of the four countries of the UK: England, Scotland, Wales and Northern Ireland, and the combined area of the Overseas Territories and Crown Dependencies (GPG LULUCF Reporting Method 1). There is sufficiently detailed data to allow UK 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.

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 for England, Scotland and Wales, and from 1900 to the present by the Northern Ireland Forest Service. For England, Scotland and Wales estimates of the planting years for pre-1921 planting area were made using information on the distribution of forest area by age class from the National Inventory of Woodland and Trees and an algorithm to assign areas of forest to years based on assumed management and rotation length. 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, so it is assumed that for areas that have been afforested since 1990 very little deforestation will have taken place. 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. In this submission deforestation rates were increased from 2000 onwards based on expert knowledge from representatives of the devolved administrations in the Forestry Commission and Natural Resources Wales. The NFI statistics used in previous submissions were deemed to underestimate deforestation. Gap-filling for conversions to other land use types 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 before 1990, adjusted to take account of the area lost by deforestation (**Figure 11.5**). The area of Other Land in table NIR 2 is adjusted 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 Land area and changes in land areas in 2012 (including area of Overseas Territories and Crown Dependencies)

To current inventory year (2012)			Article 3.3 activities		Article 3.4 activities	Other	Total (beginning of year)
From previous inventory year (2011)			Afforestation and Reforestation	Deforestation	Forest Management		
Article 3.3 activities	Afforestation and Reforestation	kha	316.30	0.00			316.30
	Deforestation			50.49			50.49
Article 3.4 activities	Forest Management			3.04	2,325.39		2,328.43
Other			11.09	0.00	0.00	23,043.35	23,054.44
Total (end of year)			327.39	53.53	2,325.39	23,043.35	25,749.66

Figure 11.3 Forest area planted since 1990 in the countries, Overseas Territories and Crown Dependencies of the United Kingdom.

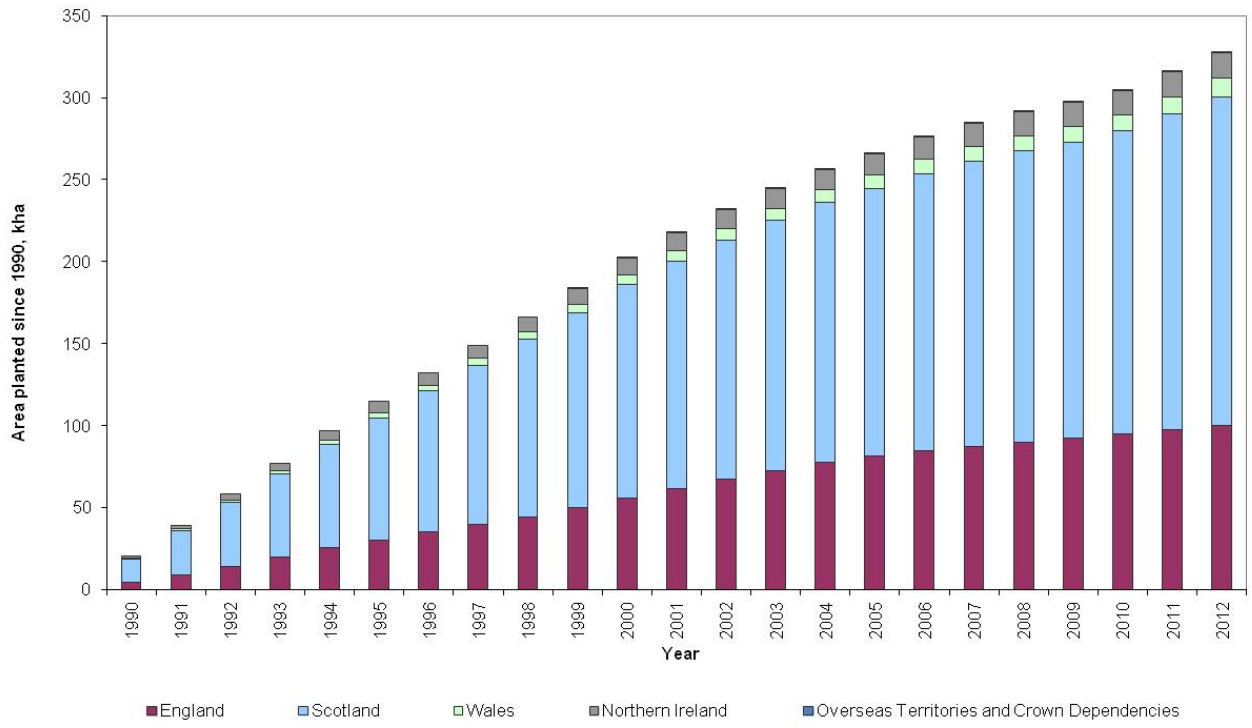


Figure 11.4 **Area deforested since 1990 in the countries of the United Kingdom (note different scale from previous figure, no deforestation is estimated to have occurred in the OTs and CDs)**

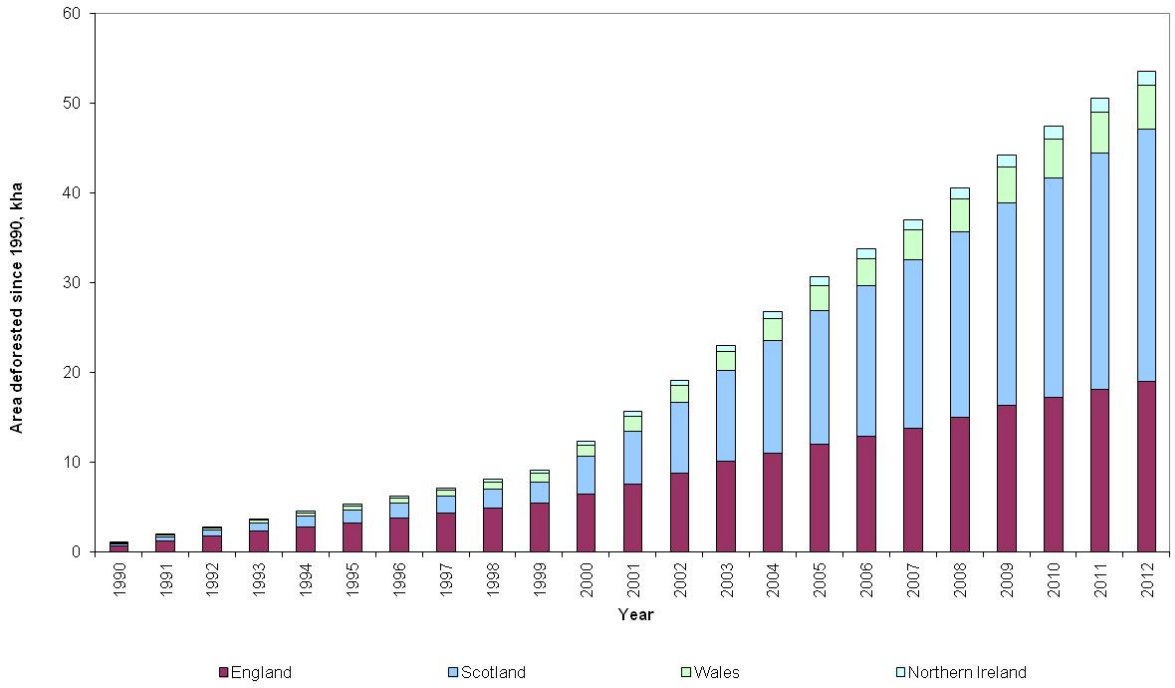


Figure 11.5 **Area of Forest Management land 1990-2012 in the countries, Overseas Territories and Crown Dependencies of the United Kingdom (note different scale from previous figures)**

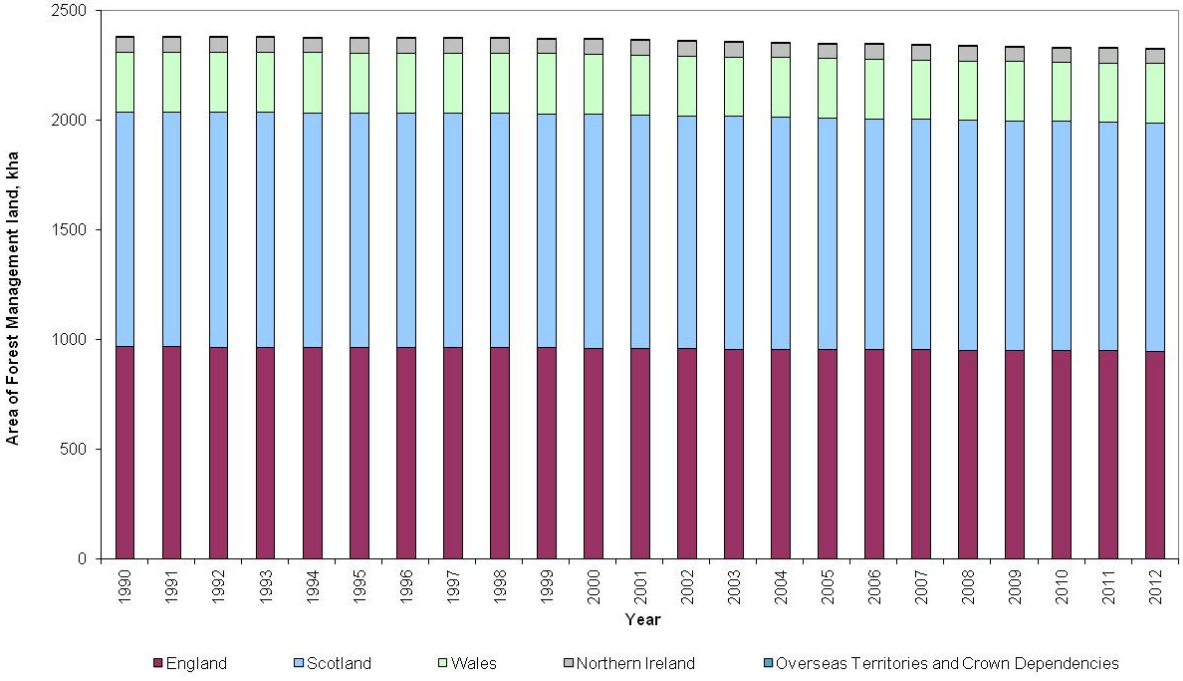


Table 11.2 Data Sources on Afforestation, Reforestation and Deforestation (ARD), and Forest Management (FM) Activities

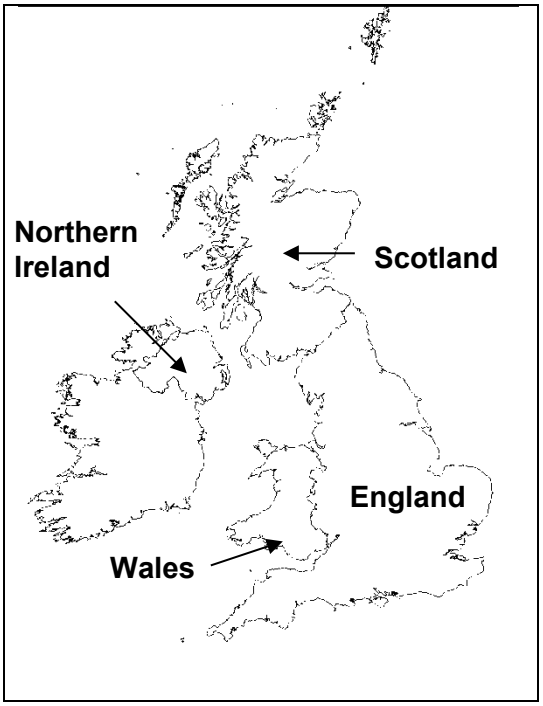
Activity	Dataset	Available scale	Time period	Details
AR & FM	Annual planting statistics	Country (England, Scotland, Wales, Northern Ireland)	1921 - 2012	New planting on previously non-forested land. Updated annually. Categorized into conifer and broadleaved woodland.
AR & FM	Annual restocking statistics	Country (England, Scotland, Wales, Northern Ireland)	1976 - 2012	Restocking of existing forest. Updated annually. Categorized into conifer and broadleaved forest. http://www.forestry.gov.uk/forestry/infd-7aqknx. Used to estimate the pre-1921 planting years.
AR & FM	National Inventory of Woodland and Trees	Country (England, Scotland, Wales)	2000	Inventory of conifer and broadleaf forest area by age class for a base year of 2000. Used to estimate the pre-1921 planting years.
AR & FM	Forestry Commission Subcompartment Database	Every area of forest managed as part of the public forest estate	2011	Contains information on the growth rate and management of every area of forest in the public forest estate. Used to estimate the distribution of tree species, growth rates and management of forests.
AR & FM	Timber production statistics	Country (England, Scotland, Wales, Northern Ireland)	1970 - 2012	Estimates from the Forestry Commission of timber production by year based on outturns from sawmills http://www.forestry.gov.uk/forestry/infd-7aql5b. Used to estimate the percentage of private sector woodland that is managed (thinned or felled).
D	Forestry Commission Unconditional Felling Licence data	England, Scotland, Wales	England: 1992-2012; Scotland: 1998-2012; Wales: 1996-2012	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 are extrapolated to GB scale and to current reporting year.

Activity	Dataset	Available scale	Time period	Details
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). The CS over-estimates 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.
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.
D	Forestry Commission Expert Opinion	England, Scotland, Wales	2000-2012	Update to the deforestation to grassland areas based on expert opinion within the Forestry Commission.

11.2.3 Maps and database to identify the geographical locations, and the system of identification codes for the geographical locations

The constituent countries of the United Kingdom have been used as the geographical units for reporting (**Figure 11.6**). The Forestry Commission and Forest Service for Northern Ireland maintain administrative systems that allow areas of land to be tracked within each country. These are known as sub-compartment databases for state forests and grant scheme data for other woodland.

Figure 11.6 Geographical areas 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 3.6.1** A carbon accounting model, CARBINE, 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, because below-ground biomass is calculated as part of the above-ground biomass and dead wood is calculated as part of the litter pool. CARBINE will be revised in time for the next submission to give separate above ground and below ground biomass data.

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 does not pay grants prior to the planting taking place so it is assumed the areas are 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 3.6.4**). During deforestation, 40% of the above-ground biomass is assumed to be 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 3.6. 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 CARBINE model, as described in **Annex 3.6.4**. 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 3.6.1.2**. 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
The method used to estimate emissions is the same as that used in the UNFCCC greenhouse gas inventory and described in **Annex 3.6.1.3** Drainage of forest land only occurs on certain soil types in the UK (see Annex 3.7 for more detail).

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 3.6), 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 3.6. 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 7:50 for the UK in 2012). As described above, it is assumed that 40% of the standing biomass and DOM 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. However, it is possible for previously deforested land to undergo wildfire (for example on restored heathland). The new wildfire activity data are spatially explicit, so it was possible to assess whether there was any co-location of deforested areas (from the unconditional felling licence dataset) and wildfires. There have been two occurrences of wildfires on previously deforested land, one in England in 2010 (57 ha) and one in Scotland in 2012 (200 ha). Estimated emissions from these events are included in Table 5(KP-II)5.

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

For areas that have been afforested since 1990 it is assumed that very little harvesting has taken place in the period 1990-2012, so carbon stock changes in this table are reported as IE (Included Elsewhere). There is an assumption that the species planted are managed with harvesting at a range of ages almost all greater than the current age of the 1990 trees. If any units of land planted since 1990 have been harvested then they are included with the 5(KP-I)A.1.1.

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. All forest land that is not reported under Article 3.3 is otherwise reported under Article 3.4 Forest Management.

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, and therefore that no N fertilization occurs on Forest Management land.

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 for management 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 other years). Wildfires on deforested land will be reported when they occur (as has happened in 2010 and 2012) but they are infrequent, so otherwise they will be reported as Not Occurring.

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 CARBINE 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 fifth official submission of Article 3.3 and Article 3.4 estimates, and some recalculations have been made since the previous submission. This is due to the inclusion of carbon stock changes from pre-1921 forest and more detailed representation of the tree species, growth rates and management practices used in the UK, which all arise from the move to using the CARBINE model. In addition, the emissions from wildfires on Forest Land are now calculated using the data on biomass and dead organic matter carbon stocks calculated by CARBINE. The deforestation areas for 2000 onwards were also updated for this submission. Full details of the changes listed and additional minor changes are detailed in **Table 11.3**.

Table 11.3 Recalculations of 2011 emissions/removals in the 2014 KP-LULUCF submission

IPCC Category	Source Name	2013 Submission 2011	2014 Submission 2011	Units	Comment/Justification
KP.A.1.1	Carbon stock change in mineral soils	61.76	313.61	Gg C	Change to using the CARBINE carbon accounting model for forest modelling. Afforestation areas changed slightly due to update of new planting and increased accuracy.
KP.A.1.1	Carbon stock change in organic soils	13.01	67.67	Gg C	
KP.A.1.1	Carbon stock change in above-ground biomass - gains	1685.98	373.63	Gg C	
KP.A.1.1	Carbon stock change in above-ground biomass - losses	-947.57	-15.62	Gg C	
KP.A.1.1	Carbon stock change in litter - net change	26.83	18.11	Gg C	
KP.A.1.1/5(KP-II)1	Direct N2O emissions from N fertilization	0.01	0.01	Gg N2O	Afforestation areas changed slightly due to update of new planting and increased accuracy.
KP.A.1.1/5(KP-II)5	Biomass burning - wildfires	17.91	8.78	Gg C	Change to using the CARBINE carbon accounting model for forest modelling leading to updated biomass densities. Update to IRS (fire service database) activity data.
KP.A.1.1/5(KP-II)5	Biomass burning - wildfires	0.06	0.03	Gg CH4	
KP.A.1.1/5(KP-II)5	Biomass burning - wildfires	0.00	0.00	Gg N2O	
KP.A.2	Carbon stock change in above-ground biomass - losses	-63.74	-134.39	Gg C	Change to using the CARBINE carbon accounting model for forest modelling. Update to deforestation area estimate.
KP.A.2	Carbon stock change in litter - net change	-8.07	-21.70	Gg C	
KP.A.2/5(KP-II)4	Carbon emissions from lime application.	0.01	0.01	Gg C	Inclusion of LimeX data (limestone by-products from sugar refinery applied to soils). Correct 2011 values of the volume of limestone and dolomite sold for liming now available.

IPCC Category	Source Name	2013 Submission 2011	2014 Submission 2011	Units	Comment/Justification
KP.A.2/5(KP-II)5	Biomass burning - controlled burning	157.98	343.39	Gg C	Change to using the CARBINE carbon accounting model for forest modelling leading to updated biomass densities.
		0.69	1.50	Gg CH4	
		0.00	0.01	Gg N2O	
KP.B.1	Carbon stock change in mineral soils	616.52	471.01	Gg C	Change to using the CARBINE carbon accounting model for forest modelling. Afforestation areas changed slightly due to update of new planting and increased accuracy.
KP.B.1	Carbon stock change in organic soils	124.27	189.58	Gg C	
KP.B.1	Carbon stock change in above-ground biomass - gains	9506.31	5977.51	Gg C	
KP.B.1	Carbon stock change in above-ground biomass - losses	-8856.52	-3000.60	Gg C	
KP.B.1	Carbon stock change in litter - net change	603.28	491.45	Gg C	
KP.B.1/5(KP-II)2	N2O emissions from drainage of soils	0.12	0.13	Gg N2O	Total Forest Management area changed due to move to CARBINE model.
KP.B.1/5(KP-II)5	Biomass burning - wildfires	81.59	45.38	Gg C	Change to using the CARBINE carbon accounting model for forest modelling leading to updated biomass densities. Update to IRS (fire service database) activity data.
		0.27	0.16	Gg CH4	
		0.02	0.01	Gg N2O	

11.3.1.5 Uncertainty estimates

Uncertainty assessment and quantification of the inventory was undertaken during 2007-2009, with particular focus on the forest carbon modelling components (van Oijen 2007; 2008; 2009; van Oijen and Thomson 2010). This analysis was based on the previously used carbon accounting model used to model carbon pools and fluxes in UK forests, CFlow (Dewar and Cannell 1992), but much of the analysis will also apply to the CARBINE model (described in Annex 3.6) as they are very similar models, though CARBINE allows wider range of representation of species, growth rates (yield class) and assumed management. 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 (see Chapter 11, Section 11.3.1.5).

This work has not yet produced a simple uncertainty estimate for reporting, and work is continuing in this area. Meanwhile, 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).

Uncertainty from model inputs.

CARBINE requires input data on the afforestation rate (ha yr^{-1}), species, yield class (mean wood volume production at time of maximum mean annual increment, m^3 ha^{-1} yr^{-1}), whether the forest is thinned and felled, the age of harvesting, and whether the forest is clearfelled or not for different forest types and countries in the UK. The management and yield class of private sector woodlands is assumed to be the same as for the public forest estate. Information on the percentage of private sector woodland in production was estimated for each country by comparing the timber production estimated by CARBINE to the timber production statistics for each country.

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.). Similarly no measures of statistical uncertainty are available for the estimated pre-1920 planting data derived from the National Inventory of Woodlands and Trees. Future work will involve the use of data from the National Forest Inventory, which does have estimates of the sampling error.

11.3.1.6 Information on other methodological issues

Disturbances.

Data are available on fire damage to state-managed forests and extrapolated to privately-managed forests (see **Chapter 7** and **Annex 3.6** for further details). No data are 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 CARBINE 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.

11.3.1.7 The year of the onset of an activity, if after 2008

5,718 ha of land were afforested in 2009, 7,529 ha in 2010, 11,603 ha in 2011 and 11,085 in 2012. 3,583 ha of land were deforested in 2009, 3,245 ha in 2010, 3,121 ha in 2011 and 3,037 in 2012. These values have changed since the last submission due to changes in the activity data, see **Table 11.3** for more information.

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 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 and expert judgement of the forestry representatives of the devolved administrations 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 confuse 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 has been partially completed, but can only currently identify deforestation where it is obvious that forest has been converted to another land use. It has been necessary to supplement this information with the expert judgement of the forestry representatives from the devolved administrations.

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 before 1989) are included in Article 3.4 Forest Management because forest management is an on-going activity. The CARBINE 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 2013, 1362 kha of woodland in the UK (44%) was certified under the FSC scheme (Forestry Statistics 2013). 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 certified (22% in 2013). These percentages have changed with the change in

woodland areas from the NIWT to the NFI baseline. Some sustainably managed woodland is not included in the certification, including smaller or non-timber producing woodlands where certification is not considered worthwhile. In particular, many broadleaved woodlands may be omitted, 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 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 (2012) based on level of emissions (including LULUCF).

Article 3.3 Afforestation and Reforestation (CO_2): The associated UNFCCC category 5A (-16 723 Gg CO_2) is a key category and the AR component (forest planted since 1990) is key on its own (i.e. its category contribution (-2 918 Gg CO_2) is greater than the smallest UNFCCC key category (2B5 Non-energy use of products)). 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 (11 173, -7 728 and 6 376 Gg CO_2 respectively). However, the Deforestation category contribution (1 045 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 (-16 723 Gg CO_2). The Forest Management category contribution (-14 626 Gg CO_2) is also greater than other categories in the UNFCCC key category analysis.

These categories have all had major recalculations this year due to the move to using the CARBINE carbon accounting model for forest carbon stock change modelling, the inclusion of all pre-1921 forest and increased deforestation rates from 2000 onwards (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 2013 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 within file:

SEF_GB_2014_1_17-6-31 9-1-2014.xls.

12.2 SUMMARY OF INFORMATION REPORTED IN THE SEF TABLES

At the end of 2013, there were 3,305,995,698 AAUs in the UK registry of which 2,375,484,897 were in the party holding account, 8,180,485 in the entity holding account, 45,658 in other cancellation accounts and 922,284,658 in the retirement account. The registry also contained a total of 92,942,547 CERs and 65,124,830 ERUs.

In total for 2013, the UK Registry received 10,191,419 AAUs, 107,600,756 ERUs, and 108,027,261 CERs. Conversely, 456,213,164 AAUs, 131,085,187 ERUs, and 79,913,036 CERs were externally transferred to other national registries.

During 2013, no units of any type 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/ and also on www.gov.uk when the transition to this website is complete.

Annual Submission Item	Reporting Guidance
15/CMP.1 annex I.E paragraph 11: Standard electronic format (SEF)	UK's Standard Electronic Format report for 2013 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_2014_1_17-6-31 9-1-2014.xls The contents of the SEF report (R1) can also be found in **Annex 6** of this document.

12.3 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, SIAR Reports 2013-GB v1.0.xls The contents of the Report R2 can also be found in **Annex 6** of this document.
15/CMP.1 annex I.E paragraph 13 & 14: List of CDM notifications	No CDM notifications occurred in 2013. Refer to Separate Electronic Attachment "SIAR Reports 2013-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 2013. Refer to Separate Electronic Attachment "SIAR Reports 2013-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 2013. Refer to Separate Electronic Attachment "SIAR Reports 2013-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

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 new.gov website at; https://www.gov.uk/ A search on the website for 'Public Reports – EU ETS' and Public Report – Kyoto' will navigate you to the correct webpage. 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)

Annual Submission Item	Reporting Guidance
	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 2012. 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

Annual Submission Item	Reporting Guidance
	No ERUs, CERs, AAUs nor RMUs have been retired. 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)

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: 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 (2010) = 5 x 599,414,598,273,265 tonnes CO2 equivalent = 2,997,072,992,201,366,325 tonnes CO2 equivalent The lower of the two numbers is that calculated as 90 per cent of the UK's assigned amount. The UK's Commitment Period Reserve is therefore **2,997,072,992,070,872,567 tonnes of CO2 equivalent (or assigned amount units)**. The 1990-2010 inventory has been taken as the most recently reviewed inventory, because the report of the 1990-2011 inventory is not yet finalised.

13 Information on Changes to the National System

13.1 CHANGES TO THE NATIONAL SYSTEM

There have been no changes to the National System since the 2013 inventory submission. Key roles within the National Inventory System remain the same, as shown in **Table 1.3** in the Introduction.

14 Information on Changes to the National Registry

The following changes to the national registry of United Kingdom have occurred in 2013.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(a) Change of name or contact	No change of name or contact during the reporting period.
15/CMP.1 annex II.E paragraph 32.(b) Change regarding cooperation arrangement	No change of cooperation arrangement occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(c) Change to database structure or the capacity of national registry	An updated diagram of the database structure is attached as Annex A. Iteration 5 of the national registry released in January 2013 and Iteration 6 of the national registry released in June 2013 introduces changes in the structure of the database. Changes introduced in release 5 and 6 of the national registry were limited and only affected EU ETS functionality. No change was required to the database and application backup plan or to the disaster recovery plan. No change to the capacity of the national registry occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(d) Change regarding conformance to technical standards	Changes introduced in release 5 and 6 of the national registry were limited and only affected EU ETS functionality. However, each release of the registry is subject to both regression testing and tests related to new functionality. These tests also include thorough testing against the DES and were successfully carried out prior to the relevant major release of the version to Production (see Annex B). Annex H testing was carried out in February 2014 and the successful test report has been attached. No other change in the registry's conformance to the technical standards occurred for the reported period.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(e) Change to discrepancies procedures	No change of discrepancies procedures occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(f) Change regarding security	No change of security measures occurred during the reporting period
15/CMP.1 annex II.E paragraph 32.(g) Change to list of publicly available information	The following information is now deemed publicly accessible and as such is available via the new.gov website at; https://www.gov.uk/ A search on the website for 'Public Reports – EU ETS' and Public Report – Kyoto' will navigate you to the correct webpage.
15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address	No change of the registry internet address occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(i) Change regarding data integrity measures	No change of data integrity measures occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(j) Change regarding test results	Changes introduced in release 5 and 6 of the national registry were limited and only affected EU ETS functionality. Both regression testing and tests on the new functionality were successfully carried out prior to release of the version to Production. The site acceptance test was carried out by quality assurance consultants on behalf of and assisted by the European Commission; the report is attached as Annex B. Annex H testing was carried out in February 2014 and the successful test report has been attached.
The previous Annual Review recommendations	None

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. This chapter has been updated for the 2014 NIR submission.

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 ongoing work include:

To support the UK 2050 Pathways Analysis DECC developed a 2050 Energy and Emissions Calculator model. The Calculator is a tool that helps strengthen the level of debate on energy issues in the UK. DECC is now supporting countries around the world to develop their own calculators to explore their options to reduce greenhouse gas emissions and help tackle energy challenges.

- The DECC 2050 team works with teams in India, Indonesia, Brazil, Mexico, Colombia, Nigeria, South Africa, Algeria, Vietnam, Thailand and Bangladesh. In February 2014 a team from the Indian Government Planning Commissions published their version of the 2050 tool (http://www.indiaenergy.gov.in/).
- DECC is also working in collaboration with a number of other organisations to build a Global Calculator, which will enable users to explore the options for reducing global emissions, and the impact of climate change associated with them. Please see the Global Calculator website for more information on the project (https://www.gov.uk/government/publications/the-global-calculator/the-global-calculator).

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[48].
- In 2013 the Department of Transport published a report on the sustainability of feedstock[49].

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[50].

  This year's output from the monitoring, which is published in the Official Statistics Release, can be found online[51].

[48] http://www.dft.gov.uk/publications/regional-level-actions-to-avoid-iluc
[49] https://www.gov.uk/government/publications/biofuel-research
[50] 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
[51] http://www.defra.gov.uk/statistics/environment/green-economy/scptb01-ems/

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.
- 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% below 2005 levels by 2020. For the EU as whole, the reduction target is approximately 10%. The Decision promotes domestic action and limits the use of international project credits, such as the Clean Development Mechanism (CDM), to meet targets. They are limited (annually) to 3% of Member States' 2005 emissions in the non-ETS.
- A Renewables Directive sets targets for each member state for the proportion of renewable energy generation by 2020. The EU has a 20% renewables target by 2020. The UK's legally binding target is 15%. The Renewables Directive also set every Member State a target of supplying 10% of transport fuel from renewable sources by 2020.
- The Directive on the geological storage of CO_2 outlines a regulatory framework for the safe capture, transport and storage of carbon dioxide in the EU. Up to 300 million allowances from the new entrants reserve of the EU ETS will be used to support the demonstration of carbon capture and storage (CCS) and innovative renewable technologies. The UK's actions on CCS are expanded in the sections below.

Further information can be found in the 1990-2009 EU inventory report.

15.2.3 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 has taken action to minimize adverse impacts in accordance with article 3, paragraph 14 through fast start finance. Additionally, the UK's International Climate Fund (ICF) will provide £3.87bn of climate finance from 2011 to 2016. 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. The ICF also demonstrates the UK's commitment to scaling up climate finance beyond the fast start period to meet its fair share of $100bn of public and private international finance per year from 2020.

15.2.4 The International Climate Fund (ICF)

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. Detailed information on the fund, including on the projects that it is supporting, can be found on our website[52]. Some examples of the types of projects that are supported by the fund follow:

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.

ICF funds of £98million over 2012 to 2015 will support the Green Africa Power (GAP) project, to tackle specific constraints to private sector investment in renewable power generation in Africa. The UK will provide £95 million to capitalise GAP - a new company that will be established under the Private Infrastructure Development Group (PIDG) Trust. GAP will invest in renewable energy projects to demonstrate the viability of renewable energy in Africa so that future projects are more likely to happen and attract private developers and investors. A further £3 million will be used to set up the project, monitor and evaluate these impacts and capture and disseminate this knowledge. GAP aims to support projects that will install ~270MW of renewable energy in Africa in 4 years, avoiding an estimated 2.3m tonnes of CO2 emissions.

A £15m grant will support the growth of silvopastoral systems (SPS) in Colombia to reduce greenhouse gas emissions, improve the livelihood of farmers, protect local forests and increase biodiversity. Agriculture is one of the biggest sources of greenhouse gas emissions in Colombia and many other developing countries, and a key driver of deforestation. Addressing this fact, the UK and partners are working with cattle ranchers to improve degraded grazing land by using SPS. This means managing the land in a different way: planting trees, shrubs, fodder crops and living fences and conserving existing forest. Participating small farmers, the majority of whom are living in conditions of rural poverty, are able to raise more, healthier cattle on their existing land using SPS, increasing their income and reducing the need to clear forest. This project aims to convert 28,000 hectares of grazing land to SPS, saving around 2MtCO2e over the next 8 years, and create a strategy for increasing the use of SPS in Colombia and beyond.
The UK has also contributed £7m and technical support to the World Bank's Partnership for Market Readiness to help developing countries design market-based mechanisms for reducing their greenhouse gas emissions. This will foster increased investment in green

[52] https://www.gov.uk/government/policies/taking-international-action-to-mitigate-climate-change/supporting-pages/international-climate-fund-icf

technologies across the world and help stimulate private sector low carbon investment opportunities. The Partnership aims to increase the number of experts in 16 developing countries to design and implement market-based schemes, and create a knowledge sharing forum.

To date the UK has contributed an estimated $1.4 billion to the Climate Investment Funds. These funds include 4 key programmes that help 48 developing countries pilot low-emission and climate resilient development. Scaling up Renewable Energy Program (SREP) is an example if one of these programmes, which aims to help to support securing access to clean energy including in Ethiopia, Honduras, Kenya, Mali, Liberia, Maldives, Nepal, and Tanzania. 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.

The UK has committed up to £60 million of finance from the ICF to support developing countries to develop both the technical and institutional knowledge necessary to enable the deployment of CCS technologies. The UK has agreed to fund £35m and £25m respectively to Asian Development Bank and World Bank Trust Funds to support CCS capacity building projects. Financial support would be channelled toward a range of projects in China, South Africa and Indonesia with the aim of ensuring sufficient political support is created to pave the way for full scale demonstration and ultimately the deployment of CCS.

The Nationally Appropriate Mitigation Actions (NAMA) Facility was launched by the UK and German governments in December 2012. The UK has committed £50 million (approximately €60 million) to the NAMA Facility with Germany committing another €60 million. The Facility will fund the most transformational parts of NAMA plans. NAMAs are concrete projects, policies, or programmes that shift a technology or sector in a country onto a low-carbon development trajectory. This project will focus on those parts of the projects that are stretching and aspirational, that are pushing to do much more than business as usual to mitigate the impacts of climate change.

15.2.5 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 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 supporting the concept of Climate Innovation Centres (CICs) in developing countries, including in Kenya, Ethiopia and Vietnam. These centres will provide a national focal point for innovation in and deployment of climate-friendly technologies, providing business development support to SMEs through mentoring and training; the provision of technological and office facilities, R&D grants and seed capital investments; links to local universities; links to local financiers establishing links to government and conducting market analysis and research within that country. The Global Network of Climate Technology Innovation Centres, funded through the ICF, supports the design and establishment of 9 new CICs will be linked to other CICs by InfoDev (the implementing partner) and the coordination of the growing network of the CICs to encourage cross-border learning and knowledge sharing. The first centre has opened in Kenya in September 2012, with Ethiopia closely following. Scoping work is also underway in other countries.

15.2.6 Research Collaboration

Enhancing global collaboration on research, development and demonstration (RD&D) will be essential to ensure innovation and take-up of climate technologies in developing countries. The UK is cooperating in the technological development of non-energy uses of fossil fuels, and doing so in partnership and supporting developing countries. We are exploring opportunities to support RD&D 'gap-filling' activity on climate technologies (both for mitigation/low carbon development and adaptation activities).

Recent examples of this commitment to collaborative research are 2010-2011 projects on low carbon technology transfer to China and India that the Department of Energy and Climate Change has supports. The main focus of the studies is to provide new empirical evidence to low carbon innovation in developing countries to inform international policy development. Both studies feature a range of low carbon technologies and examine the factors that influence innovation and technology transfer, including technological capacity, access to intellectual property rights and the role of policy frameworks.

The Department for Energy and Climate Change (DECC) in collaboration with Department for International Development (DFID) and the Engineering and Physical Sciences Research Council (EPSRC), on behalf of the Research Councils UK (RCUK) are jointly funding a programme of research in the field of energy and international development. Understanding Sustainable Energy Solutions in Developing Countries (USES) is the first major joint call between DFID, DECC and EPSRC. With a focus on research that will improve our understanding of the opportunities and challenges associated with scaling up sustainable access to modern energy services in developing countries, the Programme has been established to help build the evidence base that supports how the UK will spend its International Climate Fund (ICF)

The programme is supporting 12 projects between UK and developing country institutions. It is hoped that this will deliver high quality research that addresses key development challenges in one or more of the following five areas: bioenergy; solar; decentralised generation; urban and transport; and energy efficiency.

International engagement is a significant part of the Avoiding Dangerous Climate Change Research Programme (AVOID). For example the first phase of the programme investigated technology options for reducing CO2 emissions from the energy sector in India and China in order to meet a national 2050 emissions target consistent with limiting global temperature rise to below 2°C, and shared these results with Indian and Chinese officials at international

workshops. The second phase of AVOID was commissioned in early 2014 and will involve a 2-year work programme including extensive engagement with international researchers and officials on a range of issues including regional climate impacts, feasibility of energy sector decarbonisation and the potential role of land-use in both mitigating and contributing to climate change.

The UK is playing a key role on promoting knowledge sharing and capacity building in developing countries on Carbon Capture & Storage (CCS). The UK has committed up to £60 million of finance from the International Climate Fund (ICF) to support developing countries to develop both the technical and institutional knowledge necessary to enable the deployment of CCS technologies. The UK continues to jointly lead with Australia the CCUS initiative under the Clean Energy Ministerial, the next meeting of which will be held in Korea in May 2014 involving governments of both developed and developing nations. The UK is active in a number of multilateral organisations such as the Carbon Sequestration Leadership Forum (CSLF) which aims to promote the deployment of CCS worldwide in both developed and developing countries. In addition, in April 2013 the UK co-hosted the third 4 Kingdoms Initiative workshop with the government of Norway, bringing together representatives of four oil-producing countries to drive efforts to reduce the economic losses of CCS through alternative uses for CO_2.

15.2.7 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 £385m 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 is working within the International Partnership for Energy Efficiency Co-operation (IPEEC) with key developed and developing countries 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 (UK-led) and capacity building activities.

15.2.8 Capacity Building Projects on Adapting to Climate Change

The UK Government is working to address 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.

As a consequence 50% of ICF funding is allocated for adaptation which is being used for practical on-the-ground support for the climate vulnerable, building climate knowledge and developing capacity in climate vulnerable countries. By 2015 the UK aims to have provided support to over 20m climate vulnerable people.

Examples include:

- £100m 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.

- £50m in 2013 to the least developed countries fund to support concrete adaptation activities that reduce vulnerability and increase the adaptive capacity of over 860,000 of the most climate vulnerable people.

- The UK is also providing up to £140m to the Building Resilience and Adapting to Climate Extremes and Disasters (BRACED) programme, which will help up to 5 million climate vulnerable people cope better with extreme weather events, building their capacity to cope so that shocks do not force them to resort to humanitarian relief. It focuses mainly on the Sahel region of Africa but also works in other highly climate vulnerable countries around the world such as Nepal and Pakistan.

- Adaptation for Smallholder Agriculture Programme (ASAP). DFID's support of £150 million from the International Climate Fund (ICF) will help up to 6 million smallholder farmers in 30 countries cope with the impacts of climate change. ASAP won a 2013 Momentum for Change Lighthouse award at this year's climate change conference in Warsaw for its innovative work in delivering social and economic benefits to smallholder farmers while helping them adapt to climate change.

15.2.9 Electricity Market Reform: Responding to Energy Market Imperfections

Electricity 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.

The Energy Act 2013 received Royal Assent in December 2013. The Energy Act includes the provisions for EMR:

- **Contracts for Difference (CfDs)** – long-term contracts to provide stable and predictable incentives for companies to invest in low-carbon electricity generation.

- **Capacity Market** – to provide security of electricity supply, by ensuring sufficient reliable capacity is available, including provisions to allow Electricity Demand Reduction to be delivered.

- **Conflicts of interest** and **contingency arrangements** – to ensure the institutions which deliver these schemes are fit for purpose.

- **Investment Contracts** – a form of early CfD entered into by the Secretary of State, designed to enable early investment in advance of the CfD regime coming into force.

- **Transitional arrangements for renewables** – to ensure that existing investments under the Renewables Obligation (RO) remain stable.

- **An Emissions Performance Standard (EPS)** – to limit the carbon emissions from the most polluting fossil fuel power stations, i.e. unabated coal.

EMR is due for implementation in 2014, with the first capacity auction and allocation under contracts for difference taking place before the end of the year.

16 Other Information

There is no additional information to include in this chapter.

17 References

References for the main chapters and the annexes are listed here and are organised by chapter and annex. During 2008 the BERR energy team and the Defra climate teams formed the Department of Energy and Climate Change (DECC), references in this document refer to correct name at the time of original publication.

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Table 18.1 Contributors to this National Inventory Report and the CRF

Person	Technical work area and responsibility
Main authors	
Broomfield, Mark	Sector expert for solid waste disposal on land
Brown, Peter	Author and report manager: Inventory Trends, Recalculations and Improvements, Sector Overviews
Buys, Gwen[53]	Main author of LULUCF Cpt7, Cpt 11, Annex 3.6 and sections in Cpt1 and Cpt2
Cardenas, Laura[54]	Sector expert for agriculture; author of all sections on agriculture. Compilation of Sector 4 of the CRF
Murrells, Tim	NAEI transport manager. Technical Director of NAEI Programme. Contributing author to all sections on transport
Pang, Yvonne	Approach 1 (error propagation) uncertainty analysis. Responsible for road transport data compilation. Project manager for the air quality inventory, assistance with inventory QA/QC
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 9
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, stakeholder consultation, and the reference approach. Knowledge leader responsible for final review of this report.
Watterson, John	Lead compiler and author: F-gases, uncertainty analysis and Key Category Analysis
Webb, Nicola	Project Manager for the UK Greenhouse Gas Inventory with overall responsibility for the NIR and the CRF[55]. Author of Chapter 1, the and Executive Summary. Contributor and reviewer for all sections.
Contributors	
Abbott, John	Assistance with the development of the error propagation and Monte Carlo uncertainty models
Champion, Helen[56]	Review of the draft NIR and contributions regarding National Inventory System. Author of Chapter 15

[53] Centre for Ecology and Hydrology

[54] Rothamsted Research

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Person	Technical work area and responsibility
Choudrie, Sarah	Contributed to Chapter 1,2 and the sections regarding F-gases.
Coleman, Caroline	Contributions to Waste Water Treatment text
Gilhespy, Sarah[48]	Contributions to agriculture inventory compilation and text
Gluckman, Ray[57]	UK F-gas sector expert providing input and review of methodologies and activity data
Goodwin, Justin[58]	Contribution to text on QA/QC plan
Henshall, Paul[54]	CARBINE modelling for LULUCF inventory for 5A Forestry, 5G Harvested Wood Products and KP, contributions to text for these sections in 1990-2012 NIR LULUCF sections in Cpt 7, Cpt 11 and Annex 3.6.
Hobson, Melanie[52]	Compilation of rail emissions estimates and text for this sector
Levy, Peter[54]	Responsible for uncertainty analysis of LULUCF inventory
MacCarthy, Joanna	Project Manager for the UK Greenhouse Gas Inventory until June 2013.
Malcolm, Heath[47]	Land Use and Ecosystem Modelling Group Leader, CEH. Contribution to LULUCF data analysis
Manning, Alistair[59]	Verification of the UK greenhouse gas inventory (Annex 10)
Matthews, Robert[60]	CARBINE modelling for LULUCF inventory for 5A Forestry, 5G Harvested Wood Products and KP, contributions to text for these sections in 1990-2012 NIR LULUCF sections in Cpt 7, Cpt 11 and Annex 3.6
Miles, Stephanie[47]	Responsible for compiling LULUCF emissions for soil liming, peat extraction, OTs and CDs. Updating text for these sections in 1990-2012 NIR LULUCF sections in Cpt 7 and Annex 3.6. Updating LULUCF text for Cpt 1 and Cpt2. Graphs of LULUCF data for text. Carrying out inventory QA/QC
Misselbrook, Tom[48]	Contributions to agriculture inventory compilation and text
Moxley, Janet[48]	Responsible for compiling LULUCF emissions for wildfires and the Falklands islands, contributions to text for these sections in 1990-2012 NIR LULUCF sections in Cpt 7 and Annex 3.6. Carrying out LULUCF inventory QA/QC
Pearson, Ben	Methodological development of the Monte Carlo model
Salisbury, Emma[52]	Responsible for compilation of emission estimates for the OTs and CDs, and report text relating to this
Walker, Charles	Sector expert for aviation in the NAEI
Additional assistance	
Aston, Clare	Data acquisition, report printing
National Inventory Steering Committee	Suggestions and improvements to draft versions of the NIR

[56] Climate, Energy, Science and Analysis, Department for Energy and Climate Change (DECC)
[57] SKM Enviros
[58] Aether
[59] The Met Office
[60] Forest Research

Table 18.2 Key Data Providers to the Greenhouse Gas Inventory

Organisation	Summary of Data Provided
DECC	Energy statistics (DUKES) including fuel activity and GCVs; Oil and gas production, flaring and venting statistics; Upstream oil and gas emissions data (EEMS).
Defra	Solid waste disposal / fate statistics; Waste water treatment activity data; Food and protein survey data; Agricultural survey data, activity statistics (livestock, crops).
DfT	Road traffic statsitics; Marine transport statistics; Rail activity and emission estimates (REM); Aviation movement statistics.
ONS	PRODCOM statistics (industrial production data); Housing and population data; Economic activity statistics (GDP, GVA);
Environment Agency SEPA NIEA NRW	Industrial activity and emissions data (EU ETS); Industrial emissions data from IPPC/EPR regulation; Waste management and disposal statistics, including incineration data;
UKPIA	Refinery emissions data by source; Oil products characteristics (RVP, sulphur content)
Mineral Products Association	Mineral processing activity and emissions data; fuel quality data;
UK Gas Distribution Networks	Natural gas compositional analysis (annual for each LDZ); Gas leakage estimates from transmission and distribution network;
ISSB	Iron and steel production statistics, by technology; Iron and steel fuel use, by fuel, by source;
Tata Steel SSI Steel	Iron and steel facility emissions by source for integrated works; Fuel quality data and other raw material parameters;
Rio Tinto Alcan	Aluminium production data, facility emissions data, supporting data on plant performance and controls.
British Glass	Glass production data.
Ineos BP Chemicals Kemira GrowHow SABIC Shell	Facility emissions data by source, aligned to specific inventory reporting requirements.

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