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UK Greenhouse Gas Inventory, 1990 to 2013

Annual Report for Submission under the Framework Convention on Climate Change

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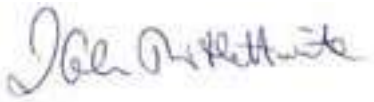
	Signature	
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Preface

This is the United Kingdom's National Inventory Report (NIR) submitted in 2015 to the United Nations Framework Convention on Climate Change (UNFCCC). It contains national greenhouse gas emission estimates for the period 1990-2013, and descriptions of the methods used to produce the estimates. The report is prepared in accordance with decision 24/CP.19[1] and includes elements required for reporting under the Kyoto Protocol, as 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.

Following the adoption of the revised guidelines for reporting GHG inventories from Annex I Parties (decision 24/CP.19), the common reporting format (CRF) software had to be redesigned. Decision 13/CP.20 recognised that the deadline for providing the redesigned version of the CRF Reporter to Annex I Parties, enabling them to submit their greenhouse gas inventories, was not met and that the CRF Reporter version available by that time was not functioning. Accordingly, decision 13/CP.20 reiterated that "Annex I Parties in 2015 may submit their common reporting format tables after 15 April, but no longer than the corresponding delay in the CRF Reporter availability". As a result of this situation, the 2015 submission by some Parties of their GHG inventories is delayed.

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 these other air emissions inventories 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 Energy & Environment. 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 2006 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, and new research, sponsored by DECC or otherwise.

[1] FCCC Decision 24/CP.19. Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention http://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf

[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 convert 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	NF_3	Nitrogen trifluoride
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, NF_3 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
1A2f	Non-metallic minerals
1A2gvii	Mobile combustion in manufacturing industries and construction
1A2gviii	Stationary combustion in manufacturing and construction: Other
1A3	**Transport**
1A3ai	International Aviation
1A3aii	Civil Aviation
1A3b	Road Transportation
1A3c	Railways
1A3di	International Navigation
1A3dii	National Navigation
1A3e	Other (to be specified)
1A4	**Other sectors**

IPCC Category	Source Description
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	Glass Production
2A4	Other Process uses of Carbonates
2B	**Chemical Industry**
2B1	Ammonia Production
2B2	Nitric Acid Production
2B3	Adipic Acid Production
2B4	Caprolactam, Glyoxal and Glyoxylic Acid Production
2B5	Carbide production
2B6	Titanium Dioxide Production
2B7	Soda Ash Production
2B8	Petrochemical and Carbon Black Production
2B9	Fluorochemical Production
2B10	Other
2C	**Metal Production**
2C1	Iron and Steel production
2C2	Ferroalloys Production
2C3	Aluminium Production
2C4	Magnesium Production
2C5	Lead Production
2C6	Zinc Production
2C7	Other Metal Production
2D	**Non-energy Products from Fuels and Solvent Use**
2D1	Lubricant Use
2D2	Paraffin Wax Use
2D3	Other
2E	**Electronics Industry**
2E1	Integrated Circuit or Semiconductor
2E2	TFT Flat Panel Display
2E3	Photovoltaics
2E4	Heat Transfer Fluid
2E5	Other

IPCC Category	Source Description
2F	**Product Uses as Substitutes for ODS**
2F1	Refrigeration and Air Conditioning Equipment
2F2	Foam Blowing Agents
2F3	Fire Extinguishers
2F4	Aerosols
2F5	Solvents
2F6	Other
2G	**Other Product Manufacture and Use**
2G1	Electrical Equipment
2G2	SF_6 and PFCs from Other Product Use
2G3	N_2O from Product Uses
2G4	Other
2H	**Other**
3	**Agriculture**
3A	Enteric Fermentation
3B	Manure Management
3C	Rice Cultivation
3D	Agricultural Soils
3E	Prescribed Burning of Savannas
3F	Field Burning of Agricultural Wastes
3G	Liming
3H	Urea Application
3I	Other Carbon-containing Fertilisers
3J	Other
4	**Land use, land use change and forestry**
4A	Forest Land
4B	Cropland
4C	Grassland
4D	Wetlands
4E	Settlements
4F	Other Land
4G	Harvested Wood Products
4H	Other
5	**Waste**
5A	Solid Waste Disposal
5B	Biological Treatment of Solid Waste
5C	Incineration and Open Burning of Waste
5D	Wastewater Treatment and Discharge
5E	Other
6	**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

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 for the first commitment period, and a Burden Sharing Agreement allocated the target between Member States of the European Union. Under this agreement, the UK reduction target was -12.5% on base-year levels. The first commitment period of the Kyoto Protocol was from 2008 to 2012.

The second commitment period of the Kyoto Protocol will run for eight years, from 2013 to 2020 inclusive. For this second commitment period, alongside the EU and its member States, the UK (including Gibraltar) communicated an independent quantified economy-wide emission reduction target of a 20 percent emission reduction by 2020 compared with 1990 levels (base year). The target for the European Union and its Member States is based on the understanding that it will be fulfilled jointly with the European Union and its Member States. The 20 percent emission reduction target by 2020 is unconditional and supported by legislation in place since 2009 (Climate and Energy Package). Once ratified this Kyoto target will cover the UK, and the relevant Crown Dependencies and Overseas Territories that wish to join the UK's ratification. As ratification is not yet complete the exact details of the UK's target for the second commitment period are still being finalised.

The UK ***Climate Change Act,*** which became part of UK law in November 2008, 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 acheived 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 had 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 United Kingdom's National Inventory Report (NIR) submitted in 2015 to the United Nations Framework Convention on Climate Change (UNFCCC). It contains national greenhouse gas emission estimates for the period 1990-2013, and the descriptions of the

methods used to produce the estimates. The report is prepared in accordance with decision 24/CP.19[3] and includes elements required for reporting under the Kyoto Protocol.

The UK Greenhouse Gas Inventory is compiled and maintained by a consortium led by Ricardo Energy & Environment – the **Inventory Agency** - under contract to the UK Department of Energy and Climate Change (DECC). Ricardo Energy & Environment is directly responsible for producing the emissions estimates for CRF categories Energy (CRF sector 1), Industrial Processes and Product Use, and Waste (CRF Sector 5). Ricardo Energy & Environment 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 3) 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 4) 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; information from these programmes is fed into the inventory via the national inventory system.

The inventory covers the seven direct greenhouse gases under the Kyoto Protocol (NF_3 was included under the Doha Amendment). These are as follows:

- Carbon dioxide (CO_2);
- Methane (CH_4);
- Nitrous oxide (N_2O);
- Hydrofluorocarbons (HFCs);
- Perfluorocarbons (PFCs);
- Sulphur hexafluoride (SF_6); and
- Nitrogen trifluoride (NF_3).

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).

Emissions of indirect N_2O from emissions of NO_x and NH_3 are also estimated and reported as a memo item, these emissions are not included in the national total.

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

[3] FCCC Decision 24/CP.19. Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention http://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf

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 MMR coverage: The UK's commitments under the EU Monitoring Mechanism Regulation, 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 MMR. **Table ES 2.1** to **Table ES 2.2** 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 **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, 1990-2013. (Mt CO_2 Equivalent)

Table ES2.1	Mt CO_2 Equivalent										% change
	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	1990 - 2013
CO_2 (Inc. net LULUCF)	599.31	563.42	560.96	559.55	534.68	484.01	502.52	459.33	477.93	469.19	-22%
CO_2 (Exc. net LULUCF)	596.44	561.25	561.17	563.38	539.60	488.89	507.59	464.94	483.71	475.18	-20%
CH_4 (Inc. net LULUCF)	137.24	130.21	114.14	92.31	78.60	72.14	67.26	64.20	61.45	56.43	-59%
CH_4 (Exc. net LULUCF)	137.22	130.17	114.10	92.26	78.56	72.09	67.21	64.16	61.38	56.39	-59%
N_2O (Inc. net LULUCF)	57.17	47.32	36.69	32.25	30.27	28.55	28.99	27.78	27.75	27.71	-52%
N_2O (Exc. net LULUCF)	56.09	46.25	35.67	31.39	29.49	27.79	28.24	27.04	27.00	27.00	-52%
HFCs	14.55	19.56	10.47	13.17	14.83	15.22	15.71	16.03	16.24	16.26	12%
PFCs	1.65	0.60	0.60	0.39	0.27	0.20	0.29	0.42	0.26	0.25	-85%
SF_6	1.28	1.26	1.82	1.06	0.67	0.65	0.73	0.65	0.63	0.60	-53%
NF_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-13%
Total (Inc. net LULUCF)	811.21	762.37	724.68	698.72	659.33	600.76	615.50	568.41	584.27	570.45	-30%
Total (Exc. net LULUCF)	807.22	759.09	723.83	701.63	663.42	604.82	619.78	573.24	589.22	575.70	-29%

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 82% to total net emissions in 2013. Methane emissions account for the next largest share (10%), and N_2O emissions make up a further 5%. Emissions of all of these gases have decreased since 1990, contributing to an overall decrease of 30%.

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; and
- **Article 3.4**, the net flux due to Forest Management (FM) since 1990 (mandatory for the second commitment period) and the elected activities of Cropland Management, Grazing Land Management and Wetland Drainage and Rewetting. Accounting for emissions/removals from FM is on the basis of the Forest Management Reference Level (projected emissions/removals 2013-2020 under business-as-usual). Any additions to the UK's assigned amount resulting from Forest Management (removals exceeding the reference level) are capped at 3.5% of the national total emissions excluding LULUCF in 1990 times eight (the number of years in the second commitment period). There is insufficient data to allow reporting of the newly elected Article 3.4 activities in this submission but a programme of research and development is underway to enable reporting and accounting before the end of the second commitment period.
- Both Afforestation/Reforestation (AR) and Farm Management (FM) total emissions now include carbon stock changes in the Harvested Wood Products pool.

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	0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.1
Article 3.4 FMRL												
Article 3.4 Forest Management removals compared to FMRL (capped)												
Article 3.4 Cropland Management	*	*	*	*	*	*	*	*	*	*	*	*
Article 3.4 Grazing Land Management	*	*	*	*	*	*	*	*	*	*	*	*
Article 3.4 Wetland Drainage and Rewetting	*	*	*	*	*	*	*	*	*	*	*	*

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Article 3.3	-0.1	-0.3	-0.2	-0.5	-0.6	-1.0	-1.0	-1.2	-1.4	-1.6	-2.0	-2.2	-2.4
Article 3.4 FMRL													-8.3
Article 3.4 Forest Management removals compared to FMRL (capped)													-9.4
Article 3.4 Cropland Management	*	*	*	*	*	*	*	*	*	*	*	*	*
Article 3.4 Grazing Land Management	*	*	*	*	*	*	*	*	*	*	*	*	*

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Article 3.4 Wetland Drainage and Rewetting	*	*	*	*	*	*	*	*	*	*	*	*	*

*Not yet reported (data and methodology under development)

Article 3.4 FMRL-related cells for 1990-2012 are blanked out because the FMRL is only calculated from, and applied, from 2013 onwards.

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**	**1995**	**2000**	**2005**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
1. Energy	610.8	566.9	559.4	556.5	532.2	486.3	503.2	461.3	480.4	468.9
2. Industrial Processes and Product Use	66.4	61.1	41.1	39.5	38.7	32.1	34.5	32.7	32.7	34.6
3. Agriculture	60.5	59.5	56.4	52.5	50.2	49.9	50.3	50.2	49.7	49.5
4. LULUCF	4.0	3.3	0.8	-2.9	-4.1	-4.1	-4.3	-4.8	-5.0	-5.2
5. Waste	69.5	71.6	66.9	53.2	42.3	36.5	31.7	29.1	26.5	22.7
Total (net emissions)	811.2	762.4	724.7	698.7	659.3	600.8	615.5	568.4	584.3	570.5

Footnotes:

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.

The largest contribution to greenhouse gas emissions is from the energy sector. In 2013 this contributed 82% 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 23%.

The second largest source of greenhouse gases is the agricultural sector. Emissions from this sector arise for both CH_4 and N_2O. Since 1990, emissions from this sector have declined by 18%, due to a decline in emissions from enteric fermentation and agricultural waste disposal (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 and product use makes up the third largest sector for greenhouse gas emissions in the UK, contributing just over 6% to the national total in 2013. Emissions of all seven 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 2013. Emissions from this sector occur for CO_2, N_2O and CH_4.

The remaining sector that contributes to direct greenhouse gas totals is waste. In 2012 this contributed 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 2013 were 67% below 1990 levels.

Total net emissions have decreased by 30% since 1990.

ES.3.2 KP Basket and KP-LULUCF Activities

Table ES 3.2 presents final UK emissions (UNFCCC coverage) for the first commitment period. The fixed base year figure is taken from the 1990 – 2004 inventory and is the total used to calculate the UK's Assigned Amount. The 2008 – 2012 figures are the final, reviewed figures for the UK inventory submitted in 2014. This was re-submitted following the UNFCCC review in September 2014, therefore the figures differ from the NIR submitted in April 2014. Table ES3.3 presents the same information as ES3.2 using MMR geographical coverage.

Table ES 3.4 presents the base year and 2013 emission calculated from the 2015 inventory submission. KP LULUCF activities are defined differently under the second commitment period – Article 3.3 now includes Harvested Wood Products (HWP), and Article 3.4 (Forest Management) now reports emissions relative to the Forest Management Reference Level (FMRL). The FMRL does not apply prior to 2013, and therefore it is not appropriate to report a full time series. **Table ES 3.5** presents the same information as **Table ES 3.4** using MMR geographical coverage.

Table ES 3.2 Kyoto basket of emissions, and emissions associated with Articles 3.3, 3.4 and 3.7 for the first commitment period (in Mt CO_2 equivalent) – UNFCCC Coverage.

	Fixed base year	2008	2009	2010	2011	2012
CO_2		536.7	487.4	505.0	464.0	483.4
CH_4		62.8	59.4	56.7	54.8	52.8
N_2O		38.4	36.2	37.1	35.7	35.4
HFCs		12.8	13.2	13.6	13.8	14.0
PFCs		0.2	0.1	0.2	0.3	0.2
SF_6		0.6	0.6	0.6	0.6	0.5
Grand Total		651.5	596.9	613.2	569.3	586.4
Article 3.3		-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
Article 3.7						
Kyoto Protocol Total	779.9	648.9	594.3	610.3	566.2	583.1

Footnotes:

- 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 is assessed against for its Kyoto Protocol first commitment period target.
- Emissions for 2008 – 2012 are taken from the 2014 submission of the UK inventory, including the recalculation the inventory following the 2014 UNFCCC review.
- Emissions are presented as Mt CO_2 equivalent, using GWP values taken from the IPCC's Second Assessment Report.
- 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 period the 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 for the first commitment period (in Mt CO_2 equivalent) – MMR Coverage.

Table ES3.3	Fixed base year	2008	2009	2010	2011	2012
CO_2		533.7	484.4	502.0	461.1	480.5
CH_4		62.4	59.1	56.4	54.5	52.5
N_2O		38.2	36.1	37.0	35.6	35.3
HFCs		12.7	13.1	13.5	13.7	13.9
PFCs		0.2	0.1	0.2	0.3	0.2
SF_6		0.6	0.6	0.6	0.6	0.5
Grand Total		647.8	593.4	609.7	565.8	582.9
Article 3.3		-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
Article 3.7						
Kyoto Protocol Total	776.3	645.3	590.7	606.7	562.7	579.6

Footnotes:

- See table ES3.2 for full footnotes.
- The geographical coverage of this table is UK and Gibraltar only.

Table ES 3.4 Kyoto basket of emissions, and emissions associated with Articles 3.3, 3.4 and 3.7 for the second commitment period (in Mt CO_2 equivalent) – UNFCCC Coverage.

	Base year (current inventory)	2013	Base Year - 2013
CO_2	596.4	475.2	-20%
CH_4	137.2	56.4	-59%
N_2O	56.1	27.0	-52%
HFCs	19.6	16.3	-17%
PFCs	0.6	0.3	-58%
SF_6	1.3	0.6	-52%
NF_3	0.0	0.0	-57%
Grand Total	811.2	575.7	-29%
Article 3.3		-2.3	
Article 3.4 Forest Management removals and HWP compared to FMRL (capped)		-9.4	
Article 3.7	0.2		
Kyoto Protocol Total	811.4	564.0	-30%

Footnotes:

- The data in this table are all taken from the 2015 inventory submission (1990 – 2013).
- The base year emissions are made up of 1990 emissions for CO_2, CH_4 and N_2O, and 1995 for the F-Gases
- Emissions are presented as Mt CO_2 equivalent, using GWP values taken from the IPCC's Fourth Assessment Report (AR4).
- 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 definitions of Article 3.3 and 3.4 have changed from the first commitment period and so the time series is not comparable.
- 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 period of the Kyoto Protocol. These are the Cayman Islands, Falkland Islands, Bermuda, Montserrat and Gibraltar.

Table ES 3.5 Kyoto basket of emissions, and emissions associated with Articles 3.3, 3.4 and 3.7 for the second commitment period (in Mt CO_2 equivalent) – MMR Coverage.

	Base year (current inventory)	2013	Base Year - 2013
CO_2	593.7	472.3	-20%
CH_4	136.6	55.9	-59%
N_2O	55.9	26.9	-52%
HFCs	19.5	16.1	-17%
PFCs	0.6	0.3	-58%
SF_6	1.3	0.6	-52%
NF_3	0.0	0.0	-57%
Grand Total	807.6	572.1	-29%
Article 3.3		-2.3	
Article 3.4 Forest Management removals and HWP compared to FMRL (capped)		-9.4	
Article 3.7	0.218		
Kyoto Protocol Total	807.8	560.4	-31%

Footnotes:

- See table ES3.4 for full footnotes.
- The geographical coverage of this table is 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, 1990-2013 (in kt).

Gas	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013
NO_x	2,892	2,325	1,805	1,593	1,330	1,154	1,127	1,055	1,078	1,024
CO	9,022	7,472	5,598	3,533	2,814	2,336	2,209	2,031	1,996	1,989
NMVOC	2,729	2,209	1,571	1,139	978	886	858	838	826	805
SO_2	3,692	2,374	1,226	712	494	401	429	393	442	395

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 80% of emissions arise from activities within this sector. For NMVOC, 57% of emissions are from the industrial processes and product use sector, with other significant contributions from the energy sector.

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 Energy & Environment for Defra and DECC: http://naei.defra.gov.uk/

1 Introduction

This is the UK's 2015 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.

Following the adoption of the revised guidelines for reporting GHG inventories from Annex I Parties (decision 24/CP.19), the common reporting format (CRF) software had to be redesigned. Decision 13/CP.20 recognized that the deadline for providing the redesigned version of the CRF Reporter to Annex I Parties, enabling them to submit their greenhouse gas inventories, was not met and that the CRF Reporter version available by that time was not functioning. Accordingly, decision 13/CP.20 reiterated that "Annex I Parties in 2015 may submit their common reporting format tables after 15 April, but no longer than the corresponding delay in the CRF Reporter availability". As a result of this situation, the 2015 submission by some Parties of their GHG inventories is delayed.

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 for the first commitment period, and a Burden Sharing Agreement allocated the target between Member States of the European Union. Under this agreement, the UK reduction target was -12.5% on base-year levels. The first commitment period of the Kyoto Protocol was from 2008 to 2012.

The second commitment period of the Kyoto Protocol will run for eight years, from 2013 to 2020 inclusive. For this second commitment period, alongside the EU and its member States,

[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

the UK (including Gibraltar) communicated an independent quantified economy-wide emission reduction target of a 20 percent emission reduction by 2020 compared with 1990 levels (base year). The target for the European Union and its Member States is based on the understanding that it will be fulfilled jointly with the European Union and its Member States. The 20 percent emission reduction target by 2020 is unconditional and supported by legislation in place since 2009 (Climate and Energy Package). Once ratified this Kyoto target will cover the UK, and the relevant Crown Dependencies and Overseas Territories that wish to join the UK's ratification. As ratification is not yet complete the exact details of the UK's target for the second commitment period are still being finalised.

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 setting and meeting of UK carbon budgets as well as monitoring progress against them scope and level of UK carbon budgets.

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 24/CP.19[8] and includes elements required for reporting under the Kyoto Protocol, as outlined in the *Annotated outline of the National Inventory Report including reporting elements under the Kyoto Protocol*[9]. 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 2006 Guidelines.

The UK Greenhouse Gas Inventory is compiled and maintained by a consortium led by Ricardo Energy & Environment – 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 2013. To fulfil both European Union Monitoring

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

8 FCCC Decision 24/CP.19. Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention http://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf

9 Annotated NIR outline:

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

Mechanism Regulation (MMR)[10] 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. **MMR CRF (submitted to EU 26th June):** Includes UK, and Gibraltar
2. **UNFCCC CRF (submitted to EU 26th June):** 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 1990-2013, 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. Full time series of emission factors and other background data are included in a CD ROM with this report (also available from the NAEI website).

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, and is available on the NAEI website.

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 MMR 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 1.6**). The geographical coverage of DUKES is the United Kingdom (DECC, 2014). 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,

[10] REGULATION (EU) No 525/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 May 2013 on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision No 280/2004/EC http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0525&from=EN

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. Gibraltar is additionally a member of the European Union.

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)
- Nitrogen trifluoride (NF_3)

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.

In addition to the gases listed above, Parties may also report indirect emissions of N_2O resulting from NOx and NH_3 emissions, from sources other than agriculture. These are included in the UK's inventory report and are reported as a memo item.

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. Further, emissions from certain f-gas categories are also considered commercially sensitive. 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, 2007). These

are the GWP values required by FCCC/CP/2013/10/Add.3. This is a change compared to previous inventory submissions, which used the GWP values from the IPCC's Second Assessment Report (IPCC, 1996).

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

Gas		GWP
Carbon dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide	N_2O	298
Hydrofluorocarbons		
HFC-23	CHF_3	14,800
HFC-32	CH_2F_2	675
HFC-41	CH_3F	92
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$	1,640
HFC-125	C_2HF_5	3,500
HFC-134	$C_2H_2F_4$	1,100
HFC-134a	$C_2H_2F_4$	1,430
HFC-143	$C_2H_3F_3$	353
HFC-143a	$C_2H_3F_3$	4,470
HFC-152	CH_2FCH_2F	53
HFC-152a	$C_2H_4F_2$	124
HFC-161	CH_3CH_2F	12
HFC-227ea	C_3HF_7	3,220
HFC-236cb	$CH_2FCF_2CF_3$	1,340
HFC-236ea	CHF_2CHFCF_3	1,370
HFC-236fa	$C_3H_2F_6$	9,810
HFC-245ca	$C_3H_3F_5$	693
HFC-245fa	$CHF_2CH_2CF_3$	1030
HFC-365mfc	$CH_3CF_2CH_2CF_3$	794
Perfluorocarbons		
Perfluoromethane	PFC-14 -CF_4	7,390
Perfluoroethane	PFC-116 - C_2F_6	12,200
Perfluoropropane	PFC-218 - C_3F_8	8,830
Perfluorobutane	PFC-3-1-10 - C_4F_{10}	8,860
Perfluorocyclobutane	PFC-318 - c-C_4F_8	10,300
Perfluouropentane	PFC-4-1-12 - C_5F_{12}	9,160
Perfluorohexane	PFC-5-1-14 - C_6F_{14}	9,300
Perfluorodecalin	PFC-9-1-18b - $C_{10}F_{18}$	>7,500
Perfluorocyclopropanec	c-C_3F_6	>17,340
Sulphur hexafluoride		
Sulphur hexafluoride	SF_6	22,800
Nitrogen trifluoride		
Nitrogen trifluoride	NF_3	17,200

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.

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, Cropland Management, Grazing Land Management and Wetland Drainge and Rewetting as activities under Article 3.4. The calculations follow the same method and use the same models, as the UNFCCC estimates for LULUCF, which are also prepared by CEH. Further information can be found in **Chapter 11**.
Information on Kyoto Protocol units	The UK National Registry is operated and maintained by the Environment Agency on behalf of DECC. Information on accounting of Kyoto Protocol units, including a summary of information reported in the standard electronic format (SEF) tables is provided in **Chapter 12**. SEF tables 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 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 many initiatives to advance 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 Energy & Environment – the **Inventory Agency** - under contract to the Science Division in DECC. Ricardo Energy & Environment is responsible for producing the emissions estimates for CRF categories Energy (CRF sector 1), Industrial Processes and Product Use (CRF sector

2), and Waste (CRF Sector 5). Ricardo Energy & Environment 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 3) are produced by Rothamsted Research, under contract to the Department for Environment, Food & Rural Affairs (Defra). Land Use, Land-Use Change and Forestry emissions (CRF sector 4) 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.

[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

Figure 1.1 Key organisational structure of the UK National Inventory System

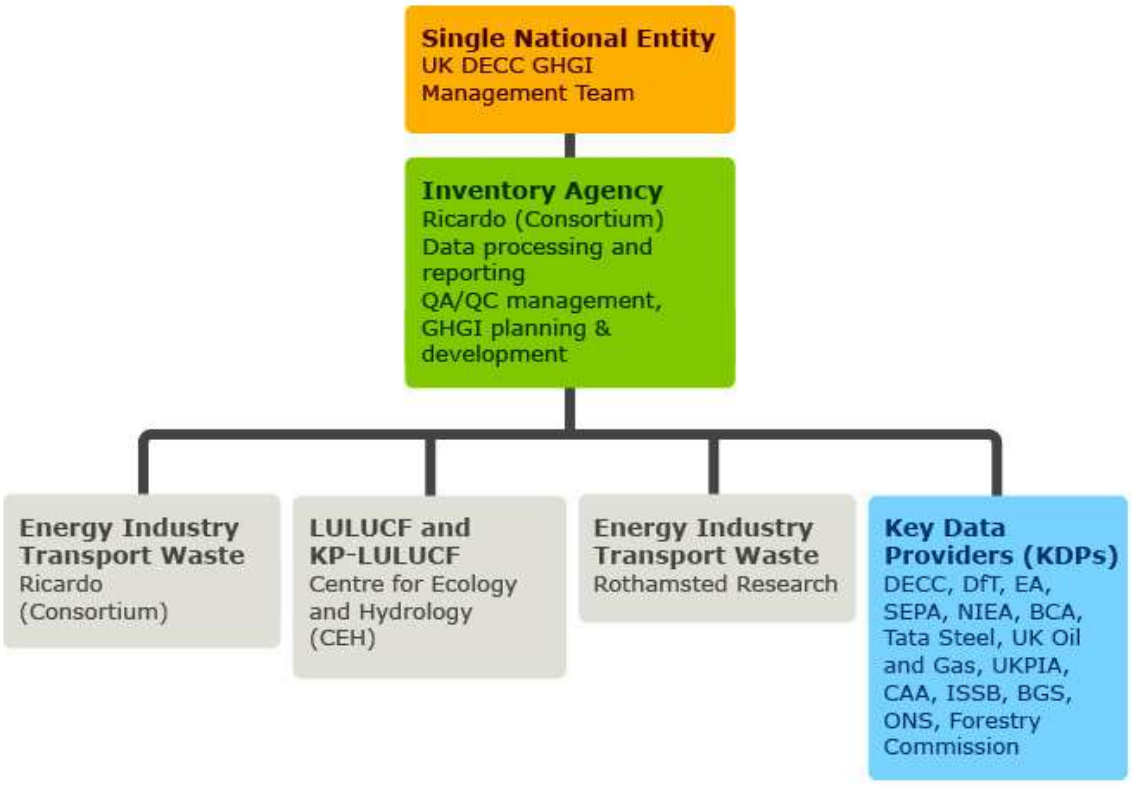
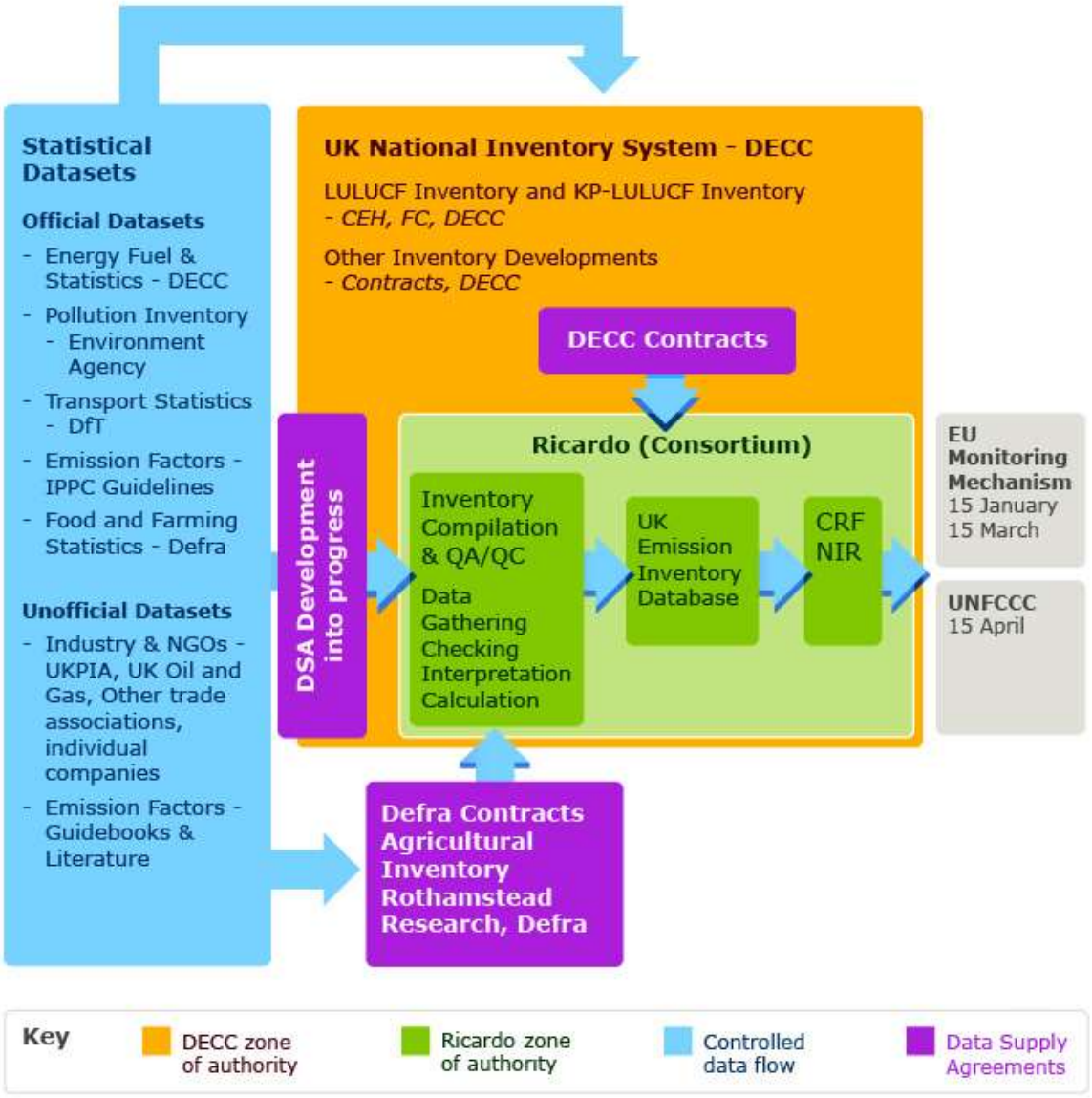


Figure 1.2 shows the main elements the UK National Inventory System, including provision of data to the European Union under the terms of the Monitoring Mechanism Regulation. DECC is the **Single National Entity** responsible for submitting the UK's GHGI to the UNFCCC. The Ricardo Energy & Environment 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 (EA), Natural Resources Wales (NRW), Northern Ireland Environment Agency (NIEA), the Scottish Environment Protection Agency (SEPA) and the Forestry Commission, 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. This legislation was updated in 2014 (The Greenhouse Gas Emissions Trading Scheme (Amendment) Regulations 2014).

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 DSAs in place with the Scottish Government, SEPA, NIEA, NRW 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's National Inventory System (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 that the UK Greenhouse Gas Inventory meets international standards set out in the UNFCCC reporting guidelines, the Kyoto Protocol and the IPCC 2006 Guidelines.

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 the GHG inventory; and
- Definition of performance criteria for NIS key organisations.

Development of legal and contractual infrastructure

- Review of legal and organisational structure; and

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

- 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 Energy & Environment 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 been agreed. Ricardo Energy & Environment leads the consortium responsible for compiling the inventory, under contract to DECC. Ricardo Energy & Environment is responsible for all aspects of national inventory preparation, reporting and quality management. The consortium consists of:

- Ricardo Energy & Environment – 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;
- Ray Gluckman Consulting – contributions to the F-gas inventory;
- CEH[14] and AMEC – part of the consortium, but with no direct input to the GHG inventory.

Ricardo Energy & Environment 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. This arrangement ensures 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 Regulation (MMR) 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 Energy & Environment has the following roles and responsibilities:

Planning

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

Preparation

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

Management

- Documentation and archiving;
- Dissemination of information regarding NIS to Key Data Providers; and

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

- 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 Energy & Environment 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 Energy & Environment 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 Energy & Environment 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 Energy & Environment for inclusion within the UK GHG inventory.

CEH and Rothamsted Research are directly responsible for compiling the LULUCF and agriculture sections of the CRF, and for maintaining documentation and archiving of their models and processes. Ricardo Energy & Environment are responsible for checking consistency between outputs.

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 Energy & Environment 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 Energy & Environment by the individual plant operators or from:

- The Environment Agency's Pollution Inventory for England;
- Natural Resources Wales's Pollution Inventory for 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 Energy & Environment.

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 Research Agency (an executive agency of the Forestry Commission, known as Forest Research), 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.

The pre submission review of the 2015 inventory took place on November 27th 2014. All methodology revisions and improvement programme items were presented to the NISC, and the proposed changes were adopted.

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 Energy & Environment, 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 Regulation 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 outcomes from QA/QC checks and reviews carried out under the MMR and ESD, 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 MMR 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 – Strategy	• 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 • MMR • 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 Energy & Environment)	• 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 – 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 and other tall tower sites.	• 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. 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.

1.2.2.6 Integrated UK-DA GHGI improvement programme

The UK compiles a national level inventory, and in addition separate inventories for the Devolved Administrations (DAs). A single improvement programme is in place to manage improvements to these inventories. During 2014-15, the integrated UK- DA GHGI improvement programme implemented a number of specific research projects to address inventory uncertainties and reporting requirements, including:

- Development of new writing guidance for the National Inventory Report, and implementation of this guidance for the chapters and annexes associated with the energy sector.
- A review of the Industrial Processes and Product Use sector, to include new sources included in the 2006 IPCC Guidelines, and to ensure methods for existing sources are compliant.
- A review of the Waste sector, to include new sources included in the 2006 IPCC Guidelines, and to ensure methods for existing sources are compliant.
- A review of available data on landfill gas flaring, to improve estimates for the landfill emissions category.
- A project to assess the impacts of moving to the 2006 IPCC Guidelines and revised UNFCCC reporting guidelines, which included structural changes to the inventory database, updates to GWP values, and the inclusion of the following new emission sources:
    - N_2O from use as anaesthesia;
    - CO_2 from urea use as a fuel additive;
    - Waste-water treatment in private (off grid) systems; and,
    - New f-gas emission sources and gases (Refrigerant cylinders, AWACS (Military Airborne Warning And Control Systems), Particle accelerators, Tracer testing, NF_3).

  The project included the results of an emission factor review, updating defaults to the 2006 IPCC GL, and ensuring completeness where missing factors were identified for certain fuels and GHGs.

- A full review of the f-gas inventory, to develop estimates for new sources and ensure estimates for existing sources are compliant.
- A review of the Approach 1 uncertainty analysis and key category analysis to ensure compliance with the IPCC Guidelines, following a recommendation from the UNFCCC ERT.
- A review of fugitive emissions from fuels to ensure compliance with the methods and nomenclature in the new 2006 IPCC Guidelines.
- Validation of emissions from leakage from the natural gas distribution network, following a recommendation from the UNFCCC ERT.
- Incorporation of changes to fuel allocations within the UK energy statistics, including developing a consistent time series back to 1990.
- New reporting of emissions of nitrous oxide from mineralisation of organic matter resulting from land use change and drainage of Forest soils.
- New reporting on the effect of Cropland Management on soil carbon stocks.
- New reporting on emissions from change in biomass carbon stocks on Flooded Land.
- New reporting of emission from drained organic soils under improved Grassland.
- Revised methodology for estimating emissions from drainage of Cropland on drained organic soils.
- Following a review of data on the effect of yield improvements due to improved agronomy on Cropland biomass, this has activity has been removed from Cropland emissions as the evidence shows that increases in harvestable yield are not matched by increases in total plant biomass.

Improvement priorities are discussed and agreed each April and incorporate the findings from the latest UNFCCC review of the inventory.

1.2.2.7 Agriculture inventory improvements

The UK GHG agricultural inventory is undergoing large improvements in order to better quantify the emissions and reduce uncertainty. A 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 to ensure compliance with the 2006 IPCC Guidelines; see **Section 5.1** 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 N_2O and CH_4 emissions for the United Kingdom with an assessment of uncertainty (DEFRA project AC0114).
3. Measurements at field scale of CH_4 emissions from enteric fermentation to develop Tier 2 methodology (DEFRA project AC0115).

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

4. Measurements at field scale of direct N_2O emissions at a range of UK sites to develop new country specific emission factors for inorganic N fertiliser, manure applications and urine and dung deposition by grazing livestock (EF1, EF3) (DEFRA project AC0116). In addition, measurements of indirect N_2O losses are planned at three sites where drainage is collected and the N_2O loss from leached/drained N is quantified (EF5).
5. Measurements at field scale of NH_3 emissions from manure management systems (Agricultural GHG R&D Platform – www.ghgplatform.org.uk).
6. Development of emission factors for N_2O 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 N_2O 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;
- Allow access for authorised users[17].
- Act on instructions from Competent Authorities to manage accounts;
- Assist registry users.

1.3 INVENTORY PREPARATION

1.3.1 GHG Inventory

The present UK GHG inventory for the period 1990-2013 was compiled in accordance with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006).

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.

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

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

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.

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 Volume 1, Chapter 6 of IPCC, 2006.

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 Energy & Environment receives completed emission estimates from these organisations as part of the annual data collection process.

Ricardo Energy & Environment has work programmes in place with CEH and Rothamsted to help harmonise the quality systems used with those Ricardo Energy & Environment 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 6, Section 6.10 and Chapter 5, Section 5.9 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 1.5 provides a brief summary of the methods used to estimate UK GHG emissions, which are described in more detail in the subsequent Chapters and Appendices.

Table 1.5 Summary of methods used to estimate emissions of the direct greenhouse gases

CRF sector	Comments on methods
1A	• Basic combustion module (fuel use * emission factor); and • Transport models (see **MS 5**, **MS 6** and **MS 20**). • Carbon balance approach (See **MS 4**)
1B	• Carbon Balance approach (See **MS 4**); • DECC EEMS inventory (See , **MS 17**); and • Gas leakage data from network operators (See **MS 19**).
2A	• Cement production: IPCC Tier 2 approach (see **Section 4.2.2**). • Lime production: Approach is comparable to IPCC Tier 2, although the Tier 1 default factor is used in the reporting of emissions. • Glass: IPCC Tier 2 approach, UK-specific factors from EU ETS • Brickmaking: IPCC Tier 2 approach, UK-specific factors from EU ETS • Other carbonates – FGD: Tier 1 approach for earlier part of time-series, Tier 2 for years covered by EU ETS
2B	• Emissions calculated based on emissions data from industry, EU ETS and the environmental regulators' inventories, except for: • Use of IPCC default factors for CH_4 from ethylene oxide, acrylonitrile, carbon black in years where no environmental regulators' inventories data available • Use of IPCC default factor for CO_2 from ethylene dichloride across full time-series
2C	• Iron and Steel - 2 stage carbon balance and EU ETS/operator carbon factors for carbonate use and arc furnaces (see **MS 4**); and • Spreadsheet model and operator reported emissions for aluminium and magnesium production. • Tier 1 approach for non-ferrous metal production

CRF sector	Comments on methods
2D	• Emissions calculated based on IPCC defaults for non-energy use of fuels
2E, 2F	• Spreadsheet model to estimate emissions of F-gases
2G	• Spreadsheet model to estimate emissions of F-gases • NHS research into anaesthetic use
3A	• Emissions calculated based on animal population data and appropriate EFs
3B	• Emissions calculated based on animal population data and appropriate EFs
3D	• Emissions calculated based on animal population data, fertilizer data and appropriate EFs
3F	• Emissions calculated based on IPCC methodologies and USEPA EFs
4	• 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.
5A	• The Methane Emissions from Landfill model (MELmod)
5B	• UK waste activity data and IPCC default emission factors
5C	• Country specific emission factors, partially based on Pollution Inventory data
5D	• IPCC default method using country specific activity data for all N_2O and CH_4 from private waste-water management systems and industrial waste-water treatment • Data from operator returns to the regulator for water company waste-water management

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 1.6**. All sources are updated annually. Each of the data sources are given a short name, by which they are referred throughout the energy chapter (chapter 3), in order to improve the flow of text and clarity of the method statements.

Table 1.6 Summary of sources of activity data used to estimate greenhouse gas emissions

Source (and publisher) *Short name*	**Relevant activity data contained in the source**
Digest of UK Energy Statistics (UK Department of Energy and Climate Change) *DUKES*	• 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) *EU ETS*	• 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) *TSGB*	• 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) *ISR*	• Traffic count and vehicle km data for Northern Ireland; and • Information on regulated processes in NI.
Civil Aviation Authority *CAA*	• Detailed domestic and international civil aviation aircraft km flown.
Pollution Inventory (Environment Agency and Natural Resources Wales) *PI*	• Information on emissions from regulated processes in England and Wales
Scottish Pollutant Release Inventory (Scottish Environment Protection Agency) *SPRI*	• Information on regulated processes in Scotland.

Source (and publisher) *Short name*	**Relevant activity data contained in the source**
United Kingdom Petroleum Industry Association *UKPIA*	• Refinery emissions; • Lead and sulphur contents of fuels, benzene content of petrol, RVP of petrol.
Environmental Emissions Monitoring System (EEMS) (DECC Offshore Inspectorate) *EEMS*	• Detailed inventory of oil and gas emissions.
UK Iron and Steel Industry Annual Statistics (International Steel Statistics Bureau) *ISSB*	• 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) *UKMY*	• Statistical data on minerals production, consumption and trade.
Annual Abstract of Statistics (Office for National Statistics) *ONS*	• Population data.
Department for Transport *ANPR*	• Automatic Number Plate Recognition (ANPR) data used to help define fleet composition on different road types in the UK.

Key data sources within the Energy sector are further elaborated in **Annex 3**. These include the annually updated data sets EEMS, the PI, SPRI and ISR listed above, and other one-off studies that are used across a number of source categories (Baggott et al., 2004 and Entec, 2010). DUKES is described in more detail in **Annex 4**.

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, uncertainty or the trend. **Table 1.7**, to **Table 1.10** summarise the key source categories, for the latest reported year, and the base year, derived from the IPCC Approach 1 and 2 key category analyses. Tables are included for the analysis with and without LULUCF and for the base year and most recent year estimated. Details of the key source category analysis are given in **Annex 1**. 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.

Under the improvement programme, a review of the Key Category Analysis and Approach 1 uncertainty analysis has been carried out, in response to a recommendation from the UNFCCC ERT. Further information about the review and upgrades to the analysis are included in **Annex 1**. The improvement programme has also included a review of the NIR, with improvements made mostly to the Energy section. This review also recommended summarising the key category analysis into one table, using a ranking system, this is set out in **Table 1.11** and is explained below; it is referred to in **Table 3.1** when referencing which categories are or contain key categories within the energy sector.

The Key Category Analysis (KCA) ranking system is an additional tool that the UK has developed to aid in the prioritisation of improvement work. The KCA ranking system works by allocating a score based on how high categories rank in the base year and most recent year level assessments and the trend assessment for the approach 1 KCA including LULUCF. For example if CO_2 from road transport liquid fuel use is the 4th highest by the base year level assessment, 3rd highest by the most recent year level assessment and has the 5th highest trend assessment then it's score would be 4+3+5=12. The categories are then ranked from lowest score to highest, with draws in score resolved by the most recent year level assessment. The assessments excluding LULUCF are ignored for this exercise, as the LULUCF sectors would only be included in half of the assessments and would therefore give an unrepresentative weighting.

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**. This has not identified any further categories that are not already identified as part of the Approach 1 or Approach 2 analyses.

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

IPCC Code	IPCC Category	Greenhouse Gas	Identification Criteria
1A	(Stationary) Oil	CO_2	L2, T2
1A	Coal	CO_2	L2, T2
1A	Natural Gas	CO_2	L2, T2
1A1	Energy industries: gaseous fuels	CO_2	L1, T1
1A1	Energy industries: liquid fuels	CO_2	L1, T1
1A1	Energy industries: other fuels	CO_2	T1
1A1	Energy industries: solid fuels	CO_2	L1, T1
1A1 & 1A2 & 1A4 & 1A5	Other Combustion	N_2O	L2
1A2	Manufacturing industries and construction: gaseous fuels	CO_2	L1, T1
1A2	Manufacturing industries and construction: liquid fuels	CO_2	L1, T1
1A2	Manufacturing industries and construction: solid fuels	CO_2	L1, T1
1A3b	DERV	CO_2	L2, T2
1A3b	DERV	N_2O	T2
1A3b	Road transportation: liquid fuels	CO_2	L1, T1
1A3c	Railways: liquid fuels	CO_2	T1
1A3d	Domestic Navigation: liquid fuels	CO_2	L1
1A4	Other sectors: gaseous fuels	CO_2	L1, T1
1A4	Other sectors: liquid fuels	CO_2	L1

IPCC Code	IPCC Category	Greenhouse Gas	Identification Criteria
1A4	Other sectors: solid fuels	CO_2	L1, T1
1A5	Other: liquid fuels	CO_2	L1, T1
1B1	Coal Mining	CH_4	T2
1B1	Coal mining and handling	CH_4	T1
1B1	Coal mining and handling solid fuels	CO_2	T1
1B2	Natural Gas Transmission	CH_4	T2
1B2	Oil and gas extraction	CH_4	L1, T1
1B2	Oil and gas extraction	CO_2	L1
2A1	Cement production	CO_2	L1, T1
2B	Chemical industry	HFCs	T2
2B2	Nitric acid production	N_2O	T1, T2
2B3	Adipic acid production	N_2O	T1, T2
2B8	Petrochemical and carbon black production	CO_2	L1
2B9	Fluorochemical production	HFCs, PFCs, SF_6 and NF_3	T1
2C1	Iron and steel production	CO_2	L1, T1
2C6	Zinc production	CO_2	T1
2F	Product Uses as Substitutes for ODS	HFCs	L2, T2
2F1	Refrigeration and air conditioning	HFCs, PFCs, SF_6 and NF_3	L1, T1
2F4	Aerosols	HFCs, PFCs, SF_6 and NF_3	L1, T1
3A	Enteric Fermentation	CH_4	L2, T2
3A1	Enteric fermentation from Cattle	CH_4	L1, T1
3A2	Enteric fermentation from Sheep	CH_4	L1
3B	Manure Management	CH_4	L2
3B	Manure Management	N_2O	L2
3B1	Manure management from Cattle	CH_4	L1
3D	Agricultural soils	N_2O	L1, T1, L2, T2
4A	Forest land	CO_2	L1, T1, L2, T2
4B	Cropland	CO_2	L1, T1, L2, T2
4C	Grassland	CO_2	L1, T1, L2
4E	Settlements	CO_2	L1, T1, L2
4G	Harvested wood products	CO_2	T1
5A	Solid waste disposal	CH_4	L1, T1, L2, T2
5B	Biological treatment of solid waste	CH_4	T2
5B	Biological treatment of solid waste	N_2O	T2
5D	Wastewater Handling	N_2O	L2, T2
5D	Wastewater treatment and discharge	CH_4	L1

Table 1.8 Key Source Categories for the base year (including LULUCF)

IPCC Code	IPCC Category	Greenhouse Gas	Identification Criteria
1A	(Stationary) Oil	CO_2	L2
1A	Coal	CO_2	L2
1A	Natural Gas	CO_2	L2
1A1	Energy industries: gaseous fuels	CO_2	L1
1A1	Energy industries: liquid fuels	CO_2	L1
1A1	Energy industries: solid fuels	CO_2	L1
1A1 & 1A2 & 1A4 & 1A5	Other Combustion	N_2O	L2
1A2	Manufacturing industries and construction: gaseous fuels	CO_2	L1
1A2	Manufacturing industries and construction: liquid fuels	CO_2	L1
1A2	Manufacturing industries and construction: solid fuels	CO_2	L1
1A3b	Road transportation: liquid fuels	CO_2	L1
1A4	Other sectors: gaseous fuels	CO_2	L1
1A4	Other sectors: liquid fuels	CO_2	L1
1A4	Other sectors: solid fuels	CO_2	L1
1A5	Other: liquid fuels	CO_2	L1
1B1	Coal mining and handling	CH_4	L1, L2
1B2	Natural Gas Transmission	CH_4	L2
1B2	Oil and gas extraction	CH_4	L1
1B2	Oil and gas extraction	CO_2	L1
2A1	Cement production	CO_2	L1
2B2	Nitric acid production	N_2O	L1, L2
2B3	Adipic acid production	N_2O	L1, L2
2B8	Petrochemical and carbon black production	CO_2	L1
2B9	Fluorochemical production	HFCs, PFCs, SF_6 and NF_3	L1
2C1	Iron and steel production	CO_2	L1
3A	Enteric Fermentation	CH_4	L2
3A1	Enteric fermentation from Cattle	CH_4	L1
3A2	Enteric fermentation from Sheep	CH_4	L1
3B	Manure Management	N_2O	L2
3D	Agricultural soils	N_2O	L1, L2
4A	Forest land	CO_2	L1, L2
4B	Cropland	CO_2	L1, L2
4C	Grassland	CO_2	L1
4E	Settlements	CO_2	L1, L2
5A	Solid waste disposal	CH_4	L1, L2
5D	Wastewater Handling	N_2O	L2
5D	Wastewater treatment and discharge	CH_4	L1

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

IPCC Code	IPCC Category	Greenhouse Gas	Identification Criteria
1A	(Stationary) Oil	CO_2	L2, T2
1A	Coal	CO_2	L2, T2
1A	Natural Gas	CO_2	L2, T2
1A1	Energy industries: gaseous fuels	CO_2	L1, T1
1A1	Energy industries: liquid fuels	CO_2	L1, T1
1A1	Energy industries: other fuels	CO_2	T1
1A1	Energy industries: solid fuels	CO_2	L1, T1
1A1 & 1A2 & 1A4 & 1A5	Other Combustion	N_2O	L2
1A2	Manufacturing industries and construction: gaseous fuels	CO_2	L1, T1
1A2	Manufacturing industries and construction: liquid fuels	CO_2	L1, T1
1A2	Manufacturing industries and construction: solid fuels	CO_2	L1, T1
1A3b	DERV	CO_2	L2, T2
1A3b	DERV	N_2O	L2, T2
1A3b	Road transportation: liquid fuels	CO_2	L1, T1
1A3c	Railways: liquid fuels	CO_2	T1
1A3d	Domestic Navigation: liquid fuels	CO_2	L1
1A4	Other sectors: gaseous fuels	CO_2	L1, T1
1A4	Other sectors: liquid fuels	CO_2	L1
1A4	Other sectors: solid fuels	CH_4	T1
1A4	Other sectors: solid fuels	CO_2	L1, T1
1A5	Other: liquid fuels	CO_2	L1
1B1	Coal Mining	CH_4	T2
1B1	Coal mining and handling	CH_4	T1
1B1	Coal mining and handling solid fuels	CO_2	T1
1B2	Oil and gas extraction	CH_4	L1, T1
1B2	Oil and gas extraction	CO_2	L1
2A1	Cement production	CO_2	L1, T1
2B	Chemical industry	HFCs	T2
2B2	Nitric acid production	N_2O	T1, T2
2B3	Adipic acid production	N_2O	T1, T2
2B8	Petrochemical and carbon black production	CO_2	L1
2B9	Fluorochemical production	HFCs, PFCs, SF_6 and NF_3	T1
2C1	Iron and steel production	CO_2	L1, T1
2C6	Zinc production	CO_2	T1
2F	Product Uses as Substitutes for ODS	HFCs	L2, T2
2F1	Refrigeration and air conditioning	HFCs, PFCs, SF_6 and NF_3	L1, T1
2F4	Aerosols	HFCs, PFCs, SF_6 and NF_3	L1, T1
3A	Enteric Fermentation	CH_4	L2, T2

IPCC Code	IPCC Category	Greenhouse Gas	Identification Criteria
3A1	Enteric fermentation from Cattle	CH_4	L1, T1
3A2	Enteric fermentation from Sheep	CH_4	L1
3B	Manure Management	CH_4	L2
3B	Manure Management	N_2O	L2
3B1	Manure management from Cattle	CH_4	L1
3D	Agricultural soils	N_2O	L1, T1, L2, T2
5A	Solid waste disposal	CH_4	L1, T1, L2, T2
5B	Biological treatment of solid waste	CH_4	T2
5D	Wastewater Handling	N_2O	L2, T2
5D	Wastewater treatment and discharge	CH_4	L1

Table 1.10 Key Source Categories for base year (excluding LULUCF)

IPCC Code	IPCC Category	Greenhouse Gas	Identification Criteria
1A	(Stationary) Oil	CO_2	L2
1A	Coal	CO_2	L2
1A	Natural Gas	CO_2	L2
1A1	Energy industries: gaseous fuels	CO_2	L1
1A1	Energy industries: liquid fuels	CO_2	L1
1A1	Energy industries: solid fuels	CO_2	L1
1A1 & 1A2 & 1A4 & 1A5	Other Combustion	N_2O	L2
1A2	Manufacturing industries and construction: gaseous fuels	CO_2	L1
1A2	Manufacturing industries and construction: liquid fuels	CO_2	L1
1A2	Manufacturing industries and construction: solid fuels	CO_2	L1
1A3b	Road transportation: liquid fuels	CO_2	L1
1A4	Other sectors: gaseous fuels	CO_2	L1
1A4	Other sectors: liquid fuels	CO_2	L1
1A4	Other sectors: solid fuels	CO_2	L1
1A5	Other: liquid fuels	CO_2	L1
1B1	Coal mining and handling	CH_4	L1, L2
1B2	Natural gas transmission	CH_4	L2
1B2	Oil and gas extraction	CH_4	L1
1B2	Oil and gas extraction	CO_2	L1
2A1	Cement production	CO_2	L1
2B2	Nitric acid production	N_2O	L1, L2
2B3	Adipic acid production	N_2O	L1, L2
2B8	Petrochemical and carbon black production	CO_2	L1
2B9	Fluorochemical production	HFCs, PFCs, SF_6 and NF_3	L1
2C1	Iron and steel production	CO_2	L1

IPCC Code	IPCC Category	Greenhouse Gas	Identification Criteria
3A	Enteric Fermentation	CH_4	L2
3A1	Enteric fermentation from Cattle	CH_4	L1
3A2	Enteric fermentation from Sheep	CH_4	L1
3B	Manure Management	N_2O	L2
3B1	Manure management from Cattle	CH_4	L1
3D	Agricultural soils	N_2O	L1, L2
5A	Solid waste disposal	CH_4	L1, L2
5D	Wastewater Handling	N_2O	L2
5D	Wastewater treatment and discharge	CH_4	L1

Table 1.11 Key category ranking

KCA rank	IPCC Code	IPCC Category	Greenhouse Gas
1	1A1	Energy industries: solid fuels	CO2
2	1A3b	Road transportation: liquid fuels	CO2
3	1A4	Other sectors: gaseous fuels	CO2
4	5A	Solid waste disposal	CH4
5	1A1	Energy industries: gaseous fuels	CO2
6	1A1	Energy industries: liquid fuels	CO2
7	1A2	Manufacturing industries and construction: solid fuels	CO2
8	1A2	Manufacturing industries and construction: gaseous fuels	CO2
9	3D	Agricultural soils	N2O
10	1A2	Manufacturing industries and construction: liquid fuels	CO2
11	3A1	Enteric fermentation from Cattle	CH4
12	4A	Forest land	CO2
13	1A4	Other sectors: solid fuels	CO2
14	1B1	Coal mining and handling	CH4
15	4B	Cropland	CO2
16	1B2	Oil and gas extraction	CH4
17	1A4	Other sectors: liquid fuels	CO2
18	4E	Settlements	CO2
19	2A1	Cement production	CO2
20	2F1	Refrigeration and air conditioning	HFCs, PFCs, SF6 and NF3
21	4C	Grassland	CO2
22	2C1	Iron and steel production	CO2
23	1A5	Other: liquid fuels	CO2
24	5D	Wastewater treatment and discharge	CH4
25	1A3d	Domestic Navigation: liquid fuels	CO2
26	1B2	Oil and gas extraction	CO2
27	2B9	Fluorochemical production	HFCs, PFCs, SF6 and NF3
28	3A2	Enteric fermentation from Sheep	CH4

KCA rank	IPCC Code	IPCC Category	Greenhouse Gas
29	3B1	Manure management from Cattle	CH4
30	2F4	Aerosols	HFCs, PFCs, SF6 and NF3
31	1A3c	Railways: liquid fuels	CO2
32	2B8	Petrochemical and carbon black production	CO2
33	1A1	Energy industries: other fuels	CO2
34	1B1	Coal mining and handling solid fuels	CO2
35	2B2	Nitric acid production	N2O
36	4G	Harvested wood products	CO2
37	2B3	Adipic acid production	N2O
38	2C6	Zinc production	CO2

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 CRF Table NIR 3, reproduced in **Table A 1.8.1** 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 2006 IPCC Guidelines and has been extended to include a range of on-going bespoke sector specific QA/QC activities to comply with Tier 2. Ricardo Energy & Environment (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 Energy & Environment (the Inventory Agency), on behalf of DECC and Defra). Ricardo Energy & Environment prepares the GHG submissions to the EC under the MMR 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 Energy & Environment 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 Energy & Environment (detailed below).

Whilst these organisations have their own QA/QC systems, Ricardo Energy & Environment is responsible for co-ordinating inventory-wide QA/QC activities relating to the submitted datasets. In addition, Ricardo Energy & Environment 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 Energy & Environment) 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 MMR (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.

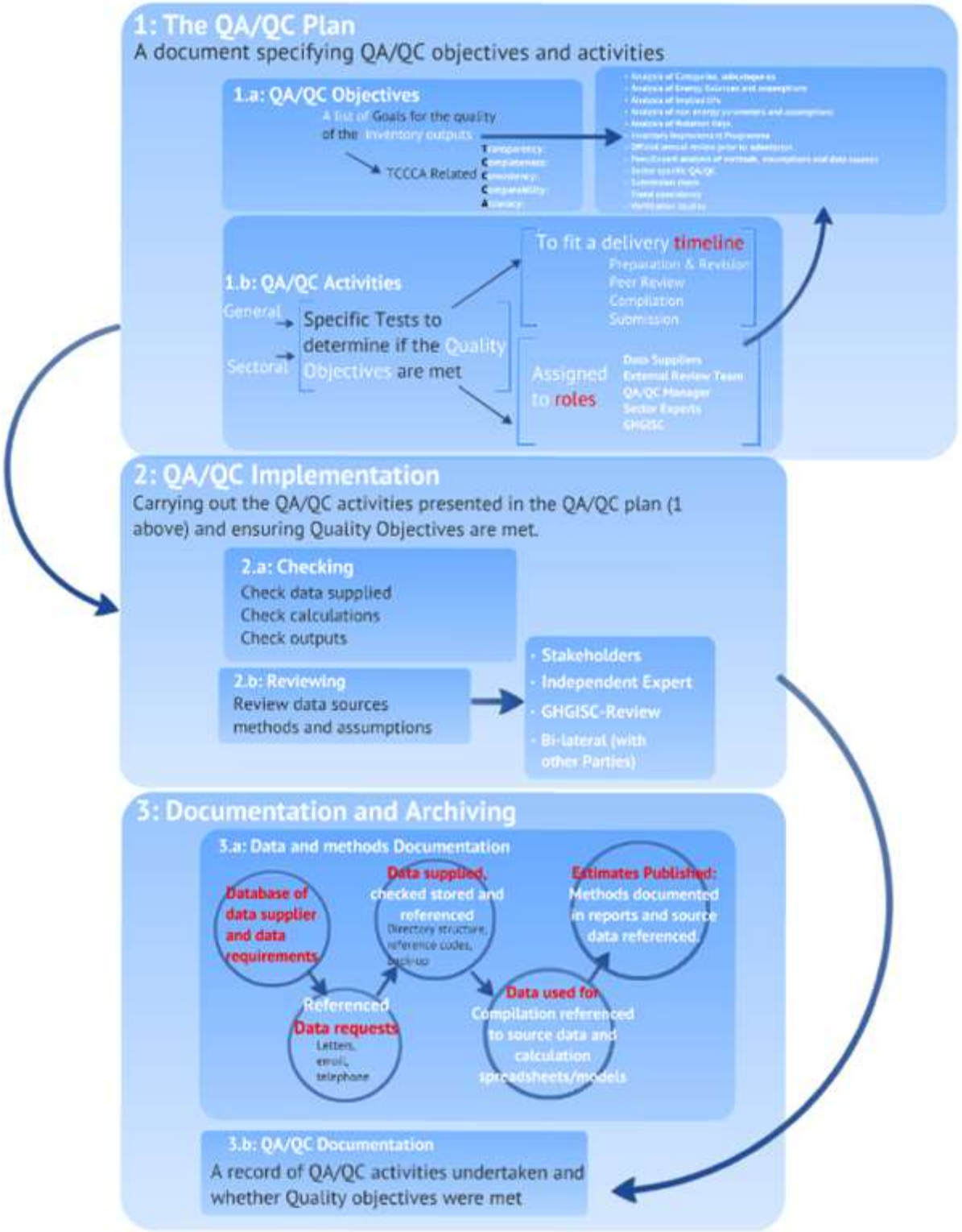
Improvements made to the QA/QC plan for the 2015 submission include:

- Further checks on consistency between calculations and reporting (e.g. inclusion of emission factors in energy units within data processing spreadsheets for cross comparison for consistency with reported EFs, and detection of outliers (within the time series, and with IPCC defaults))
- Improvements to change tracking.
  - Changes to activity data and emission factors were previously logged using simplistic pre-defined change codes (e.g. revision, correction). These have been replaced with user defined descriptions to allow more efficient checking and tracking of changes.
  - Change codes are now required for more data types, for example calorific values
- In replacing the "go between database" used for populating the previous CRF reporter software, a system has been set up which is more transparent in how the data are transferred from the inventory database to the CRF software, showing which queries have

been run for which row of data. The inventory uses Excel templates for compiling the CRF, allowing the data to be split into smaller sections to be reviewed by sector experts.

- Method and emission factor notation keys are now held in a central location, for NIR authors to reference, and for the CRF data transfer system to use.

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 Energy & Environment, a trading name of Ricardo-AEA Ltd, 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 Register Quality Assurance (LRQA) and the Ricardo Energy & Environment internal QA auditors. The NAEI has been audited favourably by LRQA 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 Ricardo-AEA in September and October 2014. 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 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

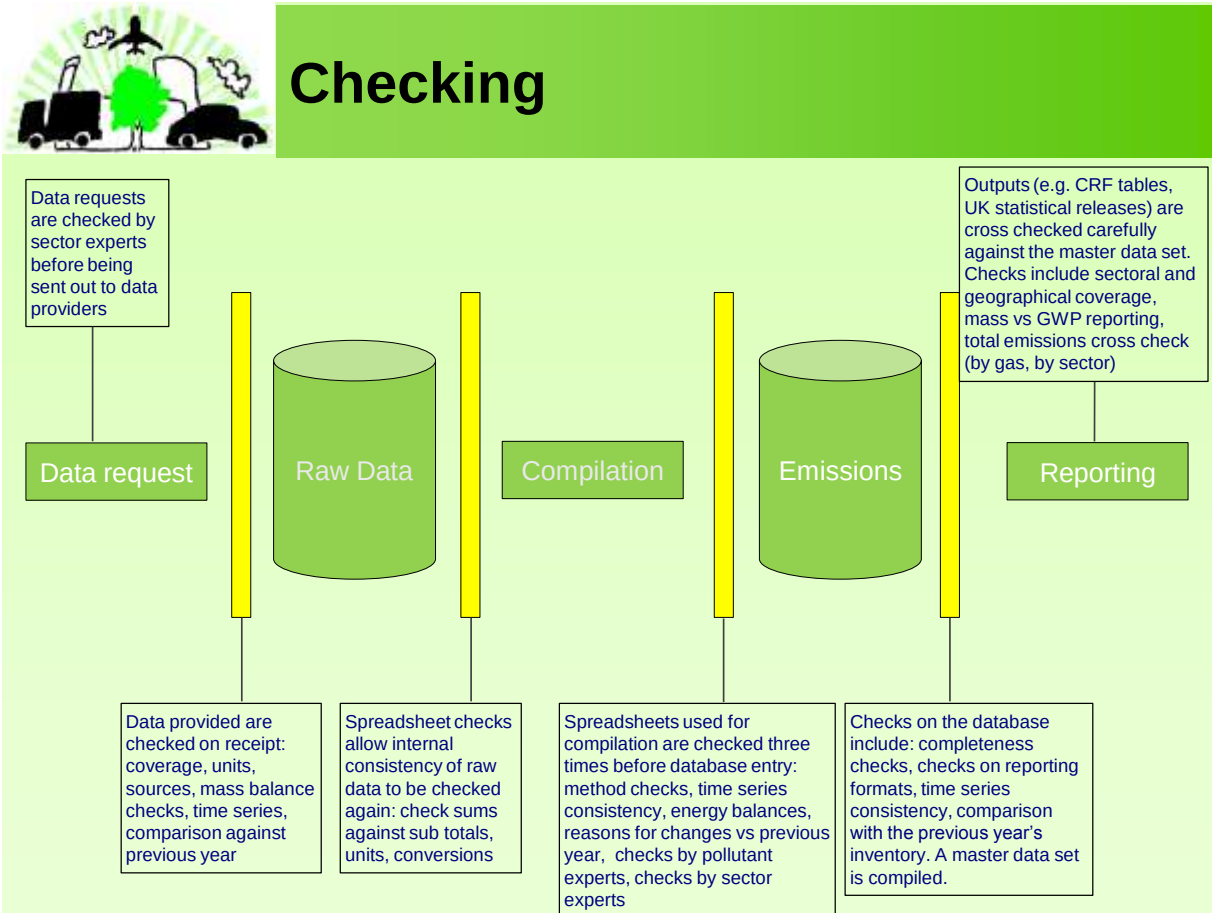
Specific responsibilities have been assigned to the different QA (review) and QC (checking) activities and to different roles within the compilation and reporting process. These are embedded within compilation and processing spreadsheets and databases. The following responsibilities are outlined in the 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, online 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 subsidiary 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 1990-2013 inventory include:

Department of Energy and Climate Change

- The Inventory Agency held a meeting with the DECC energy statistics team that produces the Digest of UK Energy Statistics to discuss what changes (to both activity and methodology) were expected in the 2014 publication of the statistics, and to clarify some outstanding queries. Some of the most significant changes were related to consultations with the Inventory Agency on investigations made in the previous year, including to iron & steel and non-energy use (NEU) of fuels.

- Following the meeting mentioned above, follow up meetings with the DUKES team were held to understand the change in methodology to NEU of fuels, in particular refinery feedstock, and how those changes in DUKES methodology could be replicated for the entire time-series (in DUKES the time series was only revised back to 2008).
- 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.
- Consultation with the DECC Offshore Inspectorate to discuss access to EU ETS data, information on the data quality checking and operator reporting system (e.g. EEMS reporting guidance), and to explore any options to access information regarding oil and gas blowouts.

Department for Transport

- The Inventory Agency had a meeting with the Department for Transport (DfT) Traffic Statistics team to review and update the use of DfT transport activity data within the inventory methodology.

Environmental Regulators

- Meetings, teleconferences and emails with sector experts and emission inventory analysts from the environmental regulatory agencies in the UK (Environment Agency - EA, National Resources Wales - NRW, Scottish Environmental Protection Agency - SEPA and Northern Ireland Environment Agency - NIEA) and plant operators. These were undertaken 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.
- As in previous years we have been contacting Environmental Regulators to clarify discrepancies between the Pollution Inventory (PI) and EU ETS, and other data sources.
- Because of the increasing responsibilities of NRW, which is taking over the roles of the EA in Wales, the Inventory Agency has had a number of consultations with NRW regarding the support required from them.
- The environmental regulators were contacted to establish the data held on private wastewater management systems, as part of compliance with the 2006 IPCC Guidelines.

Other data providers

- The Inventory Agency has had discussions with a wide range of industry contacts, primarily in industries related to the use of solvents, chemicals and pharmaceuticals, seeking data (mainly) on emissions of VOCs, nitrous oxide and F-gases including: ABPI, BASA, ECSA, FESEPA and VBRA.
- Consultation with the Food and Drink Federation to seek available production data across a range of sector products, and to explore access to data regarding waste management and waste-water treatment.
- Consultation with gas network providers to request additional information on the UK gas distribution and transmission system (in particular pipeline lengths). Several data revisions have been implemented by the Inventory Agency as a result of clarifications of data previously reported by the gas network operators, leading to more accurate UK estimates for gas leakage as well as gas compositional data.
- Consultation with UKPIA regarding carbon emission factor data for petroleum fuels in response to review questions. This led to a number of further meetings including with

the EA PI team, the International Institute of Applied Systems Analysis (IIASA) team in Austria and JRC.

- There have been continued consultations with the organisation (UKWIR) that helps water companies report emissions via the Carbon Accounting Worksheet (CAW) to clarify the information we received this year, and to request some further data in years to come.

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.

Since 2002, the UK has 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 - 2014: 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 10.
2014. Independent Review of the UK Kyoto Protocol LULUCF Inventory Estimates	Preparatory review to the UNFCCC assessment of UK KP reporting.
2014: Bilateral review of the energy and waste sectors	Bilateral review with Germany, focusing on the energy balance, iron and steel, refineries, the chemical industry and waste and biofuels. The recommendations from this review will feed into the UK inventory improvement programme.

Review description	Summary
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 have now been implemented.
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 Energy & Environment, 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.

Review description	Summary
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.
9. Knowledge sharing with the Vietnam inventory team.

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 6** of the 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 of fluorinated gases 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 PFCs or SF_6 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 5% in 1990 and 4% in 2013. The trend in the total GWP weighted emissions expressed as the fall between 1990 and 2013 is -30%, with 95% of the values found to lie within the range -25% to -34%.

A full description of the uncertainty analysis is presented in **Annex 2**.

1.8 GENERAL ASSESSMENT OF COMPLETENESS

1.8.1 GHG Inventory

The UK GHG inventory aims to include all anthropogenic sources of GHGs. Table 9 of the CRF 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 **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 30% between 1990 and 2013 and 2.4% between 2012 and 2013. This decline between 1990 and 2013 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. The decline between 2012 and 2013 is primarily due to a reduction in coal use in power stations.

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, 1990-2013 in Mt CO_2e

Emission Year	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3	**Total**
1990	599.3	137.2	57.2	14.6	1.65	1.28	0.0004	811.2
1995	563.4	130.2	47.3	19.6	0.60	1.26	0.0008	762.4
2000	561.0	114.1	36.7	10.5	0.60	1.82	0.0017	724.7
2005	559.5	92.3	32.2	13.2	0.39	1.06	0.0003	698.7
2009	484.0	72.1	28.6	15.2	0.20	0.65	0.0003	600.8
2010	502.5	67.3	29.0	15.7	0.29	0.73	0.0003	615.5
2011	459.3	64.2	27.8	16.0	0.42	0.65	0.0003	568.4
2012	477.9	61.4	27.8	16.2	0.26	0.63	0.0003	584.3
2013	469.2	56.4	27.7	16.3	0.25	0.60	0.0004	570.5

2.2 DESCRIPTION AND INTERPRETATION OF EMISSION TRENDS BY GAS

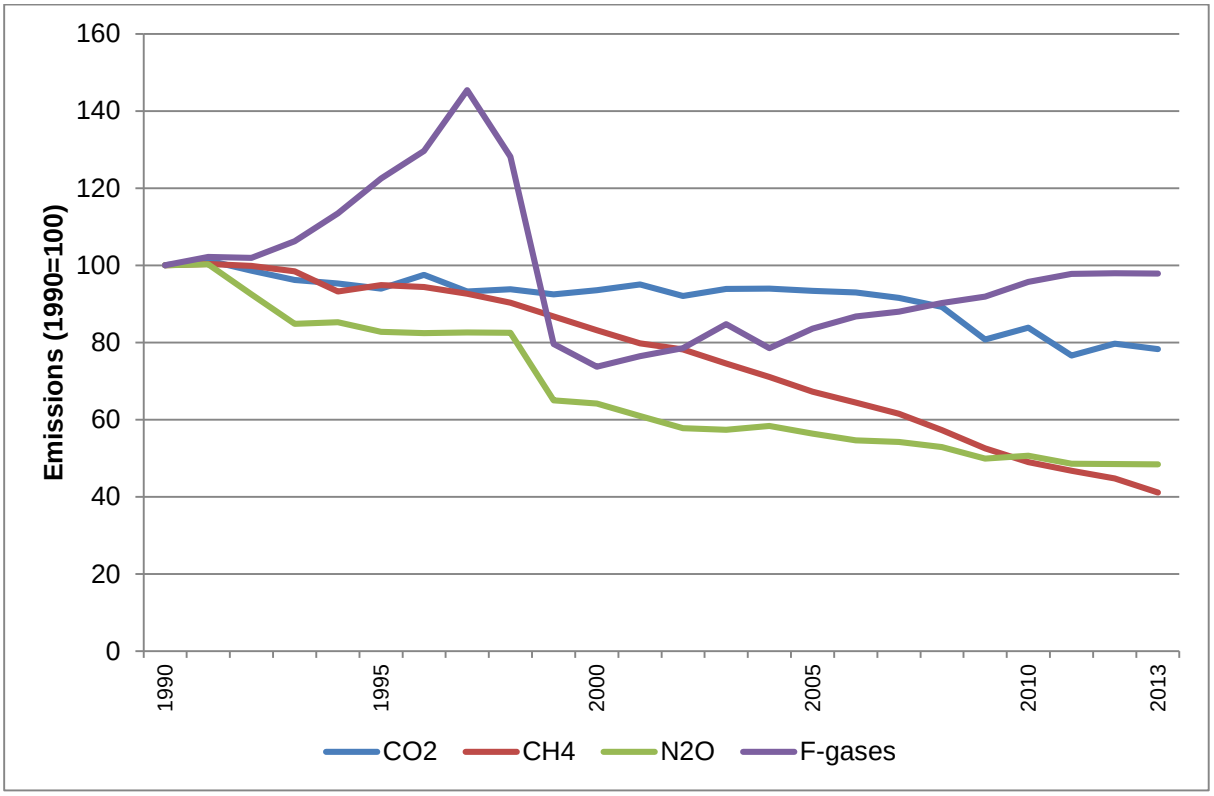
The largest contributor to global warming is CO_2 at 82% of the weighted emission in 2013 (see **Section 1.1.2** for information about weighted emissions). CH_4 contributes 10% and N_2O 5%. In spite of their high GWPs the contribution of halocarbons is small, estimated at around 3%

of total GHG emissions. This is because their mass emissions are very small. Overall the total GWP weighted emission has fallen by 30% since 1990.

Table 2.2 UK Greenhouse Gas Emissions by Gas in 1990 and 2013

Unit	Year	CO_2	CH_4	N_2O	F-Gases	Total
Mt CO_2e	**1990**	599.3	137.2	57.2	17.5	811.2
	2013	469.2	56.4	27.7	17.1	570.5
% Share	**1990**	73.9%	16.9%	7.0%	2.2%	100.0%
	2013	82.2%	9.9%	4.9%	3.0%	100.0%

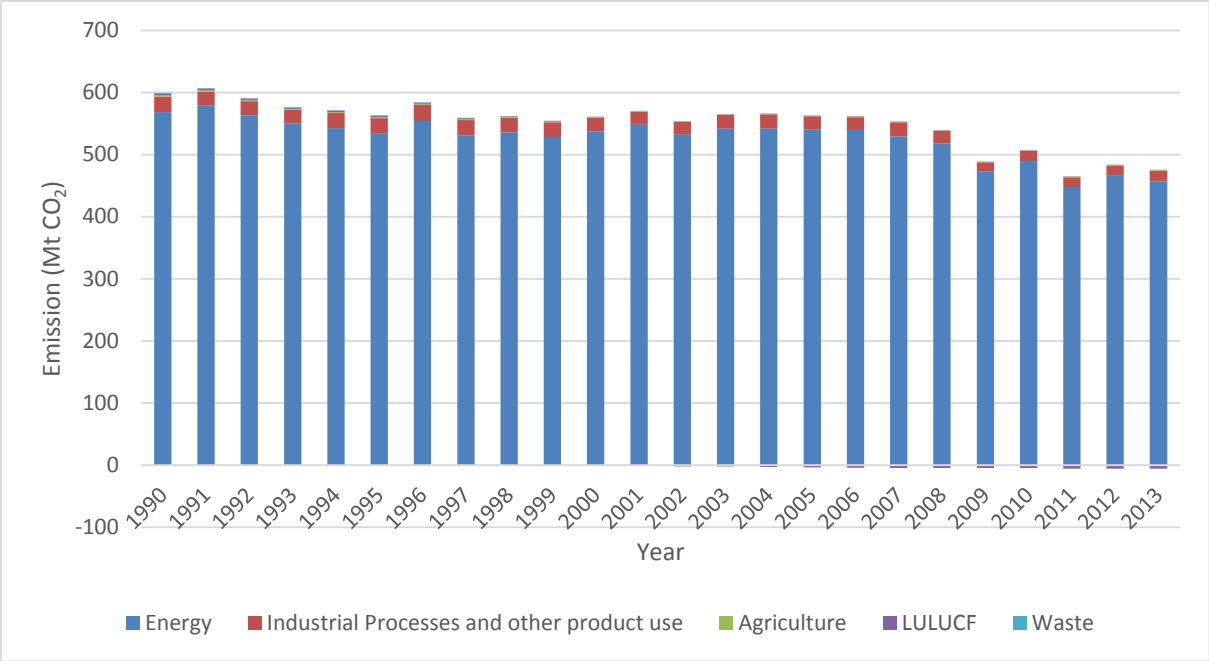
Figure 2.1 Trend in Greenhouse Gas Emissions by Gas, 1990 to 2013, Relative to 1990 Emission Levels.



2.2.1 Carbon Dioxide

In 2013, CO_2 emissions were 469 Mt CO_2 equivalent, 22% 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. Because of the strong link between power generation and CO_2 emissions, short term trends can be dominated by UK temperatures, as in cold years like 1995 and 2010 there is an increase in demand for power for heating and in warm years like 2011 there is a decrease. **Figure 2.2** includes net emissions and removals of CO_2 from LULUCF.

Figure 2.2 UK CO_2 Emissions Trend by Sector for 1990 to 2013



2.2.2 Methane

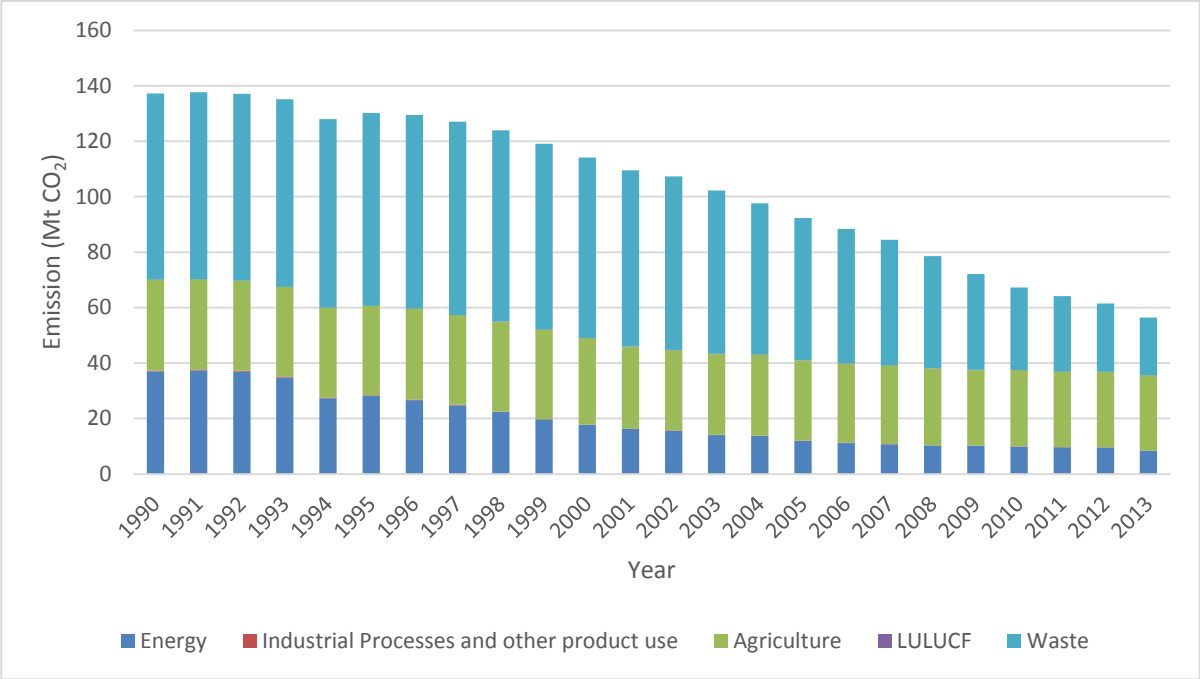
Figure 2.3 illustrates the trend in emissions of methane, broken down by source. Methane is the second most significant greenhouse gas in the UK after CO_2 and since 1990, emissions of methane have decreased by 59%. In 2013, methane emissions were 56 Mt CO_2 equivalent.

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 77% since 1990. Decreases in this sector have contributed 35% to the total decrease in methane emissions.
- Total emissions in the waste sector have decreased by 69% due to increased implementation of methane recovery systems at landfill sites. The reduction in emissions in this sector is responsible for 57% of the total decrease in methane emissions since 1990.
- Emissions from agriculture have decreased by 18% since 1990, following the trend of decreasing livestock numbers. This sector is responsible for 7% of total reductions in methane emissions.

Emissions from LULUCF and Industrial Processes and other product use are not significant sources of methane in comparison to the other sectors.

Figure 2.3 UK CH_4 Emissions (Mt CO_2e) Trend by Sector for 1990 to 2013

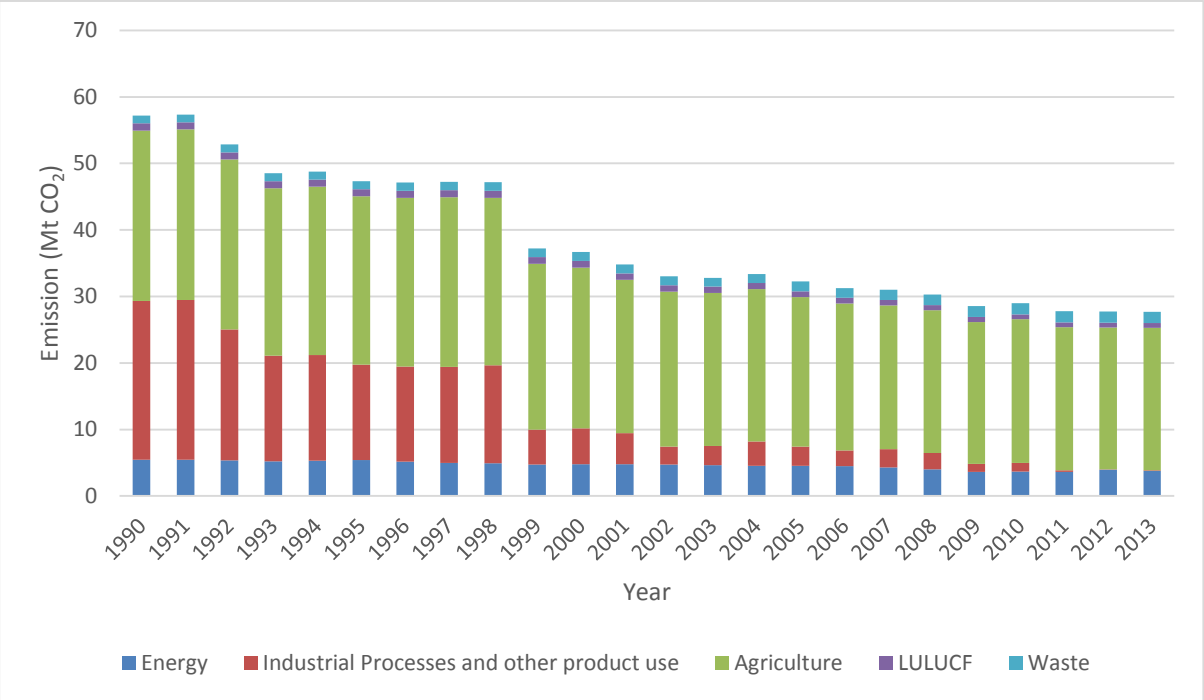


2.2.3 Nitrous Oxide

Figure 2.4 illustrates the trend in emissions of N_2O. The main anthropogenic sources are agriculture, transport, industrial processes, and coal combustion. In 2013, emissions of N_2O were 28 Mt CO_2 equivalent. Emissions have declined 52% since 1990, and the main reasons for this reduction are:

- The agriculture sector is a major source of N_2O emissions, contributing 77% to total emissions of N_2O in 2013. Emissions from this sector have decreased by 16% since 1990, mostly due to a decrease in emissions from sector 3D, 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 and other product use. In 1990, nitric and adipic acid production were both significant sources of N_2O, contributing 42% to total N_2O emissions. In 2013, these sources accounted for only 0.15%. 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 and other product use have decreased by 99.6% since 1990, contributing 81% 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 14% to total N_2O emissions in 2013. Emissions from this sector have decreased by 31% since 1990. The most significant sources within this sector are road transport, industrial combustion and power generation. Both industrial combustion and power generation have shown decreases in emissions since 1990. Road transport emissions increased between 1991 and 1995, and since 2009, consistently decreasing otherwise, primarily due to the changing catalyst technologies, some of which reduce NO_X emissions by converting it to N_2O, the sulphur content of fuel impacts the effectiveness of catalysts and fuel switching, as there's a significant difference in the nitrogen emission from petrol and diesel vehicles. The overall change in the N_2O emissions from the transport sector between 1990 and 2013 is a decrease of 20%.

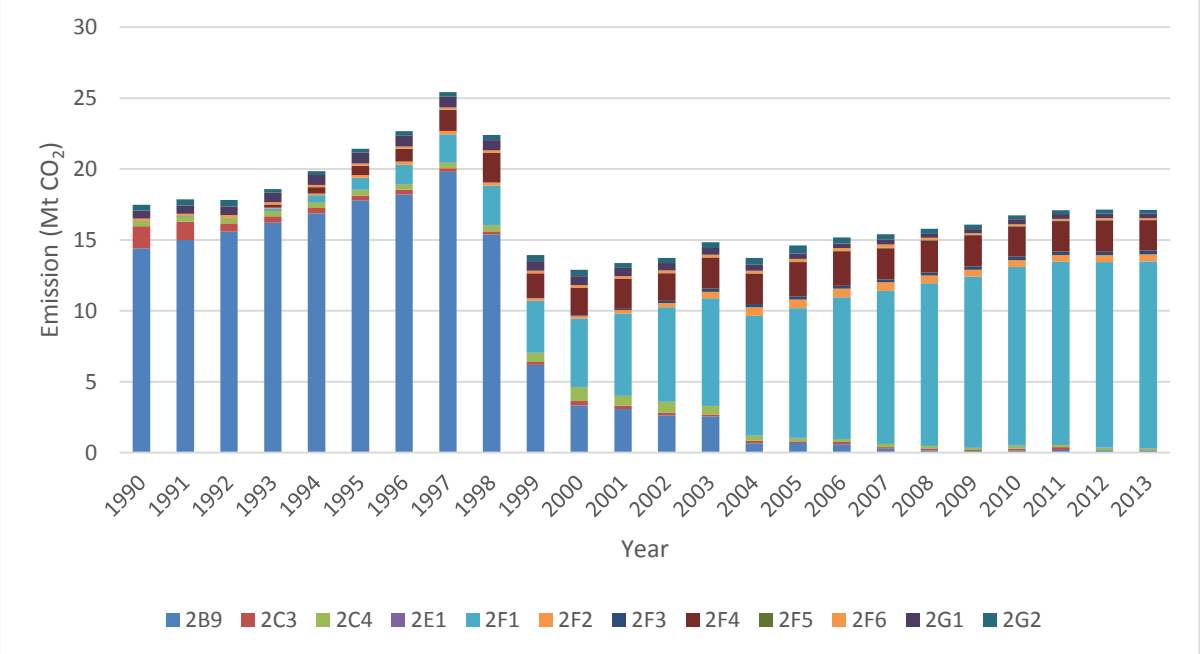
Figure 2.4 UK N_2O Emissions (Mt CO_2e) Trend by Sector for 1990 to 2013



2.2.4 Fluorinated-Gases

Emissions of the F-gases (HFCs, PFCs, SF_6 and NF_3) totalled 17 Mt CO_2 equivalent in 2013. Since 1995 – the base year used for F-gases – the overall decrease in their emissions has been 20%, mainly driven by the fall in emissions from F-gas manufacture (sector 2B9), 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 F- Gas Emissions (Mt CO_2e) Trend by Sector for 1990 to 2013



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

2B9: Fluorochemical Production

2C3: Aluminium Production

2C4: Magnesium Production

2E1: Integrated Circuit or Semiconductor

2F1: Refrigeration and Air Conditioning Equipment

2F2: Foam Blowing Agents

2F3: Fire Extinguishers

2F4: Aerosols

2F5: Solvents

2F6: Other Product Uses as Substitutes for ODS (in this case transportation of refrigerants)

2G1: Electrical Equipment

2G2: SF_6 and PFCs from Other Product Use (including trainers, electronics, AWACS, tracer gas and particle accelerators)

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, 1990-2013 (Mt CO_2e)

Year	Energy	Industrial Processes and other Product Use	Agriculture	LULUCF	Waste
1990	610.8	66.4	60.5	3.98	69.5
1995	566.9	61.1	59.5	3.28	71.6
2000	559.4	41.1	56.4	0.85	66.9
2005	556.5	39.5	52.5	-2.91	53.2
2009	486.3	32.1	49.9	-4.06	36.5
2010	503.2	34.5	50.3	-4.27	31.7
2011	461.3	32.7	50.2	-4.83	29.1
2012	480.4	32.7	49.7	-4.96	26.5
2013	468.9	34.6	49.5	-5.24	22.7

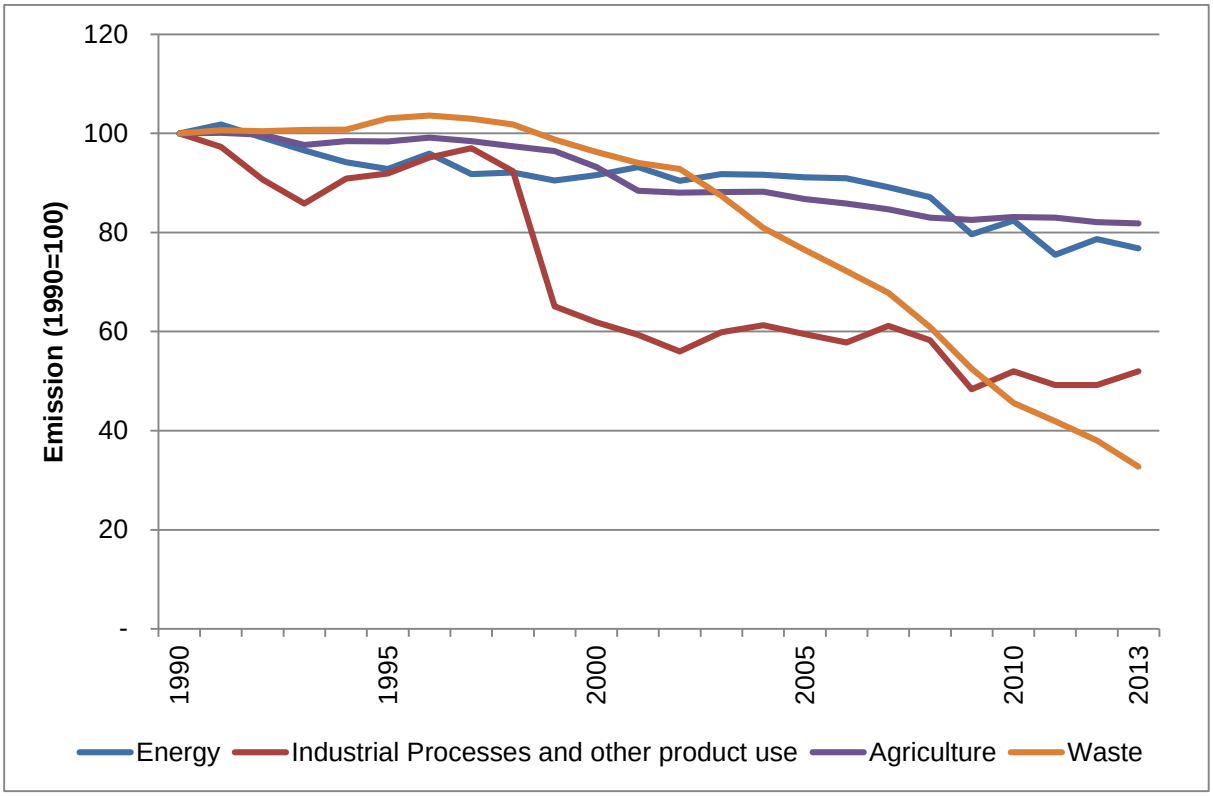
Total emissions are dominated by the energy sector in both 1990 and 2013, contributing 75% to total net emissions in 1990 and 82% in 2013. Emissions from all sectors have declined between 1990 and 2013, with the largest decline in percentage terms from the LULUCF sector,

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 2013, the emissions trend and share of the UK GHG Inventory total

Sector	Emissions (Mt CO_2e)		Trend	Share	
	1990	2013	1990-2013	1990	2013
Energy	610.8	468.9	-23%	75%	82%
Industrial Processes and other product use	66.4	34.6	-48%	8%	6%
Agriculture	60.5	49.5	-18%	7%	9%
LULUCF	3.98	-5.24	-232%	0%	-1%
Waste	69.5	22.7	-67%	9%	4%
Grand Total	811.2	570.5	-30%	100%	100%

Figure 2.6 Trend in GHG emissions by sector for 1990 to 2013, Relative to 1990 Emission Levels[18]



[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

2.3.1 Energy

In 2013 emissions in the energy sector accounted for 82% of total net direct greenhouse gas emissions and have declined by 23% since 1990.

For CO_2; 97% of total net emissions came from this sector in 2013. Energy industries (category 1A1) were responsible for 39% of the sector's CO_2 emissions in 2013. There has been an overall decline in emissions from this sector of 20% 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. Since 2010, particularly in 2012, there was a significant change in trend, with coal use increasing between 2010 and 2012 – but not in 2013, gas use decreasing since 2011 and a doubling in non-nuclear renewable electricity production since 2010.

Overall, between 1990 and 2003, there was a 20% increase in the amount of electricity generated; this has since dropped to 6.9% above 1990 generation levels in 2013, but between 1990 and 2013 there has been a 28% decrease in CO_2 emissions from power stations (Sector 1A1a). There are several reasons; firstly the shift towards use of Combined Cycle Gas Turbine (CCGT) stations rather than conventional steam stations burning coal or oil – CCGT stations operate at a higher thermal efficiency, for example in 2013 they operated on average at 48% efficiency, whilst coal-fired stations operated on average at 36% efficiency. Secondly, the calorific value of natural gas per unit mass carbon is higher than that of coal and oil. Thirdly, there has been an increase in electricity generated from non-fossil fuel energy sources, due to increased use of wastes and renewable energy sources, which in 2013 including nuclear energy provided 35% of UK electricity generation.

Emissions from category 1A2 – Manufacturing Industries and Construction contributed 12% to overall net CO_2 emissions in the UK in 2013. Since 1990, these emissions have declined by 41%, 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 2013 were responsible for 94% of the total emissions from transport. Emissions from road transport peaked in 2007 at 10% above 1990 levels. Carbon dioxide emissions from road transport have declined since 2007 mostly due to improvements in average fuel efficiency of vehicles, switching from petrol to diesel cars and a reduction in traffic volumes. Total vehicle kilometres travelled are 11% less in 2013 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 CO_2 emissions as carbon emissions from the consumption of biofuels are not included in the UK totals. Emissions of CO_2 from domestic aviation increased by 61% between 1990 and 2005, but have since shown a decrease of 35% since 2005. This is because of a move to use more fuel efficient aeroplanes in 2006 and a smaller number of air miles being flown.

Emissions of CO_2 in the domestic sector (1A4b) account for 73% of CO_2 emissions in 1A4. These emissions have changed little between 1990 and 2013 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, 64% of these emissions came from the production of solid fuels; however these emissions have decreased by 92% and now make up just 23% of fugitive CH_4 emissions. Fugitive emissions from oil and gas operations have also decreased over this period, by 49.7%.

N_2O emissions from the energy sector have decreased by 29% since 1990 and accounted for 14% of total N_2O emissions in the UK during 2013. Of this, 36% arose from energy industries (1A1). Within this category, emissions from public electricity production have shown a 33% decrease. Over this period the use of coal has decreased and the use of natural gas increased, as emissions of N_2O per GWh is significantly lower for natural gas use than coal in power generation, this represents a significant reduction in N_2O emissions.

The other major contribution towards N_2O emissions within the energy sector is the transport sector (1A3) (27%). Road transport emissions increased between 1991 and 1995, and since 2009, consistently decreasing otherwise. The trend is driven by 3 key factors; the changing catalyst technologies (some of which reduce N_2O, but others reduce NO_X emissions by converting it to N_2O, hence increasing N_2O emissions), the sulphur content of fuel (which has decreased significantly due to regulation) impacts the effectiveness of catalysts and fuel switching, as there's a significant difference in the nitrogen emission from petrol and diesel vehicles. The overall change in the N_2O emissions from the transport sector between 1990 and 2013 is a decrease of 20%.

2.3.2 Industrial Processes and Other Product Use

Emissions of direct Greenhouse gases within this sector have decreased by 48% since 1990. For 2013, 50% of emissions in this sector were of CO_2, although this made up only 3.7% of all CO_2 emissions. Only small quantities of CH_4 and N_2O came from this sector in 2013, whilst 100% of F-gases are assigned to industrial processes and other product use.

Since 1990, emissions of CO_2 have fallen by 31%, driven by reductions in activity in a number of key sectors. In particular, CO_2 emissions from 2A1 (cement manufacture) have fallen by 45% due to closure of many kilns and decreasing cement production, emissions from 2C1 (iron and steel) have fallen by 11%, also due to site closures and decreasing production, and the UK's only primary lead/zinc smelter closed in 2003. The recent upward trend in CO_2 emissions is driven by the iron and steel industry, from which emissions increased by 79% between 2011 and 2013 primarily due to the reopening of a large site that was mothballed in 2010, changed ownership in 2011 and restarted production in 2012.

Between 1990 and 2013, emissions of N_2O from this sector declined by an estimated 99.6% 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 falls due to the closure of 4 plants between 2000 and 2008 and due to the installation of abatement technology in the larger of the remaining plants in 2011. 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 12%. The largest contribution to this sector in 2013 arises from category 2F1 – refrigeration and air conditioning equipment. In 2013, these contributed 81% 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 (13%) 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% since 1990, due to plant closures and the installation of abatement equipment.

PFC emissions have declined by 85% since 1990. A significant source of PFC emissions is aluminium production, which is formed as a by-product during the process of aluminium smelting. Since 1990, emissions arising from aluminium production have decreased by more than 99% due to significant improvements in process control, an increase in the rate of aluminium recycling and the closure of aluminium plants.

The use of SF_6 in magnesium foundries contributed 24% towards total SF_6 emissions in 2013, and national emissions of SF_6 have decreased by 53% since 1990. Emissions from 2G – Other contributed the remaining 76% towards emissions, which is dominated by 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, sports shoes, particle accelerators, AWACS and tracer gas.

2.3.3 Agriculture

Direct GHG emissions from agriculture in 2013 consisted of 55% CH_4, 43% N_2O and 2% CO_2. Total agricultural GHG emissions decreased by 18% between 1990 and 2013. CH_4 emissions have declined by 18%, driven mostly by a decline in emissions from enteric fermentation from cattle due to decreased cattle numbers. N_2O emissions have decreased by 16%, which has been driven by both a decline in animal numbers and a decrease in synthetic fertiliser application, particularly to grasslands. Carbon dioxide emissions are due to liming and application of urea to farmland, CO_2 emissions have fallen by 48% since 1990.

2.3.4 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 2000. 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 4.0 $MtCO_2e$ in 1990 to a sink of 5.2 $MtCO_2e$ in 2013. The land use categories which have the greatest effect on the net LULUCF emissions/removals are forest land (a net sink) and cropland (a net source). Forest land 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 21% since 1990.

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 70% since 1990. Emissions of nitrous oxide have decreased by 35% since 1990.

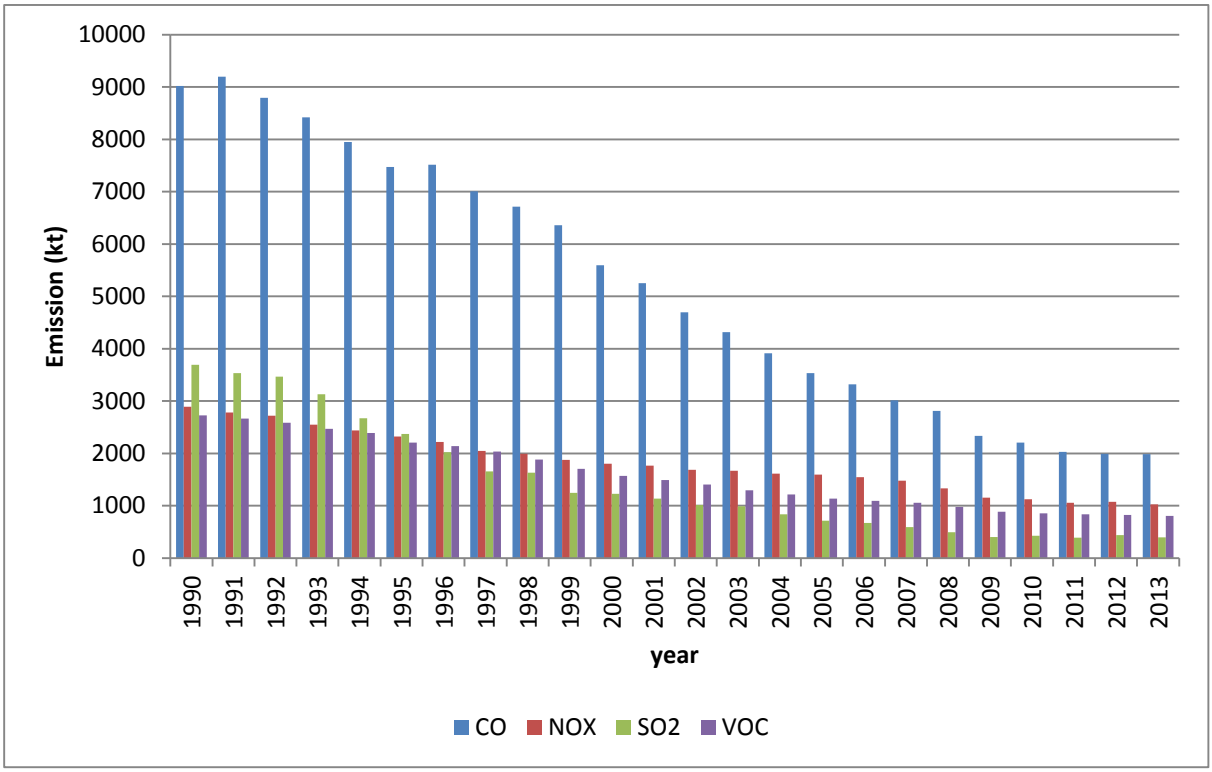
2.3.5 Waste

Total emissions from the waste sector have declined by 67% since 1990. Almost 99% 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 73% 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 2013



2.4.1 Carbon Monoxide

In 2013, the total emissions of CO were 1,989 Gg, and since 1990, emissions have decreased by 78%.

Emissions of carbon monoxide from the energy sector contributed 82% to overall UK CO emissions in 2013, 38% of these emissions occur from transport (1A3). Since 1990, emissions from 1A3 have declined by 90%, 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 22% to overall emissions of CO in 2013. Emissions from within this category mostly come biomass combustion and off-road vehicles used in manufacturing, industry and construction.

2.4.2 Nitrogen Oxides

In 2013, total emissions of NO_x were 1,024 Gg, and since 1990, emissions have decreased by 65%.

98% of NO_x emissions in the UK came from the energy sector in 2013. Since 1990 emissions from this sector have decreased by 65%, 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 2013, emissions from transport contributed 40% to the total emissions of NO_x in the UK, 80% of which arising from road transport (1A3b). From 1970, emissions from transport increased (especially during the 1980s) and reached a peak around 1990. The reduction in emissions since 1990 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 35% to total NO_x emissions in the UK during 2013. Between 1990 and 2013, emissions from this sector decreased by 59%, the main reason for this was a decrease in emissions from public electricity and heat production (1A1a) of 65%. 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 64% since 1990. In 2013, emissions from this sector contributed 13% 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 395 Gg, and since 1990, emissions have decreased by 89%.

94% of emissions of sulphur dioxide came from the energy sector in 2013, 56% of these emissions arose from energy industries (1A1). Since 1990, emissions from power stations (1A1a) have declined by 94%. This decline has been due to the increase in the proportion of electricity generated CCGT stations, other gas fired plants, the increase in the proportion of electricity generated in nuclear plants, and 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 25% of UK emissions of SO_2 in 2013. Since 1990, emissions from this category have declined by 76%. 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 2013, total emissions of NMVOCs were 805 Gg, and since 1990, overall emissions have decreased by 70%.

Emissions from the industrial processes and other product use sector contributed 57% to overall UK emissions of NMVOCs. 76% of these emissions in 2013 were from the Non-energy Products from Fuels and Solvent Use sector which contributed 44% to total NMVOC emissions in 2013, and since 1990 emissions have declined by 48%. Most of the remaining NMVOC emissions in the industrial processes and other product use sector are from the food and drink and chemicals industries.

30% of non-methane volatile organic compound emissions came from the energy sector in 2013. Of these, the largest contribution arises from the fugitive emissions of oil and natural gas (1B2), which contributed 17% towards the overall UK emissions of NMVOCs in 2013. This includes emissions from gas leakage, which comprise around 12% of the total for the energy sector, the remaining emissions arise from oil transportation, refining, storage and offshore. Emissions from transport (1A3) contribute 5.5% to overall emissions of NMVOC in the UK in 2013, but emissions from this sector have decreased by 95% since 1990 due to the increased use of three way catalysts in petrol cars.

2.5 EMISSION TRENDS FROM KP LULUCF ACTIVITIES

The main driver of the emission and removal trends for KP-LULUCF 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 14.4 kha per year since 1990 has produced 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 harvesting of mature trees and the creation of open spaces within woodlands.

Harvested Wood Products (HWP) are included in the 2nd commitment period for KP as a carbon pool. For Afforestation land this category includes all domestically produced wood products since 1990. HWP from Deforestation land are estimated on the basis of instantaneous oxidation (i.e. the loss of carbon in the biomass pools is estimated but the carbon transfers to the atmosphere rather than to a HWP pool). The 2nd commitment period of KP uses a Forest Management Reference Level (FMRL), which supersedes the Forest Management Cap used in the 1st commitment period. The UK included HWP in the FMRL using first order decay functions. HWP from Forest Management are only included from 2013 as emissions from HWP from before the commitment period can be excluded as long as there is consistency between the FMRL and the accounting during the commitment period.

For the 2nd commitment period the UK has elected to report on additional Article 3.4 activities (Cropland Management, Grazing Land Management and Wetland Drainage and Rewetting). The UK is not yet in a position to report on these activities but development is underway and they will be included before the end of the commitment period.

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).

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

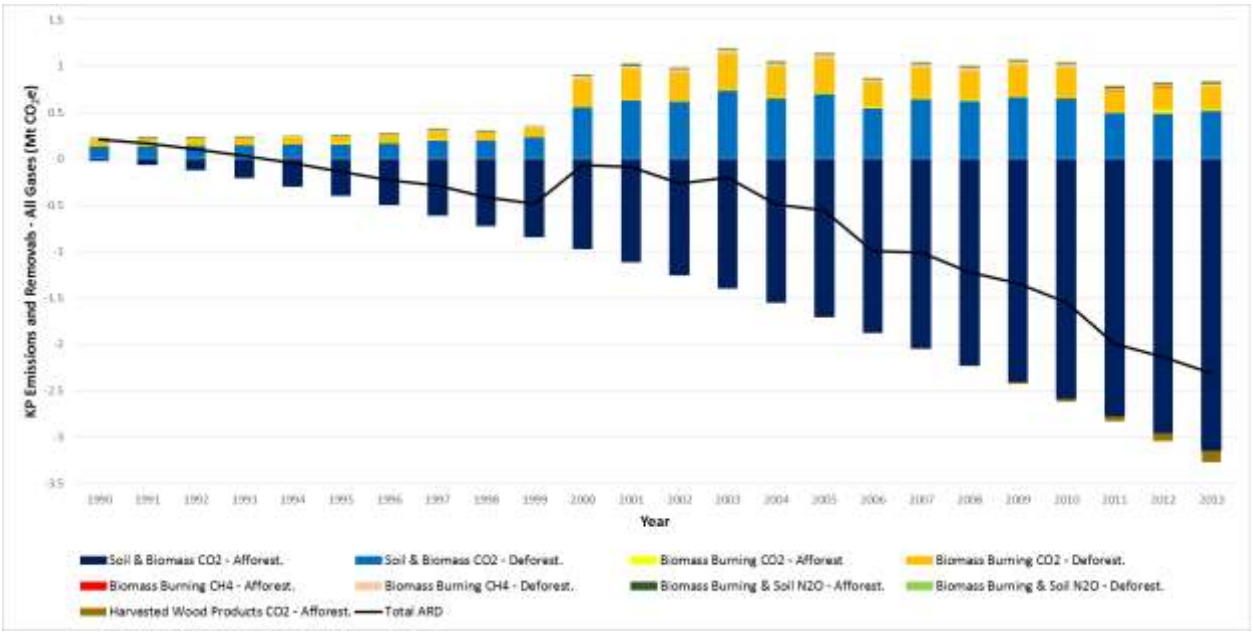
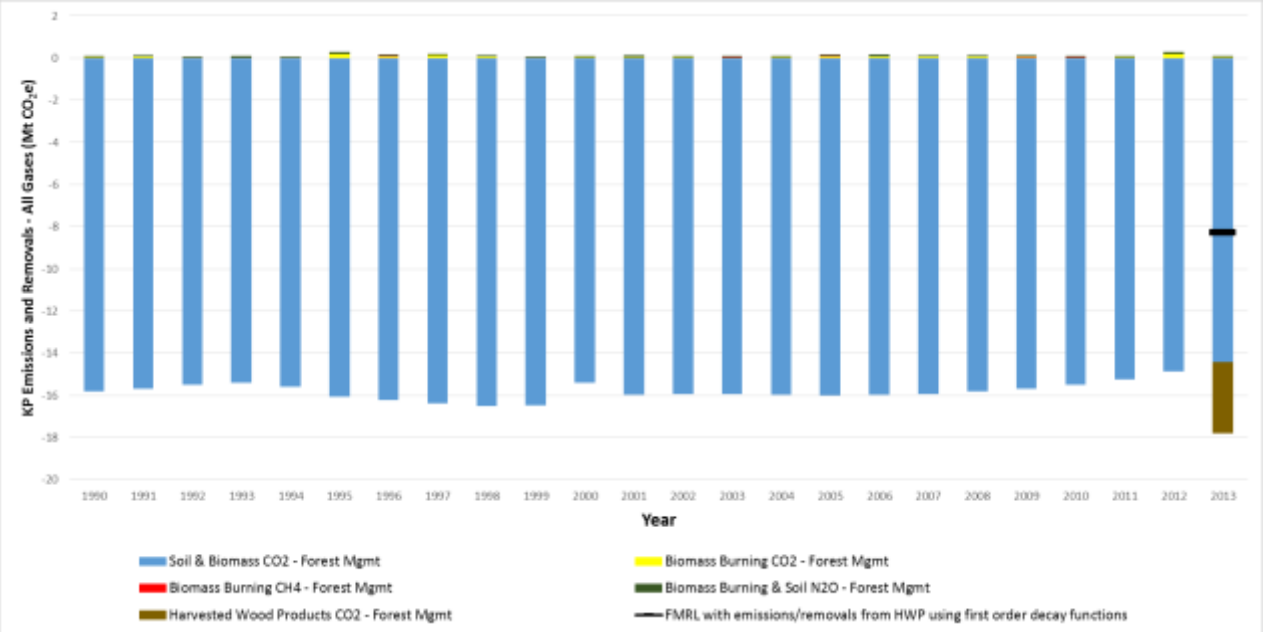


Figure 2.9 Article 3.4 Emissions and removals, by gas and activity



3 Energy (CRF Sector 1)

3.1 OVERVIEW OF SECTOR

Table 3.1 gives an overview of the energy sector. The KCA rank combines the Key Category Analyses, and gives an indication of which categories contain or are a Key Category. Smaller numbers relate to a higher ranking. More detail on how they're derived along with a KCA ranking summary table can be found in **Section 1.5.1**. The uncertainty estimate has been taken from Monte Carlo analysis.

Emission trends are presented for 1990-2013 and 2012-2013. A description of the trends and the main drivers behind these can be found in **Chapter 2**.

Recalculations are displayed at the level "1A1" since at this level, the category nomenclature within the energy sector is broadly consistent between the old and new reporting conventions. However, note that the recalculation includes the impact of the changes in GWPs (2014 submission figures calculated based on SAR, 2015 based on AR4).

The total impact of inventory recalculations for this sector are small because:

- The energy sector emissions are predominantly made up of carbon dioxide for which there is no change in Global Warming Potential (GWP);
- There are only a small number of method or source data revisions. The UK energy statistics revisions in DUKES 2014 do include some re-allocations of petroleum fuels to energy use rather than to non-energy uses (such as petrochemical feedstocks). This has led to small increases in the emissions in the Energy sector; and
- Reallocations into or out of the sector (as part of the migration from IPCC 1996 GLs reporting to IPCC 2006 GLs reporting) are not very large. Several source category emissions have been moved from Energy to IPPU due to the re-categorisation of some coke and petcoke consumption (from "energy" to "reductant" – and hence in IPPU) whilst lubricant use and all natural gas use in ammonia production are also now assigned to the IPPU sector, rather than Energy. The biggest impact is from the re-allocation (evidenced in the re-allocation data for 1A2 in the table below) of the use of process off-gases as fuels in chemical and petrochemical production. These were previously reported under 1A2c but are now allocated within 2B in the IPPU sector.

As part of the UK inventory improvement programme, the Energy chapter of the NIR has been reviewed and reorganised to reduce repetitive text and provide a clearer structure for reviewers. Inventory method descriptions have now been consolidated into a series of method statements, rather than following the order of the reporting categories (which leads to repetition of method text). The method statements are cross referenced below to allow users to find the information about each of the categories more easily.

Table 3.1 Energy Sector Overview

Energy Greenhouse Gas Source and Sink Categories	KCA Rank[1]	Uncertainty[2]	2013 emissions total (Mt CO_2e)	1990-2013 trend[3]	2012-2013 trend[3]	Recalculation: 2012[4]	Recalculation-: 1990[4]	Methodology reference (NIR Section)
Total Energy			**469**	**-23%**	**-2%**	**-1.0%**	**-0.1%**	
A. Fuel combustion activities (sectoral approach)			**458**	**-20%**	**-2%**	**-1.3%**	**-1.3%**	
1. Energy industries			**179**	**-25%**	**-7%**	**0.2%**	**0.1%**	
a. Public electricity and heat production	1, 5, 6, 33	2%	149	-28%	-7%	-0.2%	0.0%	**MS 1**
b. Petroleum refining	1, 5, 6, 33	15%	15	-18%	-8%	0.9%	1.2%	**MS 1**
c. Manufacture of solid fuels and other energy industries	1, 5, 6, 33	2%	15	8%	-2%	3%	0.1%	**MS 1, MS 2**
2. Manufacturing industries and construction			**57**	**-41%**	**3%**	**-16%**	**-8%**	
a. Iron and steel	7, 8, 10	9%	15	-32%	22%			**MS 4**
b. Non-ferrous metals	7, 8, 10	10%	1	-81%	-67%			**MS 3**
c. Chemicals	7, 8, 10	6%	5	-57%	11%			**MS 3**
d. Pulp, paper and print	7, 8, 10	6%	2	-58%	2%			**MS 3**
e. Food processing, beverages and tobacco	7, 8, 10	5%	5	-41%	2%			**MS 3**
f. Non-metallic minerals	7, 8, 10	11%	2	-67%	6%			**MS 3**
g. Other	7, 8, 10	5%	28	-30%	2%			**MS 3**, **MS 20**
3. Transport			**115**	**-1%**	**-1%**	**-0.1%**	**-0.1%**	
a. Domestic aviation		20%	2	5%	-1%	9%	12%	**MS 5**
b. Road transportation	2	2%	108	-2%	-1%	-0.1%	-0.2%	**MS 6**
c. Railways	31	18%	2	35%	-3%	-4%	0.0%	**MS 7**
d. Domestic navigation	25	18%	2	0%	-3%	-2%	-5%	**MS 8, MS 9, MS 10**
e. Other transportation		19%	1	104%	3%	-0.5%	-0.5%	**MS 20**
4. Other sectors			**104**	**-7%**	**1%**	**4%**	**1.4%**	
a. Commercial / institutional	3, 13, 17	3%	24	-5%	6%	14%	2%	**MS 12**
b. Residential	3, 13, 17	4%	75	-6%	0%	1%	1%	**MS 12**, **MS 20**
c. Agriculture / forestry / fishing	3, 13, 17	30%	5	-22%	-2%	-2%	-0.6%	**MS 12**, **MS 20**, **MS 8**, **MS 13**
5. Other *(as specified in table 1.A(a) sheet 4)*			**2**	**-57%**	**-9%**	**-0.1%**	**0.0%**	
a. Stationary	N/A	N/A	IE	N/A	N/A			
b. Mobile	23	8%	2	-57%	-9%	-0.1%	0.0%	**MS 14, MS 15**
B. Fugitive emissions from fuels			**11**	**-73%**	**-7%**	**11%**	**18%**	
1. Solid fuels		**14%**	**2**	**-92%**	**-28%**	**16%**	**23%**	
a. Coal mining and handling	14, 34		2	-92%	-31%	53%	26%	**MS 16**
b. Solid fuel transformation	14, 34		0	-89%	34%	-41%	97%	**MS 4**

Energy Greenhouse Gas Source and Sink Categories	KCA Rank[1]	Uncertainty[2]	2013 emissions total (Mt CO_2e)	1990-2013 trend[3]	2012-2013 trend[3]	Recalculation: 2012[4]	Recalculation-: 1990[4]	Methodology reference (NIR Section)
c. Other *(as specified in table 1.B.1)*	N/A	N/A	NO	N/A	N/A	-100%	-100%	
2. Oil and natural gas and other emissions from energy production		**32%**	**10**	**-48%**	**-2%**	**10%**	**12%**	
a. Oil	16, 26		0	-80%	-2%	16%	6%	**MS 17**
b. Natural gas	16, 26		5	-58%	-3%	14%	17%	**MS 17**, **MS 19**
c. Venting and flaring	16, 26		5	-19%	0%	5%	5%	**MS 17**
d. Other *(as specified in table 1.B.2)*	N/A	N/A	NO	N/A	N/A	N/A	N/A	
C. CO_2 Transport and storage	**N/A**	**N/A**	**NO**	**N/A**	**N/A**	**N/A**	**N/A**	
1. Transport of CO_2	N/A	N/A	NO	N/A	N/A	N/A	N/A	
2. Injection and storage	N/A	N/A	NO	N/A	N/A	N/A	N/A	
3. Other	N/A	N/A	NO	N/A	N/A	N/A	N/A	
Memo items:	**N/A**	**N/A**	**61**	**68%**	**-1%**	**N/A**	**-0.8%**	
International bunkers	**N/A**	**N/A**	**41**	**68%**	**-1%**	**0.2%**	**-0.8%**	
Aviation	N/A	N/A	32	107%	-1%	0.3%	-1.3%	**MS 5**
Navigation	N/A	N/A	9	-1%	-3%	-0.1%	0.0%	**MS 11**
Multilateral operations	**N/A**	**N/A**	**NE**	**N/A**	**N/A**	**N/A**	**N/A**	
CO_2 emissions from biomass	**N/A**	**N/A**	**20**	**702%**	**20%**	**-22.9%**	**-18%**	**MS 1**, **MS 3**, **MS 20**, **MS 6**
CO_2 captured	**N/A**	**N/A**	**NO**	**N/A**	**N/A**	**N/A**	**N/A**	

Notes:

1 The KCA rank is explained in **Section 1.5.1**

2 The uncertainty values given are the 95% confidence intervals

3 The values given are the % difference in 2013 emissions from 1990 or from 2012. The cell colouration indicates the direction and % of the reported trend, ranging from dark green cells (denoting a large decrease in emissions) to dark red cells (denoting a large increase in emissions).

4 The values given are the % difference in 1990 or 2012 emissions from the data reported in the previous UK GHGI submission.

3.2 FUEL COMBUSTION (CRF 1.A)

3.2.1 Comparison of Sectoral and Reference Approaches

The UK compares its Sectoral Approach (SA) and Reference Approach (RA) as one of the means of verification of its energy sector GHG estimates in accordance with the UNFCCC decision 24/CP.19 paragraph 40.

The Sectoral Approach is the detailed 'bottom up' sectoral methodology for estimating energy CO_2 emissions described in **Section 3.4**, The Reference Approach is a 'top down' approach for estimating energy CO_2 emissions using national fuel statistics that acts as a verification tool for the Sectoral Approach.

Table 3.2 summarises the Sectoral and Reference Approach comparison. The Reference Approach typically produces UK CO_2 emission estimates that are within 2% of the more detailed Sectoral Approach. This is 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.

Over the period (1990 to 2013), emissions estimated by the Reference Approach have fallen by 19.0% compared with 19.3% for the Sectoral Approach, and on average across the time series the Reference Approach emissions are 97.3% of the Sectoral Approach. However, an amended Reference Approach dataset that removes sources of known differences from the SA shows much closer comparison with the SA, at 99.9% of the SA emissions across the time series.

The RA-SA comparison shows very close consistency between the two datasets for the UK, and provides verification of the reported SA emission estimates for 1A.The UK greenhouse gas inventory is compiled using a detailed Sectoral Approach methodology, to produce sector-specific inventories of the 10 pollutants in accordance with the IPCC reporting format. These UK GHGI emission estimates are based on bottom-up activity data, including:

- national energy statistics that present annual consumption of primary and secondary fuels within different economic sectors in the UK; and
- a wide range of other statistical datasets (e.g. raw material extraction and use, production statistics for minerals, metals, glass, cement, specific chemicals, waste statistics, livestock and crop data, land use survey information) to generate estimates of non-combustion emissions from other known sources.

To provide a comparison against the detailed Sectoral Approach inventory estimates, the Inventory Agency also calculates alternative UK emission estimates for carbon dioxide from energy sources in the UK, using the IPCC Reference Approach. This is a top-down inventory compilation method, which calculates emission estimates from National Statistics on production, imports, exports, stock changes and non-energy uses of fossil fuels: crude oil, natural gas and solid fuels.

The Reference Approach inventory method utilises different sections of the UK national energy statistics, combining aggregated data on fuel inputs and outputs from the overall UK economy, using top-level data on oils, gas and solid fuels to assess the UK carbon balance for combustion sources. This more simplistic, non-source-specific methodology provides a useful quality check against the more rigorous Sectoral Approach.

Differences between the RA and SA arise primarily due to statistical differences between production-side and demand-side fuel estimates within national energy statistics, the exclusion of carbon estimates from specific activities (e.g. carbon within coke and coal deliveries to the iron and steel and non-ferrous metal industries) and the more aggregated approach to applying emission factors to activity data across fuel types.

3.2.1.1 Improvement of the Reference Approach Method

The Reference Approach calculations have been extensively revised in this inventory cycle, due to the use of the new 2006 IPCC Guidelines which introduce several methodological changes and clarifications compared to the method described under the 1996 GLs. In addition to the required revisions to the method, the Inventory Agency has implemented a number of improvements in order to improve the accuracy, completeness and transparency of the data, partly in response to UNFCCC ERT recommendations from recent centralised reviews. The main changes implemented are:

- Method revisions to follow the 2006 GLs approach to estimating “excluded carbon” for the RA calculations, including new simpler approaches for:

  - Feedstocks (i.e. to exclude all carbon contained in feedstock materials, regardless of whether any emissions from off-gases are reported in the Energy sector of the SA);
  - Reductants (i.e. to exclude all carbon from coke and coal deliveries to the iron and steel and non-ferrous metal industries, to exclude all emissions from use of coke and petcoke as a reductant in industrial processes);
  - Non-energy products (i.e. to exclude all carbon contained in non-energy products such as lubricants, petroleum waxes, regardless of whether any emissions are reported in the Energy sector of the SA).

- Weighted-average factors and Calorific Values (CVs) for key fuels such as coal and natural gas have now been applied in the RA calculations to improve the use of UK country-specific data for all emissions within Energy 1A.
- The RA method has been improved to include several (minor) fuels reported in the SA 1A such as waste (fossil carbon only) and peat, that were previously not considered in the RA.
- Default CVs and Carbon Emission Factors (CEFs) have been updated to use new default data provided within the 2006 GLs, where there are no UK country-specific data to use.
- Oxidation factors (OFs) have been revised to 1 for all commodities. This is a simplistic approach, but is closely representative of the approach to OFs in the SA. In the case of coal, the CEF applied in the RA is taken from the SA, using a weighted average of CEFs across all coal emission sources in 1A for each year; this approach (combined with applying an RA OF of 1) effectively delivers exactly the same assumptions regarding oxidation of carbon in coal combustion as in the SA, as the CEF already includes consideration of an OF (in the SA) of around 0.98.
- Other improvements in the RA calculations have improved the accuracy of the RA outputs, e.g. through the use of revised time series of weighted-average CVs for "DERV plus gas oil", and calculations are now performed separately for anthracite, coking coal and steam coal (replacing a more aggregated approach across "coal" in previous RA analysis).
- Two errors in the previous submission have been corrected. These errors were the omission of imports of coke oven/gas coke from the RA calculations, and the use of an erroneous CEF for BKB & Patent Fuel.

In addition to these improvements to the method to derive RA outputs, the Inventory Agency has also conducted extensive additional analysis on the outputs of the RA and in seeking to reconcile the differences observed between RA and SA outputs. In previous years, ERTs have commented that whilst the overall RA-SA outputs are very closely comparable, the fuel-specific comparisons show greater disparity in the UK inventory. Therefore the Inventory Agency has sought to develop a method to effectively "bridge" the gap between RA and SA by deriving an amended RA total through applying corrections to sources of known difference in source data and methods. This approach has derived an "amended" RA output, which shows much closer comparison to the SA totals across all fuels and all years; this approach has enabled the UK Inventory Agency to identify and quantify the sources of difference between the two approaches, and improve the overall verification of the SA totals.

Steps taken to improve the RA-SA reconciliation include:

- A comparison of the carbon contents of all refinery inputs (crude oil, NGLs, other condensates) – *the starting point for the RA estimates of emissions from liquid fuels* - against the carbon contents of all of the secondary fuel outputs from refineries - *the*

starting point for the SA estimation method for liquid fuels. This comparison enables the Inventory Agency to quantify the difference for liquid fuels between the RA and SA in the application of CEFs against primary fuels (RA) and secondary fuels (SA);

- Accounting for the carbon content of blast furnace gas, from the solid fuel transformation processes in the iron and steel industry. Gases derived from coking coal and coke are excluded from the RA, but some blast furnace gas is allocated to energy sector sources in the SA in the UK GHGI;
- Accounting for other specific known deviations from UK energy statistics that are applied in the SA estimates for 1A, including:
    - Natural gas allocations to oil and gas sector in 1990-2000;
    - LPG and OPG allocations to oil and gas sector from 2003 onwards;
    - Emissions from use of waste oils, fossil-containing wastes, scrap tyres and waste solvents that are reported within the SA but are not currently included in the estimates for the RA in the UK;
    - OPG allocations to the refinery sector from 2004 onwards, where the SA for most years assumed greater consumption for energy than DUKES;
    - Fuel use in the Overseas Territories, the activity data for which are not included in the UK energy statistics and hence are excluded from the RA but included in the SA. (This is almost entirely liquid fuels, as the OTs use predominantly gas oil, fuel oil, road transport fuels and aviation fuels);
    - Additional allocations in the SA for petroleum coke use in energy sources.

Once these “known differences” are taken into account, an amended RA-SA comparison can be presented. The next section describes the outcomes of the RA-SA comparisons.

3.2.2 Discrepancies between the IPCC Reference and Sectoral Approach

The IPCC Reference Approach total can be compared with the IPCC Table 1A total for all fossil fuels, and under the new 2006 GLs approach the Reference Approach CO_2 estimates for the UK are typically 3% lower than the comparable bottom-up emission totals of the Sectoral Approach. The comparison at the fuel-specific level shows somewhat higher differences, however, with RA solid fuel estimates on average **10% lower** than SA estimates and RA liquid (i.e. petroleum) fuels estimates on average **1% higher** than SA estimates

As outlined above, the Inventory Agency has subsequently sought to derive an amended RA total to present an improved comparison between the RA and SA totals. The main reasons for differences between the RA and SA estimates are summarised below.

3.2.2.1 Statistical Differences in Energy Balance Data

The IPCC Reference Approach is based on statistics of production, imports, exports, stock changes and non-energy use of fuels whilst the Sectoral Approach uses fuel consumption data by source sector. The two sets of statistics can be related using mass balances (see the publication ‘Digest of UK Energy Statistics’ DECC, 2014), but these show that some fuel is unaccounted for. This unaccounted fuel is reported in DUKES as statistical differences, which consist of measurement errors and losses. The system of energy statistics operated by DECC aims to keep UK statistical differences (without normalisation) at less than 0.5% of energy supply, for total supply and also for each fuel.

Nevertheless a proportion of the difference between the Reference Approach and the Sectoral Approach totals will be accounted for by statistical differences, particularly for solid and liquid fuels.

3.2.2.2 Application of Carbon Factors: Aggregated (RA) vs. Detailed (SA)

The IPCC Reference Approach uses data on primary fuels such as crude oil and natural gas liquids, which are then corrected for imports, exports, stock changes and non-energy uses of secondary fuels. Thus the estimates obtained will be highly dependent on the default carbon contents used for the primary fuels. The Sectoral Approach is based on the consumption of secondary fuels where the carbon contents are known with greater certainty. In particular the carbon contents of the primary liquid fuels are likely to vary more than those of secondary fuels, and hence the estimates from the Reference Approach are associated with higher uncertainty.

3.2.3 Comparisons of UK Emissions: Sectoral Approach vs. Reference Approach and *Amended* Reference Approach

Table 3.2 shows the percentage differences in CO_2 emissions from fuel combustion sources between the UK GHGI (Sectoral Approach) IPCC sector 1A, the IPCC Reference Approach and the amended (for known differences) IPCC Reference Approach, for each year since 1990.

The overall comparison between the Reference Approach (RA) and the Sectoral Approach (SA) indicates that in most years the RA estimates are around 3% lower than the SA estimates. However, once the RA is amended for known differences, the comparison is much closer with the RA estimates at 99.9% of the SA estimates across the time series, with a range of 99.1% (1990) to 100.8% (2000, 2005). For the reported 1990-2013 trend in emissions, the SA shows a fractionally higher reduction in emissions at -19.3%, whereas the RA shows -19.0% and the amended RA -18.7%. This difference reflects the SA-RA discrepancy in 1990.

The fuel-specific comparisons are summarised below:

- **Liquid Fuels**. Average RA/SA across time series: **100.7%** (Range: 98.6%-104.7%)

  Average *Amended* RA/SA across time series: **100.0%** (Range: 98.1%-101.9%)
- **Solid Fuels**. Average RA/SA across time series: **89.7%** (Range: 85.2%-92.9%)

  Average *Amended* RA/SA across time series: **99.2%** (Range: 97.5%-100.6%)
- **Gaseous Fuels**. Average RA/SA across time series: **100.4%** (Range: 98.7%-101.8%)

  Average *Amended* RA/SA across time series: **100.7%** (Range: 99.7%-102.7%)

Overall the SA-RA-amended RA comparison shows that there is very close consistency between the SA and amended RA datasets for the UK, and provides verification of the reported SA emission estimates for 1A.

Table 3.2 Comparison of the UK Sectoral Approach, IPCC Reference Approach and Amended Reference Approach (total CO_2)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Sectoral Approach 1A (Mt CO_2)	560.9	571.7	556.1	542.2	534.8	524.2	544.5	523.3	528.1	521.9	531.1	541.8
Reference Approach (Mt CO_2)	541.0	555.5	545.2	525.5	518.9	509.6	524.5	502.9	511.4	508.5	523.1	530.1
Reference Approach (Amended for known differences) (Mt CO_2)	556.0	570.9	559.4	540.1	534.6	525.9	541.6	520.9	524.8	522.2	535.2	540.5
RA/SA %	96.4%	97.2%	98.0%	96.9%	97.0%	97.2%	96.3%	96.1%	96.8%	97.4%	98.5%	97.8%
RA/SA (amended) %	99.1%	99.9%	100.6%	99.6%	100.0%	100.3%	99.5%	99.5%	99.4%	100.1%	100.8%	99.7%

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Trend
Sectoral Approach 1A (Mt CO_2)	526.1	536.3	536.3	534.0	534.5	524.2	513.3	467.9	485.1	443.8	463.2	452.7	*-19.3%*
Reference Approach (Mt CO_2)	514.5	519.8	522.1	524.5	520.8	508.4	497.0	455.8	476.7	433.2	452.9	438.4	*-19.0%*
Reference Approach (Amended for known differences) (Mt CO_2)	523.8	534.4	537.6	538.1	536.2	525.2	511.1	467.0	486.1	442.1	462.8	451.8	*-18.7%*
RA/SA %	97.8%	96.9%	97.4%	98.2%	97.4%	97.0%	96.8%	97.4%	98.3%	97.6%	97.8%	96.8%	*(97.3% average)*
RA/SA (amended) %	99.6%	99.7%	100.3%	100.8%	100.3%	100.2%	99.6%	99.8%	100.2%	99.6%	99.9%	99.8%	*(99.9% average)*

3.2.4 International Bunker Fuels (memo item)

International bunker emissions (international aviation and shipping) are not included in the national total but are reported separately.

These estimates are consistent with the revised Tier 3 method now adopted for aviation and described in **MS 5** and the revised Tier 2 method adopted for shipping as described in **MS 11.** The methods for the calculation of international bunker fuels are presented in the relevant method statements.

Each year the Inventory Agency confirms that the UK energy balance is consistent with data submitted to EUROSTAT and IEA and that the total fuel consumption used for the GHG estimates is consistent with the UK energy balance. For marine bunkers the UK GHG estimates are based on the difference between a bottom up calculation of domestic fuel use for domestic shipping (including military uses of fuels allocated to domestic) and the UK energy balance allocation for all marine fuels. 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.

3.2.5 Feedstock and Non-Energy Use of Fuels

The methodology for estimating emissions from fuels used for non-energy purposes is set out in the relevant sections of this NIR. A summary of the method, including all non-energy uses is included in **Annex 3**.

The UK energy statistics (DUKES, 2014) contain an allocation for non-energy use for each fuel in the commodity balance tables. The UK inventory estimates emissions from fuels, including emissions arising from non-energy uses. In some cases, the inventory estimate for non-energy use does not agree with the DUKES allocation, and reallocations are made between energy and non-energy use for inventory reporting. In 2013, the Inventory Agency carried out research into non-energy uses of fuels; this was followed up by the DECC energy statistics team during 2014, and a series of revised allocations are now included in the UK energy balance (DUKES 2014), bringing the inventory more closely into line with the energy statistics. The energy balance for the UK is set out in **Annex 4**.

The evidence that the Inventory Agency uses to make estimates for NEU 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.

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).

3.2.6 Use of UK Energy Statistics in the GHG inventory

The main source of official national statistics and energy balances data used in the UK inventory is the Digest of UK Energy Statistics (DECC, 2014), hereafter referred to as DUKES. This annual publication gives detailed sectoral energy consumption broken down by fuel type, and covering the entire time period relevant to 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, such as 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 modifications is given in **Annex 4**.

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 4** 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.

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, 2014), 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 7**. Further fuel consumption data are taken from the EEMS data set (DECC Offshore Inspectorate, 2014) and from data supplied by the UK Mineral Products Association (MPA, 2014), and from the UK solid fuel supply sector (Roberts, 2014). 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.

3.2.7 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, 1A2g, 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. The impact of biomass use on carbon stocks in the UK is recorded in the LULUCF sector; biomass imported into the UK will affect the LULUCF sector in the country from which the biomass is imported.

3.2.8 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 3.3** summarises the assumptions used.

Table 3.3 Levels of unoxidized carbon assumed for the UK GHGI

Fuel Type	Fuel sub-type	Source Sector	Years	Assumed unoxidized carbon	
				UK GHGI[c]	IPCC default[c]
Gaseous	All fuels	All sectors	All	0%	0%
Liquid	All fuels (incl. petroleum coke)	All sectors	All	0%	0%
Solid	Coal	1A1a	1990-2004	2%[a]	0%
			2005	1.8%[b]	
			2006	2.0%[b]	
			2007	1.7%[b]	
			2008	2.0%[b]	
			2009	1.9%[b]	
			2010	1.9%[b]	
			2011	1.8%[b]	
			2012	1.7%[b]	
			2013	1.8%[b]	
		1A2f (cement)	All	0%	
		1A4b	All	0%	
		All others	All	0%	
	Anthracite	1A4b	All	0%	
	Coke, solid smokeless fuel	1A4b	All	0%	
		All others	All	0%	

[a] Expert judgements provided by UK fuel producers and fuel users (see Baggott *et al, 2004*).

[b] Calculated from site-specific EU ETS returns for all UK coal-fired power stations.

[c] From the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, unless otherwise stated.

3.2.9 Energy: Method Statements

The energy chapter has been reformatted to group text into "method statements" with the aim to group together categories where the source data and methods are the same, in order to avoid repetition and improve the clarity of the NIR. The method statements are numbered, and are cross referenced with the summary table for the sector (**Table 3.2**).

3.3 CO_2 TRANSPORT AND STORAGE

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

3.4 METHOD STATEMENTS

MS 1 Power stations, refineries and other energy industries (excluding coke and SSF production, and upstream oil and gas production)

Relevant Categories, source names

1A1a: Power stations

1A1b: Refineries

1A1ciii: Collieries, gas production and nuclear fuel production

Relevant Gases

CO_2, CH_4, N_2O

Relevant fuels, activities

Burning oil, Coal, Colliery methane, Fuel oil, Gas oil, Landfill gas, Liquid bio-fuels, LPG, MSW, Naphtha, Natural gas, OPG, Orimulsion, Petrol, Petroleum coke, Poultry litter, Refinery miscellaneous, Scrap tyres, Sewage gas, Sour gas, Straw, Waste oils and Wood

Background

This Method Statement (MS) includes information about UK power stations, refineries and other energy industries.

Table 3.4 shows the number of power stations in the UK, by the type of fuel burnt. The main fossil fuels used by the UK electricity supply industry are bituminous coal and natural gas. The number of coal stations has decreased markedly across the time series, and the number of gas fired stations has increased. The share of electricity from coal and gas in 2013 was 36% and 27%, respectively.

Bio-fuels are burnt at an increasing number of power generation sites to help electricity generators meet Government targets for renewable energy production. These sites use poultry litter, straw and wood as the main fuel, whilst many coal-fired power stations have increased the use of biofuels such as short-rotation coppice to supplement the use of fossil fuels.

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 here; these emissions will be reflected in the LULUCF carbon stocks of the country producing the fuel. 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 an increasing number of 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 5C (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 3.4 Power stations in the UK by type

Year	Coal	Fuel oil	Gas oil	Gas	Waste	Biomass	Biogas	Nuclear Fission
1990	44	9	11	0	2	0	Unknown[a]	19
1995	23	8	11	5	4	0	Unknown[a]	16
2000	22	5	11	35	15	4	267	15
2005	17	5	12	47	20	5	461	12
2010	17	4	12	53	23	6	554	10
2012	17	2	12	59	26	8	565	10
2013	15	2	12	53	27	11	621	10

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

Table 3.5 shows how the numbers of refineries vary over the period covered by the inventory. The UK now has 10 operating refineries of which 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, influencing the energy use and emissions from the sector.

Table 3.5 Refineries in the UK by type

Year	Crude oil refineries	Specialist refineries
1990	11	4
1995	11	4
2000	9	3

Year	Crude oil refineries	Specialist refineries
2005	9	3
2010	8	3
2011	8	3
2012	7	3
2013	7	3

Crude oil and natural gas input to the refineries comes from a large number of offshore installations in UK waters, together with a small number of onshore production facilities. Emissions estimates from these activities are described in **MS 2**, **MS 17** and **MS 19**. Coal is extracted in the UK from deep mines and open-cast sites. The UK production of coal (especially from deep mines) is a rapidly declining industry and levels of UK activity are far lower in recent years than in 1990. Emissions from combustion at UK collieries are covered in this MS. Fugitive emission estimates from these mining and extraction activities are included in **MS 16** and **MS 17**MS 16

Nuclear fuel production is a very minor user of fossil fuel in the UK, and is included in this MS.

Key Data sources

Activity data: DUKES, EU ETS, UK PIA

Emission Factors: Carbon factors are predominantly derived from EU ETS data (2005 onwards) and from the 2004 Carbon Factors Review (Baggott et al., 2004), with some solid fuel factors derived from UK research (Fynes and Sage, 1994); non-CO_2 EFs are predominantly IPCC defaults (IPCC, 2006).

Annex 3 *lists all emission factors used in the energy sector, including a full list of references.* ***Table 1.6*** *gives additional information for common activity data sources.*

Method approach

The calculation of direct greenhouse gases for the sources covered by this MS is:

UK Emissions = EF x AD

The sources of emission factors and activity data are summarised under “key data sources” above, with a full list of emission factors set out in **Annex 3**. The activity data are taken from DUKES, noting the exceptions set out under Assumptions & observations, below. **Annex 4** described the energy balance for the UK and how this is used for the inventory, and any deviations from these data.

Assumptions & observations

- **Power stations - gas oil / fuel oil / burning oil activity data**: 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 (1A2) to power stations to ensure consistency with operator data, while maintaining consistency with the overall fuel consumption data in DUKES.

- **Refineries - OPG activity data**: As noted in the Recalculation justification & summary of change section below, for OPG, discrepancies in activity data are evident 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.
- **Refineries - Petroleum coke activity data**: Similar to the issue noted above for OPG, comparison of the AD presented in DUKES versus the AD reported via the EU ETS indicates for several years that the DUKES AD are under-reported. The UK GHGI estimates from refinery petroleum coke use are therefore based on the higher value of DUKES or EU ETS and applying the EF for petroleum coke provided by UKPIA; EU ETS data are higher (and therefore used in the GHGI, deviating from DUKES) for all years 2005 to 2010 and again in 2013. In 2011 and 2012, the DUKES data are higher than EU ETS and are therefore retained; we note, however that this is a possible over-report and leads to UK GHGI emission estimates being higher than EU ETS totals for the sector in 2012. The Inventory Agency retains this approach in order to use EU ETS emission estimates as a de-minimis, and taking a conservative approach to deriving the time series of refinery emissions.

Recalculation justification & summary of change

Method Changes	Y
Recalculation	Y

Method revisions include:

- The analysis of the EU ETS and consultation with UKPIA and DECC energy statisticians identified that the use of natural gas in the refinery sector is evidently greater than the AD reported in DUKES; further work with the DECC energy statistics team identified specific data on natural gas use in autogeneration in the refinery sector. This new time series of data has now been taken into consideration in the derivation of refinery estimates in the UK GHGI, effectively re-allocating some gas use from autogeneration to refineries in the GHGI. This new information has reduced the gap in emission estimates for refineries derived from EU ETS vs estimates derived from DUKES data, and therefore the 2015 submission has a smaller additional allocation of OPG to the refinery sector.
- Assumptions for waste oil have been changed. Previously it was assumed that 10% of total waste oil recovered in the UK was used in power stations, and the remainder of the “fuel oil” reported in EU ETS was heavy fuel oil. This assumption has been replaced by allocating the remainder of all waste oil recovered that has not been allocated to other known uses. This is balanced with fuel oil use, allocated to power stations, industry and commercial in DUKES. The revision has been made since the previous method introduced negative values

Activity data revisions include:

- Revisions to DUKES (for all categories)
- Revisions to assumptions for fuel oil use in power stations, to reconcile DUKES data and EU ETS data (balanced with industrial and commercial fuel oil use)
- MSW incineration has been reallocated from waste to energy for the Cayman Islands and Bermuda
- For refineries, some natural gas has been reallocated between autogenerators and refineries, based on analysis of ETS and discussion with the DUKES team (described under method changes)

- Minor revisions to activity for gas separation plant due to correction in analysis to determine installation-specific fuel use that is not reported in DUKES.

For emission factors:

- The carbon factor for coal used in collieries has been revised to use Fynes and Sage, 1994

CH_4 and N_2O emission factors have been revised to use defaults from IPCC, 2006.

Quantitative information on recalculations is included in **Chapter 10**.

Improvements (completed and planned)

Completed: Recalculations and updates completed as described above.

Planned/Ongoing: Emission factors and activity data remain under annual review.

QA/QC

Specific QA/QC and validation exercises relevant to these source categories include:

- The Inventory Agency conducts extensive quality checks on the operator-reported EU ETS data covering: emissions, AD, EFs, NCVs. The QC assesses the fuel quality data, time-series consistency of reported data by installation, detailed source-specific EU ETS data against the installation-wide total emissions reported to the EU Transaction Log, and comparisons between DUKES and EU ETS AD to identify and resolve any potential mis-allocations or under-reports in the DUKES dataset. Findings are discussed with the DECC energy statistics team and (where necessary) the EU ETS regulators and/or operators. This process has led to many significant improvements in UK GHGI accuracy.
- the comparison of the reference/sectoral approach
- a bilateral exchange with Germany in 2014, providing peer review and quality assurance of the energy sector, and refineries, estimates. (Ricardo-AEA, 2014)

The energy AD used in these estimates that come from DUKES are subject to the UK Statistics Authority's *Official Statistics Code of Practice*, available from http://www.statisticsauthority.gov.uk/assessment/code-of-practice.

The EU ETS data, is subject to its own QA process, defined and managed by the competent authority and compliant with EU rules.

Time series consistency

Activity data for petroleum coke and OPG consumption in refineries are based on DUKES data for certain years, and EU ETS or trade association (UKPIA) data for other years in the time series. This is described in the method approach section above. The differing data sources have been used to ensure a consistent complete coverage of emissions from refineries, addressing under-reports in DUKES and ensuring the time series consistency is maintained.

For some sources and fuels, carbon emission factors are taken from Baggott et al., for the period 1990-2003, and from ETS for 2005 onwards (2004 is interpolated). This makes best use of available data and the time series trend of EFs shows a smooth transition between data sources. We note that the key data providers that informed the 2004 Carbon Factors Review are the same operators of high-emitting plant (i.e. power stations, refineries, cement kilns, iron and steel works) that subsequently provide data to the EU ETS; therefore whilst the EU ETS data provides a larger dataset of more detailed, installation-specific fuel composition and hence carbon emission factors for recent years, the underlying source data prior to EU ETS may be a smaller dataset but comes from the same operators and therefore the time series consistency of the approach is good.

Uncertainties

Uncertainties for both activity and emission factors are based on expert judgement. The uncertainty analysis set out in **Annex 2** provides details of these uncertainty values. Uncertainties in fuel use statistics are typically low. The carbon emission factors are based on UK specific data. Since there is a direct link between the carbon emitted and the carbon content of the fuel, it is possible to estimate CO_2 emissions accurately. Non-CO_2 emissions are dependent on a greater number of parameters, and are largely based on defaults. As such, the uncertainties are higher, but since the emissions are smaller, this does not have a significant impact on the overall uncertainty of total GHG emissions.

MS 2 Upstream oil and gas production – fuel combustion

Relevant Categories, source names

1A1cii: Upstream gas production – combustion;

Upstream oil production - combustion;

Upstream oil and gas production – combustion at gas separation plant

Relevant Gases

CO_2, CH_4, N_2O

Relevant fuels, activities

Gas oil, Natural Gas, LPG, OPG

Background

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. In addition, crude oil, gas and condensate are treated at onshore terminals in the UK. The emissions in 1A1cii comprise all of the fuel combustion emissions at these installations; LPG and OPG are only used for fuel combustion at onshore terminals. Gas oil and natural gas (i.e. untreated natural gas, upstream of gas processing facilities) are widely used as fuels in combustion units across the upstream oil and gas industry.

Key Data sources

Activity Data: Primarily taken from DUKES (DECC, 2014), with some supplementary data from the EU ETS and EEMS data sets (both from DECC Offshore Inspectorate, 2014).

Emission Factors: Carbon factors for natural gas are derived from operator-reporting to EU ETS and EEMS (both from DECC Offshore Inspectorate, 2014), supplemented by periodic analysis for the earlier years in the time series (UKOOA, 2005); the carbon factors for LPG and gas oil are derived from the 2004 Carbon Factors Review (Baggott et al, 2004); the carbon factor for OPG used at gas separation plant is taken from the IPCC 2006 Guidelines CEF for ethane. Methane and Nitrous Oxide EFs are based on operator reporting via EEMS from 1998 onwards with earlier data based on industry research (UKOOA, 2005).

Annex 3 *lists all emission factors used in the energy sector, including a full list of references.* ***Table 1.6*** *gives additional information for common activity data sources.*

Method approach

Fuel consumption data for this source are largely taken from DUKES, with the exceptions noted below.

Amendments are made to DUKES activity data for LPG, OPG and natural gas, in consultation with the DECC DUKES team as the combined EEMS and EU ETS activity data for these fuels are considered to be more complete. These deviations from DUKES are as follows:

- From 2003 onwards there are no data in DUKES for LPG/OPG use in oil & gas terminals and therefore EU ETS data are used to provide activity and emission estimates; and
- Prior to 2001 (when DECC energy data gathering systems were updated) the collection of data on natural gas use at oil and gas facilities was incomplete. Therefore the more complete and consistent data available from EEMS has been used to generate new estimates of natural gas use for the upstream sector back to 1990.

Operator reporting via the EEMS and EU ETS mechanisms both provide activity and emissions data from the consumption of gas oil and natural gas in combustion units in the upstream oil and gas industry. EU ETS data are only available from 2005 onwards and have an incomplete scope (i.e. not all combustion activities are included within EU ETS), whilst EEMS data are available from 1998 onwards with more limited periodic industry research available to inform activity and emission estimates for 1990-1997 (UKOOA, 2005).

Activity data for natural gas use from DUKES is compared against data reported via EEMS and EU ETS; where any DUKES under-reports are observed then the DUKES data are modified (see above). Carbon emission factors for natural gas are derived from the EEMS data and applied to the DUKES (or modified DUKES) activity data. The calculated (implied) emission factor is cross checked with UK specific natural gas emission factors to ensure that the upstream gas composition is broadly consistent with downstream gas CEFs.

The method for gas oil is simpler; the activity data are taken from DUKES and a carbon emission factor is applied that is derived from the 2004 Carbon Factors Review. There are no modifications to DUKES activity data, as analysis of the EEMS dataset is used by the DECC energy statistics team in deriving the commodity balance estimates for gas oil, i.e. the EEMS data are ultimately the source of the DUKES allocation for the sector, so there are no data discrepancies.

For LPG and OPG combustion, the DUKES activity data are used from 1990-2002. For 2003 onwards the operator-reported activity data within EEMS are used, with (from 2008) the EU ETS activity data also considered. Carbon emission factors are applied derived from the 2004 Carbon Factors Review (for LPG) and from the IPCC 2006 GLs (for OPG).

Assumptions & observations

Emissions from OTs and CDs are Not Occurring for this source.

Recalculation justification & summary of change

Method Changes	N
Recalculation	Y

DUKES data revisions for gas oil use for upstream oil and gas production. The impact of changes is set out in **Section 10**.

Improvements (completed and planned)

Emission factors and activity data remain under review.

QA/QC

Specific QA/QC and validation exercises relevant to these source categories include:

- The comparison of the reference/sectoral approach;
- Comparison of EEMS, EU ETS and DUKES activity data for natural gas combustion. The data underpinning DUKES estimates are gathered via the Petroleum Producers Reporting System (PPRS) which presents facility-level activity data that are compared against EEMS and EU ETS to identify and reconcile any data inconsistencies;
- Comparisons between EEMS and EU ETS, to review installation-specific activity data and emissions data (and hence implied IEFs for each site and source) to identify any possible gaps in the EEMS dataset, using EU ETS as a de-minimis. *The EU ETS data typically covers a smaller scope of activities on a given installation, but the data quality (AD, EFs) are third-party verified, whereas the EEMS dataset should be a comprehensive record of all combustion activities on upstream oil and gas installations but the data are subject to less rigorous QC.*

These emission sources use DUKES data, which is subject to the UK Statistics Authority's *Official Statistics Code of Practice* and ETS data, which is subject to its own QA process.

Time series consistency

Extensive consultation over many years with the DECC energy statistics team has enabled the Inventory Agency to clarify areas of the DUKES data that are incomplete for the upstream oil and gas sector, and to take steps to address these gaps. Wherever possible the Inventory Agency has filled activity data gaps with operator-reported estimates; this is possible as there are a defined number of installations that are active in this sector and their activities are generally well documented with gaps in data being relatively minor.

The quality checks between different reporting mechanisms (PPRS and DUKES, EEMS, EU ETS) and significant overlap of the data reported (DUKES across all years; EEMS all years since 1998 with limited data for 1996 and 1997; periodic industry reports by the trade association, UKOOA; EU ETS all years since 2005) enables the Inventory Agency to deploy gap-filling techniques that are consistent with IPCC GLs and GPG. For example, the extrapolation of natural gas activity data from 1990 to 2000 (to address a gap in DUKES) is based on analysis of the data reported during 1998 to 2000 ("overlap" years) in EEMS and DUKES, which indicates a systematic under-report in DUKES data of an estimated 14% per year (then used to uplift the reported DUKES data for 1990-1997). There is a higher uncertainty associated with the estimates for earlier years, but the inventory method has been developed to minimise that uncertainty despite the data limitations.

Uncertainties

Uncertainties for both activity and emission factors are based on expert judgement. The uncertainty analysis set out in **Annex 2** provides details of these uncertainty values. Uncertainties in fuel use statistics are typically low. However, we note (as outlined in the section above) that there are known data gaps in national statistics for earlier years of the time series and hence uncertainties for the estimates in 1990 are higher than for recent years where much more extensive and complete operator-reporting of activity and emissions are evident. The carbon emission factors are based on UK specific data. Since there is a direct link between the carbon emitted and the carbon content of the fuel, it is possible to estimate CO_2 emissions accurately. Non-CO_2 emissions are dependent on a greater number of parameters, and are largely based on defaults. As such, the uncertainties are higher, but since the emissions are smaller, this does not have a significant impact on the overall uncertainty of total GHG emissions.

MS 3 Manufacturing industries and construction (excluding iron and steel, and off road machinery)

Relevant Categories, source names

1A2a – Iron and Steel (combustion) – excluding blast furnace gas, coke oven gas and coke (see **MS 4**)

1A2b - Non-Ferrous Metal (combustion)

1A2c - Chemicals (combustion)

1A2d - Pulp, Paper and Print (combustion)

1A2e - Food & drink, tobacco (combustion)

1A2f - Cement production – combustion, Lime production - non decarbonising

1A2gvii - Other industrial combustion, Autogeneration - exported to grid, Autogenerators

Relevant Gases

CO_2, CH_4, N_2O

Relevant fuels, activities

Biogas, Biomass, Burning oil, Coal, Coke, Coke oven gas, Colliery methane, Fuel oil, Gas oil, LPG, Natural gas, OPG, Petroleum coke, Scrap tyres, Waste, Waste oils, Waste solvent, Wood, SSF

Background

This MS covers the use of fossil fuels for heat and power production uses in industry. Estimates cover a range of large and small installations. Many are included in the EU ETS, plus there are large number of small industrial plants. Sectoral emissions for iron and steel, non-ferrous metal, chemical, paper, food and drink, and mineral industries are reported under 1A2a to 1A2f. In addition, residual emissions for fuel use that cannot be allocated to these industries are reported under 1A2g.

According to the 2006 IPCC GLs, 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 1A2g, except for where further information is available to allow the allocation to an individual source category.

The sectoral estimates reported under 1A2a to 1A2g 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.

Key Data sources

Activity Data: DUKES (DECC 2014), cement and lime sector fuel use estimates (MPA, 2014), installation-specific activity data from EU ETS (EA, SEPA, NIEA, all 2014)

Emission Factors: Where available operator-reported EFs from EU ETS are used for high-emitting source sectors. Other UK CS CEFs are taken from the 2004 Carbon Factors Review (Baggott et al., 2004). Defaults for non-CO_2 gases are derived from IPCC (IPCC 2006),.

Annex 3 *lists all emission factors used in the energy sector, including a full list of references.* ***Table 1.6*** *gives additional information for common activity data sources.*

Method approach

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) for other gases (Tier 1) (See **Annex 3** for details).

DUKES provides most of the energy activity statistics. The full breakdown is available for all categories under 1A2 for coal, natural gas, fuel oil and gas oil. Other fuels such as LPG, coke and burning oil cannot be split within 1A2 and are therefore allocated solely under 1A2g due to a lack of any data on sectoral use in DUKES. A number of approaches are used to fine tune the allocation of energy use under the different subcategories to ensure consistency with other datasets such as EU ETS, industrial data (e.g. from trade associations) and other estimates in the GHG inventory (e.g. the off-road machinery model). These approaches are listed below.

- Fuel use in cement kilns (1A2f) is collected from process operators, via the Mineral Products Association (MPA). 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 (see Assumptions). Reallocations are sometimes made between subcategories to account for known fuel uses;
- Balancing of energy consumption data between 1A2 and other source categories, to accommodate source-specific AD from other data sources (e.g. operator data, EUETS) in preference to DUKES data. Key examples of fuel re-allocations in 1A2 are: AD for natural gas for gas network operators (i.e. gas use re-allocation between 1A2 and 1A1c); AD for oils for power stations (i.e. gas and fuel oil re-allocations between 1A2 and 1A1a).
- Analysis of EU ETS indicates that there are a number of installations which use petroleum coke as a fuel, where there is no such allocation of petroleum coke as a fuel for that source in DUKES. The inventory agency therefore re-allocates some petroleum coke from the non-energy use estimate in DUKES to address this reporting discrepancy and align emission estimates in 1A2f and 1A2g with EUETS. This re-allocation increases the overall reporting of petroleum coke as an emissive energy use, deviating from DUKES;
- Analysis of EU ETS data has identified several chemical and petrochemical manufacturers that utilise carbon-containing process off-gases and residues as fuel sources. Consultation with industry and with the DECC energy statistics team has clarified that in DUKES the delivery of feedstock materials to chemical and petrochemical sites are reported as non-energy use, with no subsequent reporting in DUKES of the use of these process off-gases as an energy source in these industries. The EU ETS data are therefore used to derive inventory estimates to account for this use of feedstock-derived process gases, which are reported as “other petroleum gas” use within the inventory, in addition to DUKES allocations to fuel use in these sectors. *We note, however that under the 2006 GLs these emissions that were previously reported under 1A2c are now re-allocated to IPPU source category 2B8 (see IPPU chapter)*; and
- Separation of gas oil used for stationary and mobile machinery is based on data on populations of mobile equipment, or train or ship movements etc. The approach

developed for allocating gas oil between different source categories is described in **Annex 4**.

Emission factors for carbon are almost exclusively derived from country specific 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. The factors for coke and other manufactured fuels are based on carbon balance approaches (see MS 4 for coke, MS 18 for manufactured fuels). Emission factors for methane and nitrous oxide are largely IPCC defaults. The full set of emission factors are presented in **Annex 3**.

Assumptions & observations

- Breakdown of fuel use for cement from the 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 into account changes in cement clinker production in each year.
- CHP systems where all of the electricity is fed into the public supply are classified as power stations and excluded from estimates described here.

Allocation of industrial electricity generation:

- The UK's statistical data for autogenerators relate to fuels used for electricity generation by companies primarily for their own consumption. This includes CHP systems where electricity is used by the generator. The UK methodology allocates autogenerators to 1A2g (as no other sub-categorisation is available) except for coal use by autogenerators which is allocated to 1A2b since this is known to be used in a power station to support aluminium production (closed in 2012 and now that site is re-allocated to 1A1a).

Recalculation justification & summary of change

Method Changes	N
Recalculation	Y

- DUKES data revisions have affected data in later years
- Default emission factors for CH_4 and N_2O have been updated to use the 2006 IPCC Guidelines
- Combustion of natural gas for the production of ammonia has been reallocated from 1A2c to the IPPU sector 2B1, in line with the 2006 IPCC GLs
- 1A2 emission estimates have been reduced due to re-allocations of coke and petroleum coke use from Energy to IPPU, based on new research to ensure compliance with the 2006 IPCC Guidelines; coke and petroleum coke used in titanium dioxide manufacture is allocated to 2B6, and other emissive NEU of petroleum coke are reported in 2D4.
- Emissions from combustion of process off-gases in chemical and petrochemical installations have been re-allocated from 1A2c to 2B8, in line with the 2006 GLs. These estimates have also been slightly increased through analysis of 2013 EU ETS data which identified a small number of additional chemical industry sites burning off gases and waste residues.
- Coal CEFs are based on UK research (Fynes and Sage, 1994), replacing a personal communication from British Coal in 1989. The oxidation factor has been changed to use the IPCC default (1.0) in response to the ERT's recommendations.

Improvements (completed and planned)

Completed: During 2014-15 a research project was commissioned to ensure that the reporting under 2006 GLs for the Energy and IPPU sectors was complete and consistent with the new method guidance. As outlined in the above section on recalculations, this report (Ricardo-AEA, 2015) has led to a series of revisions to estimates in the 1A2; new IPPU source category methods have been developed and include re-categorisation of consumption of commodities. Specifically, the use of coke and petcoke has been revised to report the emissions from use as a reductant (in IPPU) rather than as an energy source (in 1A2). Also emissions from use of carbon-containing process off-gases have been moved from 1A2c to 2B8.

Planned/Ongoing: Emission factors and activity data remain under annual review.

QA/QC

Specific QA/QC and validation exercises relevant to these source categories include:

- the comparison of the reference/sectoral approach
- comparison of EU ETS data with DUKES and data direct from industry

These emission sources use DUKES data, which is subject to the UK Statistics Authority's *Official Statistics Code of Practice* and ETS data, which is subject to its own QA process , available from http://www.statisticsauthority.gov.uk/assessment/code-of-practice/

The EU ETS data, is subject to its own QA process, defined and managed by the competent authority and compliant with EU rules.

Time series consistency

Differences in data sources across the time series are noted in the method approach section above. These do not lead to time series consistency issues, since they have been introduced in order to ensure the scope of emissions included remains consistent.

Uncertainties

Uncertainties for both activity and emission factors are based on expert judgement. The uncertainty analysis set out in **Annex 2** provides details of these uncertainty values. Uncertainties in fuel use statistics are typically low. The carbon emission factors are based on UK specific data. Since there is a direct link between the carbon emitted and the carbon content of the fuel, it is possible to estimate CO_2 emissions accurately. Non-CO_2 emissions are dependent on a greater number of parameters, and are largely based on defaults. As such, the uncertainties are higher, but since the emissions are smaller, this does not have a significant impact on the overall uncertainty of total GHG emissions.

MS 4 Iron and steel, and coke manufacture

Relevant Categories, source names

1A1ci: Coke production

1A2a: Blast furnaces, Iron and steel - combustion plant (coke oven gas, blast furnace gas & coke oven coke only)

1B1b: Coke production

Iron and steel - flaring

2C1a: Basic oxygen furnaces

2C1b: Iron and steel - flaring

2C1d: Sinter production

Relevant Gases

CO_2, CH_4, N_2O

Relevant fuels, activities

Blast furnace gas, Coal, Coke, Coke oven gas, Coke produced, Colliery methane, Dolomite, Fuel oil, Gas oil, Limestone, LPG, Natural gas

Background

This MS covers the carbon balance approach used for integrated steelworks and independent coke manufacture. Integrated steelworks use the blast furnace/basic oxygen furnace route to produce steel from iron ore.

Most UK coke is produced at coke ovens associated with the UK's three integrated steelworks, although one independent coke manufacturer also exists. At the end of 2013, there were four coke ovens at the steelworks and one independent coke oven. Four other coke ovens were in existence in 1990 but subsequently closed due to closure of two integrated steelworks and the closure of other coke consumers, such as the UK's only lead/zinc smelter in 1999. **Table** 3.6 shows how the numbers of coke ovens and steelworks vary over the period covered by the inventory. Coke production emissions are reported under 1A1ci (combustion) and 1B1b (fugitive).

Table 3.6 Number of coke ovens and steelworks in the UK

Year	Coke ovens	Integrated steelworks	Electric arc steelworks
1990	9	5	Unknown
1995	8	4	20
2000	8	4	19
2005	5	3	12
2006	5	3	11
2007	5	3	10
2008	5	3	8
2009	5	3	7
2010	5	3	7
2011	5	2	7
2012	5	3	6
2013	5	3	6

The carbon balance method described in this method statement covers the use of coke oven coke, blast furnace gas and coke oven gas as fuels throughout the iron and steel industry, whereas the use of primary fossil fuels in boilers and heat treatment or melting furnaces is

described in the method statement for 1A2. All fuels used in coke ovens, sinter plant, and blast furnaces are included in the carbon balance.

The key processes and related emission activities covered by this method statement are summarised below.

1. Coke oven coke is produced by heating coking coal in ovens in order to drive off volatiles which are collected as gases (coke oven gas, used as a fuel to heat the ovens) or liquids (coal tars and benzole, recovered for use in chemicals manufacture and other processes). The solid residue is coke oven coke which is used as a fuel for sintering, as a reductant in blast furnaces, or sold for use in other industrial processes. Emissions of greenhouse gases resulting from combustion to heat the coke ovens are reported in 1A1c, whereas fugitive emissions of methane from the coke ovens are reported in 1B1b.
2. 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. Emissions from integrated steelworks are estimated for these three processes, as well as other minor processes such as slag processing.
3. Sintering involves the agglomeration of raw materials for the production of pig iron by mixing these materials with fine coke (coke breeze) and placing it on a travelling grate where it is ignited. The heat produced fuses the raw materials together into a porous material called sinter. Emissions from sintering are reported in 2C1d.
4. 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, fuel oil and coal. Hot air is blown into the lower part of the furnace and reacts with the reducing agent, producing carbon monoxide, which reduces the iron ore to iron.
5. 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. 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.
6. 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.
7. 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. In DUKES, basic oxygen furnace gas is combined with blast furnace gas and so separate figures for production and use of the two gases are not given.
8. The fuels derived in coke ovens and integrated steelworks are used in boilers and in heat treatment or melting furnaces and CO_2 emissions from these energy uses are calculated using emission factors derived using the carbon balance.

Key Data sources

Activity Data: Main sources of activity data (fuel use, production data) are DUKES (DECC, 2014), ISSB annual statistics (ISSB, 2014), installation-specific

activity data from EU ETS (EA, NRW, both 2014), operator information for integrated steelworks (Tata Steel and SSI Steel, both 2014)

Emission Factors: Input parameters for the carbon balance method are derived from EUETS data or operators of integrated steelworks (reference as for AD). Other UK CS CEFs are derived from the 2004 Carbon Factors Review (Baggott et al., 2004). EFs for non-CO_2 gases are predominantly IPCC defaults (IPCC 2006), Baggott et al., 2004.

Annex 3 *lists all emission factors used in the energy sector, including a full list of references.* ***Table 1.6*** *gives additional information for common activity data sources.*

Method approach

The carbon balance for the combined coke ovens and integrated steelmaking processes is based on tracking the carbon through four 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 carbon flow description and **Figure 3.1** below presents a simplified version of the model listing main inputs and outputs:

Carbon Flow Description

coal $\rightarrow$ coke + coke oven gas + benzole & tars + fugitive carbon emission

coke + limestone + iron ore $\rightarrow$ sinter + carbon emission

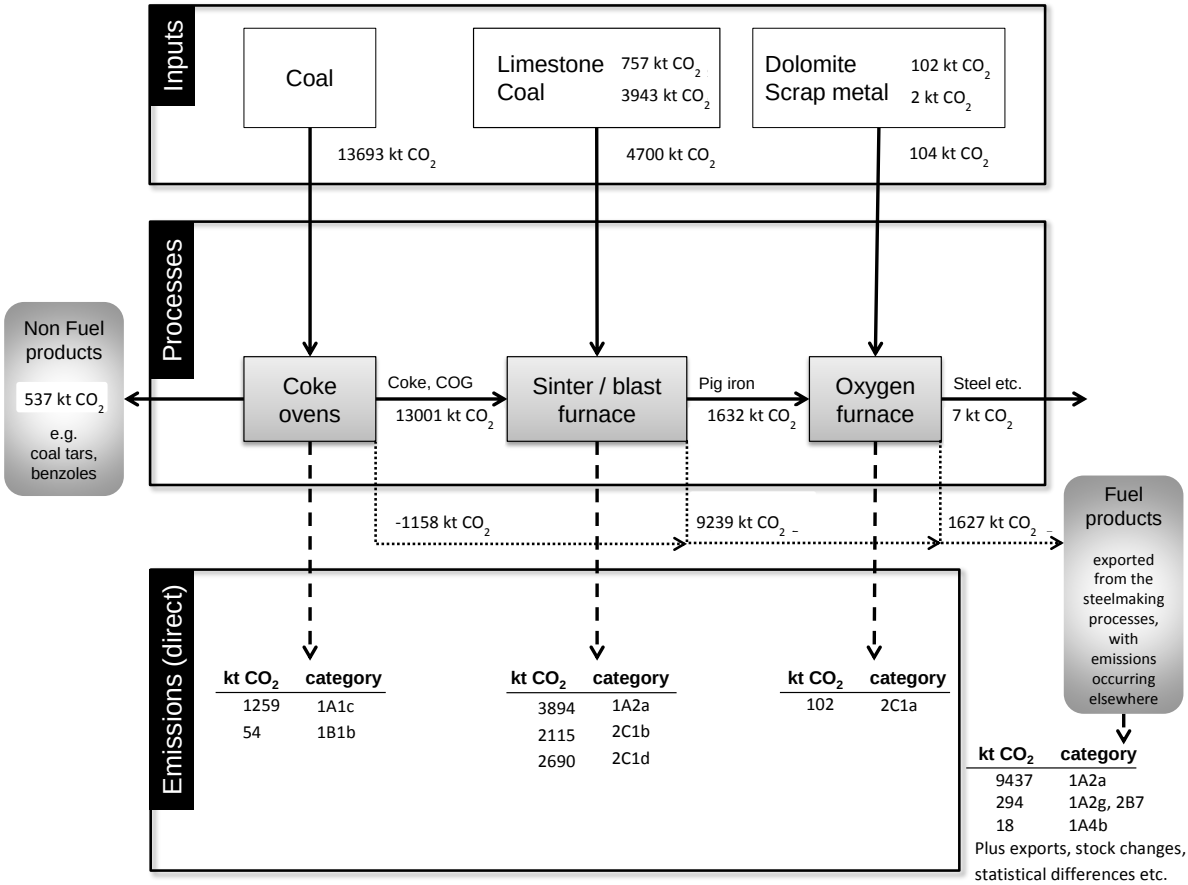
sinter + coke + other reducing agents $\rightarrow$ pig iron + blast furnace gas

pig iron + scrap + dolomite $\rightarrow$ 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.

The carbon balance model used is shown in a simplified form in **Figure 3.1**, with inputs and outputs of carbon (expressed as CO_2) given for the year 2013 as an example. Note that there is one negative value in the diagram because the figures take into account imports, exports, and stock changes.

Figure 3.1 Carbon balance model for 2013



Emission estimates for limestone and dolomite added to sinter plants, blast furnaces, and oxygen furnaces are based on industry consumption data (Iron & Steel Statistics Bureau, 2014) and carbon contents from the operators (Tata Steel, SSI Steel, both 2014), and based on their EU ETS reporting (EA, NRW, both 2014).

Emissions of CH_4 and N_2O are estimated using IPCC 2006 default emission factors.

Assumptions & observations

A detailed description of the carbon balance methodology has been given in Ricardo Energy & Environment, GHG Inventory Research: Use of EU ETS Data - Iron & Steel Sector, Chemical Industry Feedstock Use, April 2014 (available for download on the NAEI website[19]) and so only a brief summary of assumptions is given here.

The carbon balance method requires the carbon content in input fuels and feedstocks to be estimated using consumption data and carbon contents for each fuel or feedstock. The balance is then used to distribute that carbon amongst the various derived fuels, products and wastes from the coke ovens and steelmaking processes. The total emission of CO_2 is therefore dependent upon the assumptions made about the quantity of carbon in inputs, and in the main input – coking coal – in particular. The carbon content of coking coal and blast furnace coal has, in recent years, been measured by operators as a result of their need to collect data for EU ETS reporting purposes, and operators have also been able to supply high quality

19 http://uk-air.defra.gov.uk/assets/documents/reports/cat19/1405081135_GHG_Inventory_Research_Report_EU ETS_final.pdf

measurement-based data for the carbon contents of derived fuels, coal tars, benzole, limestone, dolomite, steel scrap, and steel product. The EU ETS data indicate that the carbon contents of fuels do not vary greatly from one year to another and therefore, for earlier years, where EU ETS data are not available, carbon factors are assumed to be the same as for those years where EU ETS data are available. For each fuel, the average carbon content is calculated for years with EU ETS reporting, and these values then used for the earlier years.

The operators also supply data on the consumption and production of fuels and these data should be consistent with UK energy statistics. This is largely so, but in a couple of instances where the UK statistics seem to underestimate consumption of a particular fuel in a particular year, we have used the operators' data instead. For example, operator data for the consumption of coking coal in coke ovens for the years 2003-2013 is higher than the figures given in DUKES, and the operator data is used in preference. The coal consumption figures for other industrial use are also modified by an equal and opposite amount so that overall coal consumption in the GHGI is the same as in DUKES. DUKES also excludes a small quantity of coke oven gas generated at one steelworks which is then supplied as a fuel to a co-located process, and so we have used operator data on this fuel in the inventory. In this case, it would not be appropriate to maintain consistency with overall UK demand figures in DUKES (since this fuel is missing from DUKES, not classified to a different sector). Finally, some small deviations are made for 2009, where operator data on consumption of coal and coke oven coke in blast furnaces are somewhat higher. The changes to coal are treated as misallocations in DUKES (so UK totals for coal consumption are adhered to), whereas for coke oven coke, it is necessary to increase UK consumption to above the level given in DUKES, since coke consumption by known users exceeds the DUKES figure.

Recalculation justification & summary of change

Method Changes	N
Recalculation	Y

Minor recalculations only due to revisions to UK energy statistics and other input data.

Improvements (completed and planned)

The carbon balance methodology was reviewed and improved for the 2014 submission of the UK inventory, to ensure the 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 reduced uncertainty in the estimates of carbon input in coking coal, which in turn lowered the uncertainty in estimates of carbon outputs including emission estimates in the UK GHGI. The industry data also led to relatively small changes in the allocation of carbon to each output and thus had a small impact on the distribution of emissions reporting across 1A1c, 1A2a and 2C1.

The results from the carbon balance approach are compared with industry emission estimates and any significant differences will be followed up and, if necessary, further refinement of the methodology considered.

QA/QC

Specific QA/QC and validation exercises relevant to these source categories include:

- the comparison of the reference/sectoral approach;
- comparison of inventory estimates based on the carbon balance, with EU ETS data and detailed emission estimates provided by the operators;
- comparison of DUKES data with industry-reported activity data (e.g. from ISSB);

- comparison of carbon emission factors derived from the carbon balance, with IPCC default emission factors;
- checks on the time-series consistency of carbon emission factors generated by the carbon balance method.

These emission sources use DUKES data, which is subject to the UK Statistics Authority's *Official Statistics Code of Practice* and ETS data, which is subject to its own QA process. A bilateral exchange was undertaken in May 2015 with the inventory agency from Germany, which included a review of the revisions to the iron and steel sector method in the 2014 submission.

Time series consistency

All activity data used are available for the full time series of the estimates. Carbon factors for key inputs such as coking coal and blast furnace coal are available from operators only for recent years (2005 onwards in the case of coking coal, 2007 onwards for other fuels) so the same values must be assumed to be appropriate in earlier years. While this does introduce some additional uncertainty for the earlier part of the time-series, the assumed factors for coking coal and blast furnace coal, and the derived factors for coke oven coke, coke oven gas and blast furnace gas for these earlier years are all within the ranges suggested in the IPCC 2006 Guidelines.

Uncertainties

Uncertainties for both activity and emission factors are based on expert judgement. The uncertainty analysis set out in **Annex 2** provides details of these uncertainty values. Uncertainties in fuel use statistics are typically low. The carbon emission factors are based on UK specific data. Since there is a direct link between the carbon emitted and the carbon content of the fuel, it is possible to estimate CO_2 emissions accurately.

MS 5 Aviation

Relevant Categories, source names

1A3a: Aviation

International bunkers - Aviation

Relevant Gases

CO_2, CH_4, N_2O

Relevant fuels, activities

Aviation turbine fuel (jet kerosene), Aviation spirit (aviation gasoline)

Background

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. 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 full description is given in Watterson *et al.* (2004). The method used to estimate emissions from military aviation can be found in **MS 15**.

Key Data sources

Activity data: CAA (2014), DUKES, DfT (2014)

Emission Factors: Baggott et al., 2004 and EMEP/EEA, 1996

Annex 3 *lists all emission factors used in the energy sector, including a full list of references.* ***Table 1.6*** *gives additional information for common activity data sources.*

Method approach

Estimates are based on IPCC Tier 3 and use the number of aircraft movements broken down by aircraft type at each UK airport.

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. The CAA also compiles summary statistics at reporting airports, which include air-taxi and non-ATMs.

- **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 2014). 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**

  These data are supplied by the MOD. Military aviation estimates are included in **MS 15**. The data for total fuel use for military aviation is used in the normalisation to the DUKES total.

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

Table 3.7 Aircraft Movement Data: LTOs and Cruise distances for Domestic and International Flights from UK Airports, 1990-2013

Year	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

Year	International LTOs (000s)	Domestic LTOs (000s)	International Aircraft, Gm flown	Domestic Aircraft, Gm flown
2010	733.97	393.88	1395.08	146.35
2011	769.22	381.18	1465.19	141.56
2012	765.67	365.20	1444.63	137.51
2013	786.65	360.92	1471.09	134.36

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.

Emission factors used

Annex 3 lists all emission factors used in the Energy sector, including aviation, and associated references. Carbon emission factors are country specific, whereas defaults are used for other gases.

Method

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.

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.

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 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)

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 (IPCC, 2006).

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).

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.

Assumptions & observations

The following modifications are made to the CAA data in order to ensure complete geographical coverage of the inventory and full compliance with the IPCC definitions of domestic and international:

- Flights between the UK and overseas territories are reclassified from international to domestic.
- International flights with an intermediate stop at a domestic airport are considered international in the CAA aircraft movement data. These are reclassified as having a domestic leg and an international leg in response to a recommendation from the UNFCCC centralised review in 2013.
- The CAA data have been supplemented with data from overseas territories, supplied by DfT.

Recalculation justification & summary of change

Method Changes	N
Recalculation	Y

See improvement listed below (for 2015).

Improvements (completed and planned)

A number of improvements have been made to the model over recent years, to include findings from UK specific research. The 2015 inventory submission has incorporated revised cruise emissions in line with EMEP-EEA air pollutant emission inventory guidebook. Errors were also corrected in the assumptions regarding climb thrust settings and engine bypass ratios.

A watching brief is kept on developments in emission factors and activity data for all modes of transport.

QA/QC

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

Time series consistency

Consistent data sets and methods are used across the full time series to ensure time series consistency.

Uncertainties

Uncertainties for both activity and emission factors are based on expert judgement. The uncertainty analysis set out in **Annex 2** provides details of these uncertainty values. Uncertainties in fuel use statistics are typically low. The carbon emission factors are based on UK specific data. Since there is a direct link between the carbon emitted and the carbon content of the fuel, it is possible to estimate CO_2 emissions accurately. Non-CO_2 emissions are dependent on a greater number of parameters, and are largely based on defaults. As such, the uncertainties are higher, but since the emissions are smaller, this does not have a significant impact on the overall uncertainty of total GHG emissions.

MS 6 Road Transport

Relevant Categories, source names

1A3bi: Road transport - cars - cold start

Road transport - cars - motorway driving

Road transport - cars - rural driving

Road transport - cars - urban driving

1A3bii: Road transport - LGVs - cold start

Road transport - LGVs - motorway driving

Road transport - LGVs - rural driving

Road transport - LGVs - urban driving

1A3biii: Road transport - buses and coaches - motorway driving

Road transport - buses and coaches - rural driving

Road transport - buses and coaches - urban driving

Road transport - HGV articulated - motorway driving

Road transport - HGV articulated - rural driving

Road transport - HGV articulated - urban driving

Road transport - HGV rigid - motorway driving

Road transport - HGV rigid - rural driving

Road transport - HGV rigid - urban driving

1A3biv: Road transport - mopeds (<50cc 2st) - urban driving

Road transport - motorcycle (>50cc 2st) - rural driving

Road transport - motorcycle (>50cc 2st) - urban driving

Road transport - motorcycle (>50cc 4st) - motorway driving

Road transport - motorcycle (>50cc 4st) - rural driving

Road transport - motorcycle (>50cc 4st) - urban driving

1A3bv: Road transport - all vehicles LPG use

Relevant Gases

CO_2, CH_4, N_2O

Relevant fuels, activities

Petrol (gasoline), Diesel (DERV), LPG

Background

This MS includes all fuel related emissions from road transport. Emissions from Urea consumption are reported under IPPU, in chapter 4.

Key Data sources

Activity data: DfT (traffic data, vehicle licensing statistics, ANPR data), DUKES (total fuel sales)

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

Annex 3 *lists all emission factors used in the energy sector, including a full list of references.* ***Table 1.6*** *gives additional information for common activity data sources.*

Method approach

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).

Petrol and diesel vehicle fuel consumption (and emissions) are estimated from the bottom up data using an array of traffic statistics and exhaust and fuel consumption measurements. These estimates are reconciled to national energy consumption statistics from DUKES. This approach provides estimates that are consistent with the IPCC and include inherent QA/QC in the comparison of bottom-up traffic activity related estimates and top down fuel sales data.

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. 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 only a small percentage (<1%) of the total amount of petrol and diesel consumed by road transport and vehicle licensing data suggest a similar percentage of all light duty vehicles run on LPG.

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, and therefore the omission of this source does not represent an underestimate in the UK inventory.

Traffic-based emission calculations: an overview

A Tier 3 method is used to calculate fuel consumption and emissions from different types of petrol and diesel vehicles using detailed traffic information before a final fuel reconciliation is done.

Fuel consumption and 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. This level of detail is necessary because CH_4 and N_2O emissions are dependent on the types of exhaust technologies used to control the regulated air pollutant emissions.

Activity data for traffic-based emission calculations:

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 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/4248/report-2.pdf). Emission factors for average speeds on the road network are then combined with the national road traffic data.

Cold start emissions are the excess emissions that occur when a vehicle is started with its engine below its normal operating temperature. These are calculated separately from the hot exhaust emissions.

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.

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, 2014a). DfT provides a consistent time series of vehicle km data by vehicle and road types going back from 1993 to the latest inventory year, 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, 2013). These provided a consistent time-series of vehicle km data for all years up to 2012. Data for 2013 were not available in time for the current inventory compilation and thus they were extrapolated from 2012 vkm data for Northern Ireland based on the traffic growth rates between 2012 and 2013 in Great Britain. 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, 2014).

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 1990 to 2013. An extract of the vkm times series is shown in **Table 3.8**.

Table 3.8 UK Vehicle km by Type of Road Vehicle, 1990-2013

Billion vkm		1990	1995	2000	2005	2010	2012	2013
Petrol cars	urban	142.2	137.9	135.1	119.9	99.5	93.5	89.3
	rural	141.1	134.1	134.2	127.3	109.1	100.6	97.5
	m-way	49.2	48.4	53.0	48.8	41.7	37.8	35.9
Diesel cars	urban	5.8	17.2	26.1	40.8	54.1	60.6	63.1
	rural	6.1	18.0	28.3	47.6	65.8	72.9	76.5
	m-way	2.8	8.5	14.6	25.1	33.5	39.1	41.7
Petrol LGVs	urban	11.1	7.5	4.2	1.9	1.3	1.1	1.0
	rural	11.4	8.3	5.0	2.3	1.6	1.4	1.3
	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	22.9	23.2
	rural	6.1	11.5	18.8	26.0	29.5	28.9	30.2
	m-way	2.0	4.4	7.4	10.5	11.4	12.5	13.2
Rigid HGVs	urban	4.5	3.7	3.9	4.0	3.2	3.0	2.9
	rural	7.1	6.8	7.2	7.5	6.6	6.1	6.1
	m-way	3.7	3.7	4.2	4.2	4.1	3.5	3.4

Billion vkm		1990	1995	2000	2005	2010	2012	2013
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	4.9	5.0
	m-way	4.7	6.0	7.4	7.9	7.5	7.6	7.8
Buses	urban	2.4	2.9	3.0	3.2	3.1	2.7	2.8
	rural	1.7	1.5	1.7	1.5	1.6	1.3	1.4
	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	2.3	2.1
	rural	2.0	1.6	2.0	2.2	1.8	2.0	1.9
	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	506.9	508.7

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 information is not available, assumptions were made or road speed limits used for the vehicles expected to observe these on the type of road concerned. **Table 3.9** shows the speeds used in the inventory for light duty vehicles, HGVs and buses.

Table 3.9 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

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. The inventory uses the Automatic Number Plate Recognition (ANPR) data provided by DfT (2014b) to define 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 and 2013. Since 2011, measurements have been made biennially. 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, 2014b). 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 and for 2013, 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 Devolved Administration 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 three years of ANPR data (2010, 2011 and 2013) 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 3.8**.

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 to control air pollutant emissions. These technologies can also affect GHG emissions.

Table 3.10 shows the regulations that have come into force up to 2013 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 3.10 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) 94/12/EC (Euro 2) 98/69/EC (Euro 3) 98/69/EC (Euro 4) EC 715/2007 (Euro 5)	 1/7/1992 1/1/1997 1/1/2001 1/1/2006 1/7/2010
	Diesel	Pre-Euro 1 91/441/EEC (Euro 1) 94/12/EC (Euro 2) 98/69/EC (Euro 3) 98/69/EC (Euro 4) EC 715/2007 (Euro 5)	 1/1/1993 1/1/1997 1/1/2001 1/1/2006 1/7/2010
LGVs	Petrol	Pre-Euro 1 93/59/EEC (Euro 1) 96/69/EEC (Euro 2) 98/69/EC (Euro 3) 98/69/EC (Euro 4) EC 715/2007 (Euro 5)	 1/7/1994 1/7/1997 1/1/2001 (<1.3t) 1/1/2002 (>1.3t) 1/1/2006 1/7/2011
	Diesel	Pre-Euro 1 93/59/EEC (Euro 1) 96/69/EEC (Euro 2) 98/69/EC (Euro 3) 98/69/EC (Euro 4) EC 715/2007 (Euro 5)	 1/7/1994 1/7/1997 1/1/2001 (<1.3t) 1/1/2002 (>1.3t) 1/1/2006 1/7/2011

Vehicle Type	Fuel	Regulation	Approx. date into service in UK
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
		EC 595/2009 (Euro VI)	1/7/2013
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

The ANPR data provides direct evidence on the age mix of vehicles on the road and how this varies on different road types. The information shows that the diesel car, LGV and HGV fleet observed on the road is newer than inferred from the licensing records and mileage surveys. However, this information was only available for 2007-2011, 2013 and it is important to consider how the trends observed in these limited years of ANPR data availability can 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 2013 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 and 2013 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.

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 Bus Service Operators Grant system (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, 2014c). 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. Data for 2011 to 2013 were not available due to a delay in the publication of the Road Freight Statistics and so data for 2010 have been applied to these years to define the split in HGV kilometres by vehicle weight class. 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, 2013).

For motorcycles, 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.

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.

Emissions from black cabs (taxis) in London

Information from TfL was 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.

Fuel Consumption Factors for Vehicle Types:

Equations relating fuel consumption to average 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 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/4249/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 (urban, rural and motorway (highway)) and vehicle engine types to calculate fuel consumption (different Euro emission standards and engine sizes).

Table 3.11 Fuel Consumption Factors for Light Vehicles (in g fuel/km)

Vehicle	Euro-standard	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	

Vehicle	Euro-standard	Urban	Rural	Motorway
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 vehicles within this class (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 2011-2013 from Road Freight Statistics were not available so overall HGV fuel efficiencies for 2010 were carried over to these years.

Table 3.12 presents the fleet-averaged fuel consumption factors for rigid and articulated HGVs from 1990-2013 calculated for urban, rural and motorway conditions based on the road freight statistics published in DfT (2011a) up to 2010.

Table 3.12 Average fuel consumption factors for HGVs (in g fuel/km) in the fleet based on DfT's road freight statistics

Year	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	250.9	205.0	217.3	361.2	279.7	285.2
2008	279.8	226.0	238.4	380.1	293.5	299.3
2009	281.9	228.0	240.7	381.4	294.3	300.1
2010	285.3	229.9	242.4	385.3	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
2013	285.8	229.6	242.0	385.8	296.7	302.5

For buses and coaches, the principal data source used was figures from DfT on the 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. Data were not available for 2013/14 in time for the current inventory compilation and so the 2012/13 figures were also used for the 2013 calendar year.

Table 3.13 presents the fleet-averaged fuel consumption factor for buses and coaches from 1990-2013 for urban, rural and motorway conditions based on this method.

Table 3.13 Average fuel consumption factors for buses and coaches (in g fuel/km) in the fleet based on DfT's BSOG data.

Year	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
2013	327.1	207.6	246.1

Carbon Factors

CO_2 can be calculated from the carbon content of the fuel and the fuel used (calculated as above), emission factors are set out in **Annex 3**.

CH_4 and N_2O Emission Factors for Vehicle Types

The emission factors for N_2O for all vehicle types in g/km are based on the recommendation of the Emissions Inventory Guidebook (EMEP, 2013) 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. The factors for HGVs and buses are provided for different Euro standards, weight classes and driving conditions.

Table 3.14 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. The fuel sulphur content of road fuels has been steadily declining since 2000 with the requirements of the European Fuel Quality Directive and is now less than 10ppm since January 2009 according to Directive 2009/30/EC.

Road transport is a relatively unimportant emitter of CH_4, only being 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 3.14 also summarises the CH_4 emission factor for all vehicle types and road conditions in mg/km.

Table 3.14 N_2O and CH_4 Emission Factors for Road Transport (in mg/km)

Vehicle Type	Standard	N_2O			CH_4		
		Urban	Rural	Motorway	Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	10.0	6.5	6.5	73.0	21.8	57.7
	Euro 1	21.3	13.8	6.9	15.0	5.2	20.9
	Euro 2	10.7	3.4	1.8	15.8	9.6	9.7
	Euro 3	1.4	0.6	0.5	5.0	4.1	7.2
	Euro 4	1.8	0.6	0.5	1.3	1.0	1.8
	Euro 5	1.8	0.6	0.5	1.3	1.0	1.8
Diesel cars	Pre-Euro 1	0.0	0.0	0.0	12.3	10.2	10.0
	Euro 1	2.0	4.0	4.0	6.1	6.3	6.2
	Euro 2	4.0	6.0	6.0	2.9	1.7	1.2
	Euro 3	9.0	4.0	4.0	1.4	1.1	1.1
	Euro 4	9.0	4.0	4.0	1.0	0.8	0.7
	Euro 5	9.0	4.0	4.0	1.0	0.8	0.7
Petrol LGVs	Pre-Euro 1	10.0	6.5	6.5	73.0	21.8	57.7
	Euro 1	22.0	13.8	6.9	15.0	5.2	20.9
	Euro 2	16.3	9.3	5.8	15.8	9.6	9.7
	Euro 3	10.5	4.6	4.6	5.0	4.1	7.2
	Euro 4	0.8	1.3	1.3	1.3	1.0	1.8
	Euro 5	0.8	1.3	1.3	1.3	1.0	1.8
Diesel LGV	Pre-Euro 1	0.0	0.0	0.0	11.8	4.0	22.0
	Euro 1	2.0	4.0	4.0	6.7	1.7	5.8
	Euro 2	4.0	6.0	6.0	2.9	1.7	1.2
	Euro 3	9.0	4.0	4.0	2.2	0.6	1.0
	Euro 4	9.0	4.0	4.0	1.5	0.4	0.7
	Euro 5	9.0	4.0	4.0	1.5	0.4	0.7

Vehicle Type	Standard	N_2O			CH_4		
		Urban	Rural	Motorway	Urban	Rural	Motorway
Rigid HGVs	Pre-Euro I	30.0	30.0	30.0	185.5	50.2	43.6
	Euro I	10.4	8.6	6.1	85.0	23.0	20.0
	Euro II	10.0	8.6	5.7	54.4	20.0	18.6
	Euro III	4.9	4.9	3.7	47.6	21.4	18.2
	Euro IV	10.6	12.9	10.6	2.6	1.6	1.2
	Euro V	27.6	37.1	31.3	2.3	1.4	1.1
	Euro VI	34.0	35.6	26.9	0.77	0.48	0.36
Artic HGVs	Pre-Euro I	30.0	30.0	30.0	381.8	174.5	152.7
	Euro I	17.6	14.7	10.8	175.0	80.0	70.0
	Euro II	17.6	14.7	9.8	112.0	69.6	65.1
	Euro III	8.8	8.8	6.8	98.0	74.4	63.7
	Euro IV	18.6	22.9	18.8	5.3	5.6	4.2
	Euro V	47.9	65.1	54.5	4.7	5.0	3.8
	Euro VI	59.6	62.6	46.9	1.6	1.7	1.3
Buses	Pre-Euro I	30.0	30.0	30.0	381.8	174.5	152.7
	Euro I	11.7	11.2	7.0	175.0	80.0	70.0
	Euro II	11.7	11.2	6.0	113.8	52.0	45.5
	Euro III	5.7	5.7	4.0	103.3	47.2	41.3
	Euro IV	12.4	13.1	11.4	5.3	5.6	4.2
	Euro V	32.2	35.2	33.6	4.7	5.0	3.8
	Euro VI	41.5	41.5	29.0	1.6	1.7	1.3
Mopeds, <50cc, 2st	Pre-Euro 1	1.0			219.0		
	Euro 1	1.0			43.8		
	Euro 2	1.0			24.1		
	Euro 3	1.0			19.7		
Motorcycles, >50cc, 2st	Pre-Euro 1	2.0	2.0		150.0	150.0	
	Euro 1	2.0	2.0		99.0	106.5	
	Euro 2	2.0	2.0		30.0	31.5	
	Euro 3	2.0	2.0		12.0	13.5	
Motorcycles, >50cc, 4st	Pre-Euro 1	2.0	2.0	2.0	200.0	200.0	200.0
	Euro 1	2.0	2.0	2.0	127.9	138.6	148.7
	Euro 2	2.0	2.0	2.0	126.7	93.1	107.1
	Euro 3	2.0	2.0	2.0	76.2	32.6	31.8

Cold start emissions

Cold start emissions of N_2O were estimated using a method provided by the COPERT 4 methodology for the Emissions Inventory Guidebook (EMEP, 2013). The method uses a mg/km emission factor 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 3.15**. There are no cold start factors for HGVs and buses.

Table 3.15 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.

Using the CH_4 and N_2O emissions and fuel consumption calculated from the traffic data, it is possible to derive fuel-based emission factors of CH_4 and N_2O for each vehicle type which is used in conjunction with the normalised fuel consumption (see below) to estimate their emissions. This ensures all pollutant emissions are consistent with fuel sales.

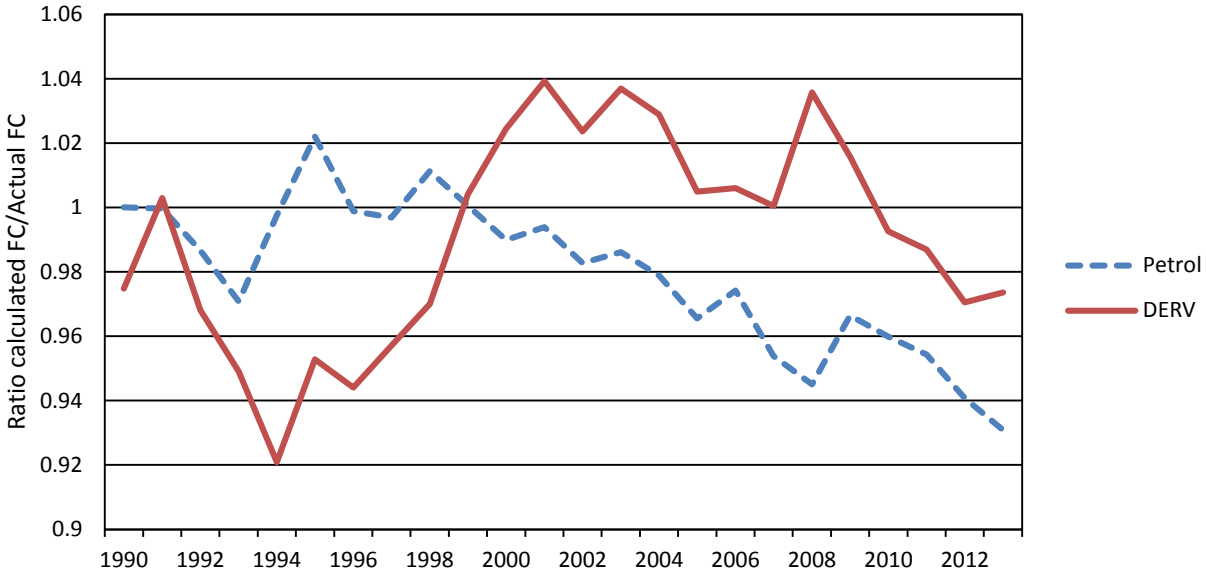
Fuel reconciliation with national statistics and normalisation

The “bottom-up” calculated estimates of petrol and diesel consumption described above are compared with DECC figures for total fuel consumption in the UK published in DUKES. The total amounts in DUKES are adjusted to remove the small amount of consumption by inland waterways, off-road machinery and consumption in the Crown Dependencies. For a valid comparison with DUKES which covers only fossil fuel petrol and diesel, the amount of petrol and diesel displaced by biofuel consumption has been used to correct the calculated consumption of petrol and diesel.

This comparison has always shown a small difference between the bottom-up estimated fuel consumption and DUKES-based figures. In order to be consistent with the IPCC methodologies and ensure that the fuel consumption data matches national statistics it is necessary to adjust the calculated estimates for individual vehicle types by using a normalisation process to ensure the total calculated consumption of petrol and diesel equals the DUKES-based figures.

Figure 3.2 shows the ratio of bottom-up 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 and biofuel displacement as described above. The ratio fluctuates just above and below a perfect match line. The difference is never higher than 8% and considered well within the uncertainty of the factors used to derive the bottom-up estimates.

Figure 3.2 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. 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.

In consultation with 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). This is because HGVs are the largest overall consumer of diesel, so the 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 3.2**) may indicate increasing differences between real-world fuel efficiencies of modern vehicles compared with the factors used in the inventory.

The fuel consumption, normalised to DUKES in the manner described above, is used to calculate CO_2 emissions. For CH_4 and N_2O, the implied fuel-based emission factors derived from the traffic data are combined with the normalised fuel consumed by each vehicle type with the amount of displaced biofuel added to the DUKES total. This is so that these non-CO_2 emissions cover all the fuel consumed by the road vehicles, including the biofuel, and not just the fossil-fuel amounts included in DUKES.

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).

Reliable vkm statistics for LPG vehicles are not readily available. 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. It is estimated that less than 0.5% of all light duty vehicles run on LPG in all years. 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.

Based on this approach, **Table 3.16** shows fleet-averaged emission factors for vehicles using LPG in the UK in 2013 for each main road type.

Table 3.16 Fleet-weighted emission factors for light duty vehicles running on LPG in 2013

g/km	Urban	Rural	Motorway
CH_4	0.0211	0.0120	0.0129
N_2O	0.0085	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.

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. Emissions of CO_2 from lubricants are reported in the IPPU sector (Chapter 4).

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.

Assumptions & observations

There are many assumptions made, using expert judgement, in the Tier 3 approach and these are referred to in the Method Approach section.

Emissions of direct greenhouse gases are calculated on the basis of fuel sold (and not vkm travelled) and are consistent with UK energy statistics.

For CO_2, the assumptions have little effect on total road transport emissions as this is based on fuel sales figures in DUKES, but the assumptions used during the normalisation process affect the distribution of emissions between vehicle types. In particular, the procedure used to normalise the diesel consumption calculated for each vehicle type with the total DUKES figure.

For CH_4 and N_2O emissions, the diesel normalisation method assumed has a direct effect on emission estimates as emissions per unit of fuel consumed vary for each vehicle type.

A sensitive parameter in the emission calculations of CH_4 and N_2O 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.

Other key assumptions that affect CH_4 and N_2O emissions include:

- Extension of the evidence on vehicle usage based on ANPR data to years before 2007
- Application of vehicle speeds measured on a sample of roads to cover the whole road network
- Distances covered by petrol car engines not fully warmed up in calculation of cold start emissions
- All LPG is consumed by light goods vehicles

Recalculation justification & summary of change

Method Changes	N
Recalculation	Y

Revision to total diesel fuel sales in DUKES for 2007 (1.8% lower than the previous year's figures for 2007).

2012 emissions have been slightly revised due to an update to the petrol/diesel share for cars in Great Britain for 2012 and availability of ANPR data for 2013.

Improvements (completed and planned)

A watching brief is kept on developments in emission factors and activity data for all modes of transport.

QA/QC

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

An internationally established Tier 3 method is used consistent with IPCC Guidelines and EMEP/EEA Emissions Inventory Guidebook approaches. The Method Approach section has described a comparison between the bottom-up, traffic-based approach for calculating fuel consumption and the total fuel sales figures provided in DUKES; the agreement is within 8% across the time-series.

The traffic data (vkm) and fleet composition data are provided by DfT and have been assessed by the UK Statistics Authority and confirmed as National Statistics. A Statement on Quality Strategy Principles and Processes for DfT statistics is provided at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/10957/statement-on-quality.pdf

Emission factors and fuel consumption factors are from standard IPCC and EMEP/EEA Inventory Guidebooks and COPERT and from TRL reports published by DfT. These are peer-reviewed sources.

Time series consistency

There are no time-series issues. Time-series consistency is ensured by the use of DUKES fuel consumption and use of continuous, consistent vkm traffic data from DfT. **Chapter 2** describes trends in implied emission factors for CH_4 and N_2O . These are consistent with trends in fleet turnover made using trends in new vehicle sales, constant survival rates combined with ANPR observations showing usage patterns from 2007-present. Extrapolation methods are used to extend the usage patterns implied by the ANPR data to years back to 1990 and interpolation method was used for year 2012 as data was not available.

Uncertainties

The uncertainty analysis is set out in **Annex 2**. The reconciliation between bottom up and top down approaches gives a high level of confidence in the calculated emissions for road transport. There is greater uncertainty in the division in CO_2 emissions between vehicle types.

There are greater uncertainties in the emission factors for CH_4 and N_2O because of limited measurements, in particular for more recent vehicle technologies and emission standards entering service. The main sources of uncertainties in the activity data affecting the CH_4 and N_2O inventories are in the division of diesel fuel consumption between vehicle types. Also in the on-road fleet composition, catalyst failure rates, trip lengths (cold start emissions).

MS 7 Railways

Relevant Categories, source names

1A3c: Rail - coal

Railways: freight – gas oil

Railways: intercity – gas oil

Railways: regional – gas oil

Relevant Gases

CO_2, CH_4, N_2O

Relevant fuels, activities

Gas oil, coal

Background

This MS includes emissions from gas oil used to power diesel trains and from the consumption of coal used to power steam trains. The methodology for gas oil is based around three categories of railway locomotive: freight, intercity and regional. Stationary combustion in the rail sector is included in **MS 12**. 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.

Key Data sources

Activity:	DUKES, Office of Rail Regulation (ORR) National Rail Trends Yearbook (NRTY), ORR data portal
Emission factors:	Baggott et al., 2004, Fynes and Sage (1994), EMEP/EEA 2013, DfT's Rail Emissions Model (DfT 2012b), AP-42 (USEPA)

Annex 3 *lists all emission factors used in the energy sector, including a full list of references.* ***Table 1.6*** *gives additional information for common activity data sources.*

Method approach

Emissions are calculated based on AD x EF.

Coal consumption data has been obtained from DUKES. Estimates have been made across the time-series from 1990-2013 and are believed to be due to consumption by heritage trains. For the indirect GHG emissions, US EPA emission factors for hand-stoked coal-fired boilers are used to estimate emissions from coal-fired steam trains.

The UK GHGI reports emissions from trains that run on gas oil in three categories: freight, intercity and regional. Emissions from these are reported under the IPCC category 1A3c Railways. Emission estimates are based on:

- Vehicle kilometres travelled and emission factors in grams per vehicle kilometre for passenger trains
- Train kilometres travelled and emission factors in grams per train kilometre for freight trains.

Vehicle kilometre data for intercity and regional trains has been obtained from the UK's Department for Transport's Rail Emissions Model for 2009 to 2011 and then estimated for other years from ORR's National Rail Trends Yearbook (NRTY) and data portal. Train kilometre data for freight trains has been estimated from ORR's National Rail Trends Yearbook (NRTY) and data portal.

Gas oil consumption by passenger and freight trains was obtained from the ORR's data portal for the years 2005 to 2013. No data was available for the years prior to 2009 and therefore fuel consumption for these years was estimated on the basis of the trend in train kilometres.

Carbon, sulphur dioxide and nitrous oxide emissions are calculated using fuel-based emission factors and the total fuel consumed. The CEF for coal is derived from Fynes & Sage (1994) whilst the CEF for gas oil is taken from Baggott et al (2004).

Emissions of other pollutants 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 and extrapolations for the years 2010 to 2013;
- For freight trains: Train kilometre data taken from the NRTY and extrapolations for the period 2010 to 2013 and the assumed mix of locomotives and fuel consumption factors for different types of locomotive.

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 gas oil to 10ppm.

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.

Assumptions & observations

It has been assumed that the new trains introduced since 2012 are compliant with the European Non Road Mobile Machinery Stage IIIB regulations.

As with passenger trains, it has been assumed that the new freight trains introduced since 2012 are compliant with the European Non Road Mobile Machinery Stage IIIB regulations.

Recalculation justification & summary of change

Method Changes	N
Recalculation	Y

Changes to the emissions inventory for rail, primarily stem from fuel consumption data for both passenger and freight trains coming available for the years 2011, 2012 and 2013. This data was previously estimated based on vehicle / train kilometre data.

Improvements (completed and planned)

A watching brief is kept on developments in emission factors and activity data for all modes of transport.

QA/QC

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

Time series consistency

Coal use in heritage railways is not reported in DUKES for all years. For the years in which no activity data are reported, emissions are reported as "IE." Consultation with the DUKES team has indicated a high level of confidence in total coal use for the UK. As such although no data are available to allocate emissions to rail for earlier years in the time series, this does not represent an under report in the UK inventory.

Gas oil consumed by the rail sector is estimated based on change in train / vehicle kilometres prior to 2009. However, the total amount of gas oil consumed in the UK is thought to be reliable and therefore this does not represent an under report in the UK inventory as a whole.

Uncertainties

The uncertainty analysis is set out in **Annex 2**. The main uncertainties for the rail sector relate to the poor emission factor data across all sources and the lack of detailed train kilometre data by train class.

MS 8 Shipping – coastal and fishing in UK waters

Relevant Categories, source names

1A3d: Shipping – coastal

1A4ciii: Fishing vessels

Relevant Gases

CO_2, CH_4, N_2O

Relevant fuels, activities

Gas oil, fuel oil

Background

This MS includes emissions from coastal shipping and fishing in UK territorial waters. Shipping outside of UK territorial waters is included in **MS 13**, inland waterways in **MS 10**, and shipping between the UK and OTs (classified as domestic) are described in **MS 9**.

Key Data sources

Activity: DUKES (DECC 2014), Entec, 2010, DfT Maritime Statistics, MMO Fishing statistics.

Emission factors: Baggott et al., 2004, EMEP/EEA 2006

Annex 3 *lists all emission factors used in the energy sector, including a full list of references.* ***Table 1.6*** *gives additional information for common activity data sources.*

Method approach

Emissions from coastal shipping and fishing vessels are based on Entec, 2010. This study is described in **Annex 3**. This MS describes how the Entec study is used for inventory reporting. The method is consistent with a Tier 3 approach.

The Entec study produced bottom up estimates of fuel consumption and CO_2 emissions for 2007. The study also produced a method for extrapolating the estimates for the full time series. The Entec data and method is used directly for the GHG inventory data for coastal shipping and fishing. CH_4 and N_2O were not considered by Entec, these are estimated using Entec's fuel consumption estimates and default emission factors from EMEP/EEA 2006.

Using this data leads to a deviation from DUKES national energy statistics for shipping. **Annex 3** describes how fuel use for all of the shipping related sources are reconciled with the DUKES data.

Recalculation justification & summary of change

Method Changes	N
Recalculation	Y

DfT Maritime statistics and MMO Fishing statistics are used as proxies to produce the time series of emissions. These have been revised for 2010 to 2012 in the latest publication and

these revisions have been incorporated into the inventory to use the latest available data. This leads to a 0.2% increase for shipping, and 0.02% for coastal fishing.

Improvements (completed and planned)

The Entec, 2010 study was very resource intensive, and only carried out detailed calculations for one year (2007). It is anticipated that this will be carried out again for another year within the next few years.

QA/QC

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. All fishing and shipping estimates are reconciled with total DUKES fuel use estimates to ensure completeness.

Time series consistency

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.

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.

These fluctuations and breaks in the time series are not considered to be time series consistency issues.

Uncertainties

The uncertainty analysis is set out in **Annex 2**. The uncertainty in the bottom up calculated estimates are considered to be less than the energy statistics. Additional uncertainty is introduced through the use of proxy statistics to develop the time series. The uncertainty in the carbon emission factor is low since this is UK specific, whereas the uncertainties for non-CO_2 gases are higher.

MS 9 Shipping between UK and OTs

Relevant Categories, source names

1A3d: Shipping between UK and Gibraltar

Shipping between UK and OTs (excl. Gibraltar)

Relevant Gases

CO_2, CH_4, N_2O

Relevant fuels, activities

Fuel oil

Background

This MS includes estimates of emissions from shipping movements between the UK and the Overseas Territories. These were not included in the Entec 2010 study A 3.(described in **Annex 3**) and are therefore calculated separately. These are included as domestic emissions for UNFCCC reporting, and reported under 1A3d.

Key Data sources

Activity: DfT (personal communication), OT port authorities (personal communications), EMEP/EEA 2009

Emission factors: Baggott et al., 2004, EMEP/EEA 2009

Annex 3 *lists all emission factors used in the energy sector, including a full list of references.* ***Table 1.6*** *gives additional information for common activity data sources.*

Method approach

a) Activity data

The total fuel consumed by vessels moving between the UK and each OT is calculated as the sum of all fuel consumed by freight and passenger vessels. This is calculated separately for movements from the UK to each OT and from each OT to the UK.

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 (DfT, Personal communication, 2014) 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 the latest inventory year.

The information on the type of vessel combined with information from EMEP Emissions Inventory Guidebook 2009[20] 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)

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 for shipping 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

[20] http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009

port authority of Gibraltar listing all voyages departing to or arriving from the UK back to 2003[21]. 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[22]. 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.

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.

Distance travelled: Distances for each voyage for freight and passenger 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.

Emission factors

The emission factors used are average factors implied by Entec,2010, for all vessels involved in international voyages supplemented by factors from the EMEP/EEA emissions inventory guidebook (2009) for marine engines.

Assumptions & observations

Total fuel use for these shipping movements is reconciled with DUKES.

All fuel used for voyages between the UK and OTs is assumed to be fuel oil.

Data provided by various data sources are assumed to be complete.

Recalculation justification & summary of change

Method Changes	N
Recalculation	Y

The carbon emission factor used has been corrected in 2012 from 880 to 879 kt/Mt fuel consumed.

The statistics for shipping movements between the UK and Bermuda, as provided by DfT, have been revised in 2012. The revision to the statistics has been incorporated into the inventory, leading to an increase in activity data from this source of 28%. This emissions source remains a very small component in the UK inventory.

[21] http://www.gibraltarport.com/cruise/schedules

[22] 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

Improvements (completed and planned)

This emission source was introduced in response to the UNFCCC ERT in 2012. No improvements to this method are currently planned.

QA/QC

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. There are no official statistical data sets available to verify the information provided for the calculation of these estimates. They are considered to be the best available data. Total fuel use for all shipping sources is reconciled with DUKES.

Time series consistency

The method approach section above details which years data were available for. Gaps have been filled for the early part of the time series based on other statistics, to ensure that the inventory is complete for all years.

Uncertainties

The uncertainty analysis is set out in **Annex 2**. The uncertainty in this particular source is high although the contribution to the total inventory is low and as such, it does not warrant further research. Estimates are included for completeness, following a recommendation from the ERT.

MS 10 Inland Waterways

Relevant Categories, source names

1A3d Inland goods-carrying vessels

Motorboats / workboats (e.g. canal boats, dredgers, service boats, tourist boats, river boats)

Personal watercraft e.g. jet ski

Sailing boats with auxiliary engines

Relevant Gases

CO_2, CH_4, N_2O

Relevant fuels, activities

DERV, Gas oil, Petrol

Background

The category 1A3dii Waterborne Navigation includes emissions from fuel used for passenger vessels, ferries, recreational watercraft, other inland watercraft, and other gasoline-fuelled watercraft. Methods for estimating emissions for these small vessels are presented separately here as they are calculated using different approaches to other marine emissions in the UK inventory.

Key Data sources

Activity:	Walker et al (2011), ONS Social Trends, OECD Stat, Visit England, DfT Maritime Statistics (elaborated under Method approach, below).
Emission factors:	EMEP/EEA 2007 and 2009

Annex 3 *lists all emission factors used in the energy sector, including a full list of references.* ***Table 1.6*** *gives additional information for common activity data sources.*

Method approach

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 separate national fuel consumption statistics on the amount of fuel used by inland waterways in DUKES. However, 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 shipping totals.

The methodology applied to derive emissions from the inland waterways sector uses the 2007 and 2009 EMEP/EEA Emissions Inventory Guidebooks (EMEP, 2009b) approach.

Emissions from individual vessel types are calculated using the following equation:

$$E = \sum_{i} N \times HRS \times HP \times LF \times EF_i$$

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,
EF_i = 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.

The inland waterways class is divided into four categories and sub-categories (Walker et al, 2011):

- 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.

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.

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:

- 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 to all other years in the inventory.

Emission factors

The fuel-based emission factors used for all inland waterway vessels for CH_4 and N_2O were taken from the EMEP/EEA 2009. Emission factors for carbon are from Baggott et al, 2004.

Assumptions & observations

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.

Recalculation justification & summary of change

Method Changes	N
Recalculation	Y

Recalculations relate to revisions to the published proxy statistics for household expenditure, and updating extrapolated figures for freight in 2012 to actual data. The revised household expenditure figures have reduced estimated activity data by about 0.5% for the relevant source categories (Personal watercraft e.g. jet ski, Sailing boats with auxiliary engines). For freight transport the revision leads to an increase of 5% for inland goods carrying vessels.

Improvements (completed and planned)

No improvements to this method are currently planned. Emission factors and activity data are kept under review.

QA/QC

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

Time series consistency

The bottom up analysis for this source category was carried out for one year, and the time series is generated using proxy statistics, as set out in the method approach section, above. Consistent time series of proxy statistics, where available, have been used to estimate the time series. For private water craft, two data sets have been combined. Where the two data sets overlap, there is a correlation in the trend. The combination of these data sets does not introduce any time consistency issues.

Uncertainties

The uncertainty analysis is set out in **Annex 2**. There are no official statistics for the population of vessels, the total fuel consumption or the annual usage of the vessels. There may also be some overlap in definitions between coastal shipping and inland waterways. Total fuel use for shipping is reconciled with the DUKES total to ensure completeness.

MS 11 International shipping

Relevant Categories, source names

Marine bunkers: Shipping - international IPCC definition

Relevant Gases

CO_2, CH_4, N_2O

Relevant fuels, activities

Gas oil, fuel oil

Background

This method statement covers estimates of international marine bunkers which are reported as a Memo item and not included in the UK totals.

Key Data sources

Activity: DUKES (DECC, 2014); other shipping source AD

Emission factors: Entec, 2010, EMEP/EEA 2009, Baggott et al., 2004

Annex 3 *lists all emission factors used in the energy sector, including a full list of references.* ***Table 1.6*** *gives additional information for common activity data sources.*

Method approach

Activity data

Fuel consumption for international shipping is calculated as the difference between total shipping fuel use in DUKES and all other shipping uses:

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)

Emission factors

Emission factors for CH_4 and N_2O were taken from EMEP/EEA 2009, and emission factors for carbon are from Baggott et al., 2004. .Emissions of other gases from 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).

Assumptions & observations

Calculation of international emissions as the residual

The method 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.

Process for agreeing changes to shipping inventory approach and reasons behind deviation from DUKES

Following the results of the Entec, 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.

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.

Recalculation justification & summary of change

Method Changes	N
Recalculation	Y

Fuel use is calculated as a residual and as such will change following recalculations to

- Domestic coastal shipping (**MS 8**)
- Fishing vessels (**MS 8**)
- Inland waterways (**MS 10**)
- Naval shipping (**MS 14)**
- Shipping between the UK and OTs (**MS 9**)

Activity data is also recalculated based on DUKES revisions.

Improvements (completed and planned)

No improvements to this method are currently planned. Emission factors and activity data are kept under review.

QA/QC

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

Time series consistency

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.

Uncertainties

The uncertainty analysis is set out in **Annex 2**. Uncertainty for international bunkers is not estimated.

MS 12 Other stationary combustion

Relevant Categories, source names

1A4ai: Miscellaneous industrial/commercial combustion

Public sector combustion

Railways - stationary combustion

1A4bi: Domestic combustion

1A4ci: Agriculture - stationary combustion

Miscellaneous industrial/commercial combustion

Relevant Gases

CO_2, CH_4, N_2O

Relevant fuels, activities

Anthracite, Burning oil, Charcoal, Coal, Coke, Fuel oil, Gas oil, LPG, Natural gas, Peat, Petroleum coke, Straw, Wood, SSF

Background

This method statement covers emissions from fuel combustion by non-industrial sectors including commercial, agricultural public sector and residential. Most stationary plants are small-scale, apart from a few large installations providing energy for large commercial or public sector buildings (e.g. banks, hospitals, schools, sport centres). Emissions from stationary railway sources are reported under 1A4a where the fuel is used in stationary 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 'miscellaneous' source includes energy use by a range of other users including the sewage and refuse disposal sector, and fuels used by television and radio broadcasters.

Key Data sources

Activity: DUKES (DECC, 2014)

Emission factors: Baggott et al., 2004, IPCC, 2006

Annex 3 *lists all emission factors used in the energy sector, including a full list of references.* ***Table 1.6*** *gives additional information for common activity data sources.*

Method approach

Emissions for this category are calculated based multiplying activity data by an emission factor. Activity data is taken directly from DUKES, with a few exceptions (see assumptions and observations). A full list of emission factors is included in **Annex 3**. Carbon emission factors are largely UK specific, whereas non-CO_2 emissions use default emission factors.

Assumptions & observations

The NAEI source 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.

Bottom up estimates are made for a number of categories using gas oil (railways, off road machinery etc.). In order to reconcile the gas oil used in these categories with the total in DUKES, reallocations (subtractions) are made from other categories, including AD used for the estimates of 1A4. These deviations from DUKES are presented in **Annex 4**.

Activity data estimates for domestic sector use of fuels derived from petroleum coke are based on annual estimates provided by industry experts (CPL, 2013).

Recalculation justification & summary of change

Method Changes	N
Recalculation	Y

- Default emission factors used for CH_4 and N_2O have been updated to use IPCC, 2006
- Emission factors for coal and anthracite have been replaced to use Fynes and Sage, 1994. This is in place of a personal communication from British Coal in 1989.
- Oxidation factors for coal, anthracite and other solid fuels have been updated to use the IPCC default (1).
- DUKES data have been revised
- Estimates for off road machinery (see **MS 20**) have been updated and improved, gas oil is balanced with other source categories (including residential, public and commercial) therefore leading to recalculations
- Revised data have been received for fuel consumption in the Cayman Islands
- A correction has been made for gas use in hotels in Gibraltar, which was missing in the 2014 submission
- The FAO statistics for charcoal consumption have been revised
- Revised statistics for peat consumption in Scotland have been supplied by CEH

The impact of changes is set out in Chapter 10.

Improvements (completed and planned)

No improvements to this method are currently planned. Emission factors and activity data are kept under review.

QA/QC

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Fuel combustion estimates are verified through the comparison of the reference and sectoral approaches.

The energy AD used in these estimates that come from DUKES are subject to the UK Statistics Authority's *Official Statistics Code of Practice*, available from http://www.statisticsauthority.gov.uk/assessment/code-of-practice/

For gas oil, bottom up estimates are made for various sources, which leads to changes in the sectoral allocations within DUKES. There are no official top down statistics to verify the bottom up statistics, however, the totals are reconciled with DUKES. Pet coke and peat data are outside of DUKES, but are small emission sources included for completeness.

Time series consistency

Emission factors and activity data are taken from consistent data sets, there are no time series consistency issues to note.

Uncertainties

Uncertainties for both activity and emission factors are based on expert judgement. The uncertainty analysis set out in **Annex 2** provides details of these uncertainty values. There are no additional official statistics to compare the category specific fuel use for 1A4 with, as such it is difficult to verify the activity data allocations in DUKES. As such the uncertainty for the sources included in this MS will be higher than for power stations, for example. Uncertainties in total fuel use statistics are typically low. The carbon emission factors are based on UK specific data. Since there is a direct link between the carbon emitted and the carbon content of the fuel, it is possible to estimate CO_2 emissions accurately. Non-CO_2 emissions are dependent on a greater number of parameters, and are largely based on defaults. As such, the uncertainties are higher, but since the emissions are smaller, this does not have a significant impact on the overall uncertainty of total GHG emissions.

MS 13 Fishing outside of UK territorial waters

Relevant Categories, source names

1A4ciii: Fishing vessels (outside UK waters)

Relevant Gases

CO_2, CH_4, N_2O

Relevant fuels, activities

Gas oil, fuel oil

Background

A separate method as required for fishing vessels outside UK waters as the approach used for calculating shipping (Entec, 2010) is based on geographical boundary and 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. It is therefore assumed that this study does not include the full fuel consumption from fishing vessel operations. 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 are included in the UK national totals and reported under 1A4ciii.

Key Data sources

Activity: MMO, 2014. Borges et al., 2008

Emission factors: Baggott et al., 2004, EMEP/EEA 2009, Entec 2010

Annex 3 *lists all emission factors used in the energy sector, including a full list of references.* ***Table 1.6*** *gives additional information for common activity data sources.*

Method approach

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

Activity data

The Marine Management Organisation (MMO) produces a report annually on the UK fishing industry[23] entitled "*UK Sea Fisheries Statistics*[24]". This is classed as a National Statistics Publication. This report gives the tonnes of fish landing into the UK and abroad by UK vessels by **area of capture**. The areas of capture are listed in terms of the ICES[25] sea area classification system. The sea areas covered by Entec, 2010 are broadly the ICES areas IV, V, VI and VII and these are is included in calculation for fishing within UK waters (see MS8). The method statement considered activities outside these areas only. According to the MMO reports, these other areas where the UK actively fishes are listed below:

[23] 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)

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

[25] ICES is the International Council for the Exploration of the Sea. See for example http://www.fao.org/docrep/009/a0210e/a0210e12.jpg

- 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 of fish landed in the UK from each of these areas from 1994-the latest year.

The approach involved in 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[26] 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.

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.

[26] 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

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 of 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 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 3.17 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 Marine Diesel/Gas Oil (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.

Emission factors

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 and Baggott et al., 2004 for carbon factors.

Assumptions & observations

All the fuel used for deep sea fishing in non-UK waters is assumed to be gas oil sourced in the UK. All other assumptions are documented in the Method Approach, above.

Recalculation justification & summary of change

Method Changes	N
Recalculation	N

Improvements (completed and planned)

No improvements to this method are currently planned. Emission factors and activity data are kept under review.

QA/QC

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

Time series consistency

No data are available to estimate emissions for years prior to 1994. Emissions for 1990 to 1993 are assumed to be the same as 1994.

Uncertainties

The estimates of fuel consumption are very uncertain, owing to the number of assumptions used, limited data availability and reliance on Dutch data. There is no top down number available to verify the estimates or constrain to. However, where possible, other data sources have been considered to validate some of the assumptions (see method approach section). The uncertainty in the carbon emission factor is low, since this is based on UK specific data. The emission factors for CH_4 and N_2O are higher since these are based on defaults, however, these make up a small proportion of the total emission. These estimates are included in the UK inventory for completeness. The uncertainty analysis for the UK inventory is set out in **Annex 2**.

MS 14 Naval shipping

Relevant Categories, source names

1A5b: Shipping - naval

Relevant Gases

CO_2, CH_4, N_2O

Relevant fuels, activities

Gas oil

Background

Emissions from military shipping are reported separately under IPCC code 1A5b.

Key Data sources

Activity: MoD, 2014

Emission factors: Baggott et al., 2004, EMEP/EEA 2009

Annex 3 *lists all emission factors used in the energy sector, including a full list of references.* ***Table 1.6*** *gives additional information for common activity data sources.*

Method approach

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.

Carbon emission factors are based on Baggott et al., 2004 and CH_4 and N_2O use emission factors from EMEP/EEA 2009. For other pollutants, implied emission factors derived for international shipping vessels running on marine distillate (MGO and MDO) from the Entec (2010) study, where available, were assumed to apply for military shipping vessels

Assumptions & observations

Fuel use for military shipping is included in the DUKES totals. 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) is subtracted from DUKES to ensure there is no double counting (see **Annex 4**)

Recalculation justification & summary of change

Method Changes	N
Recalculation	N

Improvements (completed and planned)

No improvements to this method are currently planned. Emission factors and activity data are kept under review.

QA/QC

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Total fuel use is verified through the comparison of the reference and sectoral approaches.

Time series consistency

The time series is generated from consistent data sets for all years, there are no known issues to raise.

Uncertainties

The uncertainty in the fuel use estimates is low since these are taken from a reliable source. Carbon emission factors are based on country specific data, whereas the non-CO_2 gases are reliant on defaults, which can lead to higher uncertainties. Total fuel use for all shipping categories are reconciled with the DUKES total, and total uncertainties for all users of a given fuel are constrained to the total uncertainty for the fuel.

MS 15 Military aircraft

Relevant Categories, source names

1A5b: Aircraft - military

Relevant Gases

CO_2, CH_4, N_2O

Relevant fuels, activities

Aviation spirit, aviation turbine fuel

Background

Emissions from military aviation are reported separately under IPCC code 1A5b.

Key Data sources

Activity: MoD, 2014

Emission factors: Baggott et al., 2004, EMEP/EEA 1999, IPCC, 1997.

Annex 3 *lists all emission factors used in the energy sector, including a full list of references.* ***Table 1.6*** *gives additional information for common activity data sources.*

Method approach

LTO data are not available for military aircraft movements, so a simple, Tier 1 approach is used to estimate emissions from military aviation. The estimate of military emissions is made using military fuel consumption data (MoD, 2014) and IPCC (1997) and EMEP-EEA (1999) cruise defaults shown in Table 1 of EMEP-EEA (1999). 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.

Assumptions & observations

Fuel use for military aviation is included in the DUKES totals. Military aircraft consumption data provided directly by the Sustainable Development and Continuity Division of the Defence Fuels Group of the MoD (MoD, 2014) is subtracted from Dukes to ensure there is no double counting (see **Annex 4**). Fuel use for casual uplift is considered to be outside of DUKES.

The EMEP-EEA (1999) factors used are considered appropriate for military aircraft.

Recalculation justification & summary of change

Method Changes	N
Recalculation	Y

Revised fuel use statistics from the MoD

Improvements (completed and planned)

No improvements to this method are currently planned. Emission factors and activity data are kept under review.

QA/QC

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

Time series consistency

The time series is generated from consistent data sets for all years, there are no known issues to raise.

Uncertainties

The uncertainty in the fuel use estimates is low since these are taken from a reliable source. Carbon emission factors are based on country specific data, whereas the non-CO_2 gases are reliant on defaults, which can lead to higher uncertainties.

MS 16 Coal mining and handling

Relevant Categories, source names

1B1a1i: Deep-mined coal

1B1a1ii: Coal storage and transport

1B1a2i:Open-cast coal

Relevant Gases

CH_4

Relevant fuels, activities

Coal produced

Background

In 2013 there were 12 deep-mining collieries operational, of which 4 have methane drainage and recovery systems used to collect and burn mine gas to raise power. A further 34 open cast coal mines were also operating in the UK in 2013. This is compared with 188 deep mining collieries and 126 open cast mines operating in 1990[27]. The UK coal industry is undergoing considerable restructuring with mine closures continuing under difficult economic circumstances, and this is evidenced by the 34% reduction in UK deep mined coal production between 2012 and 2013.

Key Data sources

Activity Data:	All activity data on coal production at open cast and deep mines is from DUKES (DECC, 2014), except for production at licensed mines during 1990-1995 (only) which are from an industry reference (Barty, 1995).
Emission Factors:	Operator reported data on methane emissions from deep mines are used to derive CS EFs (UK Coal, 2014; Coal Authority, 2014). Methane EFs from mining operations from UK research are used to estimate emissions from open cast mines and licensed mines (both from Williams, 1993), and emissions from coal storage and transport (Bennett et al, 1995).

Annex 3 *lists all emission factors used in the energy sector, including a full list of references.* ***Table 1.6*** *gives additional information for common activity data sources.*

Method approach

Emissions are calculated from saleable coal production statistics for open cast and deep mined coal, taken from DUKES. 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 Bennett 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.

[27] http://coal.decc.gov.uk/assets/coal/DyGgJafg_pdf_part.pdf

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.

1998-2013The emission factors for UK mines in 1998-2013 are based on operator measurements of the methane extracted by the mine ventilation systems for all collieries operated by UK Coal (UK Coal, 2014) and for collieries owned by other operators that report methane utilisation and venting data (Coal Authority, 2014). 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, Bennett 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. 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.

Assumptions & observations

- **Open cast coal emission factor:** As noted in the method section, the CS EF for CH_4 emissions from open cast coal production are based on analysis of the total methane content of freshly sampled coal cores and these EFs reflect the total methane emissions for all open-cast coal produced, 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 1B1a2i open-cast coal mining (Mining activities). This is consistent with the 1996 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." Furthermore the UK approach is consistent with the general equation for estimating fugitive emissions from surface coal mining presented in section 4.1.4 of the 2006 GLs, as the UK EF

comprises all methane in the coal produced that could be released at any stage post-mining. 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.

- **Other coal:** 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 (175 kt in 2013) 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.

Recalculation justification & summary of change

Method Changes	N
Recalculation	Y

The estimates of methane emissions from deep-mined coal have been revised for all years from 2005 onwards, due to a method improvement implemented by the Inventory Agency. The recalculation did not have a systematic effect across all years affected; slightly lower estimates are now derived for 2005 and 2006 (around 1% lower), whilst emissions from 2007 onwards are increased by around 2-3% until 2012 when a 5% increase compared to the previous submission has resulted. In previous submissions the methane emissions and production data from a small number of larger coal mines (that together covered around 90% of UK deep-mined coal production) were used to derive an IEF that was then applied to the total UK deep-mined coal production. This approach assumed that the level of methane emissions per unit production at the smaller sites was equivalent to that at the larger mines. Due to mine closures and changes in production levels, in 2013 the proportion of UK deep-mined coal production that was covered by non-reporting sites rose to 28%. Therefore the Inventory Agency reviewed the method to seek a more representative approach for this increasingly significant component of overall UK deep mined production (i.e. production at non-reporting – typically smaller – mines).

Annual data (methane generation, methane utilisation, coal production) have been obtained from mine operators that run the sites used to derive the CS IEF for methane emissions. In 2005 there were 7 mines that reported methane emissions, then 6 in 2006, 5 in 2007 to 2010, 4 in 2011-12 and only three in 2013 (one of which was in the process of closing down). For these mines the aggregate emissions of methane (before any utilisation in gas engines) has been used together with the annual production data to derive an "unabated" methane IEF that is now regarded as a more representative factor to apply to the production data from the smaller non-reporting (of emissions) UK deep coal mines.

The new methane emission estimates in the UK are then calculated as follows:

$$\text{UK Emissions} = A + (B*C)$$

Where:

A = the sum of methane emissions reported (after any utilisation in gas engines) by the (typically larger) UK deep coal mines that can provide annual methane emission estimates;

B = UK total deep mined coal production from DUKES – Annual coal production at all sites included in A; and

C = IEF for unabated methane emissions, based on reported methane emissions data from sites included in A (i.e. methane elution before any utilisation) / production at the sites included in A.

This more detailed approach using installation-specific data on total methane elution, methane utilisation and annual production has led to a more accurate CS estimate for the deep-mined coal sector.

Improvements (completed and planned)

Method improvement in the latest submission is outlined above.

No improvements to this method are currently planned. Emission factors and activity data are kept under review. As the UK deep mined coal market continues to undergo restructuring and closures due to economic constraints, we anticipate that the number of mines that will remain operating and reporting may continue to reduce and therefore the data availability and method options may be impacted.

QA/QC

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).

Time series consistency

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. The variability of the time series of emission factors represents changes in UK coal mining, and not time series consistency issues.

Uncertainties

The uncertainty in the coal production statistics is low, since these are based on national statistics. The emission factors applied are country specific, and in some cases based on mine specific data, and therefore the uncertainty is lower than using default literature values. Additional uncertainty is introduced through the application of emission factors based on a sub-set of mines to represent full UK coal production, but we note that the total UK deep mined production where a methane elution factor is applied based on data from other sites is typically smaller sites that together produce (for many years in the time series) only around 10% of UK coal. However, we also note that the proportion of UK production at non-reporting deep mines

has grown in 2013 to 28%, and therefore the overall uncertainty of deep-mined coal methane emissions is higher for 2013 than other years.

MS 17 Closed coal mines

Relevant Categories, source names

1B1a1iii: Closed Coal Mines

Relevant Gases

CH_4

Relevant fuels, activities

Modelled emissions

Background

Methane emissions from **closed coal mines** are accounted for within category 1B1a1iii (reallocated from 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).

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.

Data for 25 mines closed between 1990 and 2013, and 121 mines closed before 1990 are included in the model. The model also includes projections, which can be changed to account for mine closures occurring earlier or later than predicted. Methane utilisation has increased significantly across the time series, up to a maximum of 94% in 2004.

Key Data sources

WSP, 2011 and White Young Green, 2005

Annex 3 *lists all emission factors used in the energy sector, including a full list of references.* ***Table 1.6*** *gives additional information for common activity data sources.*

Method approach

The UK model that was developed in 2005 (White Young Green, 2005) and revised in 2011 (WSP, 2011). The 2011 study used the same method, updating data for mine closures during 2005-2010.

The model 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.

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 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.

WSP, 2011 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.

Assumptions & observations

Recalculation justification & summary of change

Method Changes	N
Recalculation	N

Improvements (completed and planned)

No improvements to this method are currently planned. The model is periodically reviewed and updated.

QA/QC

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. WSP, 2011 was subject to review by a steering committee, and final sign off by DECC. The research also includes benchmarking of UK specific estimates with other inventories to ensure that the method used remains appropriate for the UK.

Time series consistency

No time series consistency issues have been identified.

Uncertainties

The uncertainty in the emissions from this source was assessed as part of WSP, 2011. The uncertainty assessment indicated a range of ±17% to ±41% over the period 1990-2050. This level of uncertainty is in line with IPCC guidance on Tier 2 and Tier 3 methodologies. This considered the uncertainty in the future mine closure dates, gas reserve estimates, the annual methane emissions rate as % of gas reserve, the open cast mine methane emissions factor and the methane utilisation factor.

MS 18 1B2 excluding: Oil refining, storage and distribution (1B2aiv to v) and natural gas distribution (1B2biii to v)

Relevant Categories, source names

1B2a1: Upstream Oil Production - Offshore Well Testing

1B2a2: Petroleum processes

Upstream Oil Production - process emissions

1B2a3: Upstream Oil Production - Offshore Oil Loading

Upstream Oil Production - Onshore Oil Loading

1B2a4: Upstream Oil Production - Oil terminal storage

1B2b1: Upstream Gas Production - Offshore Well Testing

1B2b3: Upstream Gas Production - process emissions

1B2b4: Upstream Gas Production - Gas terminal storage

1B2c1i: Upstream Oil Production - venting

1B2c1ii:Upstream Gas Production - venting

1B2c2i: Upstream Oil Production - flaring

1B2c2ii:Upstream Gas Production - flaring

Relevant Gases

CO_2, CH_4, N_2O

Relevant fuels, activities

All fugitive releases from oil and gas production, excluding leakage from gas transmission and distribution. Distribution of oil products is not described since there are no direct GHG emissions.

Background

This source category covers emissions which occur during the production, transportation, or use of liquid and gaseous fuels. It excludes combustion of those fuels used by the industry during the production, transportation, or use of liquid and gaseous fuels. Fuel combustion emissions associated with upstream oil and gas exploration and production are reported within 1A1cii Oil and Gas Extraction, the method for which is presented in MS2. Emissions from leakage during gas transmission and distribution, and the point of use are included in method statement **MS 19**.

UK upstream oil and gas exploration and production is almost entirely offshore, with a very small number of onshore oil wells. No onshore gas production occurs in the UK. Shale gas

reserves have been identified and some preliminary research into prospective shale gas extraction is on-going, but there is no active exploration or production currently in the UK.

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. Emissions of CH_4 and VOC also occur from storage tanks at oil terminals.

Key Data sources

Activity data: EEMS (DECC, 2014), DUKES (DECC, 2014), IPPC/EPR-reported data (EA and SEPA, 2014) EU ETS data (DECC, 2014), UKOOA (2005), UKPIA (2014)

Emission factors: EEMS (DECC, 2014), EU ETS (DECC, 2014), UKOOA (2005)

Annex 3 *lists all emission factors used in the energy sector, including a full list of references.* ***Table 1.6*** *gives additional information for common activity data sources.*

Method approach

An overview of the data sources and methods used to derive estimates for the categories included in this MS is below.

The key methodology for 1B2 source categories is based around a number of data sources/studies.

- Oil and gas operators submit annual source-specific emission estimates to the **Environmental and Emissions Reporting System (EEMS)**, regulated by the DECC Offshore Inspectorate and developed in conjunction with the trade association Oil & Gas UK. For further details see **Annex 3**. UK GHGI estimates are based on EEMS (activity data and emission factors derived from operator-reported emissions) from 1998 to the latest inventory year for all offshore installations. Industry studies from the trade association **(UKOOA, 2005)** are used to inform estimates prior to the EEMS system, 1990-1997.
- Annual reporting of emissions by pollutant aggregated across all emission sources under the **IPPC/EPR reporting system** to the UK environmental regulatory agencies (i.e. EA, NRW, SEPA) are available for onshore sites only (i.e. including oil and gas terminals, but excluding all offshore oil and gas installations). 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, and 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 from upstream oil and gas facilities have been reported under **EU ETS**, and from 2008 onwards **combustion and flaring CO_2** emissions from upstream oil and gas facilities 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. 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, enabling more accurate source-specific emission reporting.

- The EEMS data is only comprehensive post 1998, as such further data sets are used to compile the time series: To do this the **Petroleum Processing Reporting System (PPRS) is used** to provide data on **gas flaring volumes** at offshore and onshore installations, as well as **oil and gas production data** to extrapolate the activity data back to 1990. 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.
- The UK GHG inventory estimates for categories 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.
- The inventory agency continues to investigate ways in which methane emissions from **oil and gas well blow outs** can be estimated, however no data is currently available with which to make a timeseries. The inventory agency will continue to explore the possibility of data with other countries, by reviewing published research or through engagement with experts.

A summary of how the data sources above are applied to the detailed categories and subcategories under 1B2 are presented in **Table 3.18** below.

Table 3.18 Summary of Data Sources and Estimation methods for 1B2 source categories in the UK GHG Inventory

Categories and subcategories		Methodology
Onshore terminals, Offshore oil and gas platforms & Offshore floating production and storage vessels, well testing rigs	1B2aii, 1B2bii Oil, Gas Production: Upstream facility process and fugitive releases	1990-1997 (UKOOA 2005): 1998-Latest year (EEMS): For onshore terminals and wells, missing sites from EEMS are estimated based on IPPC/EPR-reported data (EA and SEPA, 2014).
	1B2aiii Transport: Offshore loading of oil, 1B2avi Other: Onshore loading of oil	1990-1997 (UKOOA 2005): 1998-Latest year (EEMS): Assumes CH_4 IEF from 1998 applies to all years 1990-1997. For onshore terminals and wells, missing sites from EEMS are estimated based on IPPC/EPR-reported data (EA and SEPA, 2014).
	1B2ci,ii Venting at upstream oil, gas facilities	1990-1997 (UKOOA 2005): 1998-Latest year (EEMS): For onshore terminals and wells, missing sites from EEMS are estimated based on IPPC/EPR-reported data (EA and SEPA, 2014).
	1B2ci,ii Flaring at upstream oil, gas facilities	1990-1996 (UKOOA 2005): 1997-Latest year (EEMS): Assuming the same oil:gas split as in EEMS 1997, and aggregate oil and gas flaring volumes 1990-2013 (DECC 2014). For onshore terminals and wells, 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.
	1B2ai, 1B2bi Oil, Gas Exploration: well testing	1990-1996 (UKOOA 2005): 1997-Latest year (EEMS): AD estimated assuming CO_2 IEF from 1998 is valid for earlier years.
Refineries	1B2aiv Refining / Storage: Petroleum processes, Oil Terminal storage	All years - Fugitive emissions from oil storage and refinery processes are derived from aggregate industry estimates provided by the refinery trade association (UKPIA, 2014).

Assumptions & observations

The EEMS data set allows for emissions to be accurately allocated between oil and gas production between 1998 and the latest year. Prior to 1998, 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.

Recalculation justification & summary of change

Method Changes	N
Recalculation	Y

There have been some minor revisions to UK estimates for sources from the upstream oil and gas sector and downstream petroleum processes, where QC and stakeholder consultation with regulators and operators has enabled the Inventory Agency to address any identified reporting gaps or inconsistencies. These are summarised below, with quantitative data presented in **Section 10**.

1B2c2i Oil Production – Flaring

Quality checking of data (EEMS and EU ETS) for the Dunlin platform led to a recalculation (small increase, ~0.6% of the source category total) in total carbon dioxide emissions for this source in 2012.

1B2a2 Petroleum processes

Revised operator data have led to a very small (0.1%) increase in the estimated methane emissions from petroleum processes.

Improvements (completed and planned)

No improvements to this method are currently planned. Emission factors and activity data are kept under review.

QA/QC

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.

Time series consistency

The emission estimates for the offshore industry are based on the EEMS dataset for 1998-2013, 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, 2014) 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.

Uncertainties

Uncertainties are presented in **Annex 2**. Emissions data taken from the EEMS reporting system 1998 onwards are considered to be high quality, emissions data for other years are subject to greater uncertainties.

MS 19 Gas leakage

Relevant Categories, source names

1B2b4: Natural Gas (transmission leakage)

1B2b5: Natural gas (distribution leakage)

Natural Gas (leakage at point of use)

Relevant Gases

CO_2, CH_4

Relevant fuels, activities

Leakage from gas transmission and distribution, leakage at the point of use

Background

The UK GHG inventory includes estimates of methane and carbon dioxide emissions from natural gas leakage from the downstream gas supply network, including releases from: high pressure transmission network; distribution network; gas leaks at point of use. Annual activity data and gas compositional analysis are provided by National Grid, four companies (formed in 2005) that operate the low-pressure gas distribution networks within Great Britain, and Airtricity in Northern Ireland.

Key Data sources

Activity data: Natural gas leakage data in energy and mass units, from the UK downstream natural gas network operators: National Grid, Scotia Gas, Northern Gas Networks, Wales & West, and Airtricity (NI).

AD for gas use in domestic and commercial sectors from DUKES (DECC, 2014) are used to generate leakage at point of use estimates.

Emission factors: Natural gas compositional data (mass % data for: nitrogen, carbon dioxide, methane, ethane, propane, i-butane, n-butane, neo-pentane, i-pentane, n-pentane, hexanes+) supplied by the gas network operators as listed above. UK estimates of natural gas consumption within each Local Distribution Zone (LDZ) are used to generate a weighted-average UK compositional analysis of natural gas consumed annually. From 2007 these data are available from Long Term Development Plans published by each of the gas network operators; earlier data by LDZ are based on Local Authority-level consumption estimates aggregated into LDZs (CLARE database, 2012).

EFs for the gas leakage at point of use are derived from UK data on gas fitting performance and assumptions regarding unit operational cycles, ignition times.

Annex 3 *lists all emission factors used in the energy sector, including a full list of references.* ***Table 1.6*** *gives additional information for common activity data sources.*

Method approach

The leakage estimates are calculated using separate methodologies to cover:

1. Natural gas leaks from the high-pressure transmission mains (National Grid Gas); (reported under **1B2b4 Transmission**)
2. Natural gas leaks from the low pressure distribution network, medium pressure gas mains, Above Ground Installations (AGIs), AGI working losses and interference (National Grid Gas, Scotia Gas, Northern Gas Networks, Wales & West, Airtricity); (Reported under **1B2b5 Distribution**)
3. Other losses of natural gas at the point of use (DECC DUKES, UK research). (Reported under **1B2b5 Distribution**)

For methods 1 and 2 above, from 2004 onwards the gas network operators provide annual gas leakage estimates on a mass basis, providing a breakdown of emissions across all 14 regional gas networks in the UK, which are called Local Distribution Zones (LDZs). National Grid Gas operates the high-pressure natural gas transmission network and 5 of the LDZs; Northern Gas Networks operates 2 LDZs; Scotia Gas operates 3 LDZs; Wales and West Utilities operates 3 LDZs; Airtricity operates 1 LDZ. In addition, each of the gas network operators provides annual natural gas compositional analysis for their networks. Prior to 2004, the data on gas leakage (activity data and compositional analysis) was all provided by British Gas, which operated all of the UK networks before the industry was privatised.

The information on methane losses from the high pressure transmission system (1B2b4) are estimated by National Grid based on (i) periodic fugitive emission surveys for the NTS, compressor stations and LNG terminals, and (ii) NG records of intentional venting actions on the network. These data have not been available for every year across the time series, with only two data points in the 1990s, annual data from 2000-2004, then data for 2011 and 2012. Data for other years are estimated using interpolation (2005-2010) and extrapolation (early time series and for 2013, as the data for 2013 was provided by NG too late for inclusion into the UK inventory 2015 submission).

The UK GHG inventory estimates for 1B2b5 (distribution leakage) 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 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 from the low and medium pressure distribution systems. 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. Historical 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

Data on the methane and NMVOC content of natural gas have been 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. 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 Airtricity 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. The estimates of gas consumption within each LDZ are based, from 2007 onwards, on LDZ throughput data presented within Long Term Development Statements by each of the gas network operators; prior to 2007 these data are unavailable, and the best available data to inform the UK weighted average composition are sub-national gas use statistics at local authority level (then aggregated to LDZs) which are published by DECC annually and processed for UK Local Authority CO_2 emission estimates via the CLARE database.

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 (Airtricity, 2014), and the data for 1999 to 2004 have been extrapolated back from the 2005 figure.

The third inventory estimation methodology is used to determine estimates of natural gas leakage at the point of use, and these estimates are also reported in 1B2b5. Leakages are estimated for a range of different appliances that use gas, combined with national statistics on natural gas consumption in the domestic and commercial sectors (DECC, 2014).

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, Water Heating Boilers and cooking.

Methane emission from pre-ignition losses of gas appliances domestic properties are based on activity data from Energy Consumption in the UK (DECC, 2014) which provides the full time series of gas use for heating, water heating and cooking in the domestic sector and a series of assumptions regarding the size of units, number of units, age of units, gas flow rates, air

flow rates, delays to ignition, operation times from used to determine the percentage of gas that is not burned. The estimates of UK appliance stock, by capacity and design and estimated average gas consumption per appliance per day are all derived from Ecodesign studies (energy efficiency analysis) through the UK Government Market Transformation Programme (Ecodesign Lot 22 and Lot 23, 2011). The estimates of appliance cycle operation times and estimated delays to ignition for different appliances are based on expert judgement of UK combustion technology experts (Personal communication, Stewart, 2012).

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, 2014) 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 using references and expert judgements as noted above for domestic 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 in **Annex 3**.

Assumptions & observations

Assumptions used to estimate the leakage at point of use for domestic heating and water heating boilers are as follows:

- average boiler size in the UK of 30kW
- a burn chamber size, natural gas flow rate taken from a typical combination boiler
- Estimated delay to ignition: 0.25 seconds for automatic ignition, 2 seconds for manual ignition
- 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
- assumptions relating to the boiler yearly operation and cycling frequency, between heating and water heating applications
    - 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.
    - All UK domestic properties that have hot water heating systems also have gas heated hot water.
    - Average water heating is on for 4 hours per day every day of the year.
    - During each hour that a boiler is heating water, the boiler cycles on and off 5 times.

The number of boilers from 1990 to 2013 is thought to have increased (ca. 22 million in 2008) due to the increasing use of gas central heating for space heating, and the increase in the number of houses. However, 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. Therefore it is 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.

Assumptions used to estimate the leakage at point of use for domestic cooking appliances (manual and automatic ignition) and gas fires are as follows:

- 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;
- 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).

Assumptions used to estimate the leakage at point of use for commercial gas appliances (catering and other uses) are as follows:

- 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).

Recalculation justification & summary of change

Method Changes	N
Recalculation	Y

1B2b4 Natural Gas (transmission leakage)

Through consultation with National Grid, updated data were provided for transmission network leakage in 2012, and a correction to previous data for 2011 (data transcription error by data provider) was also identified through Inventory Agency quality checks. These changes also affected the 2005 to 2010 time series, as these are interpolated between 2004 and 2011 (as no annual data are available for those years).

1B2b5 Natural gas (distribution leakage)

Estimates of methane leakage from the distribution system have been revised due to two factors. Firstly through consultation with data suppliers, the 2012 estimates of gas leakage from one network operator (Scotia Gas) for 2012 have been revised. Secondly in the 2015 submission the Inventory Agency has reviewed the data available to derive the UK weighted average compositional analysis and has implemented a method improvement to the data from 2007 onwards, where actual LDZ gas use data have been identified within network operator Long Term Development Plans. Previously estimates of Local Authority gas use that are used in DECC sub-national energy statistics were used (and still are for earlier years, as the best available data to estimate gas throughout for each LDZ); however, where the actual LDZ throughput data are published (for 2007 onwards) then a small improvement in overall accuracy of the UK weighted average natural gas composition has been made.

1B2b5 Natural Gas (leakage at point of use)

Estimates of natural gas use in domestic and commercial appliances in recent years have been significantly revised by DECC (DECC DUKES, DECC ECUK, 2014) leading to revisions in the estimates for gas leakage at point of use from 2008 onwards.

Improvements (completed and planned)

No improvements to this method are currently planned. Emission factors and activity data are kept under review.

QA/QC

The sector estimates are subject to the same Tier 1 QA/QC routines as all other source categories in the UK GHGI.

Checks on data reported by gas network operators are conducted to check consistency across the time series and also between operators; for example in compiling the 2015 submission data, through quality checks between gas network operators it was noted that the gas compositional data for 2013 from Wales and West Utilities was an outlier. The Inventory Agency identified that estimated mass percentage calculations were incorrect, and the values were subsequently revised and then used in the UK GHGI compilation.

As recommended during the September 2014 centralised review of the UK inventory, the UK Inventory Agency has also conducted verification checks on the UK GHGI estimates, by deriving separate emission estimates for methane using the Tier 1 default methods outlined in both the 1996 GLs and the 2006 GLs. The method in the 1996 GLs uses max and min default factors based on the pipeline length of the transmission and distribution network, whilst the 2006 GLs Tier 1 method uses max and min default factors based on the total volume of delivered natural gas. The results are summarised below for 1990 and 2013 data:

1990 UK GHGI total (transmission plus distribution) = 378.8 kt CH_4

> Using IPCC 1996 GLs Tier 1 method, the range for emissions is derived as 155 to 215 kt CH_4
>
> Using IPCC 2006 GLs Tier 1 method, the range for emissions is derived as 67 to 105 kt CH_4

Therefore, compared to both Tier 1 methods, the 1990 UK GHGI estimate is higher than the range of values.

2013 UK GHGI total (transmission plus distribution) = 168.5 kt CH_4

> Using IPCC 1996 GLs Tier 1 method, the range for emissions is derived as 155 to 215 kt CH_4
>
> Using IPCC 2006 GLs Tier 1 method, the range for emissions is derived as 95 to 148 kt CH_4

Therefore, compared to the Tier 1 methods, the 2013 UK GHGI estimate is within the range of values for the 1996 GLs method and higher than the range of values for the 2006 GLs method.

The comparison against the IPCC Tier 1 methods indicates that the UK GHGI estimates are of a similar order of magnitude as the Tier 1 defaults. The 1990 UK GHGI value appears to be high, as it is above the range of values derived from the IPCC Tier 1 methods, whilst the 2013 UK GHGI value is also higher than the range for the 2006 GLs Tier 1 method. However, the UK estimates are derived from a country-specific method and we note that the uncertainty estimates provided in the 2006 GLs for the default EFs provided for gas network distribution (which is by far the greatest contributor to overall methane leakage) are cited as -20 % to

+500% for factors for developed countries. Therefore, given the large uncertainty range, the UK data are consistent with the IPCC Tier 1 estimates.

Time series consistency

As far as possible, consistent source data and methods are used across the time series. However, we note the following limitations of the current methods:

- The available data on methane leakage from the high pressure gas transmission system is limited. Data are not available for all years of the time series and therefore gap-filling techniques (extrapolation and interpolation) are used;
- The calibration of the UK gas leakage model used by all natural gas network operators in based on two in-depth studies of the leakage rates from different constituent elements of the UK gas network – one in 1992, another in 2002. These studies have been used to establish estimated leakage rates in the UK model that are then applied to activity data gathered annually through surveys and from gas network renewal projects.
- The derivation of the UK average natural gas composition uses the best available data for every year of the time series, as the factors are critical for the UK GHGI estimates as a whole (not just for the leakage estimates, but also for natural gas combustion estimates). Since 2007 the weighted average has been calculated using actual data available on gas throughout for each LDZ; prior to 2007 these data are not available and the LDZ gas throughput estimates used in the calculation of the UK average gas composition use Local Authority level gas use estimates, aggregated up to LDZs. These earlier data at Local Authority level were regarded as “experimental statistics” by DECC until the 2005 dataset were published as national statistics, and as such are regarded as more uncertain than the more recent data.

Uncertainties

Uncertainties are presented in **Annex 2**. 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.

MS 20 Off road machinery

Relevant Categories, source names

1A2gvii: Industrial off-road mobile machinery

1A3eii: Aircraft - support vehicles

1A4bii: House and garden machinery

1A4cii: Agriculture - mobile machinery

Relevant Gases

CO_2, CH_4, N_2O

Relevant fuels, activities

DERV, Gas oil, Petrol

Background

This MS includes all emissions from off road machinery. These are compiled in a single model, and the outputs reported in the IPCC categories set out above.

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 1A2gvii
- Aircraft support machinery – reported under 1A3e.

Key Data sources

Activity:	Netcen, 2004a, ONS, UKMY, DECC Projections (pers. comm.), CAA
Emission factors:	Baggott et al., 2004, EMEP-EEA Guidebook, EU Non-Road Mobile Machinery Directive.

Annex 3 *lists all emission factors used in the energy sector, including a full list of references.* ***Table 1.6*** *gives additional information for common activity data sources.*

Method approach

A Tier 3 methodology is used for calculating emissions from individual types of mobile machinery. Default machinery or engine-specific fuel consumption and emission factors (g/kWh) are taken from EMEP-EEA Guidebook. For methane, emission factors for more modern machinery based on engine or machinery-specific emission limits for total hydrocarbons established in EU Non-Road Mobile Machinery Directive are also included where available. The measures introduced to reduce total hydrocarbon emissions are assumed to effect methane emissions. Activity data are based on bottom-up estimates of equipment numbers and hours of use in 2004 (Netcen, 2004a). Various proxy statistics are used as activity drivers for different groups of machinery types to estimate fuel consumption across the full time series.

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/ EEA (2009).

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. Part of the 2014 Improvement Programme for the air pollutant emissions inventory led to some minor changes in activity data for certain types of construction and airport support machinery, but these had minor effects on GHG emissions.

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 2005-2013.

Table 3.19 below details the drivers used for each of the equipment categories.

Table 3.19 Activity drivers used for off-road machinery

Category	Driver source	Machinery types
Domestic house and garden	CLG household statistics (number of households)	All types of garden equipment, e.g. lawn mowers, garden tractors, leaf blowers, chain saws, trimmers
Airport machinery	CAA, 2013 terminal passenger statistics	All types of airside machinery and transport, e.g. terminal tractors
Agricultural machinery	DUKES, gas oil consumption in agriculture	All types of agricultural and forestry machinery, e.g. tractors, combines, balers, tillers, fellers, chain saws, shredders
Construction	ONS construction statistics. "Output in the Construction Industry. Supplementary Tables July 2014", Table 2b – 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 (2010) 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 equipment
		surfacing equipment
		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 (2014).	bore/drill rigs
		off highway trucks
		crushing/processing equipment
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

Category	Driver source	Machinery types
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 equipment
		pressure washers
		aerial lifts
		forklifts
		sweepers/ scrubbers
		other general industrial equipment
		other material handling equipment

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 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 the air pollutants and for those 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 trends in total hydrocarbon (THC) emissions across the emission regulation stages were applied to the trends in methane emissions as it is assumed that measures to control THC emissions will also impact methane emissions.

Assumptions & observations

The assumptions made to estimate emissions from this source are described in the methods and approach section above. There are no data available on trends in fuel consumption or activities (population x usage) by these specific groups of machinery to corroborate the choice of proxies used as activity drivers. The drivers chosen are considered by expert judgement to be most appropriate among all the statistical data that are available. The Inventory Agency consider that the drivers used for household garden and machinery and airport support equipment are likely to be more robust than the drivers used for general industry.

A fuel reconciliation procedure is followed for gas oil which takes account of consumption from all sources, as described in **Annex 4**. For the industrial and construction machinery, the fuel reconciliation process essentially overrides any changes in estimates of fuel consumption calculated from the bottom-up procedure arising from the 2014 review of activity data for some selected machinery types. However, this review still affects the emissions of methane by leading to changes in implied emission factors for these machinery types, e.g. through revisions to the lifetime and turnover in the machinery fleet.

Recalculation justification & summary of change

Method Changes	N
Recalculation	Y

Changes occurred due to revisions in activity drivers used to derive the time-series in fuel consumption:

- Changes in activity driver for industrial and quarrying machinery coupled with changes in gas oil used for other inventory sources leading to a change in overall fuel consumption for industrial off-road machinery in order to retain the gas oil fuel balance with DUKES
- Changes in number of households across the time-series from 2001 used to estimate fuel consumption by house and garden machinery. Smaller growth in households leads to a slower rate of change in driver
- Changes in gas oil consumption by agriculture in DUKES used as a driver for fuel consumption by agricultural machinery.

Improvements (completed and planned)

Part of the 2014 Improvement Programme for the air pollutant emissions inventory led to some minor changes in activity data for certain types of construction and airport support machinery, but these had minor effects on GHG emissions. The activity parameters considered were population, lifetime, engine power, and hours of use per year.

- **Airport support equipment**: the review indicated that many of the smaller equipment had smaller engines than previously estimated, i.e. <56kW rated power which means they will not need to conform to Stage IV NRMM Directive regulations. Engine power was reduced to 40kW. To maintain the same overall fuel consumption rate for airport machinery, the activity rate for larger machinery (terminal tractors) was increased to compensate for the decrease in engine power for the small machinery.
- **Generator sets**: the hours of use for the large 100-1000kW generators was reduced from 844 hours/year to 500 hours/year. This followed discussions with organisations that use generators this size mainly as standby/emergency generators which are used less frequently than smaller generators. The new estimate comes from a study of the Swiss Federal office for the Environment.
- **Rollers, cranes and tracked bulldozers**: Lifetime reduced from 8.75 to 5 years (rollers), 11 to 6 years (cranes) and 15 to 10 years (bulldozers). Our study found that construction equipment is mostly hired rather than owned by the user so the population of used equipment is relatively young. The new shorter lifetimes were taken from Swiss Federal office for the Environment, except for bulldozers where a smaller reduction in lifetime was assumed compared with the Swiss study.
- **Dumpers**: Population increased from 850 to 8,500 units and engine power increased from 10 to 30kW. The increase in population was based on evidence from DfT licensing statistics.

These changes affected the estimated fuel consumption, but also the designated emission factor (where the engine size banding had changed) and the rate of turnover in the fleet.

QA/QC

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

An expert judgement quality check has been done to verify that the amount of gas oil used by off-road machinery estimated from the bottom-up approach is neither excessively high or low as a proportion of total UK gas oil available for consumption as given in DUKES.

Time series consistency

Although the bottom up data for machinery population and usage is only available for one year, the proxy statistics used to generate the time series are consistent across the time series.

Uncertainties

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.

The highest uncertainties are considered to be in the estimates for general industrial machinery as these cover a wide range of machinery types of a fairly diffuse nature, e.g. portable generators. The estimates in the year-to-year trends for this particular off-road source are also influenced by the uncertainties in the other sources using gas oil via the fuel reconciliation step. Uncertainties in the trends for the other off-road sources (domestic house and garden, airport machinery and agricultural machinery) are considered to be smaller and less biased by the choice of proxy data.

4 Industrial Processes (CRF Sector 2)

4.1 OVERVIEW OF SECTOR

IPCC Categories Included	2A: Mineral Products 2B: Chemical Industry 2C: Metal Production 2D: Non-energy Products from Fuels and Solvent Use 2E: Electronics Industry 2F: Product Uses as Substitutes for ODS 2G: Other Product Manufacture and Use 2H: Other
Gases Reported	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, NF_3, NO_x, CO, NMVOC, SO_2
Key Categories ('T' or 'L' indicates whether it's been identified in the trend or level assessment respectively and the number indicates which KCA approach it was identified in)	2A1: Cement production - CO_2 (L1, T1) 2B: Chemical industry - HFCs (T2) 2B2: Nitric acid production - N_2O (L1, T1, T2) 2B3: Adipic acid production - N_2O (L1, T1, T2) 2B8: Petrochemical and carbon black production - CO_2 (L1) 2B9: Fluorochemical production - HFCs, PFCs, SF_6 and NF_3 (L1, T1) 2C1: Iron and steel production - CO_2 (L1, T1) 2C6: Zinc production - CO_2 (T1) 2F: Product Uses as Substitutes for ODS - HFCs (L2, T2) 2F1: Refrigeration and air conditioning - HFCs, PFCs, SF_6 and NF_3 (L1, T1) 2F4: Aerosols - HFCs, PFCs, SF_6 and NF_3 (L1, T1)
Key Categories (Qualitative)	2A1 Cement Production – CO_2
Overseas Territories and Crown Dependencies Reporting	For most sectors emissions are reported as not occurring. Estimates for use of F-gases based on scaled UK estimates are reported in the relevant categories under 2F and 2G.
Completeness	No known omissions. A general assessment of completeness for the inventory is included in **Section 1.8**.

Major improvements since last submission	2A3: Use of EU ETS data for CO_2 emission estimates for 2008 onwards 2A4: Use of EU ETS data for fletton works, and inclusion of emissions at non-fletton brickworks for the first time. 2B1: The activity and emissions data reported under 2B1 now includes gas used as a fuel in the ammonia production process, in line with the requirements of the 2006 Guidelines. In previous submissions, the Inventory Agency had reported activity data for gas used as a fuel in the ammonia plant under 1A2c. 2B6: New to the 2015 submission 2B7: Emission estimates for soda ash production were added. Estimates of emissions as a whole not included previously, although the component of the emissions from the coke oven coke were previously included in 1A2f 2B8: Estimates reviewed and revised. Emissions for ethylene dichloride, ethylene oxide, and carbon black included for the first time. 2C4: 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. 2C6: Emissions for this category included for the first time this submission, although those emissions are re-allocated from 1A2f. 2D1 and 2D2: Revision to methodology with IPCC Tier 1 now used. 2D3: Emission estimates included for road transport – urea for the first time. 2F3: Time series updated to be compliant with 2006 GL methodology and utilising revised AD and assumptions 2F6, 2G2, 2G3: A number of new sources identified

The industrial processes and other product use sector (IPCC Sector 2) contributes 6.1% to total greenhouse gas emissions. Emissions from this sector include non-energy related emissions from mineral products, chemical industry and metal production and product use, including emissions of F-gases. Since 1990, this category has seen a 48% 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]	10	0	33[d]	8	4
1995	23	9	9	1	33[d]	5	4
2000	21	9	9	2	34	3	4
2005	16	9	6	5	32	3	4
2006	16	9	6	5	30	3	4
2007	15	9	6	5	28	3	4

Year	Cement	Lime – merchant[a]	Lime – captive[a]	Power stations with FGD[b]	Glass-Works[c]	Fletton brick works	Ammonia
2008	15	9	6	7	26	3	3
2009	13	9	4	8	25	3	3
2010	12	9	4	8	25	2	3
2011	12	9	4	8	25	1	3
2012	12	9	4	8	25	1	3
2013	11	9	4	9	25	1	3
Year	Nitric acid	Adipic acid	Steel-works	Electric arc furnaces	Primary aluminium	Other non-ferrous[e]	Soda ash
1990	8	1	4	20	4	5	2
1995	6	1	4	20	4	4	2
2000	6	1	4	19	4	3	2
2005	4	1	3	12	3	2	2
2006	4	1	3	11	3	2	2
2007	4	1	3	10	3	2	2
2008	4	1	3	8	3	2	2
2009	2	1	3	7	3	2	2
2010	2	0	2	7	2	2	2
2011	2	0	2	6	2	2	2
2012	2	0	3	5	1	2	2
2013	2	0	3	5	1	2	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.

Figure 4.1 Breakdown of total GHG emissions in Industrial Processes sector

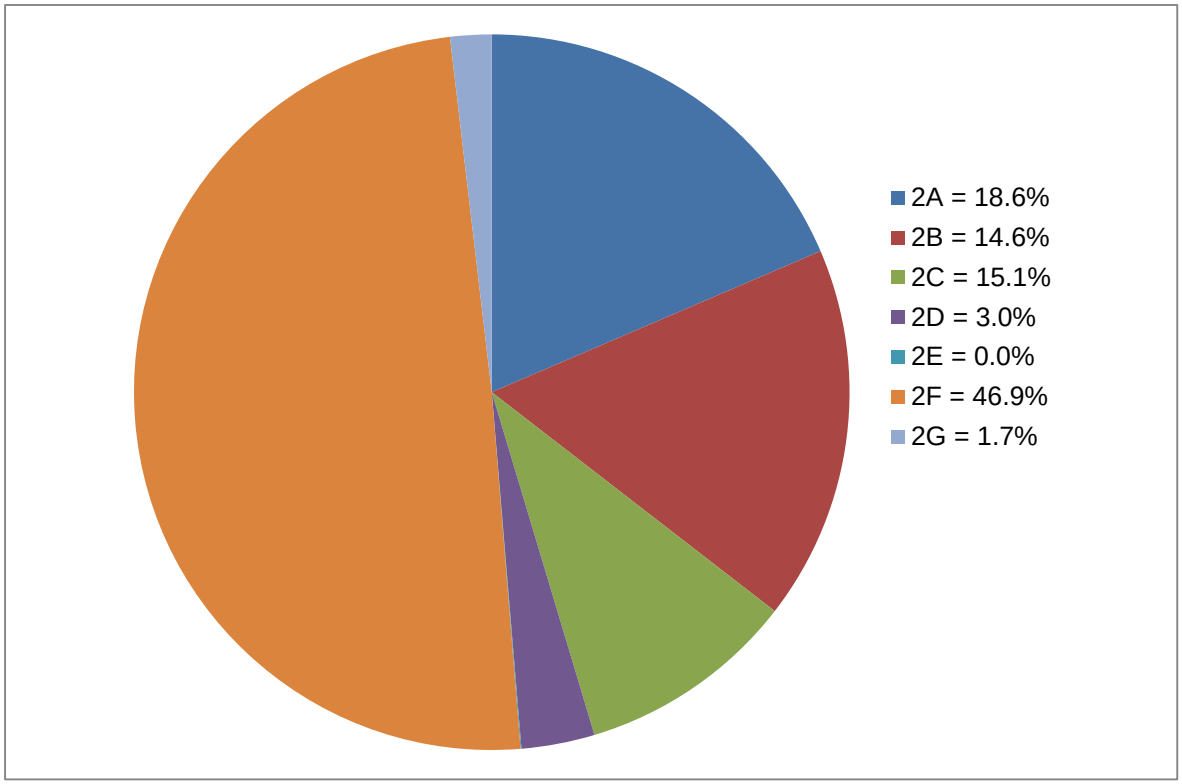
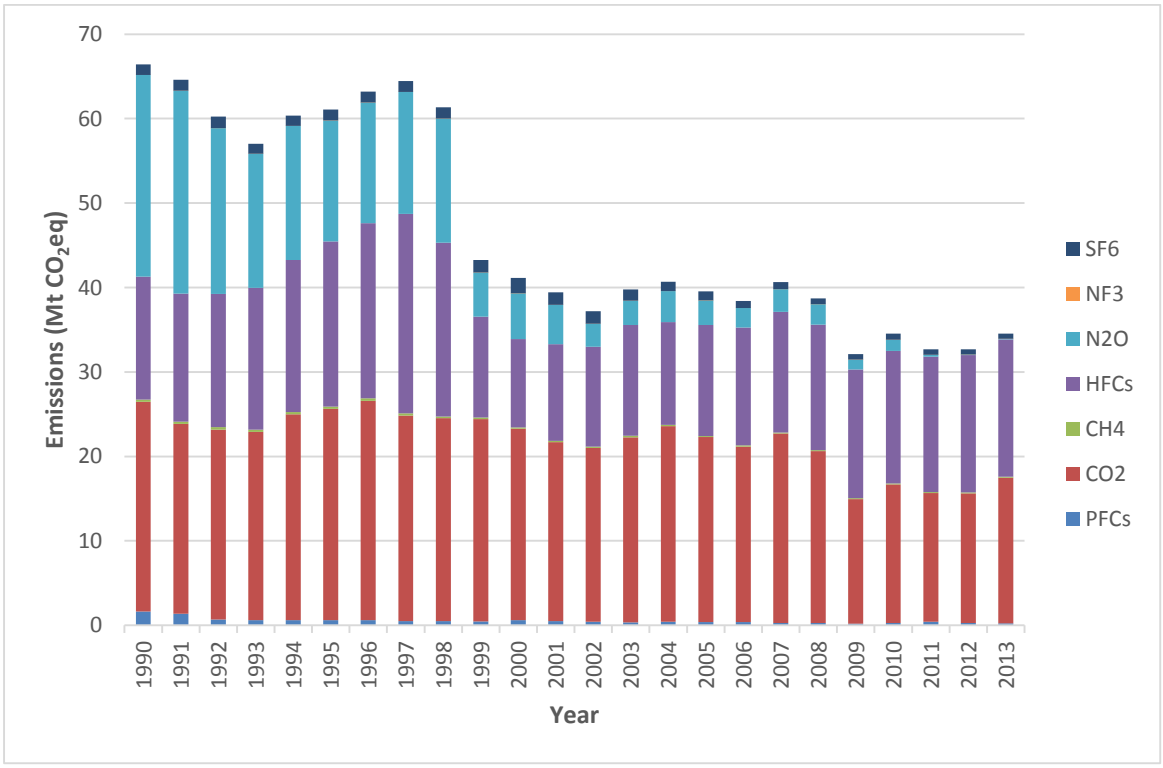


Figure 4.2 Trend in total GHG emissions in Industrial Processes sector



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	2A1: Cement production - CO_2 (L1, T1)		
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 **Section 1.8**.		
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 11 sites producing cement clinker during 2013.

4.2.2 Methodological Issues

Emission estimates for 2005-2013 are available 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. Data received from the MPA have been cross-checked against the EU ETS data set supplied directly by regulators for use in the inventory. For 2012, the emission reported in the EU ETS was slightly higher, while for 2013 there was a more significant difference, again with the figure from the EU ETS dataset higher than that provided by the MPA. In other years, the MPA figure was either slightly higher or identical to the EU ETS figure. As a conservative approach, we have therefore used the higher of the two figures each year i.e. MPA data for 2005-2011 and EU ETS for 2012-2013. The EU ETS and MPA/BCA data include emissions associated with cement kiln dust.

EU ETS data for 2005-2006 were incomplete, and differences between the two data sets are small for 2007-2012. Subsequent to the finalisation of the inventory, we have received confirmation from the MPA that their 2013 emissions data were incomplete (with data for one site omitted in error), so the use of EU ETS data for that year was justified.

EU ETS and MPA data are available for 2005 to 2013 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
2005-2011	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
2012-2013	Mineral Products Association, clinker production data for UK	Factor derived from site-specific EU ETS returns for all UK sites	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. Cross-checks with the EU ETS data received directly from UK regulators indicates only very small differences apart from in the case of 2013 data, where a gap has been identified in the MPA data.

Table 4.4 summarises activity data and implied emission factors over the time series. The activity data for 2001 onwards **are for Great Britain only** due to confidentiality issues surrounding data for the few sites located in Northern Ireland. The CO_2 emissions data in the table are for the whole of the UK. The CO_2 emission factors are therefore a mixture of those based entirely on UK data (for 1990-2000) and those that mix UK emissions and GB activity data (2001 onwards), but are presented to give an indication of the trend in the factor over time.

Table 4.3 Time series of activity data and CEF for cement production.

Year	Cement Clinker production (kt)	CO_2 emitted (kt)	CO_2 emission factor, (t / t clinker)
1990	13,199	7,295	0.553
1991	10,845	5,994	0.553
1992	9,872	5,456	0.553
1993	9,996	5,525	0.553
1994	11,521	6,368	0.553

Year	Cement Clinker production (kt)	CO_2 emitted (kt)	CO_2 emission factor, (t / t clinker)
1995	11,371	6,285	0.553
1996	11,609	6,416	0.553
1997	12,141	6,710	0.553
1998	12,372	6,838	0.553
1999	11,816	6,531	0.553
2000	11,456	6,332	0.553
2001	*10,183*	5,844	0.574
2002	*10,327*	5,988	0.580
2003	*10,146*	5,868	0.578
2004	*10,402*	5,977	0.575
2005	*10,074*	5.941	0.590
2006	*10,069*	5,893	0.585
2007	*10,227*	6,117	0.598
2008	*8,700*	5,203	0.598
2009	*6,421*	3,720	0.579
2010	*6,598*	3,792	0.575
2011	*7,096*	4,096	0.577
2012	*6,555*	3,724	0.568
2013	*6,712*	4,029	0.600

Figures in italics exclude production in Northern Ireland

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. The drop in activity data between 2000 and 2001 is at least partially due to the change in the scope of the data, with data for 2001 onwards excluding Northern Ireland. A sharp decrease in clinker production between 2007 and 2009 is linked to the recession, which 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. Clinker production in the period 2009-2013 has been relatively constant.

The country-specific emission factors for cement clinker production are constant for the period 1990-2000 because no data are available, and so a default UK factor is applied. Factors presented in Table 4.2 for the period 2001-2013 are all higher than the factor for 1990-2000, because of the change in the activity data from UK to GB in 2001. Since the later activity data exclude a small number of sites in Northern Ireland, the activity data are lower, and the CO_2 emission factors are therefore higher. The factors in the period 2001-2013 do vary from year to year, from a minimum value of 0.568 t CO_2 / t in 2012 and a maximum value of 0.600 t CO_2 / t in 2013. The reason for the large increase in the IEF in 2013 compared with the previous year is not known.

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	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 **Section 1.8**.		
Major improvements since last submission	No major improvements		

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, none of the carbon dioxide is emitted to atmosphere, apart from the exception listed in the next section. Lime production related to the manufacture of sodium carbonate was previously included in emissions reported under 2A2, but these emissions, in line with IPCC Guidelines, are now reported in 2B7.

Lime was produced at 13 UK sites during 2013. Four of these 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 (including emissions associated with lime kiln dust) 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. The PI data is assumed to cover the same scope as the later EU ETS data i.e. to include emissions from lime kiln dust as well as lime product. 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 4.4 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
2007-2013	(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, for which emissions are reported in 2B7.

The EU ETS data used for merchant lime production do not report any emissions from calcination at sugar plant, although these sites are covered by EU ETS. 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 were therefore included for the 2014 submission onwards, 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 agriculture as described in **Section 5**.

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 EU ETS 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). Estimates for the years 1990 to 1993 are the most uncertain, because no reported CO_2 emissions data are available, and emissions have therefore to be based on the BGS data that are known to be inaccurate for later years. An adjustment is made to the BGS data to try to deal with the expected underestimating of activity by BGS, but a comparison of BGS and other data for later years indicates that the BGS underestimates are not consistent and so the scale of any underestimation in 1990-1993 is difficult to predict with any confidence.

The estimates for lime kilns at 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, 2009b) 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

For information on the magnitude of recalculations, see **Section 10**.

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 – GLASS PRODUCTION

4.4.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	Glass Production Glass (continuous filament glass fibre) Glass (glass wool)	T2	CS, D
Gases Reported	CO_2, NMVOC		
Key Categories	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 **Section 1.8**.		
Major improvements since last submission	Use of EU ETS data for CO_2 emission estimates for 2008 onwards		

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. Emissions from fuels used in glass furnaces are reported in 1A2g.

The UK had 21 large sites making glass at the end of 2013, for the production of container glass (12 sites), flat glass (4 sites), continuous filament glass fibre (1 site), or glass wool (4 sites). A fifth site producing flat glass by the float process closed in November 2014. There are also 2 sites producing stone wool. Ballotini are produced at three sites, but production is small - output was less than 1% of UK glass production in 2013. These processes are also based almost exclusively on the use of recycled glass (cullet) and therefore carbonates will not be used in significant quantities at these sites, and emissions are therefore not estimated. Special and domestic glasses are no longer manufactured 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 and stone wool. Any use of carbonates in frits and lead glass is assumed to be trivial because of the small-scale production of these in the UK (together, both sectors account for about 0.1% of UK glass production). EU ETS data for the sole UK site making ceramic fibres indicate that this process does not involve the use of the three carbonate minerals.

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 VOC emissions 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.

Process emissions of N_2O are not estimated for production of glass 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.

4.4.2 Methodological Issues

Emissions from the use of carbonates in glass production are calculated using data from two sources:

- A detailed, site by site survey of raw material usage in the glass industry, carried out in 2006 (GTS, 2008). This report covered the flat, container, and fibre sectors;
- Data reporting under the EU Emissions Trading System (EU ETS) from 2008 onwards.

In the case of the survey of raw material usage, data are available on the quantities of each type of carbonate used by each sub-sector of the industry during 2006. Emissions must be estimated, and this is done based on the stoichiometric relationship between carbon and the related carbonate i.e.

120 t carbon/kt limestone;

130 t carbon/kt dolomite;

113 t carbon/kt soda ash.

These factors assume that all of the carbon in the carbonates is released to atmosphere.

The data from the EU ETS are for emissions of CO_2, but disaggregated by the source of the emission (e.g. use of natural gas, or use of limestone etc.) The data have first to be analysed so that the emissions can be separated into those that occur due to use of various fuels, and those that are due to use of the three carbonates. Data are available for all significant glassmaking sites for the period 2008-2013 i.e. all sites manufacturing flat, container, continuous filament glass fibre, glass wool and stone wool. Consumption of carbonates can be back-calculated, using the same stoichiometric relationships as given above. Since ETS data are available on a site by site basis, the emissions data and the derived activity data can be agglomerated to give estimates for each sub-sector of the glass industry. The EU ETS data set also includes details of extremely small CO_2 emissions (less than 1 tonne) occurring due to the use of barium carbonate or potassium carbonate by the UK glass sector, but these have been ignored from the UK inventory due to their trivial nature.

The two data sources can be used to derive estimates of carbonate use / CO_2 emissions for each sub-sector of the glass industry as follows:

2008-2013:flat, container, glass fibre, glass wool, stone wool;

2006: flat, container, glass fibre/glass wool (combined in the survey).

The two data sets indicate some changes over time in rates of carbonate use for flat, container and glass wool, and partial EU ETS data for 2005-2007 also support this. Therefore the 2006 survey, rather than the later EU ETS data, is assumed to be more reliable as a guide to the rates of carbonate usage in the three sectors in the years 1990-2005. Carbonate usage for that period is therefore extrapolated from the 2006 figures on the basis of production in each sub-sector in each year.

For stone wool, we only have data from the EU ETS for 2008-2012, and so the average consumption rate calculated for those years is then applied to the period 1990-2007 using stone wool production estimates for each year.

Neither data source contains information on special or domestic glasses because the only significant UK sites producing either type of glass closed before 2006. Therefore, carbonate consumption rates for both types of glass have been assumed to be equal to the average rate for container, flat and glass wool in 2006, as given in the raw material usage study.

Glass production data are available on an annual basis for container glass only (British Glass, 2014), and a full time-series of production for other types of glass has therefore to be estimated based on the partial time series of production data covering a limited number of years (e.g. data for late 1990s from EIPPCB, 2000, flat glass data for 2003 onwards from British Glass). These are then extrapolated to other years on the basis of estimated plant capacity. In the case of flat and container glass, the glass production data used to estimate carbonate usage are corrected for the amount of cullet used in each year, so the estimates do take into account changes over time in recycling rates and use of cullet. This is not possible for other types of glass, and so the calculation of carbonate usage for these glass types is based on total production. Therefore, the estimates for glass wool, special glasses and domestic glass implicitly assume that the rate of recycling in these sectors remains constant over the time series.

Table 4.5 Summary details for the UK glass industry and the scope of estimates for CO_2 emissions from carbonate use

Glass Sector	1990 production, kt	2013 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	-	Yes	Yes	Yes
Domestic, including lead	76	0.1	Yes	Yes	Yes
Continuous filament glass fibre	82	37	Yes	Yes	Yes
Glass wool	104	278	Yes	Yes	Yes
Stone wool	83	93	Yes	Yes	Yes
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. Emissions can then be calculated both to include all processes throughout the UK and, by extrapolation, to include other years.

4.4.3 Uncertainties and Time Series Consistency

For the years 2008-2013, the methodology is based on the use of highly accurate emissions data reported under the EU ETS for all significant UK glass producers.

The emission estimates for 2006 are based on activity data given in a detailed industry study. These emission estimates should be assumed to be slightly more uncertain than the EU ETS data of 2008-2013 since the source gives carbonate usage figures only, and emissions have to be calculated assuming that the carbonate usage figures refer to pure carbonates and that all carbon in the minerals is released to atmosphere. While the emissions data are therefore conservative, we think that the uncertainty is still likely to be relatively low since fairly pure carbonate minerals are readily available.

For the remaining years in the time-series, the methodology relies upon the extrapolation of highly accurate activity/emissions data for one year to all other years based on glass production. The glass production data are, however, a mixture of actual production data from the glass industry, and Ricardo Energy & Environment estimates, which are far more uncertain. The emission estimates for 2A3 are therefore subject to far greater uncertainty for the earlier part of the time-series than for recent years, because of the greater reliance on extrapolation, and the lower quality of the glass production estimates for the earlier part of the time-series.

4.4.4 Source Specific QA/QC and Verification

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

4.4.5 Source Specific Recalculations

For information on the magnitude of recalculations, see **Section 10**.

4.4.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.5 SOURCE CATEGORY 2A4 – OTHER PROCESS USES OF CARBONATES

4.5.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2A4a Fletton Bricks 2A4a Brick manufacture 2A4d Power stations - FGD	T2 T2 T2	CS CS CS
Gases Reported	CO_2, CH_4, CO, SO_2, NMVOC		
Key Categories	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 **Section 1.8**.		
Major improvements since last submission	Use of EU ETS data for fletton works, and inclusion of emissions at non-fletton brickworks for the first time.		

The UK has a large number of sites involved in the production of heavy clay goods – bricks and roofing tiles, and similar items. These sites range from the smallest operations where bricks are hand-made, to bigger sites where bricks are manufactured on a large scale, using automatic production methods. The brick industry can also be divided into fletton and non-fletton types. Fletton bricks are manufactured using the Lower Oxford Clay, found in South-East England only. This clay has an exceptionally high content of carbonaceous material which acts as an additional fuel when the bricks are fired, but also produces a characteristic appearance in the finished bricks. The Lower Oxford clay also contains sulphurous material, which results in SO_2 emissions during firing. Non-fletton bricks are made from other clays and shales and these have much lower carbon contents. For all bricks, firing leads to emissions of CO_2 from the carbonaceous material in the clay. Limestone, dolomite and barium carbonate can also be used in brickmaking and also release CO_2 when fired. Finally, many brick manufacturers add crushed coke ("colourant") to some bricks to change the final appearance of the bricks. Coke oven coke is known to be used in this manner, and we have assumed that petroleum coke is as well, and colourant is added at rates of up to 15% of the raw material weight. A high proportion of the carbon in the colourant is known not to be oxidised during firing and remains in the brick: for EU ETS reporting purposes, all UK brick makers use a figure of 50% oxidation. Although 2A4 explicitly covers use of carbonates, we have included carbon emissions from the use of colourants in bricks here as well, in the absence of anywhere more appropriate to report them.

Other types of ceramics are manufactured in the UK, including wall and floor tiles, refractories, sanitaryware, household ceramics etc. However, we do not have data on either the levels of production or suitable emission factors for these types of ceramic goods, so no emission estimates can be made. Emissions are, however, likely to be very much smaller than in the case of brickmaking, simply because the scale of manufacture will be much lower.

The 2006 GLs draws attention to other sources of CO_2 emissions from use of soda ash and other carbonates. These other uses include flue gas desulphurisation (FGD), magnesia production, and use of soda ash in soaps & detergents, and other applications.

Limestone is used in FGD systems for abatement of SO_2 emissions at most remaining UK coal-fired power stations and emissions are reported under 2A4. The power stations at Drax and Ratcliffe were the first to get FGD (in 1997), followed by West Burton A in 2004, Eggborough and Cottam in 2005, then Ferrybridge C, Fiddlers Ferry and Rugeley B in 2008/2009. The very small Slough power station also has FGD. The limestone reacts with the SO_2 present in flue gases, being converted to gypsum, with CO_2 being evolved. Uskmouth B has a dry lime-injection system, so there is no potential for CO_2 emissions at this site. Seawater scrubbing systems are used at Aberthaw, Kilroot, and Longannet power stations but CO_2 emission estimates are not included in the GHGI for this type of FGD system. Some MSW incinerators are believed to use the dry lime injection process to remove SO_2 emissions: as with Uskmouth B, there will be no CO_2 emissions from this type of FGD technology.

Magnesia production in the UK is thought to be limited to a single plant that closed in 2005. This site produced magnesia from seawater, with magnesium salts in the seawater precipitated as magnesium hydroxide, followed by conversion to magnesia in kilns. No process emissions of CO_2 occurred at this site. We have no information on any use of soda ash in the UK outside of the glass industry, and so no emission estimates are made.

4.5.2 Methodological Issues

CO_2 emissions from production of bricks and tiles are based on data reported in the EU ETS. The EU ETS data set provides site by site emissions, broken down by the source of emission (e.g. from clays, fuels, colourants etc.) and begins in 2005, although the data are only representative of the sector from 2008 onwards, when practically all significant sites began to be included. The data can easily be divided into emissions from fuels and emissions from non-fuels (i.e. process emissions). It is slightly more difficult to divide the non-fuel data into sub-types such as emissions from clays, colourants, or 'pure' carbonates like limestone, dolomite and barium carbonate, since some of the information within the ETS data set on the source of the CO_2 is ambiguous. So although it is possible to make a split, we have instead reported the process emissions as a group. Note that this does mean that emissions from the colourant (coke oven or petroleum coke) are included here, but we think this is justified both because of the slight ambiguity in some of the ETS data, but also because there is no other category which would be more appropriate.

The ETS data are calculated by each brick and tile producer using site-specific activity data, and industry-wide emission factors, compiled by the industry trade association each year (British Ceramics Confederation, 2014). These factors include factors for simple carbonates based on the stoichiometric relationship of carbon to the carbonate, as well as measured emission factors for different types of clay e.g. Keuper Marl, Weald Clay, and Lower Oxford Clay. The industry factors also include an estimate for colourants which is based on the assumption that 50% of carbon in the colourant is oxidised during firing.

Based on discussions with the brick industry, we have assumed that the ETS data for 2008-2010 represents 93% of sector production. In 2013, a single further site reported in EU ETS, bringing coverage to 95%. The emissions data for 2008-2013 are therefore increased slightly to reflect non-reporting brickworks, assuming that emission rates at non-reporting sites will be the same as on average at reporting sites. With the exception of the large site that joined EU ETS in 2013, the non-reporting sites over the period 2008-2013 are all the smaller producers and it is not known how representative the industry factors will be for these atypical sites. In the absence of better data, however, we have assumed that emission rates are the same.

ETS data is very limited before 2008, and therefore is not used to derive a national total. Instead, we have used annual brick production data, available in Government Statistics (Monthly Statistics of Building Materials and Components, September 2014, available from www.gov.uk) to extrapolate back from the ETS data. These data are for total numbers of bricks produced, and it is necessary to consider what proportion of these bricks are of the fletton

type, since this type of brick is associated with higher process emissions. Fletton bricks have had a declining share of the UK brick market for many years and fletton bricks are no longer used in the construction of new buildings. Information on the market share is, however limited: Ove Arup (1990) puts it at 25%, Blythe (1995) states it is 20%, and by 2011, following the announcement that the last but one fletton brickworks was being closed, local media reports all stated that fletton bricks now accounted for less than 10% of the UK market. We have therefore assumed a 25% share in 1990, falling to 20% in 1995, then falling to 10% by 2010 and remaining at 10% thereafter. Using these assumptions, it is possible to then generate estimates of the numbers of fletton bricks and non-fletton bricks produced each year.

For non-fletton bricks, a figure of 173 grams CO_2 per brick can be calculated from the ETS-based emission estimates for 2008-2013, and then the estimates of non-fletton bricks produced can be used to generate emission estimates for the period 1990-2007.

In the case of fletton bricks, the PI provides additional data to supplement the information in the EU ETS for 2008 onwards. Total emissions of CO_2 are reported at the Stewartby site, and at the combined Saxon/Kings Dyke works for each year between 1998 and 2007. The later ETS data at these sites is used to separate the PI data for 1998-2007 into a fuel component and a process component. This gives a time series of process emission estimates back to 1998, and this is further extrapolated back to 1990 on the basis of the estimates of fletton brick production.

Table 4.6 gives a timeline for the brick sector, summarising what is known about the sites operating and the data available for emission estimates over the time series.

Table 4.6 Timeline for the brick sector in the UK: production sites and data availability

Years	Number of sites and fuels	Availability of data
1990-1997	Possibly 6 fletton 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. Unknown number of non-fletton works.	No emissions data available, annual production (numbers) of all bricks available and fletton and non-fletton brick production estimated from this. Emission estimates require use of emission factors generated from later PI and ETS data.
1998-2007	Two of the 5 fletton 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: Stewartby burns coal, the other two (Saxon/Kings Dyke), both in the same area in England, now burn natural gas only. Approximately 100 non-fletton brickworks in early 2000s.	Annual emissions of CO_2 and methane available in the Pollution Inventory for each fletton 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 and non-fletton brick production has to be estimated. Emission estimates for non-fletton bricks have to be generated using emission factors from later EU ETS data.

Years	Number of sites and fuels	Availability of data
2008	Closure of coal-burning fletton works at end of 2008, leaving only the 2 gas-burning works remaining. 63 non-fletton brickworks report in EU ETS in 2008.	Annual emissions of CO_2 and methane available in the Pollution Inventory for Stewartby, and for Saxon/Kings Dyke. EU ETS data for the same two fletton brickmaking units, and also for non-fletton brickworks. These data are detailed, allowing fuel-related and process-related emissions to be separated. Emission estimates can be based directly on EU ETS data.
2009-2013	Saxon works closed in 2011, leaving only the Kings Dyke fletton brickworks remaining. Many closures of non-fletton brickworks, with 49 reporting in EU ETS by 2011. In 2013, final large site joins EU ETS, with total of 46 non-fletton sites then reporting.	Annual emission of CO_2 and methane available in the Pollution Inventory for the Saxon/Kings Dyke works. EU ETS data for all significant fletton and non-fletton works for all years except for one site that joins ETS in 2013. Emission estimates can be based directly on EU ETS data.

Other types of ceramics are manufactured in the UK, including wall and floor tiles, refractories, sanitaryware, household ceramics etc. We do not have reliable data on either the levels of production or suitable emission factors for these types of ceramic goods, so no emission estimates can be made. However the following simple calculations have been made, which indicate that emissions are likely to be insignificant.

The UK Minerals Yearbook (BGS, 2014) gives production, imports and exports for 4 types of clay (ball clay, china clay, fireclay, other clays & shales). This reference also gives a breakdown of the uses to which the 'other clays & shales' are put – mostly bricks, cement production, and construction, with very little used for other ceramics. Fireclay is assumed to be used solely for ceramics, and the EU ETS data shows that fireclay is used by many brickmakers. It will also likely be used for refractories and sanitaryware and, in the absence of any data, we have assumed a 50/50 split of fireclay usage between bricks and other ceramics. The Kaolin and Ball Clay Association (KABCA) give estimates of the markets for both ball clay and china clay on their website[28]. Neither type of clay will be used in any significant quantity in bricks but KABCA indicate figures of 22% of china clay and 'over 80%' of ball clay used in ceramics. Based on BGS figures for 2008, 2009, 2011, and 2012 (data are not available for 2010), we can then derive some approximate figures for clays used in bricks and in other ceramics:

[28] See http://www.kabca.org/what-is-kaolin.php and http://www.kabca.org/what-is-ball-clay-.php

Table 4.7 Consumption of Clays in Brickmaking and Other Ceramics Manufacture (Mtonnes)

Product		2008	2009	2011	2012	Average
Bricks	Ball clay	0	0	0	0	
	China clay	0	0	0	0	
	Fire clay	0.092	0.066	0.082	0.049	
	Other clay & shales	4.993	2.839	4.022	3.591	
	Total	5.085	2.904	4.104	3.640	3.933
Other ceramics	Ball clay	0.224	0.196	0.199	0.161	
	China clay	0.052	0.053	0.051	0.044	
	Fire clay	0.092	0.066	0.082	0.049	
	Other clay & shales	0.160	0.120	0.137	0.023	
	Total	0.527	0.434	0.470	0.277	0.427

The consumption of clays for other ceramics is therefore estimated as approximately a tenth (11%) of the consumption of clays in bricks. The carbon content of fire clay and other clays and shales could be obtained from EU ETS data for bricks, and the carbon content of ball clay is known to be very low since the British Ceramics Confederation produce carbon emission factors for ball clay in their guidance for EU ETS reporting. No data are available for china clay, and, at the current time, we do not have data to generate a full time-series of activity data. For the purposes of determining the significance of the source, if we generate a time-series based on 11% of the clay usage in bricks, and then assume the same average carbon content in clay for ceramics as in the common clays used in brickmaking (which would be a worst case because of the very low carbon content of ball clay), this would yield emission estimates that were well below 0.05% of the national total (0.0064% in 1990 and 0.0037% in 2013) and therefore insignificant.

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 a composite series of activity data is used with BGS data for 1994-2004, and EU ETS data for 2005-2013. 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.

4.5.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to IPCC source category and fuel type.

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.

Estimates for bricks are considered to be highly reliable for the period 2008-2013 where EU ETS data are available for almost all sites. For earlier years, the emission estimates rely upon extrapolation of the 2008 emissions data using brick production estimates and this will introduce uncertainty within the earlier part of the time series. Emission estimates for methane from fletton brickworks are, similarly, based on reported data in later years and extrapolation using brick production for the early part of the time-series, so the uncertainty will again be greatest in the earlier part of the time series.

4.5.4 Source Specific QA/QC and Verification

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

4.5.5 Source Specific Recalculations

For information on the magnitude of recalculations, see **Section 10**.

4.5.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.6 SOURCE CATEGORY 2B1 – AMMONIA PRODUCTION

4.6.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2B1: Ammonia Feedstock 2B1: Ammonia Fuel	T2 T2	CS CS
Gases Reported	CO_2, CH_4, N_2O, NO_X		
Key Categories	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 **Section 1.8**.		
Major improvements since last submission	The activity and emissions data reported under 2B1 now includes gas used as a fuel in the ammonia production process, in line with the requirements of the 2006 Guidelines. In previous submissions, the Inventory Agency had reported activity data for gas used as a fuel in the ammonia plant under 1A2c.		

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. 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.

At least 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 2B10, 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.

4.6.2 Methodological Issues

IPCC source category 2B1 had, in previous versions of the UK inventory, been 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 were reported under IPCC source category 1A2c. For this version of the inventory, the emissions from both feedstock **and** fuel use of natural gas are both reported under 2B1, in line with the requirements of the 2006 Guidelines.

Emissions of CO_2 from both fuel and 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 total natural gas consumption. The ammonia plant utilising hydrogen by-product from chemical manufacture does not need to be included as there are no process emissions of CO_2.

Table 4.8 summarises the details of the UK ammonia plants and **Table 4.9** gives details of production and emissions etc. by the sector.

Table 4.8 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 4.9 UK ammonia production and emission factors

Year	Ammonia production (kt)	CO_2 emitted (kt)	CO_2 emission factor,(t / t NH_3) (all UK production plant)*
1990	1328	2004	1.51
1995	1388	2054	1.48
2000	1213	2007	1.65
2005	1172	1780	1.52
2006	949	1385	1.46
2007	1251	1865	1.49
2008	1082	1683	1.56
2009	889	1296	1.46
2010	1084	1488	1.37
2011	687	1043	1.52
2012	1017	1574	1.55
2013	957	1383	1.45

*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).

Due to the limited market for ammonia production in the UK, to present detailed technology-specific data on production and emissions would be disclosive. Full details of the installation-specific production, fuel use and emissions will be provided upon request to a UNFCCC expert Review Team. The data in the table above summarises the estimated overall UK production of ammonia (which is partly based on operator data and partly on inventory agency estimates based on plant capacity), total estimated 2B1 CO_2 emissions and ammonia IEF on a production basis, as 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 Guidelines 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. The overall UK IEF presented in

the table above are below the IPCC default, but this is due to the production at the UK plant where there are no CO_2 emissions; UK factors for the three sites with CO_2 emissions show an average of 1.87 tonnes CO_2 / tonne NH_3 for production across 1990-2013, and would only be outside the range suggested by the two IPCC defaults for two years: in 2001 and 2002, when the emission factor was slightly higher than 2.1 tonnes CO_2 / tonne NH_3. *[Note that these data are not presented in the table above due to commercial confidentiality, but full details are available to an ERT.]* 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.

4.6.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 2** 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.

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

4.6.5 Source Specific Recalculations

For information on the magnitude of recalculations to Source Category 2B1, see **Section 10**.

4.6.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.7 SOURCE CATEGORY 2B2 – NITRIC ACID PRODUCTION

4.7.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2B2: Nitric Acid Production	CS	CS
Gases Reported	N_2O, NO_x		
Key Categories	2B2: Nitric acid production - N_2O (L1, T1, T2)		
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 **Section 1.8**.		
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 2013 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 4.12** below).

4.7.2 Methodological Issues

Across the 1990-2013 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 7 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 default factor provided in the 2006 IPCC Guidelines (IPCC, 2006) for medium pressure plant.

Table 4.10 and **Table 4.11** 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 4.8**) but emissions from 1994 onwards are reported separately. This causes some inconsistency in between reporting categories, although total emissions are not affected.

Table 4.10 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		
2009-2013		2 sites	2 sites		

Table 4.11 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
2009-2013	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 4.12 Summary of Nitric Acid Production in the UK, 1990-2013

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

Year	No of sites	Production (Mt 100% Nitric Acid)	Aggregate EF (kt N_2O / Mt Acid)	Aggregate EF (kt NO_X / Mt Acid)
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	0.115	0.127
2013	2	1.01	0.142	0.107

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 NO_X 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. The large increase in N_2O emissions between 1998 and 1999 resulted from a change in the NO_X abatement system at one plant from NSCR to SCR. NSCR reduces emissions of N_2O as well as NO_X, whereas SCR only abates NO_X and can actually increase N_2O emissions.

4.7.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 2** 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 reflect the 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.

4.7.4 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

For information on the magnitude of recalculations, see **Section 10**.

4.7.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.8 SOURCE CATEGORY 2B3 – ADIPIC ACID PRODUCTION

4.8.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2B3: Adipic Acid Production	CS	CS
Gases Reported	N_2O		
Key Categories	2B3: Adipic acid production - N_2O (L1, T1, T2)		
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 **Section 1.8**.		
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.

4.8.2 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 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.

4.8.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to IPCC source category and fuel type.

Emissions data for N_2O from adipic acid production are provided by the process operator, but can be cross-checked against emissions reported in the Pollution Inventory.

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, and the related Pollution Inventory data are also checked by the Environment Agency. 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.

4.8.4 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**. 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.

4.8.5 Source Specific Recalculations

For information on the magnitude of recalculations, see **Section 10**.

4.8.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.9 SOURCE CATEGORY 2B4 – CAPROLACTAM, GLYOXAL AND GLYOXYLIC ACID PRODUCTION

Caprolactam was made at one site in the UK in the early 1970s. The site was destroyed in a serious explosion in 1974, and no other production sites have been built since. Glyoxal and glyoxylic acid have not been produced on an industrial scale in the UK at any time. A literature search of documents from the last 25 years on chemical production in Europe as well as consultation with the Chemical Industries Association has confirmed that these sources should be reported as not occurring.

4.10 SOURCE CATEGORY 2B5 – CARBIDE PRODUCTION

This source category includes silicon carbide and calcium carbide. Neither chemical is known to have been manufactured on an industrial scale in the UK since the 1960s, when calcium carbide plants at Kenfig and Runcorn closed. As above for 2B4, literature searches and consultations with UK chemical industry representatives have confirmed that this source should be reported as not occurring in the UK.

4.11 SOURCE CATEGORY 2B6 – TITANIUM DIOXIDE PRODUCTION

4.11.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2B6 Titanium dioxide	CS	CS
Gases Reported	CO_2		
Key Categories	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 **Section 1.8**.		
Major improvements since last submission	Emission estimates not previously included		

Titanium dioxide has been produced in the UK by two methods: i) from ilmenite, using the sulphate process; and ii) from rutile, using the chloride process. Only the chloride process leads to process emissions of greenhouse gases. In 1990, there were two sites each using the chloride and the sulphate process, but the two sulphate processes closed in 1997 and 2009, so all titanium dioxide in the UK is now produced using the chloride process at the two sites at Stallingborough and Greatham. The chloride process involves the chlorination of rutile ore in a reducing atmosphere to titanium tetrachloride, followed by oxidation of the $TiCl_4$ to titanium dioxide. The reducing atmosphere is produced by combustion of petroleum coke or coke oven coke.

4.11.2 Methodological Issues

The 2006 GLs recommend the use of either a Tier 1 method involving a default emission factor and national activity data, or a Tier 2 method using installation-specific data on reducing agent usage. For the UK, neither of these methods are feasible options due to limited data; there are no UK activity data (i.e. annual production statistics) for any individual chemical product, and the only site-specific data for the UK plant is in the form of CO_2 emissions data. These emissions data are available from two regulatory reporting sources:

- From the PI, covering CO_2 from reducing agents and fuel use in plant utilities;
- From the EU ETS, covering fuel use only.

Operator reporting has been variable over the years, in line with the evolving scope and detail required for EU ETS and PI data returns.

- During Phase II of the EU ETS (2008-2012), the titanium dioxide plants only reported CO_2 from fuels burnt in the site boilers;
- For Phase III (2013 onwards), coverage of EU ETS reporting was extended to cover fuels burnt in furnaces, driers etc.;
- For three years (2006-2008), the process operators were required to report thermal CO_2 and chemical CO_2 separately to the PI.

From these data it is possible to obtain the emissions from the chemical process for 4 years: 2006-2008 (using the PI data for chemical CO_2 emissions), and 2013 (by difference between the PI data covering all CO_2 emissions and the EU ETS data covering all fuel-related emissions. The fuel/process split in emissions for these 4 years can be calculated, and the PI provides total CO_2 emissions at each site back to 1998. Prior to 1998, there is no data on either emissions or production, and therefore it is assumed that emissions in 1990-1997 are at the same level as in later years (the production capacity at all UK sites producing TiO_2 by the chloride route is the same for all years).

In order to avoid a potential double-count in emissions in the UK GHGI, it is necessary to ensure that the reductant used in the processes is not included as a fuel and emissions reported in 1.A. The method developed by the study team addresses this issue by back-calculating the coke/petcoke activity data (used as a reductant) from the emissions data using UK carbon emission factors for the feedstock, and discounting this amount from the Energy sector estimates.

4.11.3 Uncertainties and Time Series Consistency

The country-specific method used is regarded as the best available method for the UK GHGI estimates, given the lack of any production activity data. The use of site-specific EU ETS and PI data, even if not relating to input materials as required by the Tier 2 method in the GLs, ensures that emissions data are quite certain for the period from 1998 onwards. Estimates for 1990-1997 are more uncertain due to the need to extrapolate 1998 data backwards in the absence of any specific information on production, materials usage or emissions in those years.

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**.

4.11.5 Source Specific Recalculations

For information on the magnitude of recalculations, see **Section 10**.

4.11.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.12 SOURCE CATEGORY 2B7 – SODA ASH PRODUCTION & USE

4.12.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2B7 Soda Ash Production	T1	CS
Gases Reported	CO_2		
Key Categories	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 **Section 1.8**		
Major improvements since last submission	Emission estimates for soda ash production were added. Estimates of emissions as a whole not included previously, although the component of the emissions from the coke oven coke were previously included in 1A2f		

Soda ash has been produced in the UK using the Solvay process at two sites both of which have been operating over the entire time period covered by the inventory. The Solvay process involves the conversion of limestone (calcium carbonate) and brine (sodium chloride) to soda ash (sodium carbonate) and calcium chloride. The initial stage in the process is the calcination of limestone in a kiln to produce lime and CO_2 gas, both of which are used in the process. Coke oven coke is used to fire the lime kilns and CO_2 from the coke is included in the gases used in the soda ash plant. In theory, if limestone and brine are converted completely to soda ash and calcium chloride, then that part of the soda ash process is carbon-neutral and the CO_2 emitted should be equal just to those emissions occurring from the coke. In practice, the process is not 100% efficient, so emissions of CO_2 are actually somewhat higher than would just be due to the coke use.

Emissions from soda ash (sodium carbonate, Na_2CO_3) used in the manufacture of soda-lime glasses is reported under source category 2A4.

4.12.2 Methodological Issues

The 2006 GLs suggests that emissions should be based "on an overall balance of CO_2 around the whole chemical process". In the UK, soda ash is produced at two sites and both began to report under the EU ETS in 2013. The EU ETS emissions data for the two sites is calculated using a carbon balance approach with inputs in coke and limestone balanced against soda ash and waste products. The 2013 EU ETS data therefore meets the requirements for the method suggested in the GLs.

Prior to 2013, no data for the UK plant were reported in EU ETS, but CO_2 emissions were reported in the PI between 1998 and 2013. Comparison of the PI and EU ETS data for 2013 shows that EU ETS data were 38% higher than emissions in the PI. The reason for this is not known, but since the PI data for 1998-2013 are fairly consistent, it is assumed that there is a systematic underestimate in the PI data (possibly they represent CO_2 releases from just part of the process, rather than the whole-process balance used in the EU ETS). In the absence of other data we have therefore used the PI data for 1998-2012 but multiplied by a factor of

1.38 to give conservative estimates of emissions in those years. For 1990-1997, no data of any type are available, but since the same two sites have been in operation in the UK across the entire time-series, emissions in 1990-1997 are assumed to be at the same level as in later years.

4.12.3 Uncertainties and Time Series Consistency

The method used is regarded as the best available given the lack of any production activity data, or a time-series of coke consumption. The use of site-specific EU ETS data for 2013 should ensure that the emission estimate for that year is quite certain. The poor agreement between the PI and EU ETS data in 2013 means that the emission estimates for 1998-2012, based on PI data, are far more uncertain. Estimates for 1990-1997 are more uncertain still due to the need to extrapolate 1998 data backwards in the absence of any specific information on production, materials usage or emissions in those years.

4.12.4 Source Specific QA/QC and Verification

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

4.12.5 Source Specific Recalculations

For information on the magnitude of recalculations, see **Section 10**.

4.12.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.13 SOURCE CATEGORY 2B8 – PETROCHEMICAL AND CARBON BLACK PRODUCTION

4.13.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2B8a Methanol 2B8b Ethylene 2B8c Ethylene Dichloride 2B8d Ethylene Oxide 2B8e Acrylonitrile 2B8f Carbon Black 2B8g Chemicals: OPG	T2 T2 T1 T1, T2 T2 T1, T2 T2	CS CS D D, CS CS D, CS CS
Gases Reported	CO_2, CH_4, N_2O		
Key Categories	2B8: Petrochemical and carbon black production - CO_2 (L1)		
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 **Section 1.8**		
Major improvements since last submission	Estimates reviewed and revised. Emissions for ethylene dichloride, ethylene oxide, and carbon black included for the first time.		

The UK has a large petrochemical industry, with manufacture of all of the chemicals explicitly mentioned in the 2006 IPCC Guidelines for at least part of the period 1990-2013, although a series of site closures in recent years has reduced the number of products manufactured in the UK.

Methanol was manufactured in the UK until 2001, at a site where the process was integrated with ammonia production. Ethylene was produced at five sites in 1990, although the closure of the Baglan Bay works in 1993, and then the Fawley works in 2010 have reduced this to three by the end of 2013. The UK ethylene crackers use either naphtha or natural gas liquids as feedstocks, and off-gases from the ethylene crackers are used as fuels on-site. Ethylene dichloride (EDC) has been produced at 4 sites over the period covered by the GHGI, although only 1 is still in operation, and only 2 of those processes used the oxychlorination route that causes process emissions of CO_2.

Ethylene oxide (EO) was produced at a single UK plant between 1990 and closure in January 2010. There is also a single site producing acrylonitrile (ACN): this has operated since 1990 and is still in operation. Two sites produced carbon black, until their closure at the very start, and in the middle of 2009 respectively. Most of the production was of furnace black.

A number of other chemical sites also emit CO_2 due to the use of off-gases as fuels. Emissions of CO_2 at these sites are very small relative to the emissions from ethylene production. All emissions of CO_2 from use of off-gases as fuels is reported under 2B8g, including the emissions from ethylene production.

Many chemical processes emit small quantities of methane, either as a result of fugitive releases from equipment, or as a component of tail gases released from vents. The inventory

includes separate emissions data for production of ethylene, methanol, ACN, EO. and carbon black. Emissions of methane from other chemical processes are reported under 2B10.

4.13.2 Methodological Issues

Details of the methodologies used for petrochemical and related processes are shown in **Table 4.13**.

Table 4.13 Methodologies for petrochemical and related processes

Chemical product	Reporting for		Methodology
	CO_2	CH_4	
Ethylene	2B8g	2B8a	Site specific emissions data from EU ETS (CO_2 only), PI and from process operators. Where no emissions data are available, these are estimated by extrapolation from data available for later years, taking into account changes in plant capacity.
Methanol	2B1[a]	2B8b	See 2B1 for CO_2 methodology. Emission estimates for methane are based on operator-reported data from the PI.
Ethylene Dichloride	2B8c	-	Emissions estimated using IPCC Tier 1 emission factor for process CO_2 assuming production is 500,000 tonnes per year[b].
Ethylene Oxide	2B8d	2B8d	CO_2 emission estimates for 1995-2009 from the PI, emissions in 1990-1994 assumed same as in 1995. CH_4 estimates for 2004-2009 from the PI. No emissions data are available for 1990-2003, so the Tier 1 IPCC default is used, combined with estimates of EO production at the plant derived from the CO_2 emitted, and assuming a CO_2 emission factor of 0.663 t CO_2 / t EO (IPCC default for oxygen process, default catalyst sensitivity).
Acrylonitrile	2B8g	2B8e	CO_2 emission estimates for 2008-2013 from EU ETS. No data on emissions for earlier years, but the capacity of the plant is thought to have been unchanged since 1990, so the average emission for the 5-year period 2008-2012 is used for 1990-2007. The operator reports methane emissions to be below the 10 tonne threshold for reporting in the PI, so an emission of 5 tonnes/annum is assumed in the UK inventory.

Chemical product	Reporting for		Methodology
	CO_2	CH_4	
Carbon black	2B8f	2B8f	CO_2 emissions are reported in the PI for 1998-2009 for one site, and 2003-2008 for the other (this site closed at the start of 2009, so emissions in 2009 are assumed zero). The emissions reported in the PI are assumed to be 100% from process sources, and emissions in earlier years are assumed to be the same as in the earliest year for which data exist. Emission estimates for methane are also based on PI data for later years, but no data are available for the period 1990-2003, and so the IPCC Tier 1 default is used instead.
Other petrochemicals	2B8g	2B10	Emissions data for other petrochemical processes is taken from EU ETS (CO_2 only), and the PI (English/Welsh sites) or SPRI (Scottish sites). For those years where operator-reported emissions data are not available, then emissions are assumed to be the same as for later years where data are available. There are no petrochemical processes located in Northern Ireland which would emit GHGs

a – this process is integrated with an ammonia production process and all emissions of CO_2 are reported in 2B1.

b – production is not known but capacity of two plant in 1987 was 500,000 tonnes and one subsequently closed so 500,000 tonnes is considered a conservative estimate.

The methodology for CO_2 estimates for 2B8g were developed through an inventory improvement research project in 2013-14 (Ricardo-AEA, 2014b), with a review 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. In addition, installation-specific (but anonymised) data from the chemical industry Climate Change Agreement (CCA) data reported for 2008 and 2010 were also reviewed. CCA data was used 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. 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 2B8g.

4.13.3 Uncertainties and Time Series Consistency

For the use of waste residues and process off-gases as fuel in the chemical industry, the emissions estimates are somewhat uncertain as the completeness of the data over the whole time-series are very hard to verify; the 2014 inventory improvement study, however, has confirmed that the inventory covers all high-emitting sites in the UK that have been in operation in recent years, and therefore the overall uncertainty on the UK inventory estimates, at least for the period covered by EU ETS data, 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). These are dominated by the four ethylene production sites and a handful of other sites producing organic chemicals, typically co-located with refineries.

Emission estimates for other sources are mostly based on a mixture of PI and/or EU ETS data with estimates for earlier years then based on the assumption that emissions are as in later years. Tier 1 IPCC default emission factors are used for the minor sources 2B8c (for CO_2), 2B8d and 2B8f (both CH_4, part of time-series only). No UK-wide activity data (production data) are available with which to generate a better time series for any of the sub-sectors within 2B8, so the earlier part of the time-series for all of the chemical industry sectors is particularly uncertain. EU ETS-based emissions are considered the most reliable basis for estimates in the GHGI and the uncertainty is estimated to be +- 5%. PI data are more uncertain, because it is not clear what methods are used and the emission sources (combustion, process, other) are not transparent. Uncertainty for GHGI estimates based on the PI data is estimated to be +- 15%. Emissions data for methane are likely to be more uncertain than those for CO_2 since the former are often fugitive in nature, or minor components in stack emissions (thus requiring stack monitoring to quantify).

4.13.4 Source Specific QA/QC and Verification

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

4.13.5 Source Specific Recalculations

For information on the magnitude of recalculations, see **Section 10**.

4.13.6 Source Specific Planned Improvements

It is noted that this sector has been identified as a key category this year, and that not all of the estimates within this sector use a tier 2 or higher approach. The UK has recently reviewed this sector and included some additional sources using what is believed to be the best currently available data. The UK will review this position should further information come to light.

4.14 SOURCE CATEGORY 2B9 – FLUOROCHEMICAL PRODUCTION

4.14.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2B9a and 2B9b: Halocarbons Production (By-Product and Fugitive respectively)	T2	PS
Gases Reported	HFCs, PFCs		
Key Categories	2B: Chemical industry - HFCs (T2) 2B9: Fluorochemical production - HFCs, PFCs, SF_6 and NF_3 (L1, T1)		
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 **Section 1.8**.		
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.

4.14.2 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.

4.14.3 Uncertainties and Time-Series Consistency

The uncertainty analysis in **Annex 2**, 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.

4.14.4 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**, and details of verification of emissions are given in **Annex 6**. Additionally, as described above in **Section 4.14.2**, 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.

4.14.5 Source Specific Recalculations

No recalculations have been made to emissions from this sector.

4.14.6 Source Specific Planned Improvements

There are currently no planned improvements for this sector, however data sources will be kept under review.

4.15 SOURCE CATEGORY 2B10 – OTHER

4.15.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2B10 Sulphuric Acid Production	CS	CS
	Chemical Industry	CS	CS
	Chemical Industry (Nitric Acid Use)	CS	CS
	Chemical Industry (Pigment Manufacture)	CS	CS
	Chemical Industry (Reforming)	CS	CS
	Chemical Industry (Sulphuric Acid Use)	CS	CS
	Coal, tar and bitumen processes	CS	CS
Gases Reported	CH_4, CO, NO_x, SO_2, VOC		
Key Categories	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 **Section 1.8**.		
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. Emissions from processes not covered elsewhere in 2B, are reported under 2B10.

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 elsewhere in 2B for emissions from specific chemical processes, but also reported in 2B10 in the case of emissions from other, general petrochemical processes. Methane emissions from ammonia production sites have historically been included in the latter, and reported under 2B10, rather than being reported separately in 2B1.

Emissions of other pollutants are reported under the following source categories:

- Chemical industry - CO, SO_2, NMVOC;
- Chemical industry (nitric acid use) - NO_x;
- Chemical industry (pigment manufacture) - SO_2;
- Chemical industry (reforming) – CO;
- Chemical industry (sulphuric acid use) - SO_2;

- Coal, tar and bitumen processes – NMVOC;
- Sulphuric acid production - SO_2.

The first source listed is the general category used where emissions occur from processes which do not fit elsewhere. The remaining categories are specific and often relate to small numbers of sites. 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 4.7**) and sulphuric acid are treated separately from use. Sulphuric acid was being produced at two sites at the end of 2013. 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. The remaining source category is reserved for minor sources of NMVOC from processes involving coal-based and bitumen-based chemicals.

4.15.2 Methodological Issues

Site-specific emissions data for chemical processes located in England and Wales are available in the Pollution Inventory (Environment Agency, 2014). Reporting generally started in 1994 or 1995, and few data exist for the years prior to 1994. Site specific emissions data for processes in Scotland have been obtained from the Scottish Pollutant Release Inventory (SEPA, 2014). 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 (2014).

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, but emission 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 (2014). In the case of SO_2 from sulphuric acid production, emissions data are available from operators across the whole time-series.

4.15.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to IPCC source category and fuel type.

Estimates 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 UK production data is not readily available for chemicals and other products from the sites reported under 2B8. 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.

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 Pollution 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 exception of sulphuric acid production. 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.

4.15.4 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.

4.15.5 Source Specific Recalculations

For information on the magnitude of recalculations, see **Section 10**.

4.15.6 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.

4.16 SOURCE CATEGORY 2C1 – IRON AND STEEL PRODUCTION

4.16.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2C1: Sinter plant – coke	T1, T2	CS
	Iron & steel flaring (BFG)	T1, T2	D, CS
	Electric arc furnaces	T1, T2	D, CS
	Ladle arc furnaces	T2	CS
	Sinter plant – limestone	T2	CS
	Sinter plant - dolomite	T2	CS
	Basic oxygen furnaces - dolomite	T2	CS
	Following for indirect gases only:		
	Blast furnaces	T2	CS
	Basic oxygen furnaces	T2	CS
	Iron and Steel (other)	T2	CS
	Rolling Mills (Hot & Cold Rolling)	T2	CS
Gases Reported	CO_2, CH_4, N_2O, CO, NO_x, SO_2, VOC		
Key Categories	2C1: Iron and steel production - CO_2 (L1, T1)		
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 **Section 1.8**.		
Major improvements since last submission	None		

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. Emissions are reported under CRF category 1A2a. Gases emitted from the top of the blast furnace are collected and emissions should only occur when this blast furnace gas (BFG) is subsequently used as fuel. These emissions from BFG combustion are reported in the UK inventory according to the process using them, rather than all being reported in 2C1. 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.

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 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 1A2a.

The UK had 3 integrated steelworks in operation at the end of 2014. In 1990, five sites had been in operation, with the steelworks at Ravenscraig in Scotland closing in 1992, followed by the closure of Llanwern in Wales in 2001. One of the three steelworks still in operation (located on Teesside) was, however mothballed between January 2010 and April 2012, due to the loss in demand for its steel products.

Electric steel is manufactured in 2 large steelworks, in Rotherham and Tremorfa, and a few smaller works. Other large steelworks once operated in Sheffield, Sheerness, and Newport but have closed.

4.16.2 Methodological Issues

The methodology for the prediction of carbon dioxide emissions from fuel combustion, fuel transformation, and related 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 steelworks are reported under 1A1c, 1B1b, 1A2a, 2A3 and 2C1, depending upon the emission source. Emissions from sintering (from use of both coke breeze and limestone & dolomite), flaring of blast furnace gas and basic oxygen furnace gas, use of dolomite in oxygen furnaces, and emissions from electric arc and ladle arc furnaces are all reported under 2C1.

Flared losses of blast furnace gas (including basic oxygen furnace gas) are given in DUKES and carbon factors are derived using the carbon balance described previously.

Data on the usage of limestone and dolomite for steel production are available from the Iron & Steel Statistics Bureau (2014). The carbon content of limestone and dolomite used at steelworks is available from operators, based on EU ETS data (Tata Steel, 2014). Separate values are available for the years 2007-2013. 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.

Carbon emissions from electrodes in electric arc furnaces and ladle arc furnaces are calculated using emission factors provided by Corus (2005). Emissions from the addition of petroleum coke to electric arc furnaces at one steelworks are based on EU ETS data for the period 2005-2013, with estimates for the period 1990-2004 being extrapolated from the 2005 data on the basis of our estimates of steel production at that site. Emissions from the use of coke oven coke in foundries and other iron & steel industry processes 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 4.14** summarises the methods used for direct gas emissions reported under 2C1.

Table 4.14 Summary of Emission Estimation Methods for Source Categories in CRF Category 2C1

Source Category	Method	Activity Data	Emission Factors
Sintering – coke breeze	AD x EF	DECC energy statistics	Carbon: UK-specific factor from carbon balance CH_4: UK-specific based on reported emissions N_2O: Fynes & Sage (1994)
Sintering – carbonates	AD x EF	ISSB	Carbon: UK-specific from EU ETS
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.

4.16.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to IPCC source category and fuel type.

Much of the activity data used to estimate emissions from this source category come from the Iron and Steel Statistics Bureau (ISSB) and DECC publication DUKES. Time-series consistency of these activity data are very good due to the continuity in data provided in these two publications.

4.16.4 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**.

The UK inventory carbon balance method uses the best available industry data across the time series, including EUETS data from integrated steelworks from 2005 onwards. The comparison in recent years between the UK GHGI method and the EUETS data for individual installations indicates that the GHGI method is somewhat conservative, as the GHGI data are generally slightly higher than installation data. The inventory agency will continue to keep the method and input data under review to ensure that the carbon balance model delivers estimates that are as accurate as possible for the UK.

4.16.5 Source Specific Recalculations

For information on the magnitude of recalculations, see **Section 10**.

4.16.6 Source Specific planned Improvements

It is noted that this sector has been identified as a key category this year, and that not all of the estimates within this sector use a tier 2 or higher approach. The UK uses what is believed to be the best currently available data, and that tier 1 methods are only used for very limited parts of this sector. The UK will review this position should further information some to light. 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.

4.17 SOURCE CATEGORY 2C2 – FERROALLOYS PRODUCTION

The term ferroalloy covers a wide range of products, manufactured by various means, only some of which lead to industrial process emissions of greenhouse gases. Potential sources of CO_2 emissions include:

- Use of reductants such as coke oven coke;
- Consumption of carbon electrodes in furnaces used for melting raw materials;
- Decarbonisation of limestone or dolomite used as a fluxing agents;
- Decarbonisation of any carbonate ores used.

The UK has been a minor producer of ferroalloys. The current version of the BREF note (Best Available Techniques Reference document) for the non-ferrous metals industry, produced by the European IPPC Bureau[29] estimates UK production in 1993 as 55 ktonnes out of a European total production of 2,620 ktonnes while the updated draft of that document, currently

[29] downloadable from http://eippcb.jrc.ec.europa.eu/reference/

in final draft form (October 2014), does not identify any production of ferroalloys at all in the UK in the period 2005-2012.

Other than the estimate for 1993 given in the BREF note, the inventory agency has not found any data on UK production of ferroalloys. The absence of the UK as a European producer in the recent update of the BREF note suggests that UK production is either zero or insignificant; through consultation with trade associations and industry statistics experts (ISSB) the inventory agency has only been able to identify a few small-scale manufacturers of specialist ferroalloys such as ferro-molybdenum and ferro-vanadium. The production data for 1993 lists 45,000 tonnes of ferromanganese production in a blast furnace (where emissions would arise from use of reductants), and 10,000 tonnes of other ferroalloys in electric furnaces. The ferroalloy producers identified as in operation in recent years either carry out exothermic processes only (for ferro-molybdenum alloys) or use electric induction furnaces for melting. None of the processes report any CO_2 emissions in the Pollution Inventory, or are included in the EU ETS; the inventory agency has not identified any process currently in operation that would cause any industrial process emissions. The estimated production of 45,000 tonnes of ferromanganese in 1993 would use coke oven coke or coal as a reductant, and therefore the emissions are already included in the inventory (*Included Elsewhere*), as all UK consumption of these fuels is assumed to lead to emissions of CO_2. Any emissions associated with ferroalloy production would therefore already be included in 1A2a or 1A2b for coal, or 1A2g for coke oven coke. Given the lack of a time-series of production data, or information on the type or quantities of any reductant used in the ferromanganese production, the inventory agency has not made any re-allocation of emissions from 1A to 2C2.

There is no evidence of any use of electric arc furnaces, or the use of limestone or dolomite fluxes or carbonate ores. Therefore, UK emissions from ferroalloys are i) **Included Elsewhere** in the case of any emissions from use of reductants; ii) **Not Occurring** in the case of emissions from other sources.

4.18 SOURCE CATEGORY 2C3 – ALUMINIUM PRODUCTION

4.18.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2C3: Non-Ferrous Metals (Aluminium Production)	T2, CS	CS, PS, D
Gases Reported	CO_2, PFCs, CO, NO_x, SO_2, VOC		
Key Categories	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 **Section 1.8**.		
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.

4.18.2 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 (or used) a Tier 2 methodology of a smelter-specific relationship between emissions and operating parameters based on default technology-based slope and over-voltage coefficients. This method uses (or used) default factors for the CWPB (Centre Worked Prebaked) plant for three of the plants, and, default factors for VSS (Vertical Stud Soderberg) for the plant which closed in 2000. The remaining operational plant uses CWPB. 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 from the plant in 2013 are set out below.

Table 4.15 Parameters for calculation of PFC emissions from Aluminium production in 2013

	Units	
CF_4 Produced (IPAI)	kg	784
C_2F_6 Produced (IPAI)	kg	94.9

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 4.16**.

Table 4.16 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 4.17** below.

Table 4.17 Time series of activity data and emission factors for aluminium production

Year	Activity data	Emission factors - kt/Mt					
	Mt Al Produced	Carbon	CF_4	C_2F_6	CO	NO_X	SO_2
1990	0.290	423.8	0.60	0.075	72.43	1.02	13.53
1995	0.238	423.2	0.16	0.019	72.43	1.02	13.53
2000	0.306	420.0	0.11	0.014	79.12	0.76	14.60
2005	0.370	420.0	0.04	0.004	77.17	0.77	15.76
2008	0.327	420.0	0.05	0.006	95.89	0.90	15.08
2009	0.254	420.0	0.03	0.004	94.84	0.84	11.71
2010	0.186	420.0	0.08	0.010	96.07	1.05	12.84
2011	0.214	420.0	0.10	0.013	78.64	1.06	15.80
2012	0.060	420.0	0.03	0.004	25.07	0.59	15.98

Year	Activity data	Emission factors - kt/Mt					
	Mt Al Produced	Carbon	CF_4	C_2F_6	CO	NO_X	SO_2
2013	0.044	420.0	0.02	0.002	1.13	0.05	13.93

4.18.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to IPCC source category and fuel type.

The source of activity data is almost always from data compiled by the British Geological Survey (production of primary aluminium). This is a long running publication and the compilers of the activity data strive to use consistent methods to produce the activity data. This helps to ensure good time series consistency of the emission estimates. The alternative data used for 2005 and 2007 is only slightly higher (<0.4%) than the BGS number and supports the view that the BGS data are reliable, although the discrepancy in the 2008 data is larger (3.4%).

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. There was a further decline in 2013.

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.

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**. Emissions data taken from the Pollution Inventory are subject to additional QA/QC from the Inventory Agency.

4.18.5 Source Specific Recalculations

For information on the magnitude of recalculations, see **Section 10**.

4.18.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.19 SOURCE CATEGORY 2C4 – MAGNESIUM PRODUCTION

Emissions sources	Sources included	Method	Emission Factors
	2C4: SF_6 Cover Gas HFC Cover Gas	T2 T2	CS, PS CS, PS
Gases Reported	HFCs, SF_6		
Key Categories	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 **Section 1.8**.		
Major improvements since last submission	No major improvements		

In the UK, SF_6 and an HFC act as cover gases to prevent molten magnesium from burning during the production of magnesium.

4.19.1 Methodological Issues

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.

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). In all cases UK magnesium companies were able to report consumption, but had 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 were 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 HFC 134a 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 HFC 134a 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). The two largest users of SF_6 and HFC 134a (that represent 99% of UK emissions from magnesium) are now contacted annually for their activity data (consumption of SF_6 and HFC 134a).

4.19.2 Uncertainties and Time Series Consistency

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 1998-2013, the uncertainty of the time-series emissions is estimated to be significantly lower. 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 150 kt CO_2 equivalent in 2013. HFC 134a emissions were zero until 2008 and are approximately 3 kt CO_2 equivalent by 2013.

4.19.3 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**.

4.19.4 Source Specific Recalculations

For information on the magnitude of recalculations to this Source Category, see **Section 10**.

4.19.5 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.20 SOURCE CATEGORY 2C5 – LEAD PRODUCTION

Primary lead production is limited in the UK to a single site, which produced zinc and lead from imported ore concentrates. Emissions are reported under 2C6 and so this process is described in the following section. Emissions of CO from a number of small secondary lead producers are estimated based on data reported by the process operators.

Emissions of CO_2 can, in theory, occur from the use of reductants such as coal, coke oven coke, or natural gas during secondary lead processes, however it is not known whether any of the UK secondary lead processes involve the use of reductants. If any use of reductant does occur, however, it would be included in UK fuel statistics as an energy use, and thus emissions of CO_2 would already be included in the UK inventory, reported under 1A2.

4.21 SOURCE CATEGORY 2C6 – ZINC PRODUCTION

4.21.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2C6 Non-ferrous metal processes Non-Ferrous Metals (primary lead/zinc)	T1 T1	CS CS
Gases Reported	CO_2, CO, SO_2		
Key Categories	2C6: Zinc production - CO_2 (T1)		
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 **Section 1.8**.		
Major improvements since last submission	Emissions are reported for this source category for the first time this submission, although those emissions are re-allocated from 1A2.		

Zinc was produced in the UK until early 2003, using the Imperial Smelting Process (ISP) at a smelter operated by Britannia Zinc at Avonmouth. The site processed imported ore concentrates, and had a capacity to produce approximately 150,000 tonnes of zinc, as well as 65,000 tonnes of lead and small quantities of other metals such as cadmium. The ISP involves the use of a blast furnace to reduce zinc and lead oxides to the metal using coke as a reductant. Limestone can also be added to act as a slag-forming agent.

The UK also had two other non-ferrous metal production facilities that would have emitted CO_2 from processes. These were:

- the Capper Pass Tin Smelter at Melton, Humberside (closed in 1991)
- IMI Refiners' secondary copper smelter at Walsall (closed in 1997)

There is very little data specific to these installations available to the inventory agency as their closure pre-dates most of the routine annual emissions reporting regulations in the UK. Both processes used coke oven coke as a reductant that would lead to process emissions of CO_2, and emission estimates from these two sites are also reported under 2C6.

4.21.2 Methodological Issues

Britannia Zinc reported CO_2 emissions in the Pollution Inventory from 1998 until 2002, at which point the site ceased operation. Emissions of CO_2 would have occurred from the use of coke in the ISP, but also from decarbonisation of any limestone used, and from the other fuels used on site e.g. gas/oil burners used on the sinter plant and oil-fired furnaces used in the zinc refinery. We have not been able to discover any data on the quantities of coke and other fuels used, or the quantities of limestone that might have been used. The operator-reported CO_2 emissions in the Pollution Inventory are totals only, and no conclusions can be drawn regarding the split between coke, other fuels and limestone. The reported emissions are, however, much higher than would be implied by the Tier 1 factors given in the 2006 GLs for the ISP at Avonmouth. There is insufficient data to determine whether this is due to a high level of fuel combustion emissions on site, or that the process-related emissions at this site were higher than is typical for this type of process.

The Digest of UK Energy Statistics (DUKES) does give a full time-series of data on the consumption of coke oven coke by the non-ferrous metal industry. The consumption shown in this source is zero after 2003, confirming that after the closure of Britannia Zinc, no other non-ferrous metal processes in the UK used coke oven coke. We also believe that very few, other than Britannia Zinc, Capper Pass and IMI Refiners have used coke oven coke at any point in the period covered by the UK inventory.

Because all three sites have been closed for many years, there is no information on the consumption of coke oven coke at each site. Of the three, it is likely that IMI Refiners used relatively small amounts of coke, whereas the Capper Pass smelter was the largest of its kind in the world, and its closure in 1991 coincides with a big reduction in the non-ferrous metal industry's consumption of coke as shown in DUKES. There is insufficient data to split the coke consumption data between the three sites, and instead all of the coke use in DUKES is reported in 2C6. This will ensure completeness and reduce the uncertainty in the reported emissions, since only the total coke use figure is known to a high level of certainty. Carbon factors for the coke oven coke are derived from the carbon balance approach previously described for 1A2a.

As previously described, limestone may have been used at Britannia Zinc (and perhaps at Capper Pass as well) but we do not have any evidence on which to base emission estimates. Since all of these plants closed more than 10 years ago, there is no scope to access new information to improve this situation, and therefore we recommend that no emission estimates for these source categories be reported. Further, we note that the UK GHGI already includes emissions from all reported limestone and dolomite activity based on data from the British Geological Survey on UK supply and demand of these materials, and hence there is no gap in the UK GHGI, but possibly a small mis-allocation with higher estimates in another sector to counter the possible under-report here.

Emissions of CO from the lead/zinc smelter are reported in 2C6, and estimates are based on emissions data reported by the process operator in the Pollution Inventory (EA, 2014).

4.21.3 Uncertainties and Time Series Consistency

The use of DUKES data for coke consumption by non-ferrous metal processes ensures time series consistency and completeness, which is important since it is impossible to now determine how much coke oven coke was used in each of the 3 three non-ferrous metal processes that once existed in the UK. Any limestone used in the blast furnaces at Brittania Zinc and Capper Pass cannot be estimated, but emissions data for 2C1 cover all use of limestone and dolomite for blast furnaces and so overall completeness is assured.

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**.

4.21.5 Source Specific Recalculations

For information on the magnitude of recalculations, see **Section 10**.

4.21.6 Source Specific Planned Improvements

It is noted that this sector has been identified as a key category this year, and that a tier 1 method is used. The UK has recently reviewed this sector and included some additional sources using what is believed to be the best currently available data. Unfortunately as the only site for this sector has now been closed for a number of years it is highly unlikely that new data will mean a better estimate will be possible; incidentally the reason it is identified as a key category is due to the fact that this one large site closed since the base year.

4.22 SOURCE CATEGORY 2D1 – LUBRICANT USE

4.22.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2D1:Industrial engines – lubricants Agricultural engines – lubricants Marine engines – lubricants Road vehicle engines – lubricants	T1 T1 T1 T1	D, CS D, CS D, CS D, CS
Gases Reported	CO_2, CH_4, N_2O		
Key Categories	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Emissions from overseas territories and crown dependencies are included, and are scaled from UK estimates.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in **Section 1.8**.		
Major improvements since last submission	Revision to methodology with IPCC 2006 GLs Tier 1 now used, applying the default ODU of 0.2.		

4.22.2 Methodological Issues

The methodology used to estimate emissions from the use of lubricants has been revised for this submission. Previously, an approach had been used which employed various factors for carbon Oxidised During Use (ODU). These ODU factors were similar but not identical to those recommended by the IPCC, but were based on expert judgement rather than specific UK data. Therefore, since this UK method was not demonstrably more appropriate or more accurate than the IPCC default methods, we have used the latter instead.

Detailed activity data on lubricants are not available in the UK; DUKES does include data on sector-specific lubricant use (e.g. use by industry, agricultural sector, shipping etc.) in addition to the total lubricant demand time-series, but this falls short of what is required for the Tier 2 method. Therefore we have used the 2006 GLs Tier 1 method, with UK lubricant activity data from DUKES and the IPCC default ODU factor of 0.2, together with the UK-specific carbon emission factor for lubricants which is based on analysis of UK waste oil samples.

4.22.3 Uncertainties and Time Series Consistency

DUKES gives a full time series of lubricant consumption data so consistency of the emission estimates is good. The use of the Tier 1 methodology means that estimates are quite uncertain.

4.22.4 Source Specific QA/QC and Verification

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

4.22.5 Source Specific Recalculations

For information on the magnitude of recalculations, see **Section 10**.

4.22.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.23 SOURCE CATEGORY 2D2 – PARAFFIN WAX USE

4.23.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2D2:Petroleum waxes	T1	D
Gases Reported	CO_2		
Key Categories	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Emissions from overseas territories and crown dependencies are included, and are scaled from UK estimates.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in **Section 1.8**.		
Major improvements since last submission	Revision to methodology with IPCC 2006 GLs Tier 1 now used, applying the default ODU of 0.2.		

4.23.2 Methodological Issues

The methodology used to estimate emissions from the use of lubricants has been revised for this submission. Previously, an approach had been used which employed an 'Oxidised During Use' (ODU) factor. This ODU factor was a US-specific value, and therefore not as appropriate as use of an IPCC default methods. The IPCC Tier 1 methodology has now been adopted instead.

DUKES gives total consumption of petroleum waxes for the years 1990-2009 only. For 2010 onwards, petroleum wax consumption is only available as part of the much larger consumption of 'miscellaneous petroleum products'. In 2009, the consumption of petroleum waxes was equal to 5.9% of the total consumption of waxes plus other miscellaneous products, so this figure of 5.9% is then applied to the DUKES figures for miscellaneous product use in 2010-2013 to obtain an estimate of petroleum wax use in those years.

Emissions are estimated using the Tier 1 ODU factor of 0.2, and the IPCC default carbon content of 20 kg C/ GJ (net basis).

4.23.3 Uncertainties and Time Series Consistency

Emission estimates for this sector are highly uncertain because of the use of a Tier 1 methodology. In addition, the activity data for 2010-2013 are especially uncertain due to the loss of detail in DUKES meaning that the consumption of petroleum waxes has to be estimated by the Inventory Agency based on trends in consumption of a much wider group of petroleum products.

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**.

4.23.5 Source Specific Recalculations

For information on the magnitude of recalculations, see **Section 10**.

4.23.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.24 SOURCE CATEGORY 2D3 – SOLVENT USE

4.24.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2D3 Road transport – urea 2D3 NMVOC sources listed in **Table 4.18**	CS CS	CR CS
Gases Reported	CO_2, NMVOC		
Key Categories	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Emissions from overseas territories and crown dependencies are included, and are scaled from UK estimates.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in **Section 1.8**.		
Major improvements since last submission	Emission estimates included for road transport – urea for the first time.		

Emissions of CO_2 are estimated from consumption of urea by road vehicles with relevant types of catalytic converters for control of pollutant emissions and are reported under 2D3. Urea has the chemical formula $(NH_2)_2CO$ and is injected into the exhaust stream of certain types of diesel vehicles (currently Euro IV and V HGVs and buses) as a 32.5% (by weight) aqueous solution. The catalytic process of converting NO_x to nitrogen in the exhaust leads to the release of CO_2 from the urea in the tailpipe.

Emissions of NMVOC from numerous uses of solvents and other volatile petroleum products are reported under 2D3. These NMVOC sources include the manufacture and use of paints, printing inks, adhesives and other types of coatings (both in industry and in households), degreasing and dry cleaning, manufacture of tyres, vegetable oil, and agrochemicals, and the use of consumer products such as aerosols, fragrances and automotive products such as screenwash. Also included is the use of kerosene as a viscosity-reducer in 'cutback' asphalt grades.

4.24.2 Methodological Issues

The 2006 IPCC Guidelines specify two approaches for estimating CO_2 emissions from urea consumption. This is either from statistics on total urea sales or by estimating urea consumption as a proportion of the amount of fuel consumed. There are no statistics on urea sales in the UK, so the approach based on fuel consumption is used. Not all diesel vehicles use urea so it is necessary to know the amount of fuel consumed specifically from those vehicles with the relevant exhaust aftertreatment technology that require urea injection.

Urea is used by HGVs and buses in the UK manufactured to Euro IV and V standards. These came into effect from 2006. The EMEP/EEA Emissions Inventory Guidebook (2013) provides the means for estimating urea consumption as a proportion of fuel consumed by these specific types of vehicles. Fuel consumption by Euro IV and V HGVs and buses was estimated using a bottom-up method described in **MS 6**. The estimations involve the use of vehicle km activity and fleet composition data from DfT and g/km fuel consumption factors, with total fuel consumption calculated for road transport by this method normalised to national fuel sales in DUKES.

Following figures given in the EMEP/EEA Guidebook for estimating other pollutant emissions, an assumption was made that 75% of Euro V HGVs and buses are equipped with SCR – the catalyst system that uses urea. The same assumption was also applied to Euro IV vehicles. Fuel consumption was calculated for these types of vehicles using SCR technology. Following the EMEP/EEA Guidebook, urea consumption is assumed to be 4% of fuel consumption for a Euro IV HGV and bus and 6% for a Euro V HGV and bus. Independent assessment in the UK from suppliers of urea and vehicle manufacturers supports these assumptions. These assumptions allowed the time-series for consumption of urea by UK road transport to be estimated. No urea was consumed before 2006.

A constant emission factor of 0.238 kgCO_2/kg urea solution, as given in the EMEP/EEA Guidebook was used. This is consistent with the factor and emission equation given in the 2006 IPCC Guidelines, assuming urea is used as a 32.5% aqueous solution which is the norm in the UK.

Solvents are used by a wide range of industrial sectors as well as being used by the general public. Many applications for industrial solvent use require that the solvent is evaporated at some stage, for example solvent in the numerous types of paints, inks, adhesives and other industrial coatings must evaporate in order for the coating to cure. The solvent contained in many consumer products such as fragrances, polishes and aerosols is also expected to be released to atmosphere when the product is used.

Emissions of NMVOC from use of these solvents can therefore be assumed to be equal to solvent consumed in these products, less any solvent that is recovered or destroyed. In the case of consumer products and smaller industrial processes, such as vehicle refinishing processes, the use of arrestment devices such as thermal oxidisers would be prohibitively expensive and abatement strategies therefore concentrate on minimising the solvent consumption. Solvent recovery and destruction can be ignored for these processes.

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In comparison, larger industrial solvent users such as flexible packaging print works, car manufacturing plants and specialist coating processes such as the manufacture of hot stamping foils are generally carried out using thermal oxidisers or other devices to capture and destroy solvent emissions. In these cases, NMVOC emissions will still occur, partly due to incomplete destruction of solvent by the arrestment device, but also because some 'fugitive'

emissions will avoid being captured and treated by that device. The level of fugitive emissions will vary from process to process, and will depend upon the extent to which the process is enclosed. For these sectors, it is still possible to estimate emissions based on solvent consumed, but allowance must be made for solvent destroyed or recovered. This can only be done accurately if the extent of abatement can be reliably estimated for each site. In most cases this means that detailed information at individual plant level must be gathered.

Other uses of solvents do not rely upon the solvent being evaporated at some stage and, in contrast, losses of solvent in this way are prevented as far as possible. Processes such as seed oil extraction, and dry cleaning include recovery and re-use of solvent, although new solvent must be introduced to balance any losses. Emission estimates for these sectors can be made using solvent consumption data (i.e. assuming that purchases of new solvent is equal to emissions of solvent) or by using solvent mass balance data at a site by site level.

Manufacturers of paints, inks and other coatings also wish to minimise losses of solvent but in these cases, the solvent is not recovered and re-used, but is instead contained in products which are then used elsewhere. Emission estimates for these sectors can be made using emission factors (i.e. assuming some percentage loss of solvent).

Finally there are some applications where solvent is used in products but is not entirely released to atmosphere. Solvent used in wood treatments and certain grades of asphalt can be retained in treated timber and in road dressings respectively. In these cases, emission estimates are based on solvent consumption data but include an allowance for solvent not released. **Table 4.18** shows how estimates have been derived for each inventory source category.

Table 4.18 Methods for Estimating Emissions from Solvent and Other Product Use.

Source Category	General method
Aerosols (car care, cosmetics & toiletries, household products) Agrochemicals use Decorative paint - retail decorative Decorative paint - trade decorative Dry cleaning Industrial adhesives (general) Industrial coatings - agricultural and construction Industrial coatings - aircraft Industrial coatings - commercial vehicles Industrial coatings - high performance Industrial coatings – marine Industrial coatings - metal & plastic Industrial coatings - vehicle refinishing Industrial coatings – wood Non Aerosol Products (household, automotive, cosmetics & toiletries, domestic adhesives, paint thinner) Other rubber products Other solvent use Printing – newspapers Printing - other flexography Printing - other inks Printing - other offset Printing - overprint varnishes Printing - print chemicals Printing - screen printing Surface cleaning - hydrocarbons Surface cleaning - oxygenated solvents Leather degreasing	Solvent consumption data for the sector, assumption that little or no solvent is recovered or destroyed.

Source Category	General method
Industrial coatings – automotive Printing - heatset web offset Printing - metal decorating Surface cleaning - 111-trichloroethane Surface cleaning – dichloromethane Surface cleaning - tetrachloroethylene Surface cleaning – trichloroethylene	Solvent consumption data for the sector, with adjustments to take account of likely abatement of solvent.
Industrial coatings - coil coating Industrial coatings – drum Industrial coatings - metal packaging Printing - flexible packaging Film coating Industrial adhesives (pressure sensitive tapes) Leather coating Paper coating Textile coating Tyre manufacture	Solvent consumption data at individual site level with adjustments to take account of abatement at each site.
Printing - publication gravure Seed oil extraction	Mass balance data at individual site level
Coating manufacture – adhesives Coating manufacture - inks Coating manufacture - other coatings Wood Impregnation, Creosote use Road dressings	Emission factor (assumed percentage loss of solvent)

All overseas territories and crown dependencies emissions arising from solvents are reported under 2D3. 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.

4.24.3 Uncertainties and Time Series Consistency

The main uncertainty on estimates of emissions from urea consumption comes from the uncertainty in the amount of urea consumed by the categories of vehicles equipped with SCR exhaust aftertreatment technologies in the UK fleet. This is linked with uncertainties in the estimates of fuel consumed by these vehicles and uncertainty in the amount of urea consumed per kg of fuel consumed. Uncertainties in the CO_2 emission factor from urea consumption are very low because the carbon content of urea is known with high accuracy.

The UK considers its inventory estimates of CO_2 from urea consumption are upper limits for the following reasons:

- The fuel normalisation method used in the calculation of fuel consumption by road transport applies an uplift to the estimate for HGVs to bring consistency with DUKES.
- There is greater uncertainty in the proportion of Euro IV vehicles that use SCR and urea. The EMEP/EEA Guidebook only considers consumption by Euro V vehicles. Industry sources suggest SCR is extensively used by Euro IV vehicles, but the requirement to do so is not as strong because alternative technological approaches can achieve the modest NO_x emission reductions needed to meet Euro IV standards. A conservative assumption was made that the same proportions of Euro IV vehicles use SCR and urea as Euro V.

Emission estimates for NMVOC from solvent use are moderately uncertain: emission estimates generally rely upon a number of assumptions and extrapolations which introduce

uncertainty, and the overall uncertainty in the NMVOC emissions from 2D3 is judged to be perhaps as much as +/- 30%.

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**.

4.24.5 Source Specific Recalculations

For information on the magnitude of recalculations, see **Section 10**.

4.24.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.25 SOURCE CATEGORY 2E1 – INTEGRATED CIRCUIT OR SEMICONDUCTOR

Emissions of SF_6 from semiconductor manufacturing are combined with emissions from training shoes and electrical insulation in source category 2G2e for reasons of commercial confidentiality. This source category is described in **Section 4.39**.

4.26 SOURCE CATEGORY 2E2 – TFT FLAT PANEL DISPLAY

4.26.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	None		
Gases Reported	None (gases possible are PFCs, NF_3 or SF_6)		
Key Categories	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	Potentially a small amount of emissions from small scale flat panel manufacturing if it occurs.		
Major improvements since last submission	NA		

4.26.2 Methodological Issues

ICF (2014) determined that the UK does not have volume Flat Panel manufacturing. ICF reached this conclusion after contacting the National Microelectronics Institute (NMI) who represent flat panel display manufacturers in the UK.

4.26.3 Source Specific Planned Improvements

Any emergence of volume manufacturing capacity of TFT flat panel display is kept under review.

4.27 SOURCE CATEGORY 2E3 – PHOTOVOLTAICS

4.27.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	None		
Gases Reported	None (gases possible are PFCs)		
Key Categories	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	Potentially a small amount of emissions from small scale photovoltaics manufacturing if it occurs.		
Major improvements since last submission	NA		

4.27.2 Methodological Issues

ICF (2014) determined that the UK does not have volume photovoltaics (PV) manufacturing. ICF reached this conclusion after contacting the British Photovoltaic Association (BPA) to gather data from PV manufacturing in the UK. The BPA also confirmed that statistics on F-gas use in the PV manufacturing in the UK are not available.

4.27.3 Source Specific Planned Improvements

Any emergence of volume manufacturing capacity of photovoltaics is kept under review.

4.28 SOURCE CATEGORY 2E4 – ELECTRONICS INDUSTRY – HEAT TRANSFER FLUID

4.28.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	None		
Gases Reported	None (gases possible PFCs)		
Key Categories	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	Under active review.		
Major improvements since last submission	New category reported from 2015 NIR onwards		

PFCs are used as heat transfer fluids (HTFs) in commercial and consumer electronic applications. The various applications of PFC as HTFs use much smaller volumes of liquid PFCs than electronics manufacturing. Some examples of consumer applications include cooling kits for desktop computers and commercial applications include cooling supercomputers, telecommunication, and radar systems, as well as drive units on high-speed trains.

4.28.2 Methodological Issues

ICF reviewed this sector (ICF, 2014). Based on ICF's preliminary research, various applications of PFCs and other F-gases may be used as HTFs in the UK, including:

- Consumer electronics: cooling apparatus in personal PCs, workstations, gaming consoles, and server microprocessors, for both commercial and residential settings. Negligible use in the UK (Gluckman 2013, per comm.)
- Cooling systems that rely on convection to remove heat from an area, rather than relying on mechanical refrigeration, including recirculating coolers (i.e., systems with fluid pumps) and thermosiphons (systems relying on natural convection currents). Negligible use in the UK of this “heat pipe” (Gluckman 2013, per comm.)

The amount of F-gases contained in these systems is wide-ranging. Consumer electronics typically have small charge sizes (e.g. of the order of 100 grams or less).

Based on ICF expert opinion, use of PFCs (e.g., C_6F_{14}) is likely to have been replaced by lower-GWP alternatives that are less costly, such as HFC-245fa, HFC-134a, HFC blends, or even new, low-GWP options such as HFO-1234ze or Solstice 1233zd(E).

However, given the niche applications of these possible uses, the development of country-level emission factor for each of these uses in order to apply IPCC’s Tier 2 methodology is a complex task. The Tier 3 mass-balance approach is also not feasible as the market research of the various uses is complex, and would be subject to large uncertainties. ICF concluded a Tier 1 method was not possible given the type of activity data.

4.28.3 Source Specific Planned Improvements

The UK is considering investigating approaches to identify companies involved in each of the niche applications and gathering activity and/or emissions data. This would require a high level of effort and will take considerable time.

4.29 SOURCE CATEGORY 2F1 – REFRIGERATION AND AIR CONDITIONING EQUIPMENT

4.29.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2F1: Commercial Refrigeration Domestic Refrigeration Industrial Refrigeration Mobile Air Conditioning Refrigerated Transport Stationary Air Conditioning	T3 T3 T3 T3 T3 T3	CS CS CS CS CS CS
Gases Reported	HFCs		
Key Categories	2F: Product Uses as Substitutes for ODS - HFCs (L2) 2F1: Refrigeration and air conditioning - HFCs, PFCs, SF_6 and NF_3 (L1, T1)		
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 **Section 1.8**.		
Major improvements since last submission	None		

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 low 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 4.19 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) and one condenser, assembled into a unit, which is located external to the sales area. The condensing unit is connected by refrigerant pipework to an evaporator located in the retail sales area (e.g. in a chilled retail display). 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, with many refrigerated displays connected to a central system. Each system typically has a cooling capacity in the 30 kW to 150 kW range.
RAC-5	Industrial Systems	Refrigeration systems including industrial process refrigeration and cold storage. Industrial refrigeration systems vary widely in cooling capacity. Many industrial systems are above 1,000 kW. However, the majority that use HFC refrigerants are relatively small, in the 50 kW to 200 kW range.
RAC-6	Small Stationary Air Conditioning	Includes small self-contained air-conditioning (including window units) and non-ducted single split air-conditioning. 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. The majority of modern systems are reversible – they can operate either as an air-conditioning unit or an air-source heat pump.
RAC-7	Medium Stationary Air Conditioning	Includes non-ducted multi-split, variable refrigerant flow (VRF) non-ducted split, ducted split, and packaged air-conditioning. Units are used in the commercial UK sector. System cooling capacities typically range from 12 to 200 kW.
RAC-8	Large Stationary Air Conditioning (Chillers)	Large water chillers used for commercial comfort air conditioning. Cooling capacity is typically in the range 100 kW to 500 kW.
RAC-9	Heat Pumps	Residential and small commercial heating only 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).

Revised Model End-Use		Description
RAC-12	Light Duty Mobile Air Conditioning	Air-conditioning 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	Air-conditioning systems for trucks (over 3.5 tonnes), buses/coaches, semi-trailers, trailers, and railcars.

4.29.2 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 9 to 13 end-use sub-sectors (as listed in **Table 4.20**), for which detailed assumptions were developed to utilise a fully bottom-up approach. Both the new model and the previous version make use of a bottom up approach with assumptions made about emission factors and stock levels. The new model is more comprehensive and allows for updating of the assumptions made. Both bottom up models are verified by comparing the predicted HFC consumption for the whole RAC sector with top-down data for the sales of HFCs in the UK.

For each of the 13 end-use sub-sectors, 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 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.

The various input assumptions used by the model can be varied on an annual basis. This allows changes in response to market growth or regulatory constraint to be reflected in the bottom-up estimates of HFC emissions made by the model. For example the 2006 EU F-Gas Regulation has led to significant reductions in the levels of leakage from some RAC sub-sectors and improvements in the level of refrigerant recovery during servicing and at end-of-life. This is reflected in the model by changes to the annual operating emission factors and end-of-life recovery factors.

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).

A summary table of the 2013 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).

A key input assumption is the split of different refrigerants used in new and existing equipment in each of the 13 sub-sectors. The accuracy of the input assumptions is checked by comparisons with top-down BRA data for the whole RAC market. The model then generates a detailed speciated split of total emissions. This is available split either by the type of refrigerant used (e.g. a blend such as HFC 404A) or by the individual HFC components within such blends (e.g. HFC 404A is a mixture of HFC 143a, HFC 125 and HFC 134a).

Table 4.20 Summary of 2013 Input Assumptions by End-Use[b]

Application		2013 Parameters[b]							
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	41,531,464	2,911,603	15	0.10	HFC-134a, HCs	0.6%	0.3%	34%[b]
Commercial Refrigeration	Small Hermetic Stand-Alone Refrigeration Units	2,622,545	271,145	10	0.5	HFC-134a, R-404A, R-407C, HCs	1%	1.4%	39%[b]
	Condensing Units	627,407	52,442	14*	5*	HFC-134a, R-404A, R-407A, R-407F,R-410A, R-507, HCs	2%	10%	15%
	Centralised Supermarket Refrigeration Systems	11,075,577 (m^2)	962,049 (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	92,548	13,450	7	3.7	HFC-134a, R-404A	0.2%	14.3%	19%
	Marine Transport Refrigeration	527	32	25*	1,500*	R-404A, R-407C, R-717	1%	39%	29%
Industrial Refrigeration	Industrial Systems	21,224	923	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	5,467,004	493,036	13	1.5	R-407C, R-410A	0.5%	3%	29%
	Medium Stationary Air Conditioning	678,441	58,081	15	15	R-407C, R-410A	1%	5.9%[b]	29%
	Large Stationary Air Conditioning (Chillers)	42,448	3,241	18	180	HFC-134a, R-407C, R-410A, R-717	0.5%	3%	19%
	Heat Pumps	39,590	7,968	15	3	HFC-134a, R-404A, R-407C, R-410A	1%	6%[b]	31%[b]
Mobile Air-Conditioning	Light Duty Mobile Air Conditioning	28,960,441	1,951,823	15	0.718	HFC-134a	0.5%	10%	29%
	Other Mobile Air Conditioning	518,890	91,219	10	4*	HFC-134a, R-407C	0.5%	10%	29%

[a] Except where otherwise noted.

[b] 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 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.

4.29.3 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.

4.29.4 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 6**.

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).

4.29.5 Source Specific Recalculations

For information on the magnitude of recalculations, see **Section 10**.

4.29.6 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.

The input assumptions to the current ICF model were made based on data collected in 2010 / 2011. The successful implementation of the 2006 EU F-Gas Regulation and the introduction of the much more far-reaching 2014 F-Gas Regulation has led to rapid changes in the UK refrigeration and air-conditioning sectors. Many of the input assumptions for 2013 onwards need to be updated to take these changes into account. An update of the ICF model will take place in 2015.

4.30 SOURCE CATEGORY 2F2A – CLOSED CELLS (FOAM BLOWING AGENTS)

4.30.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2F2a: Foam blowing agents	T3	CS
Gases Reported	HFCs		
Key Categories	2F: Product Uses as Substitutes for ODS - HFCs (L2)		
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 **Section 1.8**.		
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[30].

[30] "on disposal" is not the full story for many foams. Any building insulation that goes into landfill degrades slowly and gives off the remaining gas over many years. This is not well documented and there is little data available on rate of degradation / emission.

4.30.2 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.

An EF was determined based on a combination of country-specific data on the HFCs contained in the foam and the time dependent rate of loss of HFCs. The United Kingdom only reports emissions under stocks (lifetime) and not under manufacturing or disposal. The emissions are complete, the data from the model used to estimate emissions from foam blowing have been aggregated in the database, which did not have the capability to distinguish emissions separately for manufacturing, stocks and disposal.

The species used for foam blowing are given below.

Table 4.21 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%		

Application	HFC-245fa	HFC-365mfc	HFC-227ea	HFC-134a	HFC-152a
PF Block - Slab		90%	10%		
PF Block - Pipe		90%	10%		
PU - Appliance	50%	45%	5%		
PU - Reefer	50%	45%	5%		

No emissions are occurring for this source in 1990 or in 1995. The bank also includes HFC species not previously reported in the UK GHG inventory (i.e. HFC-365mfc and HFC-245fa), since no GWP was available in the IPCC Second Assessment Report (SAR), but they are included in the 4th Assessment Report (AR4).

Speciated emissions for the OTs and CDs are reported under 2F2. Emission estimates from the UK GHGI were scaled using the GDP of each territory.

4.30.3 Uncertainties and Time-Series Consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to IPCC source category and fuel type.

4.30.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Details of verification of emissions are given in **Annex 6**.

4.30.5 Source Specific Recalculations

For information on the magnitude of recalculations, see **Section 10**.

4.30.6 Source Specific Planned improvements

This source category is being considered for addition to the GHG inventory improvement programme.

4.31 SOURCE CATEGORY 2F2B – OPEN CELLS (ONE COMPONENT FOAMS)

4.31.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2F2b: One Component Foams	T2	CS
Gases Reported	HFCs		
Key Categories	2F: Product Uses as Substitutes for ODS - HFCs (L2)		
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 **Section 1.8**.		
Major improvements since last submission	No major improvements		

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.

4.31.2 Methodological Issues

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.

4.31.3 Uncertainties and Time-Series Consistency

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 2**.

4.31.4 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 6**.

4.31.5 Source Specific Recalculations

There have been no recalculations to the mass based estimates from this source, although due to the use of AR4 GWPs instead of SAR GWPs the CO_2e emissions have changed.

4.31.6 Source Specific Planned improvements

Emission factors and activity data will be kept under review.

4.32 SOURCE CATEGORY 2F3 – FIRE EXTINGUISHERS

4.32.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2F3: Fire Fighting	T2	D
Gases Reported	HFCs, PFCs		
Key Categories	2F: Product Uses as Substitutes for ODS - HFCs (L2)		
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 **Section 1.8**.		
Major improvements since last submission	Time series updated to be compliant with 2006 GL methodology and utilising revised AD and assumptions		

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

4.32.2 Methodological Issues

The IPCC 2006 GLs state that, because F-gases in fire protection are emitted over a period longer than one year, countries must represent emissions from equipment charged during previous years. As such, the revised emission estimation equation (Equation 7.17) requires a modified approach to the one used in 2014 NIR (2012 inventory) to consider the time dependence of the emissions. Effectively, this requires disaggregating the annual bank estimates into 'new' versus 'existing' systems and then applying emission factors accordingly (i.e., applying a lifetime loss rate to banks from both new and existing systems, a servicing loss rate to the bank of existing systems, and a disposal loss rate to the bank of existing systems reaching disposal in any given year, based on an assumed average lifetime). Further, additional research was required to ensure that a manufacture loss rate should not be applied by confirming whether there is any production of F-gas fire protection agents in the UK. These updates apply the IPCC Tier 2 methodology.

ICF reviewed available literature to confirm/update key assumptions—notably, EEA (2013)—and then refined and finalized the estimates based on consultation with ASSURE (European Association for Responsible Use of HFCs in Fire Fighting) and the UK Fire Industry Association (FIA). The sections below outline the updates implemented by key area.

4.32.2.1 Stock

Annual stock estimates from the years 1990 – 2005 (from the 2012 GHG inventory) were maintained, since they were based on historical data and input from industry experts. However, these annual stock figures were disaggregated into new versus existing systems by subtracting the current year's bank from the previous year's bank to estimate consumption in new systems, and then allocating the remainder of the bank to existing systems.

To determine the equipment stock in years beyond 2005, EEA (2013) estimates for net supply of F-gases in the fire protection sector from 2007-2012 (metric tonnes) in the EU, 85% of which is HFC-227ea, were scaled to the UK using a time-dependent GDP ratio. This annual net supply was assumed to equal annual consumption of fire protection agent in new systems. The bank estimate for 2006 was interpolated based on the existing 2005 estimate and the new 2007 estimate. The methodology and resulting stock estimates were reviewed and approved by ASSURE (2013) and FIA (2013). ASSURE confirmed that the estimates looked reasonable; FIA noted that the estimates looked reasonable for recent years, but that the 2000 estimates are slightly high. Additional information to refine these historical estimates was not available but this is a conservative bias as it will slightly overestimate emissions.

4.32.2.2 Chemicals in use

According to FIA (2013) and ASSURE (2013), HFC-227ea accounts for virtually 100% of F-gas consumption in this sector in the UK; consumption of other HFCs (e.g., HFC-23, HFC-125, and HFC-236fa) in the UK are statistically insignificant. Therefore, is it assumed that HFC-227ea accounts for 100% of F-gas consumption in this sector (over the full time period).

4.32.2.3 Equipment lifetime

According to FIA (2013) and ASSURE (2013), the average equipment lifetime of fire protection systems is 20 years.

4.32.2.4 Emission factors

The emission factors used in the current inventory were reviewed by FIA (2013) and ASSURE (2013); they confirmed that no updates were required. A summary of the emission factors is provided in the table below. ASSURE emphasised that the high cost of specialty HFC fire protection systems creates a strong incentive for recovery and recycling, minimising leaks during servicing and decommissioning. Further, ASSURE confirmed that there is no F-gas

production in the UK in this sector, which is also supported by Defra (2008). Thus, no manufacturing loss factors are applied.

Lifetime emission factors were applied to the entire bank, while servicing emission factors—which decrease over time as more efficient servicing techniques are assumed to be implemented—were applied to the bank of existing systems (not to new or decommissioned systems). The disposal loss rate is applied to the bank of existing systems assumed to reach disposal; because the equipment lifetime is assumed to be 20 years, the disposal emissions will not be modelled until 2015—i.e., 20 years following the initial installation of F-gases in 1995.

The UK has reported emissions of PFC C4F10 from 1995 to 2007. Emissions of this PFC were estimated using the methodology set out in the 2014 NIR. The research set out below has indicated that only HFC-227ea is used in this sector. These PFC emissions will be removed from the time series in the next inventory.

4.32.2.5 PFC emissions

The UK also estimates and reports emissions of PFC C_4F_{10} from 1995 to 2007. These emissions are small. Emissions of this PFC were estimated using the methodology set out in the 2014 NIR.

The emission factors for HFC use in the sector have been summarised in **Table 4.22** below.

Table 4.22 Key assumptions used to estimate HFC emissions from fire extinguishers

Parameter		1990	1995	2013
Activity data	HFC species and ratio HFC 227ea	100%	100%	100%
	Size of bank (t)	0	20	3322
	Consumption in new systems (t)	0	20	0
	Consumption in existing systems (t)	0	0	3322
	Equipment lifetime (yrs)	0	20	20
Emission factors	% released through fire (lifetime)	1.5	1.5	1.5
	% released through servicing	3.4	3.4	1.0
	% released during recovery (disposal)	0.1	0.1	0.1

Speciated emissions for the OTs and CDs are reported under 2F3. Emission estimates from the UK GHGI were scaled by the GDP of each territory.

4.32.3 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 from 2005 onwards are thought to be more uncertain since these are based on projections and anecdotal evidence. Uncertainty data from this study have been used in the uncertainty analysis presented in **Annex 2**.

4.32.4 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 6**.

4.32.5 Source Specific Recalculations

For information on the magnitude of recalculations, see **Section 10**.

4.32.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.33 SOURCE CATEGORY 2F4 – AEROSOLS

4.33.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2F4: Metered Dose Inhalers Aerosols (Halocarbons)	T2	CS
Gases Reported	HFCs		
Key Categories	2F: Product Uses as Substitutes for ODS - HFCs (L2) 2F4: Aerosols - HFCs, PFCs, SF_6 and NF_3 (L1, T1)		
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 **Section 1.8**.		
Major improvements since last submission	No major improvements		

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.

4.33.2 Methodological Issues

4.33.2.1 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.

Table 4.23 Key assumptions used to estimate HFC134a emissions from aerosols

	Parameter	1990	1995	2013
Activity data	Used for UK manufacture (tonnes)	0	509.4	582.1
	Exported (tonnes)	0	50.9	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 4.24 Key assumptions used to estimate HFC152a emissions from aerosols

	Parameter	1990	1995	2013
Activity data	Used for UK Manufacture (tonnes)	0	15.6	46.6
	Exported (tonnes)	0	1.6	25.0
	Imported (tonnes)	0	0	0
	Product lifetime (yrs)	1	1	1
Emission factors	PM %	1	1	1
	PL %	97	97	97
	D %	2	2	2

4.33.2.2 Metered Dose Inhalers (MDIs)

The methodology used to estimate emissions corresponds to an IPCC Tier 2 method. 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 estimates of the species and volumes of HFCs used as MDI propellants. Detailed data from the UK NHS are used for estimates between 1998 and 2013. 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).

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 227ea. The lower part of the table shows the average GWP of UK MDIs, based on a 96% / 4% split between these 2 propellants. The upper part of the table shows the estimated number of MDIs consumed each year in the UK, together with the CO_2 emissions for this level of MDI consumption.

Table 4.25 Key assumptions used to estimate HCF emissions from MDIs

			kt CO_2e	kt CO_2e
Year	**MDI Number (thousands)**	**Average Propellant (g per MDI)**	**GWP AR2**	**GWP AR 4**
2006	40,146	14	767	844
2007	41,874	13	743	817
2008	45,353	12	742	817
2009	48,413	12	792	872
2010	50,190	12	822	904
2011	50,644	12	829	913
2012	52,009	12	851	937
2013	51,518	12	843	928

	GWP AR 2	**GWP AR 4**
96% HFC 134a + 4% HFC 227ea	1,364	1,502

Speciated emissions for the OTs and CDs are reported under 2F4. Emission estimates from the UK GHGI were scaled by the population of each territory.

4.33.3 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 2**.

4.33.4 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 6**.

4.33.5 Source Specific Recalculations

For information on the magnitude of recalculations, see **Section 10**

4.33.6 Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

4.34 SOURCE CATEGORY 2F5 – SOLVENTS

4.34.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2F5: Precision Cleaning	T1a	D
Gases Reported	HFCs		
Key Categories	2F: Product Uses as Substitutes for ODS - HFCs (L2)		
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 **Section 1.8**.		
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.

4.34.2 Methodological Issues

Emissions from solvent applications are considered to be prompt emissions because 100% of the chemical is typically emitted within two years of initial use (IPCC 2006). To calculate HFC emissions from the solvent sector using a Tier 1a method, the 2006 IPCC Guidelines specify that activity data should be the quantity of solvent sold in a given year. Therefore, obtaining annual sales of solvents in the UK is required. Using sales data, emissions of HFCs from solvent use in year t are calculated using the following equation, as provided in the 2006 GLs:

$$Emissions_t = S_t \times EF + S_{t-1} \times (1\text{-}EF) - D_{t-1}$$

Where:

$Emissions_t$ = emissions in year t, tonnes

S_t = quantity of solvents sold in year t, tonnes

S_{t-1} = quantity of solvents sold in year t–1, tonnes

EF = emission factor (= fraction of chemical emitted from solvents in the year of initial use), fraction

D_{t-1} = quantity of solvents destroyed in year t–1, tonnes

Because of the diverse industrial and commercial applications in which solvents are used, there is no UK or EU trade association for the solvents industry from which to solicit activity data. Therefore, ICF reviewed available literature to confirm/update key assumptions—notably, Harnish & Schwarz (2003), and EEA (2013).The sections below outline the updates implemented by key area.

4.34.2.1 Stock

Annual sales data of HFCs in the UK solvent sector were not available. Therefore, consumption of HFCs in this sector was estimated using the same estimates as in the previous inventory for 2001 and 2002 (i.e., based on Harnish & Schwarz 2003) in additional to historical F-gas supply data in the EU. Because the consumption estimates in Harnish & Schwarz (2003) in years beyond 2002 were projections, EEA (2013) data on intended F-gas supply data in the EU in the solvents sector was used to estimate HFC consumption from 2007-2012. To estimate the amount of HFCs placed on the market in the UK, the EU estimates from EEA (2013) were scaled down using a time-dependent UK to EU GDP ratio from EuroStat (2013). Using GDP as a scaling factor to estimate the UK F-gas supply in the solvent sector was deemed appropriate, given the wide variety of industrial and commercial industries that use solvents.

4.34.2.2 Chemicals in use

Given the lack of data available on the extent of use of HFC-134a in the UK solvent sector, it is assumed that HFC-43-10mee accounts for 100% of UK F-gas consumption in this sector. This is consistent with assumptions previously applied by in the 2013 GHG inventory.

4.34.2.3 Product lifetime

According to the 2006 IPCC GLs, the lifetime of all solvents is assumed to be two years. Therefore, any amount not emitted during the first year is assumed to be emitted in the second, final year (IPCC 2006).

4.34.2.4 Emission factors

A global report prepared by U.S. EPA (2013) assumes that approximately 90% of solvent that is consumed in a year is emitted, while 10% is destroyed. A lifetime emission factor is applied to the total amount of solvents placed on the market. Because the 2006 IPCC GLs provide that HFCs are emitted over a two-year period, an annual emission factor of 50%[31] was applied in this analysis using the IPCC (2006) equation above. Recovery and recycling is not considered in emission estimates, per the 2006 IPCC GLs.

[31] Note the ICF report (ICF,2013) states 45%, but the spreadsheet indicates 50% was used.

Table 4.26 Key assumptions used to estimate emissions from the use of solvents

	Parameter	1990	2005	2013
Activity data	EU Estimate (tonnes of HFC placed on market)	0	145	0
	UK Estimate (tonnes of HFC placed on market)	0	24	0
	Product lifetime (yrs)	2	2	2
Emission factors	PM %	n/a	n/a	n/a
	PL %	50	50	50
	D %	n/a	n/a	n/a

4.34.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to IPCC source category and fuel type.

4.34.4 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 6**.

4.34.5 Source Specific Recalculations

There have been no recalculations to emissions from this sector.

4.34.6 Source Specific Planned Improvements

It is noted that this sector is part of an identified key category this year, and that this sector uses a tier 1 method. This sector has been reviewed recently, and is only a minor part of the key category, so the UK doesn't currently consider this to be a priority item for improvement, but obviously this position will change if new data were to come to light and activity data and emission factors will be kept under review.

4.35 SOURCE CATEGORY 2F6 – OTHER (INCLUDING TRANSPORT OF REFRIGERANTS)

4.35.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2F6b: Refrigerant Containers	Tier 2a	CS, D
Gases Reported	HFCs		
Key Categories	2F: Product Uses as Substitutes for ODS - HFCs (L2)		
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 **Section 1.8**.		
Major improvements since last submission	New to the 2015 submission		

4.35.2 Methodological Issues

Under the 2006 GLs, a new term in the IPCC Tier 2a method emissions equation for the Refrigeration and Air Conditioning sector is introduced to include emissions from the management of refrigerant containers used to service existing refrigeration/air-conditioning equipment, including refrigerant cylinders used by professional service technicians and small cans used by Do-It-Yourselfers (DIYers). No Tier 1 methodology is provided for this source.

Emissions from refrigerant containers occur when refrigerant is transferred from bulk containers (e.g., 40-tonne isotanks) to smaller capacity containers, typically ranging from approximately 300-500 grams (small cans) to 10-15 kg (cylinders). Emissions also occur at time of disposal if the refrigerant “heel” is not fully recovered. IPCC 2006 GLs require that emissions from each type of refrigerant container be calculated separately for refrigerant sold in small cans and in cylinders, including both disposables and reusables. The IPCC 2006 GLs default disposal emissions factors are 20% for small cans and 2% for disposable cylinders. Although the GLs do not specify a default emission rate for losses during the transfer of refrigerant into smaller containers, they do specify a default loss rate of 0.5 during the charging of refrigeration/air-conditioning equipment.

ICF reviewed available literature to develop key assumptions on stock and emission factors—notably, Enviros (2008), Defra (2008), BRA (2010), and contacted the five largest refrigerant Fillers & Packers in the UK that reported sales data to BRA in order to confirm/refine the estimates (BOC, A-Gas, National Refrigerant, Harp International and IDS Refrigeration Ltd.). ICF received feedback from two of these fillers and packers—Harp International and BOC—as well as from BRA. The sections below outline the assumptions and methodology applied based on this process.

4.35.2.1 Stock

Annual stock estimates were developed using data on the sales of refrigerant into the UK market from BRA (2010) for the years 2006 – 2010. This sales data disaggregated by refrigerant type and channels of distribution in 2009 and 2010. According to BRA (2013), the Fillers and Packers rebottle the refrigerant from 1 tonne containers purchased from producers into smaller containers. Average cylinders in the UK are assumed to be 13.6 kg, while small cans are assumed to be 340 g (Harp International 2013, Enviros 2008). The average growth rate of individual refrigerant sales from 2006 – 2010 (BRA 2010) was used to determine the refrigerant sales in years prior to 2006. From 2011-2012, it was assumed that refrigerant sales remained constant at 2010 levels, due to the wide ranging trends across refrigerants in recent years, and the uncertain impact of pending revisions to the EC F-gas Regulations. Based on historical refrigerant sales into the mobile versus stationary sectors from BRA (2010), it is assumed that approximately 40% of HFC-134a is sold into the mobile sector, 90% of which is sold in cylinders for professional servicing of motor vehicle air-conditioners (MVACs), while the remaining 10% is sold into small cans for use by DIYers servicing their own MVACs. It should be noted that the actual percent of service jobs performed by professionals versus DIYers in the UK, or the number of small cans sold onto the market, is highly uncertain. The remaining 60% of HFC -134a is sold into the stationary sector in 13.6 kg cylinders.

In July 2008, disposable refrigerant cylinders were banned from the UK market. Because historical data on the sale of disposable versus reusable cylinders prior to the 2008 ban are not available, ICF assumed that the UK refrigerant cylinder market included 50% disposables and 50% refillables from 1990 to 2007. To account for the transition due to the regulation from the use of disposables to the use of 100% refillables in 2009, it was assumed that the market consisted of 75% refillable containers and 25% disposables in 2008.

4.35.2.2 Chemicals in Use

According to BRA (2010), HFC-134a and HFC refrigerant blends R-404A, R-507A, R-407C, and R-410A are the dominant refrigerants sold in this sector. As BRA sales data for R-404A and R-507A are combined, it was assumed that R-404A represents 95% of sales and R-507A the remaining 5% (SKM Enviros 2014). BRA data also provides sales values for “Other HFC Blends”. “Other HFC Blends” represent only 1.4% of the market in 2006 which increases to 10.8% in 2010. Based on consultation with industry stakeholders, it was assumed that “Other HFC Blends” sales are evenly distributed amongst R-407F and R-407A. For the sake of HFC reporting, blends are shown based on their original constituents.

4.35.2.3 Emission Factors

A summary of the assumed emission factors is provided in the table below. The packaging loss rate of 0.1% is based on consultation with Harp International (2013) and SKM Enviros (2014). This rate is deemed conservative but appropriate for the UK industry as a whole, although certain facility-specific emissions are reportedly as low as 0.005%, based on mass balance measurements taken by Harp International (2013). The disposal loss rates for disposable cylinders and small cans are based on IPCC default values, which are further supported by Enviros (2008); the disposal loss rate for refillable cylinders is based on SKM Enviros (2014).

Table 4.27 Summary of Emission Factors for the Refrigerant Container Sector Emission Factor

Loss rate	Disposable cylinders	Refillable cylinders	Small Cans
Packaging Loss Rate	0.1%	0.1%	0.1%
Disposal Loss Rate	2.0%	0.1%	20%

A major industrial gas supplier in the UK confirmed that all containers (cylinders and small cans) sold on the UK market are filled and packaged in the UK (BOC 2013). Data on refrigerant container exports from the UK are not avialable. Packaging emission factors are applied to the total amount of refrigerant sold. Disposal emission factors were similarly applied annually to total refrigerant sales. As seen in the table above, these emission factors for cylinders are dependent upon the timing of the 2008 regulation. Harp International emphasized that strong economic incentives drive the recovery and recycling of refrigerants from cylinders, therefore leaks during recovery are generally minimised and these estimates are considered to be conservative (Harp International 2013).

It should be noted that the disposal emission factor for small cans may be overstated in recent years, as information indicates that there has been a UK industry take-back program in place for small cans since April 2010 to reduce refrigerant disposal losses and increase recycling; however, because the extent to which this take-back program has been implemented across the UK is unclear, emission factors have conservatively not been reduced.

4.35.3 Uncertainties and Time Series Consistency

Emissons of HFCs increase over time until the regulation in July 2008 banned disposable refrigerant cylinders. This ban caused a steep decrease in emissions from this sector. Following this legislation, emissions increased slightly due to rising servicing demand in the refrigeration and air conditioning sector.Source Specific

4.35.4 QA/QC and Verification

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to IPCC source category and fuel type.

4.35.5 Source Specific Recalculations

Not applicable.

4.35.6 Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

4.36 SOURCE CATEGORY 2G1 – ELECTRICAL EQUIPMENT

4.36.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2G1 – Electrical Equipment	T1, T2	CS
Gases Reported	SF_6		
Key Categories	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 **Section 1.8**.		
Major improvements since last submission	No major improvements		

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.

4.36.2 Methodological Issues

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.

4.36.3 Uncertainties and Time Series Consistency

As stated above, the method makes best use of good quality available data and is a considerable improvement on previous estimates.

4.36.4 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 6**.

4.36.5 Source Specific Recalculations

There have been no recalculations to emissions from this sector.

4.36.6 Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

4.37 SOURCE CATEGORY 2G2A – MILITARY APPLICATIONS – AWACS

4.37.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2G2a – Military applications - AWACS	T1	D
Gases Reported	SF_6		
Key Categories	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 **Section 1.8**.		
Major improvements since last submission	No major improvements		

Military applications include Airborne Warning and Control System (AWACS), which are military reconnaissance planes. In AWACS, the SF_6 is used as an insulating gas in the radar system.

4.37.2 Methodological Issues

A Tier 1 method, country specific activity data, and an IPCC default emission factor of 740 kg SF_6 per plane per year is used to estimate emissions.

The method use the total number of planes carrying AWACs as the activity data. ICF's research of the UK Royal Air Force (RAF) website confirmed that the RAF carries the same number of AWACS (seven) in 2012 as reported in the 2006 GLs (RAF, 2013). ICF further confirmed that RAF has had seven AWACS since 1990. Indeed, AWACS are a part of the Number 8 squadron of the RAF and they were acquired in 1985 (8 Squadron 2012). However, of the seven AWACS present in UK Fleet, not all are designated as forward available fleets. During times of low activity, some AWACS are placed as depth fleet, i.e., not operational, and therefore do not contribute to emissions. In 2012, only four AWACs were classified as forward available fields (MOD 2012).

4.37.3 Uncertainties and Time Series Consistency

The Tier 1 method relies on a constant emission factor, but actual emissions will vary based on the number of sorties (missions), with emissions higher during periods of high military operations and lower during times of low military operations.

4.37.4 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 6**.

4.37.5 Source Specific Recalculations

There have been no recalculations to emissions from this sector.

4.37.6 Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

4.38 SOURCE CATEGORY 2G2B – PARTICLE ACCELERATORS

4.38.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2G2b – Particle Accelerators	T1, T2	D
Gases Reported	SF_6		
Key Categories	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 **Section 1.8**.		
Major improvements since last submission	No major improvements		

Particle accelerators are used for research purposes (at universities and research institutions), for industrial applications (in cross-linking polymers for cable insulation and for rubber parts and hoses), and in medical (radiotherapy) applications.

Estimates of emissions in the UK are confined to those from research and university accelerators particle accelerators.

4.38.2 Methodological Issues

The emissions from industrial particle accelerators are a result of leakage during operation and repair. Research and industrial high voltage systems usually need to be opened more frequently than industrial low voltage accelerators. Hence the emission factor of low voltage industrial accelerators is comparably lower. In the case of radiotherapy applications, industrially pre-set particle accelerators with hollow conductors filled with SF_6 are used. The emissions of SF_6 are planned releases. Radiotherapy accelerators are typically opened two times a year when being serviced and the SF_6 contained is not captured but completely released. (Schwartz, 2005).

SF_6 emissions from research and university accelerators are estimated using an IPCC Tier 2 method – an accelerator-level emission-factor approach. This required information on the

individual charge of the various research and university accelerators operating in the UK. This information is used in the following equation along with default emission factors (IPCC 2006):

Total emissions = University and research particle accelerator Emission Factor x Σ Individual Accelerator Charges

Where:

SF_6 university and research particle accelerator Emission Factor = 0.07 kg SF_6 per kg SF_6 charge, the average annual university and research particle accelerator emission rate as a fraction of the total charge.

Individual Accelerator Charges = SF_6 contained within each university and research accelerator.

The SF_6 emissions from medical and industrial accelerators are estimated using a Tier 1 method – country-level method. Given the scale of the number of medical and industrial particle accelerators, it was not feasible to collect individual charge information of each accelerator. The Tier 1 estimation method consists of the following equation, which relies on default emission factors (IPCC 2006):

Emissions = (number of particle accelerators that use SF_6 by process description in the country) x (SF_6 charge factor, kg) x (SF_6 applicable particle emission factor)

Where:

Number of particle accelerators by type in the country = The total number of particle accelerators by type (industrial high voltage, industrial low voltage and radiotherapy)

SF_6 charge factor = The average SF_6 charge in a particle accelerator by process description.

SF_6 particle accelerator Emission Factor = The average annual SF_6 particle accelerator emission rate as a fraction of the total charge by process description. These factors are presented in the table below.

Table 4.28 IPCC default Tier 1 particle accelerator emission factors

Process Description	SF_6 Charge Factor, kg	Emission Factor, kg/kgSF_6 charge
Industrial Particle Accelerators – high voltage (0.3-23 MV)	1300	0.07
Industrial Particle Accelerators – low voltage (<0.3 MV)	115	0.013
Medical (Radiotherapy)	0.5	2.0

For the Particle Accelerators sector, ICF (ICF 2014) contacted the Science and Technology Facilities Council (STFC) and the Cockcroft Institute to gather activity data for the Tier 1 and Tier 2 methods. STFC and the Cockcroft Institute were able to provide ICF with the charge information, years of operation and status of usage of SF_6 in the research and university particle accelerators in the UK. It is assumed that the charges of the accelerators are constant for all the years. For one facility whose charge was unavailable, a default charge in Tier 1 was assumed.

The Cockcroft Institute also provided an approximate estimate of the number of low voltage industrial accelerators in the UK for 2012—approximately 100 (Cockcroft Institute 2013). The total number of medical accelerators for 2012 was estimated from a list of accelerators compiled by a member of STFC, estimated at 50 (STFC, 2013). Due to the large number of medical and industrial accelerators, collecting accelerator-specific charge data was not feasible. Therefore, a Tier 1 approach was used to estimate emissions. To confirm the number of accelerators, ICF also solicited information from the National Physical Laboratory and the Institute of Engineering and Technology, but without success. In the absence of specific information on the number or percent of medical particle accelerators that use SF_6, ICF conservatively assumed that 100% of UK medical particle accelerators use and emit SF_6. To estimate SF_6 emissions for years 1990-2011 and 2013, emissions have been scaled from the 2012 estimate based on historical UK GDP growth rates.

4.38.3 Uncertainties and Time Series Consistency

Emissions of research and university particle accelerators are very high for the period 1990-1992. This is because of the operation of the Nuclear Structure Facility that held 135 tonnes of SF_6 charge. After its closure in 1992 (assumed to be at the end of 1992), the emissions of research and university particle accelerators and medical and industrial accelerators are comparable. In 2004, the only operational particle accelerator ceased usage of SF_6 and, hence, the emissions are considered to be zero. Three other particle accelerators began operation in 2010, 2011, and 2012, respectively, leading to non-zero but small SF_6 emissions due to their small charges.

For the medical and industrial particle accelerators, the emissions rise as they were estimated based on GDP as proxy.

4.38.4 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 6**.

4.38.5 Source Specific Recalculations

There have been no recalculations to emissions from this sector.

4.38.6 Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

4.39 SOURCE CATEGORY 2G2E – SF_6 AND PFCS FROM OTHER PRODUCT USE

4.39.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2E1: Integrated circuit or semiconductor manufacture	T2a	D
	2G2: SF_6 as a tracer gas	T3	D, CS
	2G2: Training shoes (sporting goods)	T2	CS
Gases Reported	PFCs, SF_6, NF_3		
Key Categories	None identified		
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 from sporting goods are calculated by scaling emissions from the UK model using a suitable scaling factor (population). There are no emissions from the manufacture of integrated circuits or semiconductor manufacture, and from training shoes, from the OTs and CDs.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in **Section 1.8**.		
Major improvements since last submission	No major improvements		

Emissions of PFCs and SF_6 from the production of semiconductors, the use of SF_6 as a tracer gas, and PFCs and SF_6 from sporting goods (training shoes) have been combined in order to preserve the confidentiality of estimates of emissions of SF_6 and PFCs used in training shoes.

4.39.1.1 Integrated circuit or semiconductor manufacture:

PFCs, SF_6 and NF_3 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.

4.39.1.2 Use of SF_6 as a tracer gas in scientific research:

The UK uses of SF_6 as a tracer in scientific research.

4.39.1.3 Use and disposal of training shoes:

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

chemically and biologically inert and its high molecular weight means it cannot easily diffuse across membranes. This means the gas is not released until the training shoe is destroyed at the end of its useful life.

The manufacturer committed itself to eliminating SF_6 from its training shoes by 30 June 2003 – a goal which was achieved. It had originally planned to replace all SF_6 applications with nitrogen-filled cushioning but technical difficulties mean it had to switch temporarily to perfluoropropane (a PFC) in some high-performance applications. The use of F gases in footwear was banned in 2006 by the F-gas Regulation and discussions with the manufacturer have confirmed that they are no longer using PFCs or SF_6.

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

4.39.2 Methodological Issues

4.39.2.1 Semiconductor manufacture:

ICF (2014) updated estimates of emissions from this source.

The 2006 GLs provide an updated method for estimating semiconductor manufacture emissions as compared to the 2000 GPG. Specifically, the 2006 GLs include updated methodologies for each tier, updates to emission factors, as well as inclusion of other sectors in the electronics manufacturing source category – flat panels display manufacturing, and photovoltaic manufacturing. For the semiconductor manufacture sector, the 2006 GLs Tier 1 method estimates emissions based on the amount of substrate processed, in units of m^2. The Tier 1 method in the 2000 GPG most closely resembles the Tier 2a method of the 2006 GLs, which estimates emissions based on gas-specific consumption data, as well as the amount left in shipping containers after use, use rate of gas, fraction of gas used in processes with emission control technologies, and the fraction of gas destroyed by the emission control technology.

The 2006 GL Tier 2a method is represented by the following equation:

$$\text{Emissions for } E_i = (1-h)*FC_i*(1-U_i)*(1-a_i*d_i)$$

Where:

i = F-gas species

E_i = emissions of gas_i, kg

h = fraction of gas i remaining in container (heel)

FC_i = consumption of gas_i, kg

U_i = use rate of gas_i

a_i = abatement rate of gas_i

d_i = fraction of gas_i destroyed by the abatement

The Tier 2a method also introduces by-product emissions of CF_4, C_2F_6, C_3F_8 and CHF_3. In the 2000 GPG, by-product emissions were limited to only CF_4. The Tier 2a equation used for by-product emissions is:

$$\text{By-Product Emissions of gas j } (BPE_{j,i}) = (1-h)*B_{j,i}*FC_i*(1-a_i*d_j)$$

Where:

$BPE_{j,i}$ = by-product emissions of gas *j* from the gas *i* used, kg

$B_{j,i}$ = emission factor, kg gas *j* created/kg gas *i* used

d_j = fraction of gas *j* by-product destroyed by the abatement

j = CF_4, C_2F_6, CHF_3 and C_3F_8

The 2006 GLs also introduce updated emission factors, or use rates for gases. The destruction rates of abatement systems have been assumed to be the same in the 2006 GLs for all species except NF_3. The destruction rate of NF_3 has been updated to 0.95 from 0.90.

4.39.2.1.1 Approach to estimating emissions

ICF attempted to update consumption data based on actual consumption as opposed to the previous approach of estimating consumption based on growth rates. However, it was not feasible to collect individual gas collection data from each of the semiconductor manufacturers.

ICF identified several potential sources to use to update the activity data (i.e., consumption data) –notably, the National Microelectronics Institute (NMI) and European Semiconductor Industry Association (ESIA). ESIA collects industry F-gas emissions data at the European level and the data is not broken down by Member State; therefore UK-level emissions were not available via ESIA. ICF requested NMI to consult its members to ascertain availability of activity data, but no response was received in time for the analysis. Hence, the previous approach of estimating activity data based on assumed growth rates (which is compliant with the 2006 GLs) was kept.

The NF_3 consumption has been further sub-divided into NF_3 Remote Clean and all other NF_3 consumption (i.e., for in-situ chamber clean and etch processes). NF_3 remote clean refers to a cleaning method for chemical vapour deposition chambers in which the film cleaning-agents formed from NF_3 (F-atoms) are produced in a plasma upstream (remote) from the chamber being cleaned (IPCC 2006). In situ chamber cleans are chemical vapour deposition chamber cleaning processes, which may use NF_3 or other F-gases to generate F-atoms in the chambers whose walls are being cleaned. NF_3 may also be used to etch patterns (i.e., circuits) on semiconductors. The use of NF_3 remote clean is assumed to start in 2003 and growing increasingly over time. Because no data on the UK's use of NF_3 remote clean processes was made available from NMI, the US semiconductor market was used as a proxy to estimate the use of NF_3 in remote clean processes relative to all other processes.

Specifically, the share of NF_3 remote clean versus other uses was estimated based on industry-reported NF_3 usage data from US semiconductor manufacturers for the years 2009 and 2010 (US EPA, 2011). This US data was readily available and is believed to be a good proxy for the UK given that semiconductor processes do not typically vary by world region. The ratio of NF_3 remote to other uses was interpolated for years between 2003 and 2009, assuming 0.0 (nil) in the year 2003. This was done as 2006 GLs provide emission factors for the NF_3 use in remote clean and NF_3 in-situ and etch use.

4.39.2.1.2 Emission factors and other default factors

The emission factors used in the updated inventory were taken from 2006 GLs. A summary of the emission factors for the 2006 GL Tier 2a method is provided in the table below.

Table 4.29 Summary of 2006 GL Tier 2a emission factors for the semiconductor manufacture sector

Process Gas (i)[a]	CF_4	C_2F_6	CHF_3	CH_2F_2	C_3F_8	c-C_4F8	NF_3 Remote	NF_3	SF_6
Emission Factor (1-Ui)[b]	0.9	0.6	0.4	0.1	0.4	0.1	0.02	0.2	0.2
BCF_4	NA	0.2	0.07	0.08	0.1	0.1	0.02[c]	0.09	NA
BC_2F_6	NA	NA	NA	NA	NA	0.1	NA	NA	NA
BC_3F_8	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA = no data available based on information available during time of publication.

[a] Bx = X is a by-product from the usage of another gas (in row headings).

[b] Ui = Utilization rate of gas i.

[c] Estimate reflects presence of low-k, carbide and multi-gas etch processes that may contain C-containing FC additive.

The default value used for the fraction of gas remaining in the shipping container (heel) is 0.10, which is unchanged from the IPCC 2000 GPG. The destruction efficiencies for emission control technologies are updated according to the 2006 GLs. The new default values are unchanged from the 2000 GPG for all gases other than NF_3, 0.90. For NF_3, the default was updated from 0.90 to a new value of 0.95.

Table 4.30 Key assumptions used to estimate emissions from semiconductor manufacture

Gas	Destruction efficiency[32]	1990	1995	2000	2005	2010	2011	2012	2013
		Consumption, kg							
CF_4	0.9	1,113	2,594	5,752	3,158	3,352	3,651	3,976	4,330
C_2F_6	0.9	4,549	10,607	23,519	12,914	13,707	14,927	16,256	17,702
C_3F_8	0.9	219	440	893	601	1,027	1,119	1,218	1,327
C_4F_8	0.9	14	28	57	38	65	71	78	84
CHF_3	0.9	814	1,638	3,324	2,129	3,428	3,771	4,148	4,563
SF_6	0.9	519	1,043	2,116	1,355	2,183	2,401	2,641	2,905
NF_3	0.95	924	1,859	3,772	2,416	3,891	4,281	4,709	5,179
		Fraction fed to abatement							
CF_4		0%	0%	0%	15%	40%	45%	45%	45%
C_2F_6		0%	0%	0%	15%	40%	45%	45%	45%
C_3F_8		0%	0%	0%	15%	40%	45%	45%	45%
C_4F_8		0%	0%	0%	15%	40%	45%	45%	45%
CHF_3		0%	0%	0%	15%	40%	45%	45%	45%
SF_6		0%	0%	0%	15%	40%	45%	45%	45%
NF_3		90%	90%	90%	100%	100%	100%	100%	100%

4.39.2.2 Use of SF_6 as a tracer gas in scientific research:

SF_6 is used in a number of applications in the UK

- Tracer gas to certify fume hoods
- UK studies of greenhouse gas emissions

[32] Destruction Efficiency: Source: IPCC 2006 Guidelines, Chapter 6, Table 6.6

ICF investigated the use of tracer gas to certify fume hoods.

The use of SF_6 as a tracer gas to certify fume hoods is a practice established by ASHRAE in the test procedure ASHRAE-110, "Method of Testing Performance of Laboratory Fume Hoods" (ASHRAE,1995). SF_6 is emitted in the fume hood and the concentration of the gas is measured after some time has passed. This is to ensure that the gases created under the fumes, toxic or otherwise, are properly ventilated. The amount of gas used per test is dependent on the tester. All of the SF_6 used in tracer tests is lost in the atmosphere and so the emissions are treated as prompt emissions—i.e., each test results in direct emissions of SF_6 (IPCC 2006). SF_6 is also used for tracer testing of nuclear power plant control room emergency ventilation systems (CARB, 2009).

Due to data limitations, SF_6 emissions were estimated using a slightly modified Equation 8.23 of Volume 3 of the 2006 GLs. The SF_6 emission is calculated on a per-use basis as opposed to the amount purchased/sold as provided in the equation. This modified method relies on the number of tracer tests conducted annually as the activity data, which when multiplied by the emissions per test as the emission factor, gives the total SF_6 emissions from this sector. This method is represented in the following equation:

Total emissions = emissions per test x number of tests

Additional emissions may also occur from bottling, leakage, and piping; however, such emissions cannot be estimated without activity data and are believed to be de minimis.

In order to apply the method above, ICF had to gather information on the number of tracer tests conducted annually (activity data) and the emissions per test (emission factor). ICF first identified various companies that performed fume hood tracer testing. ICF contacted the three largest companies that perform tracer tests in the UK (Crowthorne, Dale Flow, and Invent-UK) and obtained the company-specific emissions per test and the total number of tests performed in 2012 (Crowthorne 2013, Dale Flow 2013, Invent-UK 2013). For the prior years, the total numbers of tests have been estimated by scaling the number of tests performed in 2012 to the UK's historical GDP growth rate. The amount of emissions per test for prior years was held constant unless a company specified that the volume had increased after a certain period. The value of the emissions per test differed among companies and ranged from 0.033 to 0.046 kg SF_6 per test.

ICF also verified when these companies came into existence. Other, smaller companies were identified but were not contacted as—according to qualitative information from Dale Flow (2013)—the bulk of the market is covered by the three major companies, and any additional research was not expected to result in significant changes to the emission estimates, which only account for a very small share of total F-gas emissions.

ICF also contacted Sellafield Ltd, a nuclear decommissioning company, which uses SF_6 to conduct tracer tests, and included their company specific emission factor and total number of emissions (Sellafield, 2013).

Finally, ICF contacted the UK Nuclear Regulation Agency to confirm if there is any use of SF_6 in the tracer testing of nuclear power plant control room emergency ventilation systems in the UK. ICF was unable to obtain information because the inquiry did not fall within the remit of the Office of Nuclear Regulation/Health and Safety Executive. However, ICF experts believe that such use was replaced many years ago.

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 4.31 Quantities of SF_6 used in scientific research

Year	kg SF_6
2011	1.224
2012	1.433
2013	0.270
2014	0.273
Total	**3.200**

More details of the work can be found at www.ghgplatform.org.uk.

4.39.2.3 Use and disposal of training shoes:

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).

Speciated emissions for OTs and CDs are reported in this category. Emission estimates from the UK GHGI were scaled by population of each territory as appropriate.

4.39.3 Uncertainties and Time-Series Consistency

The trend in F-gas emissions between years 2003 and 2012 is the result of two competing characteristic features used in the emission estimation methodology – (1) the growth in usage due to assumed growth rates, leading to an increase in emissions; and (2) an increase in abatement practices, leading to a decrease in emissions. After the introduction of abatement practices, the emissions are estimated to decrease despite growth in the industry. However, beginning in 2011, it is observed that the increase in abatement is not enough to keep up with the growth in the industry, resulting in a slight overall increase in emissions.

Estimates of emissions in some categories of this sector are based on very limited and uncertain data, and are therefore uncertain.

More information on uncertainty data used in the uncertainty analysis is presented in **Annex 2**.

4.39.4 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 6**.

4.39.5 Source Specific Recalculations

For information on the magnitude of recalculations, see **Section 10**.

4.39.6 Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

4.40 SOURCE CATEGORY 2G3 – N_2O FROM PRODUCT USES

4.40.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2G3a Medical applications	T1	CS
Gases Reported	N_2O		
Key Categories	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not estimated		
Completeness	Emissions from medical applications in veterinary and dental practices and private hospitals are not accounted for; total emissions from these sources will be much smaller than the uncertainty in the conservative NHS estimate. A general assessment of completeness for the inventory is included in **Section 1.8**.		
Major improvements since last submission	This is a new source to the 2015 inventory.		

4.40.2 Methodological Issues

Nitrous oxide emissions from use as an anaesthesia is a new source to be estimated in the 2015 UK greenhouse gas inventory. A report was produced on the results of research on potential methodologies for a number of sources newly identified in the 2006 IPCC guidelines which includes finding on N_2O used as an anaesthetic[33].

Suppliers of N_2O declined to provide data, therfore emissions have been calculated using the outcomes of a study by NHS England (2013). This report calculates the total N_2O emissions based on the number of bed-days in NHS England 2011 – 2012, multiplied by the EU GHG inventory derived emission factor of 10.3 kg N_2O/bed/year[34]. This provides an estimated total N_2O emission of 1,641,147 kg per annum, arising from the use of anaesthetic at NHS England facilities.

In order to expand this figure to incorporate all emissions within the United Kingdom a per-capita N_2O emission of 0.031 kg per annum has been derived from the total N_2O figure provided in the Carbon Footprint report. This has then been applied to the total population for the England, Wales, Scotland and Northern Ireland between 1990 and 2013 to provide a time-series of emissions.

[33] http://uk-air.defra.gov.uk/assets/documents/reports/cat07/1501271253_Impact_of_changes_to_IPCC_guidelines_report.pdf

[34] http://www.eea.europa.eu/publications/european-union-greenhouse-gas-inventory-2013

4.40.3 Uncertainties and Time Series Consistency

As the duration of a patient's hospital stay can vary considerably, the use of bed-days as an indicator of N_2O should be considered to have a high degree of uncertainty. Additionally this methodology doesn't take into account N_2O used in non-NHS hospital environments (for example dental and veterinary practices or private hospitals), however total emissions from these sources are estimated to be much smaller than the uncertainty in the conservative NHS estimate.

The time series estimate does not consider trends in the uptake of alternative anaesthetics or alternative approaches to applying N_2O as an anaesthetic, as some methods can reduce the consumption of N_2O. Though using population as an indicator of trend should well reflect demand for anaesthetics, it would not take into account changing practices. We also make the assumption that the rest of the UK consumes anaesthetic in the same way as England.

4.40.4 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**.

4.40.5 Source Specific Recalculations

For information on the magnitude of recalculations, see **Section 10**.

4.40.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.41 SOURCE CATEGORY 2H1 – PULP AND PAPER INDUSTRY

4.41.1 Source Category Description

Emissions sources	2H1: 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 **Section 1.8**.
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 2H1. 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.

4.41.2 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, 2014). Production of the wood products is estimated from data published by the Office of National Statistics (2014). 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.

4.42 SOURCE CATEGORY 2H2 – FOOD AND BEVERAGES INDUSTRY

4.42.1 Source Category Description

Emissions sources	2H2: 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 **Section 1.8**.
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 2014. 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.

4.42.2 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 (2014), 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 4.32 NMVOC Emission Factors for Food and Drink Processing, 2014

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		0.017[b]	kg/tonne
Margarine and solid cooking fat		10[f]	kg/tonne
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

5 Agriculture (CRF sector 3)

5.1 OVERVIEW OF SECTOR

IPCC Categories Included	3A: Enteric Fermentation 3B: Manure Management 3D: Agricultural Soils 3F: Field Burning of Agricultural Residues 3G: Liming 3H: Urea application
Gases Reported	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
Key Categories ('T' or 'L' indicates whether it's been identified in the trend or level assessment respectively and the number indicates which KCA approach it was identified in)	3A: Enteric Fermentation - CH_4 (L2, T2) 3A1: Enteric fermentation from Cattle - CH_4 (L1, T1) 3A2: Enteric fermentation from Sheep - CH_4 (L1) 3B: Manure Management - CH_4 (L2) 3B: Manure Management - N_2O (L2) 3B1: Manure management from Cattle - CH_4 (L1) 3D: Agricultural soils - N_2O (L1, T1, L2, T2)
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	A general assessment of completeness for the inventory is included in **Section 1.8**.
Major improvements since last submission	3A, 3B, 3D and 3F: Implementation of the 2006 guidelines 3D: Emissions from PRP are now included for OTs and CDs. 3H: New source identified in the 2006 IPCC GLs

The agriculture sector has the second largest contribution to total GHG emissions in the UK, after the energy sector. It contributes approximately 8.7% to the total emissions. The emissions from this sector have shown an overall decrease of 18% since 1990, reflecting trends in livestock numbers and emissions from fertiliser application.

Figure 5.1 Breakdown of total GHG emissions in the Agriculture sector in 2013

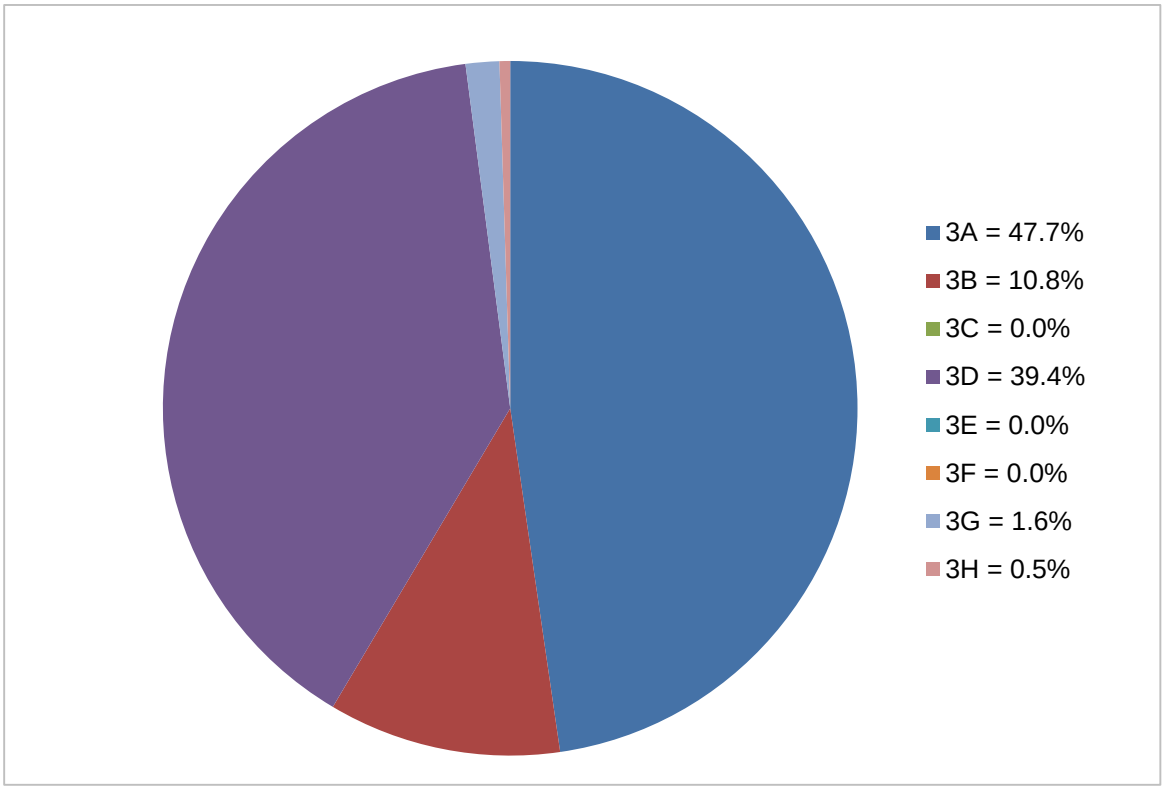
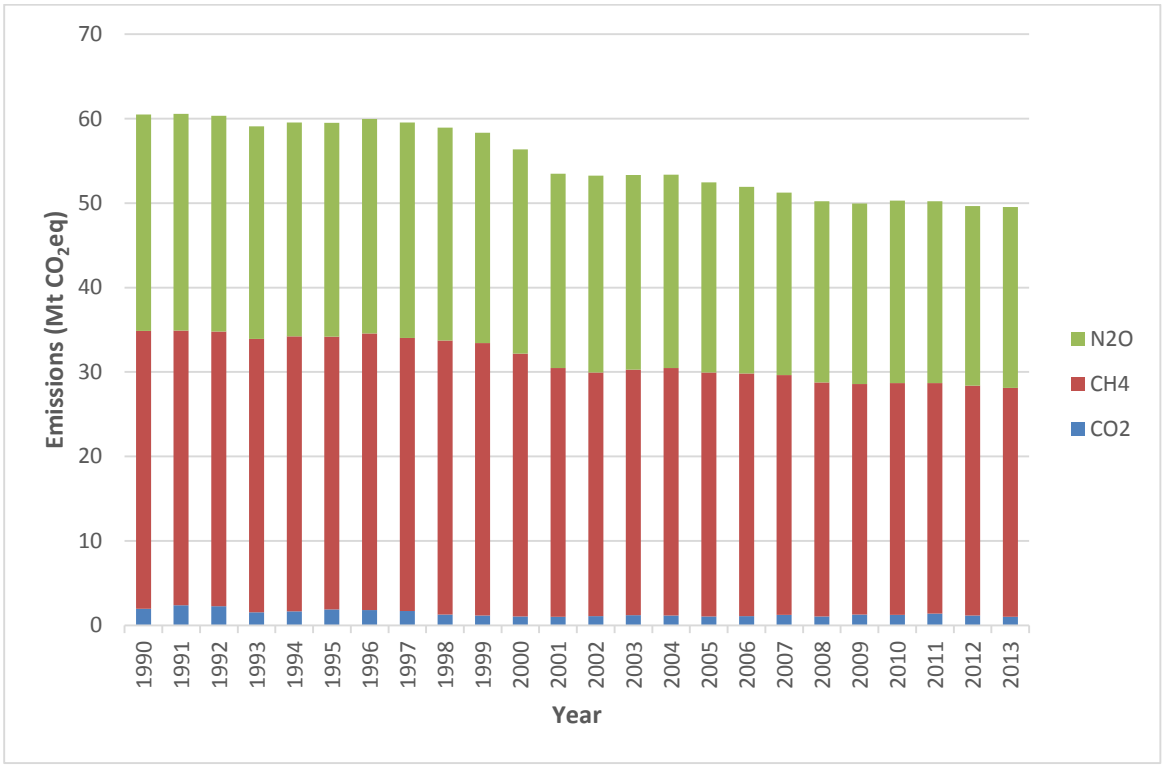


Figure 5.2 Trend in total GHG emissions in the Agriculture sector



5.2 SOURCE CATEGORY 3A – ENTERIC FERMENTATION

5.2.1 Source category description

Emissions sources	Source included	Method	Emission Factors
	3A1: Dairy Cattle Enteric Beef cattle enteric Other Cattle Enteric 3A2: Sheep Enteric 3A3: Pigs Enteric 3A4: Goats Enteric 3A4: Horses Enteric 3A4: Deer Enteric	T2 T2 T2 T1 T1 T1 T1 T1	D,CS D,CS D D,CS D D D D
Gases Reported	CH_4		
Key Categories	3A: Enteric Fermentation - CH_4 (L2, T2) 3A1: Enteric fermentation from Cattle - CH_4 (L1, T1) 3A2: Enteric fermentation from Sheep - CH_4 (L1)		
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 (3A4).2006 IPCC default EFs are applied to animal numbers. Tables of animal numbers used in calculations can be found in **Annex 3.3.**		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in **Section 1.8**.		
Major improvements since last submission	Implementation of the 2006 guidelines		

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.

5.2.2 Methodological issues

Detailed information on activity data and emissions factors can be found in **Annex 3.3**.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 3.3.3** 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[35]. These data are

[35] **England:** https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june and Jennie Blackburn (DEFRA).

Scotland: http://www.scotland.gov.uk/Resource/0045/00455080.xls; http://www.scotland.gov.uk/Resource/0043/00436132.xls and Graeme Kerr (The Scottish Government).

summed to provide UK population data for the livestock categories and subcategories as used in the inventory compilation (See **Tables A3.3.1** and **A3.3.2** 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 and lambs, the methane emission factors are IPCC Tier 1 defaults (IPCC, 2006) and do not change from year to year.

5.2.2.1 Dairy cows

The dairy cattle emission factors (for dairy cows only) are estimated following the IPCC Tier 2 procedure (IPCC, 2006), 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 A3.3.4** and **A3.3.5** 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. Milk yield is obtained from the Defra website[36]. Mature weights for the different dairy size categories were obtained from an analysis of abattoir data (net carcase weight) from four abattoir companies across Great Britain for the years 2008-2012 combined with British Cattle Movement Society (BCMS) data (analysis conducted by Tracy Pritchard, SRUC). Combining the datasets using ear tag identification enabled carcase weight to be linked with breed, gender, age, whether the animal had produced calves and location. Weighted means were obtained for all dairy females that had been slaughtered post-first calf, taking into account the average carcase weight and number of animals in different age groups. A killing out percentage of 47% was applied to all breeds (Juniper et al., 2006), although statistics are lacking on killing out percentage for different dairy breeds. The 1990-2007 time series and data for 2013 was estimated by applying the ratio of the existing UK slaughter data[2] to the estimated dairy liveweights for 2008-2012.

A country-specific value for the digestibility of feed (DE), expressed as a percentage of the gross energy, for dairy cows is used of 74.5234142710097%. This value is on the high side of the IPCC (2006) default value for Western Europe of 55-75% for pasture fed animals, 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 **Tables A3.3.5** and **A3.3.6** in **Annex 3**. 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

Wales: http://wales.gov.uk/docs/statistics/2013/131128-survey-agricultural-horticulture-june-2013-en1.xls and John Bleasdale (Welsh Government).

Northern Ireland: http://www.dardni.gov.uk/index/statistics/crops-livestock-and-labour-numbers/crop-areas-and-production-1981-onwards.htm and Conor McCormack (DARDNI).

[36] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/338225/auk-chapter08-30jul14.xls (Chapter 8 – Livestock, Table 8.5 Milk).

forage can then be derived. The relative proportions of 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 undertaking research to improve activity data on typical forage diets for a range of livestock production systems and aims to provide preliminary data feeding into 2016 submission. 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 **Tables A3.3.6** and **A3.3.7** in **Annex 3**.

5.2.2.2 Beef cows

A Tier 2 methodology is used for the calculation of the enteric emissions from beef cows. Mature weights for the different beef size categories were obtained from an analysis of abattoir data (net carcase weight) from four abattoir companies across Great Britain for the years 2008-2012 combined with British Cattle Movement Society (BCMS) data (analysis conducted by Tracy Pritchard, SRUC). Combining the datasets using ear tag identification enabled carcase weight to be linked with breed, gender, age, whether the animal had produced calves and location. Weighted means were obtained for all beef females that had been slaughtered post-first calf, taking into account the average carcase weight and number of animals in different age groups. A killing out percentage of 50% was applied to all breeds (Minchin et al., 2009), although statistics are lacking on killing out percentage for different beef breeds. The 1990-2007 time series and data for 2013 was estimated by applying the ratio of the existing UK slaughter data[2] to the estimated beef liveweights for 2008-2012. The main parameters involved in the calculation of the emissions factors for beef are shown in **Table A 3.3.8** in **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. Milk yield was from derived from data published in Energy and protein requirements of ruminants (1993).

5.2.2.3 Other cattle

A Tier 1 methodology is used for the calculation of the emissions from other cattle with default EF (2006 guidelines, **Table A 3.3.1** in **Annex 3**). The following eight groups are included: 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.

5.2.2.4 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.

5.2.2.5 Deer

The UK emission factor for deer is the default value (2006 guidelines).

5.2.2.6 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 3.6**. IPCC default emission factors were applied to these data.

5.2.3 Uncertainties and time-series consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to IPCC source category.

Emissions are calculated from animal population data and appropriate emission factors. The animal population data are collected in the June 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.

The estimates of uncertainties in emissions were calculated using Approach 2 (Monte Carlo simulation) described by the IPCC for 1990 and 2013. Activity data uncertainties were provided by the devolved administrations. Tier 2 methods were used to estimate the emission factors for dairy and beef cows and so we estimated the uncertainty in these emission factors by propagating the uncertainty through from the variables used to calculate the emission factors (see Milne et al., 2014). For all other animal categories we used the IPCC Tier 1 emission factors. We chose to use the maximum uncertainty range suggested by Eggleston et al. (2006). That is, ±50% of the expected value.

5.2.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 5.10**.

5.2.5 Source-specific recalculations

Details of and justifications for recalculations to activity data and to emission factors are given in **Table 5.1** and **Table 5.2**, respectively. For information on the magnitude of recalculations to Source Category 3A, see **Section 10** the 2006 guidelines have been adopted in this inventory.

Additionally there have been significant changes in the OT and CD emissions due to the update of the EFs to 2006 IPCC default EFs. Recalculations of emissions from cattle have had the most significant effect for all regions across the whole time series.

Table 5.1 3A Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	2014 submission		2015 submission		Units	Comment/Justification
		1990	2012	1990	2012		
3.A.1	Enteric Fermentation Dairy cows Non-dairy cows	 249.31 400.23	 200.58 348.31	 287.35 584.91	 227.95 526.18	kt	The coefficient for calculating net energy for maintenance from lactating cattle (C_f) has been increased from 0.335 to 0.386 MJ d^{-1} kg^{-1} (2006 GL) – only affects dairy and beef cows. The methane conversion rate (Y_m) has been increased for 'all cattle' from 0.06 to 0.065 (2006 GL) – only affects dairy and beef cows. Following the 2006 GL, the net energy for pregnancy calculation has been weighted by the proportion of mature cows that go through gestation in a year (90%) – only affects dairy and beef cows. The percentage of time spent grazing revised in-line with the NH_3 inventory – only affects dairy and beef cows. The enteric emission factor (EF) for 'other cattle', i.e. all cattle other than dairy and beef cows, has been updated to 57 kg/hd/yr (2006 GL). Previously, an EF of 48 kg/hd/yr was applied to dairy and beef heifers, dairy replacements and all other beef >1 yr and 32.8 kg/hd/yr was applied to dairy and beef calves. NE_l (2006 GL) included in enteric methane EF calculation for beef cows. Modified beef cow milk yield time series. Updated provisional milk yield data for dairy cows for 2012 (from 7445 to 7442 l/yr). Updated dairy and beef cow liveweights.
3.A.4	Enteric Fermentation – Deer	0.42	0.27	0.95	0.62	kt	Stags/hinds/calves all merged into one category for 'deer'. Enteric EF updated from 10.4/5.2 (stags & hinds/calves) to 20 kg CH_4 hd^{-1} yr^{-1} (2006GL).

Table 5.2 3A Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	2014 submission		2015 submission		Units	Comment/Justification
		1990	2012	1990	2012		
3.A.1	Enteric fermentation Dairy cows Non-dairy cows	 87.53 42.83	 110.71 43.06	 100.89 62.60	 125.83 65.05	kg CH_4 $head^{-1}$ yr^{-1}	As IPCC category 3.A.1 above
3.A.4	Enteric Fermentation – Deer	10.4 / 5.2	10.4 / 5.2	20.0	20.0	kg CH_4 $head^{-1}$ yr^{-1}	As IPCC category 3.A.4 above

5.2.6 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.

5.3 SOURCE CATEGORY 3B – MANURE MANAGEMENT

5.3.1 Source category description

Emissions sources	Source included	Method	Emission Factors
	3B11: Dairy Cattle Wastes	T1,T2	CS, D
	Other Cattle Wastes	T1,T2	CS, D
	3B12: Sheep Wastes	T1,T2	CS, D
	3B13: Pigs Wastes	T1,T2	CS, D
	3B14: Goats Wastes	T1,T2	CS, D
	3B14: Horses Wastes	T1,T2	CS, D
	3B14: Broilers Wastes	T1,T2	CS, D
	Laying Hens Wastes	T1,T2	CS, D
	Other Poultry Wastes	T1,T2	CS, D
	3B14: Deer Wastes	T1,T2	CS, D
Gases Reported	CH_4, N_2O		
Key Categories	3B: Manure Management - CH_4 (L2) 3B: Manure Management - N_2O (L2) 3B1: Manure management from Cattle - CH_4 (L1)		
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 3B. A separate category was therefore for N_2O emissions has been included in under Sector 3G - Other. Estimates for CH_4 emissions are calculated using 2006 IPCC default EFs. N_2O estimates are calculated using UK GHGI EFs. A time series of UK EFs are applied to animal numbers. Animal numbers can be found in **Annex 3.6**.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in **Section 1.8**.		
Major improvements since last submission	Implementation of the 2006 guidelines		

This category reports emissions of CH_4 from animal manures as well as N_2O emissions from their manures arising during its storage.

5.3.2 Methodological issues

5.3.2.1 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 5.2.2**. The emission factors are listed in **Table A 3.3.3** in **Annex 3**. **Table A 3.3.10** in **Annex 3** 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 2006, Equation 10.24) is used to determine VS), 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 2006, Table 10.17). The emission factors are listed in **Table A 3.3.3** in **Annex 3**. **Table A 3.3.10** in **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 3.3.11** to **A 3.3.13** 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 (Manure Management report (Ken Smith); Smith et al 2000, 2001; C Savery & B Cottrill, ADAS, pers comm.; ADAS 1990-2000; Sheppard, 1998, 2002; FPS 2001, 2006, 2009, 2014; BSFP 2007 - 2013 (Table D1.5); T. Watcher (EPR), pers. comm.; MMS 1996;) 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 2013 are given in **Table A 3.3.12** in **Annex 3.**).

5.3.2.2 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 (2006) (equation 10.25) 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, 2006). 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 3.3.11** 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 3.3.13** in **Annex 3**. Emissions from poultry are calculated following IPCC (2006) where manure is allocated to poultry with or without bedding or destined for incineration.

Emissions from the following AWMS are reported under the Manure Management IPCC category:

- Uncovered anaerobic lagoons. These are assumed not to be in use in the UK.
- Liquid/slurry
- Deep bedding (previously deep bedding).
- Poultry manure with/out bedding or destined for incineration; IPCC (2006)

According to IPCC (2006) guidelines, 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 bedding for electricity generation are reported under power stations. Emissions occurring during storage of poultry bedding that will later be used for energy generation are included in the agricultural inventory (tonnage of poultry bedding incinerated obtained directly from EPR (Teresa Wachter Fuel Operations Manager, Energy Power Resources Limited), a total of 462,000 tonnes for 2013.

Estimation of indirect N_2O emissions from manure management have been introduced to the IPCC (2006) guidelines. N volatilisation from manure management systems has been calculated using Equation 10.27 (IPCC 2006 guidelines), along with default fractions for N loss due to volatilisation of NH_3 and NO_x, disaggregated by manure management system ($Frac_{GasMS,}$ 2006GL Table 10.22). Emissions of N_2O from the leaching/runoff associated with the storage of deep bedding as field heaps have been estimated using Equation 10.29 (IPCC 2006 guidelines), using a country-specific $Frac_{leach}$ value of 0.03 (Nicholson et al., 2011).

Table A 3.3.13 in **Annex 3** 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.

5.3.2.3 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 3.6**. 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 Energy & Environment.

5.3.3 Uncertainties and time-series consistency

The uncertainty analysis in **Annex 2** 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.

The estimates of uncertainties in emissions were calculated using Approach 2 (Monte Carlo simulation) described by the IPCC. The uncertainties in the estimates of livestock data were provided by the devolved administrations. Tier 2 calculations were used to estimate the emission factors for all of the animal categories except for deer. We assumed that uncertainty in the calculated emission factors was normally distributed, with a 95% confidence interval of ±20 % of the expected value for Tier 2 emission factors and with a 95% confidence interval of ±30 % of the mean for Tier 1 (Eggleston et al., 2006).

5.3.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC procedures which are discussed in **Section 5.10.**

5.3.5 Source-specific recalculations

Details of and justifications for recalculations to activity data and to emission factors are given in **Table 5.3** and **Table 5.4** respectively. For information on the magnitude of recalculations to Source Category 3B, see **Section 10**.

There have additionally been significant changes in the OT and CD emissions due to the update of the EFs to 2006 IPCC default EFs. Recalculations of emissions from cattle have had the most significant effect for all regions across the whole time series.

Table 5.3 3B Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	2014 submission		2015 submission		Units	Comment/Justification
		1990	2012	1990	2012		
3.B.1.1	Methane Emissions from Manure Management Dairy cows Non-dairy cows	 97.52 141.50	 77.72 121.38	 40.28 81.61	 30.86 71.94	kt	The coefficient for calculating net energy for maintenance from lactating cattle (C_f) has been increased from 0.335 to 0.386 MJ d^{-1} kg^{-1} (2006 GL) – only affects dairy and beef cows. The methane conversion rate (Y_m) has been increased for 'all cattle' from 0.06 to 0.065 (2006 GL) – only affects dairy and beef cows. Following the 2006 GL, the net energy for pregnancy calculation has been weighted by the proportion of mature cows that go through gestation in a year (90%) – only affects dairy and beef cows. The percentage of time spent grazing revised in-line with the NH_3 inventory – only affects dairy and beef cows. NE_l (2006 GL) included in enteric methane EF calculation for beef cows. Modified beef cow milk yield time series. Updated provisional milk yield data for dairy cows for 2012 (from 7445 to 7442 l/yr). Updated dairy and beef cow liveweights. Updated MCF for liquid (crust/no crust) and deep bedding (2006 GL). Updated VS and B_o values to 2006 GL values. The VS value for dairy and beef cows has been recalculated according to equation 10.24 in the IPCC 2006 GL. Updated AWMS data to match NH_3 inventory
3.B.1.2	Methane Emissions from Manure Management – Sheep	13.45	9.79	8.65	6.30	kt	Updated MCF for liquid (crust/no crust) and deep bedding (2006 GL). Updated VS and B_o values to IPCC 2006 GL values. Updated AWMS data to match NH_3 inventory

IPCC Category	Source Name	2014 submission		2015 submission		Units	Comment/Justification
		1990	2012	1990	2012		
3.B.1.3	Methane Emissions from Manure Management – Swine	158.17	85.25	43.61	23.34	kt	Updated MCF for liquid (crust/no crust) and deep bedding (2006 GL). Updated VS and B_o values to IPCC 2006 GL values. Updated AWMS data to match NH_3 inventory
3.B.1.4	Methane Emissions from Manure Management – Goats	0.05	0.05	0.03	0.03	kt	Updated MCF for liquid (crust/no crust) and deep bedding (2006 GL). Updated VS and B_o values to IPCC 2006 GL values. Updated AWMS data to match NH_3 inventory
3.B.1.4	Methane Emissions from Manure Management – Horses	0.79	1.42	0.89	1.60	kt	Updated VS and B_o values to IPCC 2006 GL values. Updated AWMS data to match NH_3 inventory
3.B.1.4	Methane Emissions from Manure Management – Poultry	14.99	18.64	2.51	3.19	kt	Updated VS and B_o values to IPCC 2006 GL values. Updated AWMS data to match NH_3 inventory
3.B.1.4	Methane Emissions from Manure Management – Deer	0.0103	0.0068	0.0104	0.0069	kt	The deer manure management EF has been revised. Stags/hinds/calves all merged into one category for 'deer'. Updated MCF for liquid (crust/no crust) and deep bedding (2006 GL). Updated AWMS data to match NH_3 inventory
3.B.2.1	Nitrous oxide Emissions from Manure Management Dairy cows Non-dairy cows	 1.76 5.08	 0.80 4.36	 1.26 2.46	 0.93 2.11	kt	Updated AWMS data to match NH_3 inventory. Updated provisional milk yield data for dairy cows for 2012 (from 7445 to 7442 l/yr). Updated EF3 to IPCC 2006 GL.
3.B.2.2	Nitrous oxide Emissions from Manure Management – Sheep	0.31	0.22	0.15	0.11	kt	Updated AWMS data to match NH_3 inventory. Updated EF3 to IPCC 2006 GL.
3.B.2.3	Nitrous oxide Emissions from Manure Management – Swine	1.43	0.79	0.66	0.38	kt	Updated AWMS data to match NH_3 inventory. Updated EF3 to IPCC 2006 GL.
3.B.2.4	Nitrous oxide Emissions from Manure Management – Goats	0.0013	0.0013	0.0026	0.0026	kt	Updated AWMS data to match NH_3 inventory. Updated EF3 to IPCC 2006 GL. Corrected minor error (incorrect link).
3.B.2.4	Nitrous oxide Emissions from Manure Management – Poultry	2.21	2.41	0.14	0.14	kt	Updated AWMS data to match NH_3 inventory. Updated EF3 to IPCC 2006 GL.

IPCC Category	Source Name	2014 submission 1990	2014 submission 2012	2015 submission 1990	2015 submission 2012	Units	Comment/Justification
3.B.2.4	Nitrous oxide Emissions from Manure Management – Deer	0.0041	0.0027	0.0024	0.0016	kt	Updated AWMS data to match NH_3 inventory. Updated EF3 to IPCC 2006 GL. Stags/hinds/calves all merged into one category for 'deer'.
3.B.2.5	Nitrous oxide Emissions from Manure Management – Indirect emissions						New source of emissions included in IPCC 2006 GL.
	Atmospheric deposition	N/A	N/A	3.05	2.37	kt	
	Leaching and runoff	N/A	N/A	0.05	0.03		

Table 5.4 3B Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	2014 submission 1990	2014 submission 2012	2015 submission 1990	2015 submission 2012	Units	Comment/Justification
3.B.1.1	Methane Emissions from Manure Management					kg CH_4/hd/yr	As IPCC category 3.B.1.1 above
	Dairy cows	34.24	42.90	14.14	17.03		
	Non-dairy cows	15.14	15.01	8.73	8.89		
3.B.1.2	Methane Emissions from Manure Management – Sheep	0.30	0.30	0.19	0.20	kg CH_4/hd/yr	As IPCC category 3.B.1.2 above
3.B.1.3	Methane Emissions from Manure Management – Swine	20.95	19.02	5.78	5.21	kg CH_4/hd/yr	As IPCC category 3.B.1.3 above
3.B.1.4	Methane Emissions from Manure Management – Goats	0.48	0.48	0.31	0.31	kg CH_4/hd/yr	As IPCC category 3.B.1.4 above
3.B.1.4	Methane Emissions from Manure Management – Horses	1.39	1.39	1.56	1.56	kg CH_4/hd/yr	As IPCC category 3.B.1.4 above
3.B.1.4	Methane Emissions from Manure Management – Poultry	0.12	0.12	0.02	0.02	kg CH_4/hd/yr	As IPCC category 3.B.1.4 above
3.B.1.4	Methane Emissions from Manure Management – Deer	0.2197	0.2197	0.2200	0.2200	kg CH_4/hd/yr	As IPCC category 3.B.1.4 above
3.B.2.1	Nitrous oxide Emissions from Manure Management					kg N_2O/hd/yr	As IPCC category 3.B.2.1 above
	Dairy cows	0.62	0.44	0.44	0.51		
	Non-dairy cows	0.54	0.54	0.26	0.26		

IPCC Category	Source Name	2014 submission 1990	2014 submission 2012	2015 submission 1990	2015 submission 2012	Units	Comment/Justification
3.B.2.2	Nitrous oxide Emissions from Manure Management – Sheep	0.01	0.01	0.003	0.003	kg N_2O/hd/yr	As IPCC category 3.B.2.2 above
3.B.2.3	Nitrous oxide Emissions from Manure Management – Swine	0.19	0.18	0.09	0.09	kg N_2O/hd/yr	As IPCC category 3.B.2.3 above
3.B.2.4	Nitrous oxide Emissions from Manure Management – Goats	0.01	0.01	0.03	0.03	kg N_2O/hd/yr	As IPCC category 3.B.2.4 above
3.B.2.4	Nitrous oxide Emissions from Manure Management – Poultry	0.02	0.02	0.001	0.001	kg N_2O/hd/yr	As IPCC category 3.B.2.4 above
3.B.2.4	Nitrous oxide Emissions from Manure Management – Deer	0.09	0.09	0.05	0.05	kg N_2O/hd/yr	As IPCC category 3.B.2.4 above
3.B.2.5	Nitrous oxide Emissions from Manure Management – Indirect emissions Atmospheric deposition Leaching and runoff	N/A		0.02 0.01	0.02 0.01	kg N_2O/hd/yr	As IPCC category 3.B.2.5 above

5.3.6 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.

5.4 SOURCE CATEGORY 3C – RICE CULTIVATION

This source is not relevant in the UK.

5.5 SOURCE CATEGORY 3D – AGRICULTURAL SOILS

5.5.1 Source category description

Emissions sources	Source included	Method	Emission Factors
	3D1: Direct N_2O Emissions From Managed Soils 3D2: Indirect N_2O Emissions From Managed Soil	T1, T1a T1	D CS
Gases Reported	N_2O		
Key Categories	3D: Agricultural soils - N_2O (L1, T1, L2, T2)		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Emissions included under 3D1.7 'other' within the CRF. These estimates use tier 1 methodology and 2006 IPCC default EFs.		
Completeness	A general assessment of completeness for the inventory is included in **Section 1.8**.		
Major improvements since last submission	Implementation of the 2006 guidelines, emissions from PRP are now included for the OTs and CDs.		

Direct emissions of nitrous oxide from agricultural soils are estimated using the IPCC recommended methodology (IPCC, 2006) but incorporating some UK specific parameters. The IPCC method involves estimating contributions from:

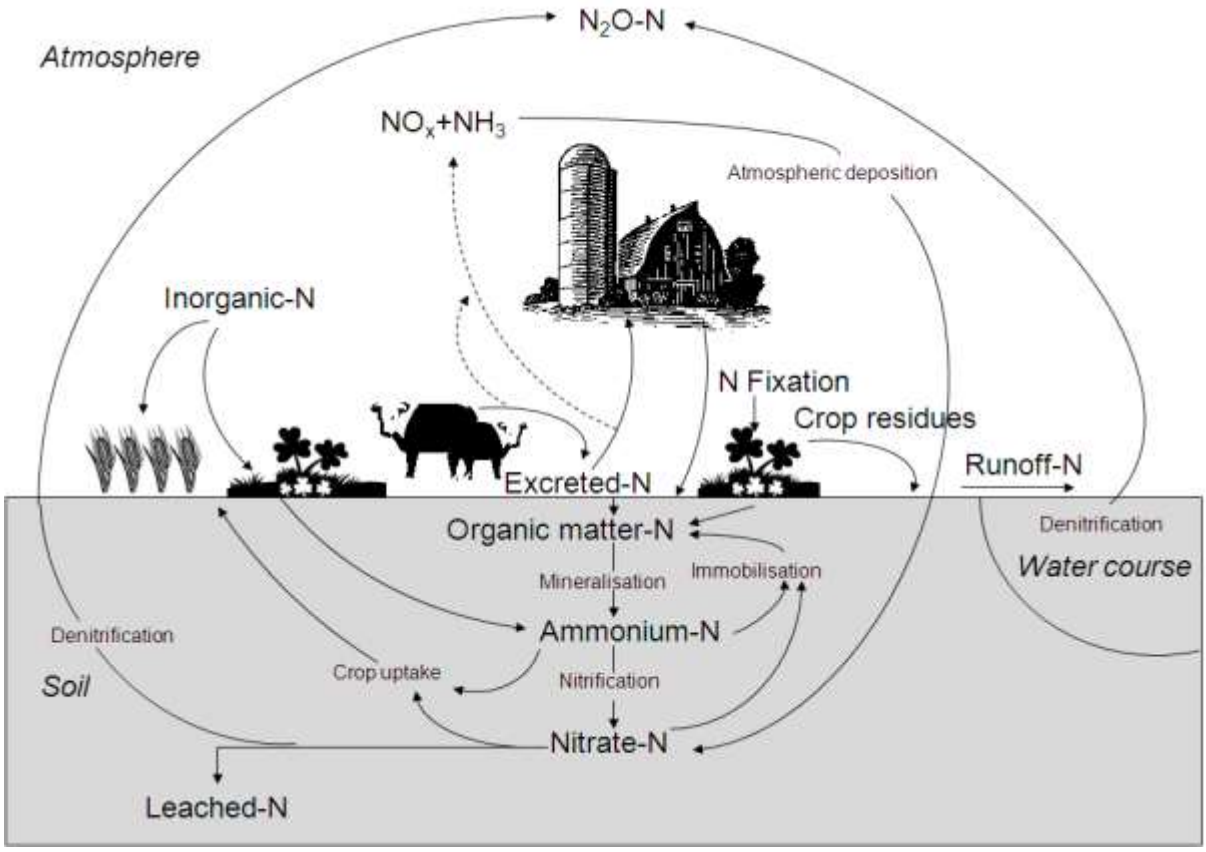
(i) The use of inorganic fertilizer
(ii) Application of livestock manures to land
(iii) Application of sewage sludge to land
(iv) Urine and dung deposited by grazing animals in the field
(v) Crop residues returned to soils
(vi) Mineralisation
(vii) Cultivation of histosols (organic soils)

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

(viii) Emission of N_2O from atmospheric deposition of agricultural NO_x and NH_3
(ix) Emission of N_2O from leaching and run-off of agricultural nitrate

Descriptions of the methods used are described in **Section 5.5.2**. A nitrogen cycle is included to describe the sources of N_2O from agriculture (**Figure 5.3**).

Figure 5.3 Simplified nitrogen cycle highlighting the steps involved in the production of N_2O from agriculture.



5.5.2 Methodological issues

5.5.2.1 Inorganic Fertiliser

Emissions from the application of inorganic fertilizer are calculated using the IPCC (2006) Tier 1 methodology (equation 11.1) and IPCC default emission factors.

Annual consumption of synthetic fertilizer is estimated based on crop areas from the Devolved Administrations[37] and the British Survey of Fertiliser Practice (plus country-specific data for Northern Ireland provided by Paul Caskie, DARDNI) as shown in **Table A 3.3.14** in **Annex 3**. **Table A 3.3.15** in **Annex 3** shows the trend in areas and fertiliser N application rates for the major crop categories over the period 1990-2013.

[37] **England**: https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june and Jennie Blackburn (DEFRA).

Scotland: http://www.scotland.gov.uk/Resource/0045/00455080.xls; http://www.scotland.gov.uk/Resource/0043/00436132.xls and Graeme Kerr (The Scottish Government).

Wales: http://wales.gov.uk/docs/statistics/2013/131128-survey-agricultural-horticulture-june-2013-en1.xls and John Bleasdale (Welsh Government).

Northern Ireland: http://www.dardni.gov.uk/index/statistics/crops-livestock-and-labour-numbers/crop-areas-and-production-1981-onwards.htm and Conor McCormack (DARDNI).Northern Ireland: http://www.dardni.gov.uk/june-agricultural-census-final-results and Paul Caskie, DARDNI

5.5.2.2 Application of livestock manures to land

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.

The summation is for all animal types and manure previously stored in categories defined as a) liquid, b) deep bedding and c) poultry manure without bedding and poultry manure with bedding (bedding) and destined for incineration.

The UK follows the 2006 guidelines. This assumes that a significant proportion of the total N excreted by animals in managed systems is lost prior to final application to managed soils. The estimate of managed manure N available for application to managed soils is based on equation 10.34 in the 2006GL which takes account of the total nitrogen loss from manure management ($Frac_{LossMS}$) and N added in the form of bedding, disaggregated by manure management system. For daily spreading of manure and application of previously stored manures to land, the emission is given by equation 11.1 of the 2006 guidelines. The summation is for all animal types and manure that is daily spread or previously stored in categories defined as a) liquid, b) deep bedding and c) other (poultry manure without bedding or poultry manure with bedding (bedding)). The fraction of livestock N excretion in excrements burned for fuel is expressed as a fraction of all livestock groups N.

5.5.2.3 Application of sewage sludge to land

Following the 2006 IPCC guidelines, 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 3.3.16**). Data sources for the annual production of sewage sludge (as dry matter) are described in Waste sector, see **Section 7.5**.

The UK follows the 2006 IPCC guidelines (equation 11.1).

5.5.2.4 Urine and dung deposited by grazing animals in the field

Emissions from urine and dung deposited by grazing animals are reported under agricultural soils by IPCC. The method of calculation is the same as that for AWMS (**Section 5.3.2.2**), 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 (**Table A 3.3.12** in **Annex 3**).

5.5.2.5 Crop Residues returned to soils

Emissions of nitrous oxide from the ploughing in of crop residues are calculated using the 2006 guidelines methodology and IPCC default emission factors using equation 11.1 of the 2006 IPCC guidelines.

Production data of crops are provided by Lindsay Holmes, DEFRA (England & Wales), Nicola Kerr, The Scottish Government and Alison Lambert, DARDNI, as well as the BHS vegetable survey (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/339108/hort-dataset-31jul14.xls) and the cereal and oilseed survey (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/267314/structure-june-ukcerealoilseed-19dec13.xls) and are shown in **Table A 3.3.18** in **Annex 3**. The dry mass fraction of crops and residue fraction are given in **Table A 3.3.17** in **Annex 3**. 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).

5.5.2.6 Mineralisation

N_2O emissions from mineralisation of soil organic matter on land converted to Cropland more than 20 years ago are included in the Agricultural inventory (emissions from more recent land use change are included in the LULUCF inventory). The emissions are estimated using the areas of Forest land and Grassland converted to Cropland from the land use change matrices and the IPCC Tier 1 emission factors. Further information is available in **Annex 3.3.3.6**.

5.5.2.7 Cultivation of histosols (organic soils)

Emissions from histosols are estimated using the IPCC (2006) default factor of 8 kg N_2O-N/ha/yr. The area of cultivated histosols is estimated at 285,700 ha (as in **Annex 3.3.3.7**).

5.5.2.8 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 2006 IPCC guidelines. 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 equation 11.9 of the 2006 IPCC guidelines.

The method used corrects for the N content of manures used as fuel (poultry bedding incineration).

5.5.2.9 Leaching and runoff

Indirect emissions of N_2O from leaching and runoff are estimated according the 2006 IPCC guidelines using equation 11.10. The sources of nitrogen considered, are synthetic fertiliser application and animal manures applied as fertiliser, sewage sludge applied to soils and crop residues.

The method used corrects for the N content of manures used as fuel (poultry bedding incineration).

5.5.2.10 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 3.9**. Emission factors taken from the 2006 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.

5.5.3 Uncertainties and time-series consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to IPCC source category.

Emissions are calculated from a range of activity data and appropriate emission factors (see **Annex 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.

The estimates of uncertainties in emissions were calculated using Approach 2 (Monte Carlo simulation) described by the IPCC. The uncertainties in the estimates of crop areas were

provided by the devolved administrations, and the uncertainties in estimates of fertilizer application rates to crops were calculated from the British Survey of Fertilizer Practice (BSFP). Together these give estimates of fertilizer use. Estimates of the uncertainty in the amount of sewage applied to the land, the nitrogen returned as crop residues and nitrogen from biological fixation were based on Monni et al. (2007) and for estimates of uncertainties associated with nitrogen excretion we followed the IPCC guidelines (Penman et al., 2000) (for more details see Milne et al., 2014). The uncertainties in the emission factors were taken from the IPCC guidelines.

5.5.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 5.10.**

5.5.5 Source-specific recalculations

Details of and justifications for recalculations to activity data are given in **Table 5.5**. For information on the magnitude of recalculations to Source Category 3D, see **Section 10**.

Emission estimates from pasture range and paddock have been added for the OTs and CDs. This has resulted in an increase in N_2O emission estimates across all regions, most notably for the Falkland Islands (0.06 kt increase in N_2O emission estimates in 2012).

Table 5.5 3D Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	2014 submission		2015 submission		Units	Comment/Justification
		1990	2012	1990	2012		
3.D.1.1	Direct Nitrous Oxide Emissions from Managed Soils – Inorganic N fertilisers	28.11	19.86	24.68	17.65	kt	The amount of applied mineral nitrogen fertilisers is no longer adjusted for the amounts of NH_3 and NO_x volatilisation after application to soil. EF_1 for N additions has been updated (2006 GL). Corrected crop area for linseed for 2002 and updated crop area data. Updated fertiliser rates.
3.D.1.2	Direct Nitrous Oxide Emissions from Managed Soils – Organic N fertilisers (Animal manure)	8.36	6.41	4.88	3.78	kt	The amount of applied organic nitrogen fertiliser is no longer adjusted for the amounts of NH_3 and NO_x volatilisation after application to soil (F_{ON} applied to soils is adjusted using eq. 10.34 of the 2006GL). EF_1 for N additions has updated (2006 GL). Updated AWMS data to match NH_3 inventory. Updated provisional milk yield data for dairy cows for 2012 (from 7445 to 7442 l/yr).
3.D.1.2	Direct Nitrous Oxide Emissions from Managed Soils – Organic N fertilisers (Sewage sludge)	0.28	0.73	0.29	0.72	kt	The amount of applied organic nitrogen fertiliser is no longer adjusted for the amounts of NH_3 and NO_x volatilisation after application to soil (F_{ON} applied to soils is adjusted using eq. 10.34 of the 2006GL). EF_1 for N additions has updated (2006 GL). Updated sewage sludge data.
3.D.1.3	Direct Nitrous Oxide Emissions from Managed Soils –Urine and dung deposited by Grazing Animals	21.78	18.77	18.06	15.59	kt	The emission factor to estimate direct N_2O emissions from grazing animals has been revised. Updated AWMS data to match NH_3 inventory. Updated provisional milk yield data for dairy cows for 2012 (from 7445 to 7442 l/yr).
3.D.1.4	Direct Nitrous Oxide Emissions from Managed Soils –Crop residues	7.06	8.06	8.76	9.11	kt	The crop residue N calculation has been modified to account for the contribution of the below-ground nitrogen to the total input of nitrogen from crop residues. EF_1 for N additions has updated. Corrected minor error in calculation of N_2O from beans (human consumption) crop residues. Updated crop production values. Added grassland to crop residues calculation.

IPCC Category	Source Name	2014 submission		2015 submission		Units	Comment/Justification
		1990	2012	1990	2012		
3.D.1.5	Direct Nitrous Oxide Emissions from Managed Soils - Mineralization/Immobilization Associated with Loss/Gain of Soil Organic Matter	N/A	N/A	0.39	0.87	kt	New source of emissions included in 2006 GL.
3.D.1.6	Direct Nitrous Oxide Emissions from Managed Soils - Cultivation of organic soils	1.89	1.89	3.59	3.59	kt	Amended histosols area.
N/A	Direct Soil Emission – N Fixing Crops	0.85	0.38	N/A	N/A	kt	Biological fixation as a direct source of N_2O has been removed (2006 GL).
3.D.2.1	Indirect Nitrous Oxide Emissions from Managed Soils – Atmospheric Deposition	6.41	5.07	5.71	4.56	kt	The amount of applied organic nitrogen fertiliser is no longer adjusted for the amounts of NH_3 and NO_x volatilisation after application to soil (F_{ON} applied to soils is adjusted using eq. 10.34 of the 2006GL). Updated AWMS data to match NH_3 inventory. Updated provisional milk yield data for dairy cows for 2012 (from 7445 to 7442 l/yr). Updated sewage sludge data. Corrected crop area for linseed for 2002 and updated crop area data. Updated fertiliser rates.
3.D.2.2	Indirect Emissions – Nitrogen Leaching and Runoff	33.39	25.63	11.17	9.16	kt	The amount of applied organic nitrogen fertiliser is no longer adjusted for the amounts of NH_3 and NO_x volatilisation after application to soil (F_{ON} applied to soils is adjusted using eq. 10.34 of the 2006GL). Inclusion of indirect emissions from crop residue N (above- and below ground as in the estimation of direct N_2O emission). N from crop residues is only included in the leaching/runoff component of indirect N_2O emission (2006GL Eq. 11.10). The default EF for leached N (EF_5) has been updated. Updated AWMS data to match NH_3 inventory. Updated provisional milk yield data for dairy cows for 2012 (from 7445 to 7442 l/yr). Updated sewage sludge data. Corrected crop area for linseed for 2002 and updated crop area data. Updated fertiliser rates.

Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	2014 submission		2015 submission		Units	Comment/Justification
		1990	2012	1990	2012		
3.D.1.1	Direct Nitrous Oxide Emissions from Managed Soils – Inorganic N fertilisers	0.0125	0.0125	0.01	0.01	kg N_2O-N/kg N	As IPCC category 3.D.1.1 above
3.D.1.2	Direct Nitrous Oxide Emissions from Managed Soils – Organic N fertilisers (Animal manure)	0.0125	0.0125	0.01	0.01	kg N_2O-N/kg N	As IPCC category 3.D.1.2 above
3.D.1.2	Direct Nitrous Oxide Emissions from Managed Soils – Organic N fertilisers (Sewage sludge)	0.0125	0.0125	0.01	0.01	kg N_2O-N/kg N	As IPCC category 3.D.1.2 above
3.D.1.3	Direct Nitrous Oxide Emissions from Managed Soils –Urine and dung deposited by Grazing Animals	0.02	0.02	0.016	0.016	kg N_2O-N/kg N	As IPCC category 3.D.1.3 above
3.D.1.4	Direct Nitrous Oxide Emissions from Managed Soils –Crop residues	0.0125	0.0125	0.01	0.01	kg N_2O-N/kg N	As IPCC category 3.D.1.4 above
3.D.1.5	Direct Nitrous Oxide Emissions from Managed Soils - Mineralization/Immobilization Associated with Loss/Gain of Soil Organic Matter	N/A	N/A	0.006	0.006	kg N_2O-N/kg N	As IPCC category 3.D.1.5 above
3.D.2.2	Indirect Emissions – Nitrogen Leaching and Runoff	0.025	0.025	0.0075	0.0075	kg N_2O-N/kg N	As IPCC category 3.D.2.2 above

5.5.6 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.

5.6 SOURCE CATEGORY 3E – PRESCRIBED BURNING OF SAVANNAS

This source is not relevant in the UK.

5.7 SOURCE CATEGORY 3F – FIELD BURNING OF AGRICULTURAL RESIDUES

5.7.1 Source category description

Emissions sources	Source included	Method	Emission Factors
	3F11: Wheat 3F12: Barley	T1 T1	D D
Gases Reported	CH_4, N_2O, NO_x, CO, NMVOC, SO_2		
Key Categories	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 **Section 1.8**.		
Major improvements since last submission	Implementation of the 2006 guidelines		

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.

5.7.2 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 (Lindsay Holmes, DEFRA (England & Wales), Nicola Kerr, The Scottish Government and Alison Lambert, 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.

5.7.3 Uncertainties and time-series consistency

The uncertainty analysis in **Annex 2**, 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 NO after this date.

5.7.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 5.10.**

5.7.5 Source-specific recalculations

For information on the magnitude of recalculations to Source Category 3F, see **Section 10**.

Table 5.6 3F Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	2014 submission		2015 submission		Units	Comment/Justification
		1990	2012	1990	2012		
3.F	Field burning of agricultural residues – N_2O Field burning of agricultural residues – CH_4	0.26 12.66	0.00 0.00	0.21 8.22	0.00 0.00	kt	The method for calculating CH_4 and N_2O emissions from the burning of agricultural residues has been updated (2006 GL).

Table 5.7 3F Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	2014 submission		2015 submission		Units	Comment/Justification
		1990	2012	1990	2012		
3.F	Field burning of agricultural residues – N_2O Field burning of agricultural residues – CH_4	N/A N/A	N/A N/A	0.7 2.7	0.7 2.7	kg/t dm	As IPCC category 3.F above

5.7.6 Source-specific planned improvements

No improvements are planned.

5.8 SOURCE CATEGORY 3G - LIMING

5.8.1 Source category description

Emissions sources	Source included	Method	Emission Factors
	3G1: Limestone $CaCO_3$ 3G2: Dolomite $CaMg(CO_3)_2$	T1 T1	D D
Gases Reported	CO_2		
Key Categories	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	No activity data available.		
Completeness	A general assessment of completeness for the inventory is included in **Section 1.8**.		
Major improvements since last submission	None		

CO_2 emissions due to the application of lime and related compounds are estimated using the Tier 1 methodology from the IPCC 2006 Guidelines. For calcium carbonate (limestone, chalk and LimeX (an emission factor of 120 tC/kt applied is used, and for dolomite application, 130 tC/kt. These factors are based on the stoichiometry of the CO_2 loss from the carbonates and assume pure limestone/chalk and dolomite. The calcium carbonate content of LimeX (a bi-product of sugar refining) is taken to be 46% based on data from British Sugar.

5.8.2 Methodological issues

The sources of activity data for liming of Agricultural Land are the Minerals Extraction in Great Britain reports, the British Sugar website, the British Survey of Fertiliser Practice, the June Agricultural Censuses and the Statistical Review of Northern Ireland Agriculture. In the LULUCF NIR this has been mentioned in the section “Information on approaches used for representing land areas and on land use databases used for the inventory preparation.

It is assumed that all Cropland is limed and that the areas of Grassland receiving lime are judged pasture grassland (short term (<5 years old) and permanent grassland (>5 years old)) areas 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.

The amount of lime, dolomite and chalk produced for agricultural use annually in Great Britain is reported in the report annual report on Minerals Extraction in Great Britain (ONS 2014a) (available from 1994, sourced from BGS for 1990-1994). All such minerals are assumed to be used within Great Britain in the year of production. Only dolomite is subjected to calcination. However, some of this calcinated dolomite is not suitable for steel making and is returned for addition to agricultural dolomite – this fraction is reported annually by the Office of National Statistics (ONS 2014a) as ‘material for calcination’ under agricultural end use. Calcinated

dolomite, having already had its CO_2 removed, will therefore not cause emissions of CO_2 and hence is not included here. Lime (calcinated limestone) is also used for carbonation in the refining of sugar and is been included in the inventory. The amount of lime purchased annually for agricultural use in Northern Ireland is reported in the Statistical Review of Northern Ireland Agriculture (Department of Agriculture and Rural Development, 2014). It is assumed that this is all limestone, as there are limestone deposits but no dolomite deposits in Northern Ireland.

In the UK lime is applied to both grassland and cropland. Totals areas of grassland and cropland are obtained from annual June Agricultural Census data. The annual percentages of arable and grassland areas receiving lime in administration in Great Britain for 1994-2012 were obtained from the British Survey of Fertiliser Practice (ONS 2014b). Percentages for 1990-1993 were assumed to be equal to those for 1994. The latest statistics were not published in time for inclusion in the inventory so the 2012 figures were used for 2013.

LimeX, by-product of sugar production, is used as a liming material but and therefore not included in BGS data on quarried liming products. Use of LimeX for agricultural liming is estimated using an approximate annual as value quoted on the British Sugar website http://www.britishsugar.co.uk/LimeX.aspx as the exact sales of LimeX are commercially confidential. LimeX is made up of two products with different carbonate content and the median value of these was used to calculate emission as data on the use of each product is commercial confidential.

5.8.3 Uncertainties and time-series consistency

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.

There is good time series consistency as there has been continuity in the published data sources.

5.8.4 Source-specific QA/QC and verification

Emissions from liming are calculated by the Centre for Ecology and Hydrology (CEH) which 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.

In addition to internal quality assurance procedures the submitted inventory data is also checked by Ricardo Energy & Environment (the national inventory compilers) and the European Commission.

In collaboration with Ricardo Energy & Environment, CEH has been developing a QA/QC plan to standardise and structure the way checks on inventory data are carried out. The plan is now being implemented and will be reviewed and updated as required. The QA/QC Plan is embedded into all planning, preparation and management activities of the Inventory. The plan sets out five key Data Quality Objectives (DQOs), covering all principles of Transparency, Consistency, Completeness, Comparability and Accuracy, which help to focus the aims of the annual checking.

5.8.5 Source-specific recalculations

None

5.9 SOURCE CATEGORY 3H - UREA APPLICATION

5.9.1 Source category description

Emissions sources	Source included	Method	Emission Factors
	3H: Urea Application	T1	D
Gases Reported	CO_2		
Key Categories	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting			
Completeness	A general assessment of completeness for the inventory is included in **Section 1.8**.		
Major improvements since last submission	Included as a result of the Implementation of the 2006 guidelines		

CO_2 emissions due to the application of urea and related compounds are estimated using the Tier 1 methodology from the IPCC 2006 Guidelines.

5.9.2 Methodological issues

The annual amount of fertiliser as urea and urea ammonium nitrate (UAN) used in ktN was taken from the NH_3 inventory and values came from the BSFP. Both fertilisers are applied to grassland and cropland in the UK. It was assumed that 35% of UAN was urea. The EF used was the IPCC default value of 0.2 tonne of C tonnes of $urea^{-1}$.

5.9.3 Uncertainties and time-series consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to IPCC source category.

Emissions are calculated from activity data and appropriate emission factors (see Section A 3.5.3). No uncertainty was calculated in the inventory - we assumed that all C in urea is converted to CO_2. According to the IPCC (2006) a default uncertainty of -50% may be applied (Note: uncertainties cannot exceed the default emission factor because this value represents the absolute maximum emissions associated with urea fertilization)

5.9.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 5.10**

5.9.5 Source-specific recalculations

None.

5.10 GENERAL COMMENTS ON QA/QC

The livestock activity data used for constructing the inventory is supplied annually from the June census[38], 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.

[38] **England:** https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june and Jennie Blackburn (DEFRA).

Scotland: http://www.scotland.gov.uk/Resource/0045/00455080.xls; http://www.scotland.gov.uk/Resource/0043/00436132.xls and Graeme Kerr (The Scottish Government).

Wales: http://wales.gov.uk/docs/statistics/2013/131128-survey-agricultural-horticulture-june-2013-en1.xls and John Bleasdale (Welsh Government).

Northern Ireland: http://www.dardni.gov.uk/index/statistics/crops-livestock-and-labour-numbers/crop-areas-and-production-1981-onwards.htm and Conor McCormack (DARDNI).

6 Land-Use, Land Use Change and Forestry (CRF Sector 4)

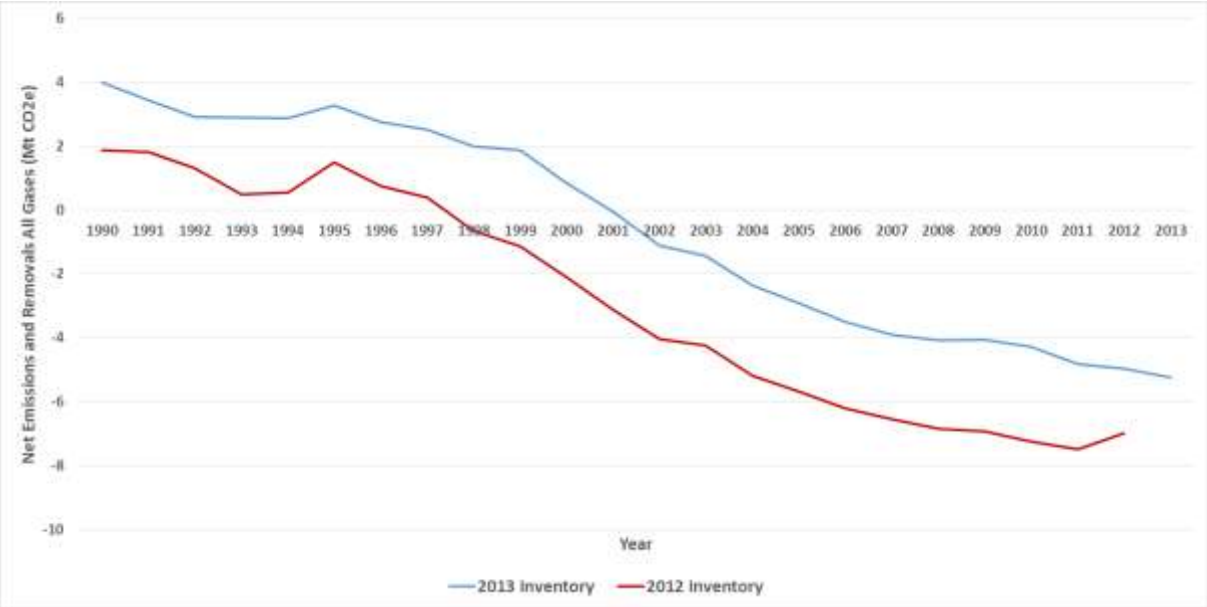
6.1 OVERVIEW OF SECTOR

IPCC Categories Included	4A: Forest Land 4B: Cropland 4C: Grassland 4D: Wetlands 4E: Settlements 4G: Harvested wood products 4H: Other
Gases Reported	CO_2, CH_4, N_2O, NO_x, CO
Key Categories ('T' or 'L' indicates whether it's been identified in the trend or level assessment respectively and the number indicates which KCA approach it was identified in)	4A: Forest Land - CO_2 (L1, T1, L2, T2) 4B: Cropland - CO_2 (L1, T1, L2, T2) 4C: Grassland - CO_2 (L1, T1, L2) 4E: Settlements - CO_2 (L1, T1, L2) 4G: Harvested Wood Products - CO_2 (T1)
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Reported under the relevant sector 4 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 **Section 1.8**.
Major improvements since last submission	Change to reporting using the 2006 AFOLU Guidance structure. Addition of cropland management activity reporting. Inclusion of emissions from drained improved Grassland on organic soils. Removal of carbon stock changes due to yield improvement. The LUC soils and biomass models were re-run using extrapolated rather than projected rates of LUC for 2010-2013.

CRF Sector 4 (LULUCF) includes carbon stock changes and emissions of greenhouse gases (CO_2, CH_4, N_2O, NO_x and CO) from land use, land use change and forestry. Removals of carbon dioxide are conventionally presented as negative quantities. In the 1990-2012 inventory, the sector reported having been a net sink since 1998, with a net removal in 2012 of -6.99 Mt CO_2 equivalent (**Figure 6.1**), or -6.98 Mt CO_2 equivalent including the Overseas Territories and Crown Dependencies (OTs and CDs). The overall trend for 1990-2013 inventory (excluding OTs/CDs) is similar to the 1990-2012 inventory, although the LULUCF sector now reports a smaller sink compared with the 1990-2012 inventory (the smallest annual

difference is between 2.93 Mt CO_2 equivalent compared with the previous submission of 1.30 Mt CO_2 equivalent for 1992, the largest annual difference is between -0.05 Mt CO_2 equivalent compared with the previous submission of -3.12 Mt CO_2 equivalent for 2001). The 1990-2013 inventory shows the sector becoming a sink from 2001, three years later than in the 1990-2012 inventory (**Figure 6.1**). In the 1990-2013 inventory, the sector has a net removal in 2013 of -5.25 Mt CO_2 equivalent, or -5.24 Mt CO_2 equivalent when the Overseas Territories and Crown Dependencies (OTs/CDs) are included. Summary analysis of the trends in greenhouse emissions from the LULUCF sector is provided in **Section 2.3.4**. The methodological differences between the 2012 and 2013 inventories are explained in this chapter, with summary information provided in the table at the start of this chapter (*Major improvements since last submission*).

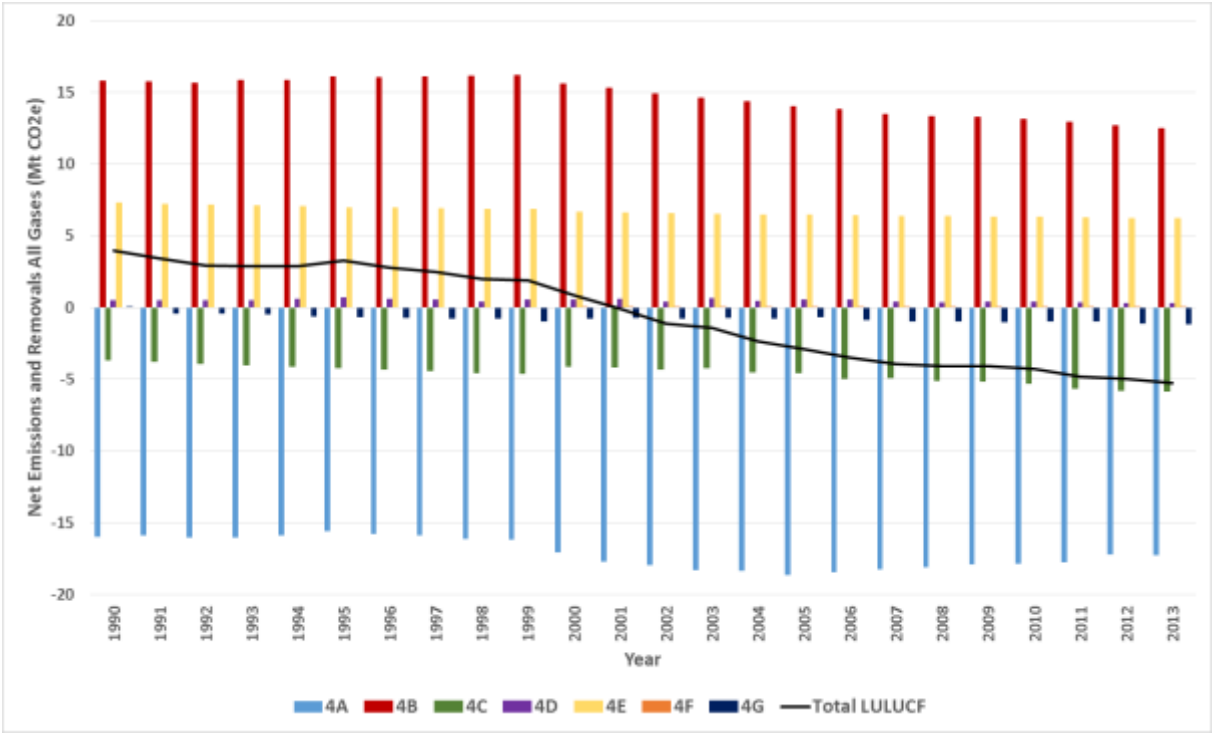
Figure 6.1 LULUCF change in net emissions for all gases between the 2012 and 2013 inventories.



The LULUCF sector covers emissions and removals of direct and indirect greenhouse gases under six categories: 4A: Forest Land, 4B: Cropland, 4C: Grassland, 4D: Wetlands, 4E: Settlements, 4G: Harvested wood products, 4H: Other.

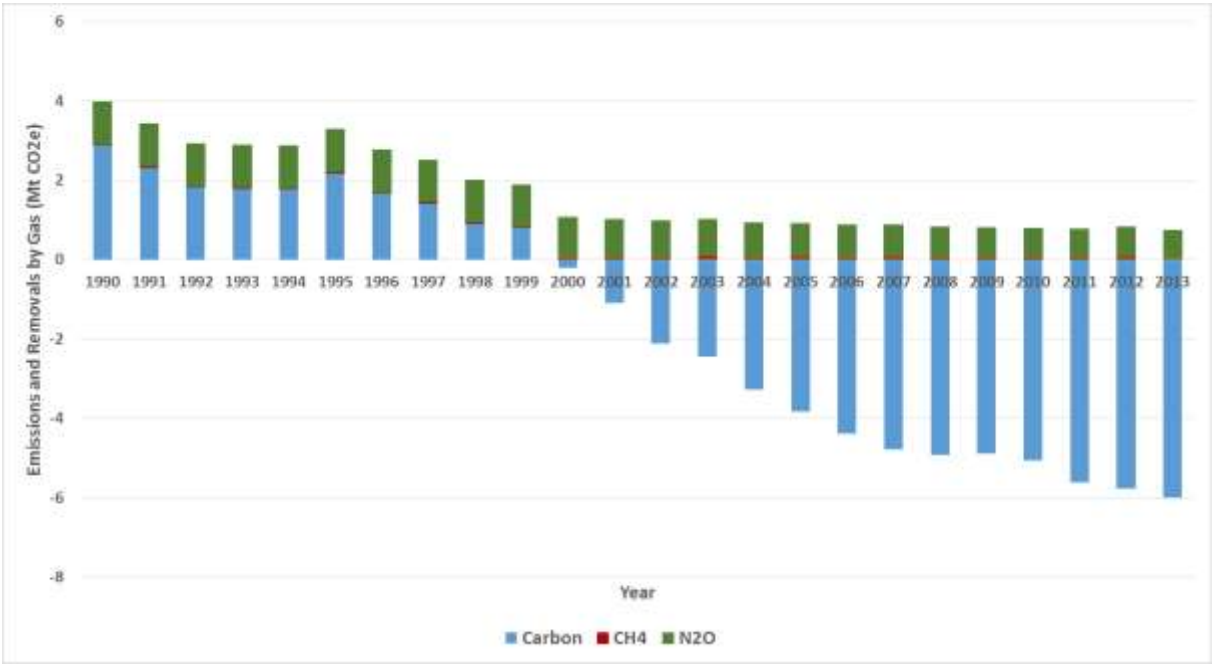
Categories 4A: Forest Land, 4C: Grassland and 4G: Harvested wood products are net sinks. 4B: Cropland, 4D: Wetlands and 4E: Settlements are net sources (**Figure 6.2**).The UK does not report any emissions or removals from 4H: Other.

Figure 6.2 LULUCF emissions and removals from the UK 1990-2013 by category



The LULUCF sector is the only sector within the national greenhouse gas inventory to report net removals. The net sink reported since 2001 is provided by removals from carbon stock gains in above- and below-ground biomass, soils and harvested wood products exceeding emissions from carbon stock losses and GHG emissions from LULUCF activities. The sector is a source of methane and nitrous oxide, but these are lower than the net carbon removals (**Figure 6.3**).

Figure 6.3 LULUCF emissions and removals from the UK 1990-2013 by gas



The inclusion of new activities and the revisions to the methodology and to activity data are described in this chapter and **Annex 3.4** on methods used to estimate emissions and removals.

Activities under Article 3.3 and Article 3.4 of the Kyoto Protocol are reported in **Section 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 4. 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 Crown Dependencies of Jersey, Guernsey and the Isle of Man and the Overseas Territory of the Falkland Islands. These four comprise over 95% of the area in all the OTs and CDs. Gibraltar wished to produce its own inventory: in this case LULUCF net emissions/removals are likely to be extremely small, given the size of the country (6km^2), and will have little impact on overall numbers. 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.

6.1.1 The land use transition matrix

Reporting in CRF Sector 4 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.

Annual land use change matrices from 1990 to the current inventory year are now reported in Table 4.1 (for each year) in the Common Reporting Format tables and are therefore no longer reported in the NIR. The Standard Area Measurement to mean high water is used for the total area of the UK (24,418 kha) (Office for National Statistics 2013). The area of each land use sub-category in the land use transition matrix is calculated as follows:

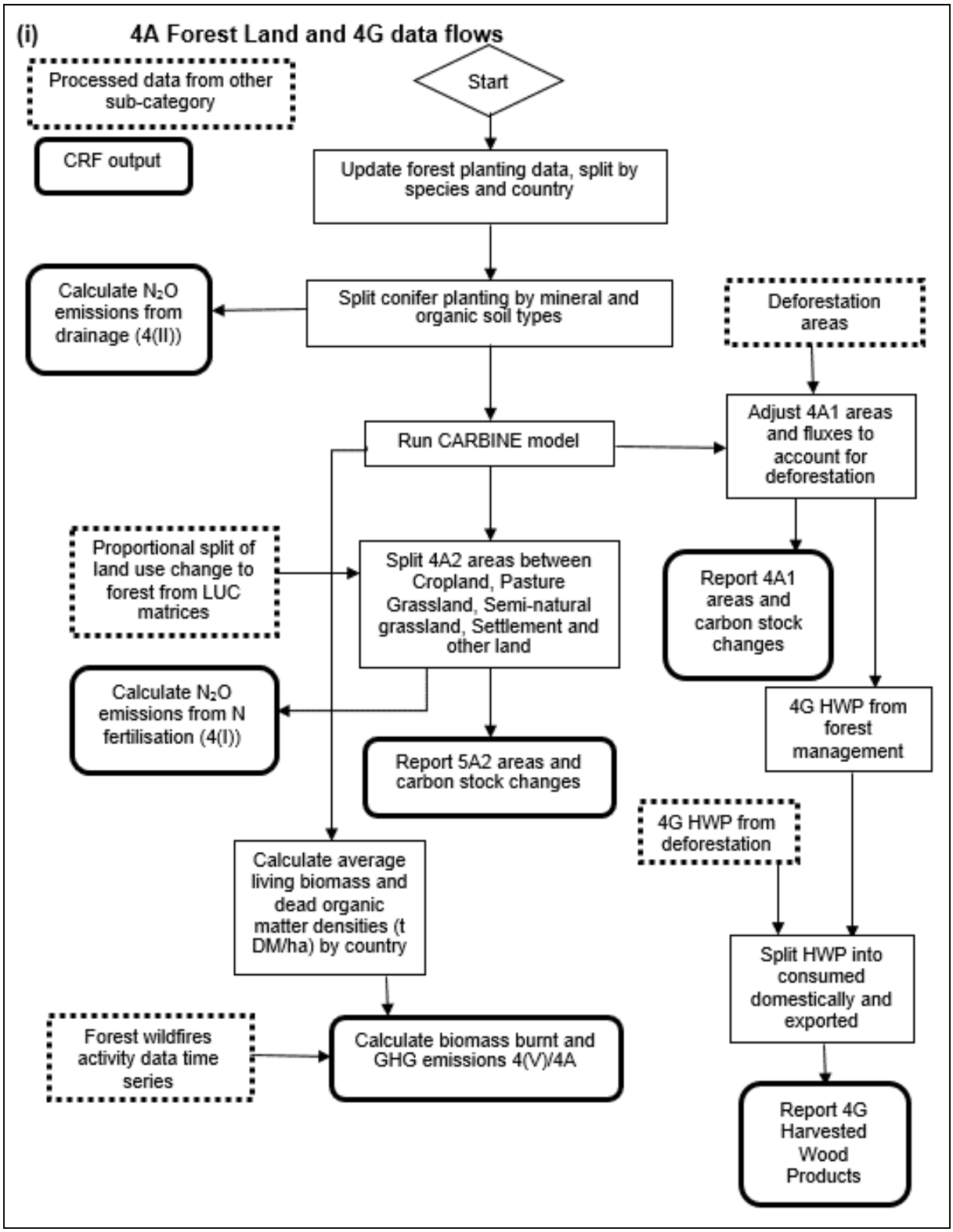
- 4A Forest Land: the area is based on the National Inventory of Woodlands and Trees for a base year of 2000, and annual planting and deforestation statistics, produced by the Forestry Commission, are used to roll the inventory forward to 2013.
- 4B Cropland: the sum of the area of drained histosols on cropland (Anthony, pers. comm.) and the total cropland area reported in the UK agricultural census (Defra 2013a)
    - 4B1 is the total cropland area minus the area of 4B2
    - 4B2 is the area of land use change to Cropland used in the deforestation and LUC soil models
- 4C Grassland: the sum of the area of drained histosols on improved grassland (Anthony unpublished report for Defra project AC0114 pers. Comm.), the area of land use change to Grassland (for 4C1 and 4C2) and a buffer area of undisturbed grassland
    - Land use change to Grassland is the sum of the areas used by the LUC soil model and conversion from forest and peat extraction areas
    - Grassland is the largest land area in the UK, the majority being extensively-grazed semi-natural grassland. The undisturbed grassland area (calculated as the area remaining after all other land use areas are subtracted from the total UK land area (Office for National Statistics 2013) is used as a buffer to ensure that all categories add up to the total area of the UK. The use of this category,

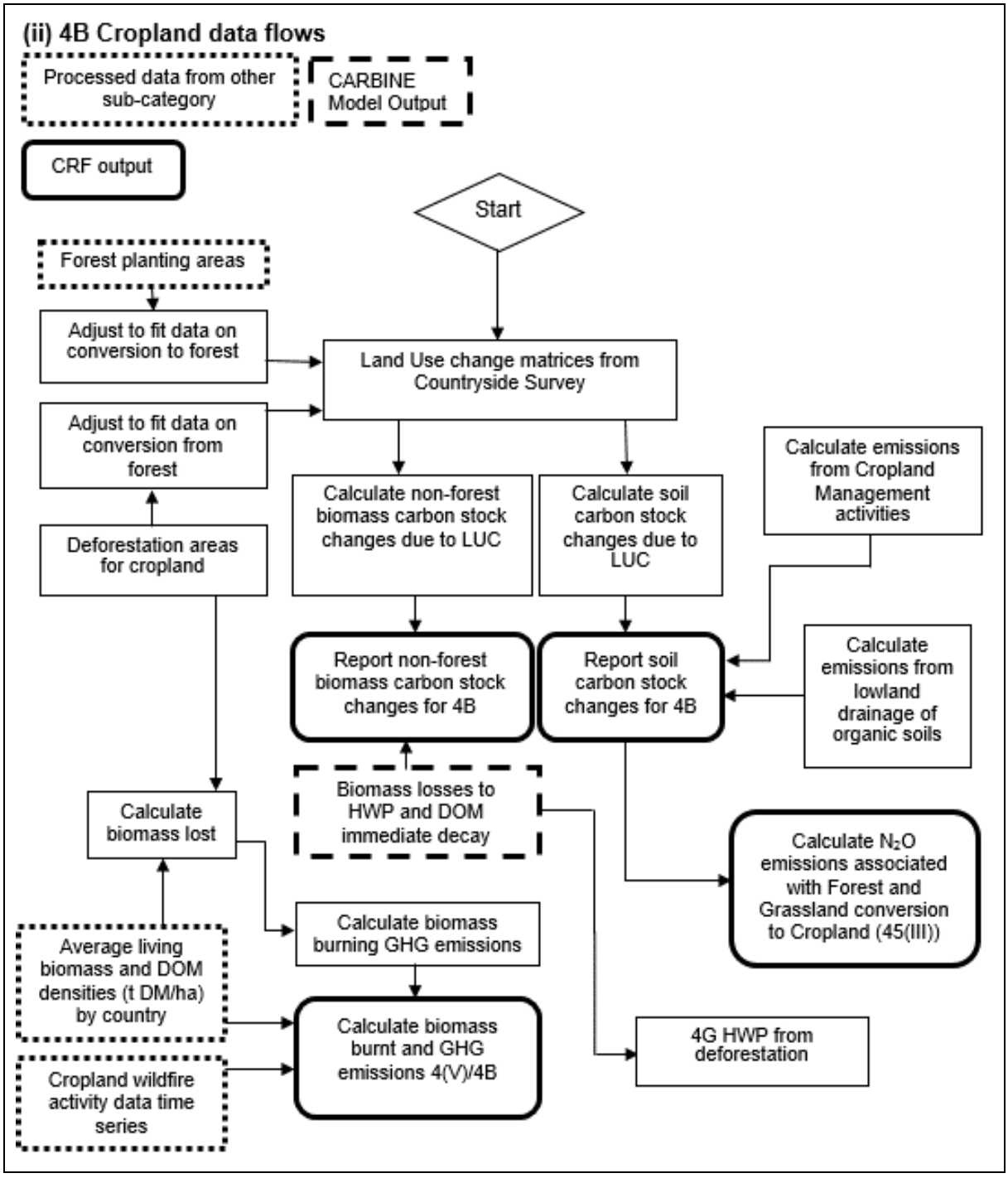
being the largest area, was recommended by UNFCCC reviewers, rather than using the Other Land category.

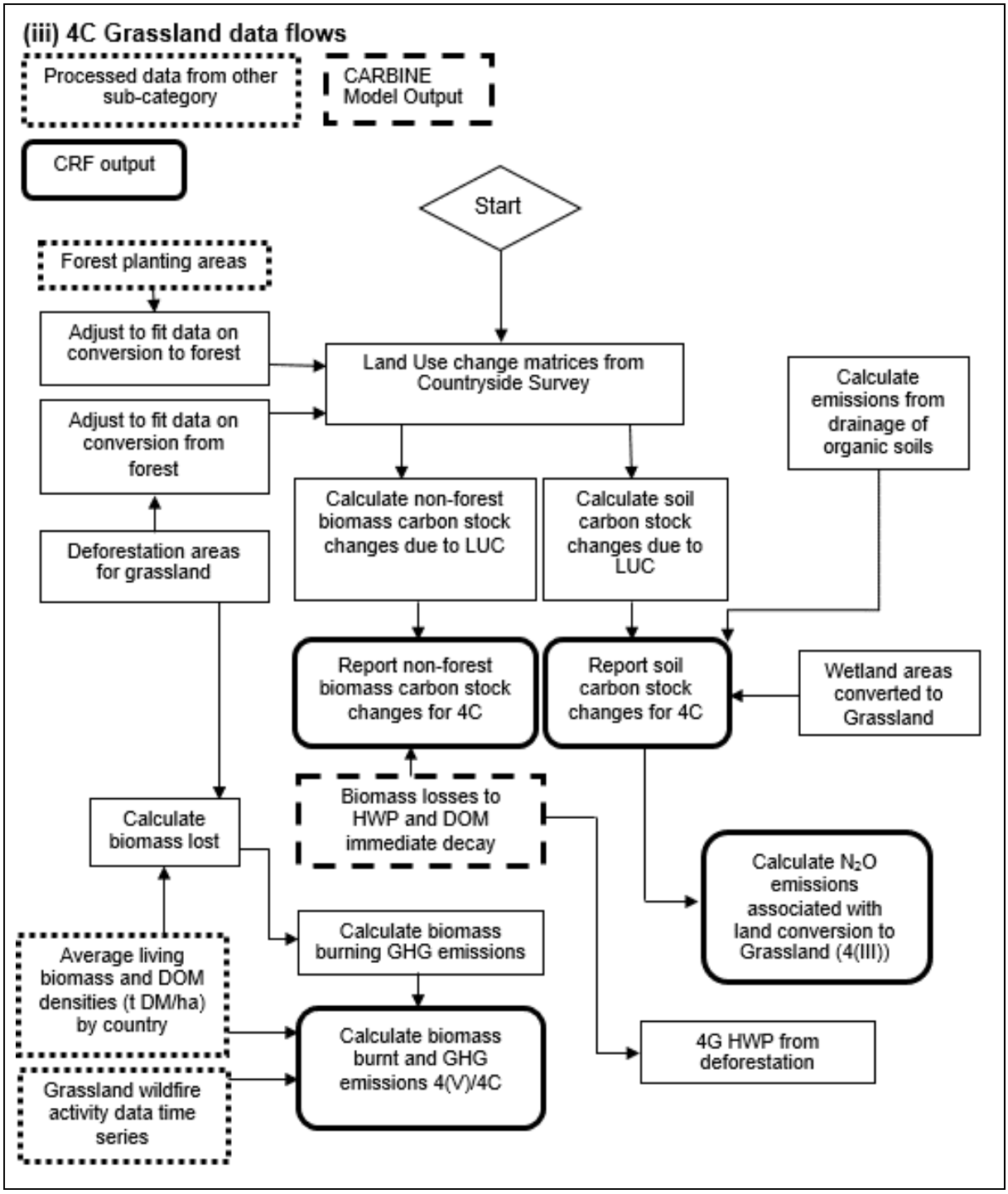
- 4D Wetlands: the sum of areas of peat extraction, Other Wetlands and areas of land use change to peat extraction and flooded land
    - Other Wetlands are the area of inland water >1 km^2 minus the area of newly flooded land (assumed to be converted from undisturbed grassland).
- 4E Settlements: the sum of areas of land use change to Settlements used in the deforestation and LUC soil model and an area of undisturbed settlement
    - Undisturbed settlement is a time series compiled from the Countryside Survey and national statistics- it has no associated emissions
- 4F Other Land: the sum of inland water <1km^2, inland rock and a forest conversion buffer (to reflect the land use change from Other Land to Forest in 4A). Generally, this land use type does not produce any emissions or removals in the UK (although there are some in the OTs and CDs), but the LUC methodology includes a small area of Other Land conversion to Forest Land, hence the need for a buffer, to ensure area matrix consistency.

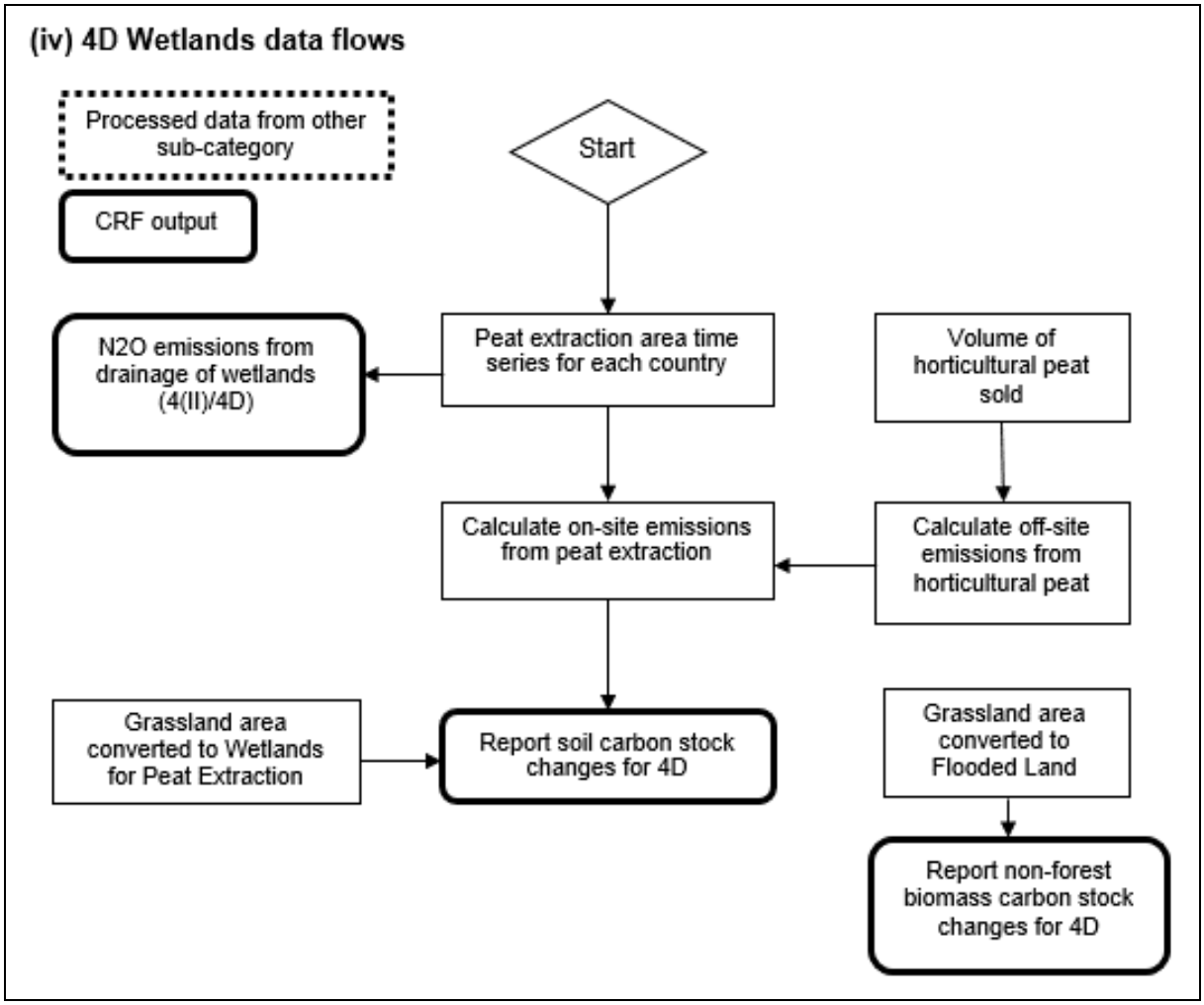
A flow chart has been developed to show the interrelationship between different data sources and the main calculation steps (**Figure 6.4**).

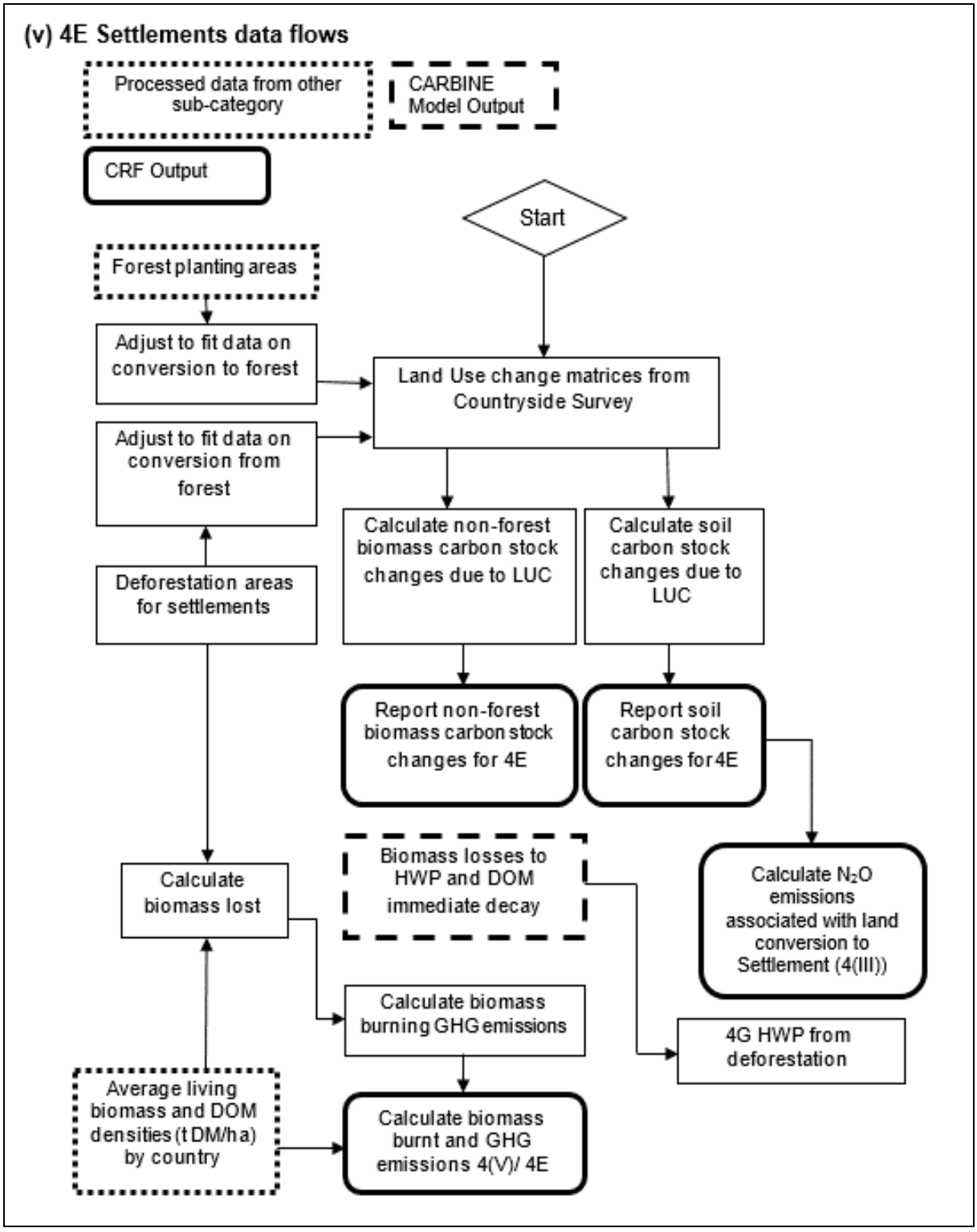
Figure 6.4 **Data flow diagrams for each land use sub-category, showing cross-linkages between sectors: (i) 4A and 4G, (ii) 4B, (iii) 4C, (iv) 4D, (v) 4E**

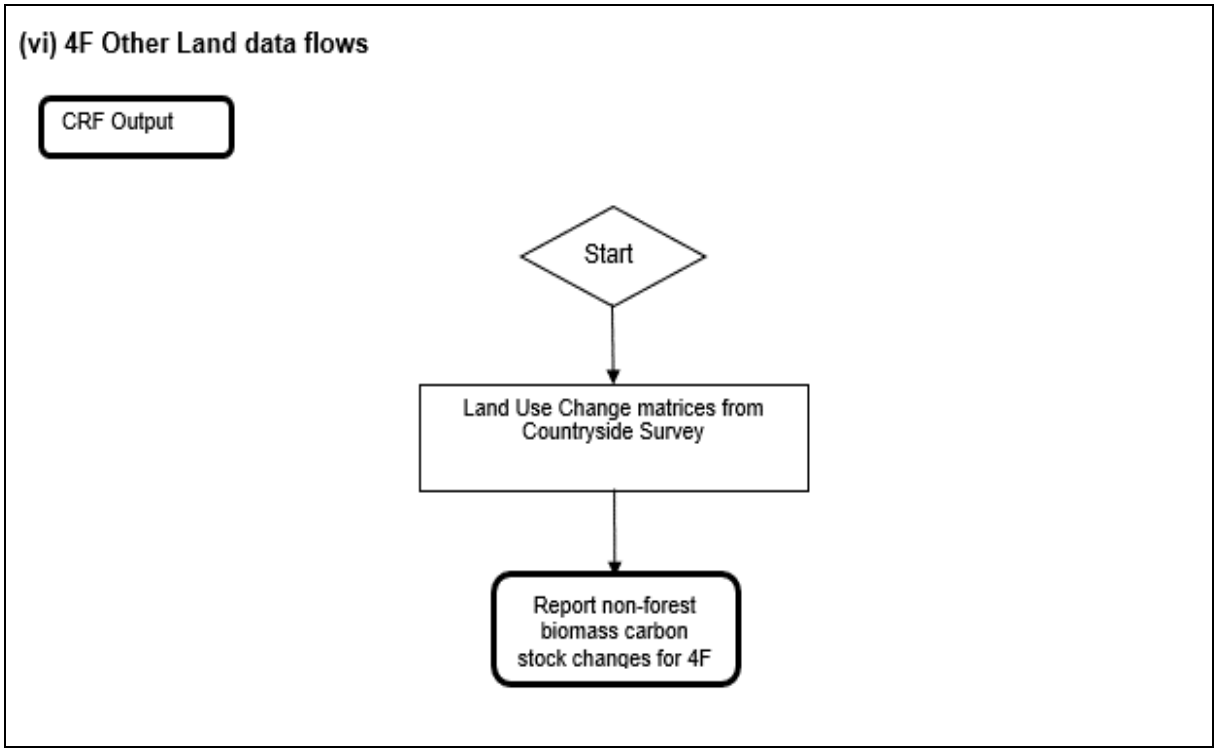



(ii) 4B Cropland data flows
Processed data from other sub-category
CARBINE Model Output
CRF output
Start
Forest planting areas
Adjust to fit data on conversion to forest
Land Use change matrices from Countryside Survey
Adjust to fit data on conversion from forest
Calculate emissions from Cropland Management activities
Calculate non-forest biomass carbon stock changes due to LUC
Calculate soil carbon stock changes due to LUC
Deforestation areas for cropland
Report non-forest biomass carbon stock changes for 4B
Report soil carbon stock changes for 4B
Calculate emissions from lowland drainage of organic soils
Biomass losses to HWP and DOM immediate decay
Calculate biomass lost
Calculate N_2O emissions associated with Forest and Grassland conversion to Cropland (45(III))
Calculate biomass burning GHG emissions
Average living biomass and DOM densities (t DM/ha) by country
Calculate biomass burnt and GHG emissions 4(V)/4B
4G HWP from deforestation
Cropland wildfire activity data time series


(iii) 4C Grassland data flows
Processed data from other sub-category
CARBINE Model Output
CRF output
Start
Forest planting areas
Adjust to fit data on conversion to forest
Land Use change matrices from Countryside Survey
Calculate emissions from drainage of organic soils
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
Deforestation areas for grassland
Report non-forest biomass carbon stock changes for 4C
Report soil carbon stock changes for 4C
Wetland areas converted to Grassland
Biomass losses to HWP and DOM immediate decay
Calculate biomass lost
Calculate N_2O emissions associated with land conversion to Grassland (4(III))
Calculate biomass burning GHG emissions
Average living biomass and DOM densities (t DM/ha) by country
Calculate biomass burnt and GHG emissions 4(V)/4C
4G HWP from deforestation
Grassland wildfire activity data time series


(iv) 4D Wetlands data flows
Processed data from other sub-category
CRF output
Start
N2O emissions from drainage of wetlands (4(II)/4D)
Peat extraction area time series for each country
Volume of horticultural peat sold
Calculate on-site emissions from peat extraction
Calculate off-site emissions from horticultural peat
Grassland area converted to Wetlands for Peat Extraction
Report soil carbon stock changes for 4D
Grassland area converted to Flooded Land
Report non-forest biomass carbon stock changes for 4D


(v) 4E Settlements data flows
Processed data from other sub-category
CARBINE Model Output
CRF Output
Start
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
Deforestation areas for settlements
Report non-forest biomass carbon stock changes for 4E
Report soil carbon stock changes for 4E
Biomass losses to HWP and DOM immediate decay
Calculate biomass lost
Calculate N_2O emissions associated with land conversion to Settlement (4(III))
Calculate biomass burning GHG emissions
4G HWP from deforestation
Average living biomass and DOM densities (t DM/ha) by country
Calculate biomass burnt and GHG emissions 4(V)/ 4E



Work is ongoing to improve the representation of land use change via a new approach to assimilate multiple land use data sets. This 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 the national scale. This should give better representation of cycles or reversals in land use change which are especially important when considering long time horizons. A non-spatially explicit dataset has been produced (the spatial component is lost during calibration). Further work to develop a spatial approach is under consideration. This would use the land parcel information arising from the Integrated Administration and Control System (IACS) data, but there have been delays in obtaining and harmonising the data from the different devolved administrations of the UK.

The areas of land in the different land use categories in the OTs and CDs are shown in **Table** 6.1. Insufficient data exist to construct full land use change matrices in these cases.

Table 6.1 Areas of land by category in the Crown Dependencies and Overseas Territories 1990-2013, kha

Land category	Sub-category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
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	3.8
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	0.8
Cropland remaining Cropland		12.0	11.9	11.8	11.8	11.6	11.0	11.0	10.7	11.0	10.5	10.0	9.5
Land converted to Cropland	Grassland converted to Cropland	0.1	0.1	0.1	0.2	0.1	0.1	0.4	0.8	0.9	0.9	1.0	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	1262.1
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	3.6
Land converted to Grassland	Settlement converted to Grassland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Settlements remaining Settlements		9.8	9.9	9.9	9.9	10.1	10.1	10.1	10.2	10.3	10.3	10.4	10.4
Land converted to Settlement	Grassland converted to Settlements	1.0	0.9	0.9	1.0	0.9	0.9	0.9	0.9	1.0	1.1	1.2	1.3

Land category	Sub-category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
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	0.0	0.0
Total area		1292.7	1292.7	1292.7	1292.7	1292.7	1292.7	1292.7	1292.7	1292.7	1292.7	1292.7	1292.7

Land category	Sub-category	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Forest remaining Forest		3.8	3.9	4.0	4.1	4.2	4.2	4.3	4.4	4.5	4.5	4.5	4.5
Land converted to forest		0.7	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.3	0.4	0.4	0.4
Cropland remaining Cropland		9.3	9.0	8.5	8.6	8.5	8.5	8.3	8.4	7.7	7.4	7.3	6.0
Land converted to Cropland	Grassland converted to Cropland	1.1	1.1	1.3	1.5	1.7	2.1	2.4	2.4	2.6	2.6	3.0	3.6
Grassland remaining Grassland		1262.2	1262.1	1262.2	1262.1	1257.5	1257.0	1256.8	1256.3	1257.0	1256.5	1255.7	1256.7
Land converted to Grassland	Cropland converted to Grassland	3.6	3.8	3.7	3.5	3.4	3.2	3.2	3.9	3.7	4.2	5.2	5.1
Land converted to Grassland	Settlement converted to Grassland	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1

Land category	Sub-category	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Settlements remaining Settlements		10.4	10.4	10.4	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.7
Land converted to Settlement	Grassland converted to Settlements	1.4	1.5	1.7	1.8	1.9	2.0	2.1	2.1	2.1	2.1	2.1	1.9
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	0.1	0.1	0.1
Total area		1292.8	1292.8	1292.8	1292.8	1288.3	1288.1	1288.3	1288.6	1288.8	1288.5	1288.9	1289.2

Total land areas for reported OTs and CDs (2013): Isle of Man = 57.20 kha, Guernsey = 6.55 kha, Jersey = 11.92 kha, Falkland Islands = 1213.52 kha. The Caribbean Overseas Territories are not included in these areas: Bermuda = 5.5 kha, Cayman Islands = 26.6 kha, Montserrat = 10.2 kha

6.2 CATEGORY 4A – FOREST LAND

6.2.1 Description

Emissions sources	4A Forest Land: carbon stock change 4(I) Direct nitrous oxide (N_2O) emissions from nitrogen (N) inputs to managed soils 4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils 4(III) Direct nitrous oxide (N_2O) emissions from nitrogen (N) mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils 4(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	4A: Forest land - CO_2 (L1, T1, L2, T2)
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Reported under the relevant Sector 4 sub-categories at Tier 3
Completeness	No known omissions
Major improvements since last submission	Change to reporting using the 2006 AFOLU Guidance structure. Refinement of the CARBINE input data and updating of the deforestation activity data

This category is divided into Category 4.A.1 Forest remaining Forest Land and Category 4.A.2 Land converted to Forest Land. 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 suitable for constructing a GHG inventory. Consequently, estimates of carbon stock gains and losses for biomass and soils are modelled based on planting history and productivity (yield class) data. The area of forest reported in 4.A.1 now includes all forest older than 20 years. The first national survey of forests was undertaken in 1921, and all forests planted since then are modelled by the CARBINE model (described in **Annex 3.4.1**). The planting year of all pre-1921 forest has been estimated, and modelled in the same way by CARBINE. The forest area and carbon stock changes in CRF Table 4.A take account of losses of forest land converted to other categories (deforestation) and the associated carbon stock changes and emissions and removals are then estimated and reported under the category concerned.

In the UK nitrogen fertilisers (inorganic only) 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 all areas of Settlements or Other Land converted to Forest Land and Grassland converted to Forest Land on organic soils. N_2O emissions from this fertilisation are reported under 4.A.2 in Table 4(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 4(I)) for 4.A.1 are reported as Not Occurring.

Drainage of forest land occurs in UK forests planted since 1920 on certain soil types. It is assumed that all forests planted on organic soils are cultivated prior to planting and therefore effectively drained. Forests planted on mineral or organo-mineral soils which have slow natural drainage and are prone to waterlogging are also assumed to be artificially drained. CO_2 emissions from drainage are included with carbon stock changes in Table 4.A and N_2O emissions from drainage in Table 4(II). There is insufficient information to enable reporting of methane and rewetting emissions.

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 4.A.1 and 4.A.2. Therefore emissions of greenhouse gases from wildfires are all reported under 4.A.1 in Table 4(V). It is assumed that land use change does not occur following wildfire.

6.2.2 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 and Scotland), Natural Resources Wales (Wales) and the Forest Service (Northern Ireland). The areas of forest planted annually are published in Forest Statistics (described below) and a detailed breakdown (by forest type and management) is used by the CARBINE model. 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.

Forestry Statistics is published each September by the Forestry Commission (FC) 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. For pre-1999, non-FC forest areas are based on the 1995-99 National Inventory of Woodland and Trees (NIWT). For 2000 onwards, non-FC forest areas for England, Wales and Scotland are based on the NIWT and adjusted for new planting and sales of FC woodland, no adjustment is made for woodland converted to another land-use, nor for changes in woodland composition at restocking. They include non-FC publicly owned woodland. The NIWT did not include Northern Ireland. 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. Currently we use the Northern Ireland new planting-based data for forest area. The methodology will move to using the Northern Irish base map data at the same time as the new National Forest Inventory data (see below).

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 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 was due for completion in 2014-15, which will enable direct verification of tree forest carbon stocks. The full National Forest Inventory results are expected to be published in 2016/17.

6.2.3 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. The minimum area of Forest currently included in LULUCF reporting is 0.5 ha. The UK has a programme of work in place to incorporate small areas of woodland covering between 0.1 and 0.5 ha. 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 have been assessed, which affect the total estimated woodland area in the GHGI (but are not yet reflected in the national Forestry Statistics). The NFI area estimates have not been used for this inventory submission, as some interpretation of the data is necessary and these assumptions still require validation.

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. The Forest Resource Assessment for the UK in 2010 estimated an area of 2881 kha of forest, with an additional 42 kha of land with tree cover which did not meet the full international forest definition. The 2010 Forestry Statistics give a UK forest area of 2846 kha, with an estimated 165 kha of woodlands between 0.1 and 0.5 ha (Forest Research expert judgement).

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 Forest Land used in LULUCF reporting is taken from the statistics published by the Forestry Commission (see also **Figure 6.4**).

6.2.4 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. Further description of CARBINE is given in Annex 3.4.1 and Matthews *et al*. (2014). 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 associated withwith 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. Carbon stock changes in dead wood are included with carbon stock changes in litter.

Other greenhouse gas emissions, including those arising from forest fertilisation and wildfires together with estimates of N_2O emissions from forest drainage, are estimated using Tier 1 or Tier 2 approaches, and are described in **Annex 3.4.**

6.2.5 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 3.4.13**). 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. 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 functionality of CARBINE is broadly similar and we assume that the uncertainty of the inputs and parameters are also similar. 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 (Matthews *et al.* 2014). Future uncertainty analyses will include the processes represented in CARBINE and the revised forestry datasets.

The planting statistics used as activity data mostly come from operational systems, for grants and for planting on the National Forest Estates of the four countries comprising the UK, and have no measures of statistical uncertainty attached to them as complete coverage is assumed. Grants are paid once planting has occurred. The grant-aided planting is allocated by year of payment, so all the recorded planting should have taken place. There is ongoing work within Forest Research to assess the level of error attached to the data, e.g. for failed planting. The inventory of trees pre-1920 is based on the National Inventory of Woodland and 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.

The combined uncertainty (based on inputs and parameters) assessed using a simple Tier 1 approach and the 2013 mean values for 4A Forest Land was 31% for CO_2. The combined uncertainty for CH_4 was 55% (wildfires) and 40% for N_2O (wildfires and forest fertilisation).

In terms of time series consistency:

- For forest carbon stock changes, N fertilization of forests and emissions from drainage, time series consistency is expected to be 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, and gives burnt areas which are the same magnitude as the previous dataset.

6.2.6 Category-Specific QA/QC and Verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 6.10**. 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 has been 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 (Matthews et al., 2014). Additional verification of forest model outputs (carbon stocks) will be possible when the full National Forest Inventory results are published in 2015 (discussed in **Section 6.2.2**), and verification of carbon stock changes once the second cycle of the NFI is completed in 2020.

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 predicted that afforestation in the UK since 1920 produced a carbon sink in the soil equivalent to one third of that sequestered in the above-ground biomass, based on a small number of long term studies. 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, Jobbagy et al. 2009); (Laganiere, Angers et al. 2010); (Poeplau, Don 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, whilst the matter is investigated is investigated. This investigation includes a literature review of forest soil carbon in the UK context, with particular reference to forest on organic soils. The findings of the review and investigation will be described and, if possible, implemented, in the next inventory submission.

6.2.7 Category-Specific Recalculations

The reported overall net GHG sink in category 4A has increased slightly by between 1% and 4% depending on the year comapared to the 2012 inventory (**Figure 6.5**). This is due to a

reduction in emissions of N_2O (as a result of a change in activity data for estimates of N_2O emissions from drainage). Details of the magnitude of the changes and the justifications for each emissions source are given in **Table 6.2**.

Figure 6.5 4A Forest Land changes in net emissions between 2012 and 2013 inventories

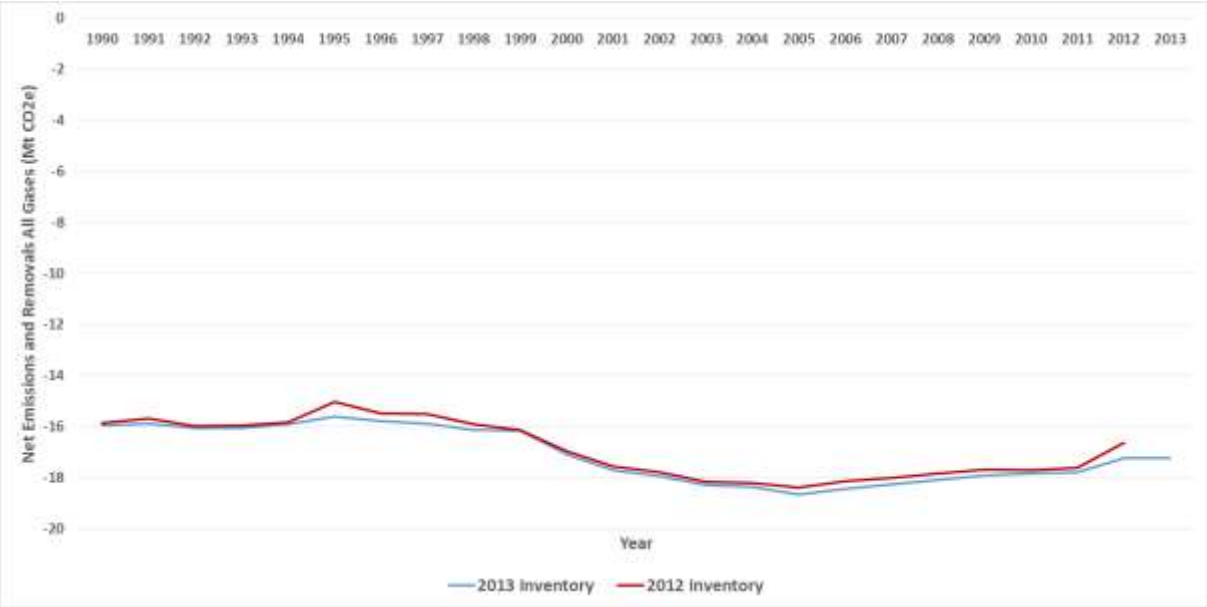


Table 6.2 4A Category specific recalculations to activity data since previous submission

IPCC Category	Source Name	2014 Submission		2015 Submission		Units	Comment/Justification
		1990	2012	1990	2012		
4A1	Carbon stock change in living biomass - gains	3436.95	5325.61	3437.22	5331.56	Gg C	Refinement of the CARBINE input data and updating of the deforestation activity data has led to minor changes.
4A1	Carbon stock change in living biomass - losses	-1596.23	-2851.94	-1596.30	-2855.14	Gg C	Refinement of the CARBINE input data and updating of the deforestation activity data has led to minor changes.
4A1	Net carbon stock change in litter	32.65	531.40	32.58	531.86	Gg C	Refinement of the CARBINE input data and updating of the deforestation activity data has led to minor changes.
4A1	Carbon stock change in soils- mineral soils	881.07	750.04	881.06	750.81	Gg C	Refinement of the CARBINE input data and updating of the deforestation activity data has led to minor changes.
4A1	Carbon stock change in soils- organic soils	262.41	435.98	262.40	436.37	Gg C	Refinement of the CARBINE input data and updating of the deforestation activity data has led to minor changes.
4A1/4(V)	Biomass burning - wildfires	42.75	226.06	11.66	67.56	Gg C	2012 values were mistakenly converted from C to CO_2 twice over due to a database error. Changes in the CARBINE model have altered the average amount of fuel burnt.
4A1/4(V)	Biomass burning - wildfires	0.15	0.78	0.15	0.86	Gg CH_4	Changes in the CARBINE model have altered the average amount of fuel burnt.
4A1/4(V)	Biomass burning - wildfires	0.01	0.04	0.01	0.05	Gg N_2O	Changes in the CARBINE model have altered the average amount of fuel burnt.
4A2	Carbon stock change in living biomass - gains	629.70	258.69	629.72	258.70	Gg C	Refinement of the CARBINE input data has led to minor changes.
4A2	Carbon stock change in living biomass - losses	-19.76	-5.11	-19.77	-5.11	Gg C	Refinement of the CARBINE input data has led to minor changes.

IPCC Category	Source Name	2014 Submission		2015 Submission		Units	Comment/Justification
		1990	2012	1990	2012		
4A2	Net carbon stock change in litter	26.93	9.47	26.93	9.48	Gg C	Refinement of the CARBINE input data has led to minor changes.
4A2	Carbon stock change in soils- mineral soils	416.14	281.14	416.14	281.14	**Gg C**	Refinement of the CARBINE input data has led to minor changes.
4A2	Carbon stock change in soils- organic soils	309.67	51.60	309.68	51.60	Gg C	Refinement of the CARBINE input data has led to minor changes.
4A/4(I)	Direct N_2O Emissions from N Inputs to Managed Soils	0.02	0.00*	0.02	0.00*	Gg N_2O	Refinement of the CARBINE input data has led to minor changes.
4A/4(II)	Emissions from drainage-mineral soils	0.08	0.10	0.07	0.07	Gg N_2O	Drainage areas were updated to use the CARBINE input area data and ensure consistency in forest areas on different soil types.
4A/4(II)	Emissions from drainage – organic soils	0.07	0.08	0.07	0.08	Gg N_2O	Drainage areas were updated to use the CARBINE input area data and ensure consistency in forest areas on different soil types.

* Appears as zero because only two decimal places are used in the table.

6.2.8 Category-Specific Planned Improvements

The area reported under 4.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. Some assumptions regarding the quantity and timing of felling and restocking also need to be validated before inclusion in the inventory calculations.

A re-examination of the soil carbon component of CARBINE (currently based on C-Flow- see section 6.2.6) is in progress, which will assess the most recent scientific literature relevant to the UK context (e.g. Yamulki et al. 2013; Vanguelova et al. 2013) in order to incorporate and parameterise an updated soil carbon model. This will be an additional output so that direct comparison can be made of the effect of this change of soil model

6.3 CATEGORY 4B – CROPLAND

6.3.1 Description

Emissions sources	4B Cropland: carbon stock change 4B Cropland: 4(II) emissions from historical drainage of organic soils. 4B Cropland:4(III) N_2O emissions from disturbance associated with LUC to Cropland 4B Cropland:4(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	4B: Cropland - CO_2 (L1, T1, L2, T2)
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Reported under the relevant Sector4 sub-categories at Tier 1
Completeness	No known omissions- areas are reported for land uses with no associated emissions.
Major improvements since last submission	Carbon stock changes due to yield improvements have been removed. New activity data for the area of Cropland on drained organic soils has been used. Emissions from agricultural lime application are now reported in the Agricultural Inventory (Sector 3). Soil carbon stock changes from cropland management are now included. The LUC soils and biomass models were re-run using extrapolated rather than projected rates of LUC for 2010-2013.

The category is disaggregated into 4.B.1 Cropland remaining Cropland and 4.B.2 Land converted to Cropland.

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 4.B.1 Cropland remaining Cropland, along with emissions from organic soils as a result of drainage.

Changes in soil carbon stock resulting from changes in Cropland Management are now included in the inventory and are reported under 4.B.1 Cropland remaining Cropland.

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 4.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.

Carbon stock changes from drainage of Cropland on organic soils arise from areas which were drained many decades ago for agriculture, allowing oxygen into previously water logged soils. As a result, soil carbon in these areas continues to oxidise and is released as CO_2, resulting in an ongoing change in soil carbon stock. These emissions are reported in Table 4(II)

Nitrous oxide emissions from soil disturbance associated with land-use conversion to Cropland (Table 4(III)) are reported: these arise from Forest Land and Grassland being converted to Cropland.

Emissions of CO_2, CH_4 and N_2O from biomass burning arising from Forest Land conversion to Cropland are reported in Table 4(V). Burning of agricultural residues (cereal straw or stubble) are reported under category 3F Field Burning of Agricultural Residues. Emissions from application of lime to Cropland, which were previously reported in the LULUCF sector, are now reported in the Agriculture sector. Emissions from wildfires on Cropland are included in the inventory and are reported in CRF Table 4(V). Full details of the method and activity data are given in **Annex 3.4.**

6.3.2 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 6.1.1.**

Data sources that contain area information for reporting carbon stock changes and/or emissions from Cropland are habitat/landscape surveys; an assessment of Cropland drainage, and data on wildfires on agricultural land from Fire and Rescue service and satellite data.

Areas of Cropland that are a losing carbon due to historical drainage (reported under Cropland remaining Cropland) have been reassessed by Anthony *et al*. (personal communication-unpublished report from Defra project AC0114, 2013) Their analysis overlaid areas of Cropland from the Land Cover Map and the Intergrated Administration and Control System (IACS) with mapping of organic soils from soil surveys. All Cropland on organic soils was assumed to be drained. This reassessment gives a more complete picture of the area of Cropland on drained organic soils than previous work by Bradley (1997). The vast majority of Cropland on drained organic soils is in England, but small areas in the other UK administrations are also identified.

The areas of the main crop types used assess changes in soil carbon stocks resulting from Cropland Management are obtained from the June Agricultural Censuses for each UK administration (Defra, 2013a; Welsh Government, 2013; Scottish Government 2013; DARDNI, 2013). The areas of Cropland receiving inputs of manure, fertiliser and crop residues are obtained from the British Survey of Fertiliser Practice (Defra, 2013b).

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 3.4.5** for details).

6.3.3 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). Land classified as Orchards in the MLC survey should also have been included in Cropland but was 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 Forest Land categories. Post-1980, Cropland is the area of cropland reported in the June Agricultural censuses (Defra 2013a). The Broad Habitat class "Arable and horticulture" (Haines-Young *et al*. 2000, Appendix A), is 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."

Crop types definitions are those used in the June Agricultural censuses.

6.3.4 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 6.1.1**. Fluxes arising from land use change in the 20 years before the inventory year are reported under 4B2 Land converted to Cropland. Fluxes from historical land use change (more than 20 years before the inventory year) are reported under 4B1 Cropland remaining Cropland. Detailed descriptions of the methods and emission factors used for the activities in this Category can be found in **Annex 3.4.2**.

A dynamic model of carbon stock change is used with the land use change matrices to estimate soil carbon stock changes due to all land use change, including change to and from Cropland. 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. It is assumed that land use change occurs does not occur on the cropland on organic soils. 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.

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.

Carbon stock change in soils as a result of Cropland Management is estimated using Tier 1 emission factors for most activities, although a Tier 2 emission factor is used for tillage reduction.

Emissions from Cropland on drained organic soils are reported using Tier 1 emission factors which assume constant rates of carbon loss and activity data from Anthony (personal communication, 2013).

Emissions from wildfires on Cropland are reporting using a Tier 1 emission factors and activity from the Fire and Rescue Service's Incident Reporting system from 2010 onwards, remotely sensed FIRMS thermal anomaly data from 2001 – 2009 and extrapolation prior to this.

6.3.5 Uncertainties and Time-Series Consistency

The uncertainty analysis in the Annexes provides estimates of uncertainty according to the GPG source category and gas. 4B Cropland was estimated to have a combined uncertainty of 45% for CO_2 (from LUC to cropland, cropland management and emissions from drained organic soils).

The areas undergoing land use change are the biggest source of uncertainty in the LULUCF inventory (see **Annex 3.4.13**), 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. Emissions from Cropland on drained organic soils has the largest uncertainties of the minor emissions sources (i.e. not land use change) as the effects of drainage are highly uncertain. Work in implementing the Wetlands Supplement may decrease this uncertainty.

The combined uncertainty of CH_4 is 54% (from wildfires) and of N_2O is 54% (from wildfires and N mineralisation associated with land conversion).

In terms of time series consistency:

- For drainage of organic soils (4B1) the activity data uses areas of drained organic soil from Anthony (personal communication, unpublished report from Defra project AC0114, 2013). It is assumed that all drainage of organic soils on Cropland occurred before 1990 as recent policy has favoured protection of organic soils. There have been no policy incentives to encourage new land drainage for agricultural use since 1990, and major drainage of large areas of Cropland on organic soils in areas such as the East Anglian fens is known to have occurred well before this. No Cropland on drained organic soils has been rewetted since 1990 as there have been no incentives to promote this, therefore a single area is used throughout the time series.
- 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 is high as country-specific data sets are used.
- 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 observed data on the extent of wildfires on Cropland, and the time series is filled by extrapolating the 2001 – 2011 average wildfire area.
- For carbon stock changes from cropland management, the activity data comes from June Agricultural censuses and from the British Survey of Fertiliser Practice. The June Agricultural censuses are very long standing datasets with good time series consistency. The British Survey of Fertiliser Practice has contained information on the

proportion of Cropland receiving manure since 2008. For years prior to 2008, the 2008 – 2014 average value has been used. The British Survey of Fertiliser Practice has contained information on the proportion of Cropland receiving fertiliser since 1992. For years prior to 1992, the 1992 - 2001 average value has been used.

6.3.6 Category-Specific QA/QC and Verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 6.10**.

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 this trend is being driven by land use change to Cropland, changes in land management or is a response to environmental change.

6.3.7 Category-Specific Recalculations

The main change between the 1990-2012 inventory and the 1990-2013 inventory is the use of more complete data on the area of Cropland on drained organic soils which has also changed the methodology used to estimate emissions as the new data does not differentiate peat depth.

Soil carbon stock changes arising from cropland management have been added.

Emissions from application of lime to Cropland have been removed from the LULUCF inventory and are now reported in the Agricultural inventory.

Increase in biomass carbon stocks as a result of improved agronomy has been removed from the inventory as a review of evidence suggests that increases in harvestable biomass are not matched by increases in total biomass.

Revisions to Deforestation data have led to small changes to the areas of Forest Land converted to Cropland since 2000.

The Land Use Change model has been re-run using extrapolated rather than projected rates of land use change from 2010 to 2013. Extrapolated rates of change continue the trend observed in from previous Countryside Surveys up to the latest year of the inventory whereas projected rates of change are applied to future years and take account of future policy targets.

The cumulative change between the 1990 – 2012 inventory and the 1990 - 2013 inventory is shown in **Figure 6.6**. Changes in emissions are described in **Table 6.3**.

Figure 6.6 4B Cropland change in net emissions between the 1990-2012 and 1990-2013 inventories

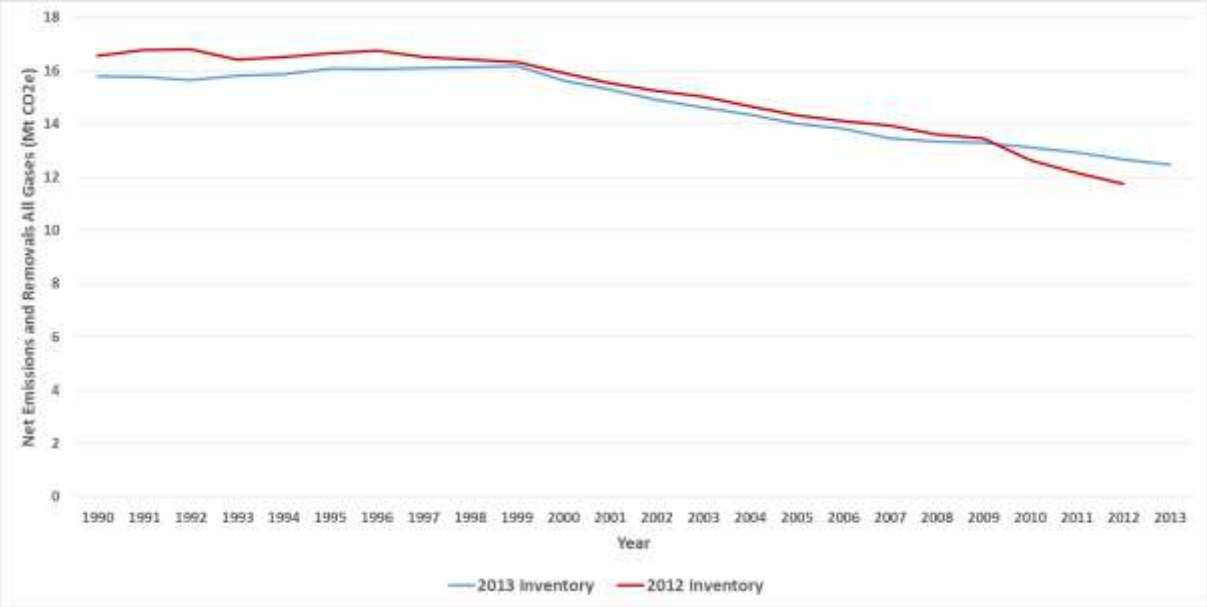


Table 6.3 4B Category specific recalculations to activity data since previous submission

IPCC Category	Source Name	2014 Submission		2015 Submission		Units	Comment/Justification
		1990	2012	1990	2012		
4B1/4(IV)	CO2 emissions from agricultural lime application	863.16	590.19	NA	NA	Gg C	CO_2 emissions from agricultural lime application now reported in Agricultural inventory
4B1	Carbon stock change in living biomass (yield improvement	174.65	174.65	NA	NA	GgC	Review of data does not support the continued inclusion of this activity.
4B1	Carbon stock change in mineral soils	-617.65	-1364.54	-354.18	-1163.91	GgC	LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013. Addition of cropland management activity reporting.
4B1	Carbon stock change in organic soils	-0.73	-0.31	-3.66	-1.02	GgC	Revision of Cropland areas on organic soils (OTs and CDs only)
4B1	Carbon stock change in organic soils (lowland drainage)	-450.00	-286.00	NA	NA	GgC	Now reported under 4B/4(II) Emissions from drainage (lowland soils).
4B2.1/4(III)	Forest converted to Cropland: Direct N_2O emissions from N mineralisation	0.00*	0.00*	0.00*	0.00*	Gg N_2O	LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013. Revised deforestation areas used for 2000 – 2013.
4B2.1/4(V)	Forest converted to Cropland :Biomass burning – controlled burning	0.22	0.62	0.22	0.25	Gg C	Changes in the CARBINE model have altered the average amount of fuel burnt. Revised deforestation areas used for 2000 – 2013.

IPCC Category	Source Name	2014 Submission		2015 Submission		Units	Comment/Justification
		1990	2012	1990	2012		
4B2.1/4(V)	Forest converted to Cropland: Biomass burning – controlled burning	0.00*	0.01	0.00*	0.00*	Gg CH_4	Changes in the CARBINE model have altered the average amount of fuel burnt. Revised deforestation areas used for 2000 – 2013.
4B2.1/4(V)	Forest converted to Cropland: Biomass burning – controlled burning	0.00*	0.00*	0.00*	0.00*	Gg N_2O	Changes in the CARBINE model have altered the average amount of fuel burnt. Revised deforestation areas used for 2000 – 2013.
4B2.1	Forest land converted to Cropland.: Carbon stock change in living biomass – losses	-0.30	-0.86	-0.30	-0.36	Gg C	Revised deforestation areas used for 2000 – 2013.
4B2.1	Forest converted to Cropland: Carbon stock change in dead organic matter	-0.06	-0.17	-0.06	-0.06	Gg C	Revised deforestation areas used for 2000 – 2013.
4B2.1	Forest: converted to Cropland: Carbon stock change in change in soils – mineral soils	-0.17	-0.53	-0.70	-0.46	GgC	LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013. Revised deforestation areas used for 2000 – 2013.
4B2.2/4(III)	Grassland converted to Cropland: Direct N_2O emissions from N mineralisation	2.48	1.85	2.18	1.13	Gg N_2O	LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013.
4B2.2/4(V)	Grassland converted to Cropland: Carbon stock change in living biomass – losses	-64.93	-2.93	-65.43	-37.73	Gg C	LUC biomass model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013.

IPCC Category	Source Name	2014 Submission		2015 Submission		Units	Comment/Justification
		1990	2012	1990	2012		
4B2.2/4(V)	Grassland converted to Cropland: Carbon stock change in soils - mineral soils	-3136.94	-1379.25	-3266.67	-1699.83	Gg C	LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013.
4B2.2/4(V)	Grassland converted to Cropland: Carbon stock change in soils - organic soils	0.00	-0.16	0.00	-1.32	Gg C	LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013.
4B2.4/4(V)	Settlements converted to Cropland: Carbon stock change in living biomass – losses	-1.23	0.00	-1.21	-0.19	Gg C	LUC biomass model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013.
4B2.4/2/4(V)	Settlements converted to Cropland: Carbon stock change in soils - mineral soils	28.37	7.13	29.99	7.91	Gg C	LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013.
4B/4(II)	Emissions from drainage (organic soils)	NA	NA	464.15	464.15	GgC	Revised areas of Cropland on drained organic soils, and change to emissions 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.

6.3.8 Category-Specific Planned Improvements

A methodology and emissions factors for reporting the effect of Cropland Management on biomass carbon stocks is being developed, and should be ready for use in the next inventory.

A vector based approach to tracking land use change is being developed which could assimilate data from the European Commission Integrated Administration and Control System (IACS) data to provide a more accurate assessment of Grassland/Cropland rotation lengths for each UK administration. This will be incorporated with the move to using a vector approach to land use change more widely in the LULUCF inventory. Incorporating IACS data in a vector based model will also allow improved tracking of changes in Cropland Management.

Work to implement the Wetlands Supplement (IPCC, 2013) guidance may yield improved emissions factors and trajectories for Cropland on drained organic soils.

6.4 CATEGORY 4C – GRASSLAND

6.4.1 Description

Emissions sources	4C Grassland: carbon stock change 4C Grassland: 4(II) Emissions from drainage of organic soils. 4C Grassland: 4(III) Direct N_2O emissions from N mineralisation. 4C Grassland: 4(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	4C: Grassland - CO_2 (L1, T1, L2)
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Reported under the relevant Sector 4 sub-categories at Tier 1
Completeness	No known omissions- areas are reported for land uses with no associated emissions.
Major improvements since last submission	New activity data on the area of Grassland on drained organic soils has been used. Emissions from agricultural lime application are now reported in the Agricultural Inventory (Sector 3). Update to the deforestation areas from 2000 onwards. The LUC soils and biomass models were re-run using extrapolated rather than projected rates of LUC for 2010-2013.

The category is disaggregated into 4.C.1 Grassland remaining Grassland and 4.C.2 Land converted to Grassland.

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 4.C.1 Grassland remaining Grassland. The area of undisturbed grassland (8,954 kha in 2013) 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 4.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.

Carbon stock changes from drainage of Grassland on organic soils arise from areas which 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, resulting in an ongoing change in soil carbon stock. These emissions are reported in Table 4(II)

Nitrous oxide emissions from soil disturbance associated with land-use conversion to Grassland (Table 4(III)) are reported: these arise from Forest Land being converted to Grassland.

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 4(V). Full details of the methods and activity data are given in **Annex 3.4.4** and **Annex 3.4.5**.

6.4.2 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 6.1.1.**

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; an assessment of the area of improved Grassland on drained organic soils; 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 3.4.4**.

Areas of improved Grassland that are a source of carbon emissions due to historical drainage (reported under Grassland remaining Grassland) have been assessed by Anthony *et al* (personal communication- unpublished report from Defra project AC0114, 2013). Their analysis overlaid areas of improved Grassland from the Land Cover Map and the Intergrated Administration and Control System (IACS) with mapping of organic soils from soil surveys. All improved Grassland on organic soils was assumed to be drained. This assessment allows emissions from drained improved Grassland to be included in the inventory for the first time. Anthony's methodology could not assess the extent of semi-natural Grassland on drained organic soils as it cannot be assumed that all unimproved Grassland on organic soils is drained. This will be included in future inventories as part of the Wetland Supplement implementation programme.

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.

6.4.3 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 on wetlands, 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 (Jackson, 2000).

6.4.4 Methodological Issues

Activity data for 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 6.1.1**. Fluxes arising from land use change in the 20 years before the inventory year are reported under 4C2 Land converted to Grassland. Fluxes from historical land use change (more than 20 years before the inventory year) are reported under 4C1 Grassland remaining Grassland. Detailed descriptions of the methods and emission factors used for the activities in this Category can be found in **Annex 3.4.2**.

The dynamic model of soil carbon stock change is described in **Section 6.3.4**.

6.4.5 Uncertainties and Time-Series Consistency

The uncertainty analysis in the Annexes provides estimates of uncertainty according to the GPG source category and gas. 4C Grassland was estimated to have an uncertainty of 45% for CO_2 (from LUC to grassland and emissions from drained organic soils).

The areas undergoing land use change are the biggest source of uncertainty in the LULUCF inventory (see **Annex 3.4.13**), 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. Emissions from Grassland on drained organic soils has the largest uncertainties of the minor emissions sources (i.e. not land use change) as the effects of drainage are highly uncertain. Work in implementing the Wetlands Supplement may decrease this uncertainty.

The combined uncertainty of CH_4 is 54% (from wildfires) and of N_2O is 33% (from wildfires and N mineralisation associated with land conversion).

In terms of time series consistency:

- For drainage of organic soils (4C1) the activity data uses areas of drained organic soil from Anthony (personal communication, 2013). It is assumed that all drainage of organic soils under improved Grassland occurred before 1990, as policy has favoured protection of organic soils. There have been no policy incentives to encourage new land drainage for agricultural use since 1990, and major drainage of large areas of

improved Grassland on organic soils in areas such as the Somerset Levels fens is known to have occurred well before this. No improved Grassland on drained organic soils has been rewetted since 1990 as there have been no policy incentives for this, therefore a single area is used throughout the time series.

- 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.

6.4.6 Category-Specific QA/QC and Verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 6.10**.

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). It was hypothesized that this loss was due to climate change because all land uses showed losses, suggesting that the UK's LUC modelling approach was incorrect. In contrast, a more recent study using Countryside Survey (CS) data (Reynolds *et al.* 2013) found no significant change in soil carbon stocks under most Grassland habitat types between 1978 and 2007. The reason for the different results obtained by NSI and CS is not clear, although there are methodological differences between the two surveys. Subsequent modelling studies (Smith *et al*. 2007; Kirk and Bellamy 2010, Foerid *et al*. 2012; Guenet *et al*. 2013) have shown that climate changes only account for a small part of the observed decrease in soil carbon in Bellamy *et al*. (2005), and therefore changes in land use and management are the main causes. Guenet *et al*. (2013) also highlighted the importance of prior land use history in priming soil carbon dynamic models.

6.4.7 Category-Specific Recalculations

The Grassland sink estimated for the years 2000 – 2012 is smaller in the 1990-2013 inventory compared to the 1990-2012 inventory. This is mainly because new data has enabled emissions from improved Grassland on drained organic soils to be included in the inventory for the first time.

Emissions from application of lime to Cropland have been removed from the LULUCF inventory and are now reported in the Agriculture sector.

FIRMS thermal anomaly data for wildfires has been revised to correct data processing errors.

Revisions to Deforestation data have led to small changes to the areas of Forest Land converted Cropland since 2000.
The Land Use Change model has been re-run using extrapolated rather than projected rates of land use change from 2010 to 2013.

Full details of changes leading to recalculations are given in **Table 6.4**.

Figure 6.7 4C Grassland change in net emissions between the 1990-2012 and 1990-2013 inventories.

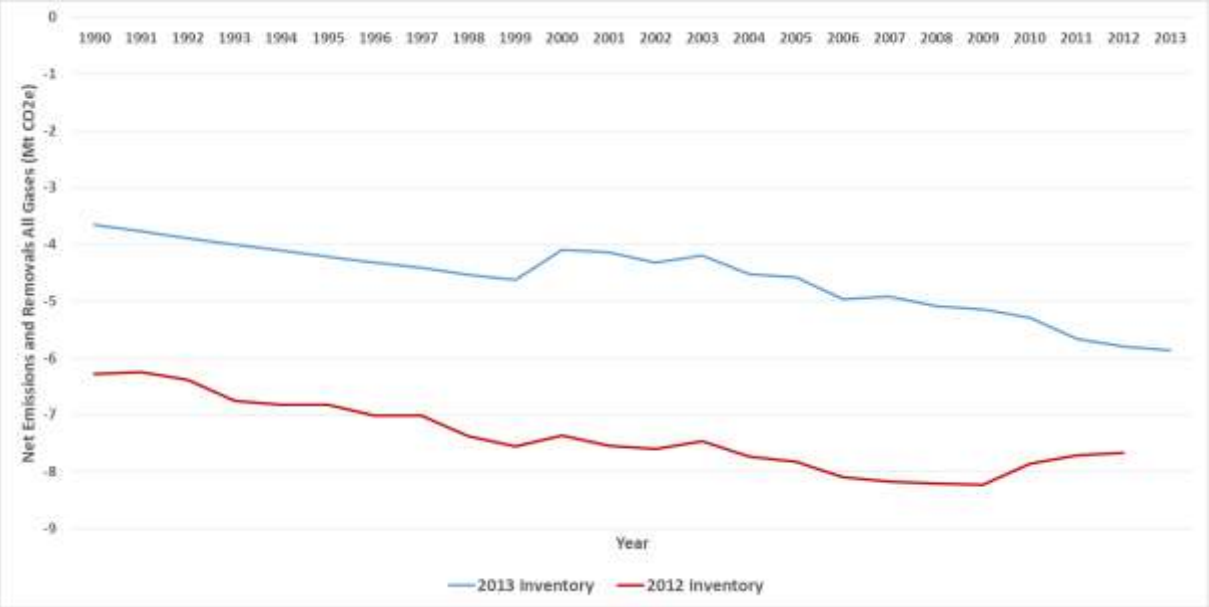


Table 6.4 4C Category specific recalculations to activity data since previous submission

IPCC Category	Source Name	2014 Submission		2015 Submission		Units	Comment/Justification
		1990	2012	1990	2012		
4C/4(II)	Emissions from drainage - organic soils	NA	NA	964.35	964.35	Gg C	Emissions from drainage of organic soils under Grassland reported for the first time in the 1990 – 2013 inventory as new activity data has become available.
4C1/4(IV)	Emissions from agricultural lime application	714.93	443.04	NA	NA	Gg C	Now reported in the agricultural sector
4C1/4(V)	Biomass burning - wildfires	0.50	0.81	0.36	0.83	Gg CH_4	FIRMS thermal anomaly data revised to correct data processing errors.
4C1/4(V)	Biomass burning - wildfires	0.05	0.07	0.03	0.08	Gg N_2O	FIRMS thermal anomaly data revised to correct data processing errors.
4C1	Carbon stock change in soils - mineral soils	465.76	1318.21	458.29	1294.00	Gg C	LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013.
4C2.1/4(III)	Forest converted to Grassland: Direct N_2O emissions from N Mineralization	NA	NA	0.01	0.01	Gg N_2O	Newly included under the 2006 AFOLU structure.
4C2.1/4(V)	Forest converted to Grassland: Biomass burning - controlled burning	5.53	72.36	5.53	59.45	Gg C	Changes in the CARBINE model have altered the average amount of fuel burnt. Revised deforestation areas used for 2000 – 2013.

IPCC Category	Source Name	2014 Submission		2015 Submission		Units	Comment/Justification
		1990	2012	1990	2012		
4C2.1/4(V)	Forest converted to Grassland Biomass burning - controlled burning	0.09	1.16	0.09	0.95	Gg CH_4	Changes in the CARBINE model have altered the average amount of fuel burnt. Revised deforestation areas used for 2000 – 2013.
4C2.1/4(V)	Forest converted to Grassland: Biomass burning - controlled burning	0.00	0.01	0.00	0.01	Gg N_2O	Changes in the CARBINE model have altered the average amount of fuel burnt. Revised deforestation areas used for 2000 – 2013.
4C2.1	Forest converted to Grassland: Carbon stock change in living biomass – losses	-7.79	-103.91	-7.79	-85.62	Gg C	Revised deforestation areas used for 2000 – 2013.
4C2.1	Forest converted to Grassland: Carbon stock change in dead organic matter	-1.43	-16.69	-1.43	-13.46	Gg C	Revised deforestation areas used for 2000 – 2013.
4C2.1	Forest converted to Grassland: Carbon stock change in soils - mineral soils	-2.62	-15.06	-10.03	-18.89	Gg C	LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013. Revised deforestation areas used for 2000 – 2013.

IPCC Category	Source Name	2014 Submission		2015 Submission		Units	Comment/Justification
		1990	2012	1990	2012		
4C2.2	Cropland converted to Grassland: Carbon stock change in living biomass - gains	57.90	0.00	58.26	70.68	Gg C	LUC biomass model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013.
4C2.2	Cropland converted to Grassland: Carbon stock change in living biomass - losses	-0.72	-1.84	-0.72	-1.36	Gg C	LUC biomass model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013.
4C2.2	Cropland converted to Grassland: Carbon stock change in soils - mineral soils	1260.43	906.73	1317.46	1137.75	Gg C	LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013.
4C2.2	Cropland converted to Grassland: Carbon stock change in soils - organic soils	0.00*	0.00*	0.00*	-0.13	Gg C	LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013.
4C2.3	Wetland converted o Grassland: Carbon stock change in living biomass - gains	0.00*	0.00*	0.00*	0.00*	Gg C	LUC biomass model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013.

IPCC Category	Source Name	2014 Submission		2015 Submission		Units	Comment/Justification
		1990	2012	1990	2012		
4C2.3	Wetland converted to Grassland: Carbon stock change in soils - organic soils	0.00*	-1.15	0.00	-1.15	Gg C	LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013.
4C2.4	Settlements converted to Grassland: Carbon stock change in living biomass - losses	-3.71	-0.12	-3.72	-6.18	Gg C	LUC biomass model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013.
4C2.4	Settlements converted to Grassland: Carbon stock change in soils - mineral soils	151.63	179.17	162.45	240.15	Gg C	LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013.

* Appears as zero because only two decimal places are used in the table.

6.4.8 Category-Specific Planned Improvements

Defra project SP1113 attempted to develop a methodology to allow reporting of changes in soil carbon stocks resulting from Grassland/Grazing Land Management. However this was not possible because of a lack of field data to inform development of stock change factors for Grassland/Grazing Land Management practices on organic and organo-mineral soils. This has been identified as a knowledge gap which will need to be filled.

A methodology and emissions factors for reporting the effect of Grassland/Grazing Land Management on biomass carbon stocks is being developed, and should be ready for use in the next inventory. This will include estimation of the biomass carbon stocks of hedgerows in rural areas.

A vector based approach to tracking land use change is being developed which could assimilate data from the European Commission Integrated Administration and Control System (IACS) data to provide a more accurate assessment of Grassland/Cropland rotation lengths for each UK administration.

Work to implement the Wetlands Supplement (IPCC, 2013) guidance should provide activity data for the area of drained Grassland under semi-natural vegetation and may yield improved emissions factors and trajectories for Grassland on drained organic soils.

6.5 CATEGORY 4D – WETLANDS

6.5.1 Description

Emissions sources	4D Wetlands: Carbon stock change 4D Wetlands: 4(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	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	Inclusion of Flooded Lands

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 as those where the water table is artificially changed (i.e. raised or drained) or those created by human activity. Natural emissions and removals from wetlands which are not the result of human activity are not estimated. The Wetlands sector includes emissions from peatlands that are cleared and drained for peat production (for energy or horticultural purposes) and for areas converted to permanently flooded land (reservoirs). As explained above, most UK wetland habitats (e.g marsh, bog, swamp and fen) are grazed and their emissions and removals are estimated with Grassland. A research project is currently in progress to identify UK-specific activity data and emission factors to use with the 2013 Wetlands Supplement methodology.

In the UK, estimates are made of emissions from on-site peat production and off-site emissions from horticultural peat under 4.D.1 Wetlands remaining Wetlands. Small areas of grassland converted to Wetland for peat extraction (4.D.2.1) and to flooded land (4.D.2.2) are included under 4.D.2 Land converted to Wetlands, with the associated soil emissions and living biomass carbon stock changes estimated using the appropriate Tier 1 methodologies. N_2O emissions from wetland drainage (as part of peat production) are reported under 4.D/4(II). There is no known commercial peat extraction data available for the Overseas Territories or Crown Dependencies.

The area of inland water (165.37 kha) is reported in this category (Other wetlands remaining other wetlands). Most of this is natural or was flooded prior to 1990. The area of reservoirs will be separated out in the reporting for the next inventory submission. A small number of reservoirs have been created since 1990, and emissions from these due to change in biomass carbon stocks on conversion are included in the inventory (under Grassland converted to Flooded Land).

6.5.2 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 and reservoirs are not explicitly identified in the habitat/landscape surveys used for the land use matrix.

Peat extraction sites are most likely to fall under the “Inland rock” broad habitat (4F Other Land) or “Bog” broad habitat (4C Grassland) if some vegetation cover remains (Maskell *et al*. 2008). Reservoirs will fall under the “Standing open water and canals” broad habitat (4F Other Land). Peat extraction sites and reservoirs need to be explicitly identified and their areas transferred into 4D Wetlands from the land use categories in which Countryside Survey places them. Three data sources were used in combination to produce an activity dataset for active peat extraction areas in the UK.

- The Directory of Mines and Quarries (Cameron *et al.* 2014): gives location, name, operator and council for currently active commercial extraction sites in Great Britain. 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 (an example is shown in Annex 3.4) (using the sites identified from the Directory of Mines and Quarries). 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.
- Information on peat extraction (for both horticultural and fuel use) in Northern Ireland from papers by Tomlinson (2010) and Cruickshank *et al*. (1995).

Activity data for reservoirs were compiled from the Public Register of Large Raised Reservoirs (supplied by the Environment Agency for England and Wales) and the SEPA Water Body Classification database (see **Annex 3.4.10** for further details).

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

The area of inland water is taken from the “UK Standard Area Measurements” (Office for National Statistics 2013). 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. Reservoirs (flooded land) were identified either by their inclusion in the Public Register of Large Raised Reservoirs or by their classification as "Heavily modified" in the SEPA Water Body Classification database.

6.5.4 Methodological Issues

Emissions from peat extraction have been estimated 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 4.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 3.4.9**.

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 sites show no change in area on the Google Earth imagery, and are assumed to be abandoned extraction sites that are still producing emissions (reported under 4D1). Sites 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 4D.2 Land converted to Wetlands, using the 5 year transition period recommended by the IPCC 2006 Guidelines.

A Tier 1 methodology was applied for emissions from Flooded Lands. In accordance with the guidance, this estimated carbon stock changes in living biomass stock in the year of flooding (for reservoirs established since 1990) but not carbon stock changes in soils. The locations of the reservoirs was established on maps, and due to their location in upland areas, all were assumed to be Grassland prior to flooding. A living biomass density of 2 t dry matter/ha was used to estimate carbon stock losses

6.5.5 Uncertainties and Time-Series Consistency

Uncertainties for the peat extraction site activity data are estimated to be >100% in 1990 and 50% in 2009 (due to improved activity data). 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. The uncertainty in emissions from Flooded Land was assumed to be the IPCC default value of 75%. Uncertainty in the activity data was very low as there were a limited number of reservoirs established since 1990 (five in total)

Time series consistency for activity data for peat extraction sites is affected by uncertainty in survey dates. Time series consistency for flooded lands was good due to the complete nature of the data set.

6.5.6 Category-Specific QA/QC and Verification

The peat extraction site 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.

The locations and previous land-use of new reservoirs were verified using the www.magic.gov.uk geographic information portal.

6.5.7 Category-Specific Recalculations

There has been an extremely small increase in the overall net GHG source in category 4D between 1990-2012 inventory and the 1990-2013 inventory due to the inclusion of change in biomass carbon stocks during reservoir creation in the inventory for the first time (**Figure 6.8**). The activity data for 2010-2011 was updated with the latest published information on peat volume sales (Office for National Statistics 2014). Volumes for 2012 were assumed to be equal to those in 2011. The changes in emissions are shown in **Table 6.5**.

Figure 6.8 4D Wetlands change in net emissions between 2012 and 2013 inventory

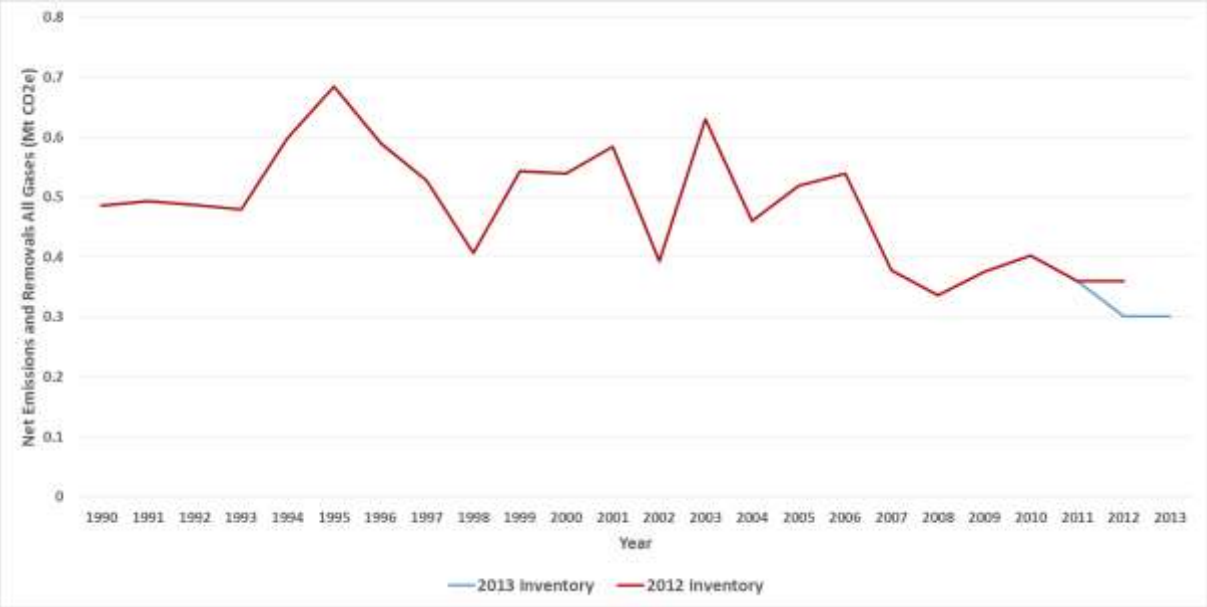


Table 6.5 4D Category specific recalculations to activity data since previous submission

IPCC Category	Source Name	2014 Submission		2015 Submission		Units	Comment/Justification
		1990	2012	1990	2012		
4D1	Carbon stock change in soils - organic soils (off-site emissions)	-124.75	-95.86	-124.75	-79.83	Gg C	Correct 2012 activity data for horticultural peat extraction now available.
4D2.2.3	Carbon stock change in living biomass - losses	NA	NA	0.00*	0.00*	Gg C	New activity, biomass stock changes as a result of reservoir creation, included in the inventory for the first time.

* 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.

6.5.8 Category-specific planned improvements

A work programme is in progress to implement the Wetlands Supplement in a UK context. This may identify UK specific emissions factors applicable to drainage activities at peat extraction sites. The area of reservoirs will be separated out as Flooded Land remaining Flooded Land from Other Wetlands remaining Other Wetlands in the reporting for the next inventory submission.

6.6 CATEGORY 4E – SETTLEMENTS

6.6.1 Description

Emissions sources	4E Settlements: Carbon stock change 4E Settlements: Direct N_2O emissions from N mineralization 4E Settlements: 4(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	4E: Settlements - CO_2 (L1, T1, L2)
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Reported under the relevant Sector 4 sub-categories at Tier 1
Completeness	No known omissions- areas are reported for land uses with no associated emissions.
Major improvements since last submission	The LUC soils and biomass models were re-run using extrapolated rather than projected rates of LUC for 2010-2013. Change to reporting using the 2006 AFOLU Guidance structure.

This category is disaggregated into 4.E.1 Settlements remaining Settlements and 4.E.2 Land converted to Settlements.

Ongoing carbon stock changes in soils and direct N_2O emissions from N mineralization arising from historical land use change to Settlements more than 20 years before the inventory reporting year are reported under 4.E.1 Settlement remaining Settlement. Carbon stock changes, N_2O emissions from N mineralization and biomass burning emissions in the previous 20 years before the reporting year are reported under category 4.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.

Direct emissions of N_2O from N mineralization associated with land use change or land management are reported under Table 4(III). 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 4(V).

6.6.2 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 6.1.1.**

The activity data on areas of Forest Land converted to Settlement (deforestation) from 2000 onwards has been updated with data collated from multiple sources (see section 1.4.2 and **Annex 3.4.4** for details). This has substantially reduced the estimated area of forest land converted to settlement by 0.4-0.7 kha per year from 2000 onwards. Before 2000, data on forest-urban land conversion in England was obtained from the Ordnance Survey (the national mapping agency) via the Department of Communities and Local Government. Land conversion ratios from Countryside Survey were then used to extrapolate from England to the other countries in the UK. Details are given in **Annex 3.4**.

6.6.3 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.

6.6.4 Methodological Issues

A summary of the land use matrix approach and the dynamic model of soil carbon stock change used to estimate changes in biomass and soil carbon due to land use change is given in **Section 6.3.4**.

Fluxes arising from land use change in the 20 years before the inventory year are reported under 4E2 Land converted to Settlement. Fluxes from historical land use change (more than 20 years before the inventory year) are reported under 4E1 Settlement remaining Settlement.

Emissions of N_2O from N mineralization associated with land use change or land management are reported for the first time this year, reflecting updated guidance in the 2006 AFOLU guidance. Detailed descriptions of the methods and emission factors used for the activities in this Category can be found in **Annex 3.4.8**.

6.6.5 Uncertainties and Time-Series Consistency

The uncertainty analysis in the Annexes provides estimates of uncertainty according to the GPG source category and gas. 4E Settlement was estimated to have a combined uncertainty of 52% for CO_2 (from LUC to settlement).

The areas undergoing land use change are the biggest source of uncertainty in the LULUCF inventory (see **Annex 3.4.13**), 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 but not yet complete. The collation of multiple deforestation datasets should have reduced the uncertainty in this area but a full assessment has not yet been carried out.

The combined uncertainty of CH_4 is 20% (from wildfires) and of N_2O is 20% (from wildfires and N mineralisation associated with land conversion).

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.

6.6.6 Category-Specific QA/QC and Verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 6.10**. Research described in **Section 6.1.1** is also relevant to this section.

6.6.7 Category-Specific Recalculations

There has been an increase in the size of the overall net GHG source in category 4E between the 2012 and the 2013 inventories (**Figure 6.9**). Emissions have been increased by the inclusion of N_2O emissions from N mineralization of soil carbon on land converted to Settlements, offsetting reduced emissions from deforestation to settlement (revised activity data). There has been a small change in trend from 2010 onwards in this inventory submission, as a result of re-running the land use-soil carbon model to use extrapolated rates of land use change rather than projected rates of land use change for 2010-2013. Changes in emissions are described in **Table 6.6**.

Figure 6.9 4E Settlements change in net emissions between 2012 and 2013 inventory

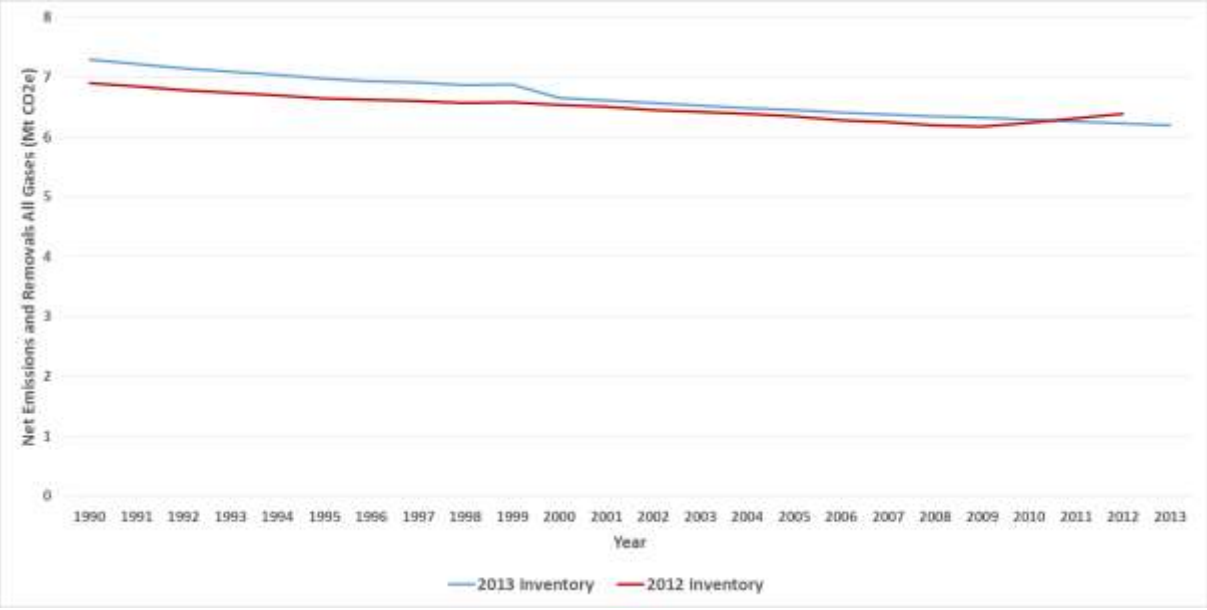


Table 6.6 4E Category specific recalculations to activity data since previous submission

IPCC Category	Source Name	2014 Submission		2015 Submission		Units	Comment/Justification
		1990	2012	1990	2012		
4E1	Carbon stock change in soils- mineral soils	-472.84	-669.67	-441.41	-630.79	Gg C	LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013.
4E2	Carbon stock change in living biomass - gains	13.97	14.98	13.92	14.49	Gg C	LUC biomass model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013. Revised deforestation areas used for 2000 – 2013.
4E2	Carbon stock change in living biomass - losses	-20.57	-28.17	-20.57	-7.04	Gg C	LUC biomass model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013. Revised deforestation areas used for 2000 – 2013.
4E2	Carbon stock change in dead organic matter	-4.76	-6.03	-4.76	-1.91	Gg C	LUC biomass model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013. Revised deforestation areas used for 2000 – 2013.
4E2	Carbon stock change in soils- mineral soils	-1374.40	-1018.88	-1419.49	-979.11	Gg C	LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013.
4E2	Carbon stock change in soils – organic soils	-6.66	-11.42	0.00	-1.65	Gg C	LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013.
4E1/4(III)	Direct N_2O emissions from N mineralization	NA	NA	0.29	0.42	Gg N_2O	Newly included under the 2006 AFOLU structure.
4E2/4(III)	Direct N_2O emissions from N mineralization	NA	NA	0.94	0.65	Gg N_2O	Newly included under the 2006 AFOLU structure.

IPCC Category	Source Name	2014 Submission		2015 Submission		Units	Comment/Justification
		1990	2012	1990	2012		
4E2/4(V)	Biomass burning - controlled burning	14.72	19.70	14.72	4.92	Gg C	Changes in the CARBINE model have altered the average amount of fuel burnt. Revised deforestation areas used for 2000 – 2013.
4E2/4(V)	Biomass burning - controlled burning	0.24	0.32	0.24	0.08	Gg CH_4	Changes in the CARBINE model have altered the average amount of fuel burnt. Revised deforestation areas used for 2000 – 2013.
4E2/4(V)	Biomass burning - controlled burning	0.00	0.00	0.00	0.00	Gg N_2O	Changes in the CARBINE model have altered the average amount of fuel burnt. Revised deforestation areas used for 2000 – 2013.

* 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.

6.6.8 Category-Specific Planned Improvements

Work on land use vectors for land use change is ongoing, but implementation was postponed to allow the inventory team to focus on the implementation of the new IPCC guidance (2006 AFOLU and 2013 Kyoto Protocol Supplement) and the new CRF reporting software.

Work is also being undertaken on carbon stock changes in perennial biomass in cropland and grassland: this will allow hedgerow areas (permanent vegetative boundaries between agricultural fields) to be separated out from the “Boundary and Linear features” habitat type and moved from the Settlement category to the Grassland category.

6.7 CATEGORY 4F – OTHER LAND

6.7.1 Description

Emissions sources	4F2 Land converted to Other Land in the Overseas Territories and Crown Dependencies
Gases Reported	4F1:None 4F2: CO_2
Methods	Tier 1
Emission Factors	Tier 1
Key Categories	None identified
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Areas reported under the relevant Sector 4 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 time series for the Overseas Territories and Crown Dependencies.

No emissions or removals are reported in this category in the UK. 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 the UK rows in Table 4.F. (Other Land) are completed with 'NO' (Not Occurring). A small area of grassland converted to Other Land is reported in the Overseas Territories and Crown Dependencies.

6.7.2 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 6.1.1**.

6.7.3 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 (Jackson, 2000). As described in **Section 6.5**, areas of inland water exceeding 1km^2 are included in 4D Wetlands, but water bodies below this threshold would still be included under Other Land.

6.7.4 Category-specific recalculations

Table 6.7 4F Category specific recalculations to activity data since previous submission

IPCC Category	Source Name	2014 Submission		2015 Submission		Units	Comment/Justification
		1990	2012	1990	2012		
4F2	Carbon stock change in living biomass- losses	NA	NA	0.00	-0.01	Gg C	A small area of conversion to Other Land is now included for the Overseas Territories and Crown Dependencies.

6.7.5 Category-specific planned improvements

None planned.

6.8 CATEGORY 4G – HARVESTED WOOD PRODUCTS

6.8.1 Description

Emissions sources	4G Harvested Wood Products
Gases Reported	CO_2
Methods	Tier 3
Emission Factors	Country-specific
Key Categories	4G: Harvested wood products - CO_2 (T1)
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Reported under the relevant Sector 4 sub-categories at Tier 3
Completeness	No known omissions
Major improvements since last submission	Update to the deforestation areas from 2000 onwards. Harvested Wood Products are now reported by product type and as either domestically consumed and exported.

HWP stocks result from normal forest management processes (thinning and harvesting) in the Forest Land category and from conversion of Forest Land to Cropland, Grassland or Settlements (deforestation), as recommended by a previous ERT.

6.8.2 Methodological Issues

The UK has elected to use the production approach B2 as set out in the IPCC 2006 Guidelines for estimating HWP. A description of the method is in **Annex 3.4.11**. The carbon accounting model (CARBINE) is used to calculate the net changes in carbon stocks of harvested wood products (at the product type level), in the same way as it is used to estimate carbon stock changes in 4.A. Changes in carbon stocks from HWP arising from deforestation (conversion of Forest Land to Grassland, Cropland or Settlement) are also estimated using CARBINE. Additional data on consumption of wood products in the UK is then used to disaggregate the HWP into either consumed domestically or exported.

6.8.3 Uncertainties and Time-Series Consistency

The uncertainty analysis in **Annex 3.4.13** provides estimates of uncertainty according to IPCC source category and gas. 4G Harvested Wood Products was estimated to have a combined uncertainty of 45% for CO_2.

Activity data for 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. Data on the consumption of products is also obtained from national forestry sources, however it is only available from 2002 onwards. The 1990-2001 values are based on the ten year average of the 2002-2011 values.

6.8.4 Category-Specific QA/QC and Verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 6.10**. 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.

6.8.5 Category-Specific Recalculations

There have been some refinement of the input data to the CARBINE model which models both forestry and harvested wood products and the deforestation activity data has been updated from 2000 onwards. The combined effect of these changes on the time series can be seen in **Figure 6.10** and **Table 6.8**.

Figure 6.10 4G Harvested Wood products change in net emissions between 2012 and 2013 inventory

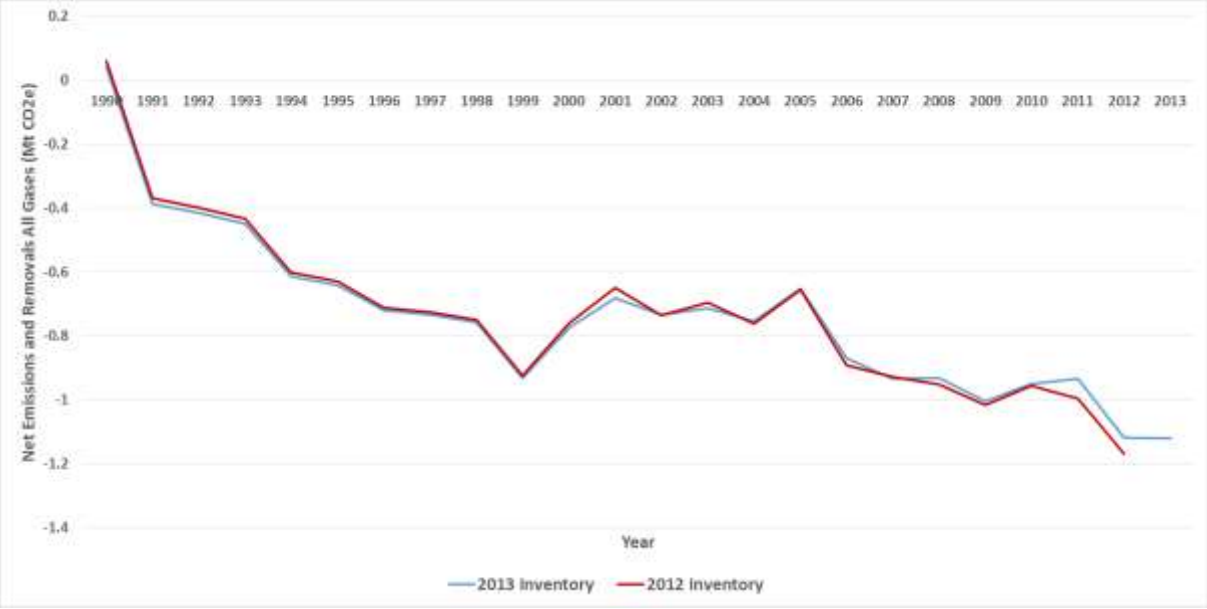


Table 6.8 4G Category specific recalculations to activity data since previous submission

IPCC Category	Source Name	2014 Submission		2013 Submission		Units	Comment/Justification
		1990	2012	1990	2012		
4G	Harvested Wood Products	16.14	-318.63	11.11	-305.09	Gg C	Minor updates to the CARBINE model and updated activity data for deforestation.

6.8.6 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.

6.9 LULUCF EMISSIONS AND REMOVALS IN THE OVERSEAS TERRITORIES AND CROWN DEPENDENCIES

The UK includes direct GHG emissions in its GHG Inventory from UK Crown Dependencies (CDs) and Overseas Territories (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. A web search of statistical publications was undertaken for any updates in datasets in 2014. 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 4. The estimates have high uncertainty and may not capture all relevant activities, but given the size of the territories any missing sources are likely to be small. **Annex 3.4.12** provides detailed descriptions of the methods and emission factors used.

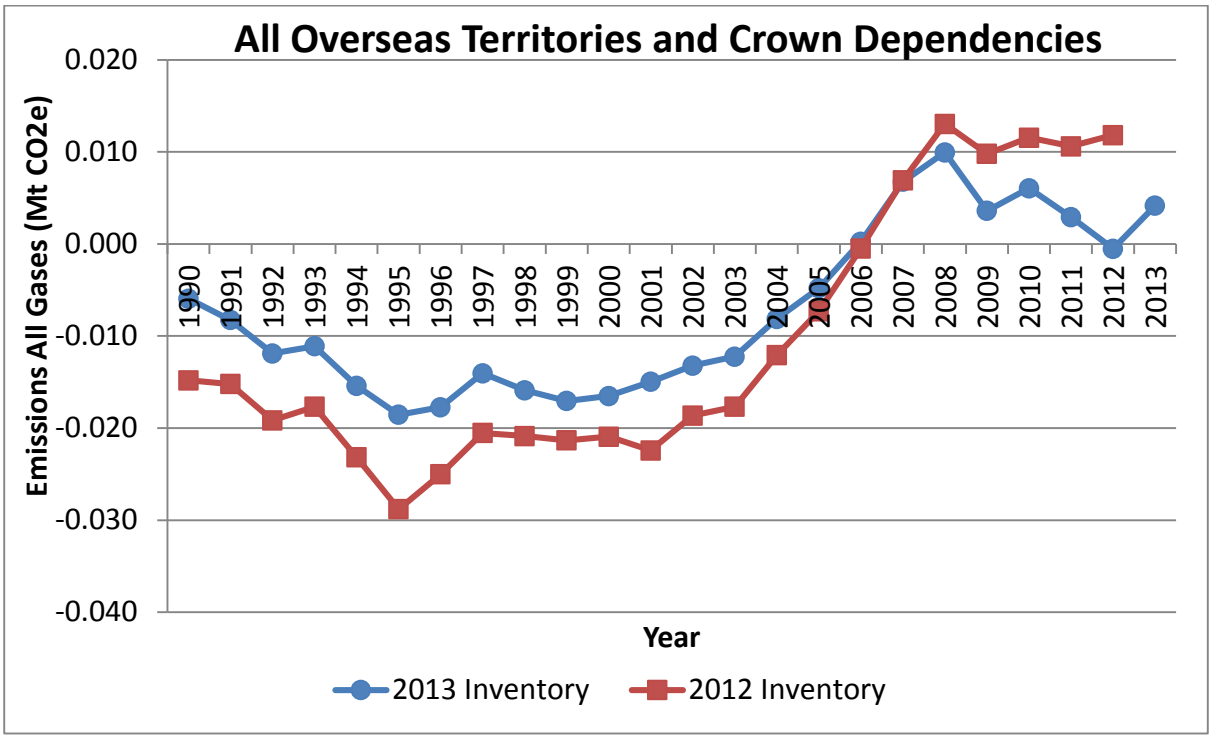
There was only sufficient published information to enable estimation of LULUCF emissions and removals from the Isle of Man, Jersey and Guernsey (CDs) and the Falkland Islands (OTs). No emissions or removals are reported for the Cayman Islands, Bermuda and Montserrat due to insufficient information on land use and land use change activities. Gibraltar emissions for this sector are considered to be negligible.

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. The IPCC Tier 1 default factors and GWPs from the 2006 AFOLU Guidelines were implemented: this resulted in the addition of sources of N_2O emissions from land use change, reported in Table 4/4(III). Specific changes to each CD and OT are listed below. CO_2 emissions from liming of Cropland and Grassland are now reported in the Agriculture sector 3G.

The overall trend in LULUCF emissions from the OTs and CDs moves from an initial net sink in 1990 to a net source from 2006 onwards. Both the net sink and the net source are smaller than estimated in the 1990-2012 inventory (**Figure 6.11**). These changes are due to the correction of errors in the previous inventory and the implementation of the 2006 AFOLU Guidelines (particularly the removal of the liming emissions). Individual graphs are shown for the four reported OTs and CDS below.

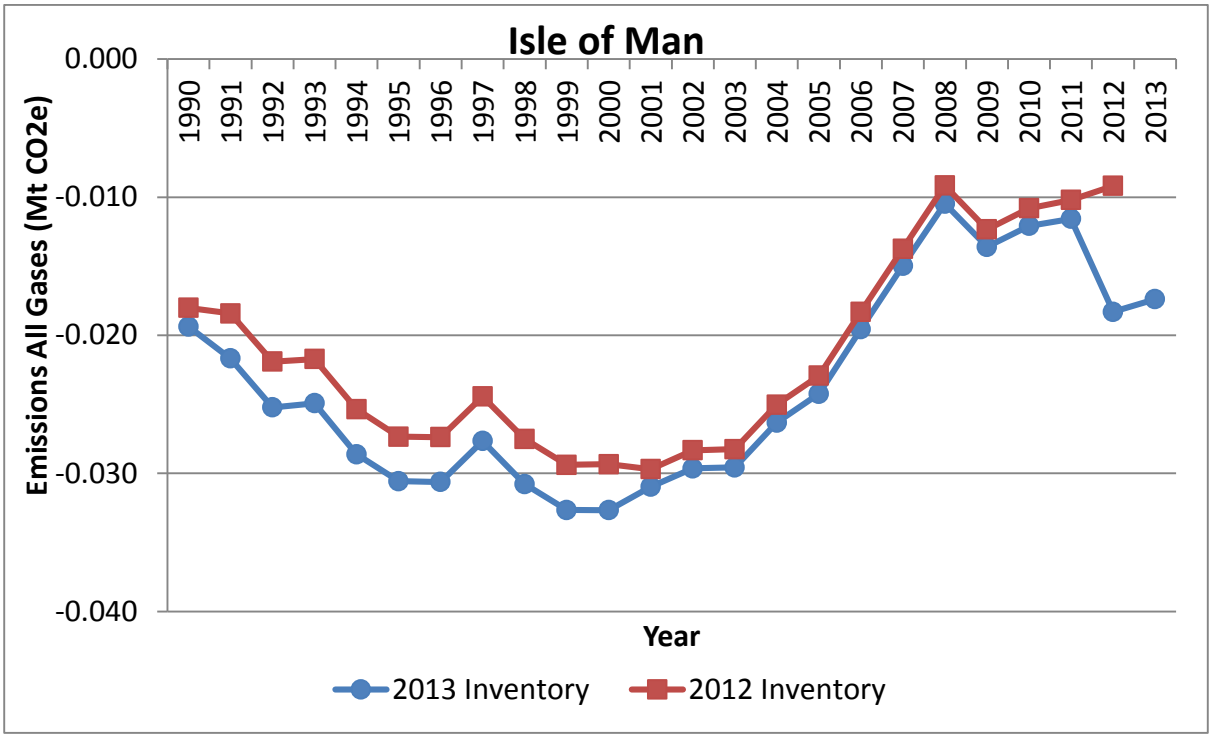
Figure 6.11 **LULUCF sector change in net emissions between the 1990-2012 and 1990-2013 inventories for the combined Overseas Territories and Crown Dependencies.**



Isle of Man

The Isle of Man is a net LULUCF sink, due to its forest area. Land use areas for 2012 and 2013 have been updated from the Isle of Man Digest of Economic and Social Statistics (2014). The total land area was also readjusted to 57.2 kha, as the 58.2 kha in the 2011 agricultural census is thought to be a misprint. The Grassland category is used as the "buffer" category to ensure consistency in total land area. The land use conversion period was corrected to be 20 years, not 21 (i.e. 1971-1990, not 1970-1990). N_2O emissions from land use change to Settlement were included for the first time. Total LULUCF net emissions for the Isle of Man are shown in **Figure 6.12** - note that this has been corrected from the previous NIR, where not all emissions had been included in the graphs.

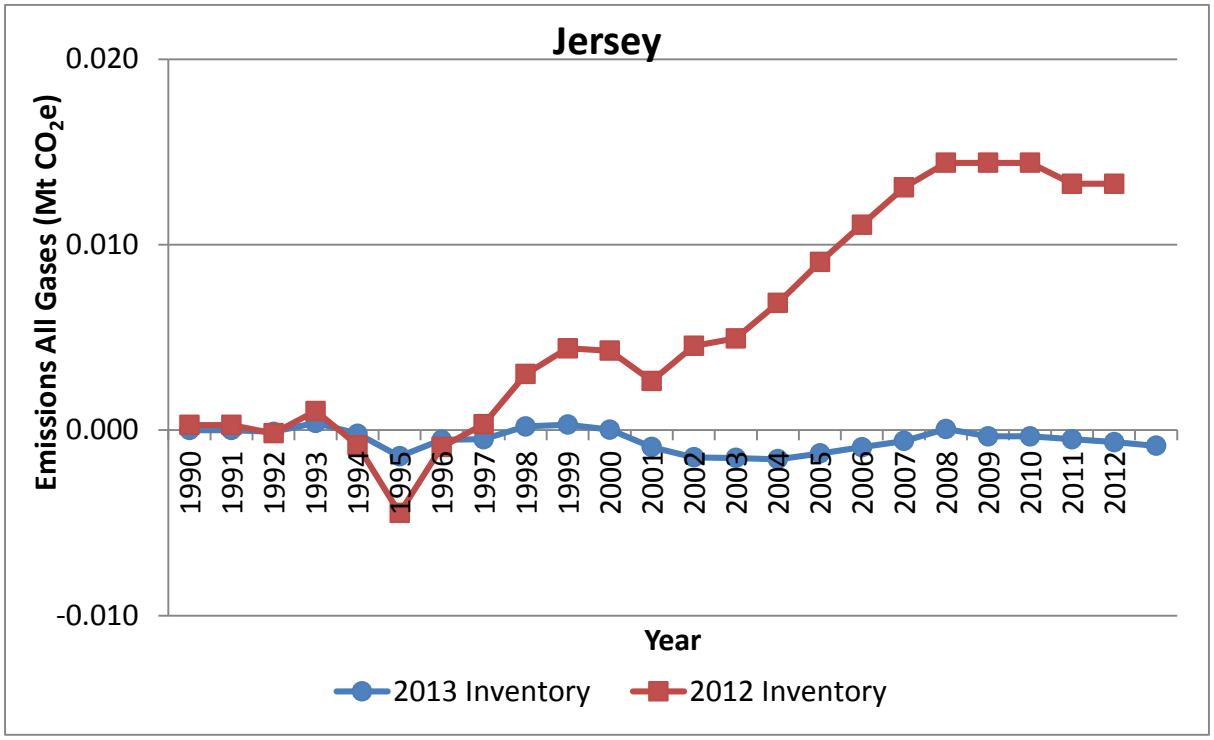
Figure 6.12 LULUCF sector change in net emissions between the 1990-2012 and 1990-2013 inventories for the Isle of Man



Jersey

Jersey is overall a very small net sink of LULUCF emissions. No new land use data was reported for Jersey. The Grassland category is used as the "buffer" category to ensure consistency in total land area. An error in the calculation in living biomass stock change was corrected to apply to the area change in a single year rather than all relevant land in the 20 year transition period. Carbon stock changes for Grassland to Other Land were added (these were previously omitted) - this conversion was to standing water, so it was assumed that there were carbon losses from biomass but none from soils, in line with Tier 1 methodology. Conversion to Settlement on Guernsey and Jersey now assumes that 30% of the area is paved over on conversion and the rest is converted to turf grass, as most of the LUC to Settlement on these islands is to amenity grassland (i.e. the extension of gardens or urban green space). Total LULUCF net emissions for Jersey are shown in **Figure 6.13**. The primary change in emissions has been due to the correction of errors and the updates to IPCC default factors, rather than the changes in assumptions described above.

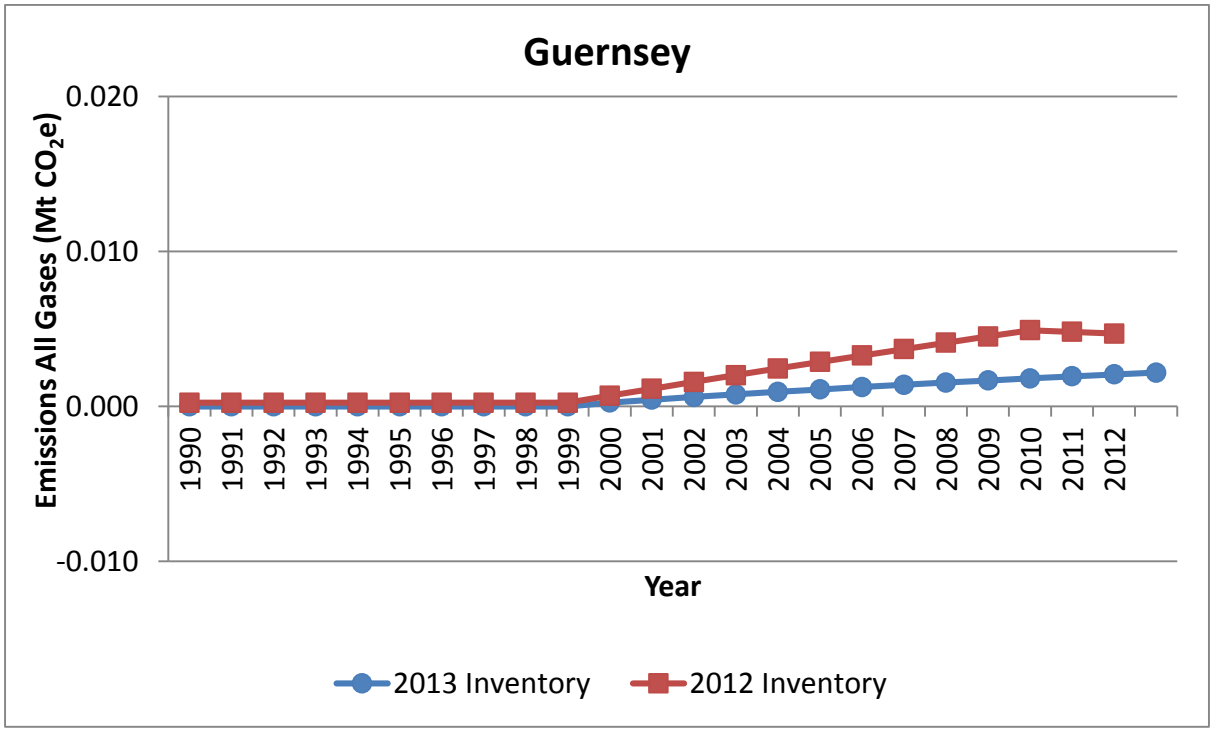
Figure 6.13 LULUCF sector change in net emissions between the 1990-2012 and 1990-2013 inventories for Jersey



Guernsey

Guernsey is a small but increasing net source of LULUCF emissions from 1999 onwards. No new land use data was reported for Guernsey. An error in the calculation in living biomass stock change was corrected to apply to the area change in a single year rather than all relevant land in the 20 year transition period. The assumption about conversion to Settlement was modified (see description above for Jersey) and the Settlement category was used as the 'buffer' category as it includes as areas that are not surveyed in the Habitat Surveys used for land category areas. Carbon stock changes for Grassland to Other Land were added (these were previously omitted) - this was mainly due to conversion to standing water and an increase in the area of cliff (probably a habitat reassignment rather than a genuine land use change). It was assumed that biomass stocks were totally lost but that there was no change in soil carbon stocks. Total LULUCF net emissions for Guernsey are shown in **Figure 6.14**. The primary change in emissions has been due to the correction of errors and the updates to IPCC default factors, rather than the changes in assumptions described above.

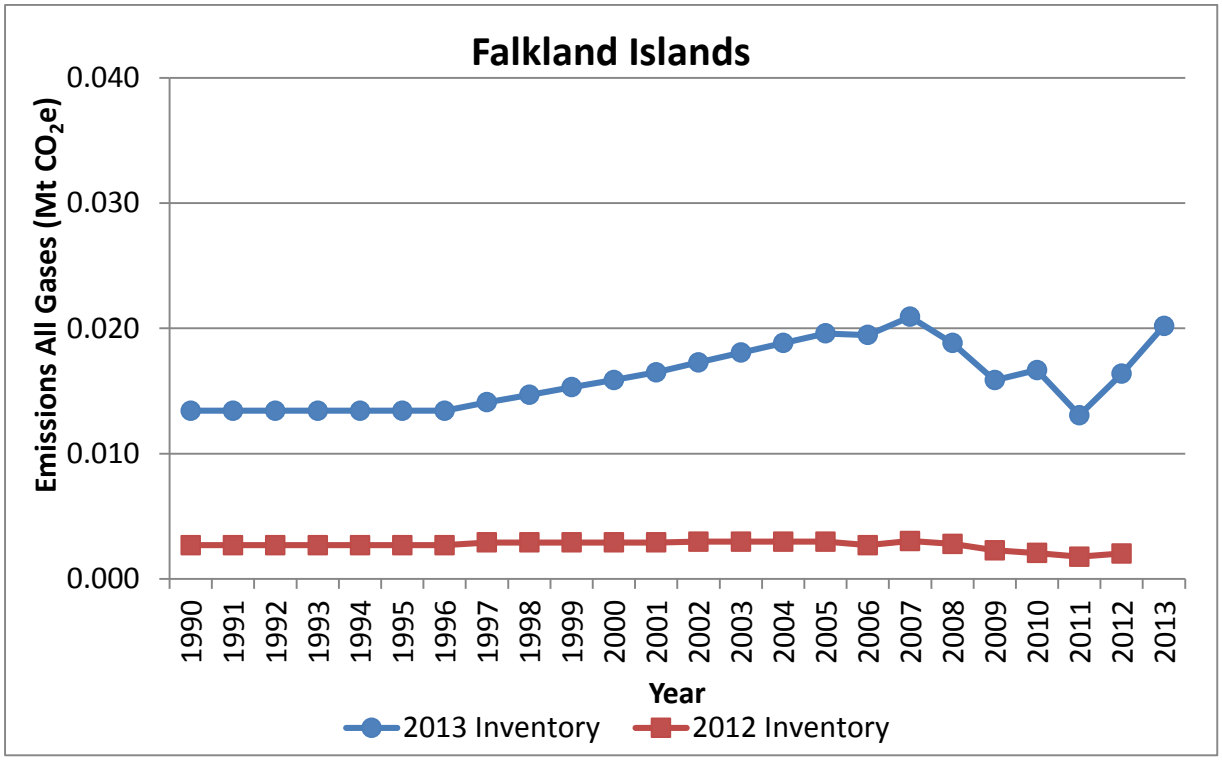
Figure 6.14 LULUCF sector change in net emissions between the 1990-2012 and 1990-2013 inventories for Guernsey



Falkland Islands

The Falkland Islands are a small net source of LULUCF emissions. Land use areas were updated with new information from Falkland Statistics (2012, 2013). An error in the calculation in living biomass stock change and soil carbon stock change was corrected to achieve consistency with the Tier 1 methodology. An error in the reporting of N_2O emissions was corrected, from LUC on mineral soils to emissions from organic soils. Total LULUCF net emissions for the Falkland Islands are shown in **Figure 6.15**. The primary change in emissions has been due to the correction of errors and the updates to IPCC default factors.

Figure 6.15 LULUCF sector change in net emissions between the 1990-2012 and 1990-2013 inventories for the Falkland Islands



6.10 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/.

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 Energy & Environment, CEH has been developing a QA/QC plan to standardise and structure the way checks are carried out within the LULUCF sector. The plan is now being implemented and will be reviewed and updated as required. The QA/QC Plan is embedded into all planning, preparation and management activities of the Inventory. The plan sets out five key Data Quality Objectives (DQOs), covering all principles of Transparency, Consistency, Completeness, Comparability and Accuracy, which help to focus the aims of the annual checking.

A major aim of the plan is to ensure appropriate QA/QC responsibilities will be applied to data suppliers, where possible and appropriate through Data Supply Agreements. Arranging these agreements is the next major QA/QC development activity for LULUCF.

7 Waste (CRF Sector 5)

7.1 OVERVIEW OF SECTOR

IPCC Categories Included	5A: Solid Waste Disposal on Land 5B: Biological Treatment of Solid Waste 5C: Waste Incineration 5D: Wastewater Handling
Gases Reported	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
Key Categories ('T' or 'L' indicates whether it's been identified in the trend or level assessment respectively and the number indicates which KCA approach it was identified in)	5A: Solid waste disposal - CH_4 (L1, T1, L2, T2) 5B: Biological treatment of solid waste - CH_4 (T2) 5D: Wastewater Handling - N_2O (L2, T2) 5D: Wastewater treatment and discharge - CH_4 (L1)
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Emissions for 5A and 5D are included as a separate category within 5A and 5D respectively. Emissions from 5C 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 **Section 1.8**.
Major improvements since last submission	5A: The methodology for calculating methane production in landfill sites has been updated. Waste composition and commercial and industrial waste data has been updated, along with updated assumptions about the two combustion of methane in landfill gas engines and the approach to flaring at non-reporting sites. 5B: Mostly consists of new sources identified in the 2006 IPCC GLs. 5D1: Inclusion of an estimate of methane emissions from private waste-water management systems (e.g. septic tanks), a general reassessment of available data for emissions from waste-water companies.

Emissions from the waste sector contributed 4.0% to greenhouse gas emission in 2013. 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 and biological treatment of solid waste. Overall emissions from the waste sector have decreased by 67% 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 7.1 Breakdown of total GHG emissions from the Waste sector in 2013

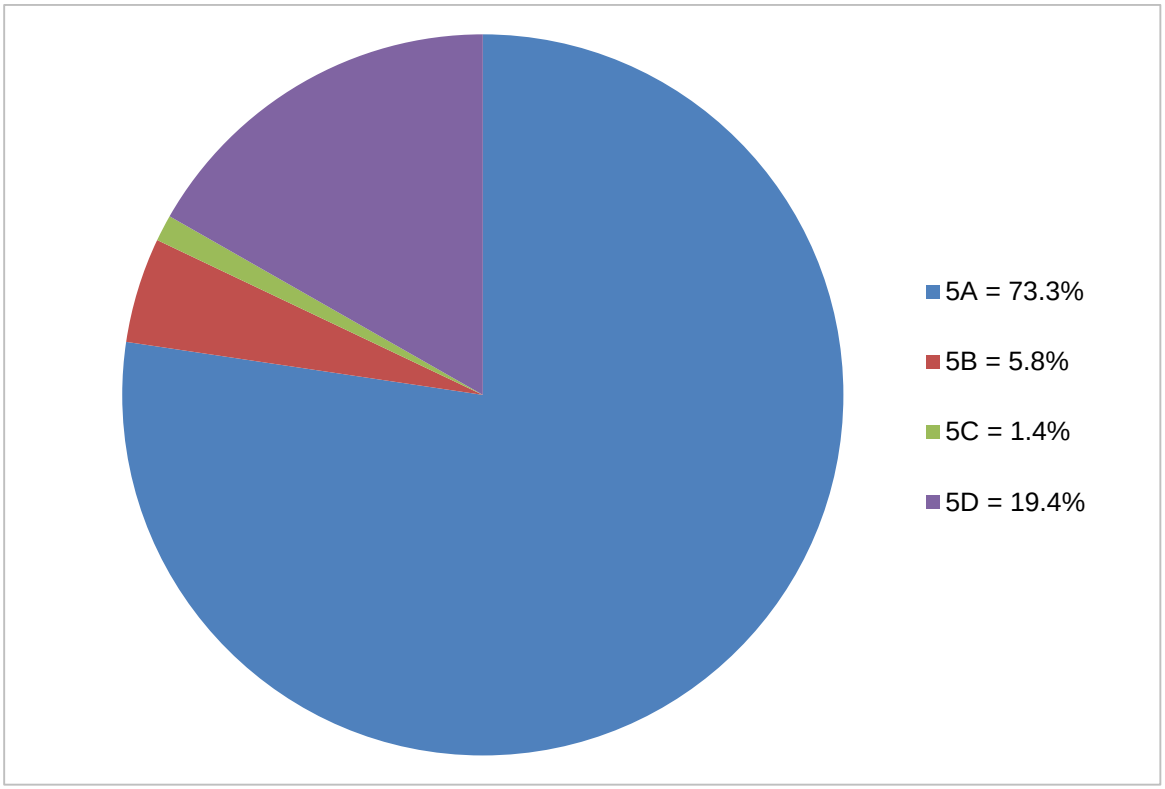
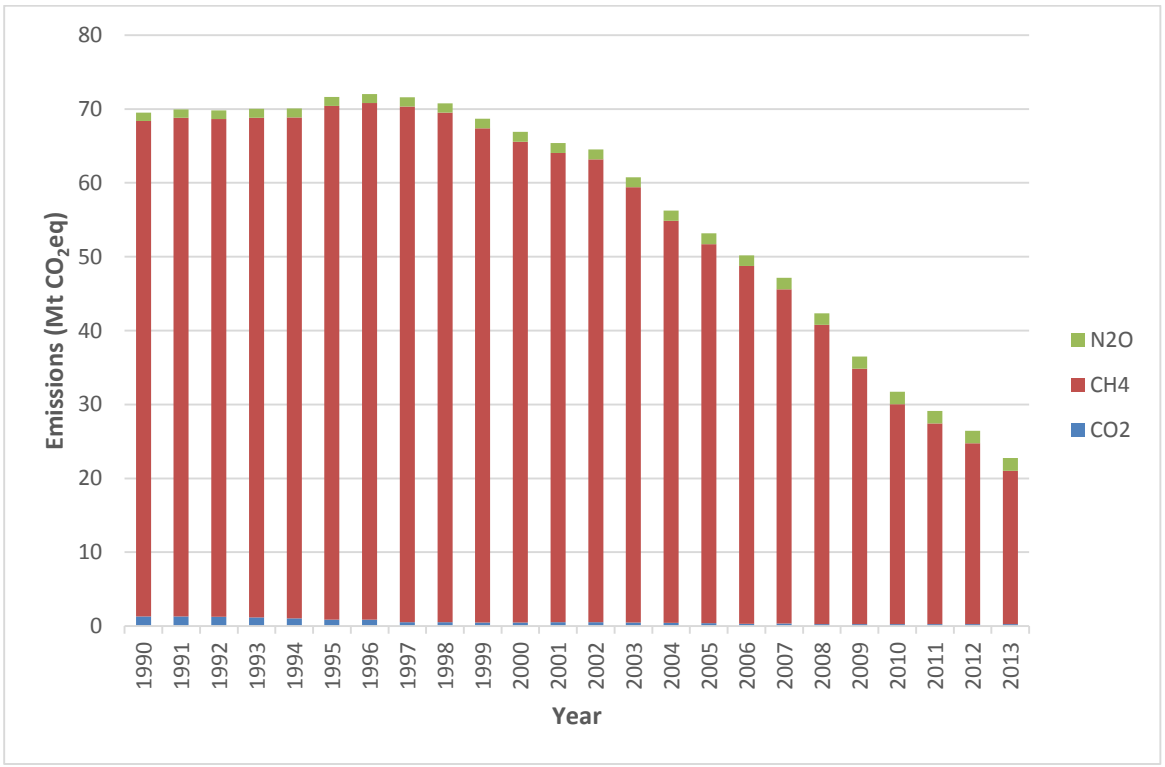


Figure 7.2 Trend in total GHG emissions in the Waste sector



7.2 SOURCE CATEGORY 5A – SOLID WASTE DISPOSAL ON LAND

7.2.1 Source category description

Emissions sources	Sources included	Method	Emission Factors
	5A: Landfill	OTH, T2	CS
Gases Reported	CH_4, NMVOC		
Key Categories	5A: Solid waste disposal - CH_4 (L1, T1, L2, T2)		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	OT & CD emissions for 5A are included within 5A.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in **Section 1.8**.		
Major improvements since last submission	The methodology for calculating methane production in landfill sites has been updated. Waste composition and commercial and industrial waste data has been updated, along with updated assumptions about the two combustion of methane in landfill gas engines and the approach to flaring at non-reporting sites.		

The NAEI category "Landfill" maps directly on to IPCC category 5A Solid Waste Disposal 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 2013 were 16.5 Mt CO_2e. Emissions have been on a downward trend since 1996.

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 0.0036 kg NMVOC/tonne landfill gas was used (Broomfield et al., 2010).

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 (1999/31/EC). 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.

7.2.2 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 (IPCC (2006) p3.6 – 3.12). The IPCC FOD methodology is based on the premise that Dissimilable Degradable Organic Carbon compounds (DDOC)[39] decay under the airless conditions in landfills to form methane, carbon dioxide and a variety of stable decomposition products that remain in the landfill, and represent a sink for carbon. First order means that the rate of reaction is proportional to the amount of reactant (i.e. DDOC) present at any given time. This means that as the reactant is used up, the rate of reaction slows down.

The IPCC Guidelines (IPCC, 2006) 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), minus the amount of remaining methane that is oxidised to carbon dioxide.

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

[39] 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.

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 updated for the 2013 inventory, as summarised in **Table A 3.5.1**.

The characteristic decay rates for these three pools are: 0.076 $year^{-1}$ (SDO), 0.116 $year^{-1}$ (MDO) and 0.694 $year^{-1}$ (RDO), based on the findings of recent research (Golder Associates, 2014). 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 using a methodology adapted from IPCC 2006 Equations 3.1 to 3.6.

The total methane generated in each inventory year is determined by summing the quantity of methane emitted over all waste types, all three decomposition pools, all landfill types, and all years in which the waste is landfilled.

A Methane Correction Factor (MCF) is used 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 2006 Table 3.1), 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 2006 Table 3.1).

The molar fraction of methane in landfill gas was assigned the value of 0.5, the default value given in the 2006 IPCC Guidelines.

A model system known as MELMod was used to carry out these calculations from 2008 (Brown et al., 2008). In 2010, the UK government commissioned further work to update the activity data and emission factors for landfill methane (Eunomia Consulting and Research, 2011), which was peer reviewed by independent experts from academia, industry, regulators and consultants in 2010. The principal changes to the input data at that time were summarised in the 2011 NIR submission for the 1990-2009 inventory. Further details on data sources and rationale are given in Eunomia's report.

Activity data for 2013 were taken from the following published data sources:

- England: "Local Authority Collected Waste Management," August 2014, Department for Environment, Food and Rural Affairs https://www.gov.uk/government/statistical-data-sets/env18-local-authority-collected-waste-annual-results-tables
- Scotland: Household Waste Interrogator (Source: http://www.environment.scotland.gov.uk/get-interactive/data/household-waste/)
- Wales: StatsWales "Waste managed (tonnes) by management method and year" (https://statswales.wales.gov.uk/Catalogue/Environment-and-Countryside/Waste-Management/Local-Authority-Municipal-Waste/Annual/wastemanaged-by-management-year)
- Northern Ireland: "LAC municipal waste sent for recycling & composting, KPI(e), and landfilled, KPI(f), for Northern Ireland, 2012/13" (http://www.doeni.gov.uk/niea/waste-home/municipal_data_reporting.html)

Data on Commercial and Industrial waste arisings in England since 2010 were taken from Defra, 2011 and the supporting report by Jacobs (2011). Data for Scotland, Wales and Northern Ireland were taken from Chartered Institute of Waste Management (2013).

Data on waste composition since 2010 was taken from research for the UK Government (Resource Futures for Defra, 2012).

7.2.2.1 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 recent analysis indicates that data on flaring prior to 2009 is either unavailable or only accessible at disproportionate cost. 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. At sites and inventory years for which robust data on landfill gas flaring are not available, it is conservatively assumed that no landfill gas was flared.

Current estimates for methane recovered are given in **Table A 3.5.2**.

Regulatory guidance[40] 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.

7.2.2.2 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. The assumed efficiency of landfill gas engines in these calculations was updated in accordance with research carried out for the UK Government (Golder Associates, 2014).

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 **Table A 3.5.2**.

7.2.2.3 Flaring

Since 2009, operators of landfills in England and Wales 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. As 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

[40] See "Guidance on the management of landfill gas" Landfill Technical Guidance Note TGN(03) The Environment Agency and Scottish Environment Protection Agency 2004.

individual site level. The use of this dataset is therefore a robust and appropriate basis on which to evaluate the quantities of methane flared by operators. Based on guidance from the Expert Review of the 2013 GHG Inventory (para 98 of the 2013 Annual Review Report), this dataset was used to estimate the quantity of methane flared at landfill sites in England and Wales in 2008.

Similarly, landfill site operators in Scotland have been required to compile a similar annual report on the quantity of landfill gas flared since 2013. This dataset was used to evaluate the quantity of methane flared by operators at landfill sites in Scotland in 2013.

A further research project was commissioned by DECC to identify all reasonably available data on the quantities of methane flared at landfill sites in England, Scotland and Wales for other years (DECC, 2015). This project identified some additional site-specific data which was also taken into account in compiling the inventory.

At all other sites and inventory years, robust data on landfill gas flaring was not available, and it was conservatively assumed that no landfill gas was flared.

The estimates shown in **Table A 3.5.2** 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 is neglected in these calculations due to a lack of data, and assumed to be emitted to the atmosphere as a conservative assumption.

7.2.2.4 Overseas Territories and Crown Dependencies

The IPCC landfill model is used for all landfill estimates apart from Isle of Man where insufficient information is currently available. Where available, country-specific waste generation and composition data have been applied and appropriate defaults chosen e.g. taking into account climatic variation. There are no landfill emissions for Gibraltar as waste is exported. Parameters used in these calculations are shown in **Annex 3.5**.

7.2.3 Uncertainties and time-series consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to IPCC source category and fuel type. 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 2** 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 **Annex 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% up to 1996, increasing linearly to 36% in 2012 and thereafter, following peer review (Golder Associates, 2014). This is considered to be an accurate calculation of the quantity of methane combusted in landfill gas engines;

- Combustion of methane in flares. This data is based on site-specific records where available and is considered to be accurate for the sites where data exist. However, records of the quantity of landfill gas are incomplete, particularly for the years prior to 2008. In cases where records of landfill gas flaring are not available, the quantity of methane flared was assumed to be zero. This means that the landfill methane inventory is subject to greater uncertainty for the years prior to 2008, although because of the conservative approach adopted in respect of landfill gas flaring, it is considered that the inventory represents a significant over-estimate of methane emissions from landfill sites in the UK, particularly for the years prior to 2008.

Because records of landfill gas flaring are incomplete, it is considered that the inventory represents a significant over-estimate of methane emissions from landfill sites in the UK, particularly for the years prior to 2008.

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 61% in 2013 derived in this analysis appears reasonable and likely to be conservative. Lower collection efficiencies in the years between 1990 and 2012 are likely to be more conservative still.

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.

7.2.4 Source-specific QA/QC and verification

The verification of MELMod has been described in the 2008 NIR. The update undertaken by Eunomia (Eunomia, 2011) in 2010 resulted in updating of input data to the model only, with no changes implemented as to calculation methodology other than where indicated. 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.

MELMod was subject to a further peer review process in 2014 (Golder Associates, 2014). In the light of this peer review, changes were made to the assumed waste decay rates, and to the assumed efficiency of landfill gas engines.

7.2.5 Source-specific recalculations

There have been significant improvements to the UK landfill methane inventory for the 2013 inventory as described above. The key improvements are:

- Update to methodology for calculating methane production in landfill sites
- Update to waste composition data
- Update to commercial and industrial waste data
- Update to assumptions in relation to combustion of methane in landfill gas engines
- Use of site-specific data only in relation to combustion of methane in landfill gas flares

The UK inventory of methane emissions from this sector has been recalculated, as set out in **Table A 3.5.2**. This table shows the quantity of methane generated, combusted in engines and flares, oxidised by the landfill surface and emitted to the atmosphere.

Emission estimates for the OTs and CDs are now calculated using the IPCC waste model taking into account country-specific data and parameters. Previously, the majority of estimates were made by scaling against historic UK data.

7.2.6 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).

7.3 SOURCE CATEGORY 5B – BIOLOGICAL TREATMENT OF SOLID WASTE

7.3.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	5B:Composting (non-household) Composting (household) Anaerobic digestion (non-agricultural) Mechanical biological treatment	T2 T2 T2 T2	D D D D
Gases Reported	CH_4, N_2O		
Key Categories	5B: Biological treatment of solid waste - CH_4 (T2)		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Estimates made for OT and CD emissions from 5B1, composting of municipal solid waste where data on total amount of waste composted is available. 2006 IPCC default EFs are applied. These estimates are included within 5B for CRF reporting.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in **Section 1.8**.		
Major improvements since last submission	New source category in the 2015 inventory.		

7.3.2 Methodological Issues

Emissions of methane and nitrous oxide from composting of MSW (Category 5.B.1.a) and anaerobic digestion (AD) and Mechanical Biological Treatment (MBT) of MSW (Category 5.B.2.a) were introduced into the inventory for 2013 using a Tier 1 methodology. This was identified as an appropriate approach in view of the scale of emissions from this sector (DECC, 2015b)

Activity data for this sector was derived from annual organics recycling reports, published between 1998 and 2012 by:

- The Waste and Resources Action Programme (WRAP - 2012, 2010 & 2009)
- The Association for Organics Recycling (2008, 2007 & 2006)
- The Composting Association (2005, 2004, 2003, 2001, 1999 & 1998)

Where necessary (e.g. for intervening years between published reports), activity data were interpolated between published values.

Emission factors for source category 5.B.1.a and the anaerobic digestion component of 5.B.1.b were taken from IPCC (2006) default emission factors. The emission factor for mechanical biological treatment was assumed to be the same as for anaerobic digestion.

7.3.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to IPCC source category and fuel type.

Activity data for industrial activities over the time series were taken from relevant publications, and are considered to provide robust and accurate data. Activity data for home composting is less reliable, but now represents a small proportion (approximately 3%) of total composting activity carried out in the UK.

IPCC Tier 1 default emission factors were used for this analysis. These are considered to be less reliable, and hence subject to greater uncertainty. This is the key source of uncertainty in emissions from the 5.B sector in 2013.

Time series consistency is based on activity data and is considered to be reasonably representative of activity in this sector between 1990 and 2013.

7.3.4 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**.

7.3.5 Source Specific Recalculations

For information on the magnitude of recalculations, see **Section 10**.

7.3.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

7.4 SOURCE CATEGORY 5C – WASTE INCINERATION

7.4.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	5C1: Incineration: MSW	T2	CS, D
	Incineration: sewage sludge	T1	CR, D
	Incineration: clinical	T1	OTH, D
	Incineration: chemical	CS, T1	CS, D
	Incineration: animal carcases	T1	CS
	Crematoria	CS	CS
	5C2: Accidental fires: dwellings	CS	CS
	Accidental fires: other buildings	CS	CS
	Accidental fires: vehicles	CS	CS
	Bonfire night	CS	CS
	Fireworks	CS	CS
	Small-scale waste burning	CS	CS
Gases Reported	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2		
Key Categories	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, apart from 5C2.1b. where estimates are now made for Guernsey using IPCC default method.		
Completeness	A general assessment of completeness for the inventory is included in **Section 1.8**.		
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), and crematoria. The UK also reports indirect GHG emissions from various other sources involving small-scale waste burning, accidental fires, and fireworks under 5C2.

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 5C 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 5C1. In-situ burning of agricultural waste e.g. crop residue burning is reported under category 3F.

The numbers of chemical waste, clinical waste and sewage sludge incinerators in the UK are not known with certainty, although that number has almost certainly decreased significantly between 1990 and 2013, and 37 large incinerators have been identified as operating in 2013. It is possible that a few very small incinerators may also exist. Approximately 2600 animal carcass incinerators are believed to be in use (estimated in AEA Technology, 2002). Animal carcass incinerators are typically much smaller than the incinerators used to burn other forms of waste. Numbers of crematoria are slowly increasing in the UK: there were 270 in 2013 compared with 239 in 1999 (based on statistics published by the Cremation Society of Great Britain, website at http://www.cremation.org.uk/).

This source category also includes emissions from the open burning of wood waste in Guernsey.

7.4.2 Methodological Issues

Emissions of CO_2, CO, NO_x, SO_2, and VOC from chemical waste incinerators are estimated based on analysis of emissions data reported to the Pollution Inventory (Environment Agency, 2014). This only covers England and Wales, but there are not thought to be any plants in Scotland and Northern Ireland. Emissions data are not available for all pollutants for all sites and so some extrapolation of data from reporting sites to non-reporting sites has been done, using estimates of waste burnt at each site as a basis. The gaps in reported data are usually for smaller plants but the need for extrapolation of data may contribute to significant variations in the quality of the estimates. Emissions of N_2O from chemical waste incinerators are estimated using the 100 g N_2O / t waste default factor for industrial waste incineration given in the IPCC guidelines (2006), Waste tonnages burnt at the largest individual chemical waste incinerators for the period 2006 – 2012 have been obtained from the Environment Agency, but the overall quantity of chemical waste burnt must then be estimated by the Inventory Agency, based on the capacity of the smaller plant. For the earlier part of the time series, we use the following estimates of waste burnt:

1993	290,000 tonnes (HMIP, 1995)
2002	284,000 tonnes (Entec, 2003)

The HMIP figure is assumed to also be applicable for 1990-1992, and we interpolate between the HMIP and Entec figures for the years 1994-2001. For the period 2003-2005, we interpolate between the Entec figure of 284,000 tonnes and our estimate for 2006 of 177,000 tonnes. We have been unable to obtain site-specific waste disposal data for 2013, so the waste burnt at each site is assumed to be the same as in 2012. The use of reported emissions data for pollutants other than N_2O avoids the need to rely upon the highly uncertain activity data.

Emissions of CH_4, CO, N_2O, SO_2 and VOC from sewage sludge incineration are estimated using literature-based emission factors, while emissions of NO_x are estimated using Pollution Inventory data. The factor for N_2O is the average of the range of emission factors given in the 2000 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 using data from various sources:

1990	RCEP, 1993
1991-1998	Digest of Environmental Statistics (Defra, 2004)
2006-2012	Environment Agency, waste disposal data for individual sites in England
2013	Scottish Environment Protection Agency, estimate of total sewage sludge incinerated in Scotland

Interpolation between the various estimates is used to fill the gaps in the activity data time series.

Emissions of CO_2, CH_4, CO, N_2O, NO_x, SO_2, and VOC from clinical waste incineration are estimated using literature-based emission factors. The factors for CO_2 and N2O are IPCC default factors. 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 the following sources:

1991	RCEP, 1993
1997	Wenborn *et* al, 1998
2002	Entec, 2003

2006-2012	Environment Agency, waste disposal data for individual sites in England and Wales
2004-2013	Scottish Environment Protection Agency, estimates of total clinical waste incinerated in Scotland

Interpolation between the various estimates is used to fill the gaps in the activity data time series.

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 (2014).

Emissions from MSW incineration for the period 1990-1996 are reported split between 1A1a and 5C, 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.

Estimates for accidental fires are based on statistics from the Fire Service of Great Britain, available from the Department for Communities and Local Government (DCLG, 2014). These statistics give the number and severity of fires in dwellings and other buildings, and the number of fires in road vehicles by type. The statistics have then been converted into masses of material burnt by applying country-specific assumptions for each type of fire e.g. for the many fires in dwellings that are limited to just a single item, the mass of material combusted is assumed to be 1 kg. The total material burnt is then combined with emission factors to obtain emission estimates for methane, CO, NO_X and NMVOC. The methane factors are taken from AP 42 (USEPA, 2014) and relate to open burning of municipal waste (for dwellings and other buildings) and automobile parts (for vehicle fires). Factors for other pollutants are taken from the same source, or from UK-specific literature.

The tonnage of MSW burnt in incinerators is provided by the Cayman Islands and the Falklands. UK GHGI EFs were then applied to these activity data to estimate emissions from this sector. Emissions from waste incineration in Jersey, Bermuda and the Isle of Man are reported under 1A1a. Data are available for the amount of waste open-burned in Guernsey, so these are used to estimate emissions for 5C2 using IPCC 2006 default EFs. It is assumed that this source is not occurring in the remaining territories.

The inventory includes estimates for emissions of:

- CO, NO_X & VOC from small-scale burning of domestic and garden waste, for example on domestic grates and on garden bonfires
- CO from open fires lit as part of 'bonfire night' celebrations
- CO from fireworks

All of these estimates are very uncertain, because of the need for expert judgements and assumptions in order to derive any activity data from waste arisings data, and the need, because of a lack of suitable emission factors, to instead use factors that were designed for other types of emission source such as domestic fires.

Activity and emissions data for this sector can be found in **Annex 3**, **Table A 3.5.4** and **Table A 3.5.5**.

7.4.3 Uncertainties and Time-Series Consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to IPCC source category and gas.

7.4.4 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**.

7.4.5 Source Specific Recalculations

For information on the magnitude of recalculations to Source Category 5C, see **Section 10**.

New information was obtained through a waste survey distributed to all OTs and CDs in 2014. As a result, emission estimates were included in this sector for Guernsey (5C2: open burning) and the Cayman Islands. (5C1: incineration of waste)

7.4.6 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 2B10. As recommended in the 2014 Expert Review and associated report, if data on flaring becomes available within the pollution inventory for chemical waste incineration this data will be included in the GHG 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.

7.5 SOURCE CATEGORY 5D – WASTEWATER HANDLING

7.5.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	5D1: Domestic Waste-water treatment 5D2: Industrial Waste-water Treatment	T1, CS, OTH T1	T1, CS, OTH D
Gases Reported	CH_4, N_2O		
Key Categories	5D: Wastewater Handling - N_2O (L2, T2) 5D: Wastewater treatment and discharge - CH_4 (L1)		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Emissions from wastewater handling within OTs and CDs are included in 5D1. Estimates are based on 2006 IPCC Guidelines and EFs with country-specific parameters applied, where available.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in **Section 1.8**.		
Major improvements since last submission	5D1: Inclusion of an estimate of methane emissions from private waste-water management systems (e.g. septic tanks), a general reassessment of available data for emissions from waste-water companies.		

Emissions reported in 5D2 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 5D2.

Emissions reported in 5D1 arise from wastewater handling, sludge treatment and disposal in the UK's municipal waste-water treatment system and private waste-water management systems. The UK's municipal waste-water treatment system 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.

7.5.2 Methodological Issues

The emissions from 5D1 and 5D2 are estimated for the following sources in the UK:

- ***5D1 Domestic and Commercial Waste-Water.*** Which consists of 4 main aspects:
  - **UK CH_4 emissions from municipal waste-water treatment.** 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;

- **UK CH_4 emissions from private waste-water management.** Default IPCC methodology using UK-specific per capita Biochemical Oxygen Demand (BOD) and estimated population using private waste-water management systems;
- ***UK N_2O* emissions.** Default IPCC methodology applied to UK time series of population and protein intake estimates from food surveys;
- ***OT and CD Sewage Treatment.*** 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.

- ***5D2 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.

7.5.2.1 5D1: UK CH_4 emissions from municipal waste-water treatment

The UK estimates for methane from municipal 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 most 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 and 2001 as the UK industry responded to the new regulations.

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 no detail on treatment) for the early part of the time series within EPSIM data published by UK Government (Defra, 2006). More detailed activity data (from each of 12 UK water companies, with details on sludge treatment and fate) most of the recent part of the time-series.

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 total dissolved solids (tds));
- Population Equivalent (PE) Served ('000), this is the estimated resident and non-resident (e.g. tourist) population served which acts as an alternative indicator of sewage load.

In addition, each company provides a detailed split of sewage sludge disposal routes, including data (kt tds 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

For the 2013 inventory cycle the Carbon Accounting Workbook (CAW), developed by UK Water Industry Research (UKWIR), which is the tool used by the water industry for reporting

emissions to Defra and OFWAT, was adapted to provide detailed data for the inventory. The inventory team was provided with a methodology report that included a number of the underlying assumptions and emission factors and activity (in PE for secondary treatment, m^3 for biogas use and kt tds otherwise), CH_4 and N_2O emissions was reported for the following:

- Mechanical treatment and short term storage of sludge (activity and CH_4 emissions only)
- Secondary treatment (activity and N_2O emissions only)
- Digestion (activity and CH_4 emissions only)
- Advanced digestion (activity and CH_4 emissions only)
- Composting (activity and CH_4 emissions only)
- Digested sludge to land
- Advanced digested sludge to land
- Composted sludge to land
- Raw and limed sludge to land
- Raw and composted sludge to landfill (activity and CH_4 emissions only)
- Digested sludge to landfill (activity and CH_4 emissions only)
- Sludge to incineration (activity and N_2O emissions only)
- Biogas used in CHP for energy generation (activity only)
- Biogas used for combustion other than by CHP (activity only)

From 2000 to 2009, 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. After 2009 the requirements of data reported to OFWAT changed, and data was no longer publically available. For 2013 company reported data from the CAW was available.

For 1991 to 2005, the EPSIM data present a breakdown of sewage sludge disposal data across five options: farmland, incineration, landfill, sea disposal and other, and for 1986-2005 this data set gives total estimates sewage sludge arisings. No additional information is available, such as the BOD loading of the municipal sewerage system, treatment methods, or the population equivalents treated by UK water companies. The overlap in time-series between the EPSIM data and company reported data confirms that the total and split of disposal methods are largely consistent with each other.

In **Scotland** the same level of detailed activity data as outlined above for companies in England and Wales have been available since 2002 and continues to be published, from the Water Commissioner for Scotland; EPSIM data are used for 1990-2001. The totals reported in the EPSIM data fit the company reported data very well, but because the disposal split fits very poorly in the overlapping years the company reported split from 2002 is used with the EPSIM total for the earlier part of the time series.

In **Northern Ireland**, data are only available from the water regulator, UREGNI, for 2006-9 and 2012 onwards, with a disposal split only available for 2013. The Defra EPSIM statistics are used to provide activity data for the early part of the time series to 2005, whilst the year gap between the 2 data sets and the 2 year gap in company reported data is interpolated. The EPSIM time-series trend fits well with the company reported trend in later years, as the disposal split is similar in the 2013 reported data and at the end of EPSIM time-series it is reasonable to assume a similar split for the intervening years.

Emission Estimation: Use of UK-specific Factors

The UK GHG inventory mostly follows the UK water industry GHG emission estimation methodology developed by UKWIR for the submission of 2013 data in 2014, and used by all UK water companies to generate their annual emission estimates from all sources / activities.

UKWIR have not provided an approach for estimating emissions associated with waste to sea in the 1990s, so to avoid an omission the 2006 IPCC default approach using the Methane Correction Factor (MCF) for sea, river and lake discharge has been used. Discharges would have only been to the cold seas with low organic loadings around the UK, so this is likely to be a very conservative approach for estimating emissions.

Methane emissions from sewage sludge disposed to landfill and incineration are accounted for in 5A and 5C, and hence no estimates are included in 5D1 to avoid a double-count. Waste disposed of via 'other' means has been given a weighted average emission factor based on the emissions from other disposal methods. Where the treatment before disposal isn't specified, the treatment split is assumed to have the same profile as that given in the 2013 CAW reported data; for example it is only in the 2013 CAW reported data that the sludge disposed to landfill has been disaggregated based on treatment, this split has been used to estimate the treatment split for the earlier years where none is specified.

UK-specific emission factors are applied to the treatment and disposal methods reported in the CAW, 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 each of the treatment and disposal approaches can be derived.

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 before 2013; for example in 2009, emission reporting by water companies was estimated to cover around 53% of total UK water treatment.

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 meant that in 2013 we received data from all 12 of the water companies, covering over 90% of water company activities (2 companies reported lower activity for disposal than treatment, which means there was a reporting omission of about 10% of the disposal emissions. This gap was filled by assuming waste was disposed of in similar ways to other companies). In future we should continue to receive this much more comprehensive data from the industry, and therefore have much more confidence in emissions estimates.

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.

The implied emission factors are given in **Annex 3.5.3**.

Reporting of Methane Recovery from Sewage Treatment

The methodology report provided by UKWIR for the 2013 version of the CAW provides the emission factor assumed for digestion without capture. Using this factor it's possible to calculate what emissions would have been reported had there been no methane capture, then necessarily the difference between reported emissions and this unabated emission estimate would be the amount of methane captured.

Data on the annual amount sewage gas being produced are provided in DUKES (DECC, 2014). Using this we can establish a link between the DUKES estimate based on energy use

and the mass based estimate based on the difference between unabated and reported methane emissions. Assuming that the relationship between energy use and methane captured is consistent throughout the time series, the amount of methane removed can be calculated for all years and removed from the estimate for unabated emissions.

Using this approach it suggests that 6-15% of potential methane emitted during digestion is captured for flaring or energy use, with the highest value being observed in 2013 after a steady increase over the previous 7 years.

7.5.2.2 5D1: UK CH_4 emissions from private waste-water management

The 2006 IPCC Guidelines provide a method for calculating emissions from off grid waste-water treatment, such as septic tanks. These emissions were previously not considered in the UK inventory.

An estimate of the number of households that are likely to be using off-grid systems in the UK in 2013 has been made based on data provided by the Environment Agency (EA), the Scottish Environmental Protection Agency (SEPA), the Northern Ireland Department of the Environment (NIEA) and Natural Resources Wales (NRW).

A time series of emissions has been developed using population data. This time series of number of households has been combined with ONS data for average household occupancy and the calculated volume of waste produced per person per year based on water company statistics to produce an estimate of total waste-water being disposed of via off-grid systems.

The emissions are then calculated following the method set out in the 2006 guidelines Volume 5, Chapter 6: Wastewater treatment and discharge. Equation 6.2 in the GLs, reproduced below, calculates the emission factor.

$$EF_j = B_0 * MCF_j$$

Where

EF_j= emission factor, kg CH_4/kg BOD (Biochemical Oxygen Demand)

j = each treatment/discharge pathway or system

B_0= maximum CH_4 producing capacity, kg CH_4/kg BOD

MCF_j= methane correction factor (fraction), See Table 6.3 of the GLs.

The table lists the parameters which were used and the calculated EF. The MCF of 0.5 was the default factor for septic tanks. The team did not have enough data to establish the activity by waste treatment process. As the vast majority of private waste management systems observed were septic tanks, and the septic tank factor is conservative when compared to other systems that could be used, it was decided that it would be the most appropriate factor to apply.

Table 7.1 New emission factors added as a result of completeness checks

Parameter	Description	Units	Value
B_o	Maximum CH_4 producing capacity	kg CH_4/kg BOD	0.6
MCF	Methane correction factor	Fraction	0.5
EF	**Emission factor**	**kg CH_4/kg BOD**	**0.3**

The emission factor is then combined with total amount of organically degradable material in the waste-water (TOW), expressed as kg BOD/year, which is calculated using Equation 6.3 in the 2006 GLs:

$$TOW = P \bullet BOD \bullet 0.001 \bullet I \bullet 365$$

Where:

TOW = total organics in wastewater in inventory year, kg BOD/yr

P = country population in inventory year, person

BOD = country-specific per capita BOD in inventory year, g/person/day

0.001 = conversion from grams BOD to kg BOD

I = correction factor for additional industrial BOD discharged into sewers (for collected the default is 1.25, for uncollected the default is 1.00).

The population figure used is for only the proportion of the population using septic tanks. The BOD value is assumed to be similar to the BOD per capita implied by the data provided by the major water companies

7.5.2.3 5D1: UK N_2O emissions from Domestic and Commercial Waste-water

Nitrous oxide emissions from the treatment of human sewage are based on the IPCC (1997) default methodology. The 1997 methodology is almost identical to the 2006 methodology, but is slightly more conservative. The most recent average protein consumption per person is based on the Expenditure and Food Survey (Defra, 2013); see **Table 7.2**. For the purposes of the 2013 estimates within the inventory, the Expenditure and Food Survey 2014 was not available in time, and therefore the data for 2012 has been used as a best estimate. Population estimates are from the Office for National Statistics (ONS, 2014).

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 7.2 Per capita protein consumption in the UK (kg/person/yr), 1990-2013

Year	Protein consumption (kg/person/yr)
1990	27.9
1995	28.6
2000	29.9
2005	29.8
2009	28.7
2010	28.7
2011	28.2
2012	27.7
2013*	27.7

*2012 data used, as 2013 data was 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) by the emission factor (0.01 kg sewage-N produced).

This derives a total for the UK nitrous oxide emissions from sewage sludge, but not all of those emissions are allocated to 5D1. The nitrous oxide emissions from sludge spread on agricultural land are reported under IPCC source category 3D Agricultural Soils and emissions from waste incineration are included in 5C. Therefore to avoid a double-count in the UK GHG inventory, the emissions reported in 5D1 are the difference between the UK total from the IPCC default method, and the estimates included in 3D and 5C.

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, 2013). 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.

7.5.2.4 5D2: 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 5D1 (see above), some of 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 5D2) is estimated to be 13.2%, but from 2009-2012 the figure has been in the range 10.8-11.7%. We are attempting to collect information on the domestic-industrial split in waterwater treatment from water companies in order to have confidence in building a timeseries that removes this double count.

In addition to the emissions reported in 5D2 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 5D2 (previously 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 to the present, as no further evidence has been obtained by the Inventory Agency.

7.5.2.5 Overseas Territories and Crown Dependencies

Estimates from the OTs and CDs are calculated using the Tier 1 approach from the 2006 IPCC Guidelines and default EFs. Country-specific parameters have been chosen based on information provided through a waste survey (distributed in 2014) and through expert judgement. Per capita protein consumption data were taken from FAOSTAT with data for Bermuda applied to all OTs, and data from the UK applied to all CDs.

Summary of Estimation method for UK 5D2 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 2006 GLs;
- 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 Defra[41], 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 3.5.3**]*

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 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.

7.5.3 Uncertainties and Time-Series Consistency

As outlined in **Section 7.5.2**, the method for deriving methane emission estimates for 5D1 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 reported 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 2014 obtained activity and emissions data from all of the 12 water companies. Therefore, we have a much more complete, consistent set of activity and emissions data reported from across the UK. This helps to further develop the UK-specific dataset from which estimates can be derived, improving accuracy through accessing more complete, representative data which

[41] http://www.defra.gov.uk/publications/files/pb6655-uk-sewage-treatment-020424.pdf

reflects the range of waste-water quality and the design / stock of waste-water treatment facilities across the UK. The template for UK water company reporting used last year will be sent to the Inventory Agency on an annual basis, and we have negotiated for further detail to be provided to improve other estimates.

The reported emissions and activity by UK water companies in 2013 has been used to derive country-specific emission factors for water treatment, methane capture, sludge treatment and most disposal routes, 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. The use of the IPCC default for methane emissions from waste disposal to sea introduces a significant uncertainty to the early part of the time series where the activity is known to have taken place. This is because the IPCC default factor is for a wide range of situations including stagnant lakes with high organic loads in temperate climates, which would have very different emissive behaviour to the cold, low organic load seas around the UK. Furthermore, the limited activity data time series for 5D1 due to changes in data reporting across the time series limits the accuracy and time series consistency of the estimates for the early part of the time series; however it is observed that the overlaps in trend between the data sets typically show strong agreement.

See **Annex 3.5.3** for further details on the activity data, implied emissions factors and emissions estimates, and **Section 7.5.6** below for an insight into the planned improvements for this source method.

7.5.4 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**.

7.5.5 Source Specific Recalculations

For information on the magnitude of recalculations, see **Section 10**.

There have been a number of significant recalculations for this submission, most are linked to the changes associated with complying with the 2006 IPCC guidelines.

7.5.5.1 Methane emissions from municipal waste-water treatment

As mentioned in **Section 7.5.2.1**, significant revisions have been made to this sector in light of new, much more comprehensive and transparent data being reveived from the water industry for 2013. This has meant that the methane captured can be based on industry data and there is a significant increase in the confidence in and granularity of the emission factors applied. Some additional historic data was found, and considerable effort was made to ensure that data was utilised to maximum effect.

Due to the presence of a clear tier 1 methodology for estimating emissions for sea, river and lake discharge in the 2006 IPCC guidelines, emissions from discharge to sea have now been estimated for 1990-2000, when the practice was occurring in the UK.

7.5.5.2 Methane emissions from private waste-water management

This is a new source identified in the 2006 IPCC guidelines, the methodology is detailed in **Section 7.5.2.2**.

7.5.5.3 Nitrous oxide emissions from sewage decomposition

In previous years N_2O emissions from incineration of sewage sludge were not removed from the estimate for 5D1; this year that double count has been removed. The 2012 data on protein consumption has been updated to use actual data for that year rather than to extrapolate

protein data from 2011, as within the 2014 submission. There have also been some revisions to the estimates for nitrous oxide emitted from sewage sludge disposal to agricultural soils (in 4D), and the population estimate has been updated based on the latest ONS statistics, and therefore this has a knock-on effect on the nitrous oxide emission estimates in 5D.

7.5.5.4 Waste-water management in OTs and CDs

The methodology used to estimate emissions from the OTs and CDs has been updated to the 2006 IPCC Guidelines and now take into account varying treatment systems across the OTs and CDs. This has resulted in increased emissions from all regions across the whole time series due to the variation in MCF. Emissions were previously estimated using scaled UK data, where country-specific data were not available. New information was obtained through a waste survey distributed to all OTs and CDs in 2014. As a result, emission estimates were included in this sector for the Falkland Islands. A more consistent methodology for indirect N_2O from wastewater was also applied, with average protein intakes sourced from FAOSTAT.

7.5.5.5 Industrial waste-water recalculations

The emission estimates from industrial waste-water treatment (5D2) have been revised for the entire time-series. The equation set out for the emission factors for industrial waste-water treatment has been amended and clarified in the 2006 GL. This amended equation has been used to recalculate emissions from this source.

The IPCC 2000 Good Practice Guidance (2000 GPG) states:

"As mentioned previously, the degradable carbon in organic waste can be measured either as BOD or COD, and the COD-based value should be converted into a BOD-based value by multiplying by a default factor of 2.5."

The IPCC 2006 guidelines state:

"a COD-based value of B_o can be converted into a BOD-based value by multiplying with a factor of 2.4."

The conversion factor has changed from 2.5 to 2.4, but more significantly, the 2006 Guidelines clarifies that this is when discussing B_o, an emission factor with units kg CH_4/kg BOD or kg CH_4/kg COD. This means that the ratio for converting the activity in the inverse of this i.e. COD=BOD*2.4.

This correction has been made to the calculations, in addition to updating the conversion factor from 2.5 to 2.4.

7.5.6 Source Specific Planned improvements

Consultation with water industry contacts and regulators will be continued during 2015, with the following aims.

i) 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
ii) To develop a more accurate method for nitrous oxide emission estimates, based on country specific reported data from water companies instead of the tier 1 default IPCC methodology;
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;

It is noted that N_2O emissions from waste-water has been highlighted as a key category this year, and we are currently using a tier 1 method, it is also noted that the 2006 IPCC GLs does

not provide a higher tier method. Despite this the UK believes that it may be possible to develop a country specific model based on company reported data and accounting for the denitrification treatment, and hence will consider this sector for the improvement programme.

8 Other (CRF Sector 6)

8.1 OVERVIEW OF SECTOR

No emissions are reported in Sector 6.

9 Indirect CO_2 and Nitrous Oxide Emissions

9.1 DESCRIPTION OF SOURCES OF INDIRECT EMISSIONS IN GHG INVENTORY

The calculation of indirect CO_2 and N_2O is not mandatory. The UK calculates indirect emissions of N_2O from emissions of NO_X and NH_3 from non-AFOLU sources. These are reported as a memo item.

The methods and data sources for the calculation of NO_X and NH_3 emissions are described in the UK's Informative Inventory Report (IIR), as submitted under the Convention on Long Range Transboundary Air Pollution.

9.2 METHODOLOGICAL ISSUES

Emissions of indirect N_2O are calculated using Equation 7.1 of Volume 1 of IPCC, 2006. EF4 within the equation is the IPCC default of 0.01 kg N_2O-N/kg NH_3-N or NO_X-N emitted.

9.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

No formal uncertainty or trend analysis for indirect N_2O emissions has been carried out. Uncertainties and trends for NO_X and NH_3 are described in the IIR.

9.4 CATEGORY-SPECIFIC QA/QC AND VERIFICATION

Emissions of NO_X reported under the GHG inventory are cross checked with those reported under CLRTAP and are consistent. NH_3 emissions are only reported under CLRTAP and not under the GHG inventory, however, calculated emissions from the UK inventory database have been carefully cross checked with the submitted totals to ensure completeness.

9.5 CATEGORY-SPECIFIC RECALCULATIONS

This is the first year in which these emissions have been reported.

9.6 CATEGORY-SPECIFIC PLANNED IMPROVEMENTS

Indirect nitrous oxide emissions will change in line with changes made to the NO_X and NH_3 inventories. Air quality pollutants are subject to a separate improvement programme to the GHG inventory, this is described in the IIR.

10 Recalculations and Improvements

This section of the report summarises the recalculations and improvements made to the UK GHG inventory since the 2014 NIR submission (1990-2012 inventory), 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 7**.

The UNFCCC reporting guidelines, IPCC methodology guidelines, and UNFCCC reporting software have all changed between the 2014 and 2015 submissions, leading to:

- the introduction of new sources;
- changes to calculation methods;
- updates to default emission factors;
- changes to reporting categories;
- changes to the global warming potentials used to calculate weighted emissions as CO_2 equivalent.

As a result, the description of recalculations is more complicated this year; in particular the last two changes listed above make it difficult to present the comparison between the 2014 and 2015 submissions on a like for like basis.

In addition, the CRF does not contain descriptions of recalculations, since the software does not include a record of the previous submission. These will be introduced in the next submission.

The tables in this chapter compare emissions using NAEI source categories, and display both the old and new reporting categories. Tables are provided separately for CO_2, CH_4 and N_2O, since GWP weighted (CO_2 equivalent) emissions are affected by changes to the GWP values, which may outweigh the changes to data or methods.

From the 2016 submission, recalculations will be described in the CRF, and set out in this chapter using the template agreed under the MMR.

In addition to the recalculations caused directly by the changes outlined above, each year, the UK greenhouse inventory is *updated*, *extended* and may be *expanded*.

Updating often entails revision of emission estimates, most commonly due to revision to underlying activity statistics, such as the core energy statistics presented in the Digest of UK Energy Statistics (DUKES). The inventory also makes use of other datasets (see **Table 1.6** for a summary), and these too may be revised. Inventory updates may also be due to the adoption of revised inventory estimation methodologies. Inventory updates may affect the whole time series, and therefore the emission estimates for a given year may differ from emission estimates for the same year reported previously. Therefore comparisons between inventory submissions should take account of whether there have been changes to the following:

- the emission estimation methodology, including revisions to assumptions or conversion factors;
- the reporting guidelines under which the submissions are made (i.e. 1996 GLs or 2006 GLs);
- the emission factors applied (noting that many IPCC default EFs used in Tier 1 methods have been revised in the 2006 GLs compared to the 1996 GLs); and/or
- the activity data.

The time series of the inventory is *extended* by including a new inventory year. 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 there are sufficient activity data and suitable emission factors.

10.1 EXPLANATIONS AND JUSTIFICATIONS FOR RE-CALCULATIONS, INCLUDING IN RESPONSE TO THE REVIEW PROCESS

Table 10.1 to **Table 10.6** summarise the recalculations that have occurred in estimates of CO_2, CH_4 and N_2O since the 2014 NIR submission (1990-2012 inventory). The changes in emissions are net changes (the sum of any increases and decreases) in the source category, for each GHG in the Base Year (1990) and latest recalculated year (2012).

Table 10.7 summarises where changes to methodological descriptions have been made and where these descriptions can be found in the main text of this document.

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 system 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 2006 IPCC Guidelines 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 (e.g. revisions to energy statistics), where less uncertain data are now available (e.g. use of EU ETS activity data to inform energy allocations, in preference to UK energy statistics data sources), or where the inventory agency has applied more representative (ideally UK-specific) EFs in estimation methods (e.g. use of carbon emission factors derived from EU ETS fuel compositional analysis);
- ✓ 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, (e.g. 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 (e.g. 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 to **Table 10.6** set out the reasons for changes to CO_2, CH_4 and N_2O. Recalculations to F-gases are discussed after these tables.

Several of the UK inventory improvements have led to recalculations across a number of source categories, and therefore to minimise repetition these cross-cutting improvements (to methods, to source data e.g. EF references) are summarised below and numbered for ease of reference in the recalculation tables that follow:

Reference numbers:

1. **Emission factors for coal and other solid fuel use**. The ERT identified that the reference (Baggott *et al*., 2004) for the carbon emission factor and oxidation factors for coal use was not sufficiently transparent and did not justify the emission factor chosen. The EF has been replaced with Fynes and Sage (1994), replacing a personal communication from British Coal in 1989 – which was used in the Baggott *et al* carbon factors review – with a published, referenced data set. The oxidation factor has been replaced with the IPCC default (1). For other solid fuel use, the oxidation factors have also been replaced with the IPCC default.
2. Fuel use **reallocations between energy and non-energy use** in UK energy statistics for petroleum fuels. The DECC energy statistics team has reviewed the source data used to determine non-energy use allocations for petroleum fuels and has revised the energy / non-energy split for several fuels including gas oil, LPG and naphtha. UK energy statistics were revised back to 2007. The inventory agency (in consultation with DECC) has estimated the revised energy / non-energy use split back to 1990 to ensure time series consistency.
3. **Revisions to the off-road machinery model**, as a result of research to improve estimates for the UK air quality inventory. This change also impacts upon the allocation of gas oil to other industry source categories within the UK inventory. The revised method for the off-road model is documented in Chapter 3, MS 20.
4. **Revisions to aviation estimates**. Cruise phase emission estimates have been revised to reflect method updates in the EMEP-EEA air pollutant emission inventory guidebook. Errors have been identified and corrected in underlying assumptions (climb thrust and bypass ratio). Revisions to military aviation data in recent years also affect estimates for civil aviation, as total fuel use is normalised to DUKES totals.
5. **Lubricants emission estimates have been revised** to use the full time series of DUKES data and to apply the 2006 IPCC GLs default oxidation factor (20%). Emissions are also now allocated in 2D1, in line with the 2006 IPCC GLs.
6. **Revisions to DUKES activity data**. Many fuel use activity data have been updated.
7. **Update to IPCC Guidelines**. Default EFs and parameters from the 1996 IPCC GLs and 2000 GPG have been superceded by new EFs and other parameters in the 2006 IPCC GLs, especially CH_4 and N_2O EFs from combustion and agriculture.
8. **Revision to carbon emission factor for petroleum coke**, to use EU ETS data.
9. **Revisions to road transport estimates** due to: correction to DUKES AD for 2005-7; time series revisions to DERV AD due to updates to gas oil mass balances; new data now available for 2012 to over-write previous assumptions to fill data gaps.
10. **New sources or methods to address the requirements of the 2006 GLs** such as to include new IPPU sources and revise allocations of activity data, e.g. for ammonia gas use (all now 2B1), coke and petcoke use as a reductant (from Energy to IPPU).

Table 10.1 Recalculations to CO_2 in 1990 (kt CO_2)

CRF category 2015	Source Name	CRF category 2014	2015 submission	2014 submission	Change (kt CO_2)	Change (%)	Reallocation due to IPCC GLs?	Justification
1A1ai	Power stations	1A1a	204,132	204,138	-7	0%	No	Estimates for MSW combustion in Jersey were available from 2 sources, the time series has been replaced with an annually updated data set.
1A1b	Refineries - combustion	1A1b	17,812	17,549	263	1%	No	2 – specifically Naptha.
1A1ciii	Collieries - combustion	1A1c	503	496	7	2%	No	1
1A2a	Iron and steel - combustion plant	1A2a	16,706	16,705	1	0%	No	1
1A2b	Autogeneration - exported to grid	N/A	994	0	994	N/A	Yes	1. In addition, reallocation of emissions from coal use from other industry to non-ferrous metals (known to be used for aluminium).
1A2b	Autogenerators	N/A	2,628	0	2,628	N/A	Yes	1. In addition, reallocation of emissions from coal use from other industry to non-ferrous metals (known to be used for aluminium).
1A2b	Non-Ferrous Metal (combustion)	1A2b	1,157	1,143	15	1%	No	1, 2, 3
1A2c	Chemicals (combustion)	1A2c	12,135	14,899	-2,764	-19%	Yes	1, 2, 3, 10 In addition, revised method to extrapolate the use of process gases in chemical/petrochemical production.
1A2d	Pulp, Paper and Print (combustion)	1A2d	4,612	4,553	59	1%	No	1, 2, 3
1A2e	Food & drink, tobacco (combustion)	1A2e	7,651	7,553	98	1%	No	1, 2, 3
1A2f	Lime production - non decarbonising	1A2f	696	599	97	16%	Yes	1. In addition, new solid fuel EFs plus revisions to AD as part of change in reporting scope: 2 lime kilns now included as part of soda ash sector rather than part of lime sector
1A2gvii	Industrial off-road mobile machinery	1A2f	7,277	7,766	-489	-6%	Yes	3
1A2gviii	Autogeneration - exported to grid	1A2f	192	1,161	-968	-83%	Yes	Reallocation of coal use for autogenerators to 1A2b, as above
1A2gviii	Autogenerators	1A2f	509	3,069	-2,560	-83%	Yes	Reallocation of coal use for autogenerators to 1A2b, as above

CRF category 2015	Source Name	CRF category 2014	2015 submission	2014 submission	Change (kt CO_2)	Change (%)	Reallocation due to IPCC GLs?	Justification
1A2gviii	Other industrial combustion	1A2f	30,452	32,322	-1,870	-6%	Yes	1, 2, 3, 10. In addition, reallocations between energy and IPPU for coke (plus reallocations between coal and coke), based on DECC, 2014.
1A3a	Aircraft - domestic cruise	1A3a	1,049	830	219	26%	No	4
1A3a	Aircraft - domestic take-off and landing	1A3a	421	440	-19	-4%	No	4
1A3a	Aircraft between UK and CDs - Cruise	1A3a	132	102	30	29%	No	4
1A3a	Aircraft between UK and CDs - TOL	1A3a	50	52	-2	-4%	No	4
1A3a	Aircraft between UK and Gibraltar - Cruise	1A3a	49	51	-2	-3%	No	4
1A3a	Aircraft between UK and other Ots (excl Gib.) - Cruise	1A3a	146	167	-21	-12%	No	4
1A3bi	Road transport - cars - urban driving	1A3b	32,205	32,215	-10	0%	No	9
1A3bii	Road transport - LGVs - urban driving	1A3b	3,731	3,732	-1	0%	No	9
1A3biii	Road transport - HGV articulated - motorway driving	1A3b	5,288	5,284	4	0%	No	9
1A3biii	Road transport - HGV articulated - rural driving	1A3b	4,809	4,805	3	0%	No	9
1A3biii	Road transport - HGV articulated - urban driving	1A3b	1,632	1,630	1	0%	No	9
1A3biii	Road transport - HGV rigid - motorway driving	1A3b	2,816	2,814	2	0%	No	9
1A3biii	Road transport - HGV rigid - rural driving	1A3b	5,072	5,068	4	0%	No	9
1A3biii	Road transport - HGV rigid - urban driving	1A3b	4,168	4,165	3	0%	No	9
1A4ai	Miscellaneous industrial/commercial combustion	1A4a	11,594	11,380	215	2%	No	1, 3. In addition, correction to Gibraltar data (gas use in hotels)
1A4ai	Public sector combustion	1A4a	13,427	13,056	371	3%	No	1, 3
1A4bi	Domestic combustion	1A4b	78,277	77,523	753	1%	No	1, 3
1A4ci	Agriculture - stationary combustion	1A4c	543	542	1	0%	No	1

CRF category 2015	Source Name	CRF category 2014	2015 submission	2014 submission	Change (kt CO_2)	Change (%)	Reallocation due to IPCC GLs?	Justification
1B1b	Solid smokeless fuel production	1B1b	1,564	720	844	117%	Yes	1,6 DUKES now allocates some petroleum coke to SSF production. Also the method has been revised to use new time series of anthracite and SSF carbon emission factors, updated to use the Fynes & Sage reference for solid fuel CEFs.
2A3	Glass - general	2A7	408	377	32	8%	Yes	Glass sector estimates revised in consultation with trade association to use EU ETS data and ensure complete estimates for all manufacturing sub-sectors
2A4a	Brick manufacture - all types	N/A	647	0	647	N/A	New Source	Includes Fletton Bricks from 2014 submission. Definition extended to include process emissions from all brickworks.
2B6	Chemical industry - titanium dioxide	N/A	105	0	105	N/A	New Source	10
2B7	Chemical industry - soda ash	N/A	232	0	232	N/A	Yes	10
2B8c	Chemical Industry – ethylene dichloride	N/A	6	0	6	N/A	New Source	10
2B8d	Chemical industry - ethylene oxide	N/A	131	0	131	N/A	New Source	10
2B8f	Chemical industry - carbon black	N/A	437	0	437	N/A	New Source	10
2B8g	Chemicals (combustion)	N/A	3,462	0	3,462	N/A	Yes	10. In addition, reallocation of estimates previously reported in 1A2c, where process off-gases are used in chemical / petrochemical production; these estimates have also been revised based on information from EUETS Phase III.
2C1a	Electric arc furnaces	2C1	71	37	35	95%	Yes	Includes allocation for petroleum coke use (new source)
2C1d	Sinter production	1A2a	3,522	2,467	1,055	43%	Yes	All sinter production now allocated to 2C1d
N/A	Sinter production	2A3	0	1,055	-1,055	-100%	Yes	All sinter production now allocated to 2C1d
2C6	Non-ferrous metal processes	N/A	1,359	0	1,359	N/A	Yes	10. Re-allocation of estimates previously reported in 1A2b, where coke is used in NFM processes (lead/zinc smelter).

CRF category 2015	Source Name	CRF category 2014	2015 submission	2014 submission	Change (kt CO_2)	Change (%)	Reallocation due to IPCC GLs?	Justification
2D1	Agricultural engines	1A4c	11	17	-6	-35%	Yes	5
2D1	Industrial engines	1A2f	288	22	267	1224%	Yes	5
2D1	Marine engines	1A3d	32	108	-76	-70%	Yes	5
2D1	Other industrial combustion	1A2f	680	677	3	0%	Yes	5
2D1	Road vehicle engines	1A3b	189	263	-74	-28%	Yes	5
2D2	Non-aerosol products - household products	2B5	33	1,224	-1,191	-97%	Yes	Oxidation during use factor from USEPA replaced with default from the 2006 GLs. Also removal of CO_2 emission estimates from product use (detergents, pesticides) as there is no such method / source in the 2006 GLs.
3G1	Liming	N/A	979	0	979	N/A	Yes	Reallocation from LULUCF sector, now split between limestone and dolomite use (rather than between cropland and grassland)
3G2	Liming	N/A	600	0	600	N/A	Yes	Reallocation from LULUCF sector, now split between limestone and dolomite use (rather than between /cropland and grassland)
3H	Agriculture - application of urea	N/A	385	0	385	N/A	New Source	10.
4A	Forest Land - Biomass Burning\Wildfires	5A	43	157	-114	-73%	Yes	1990 – 2012 inventory values were mistakenly converted from C to CO_2 twice over due to a database error. Changes in the CARBINE model have altered the average amount of fuel burnt

CRF category 2015	Source Name	CRF category 2014	2015 submission	2014 submission	Change (kt CO_2)	Change (%)	Reallocation due to IPCC GLs?	Justification
4B1	Cropland remaining Cropland	5B1	1,312	3,277	-1,965	-60%	Yes	Inclusion of the emissions and removals in soil carbon stock as a result of Cropland Management. Effect of yield improvement on Cropland biomass is no longer included, as a review of literature shows that increases in harvestable biomass are not reflected in changes in total plant biomass. Revised data on the area of Cropland on organic soils in the OTs and CDs. Revised data on the area of Cropland on drained organic soils. Revised methodology for estimating emissions from Cropland on drained organic soils as new area data does not include information on peat depth, and previous methodology did not account for change in the bulk density of drained peat. LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013. Revised deforestation areas used for 2000 – 2013. Changes in the CARBINE model have altered the average amount of fuel burnt when land is deforested to Cropland
4B2	Cropland - Drainage and rewetting and other management of organic and mineral soils	N/A	1,702	0	1,702	N/A	New Source	
4B2	Land converted to Cropland	5B2	12,116	11,643	473	4%	Yes	
4C1	Grassland remaining Grassland	5C1	-1,680	-1,708	27	-2%	Yes	
4C2	Grassland - Drainage and rewetting and other management of organic and mineral soils	N/A	3,536	0	3,536	N/A	New Source	Inclusion of emissions from improved Grassland on drained organic soils as data on areas is now available. LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013. Revised deforestation areas used for 2000 – 2013. Changes in the CARBINE model have altered the average amount of fuel burnt when land is deforested to Grassland.
4C2	Land converted to Grassland	5C2	-5,553	-5,330	-223	4%	Yes	

CRF category 2015	Source Name	CRF category 2014	2015 submission	2014 submission	Change (kt CO_2)	Change (%)	Reallocation due to IPCC GLs?	Justification
4E	Land converted to Settlements	5E2	5,247	5,106	141	3%	Yes	LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013 Revised deforestation areas used for 2000 – 2013. Changes in the CARBINE model have altered the average amount of fuel burnt when land is deforested to Settlement.
4E	Settlements remaining Settlements	5E1	1,619	1,734	-115	-7%	Yes	LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013
4G	Harvested Wood Products	5G	41	59	-18	-31%	Yes	Minor changes due to revised deforestation data
5C2.2b	Small-scale waste burning	N/A	12	0	12	N/A	New Source	New source, calculated for Jersey only
N/A	Agriculture - agrochemicals use	2B5	0	39	-39	-100%	Yes	No longer reported, not listed as a source in IPCC 2006
N/A	Brick manufacture - Fletton	2A7	0	180	-180	-100%	Yes	Reallocated to 2A4a – Brick manufacture – all types
N/A	Cropland - Liming	5B1	0	863	-863	-100%	Yes	Now reported under agriculture, split between limestone and dolomite (3G1, 3G2)
N/A	Grassland - Liming	5C1	0	717	-717	-100%	Yes	Now reported under agriculture, split between limestone and dolomite (3G1, 3G2)
N/A	Other industrial combustion	2B5	0	87	-87	-100%	Yes	Emissions from energy recovery in the chemical industry now included within estimates reported in 2B8.

Table 10.2 Recalculations to CO_2 in 2012 (kt CO_2)

CRF category 2015	Source Name	CRF category 2014	2015 submission	2014 submission	Change (kt CO_2)	Change (%)	Reallocation due to IPCC GLs?	Justification
1A1ai	Miscellaneous industrial/commercial combustion	1A1a	50.80	48.00	3	6%	No	6

CRF category 2015	Source Name	CRF category 2014	2015 submission	2014 submission	Change (kt CO_2)	Change (%)	Reallocation due to IPCC GLs?	Justification
1A1ai	Power stations	1A1a	159,048	159,230	-182	0%	No	6. In addition, revised assumptions for fuel oil, to ensure balance with industrial oil use, revised data for waste oil (see Ch3, MS1), Reallocation from Waste to Energy for MSW incineration in the Cayman Islands and Bermuda
1A1b	Refineries - combustion	1A1b	15,963	15,719	244	2%	No	2, 6. In addition, reallocation of natural gas from autogenerators (see Ch3, MS1)
1A1ci	Coke production	1A1c	1196.90	1198.20	-1	0%	No	6
1A1cii	Upstream Gas Production - fuel combustion	1A1c	2957.73	2971.92	-14	0%	No	6
1A1cii	Upstream oil and gas production - combustion at gas separation plant	1A1c	848.01	793.11	55	7%	No	Correction to AD
1A1cii	Upstream Oil Production - fuel combustion	1A1c	8702.74	8713.61	-11	0%	No	3, 6.
1A1ciii	Collieries - combustion	1A1c	164	179	-15	-8%	No	1, 6.
1A1ciii	Gas production	1A1c	1249.16	857.09	392	46%	No	6. Significant revision to DUKES allocation to this source, so EU ETS data no longer used as DUKES now > EU ETS.
1A2a	Iron and steel - combustion plant	1A2a	9,025	8,993	32	0%	No	6. In addition, minor recalculation to carbon balance, 1
1A2b	Autogeneration - exported to grid	N/A	1,063	0	1063	100%	Yes	6. In addition, reallocation of emissions from coal use from other industry to non-ferrous metals (known to be used for aluminium).
1A2b	Autogenerators	N/A	1,258	0	1258	100%	Yes	6. In addition, reallocation of emissions from coal use from other industry to non-ferrous metals (known to be used for aluminium).
1A2b	Non-Ferrous Metal (combustion)	1A2b	481	647	-166	-26%	No	1, 3, 6, 8
1A2c	Chemicals (combustion)	1A2c	4,710	9,286	-4576	-49%	Yes	1, 3, 6, 8. In addition, identification of additional petrochemical sites. Reallocation of fuel use for ammonia production to 2B1.

CRF category 2015	Source Name	CRF category 2014	2015 submission	2014 submission	Change (kt CO_2)	Change (%)	Reallocation due to IPCC GLs?	Justification
1A2d	Pulp, Paper and Print (combustion)	1A2d	1,931	2,866	-935	-33%	No	1, 3, 6, 8
1A2e	Food & drink, tobacco (combustion)	1A2e	4,425	4,540	-115	-3%	No	1, 3, 6, 8
1A2f	Lime production - non decarbonising	1A2f	356	492	-136	-28%	Yes	10. In addition, change in reporting scope. Two lime kilns now included as part of soda ash sector (IPPU) rather than part of lime sector
1A2gvii	Industrial off-road mobile machinery	1A2f	5,926	5,579	348	6%	Yes	3
1A2gviii	Autogeneration - exported to grid	1A2f	1,994	3,756	-1763	-47%	Yes	6. In addition, reallocation of coal use to 1A2b
1A2gviii	Autogenerators	1A2f	2,359	4,295	-1936	-45%	Yes	6. In addition, reallocation of coal use to 1A2b, revised method for refineries reallocates some natural gas use from here.
1A2gviii	Other industrial combustion	1A2f	16,047	16,939	-891	-5%	Yes	1, 3, 6, 8
1A3a	Aircraft - domestic cruise	1A3a	1,202	1,067	136	13%	No	4
1A3a	Aircraft - domestic take-off and landing	1A3a	411	402	9	2%	No	4
1A3a	Aircraft between UK and CDs - Cruise	1A3a	148	120	28	23%	No	4
1A3a	Aircraft between UK and CDs - TOL	1A3a	61	60	1	2%	No	4
1A3a	Aircraft between UK and Gibraltar - Cruise	1A3a	55	53	2	3%	No	4
1A3a	Aircraft between UK and other Ots (excl Gib.) - Cruise	1A3a	97	115	-18	-16%	No	4
1A3bi	Road transport - cars - motorway driving	1A3b	11,836	11,845	-10	0%	No	9
1A3bi	Road transport - cars - rural driving	1A3b	25,254	25,240	14	0%	No	9
1A3bi	Road transport - cars - urban driving	1A3b	26,723	26,742	-19	0%	No	9
1A3bii	Road transport - LGVs - rural driving	1A3b	6,646	6,640	6	0%	No	9
1A3bii	Road transport - LGVs - urban driving	1A3b	4,925	4,923	2	0%	No	9
1A3biii	Road transport - HGV articulated - motorway driving	1A3b	7,685	7,675	10	0%	No	9

CRF category 2015	Source Name	CRF category 2014	2015 submission	2014 submission	Change (kt CO_2)	Change (%)	Reallocation due to IPCC GLs?	Justification
1A3biii	Road transport - HGV articulated - rural driving	1A3b	4,890	4,883	6	0%	No	9
1A3biii	Road transport - HGV articulated - urban driving	1A3b	1,068	1,067	1	0%	No	9
1A3biii	Road transport - HGV rigid - motorway driving	1A3b	2,827	2,823	4	0%	No	9
1A3biii	Road transport - HGV rigid - rural driving	1A3b	4,687	4,681	6	0%	No	9
1A3biii	Road transport - HGV rigid - urban driving	1A3b	2,987	2,985	2	0%	No	9
1A3biv	Road transport - motorcycle (>50cc 4st) - rural driving	1A3b	208.36	209.81	-1	-1%	No	9
1A3biv	Road transport - motorcycle (>50cc 4st) - urban driving	1A3b	253.86	255.89	-2	-1%	No	9
1A3c	Rail - coal	1A3c	38.31	42.73	-4	-10%	No	1
1A3c	Railways - freight	1A3c	612.37	623.82	-11	-2%	No	Extrapolated estimates replaced with actual data for 2012
1A3c	Railways - intercity	1A3c	654.69	697.51	-43	-6%	No	Extrapolated estimates replaced with actual data for 2012
1A3c	Railways - regional	1A3c	711.53	731.06	-20	-3%	No	Extrapolated estimates replaced with actual data for 2012
1A3d	Motorboats / workboats (e.g. canal boats, dredgers, service boats, tourist boats, river boats)	1A3d	785.77	788.07	-2	0%	No	Revision to proxy statistics used for time series (UK household expenditure data)
1A3d	Personal watercraft e.g. jet ski	1A3d	119.31	119.93	-1	-1%	No	Revision to proxy statistics used for time series (UK household expenditure data)
1A3d	Shipping - coastal	1A3d	1265.86	1263.82	2	0%	No	Revision to proxy statistics used for scaling shipping data (DfT passenger movements)
1A3d	Shipping between UK and OTs (excl. Gib)	1A3d	4.17	3.26	1	28%	No	Revision to shipping movements data from DfT, correction to carbon emission factor (from 880 to 879 kt carbon/Mt fuel)
1A4ai	Miscellaneous industrial/commercial combustion	1A4a	13,725	9,946	3779	38%	No	1, 3, 6. In addition, correction to Gibraltar data (gas use in hotels), Revised assumptions for fuel oil, to ensure balance with industrial oil use. Large increase in allocation of natural gas to service sector in DUKES.

CRF category 2015	Source Name	CRF category 2014	2015 submission	2014 submission	Change (kt CO_2)	Change (%)	Reallocation due to IPCC GLs?	Justification
1A4ai	Public sector combustion	1A4a	9,252	10,116	-863	-9%	No	1, 3, 6 Large reduction in natural gas allocation to public administration in DUKES.
1A4ai	Railways - stationary combustion	1A4a	2	86	-84	-97%	No	1, 6
1A4bi	Domestic combustion	1A4b	74,039	73,036	1003	1%	No	1, 6. In addition, revised charcoal data from FAOSTAT, Revised peat use statistics for Scotland from CEH, petroleum coke used in SSF manufacture is now reported in DUKES, and therefore petroleum coke sold directly as SSF reduced to ensure no double count
1A4bii	House and garden machinery	1A4b	361	365	-4	-1%	No	3
1A4ci	Agriculture - stationary combustion	1A4c	263	331	-68	-21%	No	1, 6
1A4cii	Agriculture - mobile machinery	1A4c	3717.92	3728.82	-11	0%	No	3
1A5b	Aircraft - military	1A5b	1788.71	1791.57	-3	0%	No	Revised activity data received from MOD
1B1b	Solid smokeless fuel production	1B1b	101	200	-99	-49%	No	6, inputs to carbon balance modified (DUKES data implied more carbon out than in)
1B2b4	Gas leakage	1B2b	0.22	6.21	1	19%	No	Disaggregation between transmission and distribution losses. Correction to operator data, plus new data supplied for 2011 and 2012. Improvement to calculation of weighted average composition.
1B2b5	Gas leakage	1B2b	7	IE				
1B2c2i	Upstream Oil Production - flaring	1B2cii	3029.25	3009.72	20	1%	No	Minor revision, due to aligning EEMS reported data with EU ETS for one specific site.
2A1	Cement - decarbonising	2A1	3723.95	3715.53	8	0%	No	Revision to use EU ETS data directly where this implies a higher emission than data from the trade association
2A3	Glass - general	2A7	382	378	4	1%	Yes	Method revision, now using EU ETS data
2A4a	Brick manufacture - all types	N/A	260	0	260	N/A	New Source	Includes Fletton bricks from 2014 submission, definition extended to include all process emissions from brickworks
2B6	Chemical industry - titanium dioxide	N/A	110	0	110	N/A	New Source	10

CRF category 2015	Source Name	CRF category 2014	2015 submission	2014 submission	Change (kt CO_2)	Change (%)	Reallocation due to IPCC GLs?	Justification
2B7	Chemical industry - soda ash	N/A	295	0	295	N/A	Yes	10
2B8c	Chemical Industry – ethylene dichloride	N/A	6	0	6	N/A	New Source	10
2B8g	Chemicals (combustion)	N/A	3,233	0	3233	N/A	Yes	10. In addition, re-allocation of estimates previously reported in 1A2c, where process off-gases are used in chemical / petrochemical production; these estimates have also been revised based on information from EUETS Phase III.
2C1a	Electric arc furnaces	2C1	35	15	20	135%	Yes	Includes allocation for petroleum coke use (new source)
2C1d	Sinter production	1A2a	1,985	1,405	580	41%	Yes	All sinter production now reported under 2C1d (no change to emissions)
N/A	Sinter production	2A3	0	580	-580	-100%	Yes	All sinter production now reported under 2C1d (no change to emissions)
2C3	Primary aluminium production - general	2C3	91.64	92.40	-1	-1%	No	Replaced total from BGS with sum of operator data. The two data sets are consistent, but the latter are available to greater precision.
2D1	Agricultural engines	1A4c	2	6	-4	-68%	Yes	5
2D1	Industrial engines	1A2f	130	8	122	1458%	Yes	5
2D1	Marine engines	1A3d	9	56	-47	-83%	Yes	5
2D1	Other industrial combustion	1A2f	372	370	2	1%	Yes	5
2D1	Road vehicle engines	1A3b	118	99	19	20%	Yes	5
2D2	Non-aerosol products - household products	2B5	19	1,584	-1564	-99%	Yes	Oxidation during use factor from USEPA replaced with IPCC default from IPCC, 2006. Also removal of estimates of CO_2 emissions from product use (detergents, pesticides) as there is no such method / source in the 2006 GLs.
2D3	Road transport - urea	N/A	61.76	0.00	62	N/A	New Source	10
2D4	Non Energy Use: petroleum coke	N/A	368.24	0.00	368	N/A	New Source	Included to ensure all petroleum coke is accounted for.

CRF category 2015	Source Name	CRF category 2014	2015 submission	2014 submission	Change (kt CO_2)	Change (%)	Reallocation due to IPCC GLs?	Justification
3G1	Liming	N/A	602	0	602	N/A	Yes	Reallocation from LULUCF sector, now split between limestone and dolomite use (rather than between cropland and grassland)
3G2	Liming	N/A	231	0	231	N/A	Yes	Reallocation from LULUCF sector, now split between limestone and dolomite use (rather than between cropland and grassland)
3H	Agriculture - application of urea	N/A	326	0	326	N/A	New Source	10
4A	Forest Land - Biomass Burning\Wildfires	5A	248	829	-581	-70%	Yes	1990 - 2012 inventory values were mistakenly converted from C to CO_2 twice over due to a database error. Changes in the CARBINE model have altered the average amount of fuel burnt
4A1	Forest Land remaining Forest Land	5A1	-15,383	-15,367	-16	0%	Yes	Refinement of the CARBINE input data and updating of the deforestation activity data has led to minor changes.
4B	Cropland - Biomass Burning\Controlled Burning	5B	0.91	2.28	-1	-60%	Yes	Changes in the CARBINE model have altered the average amount of fuel burnt when land is deforested to Cropland
4B1	Cropland remaining Cropland	5B1	4,271	5,413	-1141	-21%	Yes	• Inclusion of the emissions and removals in soil carbon stock as a result of Cropland Management. • Effect of yield improvement on Cropland biomass is no longer included, as a review of literature shows that increases in harvestable biomass are not reflected in changes in total plant biomass. • LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013. • Revised data on the area of Cropland on organic soils in the OTs and CDs.

CRF category 2015	Source Name	CRF category 2014	2015 submission	2014 submission	Change (kt CO_2)	Change (%)	Reallocation due to IPCC GLs?	Justification
4B2	Cropland - Drainage and rewetting and other management of organic and mineral soils	N/A	1,702	0	1702	N/A	New Source	• Revised data on the area of Cropland on drained organic soils. • Revised methodology for estimating emissions from Cropland on drained organic soils as new area data does not include information on peat depth, and previous methodology did not account for change in the bulk density of drained peat.
4B2	Land converted to Cropland	5B2	6,351	5,048	1303	26%	Yes	• LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013. • Revised deforestation areas used for 2000 – 2013.
4C	Grassland - Biomass Burning\Controlled Burning	5C	217.98	265.32	-47	-18%	Yes	• Changes in the CARBINE model have altered the average amount of fuel burnt. • Revised deforestation areas used for 2000 – 2013.
4C1	Grassland remaining Grassland	5C1	-4,745	-4,833	89	-2%	Yes	• LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013.
4C2	Grassland - Drainage and rewetting and other management of organic and mineral soils	N/A	3,536	0	3536	N/A	New Source	Inclusion of emissions from improved Grassland on drained organic soils as data on areas is now available.
4C2	Land converted to Grassland	5C2	-4,877	-3,473	-1404	40%	Yes	• LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013. • Revised deforestation areas used for 2000 – 2013. • Changes in the CARBINE model have altered the average amount of fuel burnt when land is deforested to Grassland.
4D1	Wetlands remaining Wetland	5D1	300.49	359.24	-59	-16%	Yes	Correct 2012 activity data for horticultural peat extraction now available.

CRF category 2015	Source Name	CRF category 2014	2015 submission	2014 submission	Change (kt CO_2)	Change (%)	Reallocation due to IPCC GLs?	Justification
4E	Land converted to Settlements	5E2	3,576	3,848	-272	-7%	Yes	• LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013 • Revised deforestation areas used for 2000 – 2013. • Changes in the CARBINE model have altered the average amount of fuel burnt when land is deforested to Settlement.
4E	Settlements - Biomass Burning\Controlled Burning	5E	18.02	72.23	-54	-75%	Yes	• Revised deforestation areas used for 2000 – 2013. • Changes in the CARBINE model have altered the average amount of fuel burnt when land is deforested to Settlement.
4E	Settlements remaining Settlements	5E1	2,313	2,455	-143	-6%	Yes	LUC soils model re-run using extrapolated rather than projected rates of land use change from 2010 to 2013.
4G	Harvested Wood Products	5G	-1,119	-1,168	50	-4%	Yes	Minor updates to the CARBINE model and updated activity data for deforestation.
5C1.2a	Incineration	6C	0	18	-18	-100%	Yes	Reallocation from Waste to Energy for MSW incineration in the Cayman Islands and Bermuda
5C1.2b	Incineration - clinical waste	6C	81	85	-4	-4%	Yes	Removal of extrapolated data for plants which are assumed to have closed (permits expired)
5C2.2b	Small-scale waste burning	N/A	12	0	12	N/A	New Source	New source, included for Jersey only
N/A	Agriculture - agrochemicals use	2B5	0	39	-39	-100%	Yes	No longer reported, not listed as a source in IPCC 2006
N/A	Brick manufacture - Fletton	2A7	0	51	-51	-100%	Yes	Reallocated to 2A4a – Brick manufacture – all types
N/A	Cropland - Liming	5B1	0	709	-709	-100%	Yes	Now reported under agriculture, split between limestone and dolomite (3G1, 3G2)
N/A	Grassland - Liming	5C1	0	312	-312	-100%	Yes	Now reported under agriculture, split between limestone and dolomite (3G1, 3G2)
N/A	Other industrial combustion	2B5	0	87	-87	-100%	Yes	Emissions from energy recovery in the chemical industry now included within estimates reported in 2B8.

Table 10.3 Recalculations to CH_4 in 1990 (kt CH_4)

CRF category 2015	Source Name	CRF category 2014	2015 submission	2014 submission	Change (kt CH_4)	Change (%)	Reallocation due to IPCC GLs?	Justification
1A1ai	Miscellaneous industrial/commercial combustion	1A1a	0.44	0.63	-0.18	-29%	No	7
1A1ai	Power stations	1A1a	2.57	2.67	-0.10	-4%	No	7. In addition, estimates for MSW combustion in Jersey were available from 2 sources, the time series has been replaced with an annually updated data set
1A1b	Refineries - combustion	1A1b	0.52	0.54	-0.02	-3%	No	2, 7
1A1ciii	Collieries - combustion	1A1c	0.00	0.01	-0.01	-69%	No	7
1A2a	Blast furnaces	1A2a	0.02	0.03	-0.01	-25%	No	7
1A2a	Iron and steel - combustion plant	1A2a	0.13	0.33	-0.20	-61%	Yes	7
1A2b	Autogeneration - exported to grid	1A2f	0.01		0.01	N/A	Yes	7. In addition, reallocation of emissions from coal use from other industry to non-ferrous metals (known to be used for aluminium)
1A2b	Autogenerators	1A2f	0.02		0.02	N/A	Yes	7. In addition, reallocation of emissions from coal use from other industry to non-ferrous metals (known to be used for aluminium)
1A2b	Non-Ferrous Metal (combustion)	1A2b	0.02	0.09	-0.06	-75%	No	2, 3, 7
1A2c	Chemicals (combustion)	1A2c	0.27	0.90	-0.62	-70%	Yes	2, 3, 7. In addition, revised method to extrapolate the use of process gases in chemical/petrochemical production
1A2d	Pulp, Paper and Print (combustion)	1A2d	0.08	0.24	-0.16	-68%	No	2, 3, 7
1A2e	Food & drink, tobacco (combustion)	1A2e	0.18	0.44	-0.26	-59%	No	2, 3, 7
1A2f	Lime production - non decarbonising	1A2f	0.01	0.03	-0.03	-79%	Yes	7. In addition, change in scope – 2 lime kilns now included as part of soda ash sector rather than lime sector
1A2gvii	Industrial off-road mobile machinery	1A2f	0.94	0.96	-0.03	-3%	Yes	3
1A2gviii	Autogeneration - exported to grid	1A2f	0.00	0.03	-0.02	-87%	Yes	7. In addition, reallocation of coal use to non-ferrous metals (as above)

CRF category 2015	Source Name	CRF category 2014	2015 submission	2014 submission	Change (kt CH_4)	Change (%)	Reallocation due to IPCC GLs?	Justification
1A2gviii	Autogenerators	1A2f	0.01	0.07	-0.06	-87%	Yes	7. In addition, reallocation of coal use to non-ferrous metals (as above)
1A2gviii	Other industrial combustion	1A2f	0.99	1.97	-0.98	-50%	Yes	2, 3, 7, reallocations between energy and IPPU for coke (plus reallocations between coal and coke) based on DECC, 2014. Reallocations between lime and soda ash production.
1A4ai	Miscellaneous industrial/commercial combustion	1A4a	1.05	1.13	-0.08	-7%	No	3, 7, correction to Gibraltar data (gas use in hotels)
1A4ai	Public sector combustion	1A4a	1.14	1.20	-0.05	-5%	No	3, 7
1A4bi	Domestic combustion	1A4b	68.44	69.34	-0.90	-1%	No	3, 7
1A4ci	Agriculture - stationary combustion	1A4c	0.82	0.96	-0.14	-15%	No	7
1B2b4	Gas leakage	1B2b	9.14	381.37	0.03	0%	No	Disaggregation between transmission and distribution losses. Minor revision to data used for estimates of leakage at the point of use
1B2b5	Gas leakage	1B2b	372.25					
2A4a	Brick manufacture - Fletton	2A7	1.25	1.12	0.13	11%	Yes	Revisions to activity data from 1996 onwards, this has impacted the derived emission factor for all years
2B1	Ammonia production - combustion	1A2c	0.01	0.06	-0.05	-82%	Yes	7, reallocation from 1A2c to 2B1
2B8d	Chemical industry - ethylene oxide	N/A	0.35	0.00	0.35	N/A	New Source	New source
2B8e	Chemical industry - acrylonitrile	N/A	0.05	0.00	0.05	N/A	New Source	New source
2B8f	Chemical industry - carbon black	N/A	0.01	0.00	0.01	N/A	New Source	New source
2B8g	Chemicals (combustion)	N/A	0.06	0.00	0.06	N/A	Yes	10. This is a reallocation of estimates previously reported in 1A2c, where process off-gases are used in chemical / petrochemical production.
2D1	Other industrial combustion	1A2f	0.03	0.02	0.01	41%	Yes	5, 7
3A1	Agriculture livestock - dairy cattle enteric	4A1	388.65	251.99	136.66	54%	Yes	7
3A1	Agriculture livestock - other cattle enteric	4A1	488.21	401.88	86.33	21%	Yes	7
3A4	Agriculture livestock - deer enteric	4A10	0.92	0.42	0.51	121%	Yes	7

CRF category 2015	Source Name	CRF category 2014	2015 submission	2014 submission	Change (kt CH_4)	Change (%)	Reallocation due to IPCC GLs?	Justification
3A4	Agriculture livestock - goats enteric	4A4	0.55	0.53	0.03	5%	Yes	7
3B1	Agriculture livestock - dairy cattle wastes	4B1	57.86	98.69	-40.83	-41%	Yes	7
3B1	Agriculture livestock - other cattle wastes	4B1	65.03	142.18	-77.15	-54%	Yes	7
3B2	Agriculture livestock - sheep goats and deer wastes	4B3	8.90	13.70	-4.80	-35%	Yes	7
3B3	Agriculture livestock - pigs wastes	4B8	43.67	158.24	-114.57	-72%	Yes	7
3B4	Agriculture livestock - broilers wastes	4B9	1.19	9.56	-8.37	-88%	Yes	7
3B4	Agriculture livestock - goats wastes	4B4	0.03	0.05	-0.02	-34%	Yes	7
3B4	Agriculture livestock - horses wastes	4B6	0.90	0.80	0.10	13%	Yes	7
3B4	Agriculture livestock - laying hens wastes	4B9	1.26	5.16	-3.91	-76%	Yes	7
3B4	Agriculture livestock - other poultry wastes	4B9	0.07	0.29	-0.22	-77%	Yes	7
3F	Field burning	4F1	8.22	12.59	-4.37	-35%	Yes	7
N/A	Field burning	4F5	0.00	0.08	-0.08	-100%	Yes	7
4C	Grassland - Biomass Burning\Wildfires	5C	0.36	0.50	-0.14	-28%	Yes	FIRMS thermal anomaly data revised to correct data processing errors.
5A1a	Landfill	6A1	2509.99	2049.31	460.68	22%	Yes	Change in response to UNFCCC reviews in 2013 and 2014. Now assumes zero flaring in 1990.
5B1a	Composting (household)	N/A	0.22	0.00	0.22	N/A	New Source	New source
5C1.2a	Incineration	6C	4.44	6.30	-1.86	-29%	Yes	7
5C2.2b	Accidental fires - dwellings	N/A	0.28	0.00	0.28	N/A	New Source	Included in response to completeness checks between LRTAP and UNFCCC reporting
5C2.2b	Accidental fires - other buildings	N/A	0.66	0.00	0.66	N/A	New Source	Included in response to completeness checks between LRTAP and UNFCCC reporting
5D1	Sewage sludge decomposition in private systems	N/A	10.36	0.00	10.36	N/A	New Source	New source

CRF category 2015	Source Name	CRF category 2014	2015 submission	2014 submission	Change (kt CH_4)	Change (%)	Reallocation due to IPCC GLs?	Justification
5D1	Sewage sludge decomposition	6B2	47.61	14.73	32.88	223%	Yes	Domestic and commercial waste-water management emissions estimates have been overhauled in light of the near complete data we received from industry for 2013, consultation with industry on how assumptions are made, and new methodological details provided. Main change in 1990 is due to inclusion of default emission factor for sewage disposal to sea.
5D2	Industrial Waste-water Treatment	6B1	108.81	65.54	43.27	66%	Yes	Correction to application of IPCC method, no changes to input parameters

Table 10.4 Recalculations to CH_4 in 2012 (kt CH_4)

CRF category 2015	Source Name	CRF category 2014	2015 submission	2014 submission	Change (kt CH_4)	Change (%)	Reallocation due to IPCC GLs?	Justification
1A1ai	Miscellaneous industrial/commercial combustion	1A1a	0.30	0.41	-0.10	-25%	No	6, 7
1A1ai	Power stations	1A1a	4.21	5.03	-0.82	-16%	No	6, 7. In addition, revised assumptions for fuel oil to ensure balance with industrial oil use, revised data for waste oil (see Ch3, MS1), Reallocation from Waste to Energy for MSW incineration in the Cayman Islands and Bermuda
1A1cii	Upstream oil and gas production - combustion at gas separation plant	1A1c	0.31	0.29	0.02	6%	No	Correction to AD
1A1cii	Upstream Oil Production - fuel combustion	1A1c	2.83	2.86	-0.03	-1%	No	6. In addition, new method for deriving EF to use EEMS data for diesel combustion
1A1ciii	Collieries - combustion	1A1c	0.00	0.01	-0.01	-82%	No	6, 7
1A1ciii	Gas production	1A1c	0.02	0.02	0.01	31%	No	6, 7
1A2a	Iron and steel - combustion plant	1A2a	0.06	0.14	-0.08	-55%	Yes	6, 7

CRF category 2015	Source Name	CRF category 2014	2015 submission	2014 submission	Change (kt CH_4)	Change (%)	Reallocation due to IPCC GLs?	Justification
1A2b	Autogeneration - exported to grid	1A2f	0.01		0.01	N/A	Yes	6, 7. In addition, reallocation of coal use from other industry to non-ferrous metals (known to be used for aluminium)
1A2b	Autogenerators	1A2f	0.01		0.01	N/A	Yes	6, 7. In addition, reallocation of coal use from other industry to non-ferrous metals (known to be used for aluminium)
1A2b	Non-Ferrous Metal (combustion)	1A2b	0.01	0.05	-0.05	-87%	No	3, 6, 7
1A2c	Chemicals (combustion)	1A2c	0.07	0.80	-0.72	-91%	Yes	3, 6, 7. In addition, identification of additional petrochemical sites. Reallocation of fuel use for ammonia production to 2B1
1A2d	Pulp, Paper and Print (combustion)	1A2d	0.03	0.25	-0.22	-88%	No	3, 6, 7
1A2e	Food & drink, tobacco (combustion)	1A2e	0.08	0.42	-0.33	-80%	No	3, 6, 7
1A2f	Cement production - combustion	1A2f	0.30	0.26	0.05	19%	No	7
1A2f	Lime production - non decarbonising	1A2f	0.00	0.03	-0.02	-81%	Yes	Change in scope – 2 lime kilns now included as part of soda ash sector rather than part of lime sector, 7
1A2gvii	Industrial off-road mobile machinery	1A2f	0.82	0.82	0.01	1%	Yes	3
1A2gviii	Autogeneration - exported to grid	1A2f	0.04	0.27	-0.24	-87%	Yes	6, 7, reallocation of coal use to non-ferrous metals
1A2gviii	Autogenerators	1A2f	0.05	0.32	-0.27	-85%	Yes	6, 7, reallocation of coal use to non-ferrous metals, revised method for refineries includes estimate for autogeneration, reallocated from here
1A2gviii	Other industrial combustion	1A2f	1.22	1.85	-0.63	-34%	Yes	3, 6, 7
1A3bi	Road transport - cars - urban driving	1A3b	0.79	0.78	0.01	1%	No	9
1A4ai	Miscellaneous industrial/commercial combustion	1A4a	1.22	0.98	0.24	24%	No	3, 6, 7. In addition, correction to Gibraltar data (gas use in hotels), revised assumptions for fuel oil, to ensure balance with industrial oil use
1A4ai	Public sector combustion	1A4a	0.79	0.97	-0.17	-18%	No	3, 6, 7
1A4ai	Railways - stationary combustion	1A4a	0.00	0.01	-0.01	-98%	No	6, 7

CRF category 2015	Source Name	CRF category 2014	2015 submission	2014 submission	Change (kt CH_4)	Change (%)	Reallocation due to IPCC GLs?	Justification
1A4bi	Domestic combustion	1A4b	22.28	22.77	-0.49	-2%	No	6, 7. In addition, revised charcoal data from FAOSTAT, revised peat use statistics for Scotland from CEH, petroleum coke used from SSF manufacture now reported in DUKES, and therefore petroleum coke sold directly as SSF reduced to ensure no double count.
1A4ci	Agriculture - stationary combustion	1A4c	1.92	2.27	-0.35	-15%	No	6, 7
1B1a1i	Deep-mined coal	1B1a	68.66	65.40	3.25	5%	No	Inputs to calculation now using links to source data rather than rounded values, increase in precision has made changes to calculated emissions
1B2b4	Gas leakage	1B2b	5.43	184.59	-6.10	-3%	No	Disaggregation between transmission and distribution losses. Correction to operator data, plus new data supplied for 2011 and 2012. Improvement to calculation of weighted average composition.
1B2b5	Gas leakage	1B2b	173.07					
2B1	Ammonia production - combustion	1A2c	0.01	0.06	-0.05	-82%	Yes	7, reallocation from 1A2c
2B8e	Chemical industry - acrylonitrile	N/A	0.01	0.00	0.01	N/A	New Source	New source
2B8g	Chemicals (combustion)	N/A	0.06	0.00	0.06	N/A	Yes	10. Re-allocation of estimates previously reported in 1A2c, where process off-gases are used in chemical / petrochemical production. New source
3A1	Agriculture livestock - dairy cattle enteric	4A1	311.09	202.76	108.33	53%	Yes	7
3A1	Agriculture livestock - other cattle enteric	4A1	446.77	349.94	96.83	28%	Yes	7
3A2	Agriculture livestock - sheep enteric	4A3	165.99	166.60	-0.61	0%	Yes	7
3A4	Agriculture livestock - deer enteric	4A10	0.60	0.27	0.33	120%	Yes	7
3A4	Agriculture livestock - goats enteric	4A4	0.56	0.54	0.02	3%	Yes	7
3B1	Agriculture livestock - dairy cattle wastes	4B1	44.79	78.68	-33.89	-43%	Yes	7
3B1	Agriculture livestock - other cattle wastes	4B1	58.73	122.06	-63.33	-52%	Yes	7

CRF category 2015	Source Name	CRF category 2014	2015 submission	2014 submission	Change (kt CH_4)	Change (%)	Reallocation due to IPCC GLs?	Justification
3B2	Agriculture livestock - sheep goats and deer wastes	4B3	6.45	9.97	-3.52	-35%	Yes	7
3B3	Agriculture livestock - pigs wastes	4B8	23.35	85.28	-61.93	-73%	Yes	7
3B4	Agriculture livestock - broilers wastes	4B9	1.64	13.17	-11.54	-88%	Yes	7
3B4	Agriculture livestock - goats wastes	4B4	0.03	0.05	-0.02	-34%	Yes	7
3B4	Agriculture livestock - horses wastes	4B6	1.61	1.43	0.18	13%	Yes	7
3B4	Agriculture livestock - laying hens wastes	4B9	1.03	4.20	-3.17	-76%	Yes	7
3B4	Agriculture livestock - other poultry wastes	4B9	0.53	1.28	-0.74	-58%	Yes	7
4A	Forest Land - Biomass Burning\Wildfires	5A	0.86	0.78	0.08	10%	Yes	Changes in the CARBINE model have altered the average amount of fuel burnt.
4B	Cropland - Biomass Burning\Controlled Burning	5B	0.00	0.01	-0.01	-60%	Yes	Changes in the CARBINE model have altered the average amount of fuel burnt. Revised deforestation areas used for 2000 – 2013.
4C	Grassland - Biomass Burning\Controlled Burning	5C	0.95	1.16	-0.21	-18%	Yes	Changes in the CARBINE model have altered the average amount of fuel burnt. Revised deforestation areas used for 2000 – 2013.
4C	Grassland - Biomass Burning\Wildfires	5C	0.83	0.81	0.02	2%	Yes	FIRMS thermal anomaly data used to assess wildfire area revised to correct data processing errors.
4E	Settlements - Biomass Burning\Controlled Burning	5E	0.08	0.32	-0.24	-75%	Yes	• Revised deforestation areas used for 2000 – 2013. • Changes in the CARBINE model have altered the average amount of fuel burnt when land is deforested to Settlement.
5A1a	Landfill	6A1	818.43	884.13	-65.70	-7%	Yes	Revised estimates for flaring based on reported data only, updates to parameters for waste composition.
5B1a	Total composting (non-household)	N/A	23.40	0.00	23.40	N/A	New Source	New source
5B1a	Composting (household)	N/A	0.83	0.00	0.83	N/A	New Source	New source
5B2a	Anaerobic Digestion (other)	N/A	0.99	0.00	0.99	N/A	New Source	New source
5B2a	Mechanical Biological Treatment	N/A	1.66	0.00	1.66	N/A	New Source	New source

CRF category 2015	Source Name	CRF category 2014	2015 submission	2014 submission	Change (kt CH_4)	Change (%)	Reallocation due to IPCC GLs?	Justification
5C1.2a	Incineration	6C	0.00	0.16	-0.16	-100%	Yes	Reallocation from Waste to Energy for MSW incineration in the Cayman Islands and Bermuda
5C2.2b	Accidental fires - dwellings	N/A	0.16	0.00	0.16	N/A	New Source	Included in response to completeness checks between LRTAP and UNFCCC reporting
5C2.2b	Accidental fires - other buildings	N/A	0.14	0.00	0.14	N/A	New Source	Included in response to completeness checks between LRTAP and UNFCCC reporting
5D1	Sewage sludge decomposition in private systems	N/A	10.43	0.00	10.43	N/A	New Source	New source
5D1	Sewage sludge decomposition	6B2	20.70	17.56	3.14	18%	Yes	Domestic and commercial waste-water management emissions estimates have been overhauled in light of the near complete data we received from industry for 2013, consultation with industry on how assumptions are made, and new methodological details provided
5D2	Industrial Waste-water Treatment	6B1	103.64	60.27	43.37	72%	Yes	Correction to application of IPCC method, no changes to input parameters

Table 10.5 Recalculations to N_2O in 1990 (kt N_2O)

CRF category 2015	SourceName	CRF category 2014	2015 submission	2014 submission	Change (kt N_2O)	Change (%)	Reallocation due to IPCC GLs?	Justification
1A1b	Refineries - combustion	1A1b	0.14	0.33	-0.19	-57%	No	2, 7
1A2b	Autogeneration - exported to grid	1A2f	0.03		0.03	N/A	Yes	7. In addition, reallocation of emissions from coal use from other industry to non-ferrous metals (known to be used for aluminium)
1A2b	Autogenerators	1A2f	0.07		0.07	N/A	Yes	7. In addition, reallocation of emissions from coal use from other industry to non-ferrous metals (known to be used for aluminium)
1A2c	Chemicals (combustion)	1A2c	0.29	0.29	-0.01	-3%	Yes	2, 3, 7

CRF category 2015	SourceName	CRF category 2014	2015 submission	2014 submission	Change (kt N_2O)	Change (%)	Reallocation due to IPCC GLs?	Justification
1A2f	Lime production - non decarbonising	1A2f	0.03	0.02	0.01	57%	Yes	7, Change in scope – 2 lime kilns now included as part of soda ash sector rather than lime sector
1A2gvii	Industrial off-road mobile machinery	1A2f	2.89	3.11	-0.21	-7%	Yes	3
1A2gviii	Autogeneration - exported to grid	1A2f	0.00	0.03	-0.03	-99%	Yes	7, Reallocation of coal use for autogenerators to 1A2b, as above.
1A2gviii	Autogenerators	1A2f	0.00	0.07	-0.07	-99%	Yes	7, Reallocation of coal use for autogenerators to 1A2b, as above.
1A2gviii	Other industrial combustion	1A2f	0.49	0.71	-0.21	-30%	Yes	2, 3, 7. Reallocations between energy and IPPU for coke (plus reallocations between coal and coke), based on DECC, 2014. Reallocations between lime and soda ash production.
1A3a	Aircraft - domestic cruise	1A3a	0.03	0.03	0.01	26%	No	4
1A4bi	Domestic combustion	1A4b	0.91	0.94	-0.03	-3%	No	3, 7
2B2	Nitric acid production	2B2	12.95	12.59	0.36	3%	No	7
2B8g	Chemicals (combustion)	N/A	0.01		0.01	N/A	Yes	10. Re-allocation of estimates previously reported in 1A2c, where process off-gases are used in chemical / petrochemical production. New source
3B1	Agriculture livestock - dairy cattle wastes	4B12/13/14	1.68		1.68	N/A	Yes	7
3B1	Agriculture livestock - other cattle wastes	4B12/13/14	2.03		2.03	N/A	Yes	7
3B2	Agriculture livestock - sheep goats and deer wastes	4B12/13/14	0.15		0.15	N/A	Yes	7
3B3	Agriculture livestock - pigs wastes	4B12/13/14	0.66		0.66	N/A	Yes	7
3B4	Agriculture livestock - all poultry wastes	4B12/13/14	0.14		0.14	N/A	Yes	7
3B4	Agriculture livestock - manure leaching (indirect)	4B12/13/14	0.05		0.05	N/A	Yes	7
3B4	Agriculture livestock - manure liquid systems (indirect)	4B12/13/14	1.23		1.23	N/A	Yes	7
3B4	Agriculture livestock - manure other	4B14	0.29	2.50	-2.21	-88%	Yes	7
3B4	Agriculture livestock - manure other (indirect)	4B12/13/14	0.65		0.65	N/A	Yes	7

CRF category 2015	SourceName	CRF category 2014	2015 submission	2014 submission	Change (kt N_2O)	Change (%)	Reallocation due to IPCC GLs?	Justification
3B4	Agriculture livestock - manure solid storage and dry lot (indirect)	4B12/13/14	1.17		1.17	N/A	Yes	7
3B1 - 4	Agriculture livestock - manure liquid systems	4B12		0.26	-0.26	-100%	Yes	7
3B1 - 4	Agriculture livestock - manure solid storage and dry lot	4B13		8.33	-8.33	-100%	Yes	7
3D1	N_2O emissions from disturbance associated with land-use conversion to cropland	5B2		2.48	-2.48	-100%	Yes	7
3D	Agricultural soils	4D	77.13	108.69	-31.57	-29%	Yes	7
3D	OvTerr Agricultural Soils	4D	0.18	0.04	0.13	305%	Yes	7
3D1	Agricultural soils - Mineralization/Immobilization Associated with change in Soil Organic Matter	N/A	0.39	0.00	0.39	N/A	New Source	New source
3F	Field burning	4F1	0.21	0.25	-0.04	-16%	Yes	7
4A	Forest Land - Drainage of Organic Soils	5A	0.14	0.15	-0.01	-8%	Yes	Drainage areas were updated to use the CARBINE input area data and ensure consistency in forest areas on different soil types.
4B2	Direct N_2O Emissions from N Mineralization/Immobilisation	N/A	2.18	0.00	2.18	N/A	New Source	Newly included under the 2006 AFOLU structure.
4C	Grassland - Biomass Burning\Wildfires	5C	0.03	0.05	-0.01	-28%	Yes	FIRMS thermal anomaly data used to assess wildfire area revised to correct data processing errors.
4C	Grassland - Direct N_2O Emissions from N Mineralization/Immobilisation	N/A	0.01	0.00	0.01	N/A	New Source	Newly included under the 2006 AFOLU structure.
4E	Settlements - Direct N_2O Emissions from N Mineralization/Immobilisation	N/A	1.24	0.00	1.24	N/A	New Source	Newly included under the 2006 AFOLU structure.
5B1a	Composting (household)	N/A	0.02	0.00	0.02	N/A	New Source	New source
5C1.2a	Incineration	6C	0.00	0.08	-0.08	-99%	Yes	7
5D1	Sewage sludge decomposition	6B2	3.73	3.76	-0.03	-1%	Yes	Revision to population statistics, improvement work to OTs to use IPCC T1 methods, removal of double count with sewage incineration estimates.

Table 10.6 Recalculations to N_2O in 2012

CRF category 2015	SourceName	CRF category 2014	2015 submission	2014 submission	Change (kt N_2O)	Change (%)	Reallocation due to IPCC GLs?	Justification
1A1ai	Power stations	1A1a	3.80	3.90	-0.10	-3%	No	6, 7, Revised assumptions for fuel oil to ensure balance with industrial oil use, revised data for waste oil (see Ch3, MS1), reallocation from Waste to Energy for MSW incineration in the Cayman Islands and Bermuda
1A1b	Refineries - combustion	1A1b	0.15	0.46	-0.31	-68%	No	6, 2, 7, Reallocation of natural gas from autogenerators (see Ch3, MS1)
1A1cii	Upstream Oil Production - fuel combustion	1A1c	0.67	0.64	0.02	4%	No	6, 7, 3
1A2b	Autogeneration - exported to grid	1A2f	0.03		0.03	N/A	Yes	6, 7. In addion, reallocation of coal for autogenerators from other industry to 1A2b
1A2b	Autogenerators	1A2f	0.04		0.04	N/A	Yes	6, 7. In addion, reallocation of coal for autogenerators from other industry to 1A2b
1A2c	Chemicals (combustion)	1A2c	0.08	0.12	-0.04	-31%	Yes	3, 6, 7. In addition, identification of additional petrochemical sites. Reallocation of fuel use for ammonia production to 2B1.
1A2f	Lime production - non decarbonising	1A2f	0.01	0.02	-0.01	-55%	Yes	7, Change in scope – 2 lime kilns now included as part of soda ash sector rather than part of the lime sector
1A2gvii	Industrial off-road mobile machinery	1A2f	2.13	2.03	0.10	5%	Yes	3
1A2gviii	Autogeneration - exported to grid	1A2f	0.00	0.04	-0.03	-91%	Yes	6, 7, reallocation of coal to 1A2b as above
1A2gviii	Autogenerators	1A2f	0.00	0.04	-0.04	-89%	Yes	6, 7, reallocation of coal to 1A2b as above, revised method for refineries includes estimate for autogeneration, reallocated from here.
1A2gviii	Other industrial combustion	1A2f	0.41	0.40	0.02	5%	Yes	3, 6, 7
1A4bi	Domestic combustion	1A4b	0.37	0.38	-0.01	-4%	No	6, 7, revised charcoal data from FAOSTAT, Revised peat use statistics for Scotland from CEHs, petroleum coke used in SSF manufacture is now reported in DUKES and therefore petroleum coke sold directly as SSF reduced to ensure no double count.

CRF category 2015	SourceName	CRF category 2014	2015 submission	2014 submission	Change (kt N_2O)	Change (%)	Reallocation due to IPCC GLs?	Justification
2B2	Nitric acid production	2B2	0.13	0.20	-0.07	-33%	No	Revised emissions data supplied by plant operator
2B8g	Chemicals (combustion)	N/A	0.01	0.00	0.01	N/A	Yes	10. Re-allocation of estimates previously reported in 1A2c, where process off-gases are used in chemical / petrochemical production. New source
3B1	Agriculture livestock - dairy cattle wastes	4B12/13/14	1.26	0.00	1.26	N/A	Yes	7
3B1	Agriculture livestock - other cattle wastes	4B12/13/14	1.78	0.00	1.78	N/A	Yes	7
3B2	Agriculture livestock - sheep goats and deer wastes	4B12/13/14	0.11	0.00	0.11	N/A	Yes	7
3B3	Agriculture livestock - pigs wastes	4B12/13/14	0.38	0.00	0.38	N/A	Yes	7
3B4	Agriculture livestock - all poultry wastes	4B12/13/14	0.14	0.00	0.14	N/A	Yes	7
3B4	Agriculture livestock - manure leaching (indirect)	4B12/13/14	0.03	0.00	0.03	N/A	Yes	7
3B4	Agriculture livestock - manure liquid systems (indirect)	4B12/13/14	0.90	0.00	0.90	N/A	Yes	7
3B4	Agriculture livestock - manure other	4B14	0.23	2.66	-2.42	-91%	Yes	7
3B4	Agriculture livestock - manure other (indirect)	4B12/13/14	0.61	0.00	0.61	N/A	Yes	7
3B4	Agriculture livestock - manure solid storage and dry lot (indirect)	4B12/13/14	0.86	0.00	0.86	N/A	Yes	7
3B1-4	Agriculture livestock - manure liquid systems	4B12	0.00	0.21	-0.21	-100%	Yes	7
3B1-4	Agriculture livestock - manure solid storage and dry lot	4B13	0.00	5.96	-5.96	-100%	Yes	7
N/A	N_2O emissions from disturbance associated with land-use conversion to cropland	5B2	0.00	1.85	-1.85	-100%	Yes	7
3D	Agricultural soils	4D	64.14	87.38	-23.23	-27%	Yes	7
3D	OvTerr Agricultural Soils	4D	0.12	0.04	0.09	228%	Yes	7
3D1	Agricultural soils - Mineralization/Immobilization Associated with change in Soil Organic Matter	N/A	0.87	0.00	0.87	N/A	New Source	7

CRF category 2015	SourceName	CRF category 2014	2015 submission	2014 submission	Change (kt N_2O)	Change (%)	Reallocation due to IPCC GLs?	Justification
4A	Forest Land - Drainage of Organic Soils	5A	0.15	0.18	-0.02	-13%	Yes	Refinement of the CARBINE input data and updating of the deforestation activity data has led to minor changes.
4B2	Direct N_2O Emissions from N Mineralization/Immobilisation	N/A	1.14	0.00	1.14	N/A	New Source	Newly included under the 2006 AFOLU structure.
4C	Grassland - Direct N_2O Emissions from N Mineralization/Immobilisation	N/A	0.02	0.00	0.02	N/A	New Source	Newly included under the 2006 AFOLU structure.
4E	Settlements - Direct N_2O Emissions from N Mineralization/Immobilisation	N/A	1.07	0.00	1.07	N/A	New Source	Newly included under the 2006 AFOLU structure.
5B1a	Total composting (non-household)	N/A	1.77	0.00	1.77	N/A	New Source	New source
5B1a	Composting (household)	N/A	0.05	0.00	0.05	N/A	New Source	New source
5B2a	Mechanical Biological Treatment	N/A	0.11	0.00	0.11	N/A	New Source	New source
5D1	Sewage sludge decomposition	6B2	3.56	3.81	-0.25	-7%	Yes	Revision to population statistics, improvement work to OTs to use IPCC T1 methods, removal of double count with sewage incineration estimates.

For fluorinated gases, a study was commissioned to look at emissions of F-gases from existing sources, and to make estimates for new sources and gases included in the 2006 guidelines.

New emissions have been included for:

- Refrigerant cylinders
- AWACS (military Airborne Warning and Control Systems)
- Particle accelerators and
- Tracer testing.

Emissions have also been included for new gases:

- NF_3 from electronics
- Two new HFCs, HFC-245fa and HFC-365mfc from foam blowing

Full details of the methodology and data sources for these new emissions are included in the report *Review of data and methodologies used in the calculation of UK emissions from F-Gases* (ICF, 2014).

As part of the study updates were also made to emissions of F-gases from the following categories:

- Electronics
- Fire fighting
- Solvents

The new methods are described in detail in **Chapter 4**.

Table 10.7 Changes in Methodological Descriptions

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	DESCRIPTION OF METHODS	RECALCULATIONS	REFERENCE
Total (Net Emissions)	Y	Y	
1. Energy	Y	Y	Chapter 3
A. Fuel Combustion (sectoral approach)	Y	Y	Chapter 3
1. Energy industries	Y	Y	Chapter 3
2. Manufacturing industries and construction	Y	Y	Chapter 3
3. Transport	Y	Y	Chapter 3
4. Other sector	Y	Y	Chapter 3
5. Other	Y	Y	Chapter 3
B. Fugitive emissions from fuels	Y	Y	Chapter 3
1. Solid fuels	Y	Y	Chapter 3

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	DESCRIPTION OF METHODS	RECALCULATIONS	REFERENCE
2. Oil and natural gas and other emissions from energy production	Y	Y	Chapter 3
C. CO_2 transport and storage	Y	Y	Chapter 3
2. Industrial processes and product use	Y	Y	Chapter 4
A. Mineral industry	Y	Y	Chapter 4
B. Chemical industry	Y	Y	Chapter 4
C. Metal industry	Y	Y	Chapter 4
D. Non-energy products from fuels and solvent use	Y	Y	Chapter 4
E. Electronic industry	Y	Y	Chapter 4
F. Product uses as substitutes for ODS	Y	Y	Chapter 4
G. Other product manufacture and use	Y	Y	Chapter 4
H. Other	Y	Y	Chapter 4
3. Agriculture	Y	Y	Chapter 5
A. Enteric fermentation	Y	Y	Chapter 5
B. Manure management	Y	Y	Chapter 5
C. Rice cultivation	Y	Y	Chapter 5
D. Agricultural soils	Y	Y	Chapter 5
E. Prescribed burning of savannahs	Y	Y	Chapter 5
F. Field burning of agricultural residues	Y	Y	Chapter 5
G. Liming	Y	Y	Chapter 5

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	DESCRIPTION OF METHODS	RECALCULATIONS	REFERENCE
H. Urea application	Y	Y	Chapter 5
I. Other carbon containing fertilisers	Y	Y	Chapter 5
J. Other	Y	Y	Chapter 5
4. Land use, land-use change and forestry	Y	Y	Chapter 6
A. Forest land	Y	Y	Chapter 6
B. Cropland	Y	Y	Chapter 6
C. Grassland	Y	Y	Chapter 6
D. Wetlands	Y	Y	Chapter 6
E. Settlements	Y	Y	Chapter 6
F. Other land	Y	Y	Chapter 6
G. Harvested wood products	Y	Y	Chapter 6
H. Other	Y	Y	Chapter 6
5. Waste	Y	Y	Chapter 7
A. Solid waste disposal	Y	Y	Chapter 7
B. Biological treatment of solid waste	Y	Y	Chapter 7
C. Incineration and open burning of waste	Y	Y	Chapter 7
D. Wastewater treatment and discharge	Y	Y	Chapter 7
E. Other	N	N	
6. Other (as specified in Summary 1.A)	N	N	
KP LULUCF	Y	Y	Chapter 11

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	DESCRIPTION OF METHODS	RECALCULATIONS	REFERENCE
Article 3.3 activities	Y	Y	Chapter 11
Afforestation/reforestation	Y	Y	Chapter 11
Deforestation	Y	Y	Chapter 11
Article 3.4 activities	Y	Y	Chapter 11
Forest management	Y	Y	Chapter 11
Cropland management (if elected)	Y	Y	Chapter 11
Grazing land management (if elected)	Y	Y	Chapter 11
Revegetation (if elected)	Y	Y	Chapter 11
Wetland drainage and rewetting (if elected)	Y	Y	Chapter 11

NIR Chapter	DESCRIPTION		REFERENCE
Chapter 1.2 Description of national inventory arrangements	N	N	

10.1.2 KP-LULUCF Activities

The following changes have been made for all KP-LULUCF reporting to reflect the 2006 AFOLU Guidance:

- Revised GWPs for methane and nitrous oxide.
- Emissions from lime application to afforested land no longer included

3.3 Afforestation

Minor improvements have been made to the CARBINE model and input data.

Information on the area of wildfires on Afforested land and biomass densities has been updated.

Estimated areas of drained soils have updated to ensure consistency in forest areas on different soil types.

Harvest Wood Products from Afforested/Reforested land are now included rather than assuming instantaneous oxidation.

3.3 Deforestation

Minor improvements have been made to the CARBINE model and input data.

Post-2000 deforestation areas have been updated.

Emissions from deforestation to grassland and settlement are now included.

3.4 Forest Management

Minor improvements have been made to the CARBINE model and input data.

Post-2000 deforestation areas have been updated which affects forest management areas and carbon stock changes.

Estimated areas of drained soils have been updated to ensure consistency in forest areas on different soil types.

10.2 IMPLICATIONS FOR EMISSION LEVELS

10.2.1 GHG Inventory

Information at sector level is summarised in **Table 10.1** to **Table 10.6** above, and the text description for fluorinated gases. The overall impact of all recalculations is an increase in emissions of 30.52 Mt CO_2 equivalent in 1990, and 6.80 Mt CO_2 equivalent in 2012. Note that in these calculations (and the charts below), the impact of the GWP changes is included.

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.

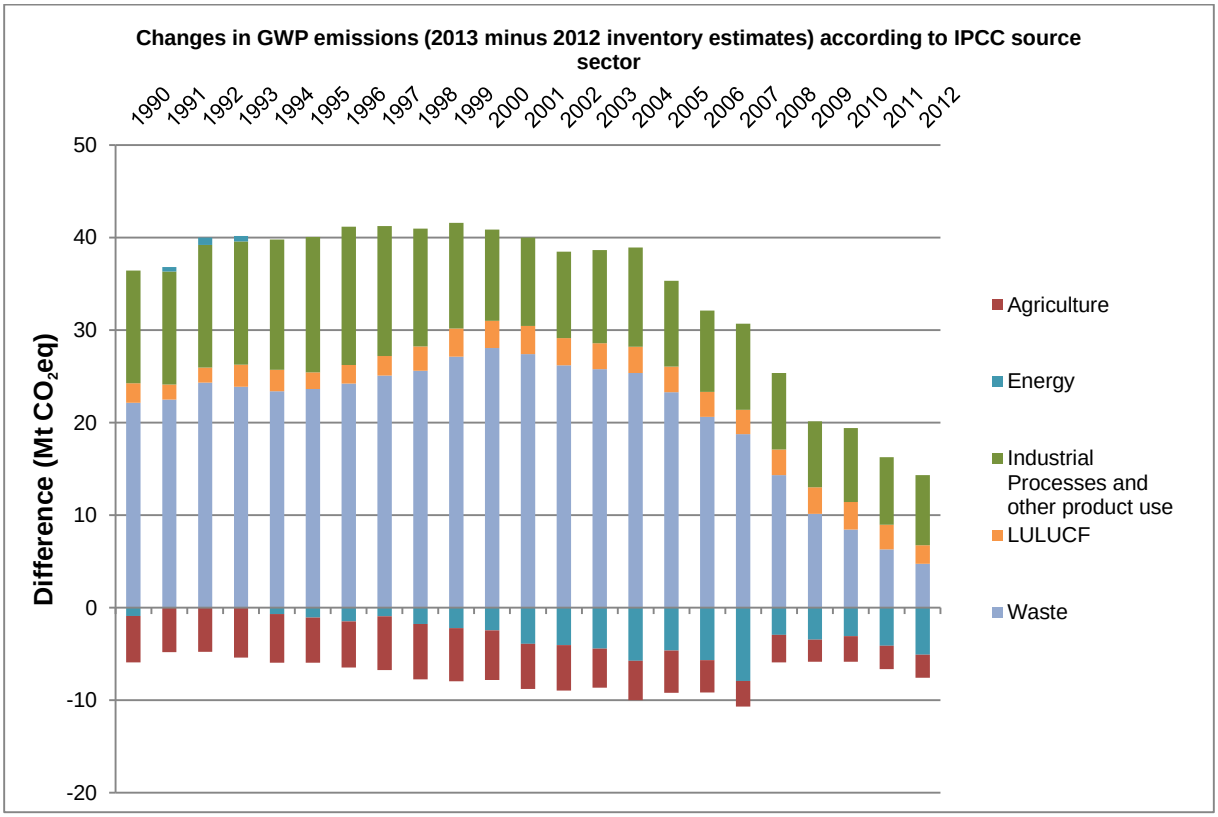
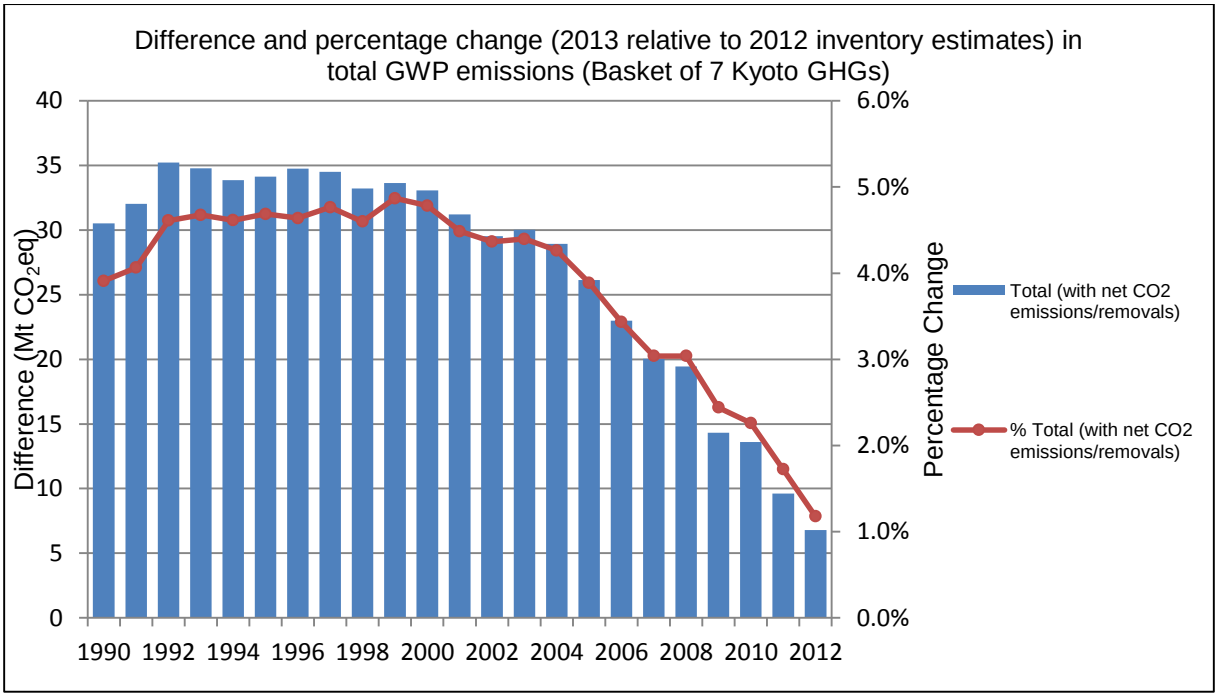


Figure 10.2 shows the net impact of all recalculations in absolute and percentage terms.

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 0** and **Section 11.3.1.4**.

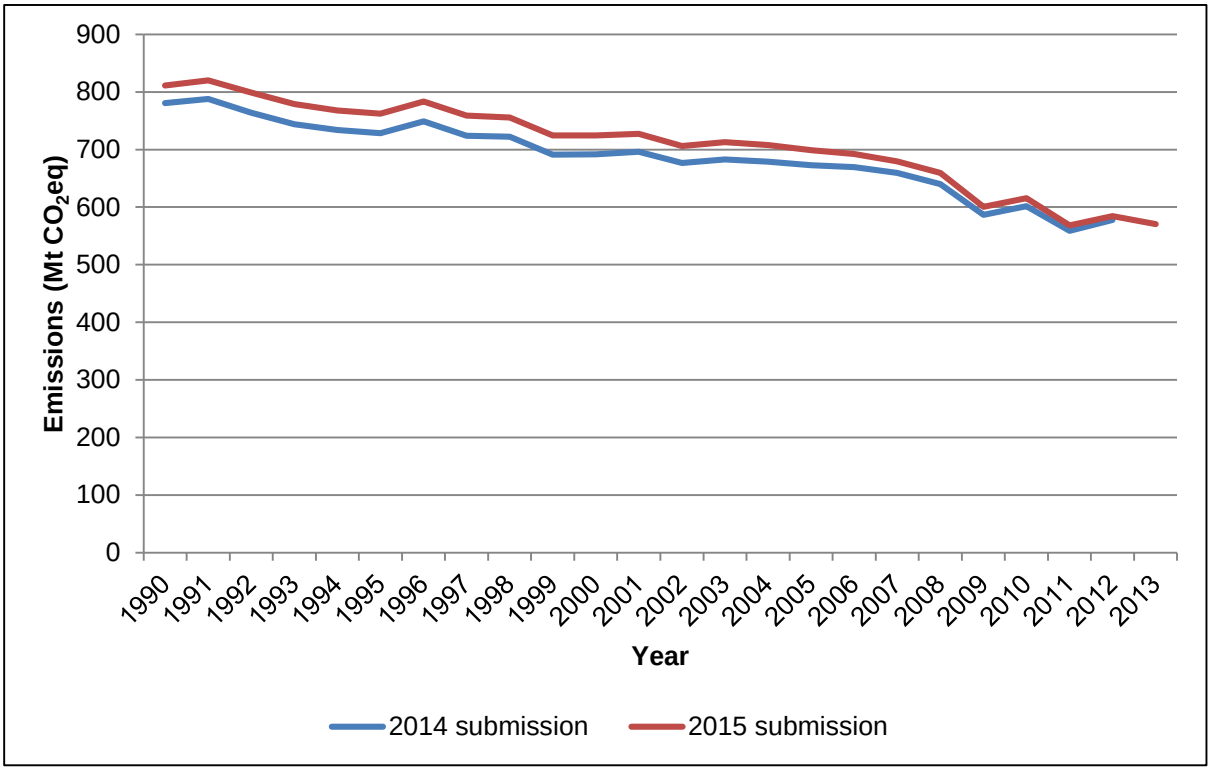
10.3 IMPLICATIONS FOR EMISSION TRENDS, INCLUDING TIME SERIES CONSISTENCY

10.3.1 GHG Inventory

There has been a change in the reported trend in emissions. The reported trend from 1990 to 2012 in the 2014 inventory submission was a decrease of 26.0%. The recalculated trend from 1990 to 2012, as presented in the 2015 submission is a decrease of 28.0%. The main reason for this change is recalculations to emissions in the base year within the waste sector. These are as a result of recommendations from the ERT.

The chart below displays the trend from both the 2014 and 2015 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 0** 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 2013 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** to **Table 10.6**. 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 2014 GHGI submission (2014 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 (2014) submission. The review took place during September 2014. The review report has been received.

Table 10.8 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 since 2013.

10.4.1 GHG Inventory

Table 10.8 Brief Details of Improvements to the NIR and the Inventory in response to UNFCCC Reviews in response to the 2013 reviews.

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter / section in the NIR
QA/QC	Describe any changes in the QA/QC procedures in the NIR	ARR 2014 – Paragraph 13	See improvements to QA/QC system, listed under section 1.6.1	Section 1.6.1
QA/QC	Provide a short summary of the pre-submission review outcome in the NIR	ARR 2014 – Paragraph 14	The outcome of the pre submission review is summarised in section 1.2.2.4	Section 1.2.2.4
Transparency	Improve the transparency of the NIR by including sufficient information in the annual submission (e.g. based on the supporting material provided during the review)	ARR 2014 – Paragraph 15	The NIR undergoes improvements annually, aiming to be as transparent as possible. Under the improvement programme, writing guidance has been drafted in order to improve the NIR, including improving transparency. This has been implemented for the Energy chapter (chapter 3), and associated annexes (3, 4). We welcome the ERT's views on this.	All, Chapter 3, **Annex 3, 4**
Inventory preparation	Perform a key category analysis following the IPCC good practice guidance at an aggregation level where individual methodologies and EFs are used	ARR 2014 – Paragraph 18	We have reviewed the KCA such that the overall method and level of detail at which calculations are currently performed is fully consistent with the requirements of the IPCC 2006 GLs	**Annex 1** of the 2015 NIR
Inventory preparation	Improve the inventory preparation in terms of prioritizing inventory improvements using the key category analysis	ARR 2014 – Paragraph 19	An additional tool for prioritising inventory improvements using the key category analysis has been developed. The key category ranking table in chapter 1 uses a scoring system to determine the how significant each category is in the different approach 1 key category analyses.	Chapter 1 of the 2015 NIR
Energy overview	Complete the improvements regarding the use of comparable units	ARR 2014 – Paragraph 28	Annex 3 now contains a full list of emission factors on an energy basis, to aid comparability with other Parties.	**Annex 3.1** of the 2015 NIR

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter / section in the NIR
Comparison of the reference approach with the sectoral approach and international statistics	Include a summary of information on the possible sources of differences between the approaches for liquid and solid fuels in the NIR	ARR 2014 – Paragraph 31	The differences between the reference approach and sectoral approach have been analysed in more detail. The results of this can be found in chapter 3.	Chapter 3 of the NIR
Comparison of the reference approach with the sectoral approach and international statistics	Investigate the possibility of using disaggregated coal data in the reference approach	ARR 2014 – Paragraph 32	The reference approach has been amended to handle bituminous coal, coking coal and anthracite separately in the 2015 submission.	Chapter 3 of the NIR
Comparison of the reference approach with the sectoral approach and international statistics	Implement checks to ensure that all imports of coke oven/gas coke are correctly accounted for	ARR 2014 – Paragraph 32	This has been corrected for the 2015 submission. Additional checks have been included witin the reference approach to improve accuracy.	Chapter 3 of the NIR
Comparison of the reference approach with the sectoral approach and international statistics	Review the EFs used in the reference approach	ARR 2014 – Paragraph 32	The application of emission factors within the RA has been reviewed, with several improvements made, including: use of weighted-average coal CEF consistent with the sectoral approach data; application of AD and EFs at a more detailed level for solid fuels, rather than aggregating across steam coal, anthracite, coking coal; update to the EFs applied for gas oil / derv.	Chapter 3 of the NIR
Comparison of the reference approach with the sectoral approach and international statistics	Apply the relevant IPCC defaults for the fractions of carbon oxidized	ARR 2014 – Paragraph 33	The method for the reference approach has been revised to use the 2006 GLs method, including for carbon oxidation factors.	Chapter 3 of the NIR
Feedstocks and non-energy use of fuels	Include the carbon content of emissions in the industrial processes sector in the amount of carbon stored in non-energy use of fuels reported in the energy sector in column E of CRF table1.A(d)	ARR 2014 – Paragraph 36	The methodological descriptions for this sector, along with the rest of the energy sector has been reformatted as part of a programme to improve the transparency of the NIR.	Chapter 3 of the 2015 NIR
Stationary combustion: solid, liquid and gaseous fuels – CO_2, CH_4 and N_2O	Implement planned improvements to avoid errors in future CRF tables	ARR 2014 – Paragraph 37	See improvements to QA/QC system, listed under section 1.6.1	Section 1.6.1

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter / section in the NIR
Stationary combustion: solid, liquid and gaseous fuels – CO_2, CH_4 and N_2O	Provide an update on the status of QA/QC improvements in the NIR	ARR 2014 – Paragraph 37	See improvements to QA/QC system, listed under section 1.6.1	Section 1.6.1
Stationary combustion: solid, liquid and gaseous fuels – CO_2, CH_4 and N_2O	Improve the text of the relevant sections of the NIR to better explain the reasons for the low EFs, and justify the extrapolation of these EFs over the entire time series	ARR 2014 – Paragraph 38	Annex 3 describes the approach to calculating the time series of carbon emission factors and how these are used in the inventory. Emission factors for CH_4 and N_2O are largely based on IPCC defaults. All emission factors are listed in Annex 3.	**Annex 3**
Stationary combustion: solid, liquid and gaseous fuels – CO_2, CH_4 and N_2O	Improve the documentation of country-specific EFs and oxidation factors, including any corrections done, in the NIR	ARR 2014 – Paragraph 39	A description of the 2004 Carbon Factors Review report (Baggott et al., 2004) is included in Annex 3, together with information on how it is used. Country specific oxidation factors that could not be fully justified have been replaced with IPCC defaults. The country specific emission factor used for coal (excluding power stations and cement) has been replaced with a literature factor. The impact of the resultant recalculations is described in Chapter 10.	**Annex 3**, Chapter 10
Stationary combustion: solid, liquid and gaseous fuels – CO_2, CH_4 and N_2O	Clearly document in the NIR any revision of the EFs to discount carbon unoxidized	ARR 2014 – Paragraph 39	As above	As above
Road transportation: liquid fuels – CO_2	Review the report on carbon factors in detail and investigate whether the EFs that are currently used are accurate	ARR 2014 – Paragraph 43	Carbon emission factors for all liquid fuels have been reviewed. UKPIA have been consulted and were not able to provide any new data. The existing carbon emission factors are within the range of the default factors in the 2006 IPCC Guidelines for all commonly used fuels. No changes have been made to the carbon emission factors as a result of this review.	N/A
Road transportation: liquid fuels – CO_2	Report the findings of the review in the NIR	ARR 2014 – Paragraph 43	As above.	N/A

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter / section in the NIR
Oil and natural gas: natural gas – CH_4	Improve the transparency of the description in the NIR of the methodology followed for the estimation of fugitive emissions from natural gas transmission and distribution systems	ARR 2014 – Paragraph 44	The methodological descriptions for this sector, along with the rest of the energy sector has been reformatted as part of a programme to improve the transparency of the NIR.	Chapter 3 of the 2015 NIR
Oil and natural gas: natural gas – CH_4	Complete the update of estimates of the length of pipelines and report the findings	ARR 2014 – Paragraph 45	The requested validation exercise has been carried out, the results of which are reported in the 2015 submission.	Chapter 3: MS19 of 2015 submission
Railways: solid fuels – CO_2, CH_4 and N_2O	Improve the time-series consistency of the estimates and consider reallocating the relevant emissions from "other industrial combustion" to railways	ARR 2014 – Paragraph 47	The UK does not have sufficient data to make an informed reallocation, and considers solid fuel combustion by heritage railways to be a source too minor to warrant additional investigation, particularly as it is known that there is no omission.	N/A
Railways: solid fuels – CO_2, CH_4 and N_2O	Use the correct notation key in the CRF tables	ARR 2014 – Paragraph 47	This has been corrected in the 2015 submission.	For the CRF submission
Industrial processes and solvent and other product use overview	Improve the consistency between what is reported in the NIR and the CRF tables focusing on the numerical descriptions of GHG emissions, including the impact of recalculations, and improve the consistency in the use of units in the NIR tables	ARR 2014 – Paragraph 51	Improvements to the QA/QC process are described in section 1.6.1. The NIR is subject to a programme of continuous improvement, including the implementation of NIR writing guidance, which will take place in stages (this has started with the Energy chapter).	Section 1.6.1
Industrial processes and solvent and other product use overview	Conduct the key category analysis for F-gases at the subcategory level (e.g. HFCs from refrigeration and air conditioning equipment)	ARR 2014 – Paragraph 52	In response to other recommendations to implement the key category analysis at a different aggregation a review of the key category analysis and uncertainties was undertaken. Part of this review included distinguishing F-gases by the second level sector (e.g. 2.B.).	**Annex 2** of the 2015 NIR
Nitric acid production – N_2O	Include information on the monitoring standards followed by plant operators in the NIR	ARR 2014 – Paragraph 53	The UK does not have any additional information on the monitoring standards of site operators or the environment agency. The UK will consider looking into this as part of its improvement programme.	Section 4.7

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter / section in the NIR
Nitric acid production – N_2O	Include the reason for the change in the N_2O IEF, together with information on specific abatement measures taken at the two nitric acid production sites in its NIR	ARR 2014 – Paragraph 53	The UK does not have any additional information on the specific of the abatement measures of sites. The UK will consider looking into this as part of its improvement programme.	Section 4.7
Consumption of halocarbons and SF_6 – HFCs, PFCs and SF_6	Incorporate in the NIR information on F-gas regulations and their coverage, and how collection/destruction is accounted for in the models to estimate emissions from consumption of halocarbons and SF_6	ARR 2014 – Paragraph 54	The information reported in the NIR has been reviewed in light of the ERT recommendations.	Chapter 4 of the 2015 NIR
Consumption of halocarbons and SF_6 – HFCs, PFCs and SF_6	Continue to refine the underlying assumptions and methodologies of the models used, together with conducting checks of the consistency of reported AD	ARR 2014 – Paragraph 55	The UK has flagged this item for the improvement programme, and will be investigated for the 2016 submission.	N/A
Consumption of halocarbons and SF_6 – HFCs, PFCs and SF_6	Provide more specific explanation of how it has determined the EF(s) for foam blowing and indicate more consistently whether or not the emissions from manufacturing, stocks and disposal are reported separately, or provide clear reasons for why these emissions are aggregated when reporting	ARR 2014 – Paragraph 56	This has been added to the 2015 improvements programme.	N/A
Consumption of halocarbons and SF_6 – HFCs, PFCs and SF_6	Improve QC procedures to ensure consistent reporting between the NIR and the CRF tables prior to submission, but in particular to ensure the provision of correct information in the tables of the NIR regarding emissions	ARR 2014 – Paragraph 57	The information reported in the NIR has been reviewed in light of the ERT recommendations. We are continually investigating methods to improve QA/QC and consistency; in particular we have compiled a table in our central database for method and emission factor information key to be used as a reference for both the CRF and NIR.	Chapter 4 of the 2015 NIR
Ammonia production – CO_2	Improve the consistency of its description of issues in the NIR, especially regarding quantitative data, and focus on the consistent use of units	ARR 2014 – Paragraph 60	Ammonia production activity cannot be presented in consistent units with the Energy chapter due to commercial in confidence data. More comparable data can be made available to an ERT.	Chapter 4 of the 2015 NIR
Agriculture overview	Enhance QC procedures so that what is reported in the NIR and CRF tables is fully consistent, but especially with regard to values for emission estimates	ARR 2014 – Paragraph 64	A QA/QC plan has been drafted that is aligned with the overall inventory plan and is being implemented. Consistency between the NIR and CRF tables has been improved by direct link of calculations outputs to tables in the NIR.	Chapter 5 of the 2015 NIR

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter / section in the NIR
Enteric fermentation – CH4	Implement the planned improvement of digestibility of feed (DE) data through the commissioned research projects as explained	ARR 2014 – Paragraph 65	This is ongoing and will be implemented as part of the improvement program (2017 submission).	N/A
Enteric fermentation – CH_4	Apply a methodology that more closely reflects the country-specific conditions, for instance, by moving to the IPCC tier 2 methodology for the sheep subcategory, in addition to documenting national circumstances leading to methodological choice	ARR 2014 – Paragraph 66	Tier 2 is currently being implemented as an outcome of the inventory improvement program.	Chapter 5 of the 2015 NIR
Manure management – N_2O	Include information on the country-specific methodology for dairy cattle in the form of a summary explanation of how the N excretion values used in the inventory were derived	ARR 2014 – Paragraph 67	These values are currently under revision and details of their derivation will be included in the next submission (2016 submission).	N/A
LULUCF overview	Incorporate an explanation on changes made from the previous NIR regarding areas allocated to land-use categories in 1990, as reported in the land-use matrix (NIR table 7.1), when appropriate	ARR 2014 – Paragraph 73	Annual land use change matrices are now reported in Table 4.1 of the CRF. The data used for the area of each sub-category has been clarified in the section describing the land use transition matrix.	Section 6.1.1 of the 2015 NIR
Forest land – CO_2	Continue efforts to gather information on the management of privately owned forests and include information on the management prescriptions and rotation ranges in the NIR	ARR 2014 – Paragraph 76	Additional information on management prescriptions and rotations has been included in the annex and reference made to a more detailed document. Further improvements to the methodological description will be made for the 2016 submission.	Annex 3.4.1 of the 2015 NIR
Forest land – CO_2	Continue efforts to improve the estimates on soil carbon and related documentation	ARR 2014 – Paragraph 77	Improvements to the soil carbon estimates and methodological description are planned for the 2016 submission.	N/A

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter / section in the NIR
Cropland and grassland – CO_2	Research again the possibility of generating suitable data and report on the progress to estimate emissions and removals from organic soil, and until additional information becomes available, report using the notation key "NE"	ARR 2014 – Paragraph 80	The 1990 – 2013 inventory uses new data on the extent of Cropland and improved Grassland on organic soils, and so has improved estimates emissions from these soils. No histosols occur in the Caribbean OTs (Soil Atlas of Latin America, JRC, 2014) or in CDs close to the UK (Soil Atlas of Europe, JRC, 2014). Histosols do occur in the Falkland Islands (Soil Atlas of Latin America, JRC, 2014) but there is no drainage on Grassland, and therefore no emissions from disturbance (disturbance results in conversion to Cropland). Therefore the NO notation key will be retained. Work to implement the Wetlands Supplement is underway which will attempt to further refine these areas including the area of Grassland on organic and organo-mineral soils in the OTs and CDs and to generate estimates for the area of drained organic soils under semi-natural grasslands. The Wetlands Supplement work will also assess whether the T1 emission factors which are currently used to assess CO_2 emissions from organic soils should be replaced with T2 or T3 factors to reflect UK circumstances.	N/A

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter / section in the NIR
Cropland and grassland – CO_2	Assign orchards to cropland and provide documentation on the method used to estimate the carbon stock changes over time, and ensure that changes in the area of orchards over time have been taken into account	ARR 2014 – Paragraph 81	The Countryside Survey (CS) Broad Habitat types shown in Table A3.6.8 are used to assign land use from 1984 onwards. Orchards are included in the Arable and Horticultural Broad Habitat type, and so for years which use CS data orchards are included in Cropland. Prior to 1984 Mapping Landscape Change (MLC) data are used to classify land use. As shown in Table A3.6.7 MLC Orchards have mistakenly been included in Forest Land. This misclassification will be addressed as part of the ongoing programme to improve the inventory. The error only applies to years before 1984 use so will only affect emissions from change in soil carbon stocks as a result of historical land use change. Orchards only cover a small area of the UK and the effect of this mis-classification is likely to be small. This submission includes reporting on emissions from changes in soil carbon stocks resulting from Cropland management including conversion of other Cropland types to orchard.	N/A
Cropland and grassland – CO_2	Report land-use changes from cropland to grassland for 2010 onward	ARR 2014 – Paragraph 82	The error in land use conversion has been corrected for the 2015 submission: extrapolated rather than projected values are now used.	Section 6.3.7 of the 2015 NIR
Settlements	Investigate the internal consistency of the reported changes in carbon stock and more transparently provide information on the methods used	ARR 2014 – Paragraph 83	This recommendation will be assessed for the 2016 submission.	N/A
Wetlands	Assess the appropriateness of the use of the notation key “NE” for the carbon stock changes in living biomass in overseas territories for forest land converted to wetlands and the related area and report on it	ARR 2014 – Paragraph 84	This recommendation has been assessed and it has been agreed that the notation key ‘NE’ is not appropriate in this situation. Due to the changes in the structure of the CRF tables, as a result of the 2006 guidelines, Forest Land to Wetland conversions are no longer reported in the 2015 submission.	For the CRF submission

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter / section in the NIR
Waste overview	Improve the QC checks in, and between, the main text of the NIR and the annexes, as well as with the CRF tables	ARR 2014 – Paragraph 87	The UK has addressed the issues flagged by the ERT for the 2015 submission.	Chapter 7 and **Annex 3** of the 2015 NIR
Solid waste disposal on land – CH_4	Implement the proposed improvements of emission estimates from solid waste disposal sites in the overseas territories and crown dependencies, by providing further information on methodologies to estimate emissions, and by completing the CRF tables with specific parameters such as AD, MCF and DOC	ARR 2014 – Paragraph 91	The UK has endeavoured to provide more detail where possible for the 2015 submission.	For the CRF submission
Wastewater handling – CH_4	Improve the transparency of the employed EFs by providing a more detailed explanation in the NIR	ARR 2014 – Paragraph 92	Due to changes in the methodology the specific transparency issue raised by the ERT is no longer relevant; however the UK has continued efforts to improve transparency.	Section 7.4 of the 2015 NIR
Waste incineration – CO_2, CH_4 and N_2O	Improve the documentation in the NIR, provide a detailed explanation of the methodology used to estimate emissions from accidental fires (vehicle) and standardize the terminology used for waste classification	ARR 2014 – Paragraph 93	The 2015 submissions includes a methodology for accidental fires and the terminology has been standardised.	Section 7.3 of the 2015 NIR
Waste incineration – CO_2, CH_4 and N_2O	Implement the improvement plan, and report only on the recovery of emissions that is based on metered data	ARR 2014 – Paragraph 94	The UK re-iterates to the ERT that the emissions from installations including chemical waste incinerators are included within the UK GHGI via the aggregated emission totals from operator-reported data, but due to the fact that operator data are not reported at the source-specific level (but rather at the "installation" level), these emissions are "IE" within IPPU emission estimates, source category 2B10. There are no available statistics in the UK that are gathered to estimate / report the methane flaring volumes or mass at chemical waste incinerators, and therefore the proposed improvement item is impossible to implement at this stage.	N/A

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter / section in the NIR
Deforestation – CO_2	Include the explanation that liming on deforested land occurs only in England	ARR 2014 – Paragraph 101	Liming has moved from the LULUCF to the Agriculture sector and is no longer reported in the KP-LULUCF tables.	N/A
Forest management – CO_2	Incorporate information on the effect of "windblow" disturbances in its next annual submission	ARR 2014 – Paragraph 103	The UK will be assessing the impacts of natural forest disturbances (including windblow) as part of its reporting in the 2nd commitment period and will report on results as they become available.	N/A
Inventory management	Describe in the NIR the role that Rothamsted Research and the United Kingdom Centre for Ecology and Hydrology have with respect to archiving	ARR 2013 – Paragraph 13	Additional text describing the role of Rothamsted and CEH relating to record keeping is included in the 2015 NIR.	Chapter 2 of the 2015 NIR
Follow-up to previous reviews	Include explicit information in the NIR whenever adjustments have been applied to the inventory, explaining how the Party has responded to the adjustments in the subsequent inventory, or at the latest, in the inventory submission following publication of the annual review report containing the adjustment	ARR 2013 – Paragraph 15	This table details the responses to reviews, including in responses to adjustments. In the 2014 review, the UK received a Saturday Paper, related to two issues. These were the emission factors for CH_4 and N_2O from blast furnace gas and coke oven gas, and the methane recovery rate for landfills. The UK submitted a recalculated inventory, and as such was not subject to an adjustment. The 2015 submission includes the recalculated data for landfills. For the EFs for derived fuels, the emissions reported in 2015 are based on the same emission factors as the original 2014 submission, since these are default emission factors from the 2006 IPCC GLs.	This table.
Comparison of the reference approach with the sectoral approach and international statistics	Describe the outcome of the review of the reference approach, in an effort to make it more comparable to the national energy statistics, and to improve the explanation of the differences in the NIR	ARR 2013 – Paragraph 19	In the 2014 submission the UK added an additional section in the Energy chapter comparing and contrasting the sectoral approach to the reference approach.	Chapter 3 of the 2015 NIR
Comparison of the reference approach with the sectoral approach and international statistics	Review the fractions of carbon oxidized for anthracite, peat, brown coal briquettes (BKB) and patent fuel, and coke oven/gas coke	ARR 2013 – Paragraph 20	In the 2014 submission the UK revised the reference approach oxidation factors to use IPCC defaults.	N/A

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter / section in the NIR
International bunkers	Rectify the reporting error in activity data for jet kerosene (international aviation) and residual fuel oil and diesel oil (marine bunkers) in 2011	ARR 2013 – Paragraph 23	The UK rectified this error in the 2014 submission as recommended	N/A
Feedstocks and non-energy use of fuels	Include any identified emissive sources of feedstocks and their exact final end use in the NIR and the CRF tables	ARR 2013 – Paragraph 24	The UK Inventory Agency worked with the UK energy statistics team throughout 2014 to further both organisations' understanding of NEU of products. The results of this discussion can be found in the Energy chapter and its associated annex.	Chapter 3 and **Annex 3.1.3** in the 2015 NIR
Feedstocks and non-energy use of fuels	In cases where a non-energy use cannot be defined with certainty, report the associated emissions of the respective fuel in an appropriate category under the energy or industrial processes sectors under the assumption that it is fully oxidized	ARR 2013 – Paragraph 25	The Inventory Agency has worked with the DECC energy statistics team to revise the time series of NEU allocations, to ensure that the estimates are based on the best available data for each fuel. In most cases, the NEU allocations are fully understood and documented. For petcoke, however, there is a residual allocation of NEU that cannot be accounted for. We have therefore assumed this to be emitted, and reported the emissions in the IPPU sector.	**Annex 3.1.3** of the 2015 NIR
Feedstocks and non-energy use of fuels	Review the allocation of fuels to non-energy uses within the Digest of United Kingdom Energy Statistics (DUKES), in order to identify any misallocations of fuels to non-energy uses that may lead to an underestimation of emissions	ARR 2013 – Paragraph 25	In response to the work that the UK Inventory Agency did on non-energy use (NEU) of fuels for the 2014 submission, the energy statistics team responsible for compiling DUKES have revised their methodology to find new sources of data and take a more conservative approach to NEU for their 2014 release.	Chapters 3 and 4 of the 2015 NIR
Stationary combustion: solid, liquid and gaseous fuels – CO_2	Implement the additional quality checks and planned method to minimize manual transposition of data across multiple data spreadsheets	ARR 2013 – Paragraph 27	The UK is constantly reviewing the QA/QC procedures at every stage of the inventory cycle, in particular with all of the changes in reporting requirements involved in using the 2006 IPCC guidelines.	N/A

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter / section in the NIR
Stationary combustion: solid, liquid and gaseous fuels – CO_2	Either justify the fractions of carbon oxidized applied for coal – other, coal – domestic, coke – power, coke – other and anthracite–domestic or apply the IPCC default value of 0.98 from the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*	ARR 2013 – Paragraph 28	Under the 2006 IPCC GL, the default oxidation factors are 1. The country specific data for the UK inventory has been reviewed, and where sufficient information is not available, the default has been used. This only affected coal and anthracite for non-power station and cement industry sources, in years where EU ETS data are not in use.	Chapter 3 of this report.
Oil and natural gas: natural gas – CH_4	Improve the transparency of the description of the methodology followed for the estimation of fugitive emissions from natural gas transmission and distribution systems	ARR 2013 – Paragraph 30	The methodological descriptions for this sector, along with the rest of the energy sector has been reformatted as part of a programme to improve the transparency of the NIR.	Chapter 3 of the 2015 NIR
Oil and natural gas: natural gas – CH_4	Conduct the verification exercise as described in paragraph 31 above	ARR 2013 – Paragraph 31	This verification exercise was conducted, it clearly demonstrated that the UK estimate from this source was more conservative than the default approach. The conclusions of which will be mentioned in the 2015 submission	Chapter 3 of the 2015 NIR
Civil aviation: liquid fuels – CO_2, CH_4 and N_2O	Perform a review of the EF for jet kerosene in civil aviation in cooperation with UKPIA and include this information in its NIR	ARR 2013 – Paragraph 34	The UK inventory team has had a number of discussions with UKPIA on this issue and related concerns, this had led to discussions with other organisations including the EA PI team, the IIASA team in Austria and JRC. These haven't yielded a satisfactory result, so consultation is ongoing.	N/A
Civil aviation: liquid fuels – CO_2, CH_4 and N_2O	Rectify the reporting error regarding the AD for civil aviation (national and international) and improve the QA/QC procedures performed during the compilation of the CRF tables	ARR 2013 – Paragraph 35	This issue was rectified for the 2014 submission	Chapter 3
Railways: solid fuels – CO_2, CH_4 and N_2O	Improve the completeness and time-series consistency of estimates of railway emissions by estimating the AD and associated GHG emissions from solid fuel consumption. In case the necessary AD are not available, estimate them by using one of the estimation techniques described in section 7.3.2.2 of the IPCC good practice guidance	ARR 2013 – Paragraph 38	After discussing with the DUKES team regarding this issue it's clear that activity for this source will be included elsewhere in the DUKES commodity balance, and hence the UK has used the notation key "IE" for the 2015 submission.	N/A

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter / section in the NIR
Coal mining and handling: solid fuels – CH_4	Revise the note on the use of the notation key for included elsewhere in CRF table 1.B.1	ARR 2013 – Paragraph 39	This has been rectified for the 2015 submission.	N/A
Sector 2 overview	Provide additional tables containing time-series overviews of the data sources, AD and methodologies applied where not currently done	ARR 2013 – Paragraph 42	In response to this recommendation additional relevant detail was provided in the 2014 submission for sector 2.	Chapter 4
Sector 2 overview	Report on the rationale for and impact of all recalculations undertaken in the NIR and in CRF table 8(b)	ARR 2013 – Paragraph 42	The UK works to ensure that the CRF and NIR are complete each year, including descriptions of the rationale for and impact of all recalculations, including text in the category specific chapters, a table in Chapter 10 detailing changes in the base year and one for the latest year, and descriptions in the CRF. For the 2015 submission, it is not possible to use the CRF to describe recalculations since the new reporting software and categories do not allow this. As such, text descriptions and numerical comparisons are included, where valid, but an overview table and the CRF table are not included.	Chapter 10
Nitric acid production – N_2O	Enhance the transparency of reporting by providing information on the methods used by plant operators to estimate N_2O emissions from nitric acid production and ensure the consistency of the data reported across the entire time series	ARR 2013 – Paragraph 43	The UK does not have any additional information on the QA/QC procedures of site operators or the environment agency. The UK will consider looking into this as part of its improvement programme.	Section 4.7
Consumption of halocarbons and SF_6 – HFCs, PFCs and SF_6	Continue to review the assumptions and methodologies applied to the model(s) used to estimate emissions from refrigeration and air-conditioning equipment	ARR 2013 – Paragraph 44	The refrigeration and air conditioning (RAC) model is now a priority item on the improvements programme for the 2016 submission.	N/A
Consumption of halocarbons and SF_6 – HFCs, PFCs and SF_6	Include in the NIR a description of the methodology applied to estimate potential emissions	ARR 2013 – Paragraph 45	This recommendation is no longer relevant since potential emissions are no longer a requirement.	N/A
Consumption of halocarbons and SF_6 – HFCs, PFCs and SF_6	Improve QA/QC procedures in the NIR and the CRF tables (for example, to identify the errors such as that observed by the ERT whereby potential emissions from foam blowing were left blank in the CRF tables)	ARR 2013 – Paragraph 45	The UK is constantly reviewing the QA/QC procedures at every stage of the inventory cycle, in particular with all of the changes in reporting requirements involved in using the 2006 IPCC guidelines.	N/A

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter / section in the NIR
Ammonia production – CO_2	Investigate the origin of the low IEF and report thereon in its NIR	ARR 2013 – Paragraph 49	The UK's IEF was lower than the 1996 IPCC default, but when compared to the 2006 guidelines new default EFs (and on a different basis as well), our IEF for UK sites covered by 2A1 is above the new default factor for 'modern plant'.	N/A
Ammonia production – CO_2	Correctly allocate natural gas used as a feedstock between the energy and industrial processes sectors	ARR 2013 – Paragraph 50	The UK believes that the allocations used in the 2015 submission will be compliant with the 2006 IPCC guidelines, which differs on this point compared to the previous guidance.	N/A
Ammonia production – CO_2	Improve the transparency and consistency of the NIR by using the same units for the AD and EF between the energy and industrial processes sector (e.g. GCV and NCV)	ARR 2013 – Paragraph 50	Ammonia production activity cannot be presented in consistent units with the Energy chapter due to commercial in confidence data. More comparable data can be made available to en ERT.	N/A
Enteric fermentation – CH_4	Continue efforts to improve the information available in terms of feeding types, amounts and digestibility rates and include this in the NIR	ARR 2013 – Paragraph 54	This is an ongoing activity of the inventory improvement program as part of the greenhouse gas platform projects.	N/A
Enteric fermentation – CH_4	Document its national feeding conditions, taking into account the seasonal variation in feeding quality for the all-year grazing animals and the election of a digestible energy value of 65.0 per cent for non-dairy cattle	ARR 2013 – Paragraph 55	For the last submitted inventory (1990-2013) the UK has used default EFs for all cattle categories except dairy and beef cows. Better characterisation of the cattle diet is an ongoing activity of the inventory improvement program as part of the greenhouse gas platform projects.	N/A
Enteric fermentation – CH_4	Provide comprehensive data for all cattle categories in the NIR	ARR 2013 – Paragraph 55	This has been improved in the most recently submitted inventory (1990-2013).	Chapter 4 of the 2014 NIR
Enteric fermentation – CH_4	Document the national circumstances in order to justify the use of the tier 1 methodology for mature breeding sheep only and the related reduction factor for producing lambs	ARR 2013 – Paragraphs 56, 62	The recently submitted inventory (1990-2013) reports 2 categories for sheep, mature sheep with an EF of 8 kg/hd/y (2006 GLs) and lambs with an EF of 2.2 kg/hd/y according to the Wheeler et al report adjusted for liveweight and lifespan. The UK is moving to full Tier 2 methodology for all sheep categories as part of the improvement program (2017 submission).	Chapter 4 of the 2014 NIR

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter / section in the NIR
Enteric fermentation – CH_4	Apply the IPCC tier 2 model for sheep, and collect proper feeding data and data on feed digestibility, taking into account the actual feeding conditions in scrubland, rangeland, lowlands and highlands throughout the year	ARR 2013 – Paragraph 56	This is currently under progress as part of the greenhouse gas platform projects.	N/A
Manure management – CH_4	Continue efforts to improve the volatile solids excretion rate for dairy cattle	ARR 2013 – Paragraph 57	This is currently under progress as part of the greenhouse gas platform projects.	N/A
Manure management – CH_4	Verify the assumption for the correction for producing lambs and whether there are implications for the CH_4 emissions from manure management.	ARR 2013 – Paragraph 62	There are small implications for CH_4 emissions from manure management as sheep manure is a small proportion of the total manure. The UK is moving to full Tier 2 methodology for all sheep categories as part of the improvement program (2017 submission).	N/A
Manure management – N_2O	Include additional information on the Nex model in the NIR and its linkage to the NH_3 emissions inventory submitted to the European Monitoring and Evaluation Programme (EMEP) and European Union (EU) directive 2001/81/EC on national emission ceilings for certain atmospheric pollutants	ARR 2013 – Paragraph 63	This has been done in the most recent inventory submission (1990-2013).	Chapter 4 of the 2014 NIR
Manure management – N_2O	Include additional information in the NIR on the assumptions used to derive the model and how this model has been implemented in the inventory of the United Kingdom	ARR 2013 – Paragraph 64	Details not included, relevant reference has been cited.	Chapter 5 of the 2015 NIR
Agricultural soils – N_2O	Implement plans, through a research and development platform, to unify the approaches to the reporting of NH_3 and NO_X losses between the two inventories (UNFCCC and LRTAP)	ARR 2013 – Paragraph 69	This is in progress as part of the greenhouse gas platform projects.	N/A
Agricultural soils – N_2O	Use revised AD for sewage sludge applied to soils and ensure consistency between the agriculture and waste sectors	ARR 2013 – Paragraph 70	This has been achieved	N/A
Agricultural soils – N_2O	Enhance QA/QC procedures and coordinate the data exchange between the waste sector and the agriculture sector	ARR 2013 – Paragraph 70	This has been achieved	N/A

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter / section in the NIR
Sector 4 overview	Prioritize work to implement a data assimilation process to resolve inconsistencies in total land area over the time series	ARR 2013 – Paragraph 76	Work is ongoing to upgrade the methodology to allow it to use IACS data to track Grassland/ Cropland rotation patterns as well as land use change more generally and this has delayed implementation. In the meantime the land use change matrices have been amended to ensure consistent land area.	N/A
Sector 4 overview	Consider the uncertainty of the model structure in the uncertainty analysis	ARR 2013 – Paragraph 76	This has been considered, and the 2014 submission explains that the effect of model choice and structure have been included in the uncertainty analysis where Tier 3 reporting is used (Forestry activities).	Section 7.3.5 in the 2014 NIR
Forest land – CO_2	Include in the NIR an explanation and any supporting documentation on how the CARBINE model addresses and resolves the identified issues that currently exist with the C-Flow model: (a) There is no evaluation against independent data provided in C-Flow; (b) The assumption that rotation lengths are fixed per species, and are therefore independent of wood demand or other factors; (c) The assumption that forests planted before 1921 – "pre-1920 forests" have reached an equilibrium and are neither sources of emissions nor sources of removals; (d) The default value of 0.05 for the fraction of aboveground biomass which is left on-site after harvest; (e) Transparency regarding whether below-ground biomass is included; (f) Parameters governing the use of harvested wood and, hence, the half-life of wood products, are not documented	ARR 2013 – Paragraph 78	This is explained in the 2014 submission Annex A3.6 and a supplementary report.	Annex 3.6 in the 2014 NIR
Forest land – CO_2	Document the high EFs for soil carbon changes to and from forest land, in particular by providing more detailed tables which simultaneously distinguish the soil type and land use	ARR 2013 – Paragraph 79	Work is ongoing to gain a better understanding of the soil carbon stocks for Forest Land, particularly for organic soils. Work on to implement Wetland Supplement reporting will contribute to this. The vector approach to land use change when implemented in the future will give more spatially explicit data on land use change which will allow more detailed consideration of soil type.	N/A

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter / section in the NIR
Cropland and grassland – CO_2	Implement, as proposed, methods for the estimation of the carbon stock changes associated with changes in management practices	ARR 2013 – Paragraph 81	The effects of Cropland Management on soil carbon stocks have been included in the 2015 submission. The effects of Cropland and Grassland Management on biomass carbon stocks will be included in the 2016 submission. More field data is needed to support inclusion of the effect of Grassland Management on soil carbon stocks.	Sections 6.3.4, 6.4.4 and A3.5 of the 2015 NIR
Cropland and grassland – CO_2	Report the results of the ongoing study related to the impacts of land management practices, particularly with respect to the ability to differentiate between mineral and organic soils when reporting land conversions to cropland and grassland and from cropland and grassland to other land	ARR 2013 – Paragraph 82	The study into the effects of land management on the soil carbon stocks of Grassland and Cropland (Defra project SP1113) has been reported. http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=18355, however this considered land management within a category rather than land use transitions. As explained above, the vector approach for land use change, will include a better consideration of soil type.	N/A
Cropland and grassland – CO_2	Specify whether orchards are included in the forest definition and estimate the changes in biomass in orchards	ARR 2013 – Paragraph 83	See response to para 81 of 2014 ARR	N/A
Cropland and grassland – CO_2	Provide an explanation for the apparent contradiction that the inventory reports grasslands as a source of removals, while independent studies find that grassland is a large source of CO_2 emissions	ARR 2013 – Paragraph 84	More recent survey literature (Reynoulds et al 2013) does not replicate the finds of Bellamy et al (2005) and Kirk and Bellamy (2010). This new literature has been referenced and discussed in the 2014 submission.	Section 7.4.6 of the 2014 NIR
Land converted to settlements – CO_2	Include clarifications provided to the ERT during the review regarding the observed trends in carbon stock changes for biomass in cropland and grassland converted to settlements and soils in cropland and grassland converted to settlements	ARR 2013 – Paragraph 85, 86	More information on the assumptions laid out in Milne and Brown (1997) which underlie the estimation of biomass and soil carbon stocks in Settlements is given in Annex 5.3 of the 2015 submission.	**Annex 5.3** of the 2015 NIR

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter / section in the NIR
Sector 5 overview	Improve the transparency of this sector, in particular: provide the assumptions used to derive the AD and methods for CH_4 recovery; the share of industrial wastewater in wastewater handling systems; the estimation of emissions from sewage sludge application to compost and farmland; and emissions estimates for OT and CDs	ARR 2013 – Paragraph 90	The methodology behind the CH_4 emissions reported in the CRF was given in the 2014 submission.	Section 8.2 and Annex 3.7.2 of the 2014 NIR
Sector 5 overview	Improve the QC checks in, and between, the main text of the NIR and the annexes, as well as in the CRF tables	ARR 2013 – Paragraph 91	The UK is constantly reviewing the QA/QC procedures at every stage of the inventory cycle, in particular with all of the changes in reporting requirements involved in using the 2006 IPCC guidelines.	N/A
Solid waste disposal on land – CH_4	Acquire additional historical CH_4 recovery data for older permitted landfills and local authority controlled closed landfills in Scotland and Wales, and for landfills in Scotland and Northern Ireland by either (a) carrying out periodic collection of the amounts of CH_4 flared from all of these landfills or (b) categorize landfills based on identified characteristics and survey and investigate recovery systems and CH_4 flared for a representative sample of landfills in all categories, except modern landfills, and extrapolate the estimated amounts of CH_4 recovered from these landfills to all landfills from these categories	ARR 2013 – Paragraph 100, 101 and 127	In response to the recommendations of the ERT the UK has carried out an improvement project to identify available data on methane recovery and flaring at older landfill sites in England and Wales, and sites in Scotland. The 2015 submission makes use of the findings of this improvement project.	Section 7.1 of the 2015 NIR
Wastewater handling – CH_4 and N_2O	Improve the accuracy and transparency of the applied EFs to ensure that they are fully representative of the activity and emissions for the entire United Kingdom	ARR 2013 – Paragraph 102	The UK inventory team have been working with water regulators and water companies to get access to better, more complete data and make sure we understand the data they're providing. The 2014 submission featured additional data that helped the completeness of our inventory, and in the 2015 submission we have formalised the data supply and hence have more complete and well understood data which the UK considers to be more accurate. We have additionally made an estimate of waste-water management not covered by the major water companies.	Section 7.4 of the 2015 NIR

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter / section in the NIR
KP-LULUCF Overview	Include in the NIR an explanation and supporting documentation on how the CARBINE model addresses and resolves the issues identified for the CFlow model, as applied to lands under Article 3, paragraphs 3 and 4 of the Kyoto Protocol	ARR 2013 – Paragraph 107	This is explained in the 2014 submission Annex A3.6 and a supplementary report.	Annex 3.6 of the 2014 NIR
KP-LULUCF Overview	Report below-ground biomass separately	ARR 2013 – Paragraph 109	This will require amendments to the output of the CARBINE model which will be implemented in the future.	N/A
Afforestation and reforestation – CO_2	Provide an explanation for why the carbon losses in above-ground biomass per area are larger than the biomass carbon density in cropland, grassland and settlements	ARR 2013 – Paragraph 110	The biomass carbon losses for KP Afforestation are cumulative and therefore can include more than one year's worth of activity, therefore the biomass carbon loss quoted for a given year may be derived from an area which is larger than the area Afforested in that year. This explanation is included in Annex 3.4.1.1 of the 2015 submission.	**Annex 3.4.1.1** of the 2015 NIR
Deforestation – CO_2	Provide an estimate for wildfires smaller than 25 hectares	ARR 2013 – Paragraph 111	Data on wildfire areas prior to 2010 is obtained from remotely sensed thermal anomaly data, this cannot reliably detect fires covering less than 25 ha. Using Fire and Rescue Service data for small fires from 2010 but omitting these from years prior to 2010 because of the lack of correlation with remotely sense data would give an inconsistent time series. This is explained in Annex A3.4.5.1 of the 2014 submission.	Annex section 3.6.5.1 of the 2014 NIR
Forest management – CO_2	Provide additional documentation in the NIR, consistent with the recommendations made in paragraphs 78 and 79 above, as applied to forest management	ARR 2013 – Paragraph 112	This is explained in the 2014 submission Annex A3.6 and a supplementary report.	Annex section 3.6 of the 2014 NIR

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter / section in the NIR
Adjustments	Recalculate the full time series of estimates of CH_4 recovery in the category solid waste disposal on land	ARR 2013 – Paragraph 128	In response to the recommendations of the ERT the UK has carried out an improvement project to identify available data on methane recovery and flaring at older landfill sites in England and Wales, and sites in Scotland. Additionally, other improvements to the inventory have been implemented in the light of recently identified and published studies. The 2015 submission includes a recalculation of the full time series of estimates of CH_4 production and recovery in this category in the light of this new information.	Section 7.1 of the 2015 NIR

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 (Quantitative)	Afforestation and Reforestation – CO_2 Deforestation – CO_2 Forest Management – CO_2
Key Categories (Qualitative)	Not undertaken
Overseas Territories and Crown Dependencies Reporting	OTs and CDs are included at Tier 1 level
Major improvements since last submission	Implementation of the AFOLU 2006 Guidance and 2013 Kyoto Protocol guidance (including changes for the second commitment period). Inclusion of Harvested Wood Products. 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), as described in section 6.1. 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 have been assessed, which affect the total estimated woodland area in the GHGI (but are not yet reflected in the national Forestry Statistics). The NFI area estimates have not been used for this inventory submission, as some of the data requires further analysis to interpret it properly and these assumptions still require validation.

11.1.2 Elected activities under Article 3, paragraph 4 of the Kyoto Protocol

The UK elected Forest Management (FM) as an activity under Article 3.4 in the first commitment period (2008-2012). For the second commitment period (2013-2020), in addition to FM, the UK has elected Cropland Management (CM), Grazing Land Management (GM) and Wetland Drainage and Rewetting (WDR), as identified in the UK's Initial Report (2015).

The UK's Forest Management Reference Level (FMRL) during the second commitment period, as identified in the appendix to the annex to Decision 2/CMP.7, is -3.442 Mt CO_2 eq/yr, or -8.268 Mt CO_2 eq/yr when applying first order decay function for harvested wood products. The UK has not applied a technical correction to the FMRL this year. The first cycle of the NFI is due to be completed in 2015 and a technical correction will be applied once the results of this are available.

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

The areas of forest land reported for AR and FM under the Kyoto protocol are broadly equivalent to the area reported under 4A Forest Land (**Figure 11.1**).

Definitions of forest are consistent with those used in the UNFCCC GHGI. The Afforestation/Reforestation area is land that has been converted to forest 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 2013 the area of forest established since 1990 was 345,850 ha in the UNFCCC GHGI and 339,538 ha under Article 3.3 Afforestation.

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 result from planting, seeding or natural colonisation. Data come from administrative systems (state forests) and grant schemes (other woodland) (Forestry Statistics 2014). 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. It is assumed that none of this area has been subsequently deforested.

The UK has elected the additional activities of Cropland Management (CM), Grazing Land Management (GM) and Wetland Drainage and Rewetting (WDR) under Article 3.4 of the Kyoto Protocol for the second commitment period. The UK is not currently able to report emissions / removals for these elected elected activities of CM, GM and WDR in this inventory cycle. To enable the UK to be able to report for emissions / removals from these newly elected activities and to account for them by the end of the commitment period Tthere is a programme of research and methodological development underway. for the newly elected activities, Cropland Management (CM), Grazing Land Management (GM) and Wetland Drainage and Rewetting (WDR) so that the UK will be able to report and account for emissions/removals from these activities by the end of the commitment period. The UK is not currently able to report elected activities of CM, GM and WDR in this inventory. However, work is in place to develop methodologies for this reporting in future years.

A methodology has been developed to estimate emissions from change in biomass carbon stocks as a result of changes in CM and GM and these activities will be reported in the 2016 submission.

A literature review (Moxley et al, 2014) has suggested that Tier 1 emission factors for the emissions as a result of changing soil carbon stocks due to GM may not be appropriate for high carbon organo-mineral soils which are present under large areas of rough grazing land in the UK, and further research development will be needed to identify suitable emission factors for these systems. A methodology forom reporting emissions from change in soil carbon stocks due to CM has been developed, but reporting of emissions from soils as a result of CM cannot be implemented in isolation from reporting emissions from soils as a result GM because CM and GM are on the same level of the KP reporting hierarchy.

The Department of Energy and Climate Change has commissioned a research project to develop reporting for WDR activity which is due to report in 2016. It is anticipated that the UK will be able to report on WDR activity once theis outcomes of this research areis complete reviewed and become operational in the inventory system.

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 4A Forest Land**

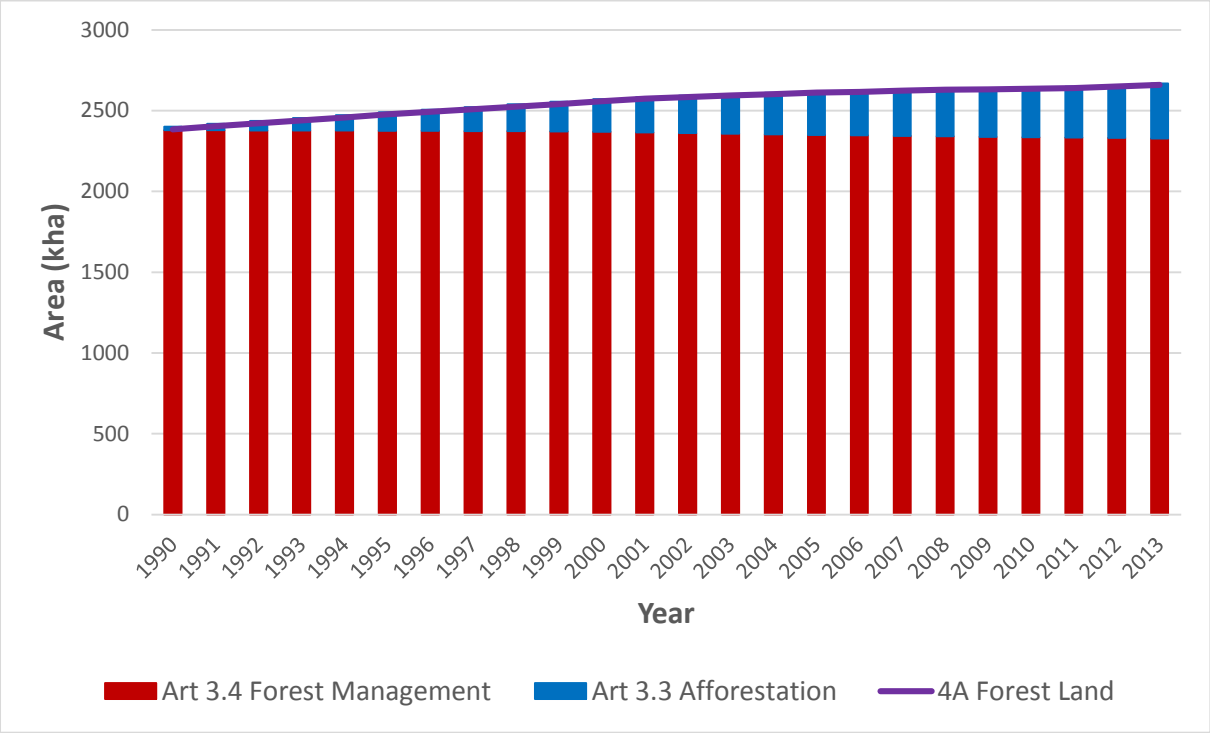
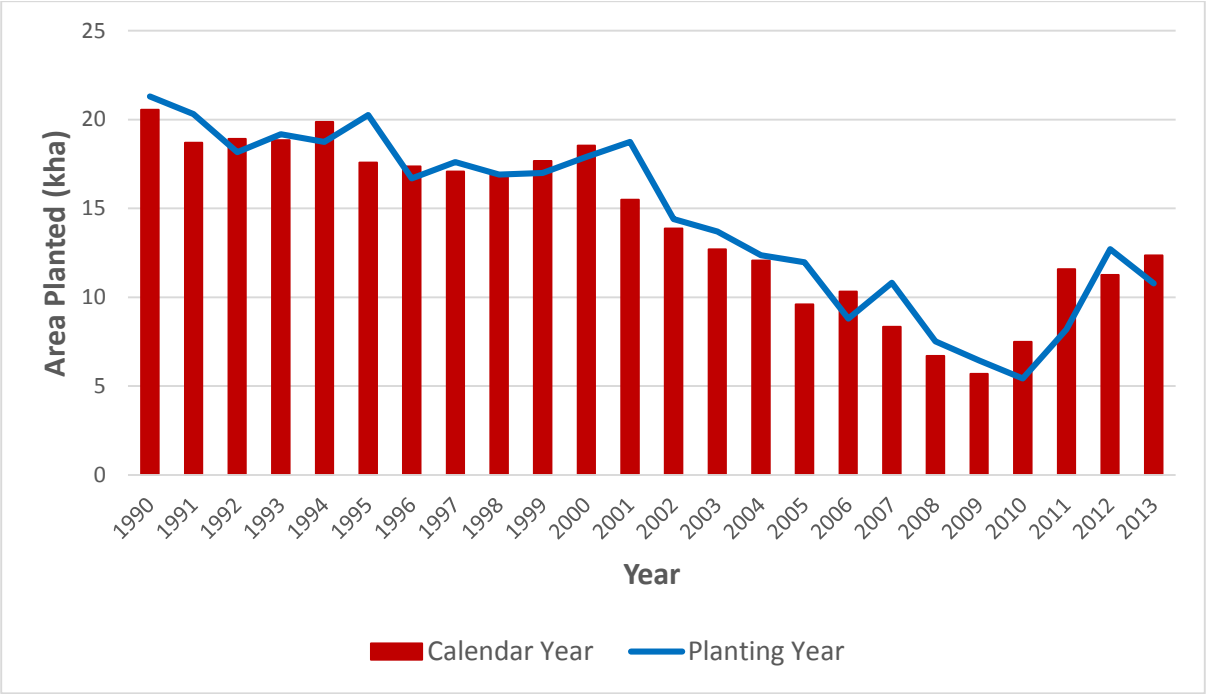


Figure 11.2 **UK afforestation since 1990 in the UNFCCC GHGI (by planting year) and in Article 3.3 (adjusted by calendar year)**



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 1990-2013 matches the area reported under Article 3.3 Deforestation (52, 321 ha).

Further work has been undertaken to identify forest loss, as this was thought to be under-reported according to UK forestry experts. Forest Research collated data from multiple sources (unconditional felling licences granted, differences between the NFI and NIWT maps, analysis of the forest sub-compartment database, information on open habitat restoration) to improve estimates of woodland loss from 2000 onwards (see Annex 3.4.4 for details). The definition of woodland loss used (from the NFI) was 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). Implementing this new dataset has modified emissions from deforestation slightly (higher 2000-2005 but lower 2006-2012) and reduced the estimated area deforested since 1990 from 53,528 ha in 2012 (1990-2012 inventory) to 50,064 ha in 2012 (current inventory). It is possible to differentiate permanently deforested land from harvested land that has not yet been replanted. 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).

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 4A1 Forest remaining Forest Land area, and carbon stock changes are adjusted accordingly. The area of Forest Management and the area of 4A1 Forest remaining Forest were comparable in 2010 at 2335 and 2341 kha, respectively, as the area of 4A1 in 2010 will include all forest planting up until 1990.

11.1.4 Precedence conditions and hierarchy among Art. 3.4 activities

The UK has elected additional activities under Article 3.4 for the second commitment period. There is a programme of research and methodological development underway for the newly elected activities (CM, GM and WDR) so that the UK will be able to report and account for emissions/removals from these activities by the end of the commitment period. The UK will follow the precedence conditions recommended by the 2013 Kyoto Supplementary Guidance (section 1.2), with Article 3.3 Deforestation highest in the hierarchy, and Article 3.4 WDR lowest. Article 3.4 CM and GM are considered equivalent in the hierarchy: however, land undergoing rotational crop/grass management will be specifically allocated to either CM or GM as a sub-category, rather than regularly moving between activities. In some regions of the UK, rotational management is dominated by crops, with the occasional grass ley, and vice versa in other regions. Development work on land use vectors (see Annex 3.4) may allow the identification and pattern of areas under rotational land use.

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 Reporting Method 1, for Article 3.3 and 3.4 activities. Data sources for tracking areas of afforestation and forest management are spatially explicit, whilst those for deforestation are mostly not. 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). Data sources for the newly elected Article 3.4 activities will also be a combination of spatially and non-spatially explicit.

The geographic boundaries used for reporting are the United Kingdom and the combined area of the UK's Overseas Territories and Crown Dependencies. Disaggregated estimates at the level of the four countries of the UK (England, Scotland, Wales and Northern Ireland) are reported after the UNFCCC submission in April (e.g. Miles et al. 2014).

11.2.2 Methodology used to develop the land transition matrix

The land transition matrix is shown in CRF Table NIR 2. The same data sources are used for the UNFCCC greenhouse gas inventory (as described in chapter 6 and Annex 3.4) and emissions/removals under Articles 3.3 and 3.4. National planting statistics from 1921 to the present are provided by the Forestry Commission. The age of establishment for pre-1921 forests is estimated using information on the distribution of forest area by age class from forest inventories 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 collated from multiple sources (unconditional felling licences granted, differences between the NFI and NIWT maps, analysis of the forest sub-compartment database, information on open habitat restoration (see Annex 3.4.4 for details). 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 6 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 CRF 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.

The UK has elected to report three new activities under Article 3.4 for the second commitment period: Cropland Management, Grazing Land Management and Wetland Drainage and Rewetting. A programme of research and methodological development has started which will enable the UK to report for these activities by the end of the commitment period. The election decision was only agreed in December 2014 and the development programme will be fully described in the 1990-2014 inventory submission.

Table 11.1 Land area and changes in land areas in 2013 (including area of Overseas Territories and Crown Dependencies)

To current inventory year (2013)			Article 3.3 activities		Article 3.4 activities	Other	Total (beginning of year)
From previous inventory year (2012)			Afforestation and Reforestation	Deforestation	Forest Management		
Article 3.3 activities	Afforestation and Reforestation	kha	327.55	0.00			327.55
	Deforestation			50.06			50.06
Article 3.4 activities	Forest Management			2.26	2,328.40		2,330.65

Other		12.38	0.00	0.00	23,029.02	23,041.39
Total (end of year)		339.93	52.32	2,328.40	23,029.02	25,749.66

Figure 11.3 Forest area planted since 1990 in the United Kingdom and its Overseas Territories and Crown Dependencies

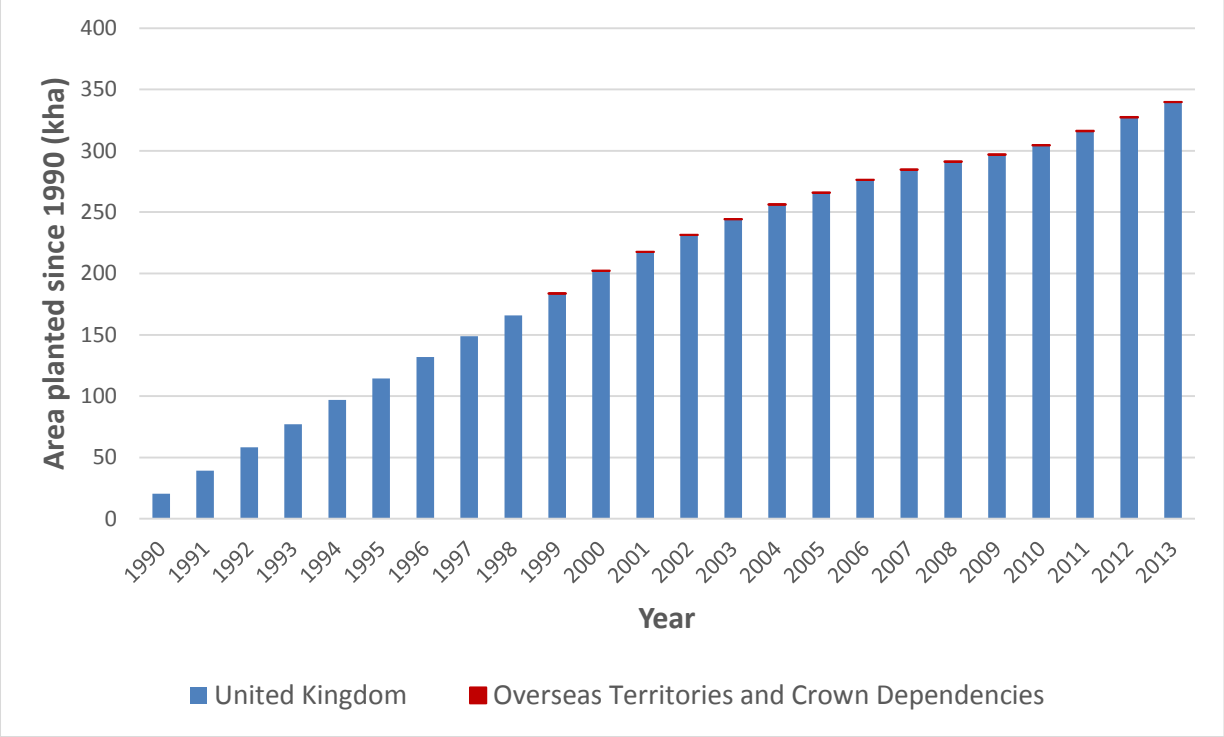


Figure 11.4 **Area deforested since 1990 in the United Kingdom (note different scale from previous figure, no deforestation is estimated to have occurred in the OTs and CDs)**

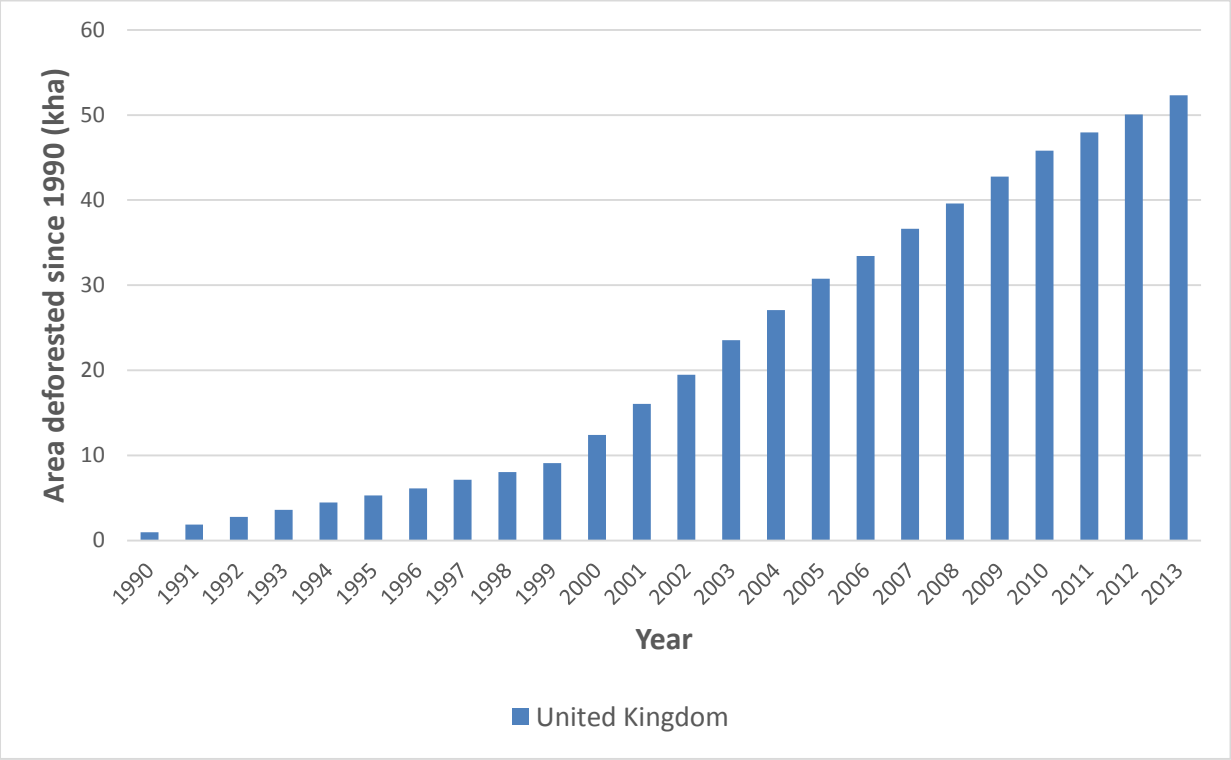


Figure 11.5 **Area of Forest Management land 1990-2013 in the United Kingdom and its Overseas Territories and Crown Dependencies (note different scale from previous figures)**

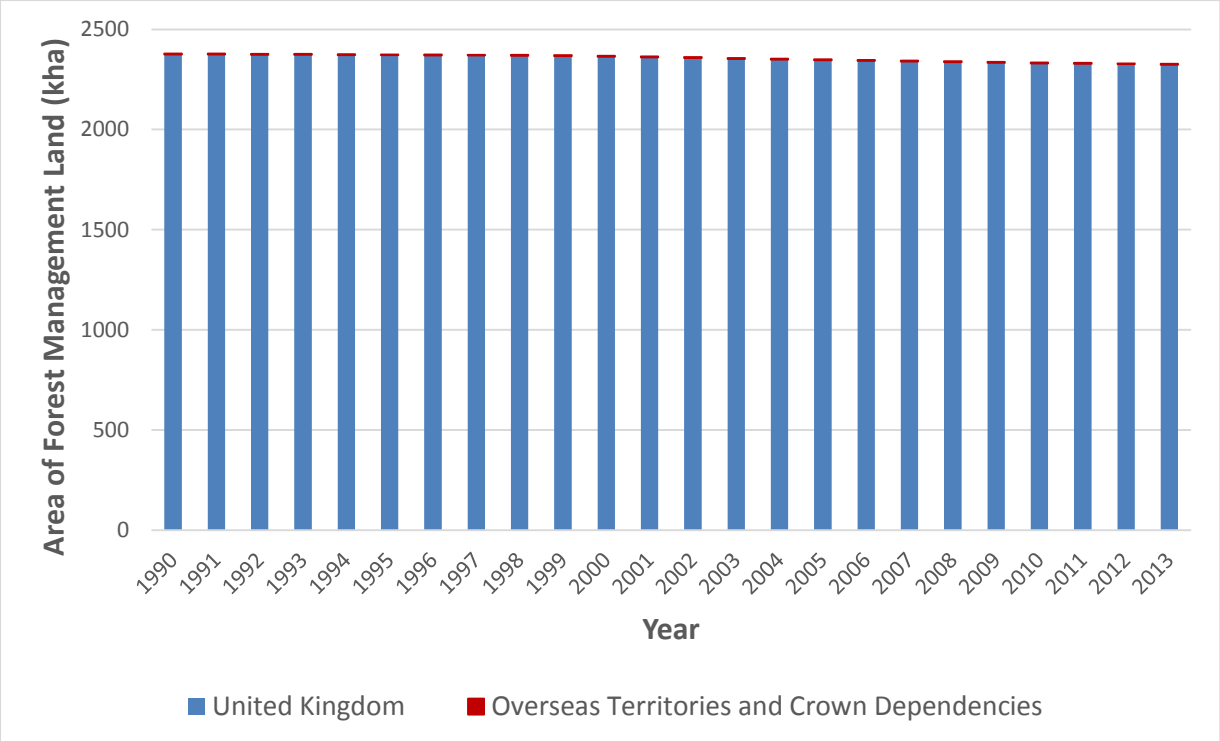


Table 11.2 Data Sources on Afforestation, Reforestation and Deforestation (ARD), and Forest Management (FM) Activities

Activity	Dataset	Available scale	Time period	Details
AR & FM	Annual planting statistics	UK	1921 - 2013	New planting on previously non-forested land. Updated annually. Categorized into conifer and broadleaved woodland.
AR & FM	Annual restocking statistics	UK	1976 - 2013	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 (NIWT)	Great Britain (not Northern Ireland)	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 Sub-compartment 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	UK	1970 - 2013	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: 1992-2013; Scotland: 1998-2013; Wales: 1996-2013	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 for pre-2000 areas.

Activity	Dataset	Available scale	Time period	Details
D	Countryside Survey (CS) 1990, 1998, 2007	UK	1990-2007	Estimated areas of woodland converted to other land uses from CS data (1990, 1998, and 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	Forestry Commission Internal Records	Great Britain (not Northern Ireland)	2000-2013	Update to the deforestation to grassland areas based on data on publicly-owned forest areas converted to non-forest land use from administrative records maintained by Forestry Commission England, Forestry Commission Scotland and Natural Resources Wales.
D	National Forest Inventory (NFI)	Great Britain (not Northern Ireland)	2009-2013	Estimates of permanent woodland loss reported in National Forest Inventory Country Reports
AR, FM	Habitat surveys and planting data	Crown Dependencies	1965-2013	Forest planting data for broadleaves and conifers was available for the Isle of Man. Habitat surveys were used to estimate forest area for Guernsey and Jersey. There is no forest meeting the forest definition in the Falkland Islands.

11.2.3 Maps and database to identify the geographical locations, and the system of identification codes for the geographical locations

The whole area of the United Kingdom and the combined area of the Overseas Territories and Crown Dependencies have been used as the geographical units for reporting (**Figure 11.6**). Only the Isle of Man, Jersey, Guernsey and the Falkland Islands have sufficient information to allow us to estimate GHG emissions and removals from KP-LULUCF.

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 3.4.1** 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. Additional information on dead wood should be available from the NFI in 2015 and CARBINE will be modified to report dead wood separately.

Annual data on forest planting is provided by the Forestry Commission, at a higher precision than that published in the annual Forestry Statistics. 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 3.4.4**). 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 in biomass is assumed to be immediately lost (instantaneous oxidation) (in the UNFCCC this biomass stock is transferred to the harvested wood products pool). This loss (in Gg C) is calculated as:

Carbon stock loss = living biomass loss + dead organic matter loss

where *living biomass loss = biomass density * area * % biomass removed,* and

*dead organic matter loss = DOM density * area * % biomass removed*

and *proportion of biomass removed = 60%*

area = area deforested, ha

biomass density = average forest living biomass density, Gg C /ha

DOM density = average dead organic matter density, Gg C/ha

Carbon stock changes in soils as a result of deforestation are calculated using the dynamic model of carbon stock change discussed in **Annex 3.4**. It is not possible to report changes in mineral and organic soils separately since there are no separate activity data. Estimates of deforestation are made for the UK only: there is no specific information on deforestation in the Crown Dependencies that have forest (the Falkland Islands do not). When the pro-rata deforestation rate for the UK was applied to the Crown Dependencies the estimated deforestation area was less than 0.003 kha per year, i.e. approximately zero.

Carbon stock changes due to Forest Management are estimated using the CARBINE model, as described in **Annex 3.4**. 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.

For the second commitment period the UK has a Forest Management Reference Level of -3442 Gg CO_2 eq. assuming instantaneous oxidation or -8268 Gg CO_2 eq. including emissions/removals from harvested wood products using first order decay functions. The calculation of the FMRL is briefly described in section 11.3.1.6, and fully in the UK's 2011 submission to the UNFCCC (DECC 2011). The FMRL has not been updated for this inventory submission, as planned updates to forestry data and planned improvements in the CARBINE model will require a technical adjustment in 2016.

The UK will take up the natural disturbances provision for forest land in the second commitment period. The UK will confirm the natural disturbances and the background level it wishes to include in its 2015 Initial Report. Any excluded emissions will be reported in subsequent inventory submissions.

Carbon stock changes in the harvested wood products (HWP) pool (Table 4(KP-I)C) are reported for the first time in the second commitment period. Carbon stock changes in the HWP pool are calculated on a first-order decay function basis for AR and FM forests and on an instantaneous oxidation basis for deforestation, in accordance with the 2013 Kyoto Protocol Supplementary Guidance (see Annex 3.4 for details). HWP from AR land includes all domestically produced wood HWP from Afforestation land since 1990. HWP is included in Forest Management in the second commitment period as the UK's FMRL was based on a projection. HWP is only included from 2013 onwards because:

- The UK accounted for FM in the first commitment period, where HWP was assumed to be instantaneously oxidised to the atmosphere; and
- As the UK's FMRL is based on a projection which represents a "business as usual scenario", inherited emissions from HWP before the start of the commitment period (i.e. all HWP from FM land produced 1990-2012) can be excluded as long as there is consistency between the FMRL and the accounting during the commitment period.

Greenhouse gas emissions (rather than carbon stock changes) from LULUCF activities under the Kyoto Protocol are reported in Tables 4(KP-II)1-5. The following text refers to emissions from ARD and FM forest land only, as the UK is not yet in a position to report emissions from CM, GM and WDR.

Table 4(KP-II)1. Direct and indirect 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 3.4.1**. It is assumed that nitrogen fertilizer is only applied to newly planted forests on settlement land (i.e. AR land) in the UK (see **Chapter 6** for more information). Indirect emissions are calculated in the Agriculture sector.

Table 4(KP-II)2. CH_4 and N_2O emissions from drained and rewetted organic soils

The method used to estimate N_2O emissions from drained forest land is the same as that used in the UNFCCC greenhouse gas inventory and described in **Annex 3.4.** Drainage of forest land only occurs on certain soil types in the UK (see Annex 3.4 for more detail) and is reported for AR and FM land. There is insufficient information to estimate CH_4 emissions from drainage and non-CO_2 emissions from rewetted soils at this time. Carbon emissions from the drainage of forest soils are included with emissions from soils in the carbon stock change tables for AR and FM. The UK has a research programme investigating the implementation of the 2013 Wetlands Supplement Guidance for the UK guidance and will report emissions from this area before the end of the commitment period.

Table 4(KP-II)3. N_2O emissions from N mineralization/immobilization due to carbon loss/gain associated with land-use conversion and management change in mineral soils

The move to the 2006 AFOLU Guidance has increased the activity that can be reported in this table (only N_2O mineralization after land conversion to cropland was considered previously). N mineralization following deforestation to Cropland, Grassland and Settlement in the UK since 1990 are reported. N_2O emissions resulting from the artificial drainage of mineral soils on AR and FM land are also reported in this table, as Table 4(KP-II)2 is for organic soils only.

Table 4(KP-II)4. 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 3.4. There is no controlled burning of AR and FM forest land in the UK. There is insufficient information on the occurrence of wildfires on different

forest types 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 0.149 AR/FM for the UK in 2013). 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 2010 (57 ha) and one 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

The UK has elected three additional Article 3.4 activities: Cropland Management, Grazing Land Management and Wetland Drainage and Rewetting. We are not yet in a position to report emissions and removals from these activities and the relevant tables are filled in with the notation key NE. The UK is putting in place a research and methodological development programme for these activities to enable full reporting by the end of the commitment period.

Table 4(KP-I)A.1.1 Article 3.3 activities: Afforestation and Reforestation. Additional information: emissions and removals from natural disturbance

The UK will confirm the natural disturbances and the background level it wishes to include in its 2015 Initial Report. Any excluded emissions will be reported in subsequent inventory submissions. The tables has been filled NA notation keys (Not Applicable) for the current submission.

Table 4(KP-I)A.2 Article 3.3 activities: Deforestation. Deforestation land previously reported under afforestation/reforestation and forest management and subject to natural disturbances

The UK will confirm the natural disturbances and the background level it wishes to include in its 2015 Initial Report. Any excluded emissions will be reported in subsequent inventory submissions. The tables has been filled NA notation keys (Not Applicable) for the current submission.

Table 4(KP-I)A.2 Article 3.3 activities: Deforestation. Information items: Land areas under deforestation by land-use category in the current reporting year

The rows for Forest Land, Wetlands and Other land are filled with the Not Occurring (NO) notation key as only deforestation to Cropland, Grassland or Settlements occurs in the UK.

Table 4(KP-I)B.1 Article 3.4 activities: Forest management. Newly established forest (CEF-ne) and Harvested and converted forest plantations (CEF-hc)

The UK has not elected to report carbon-equivalent forests and therefore the relevant cells are filled with the notation key NA (Not Applicable).

Table 4(KP-I)B.1 Article 3.4 activities: Forest management. Land subject to natural disturbances

The UK will confirm the natural disturbances and the background level it wishes to include in its 2015 Initial Report. Any excluded emissions will be reported in subsequent inventory submissions. The tables has been filled NA notation keys (Not Applicable) for the current submission.

Table 4(KP-II)1. Direct N_2O emissions from N fertilization

It is assumed that nitrogen is only applied to newly planted forests on settlement land in the UK, and therefore that no N fertilization occurs on Deforestation or Forest Management land.

Table 4(KP-II)2. CH_4 and N_2O emissions from drained and rewetted organic soils

At present there is insufficient information to allow the estimation of CH_4 fluxes and non-CO_2 fluxes from rewetted soils (reported with the Not Estimated notation key). The UK has a research project to implement the 2013 Wetlands Supplement in the UK context, which will enable reporting in this area by the end of the commitment period.

Table 4(KP-II)4. 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. 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.

11.3.1.4 Changes in data and methods since the previous submission (recalculations)

This is the sixth official submission of Article 3.3 and Article 3.4 estimates, and the first in the second Kyoto Protocol commitment period. Some recalculations have been made since the previous submission due to changes in data, and a number of changes have occurred with the implementation of the 2006 AFOLU Guidance and the 2013 Kyoto Protocol Supplementary Guidance. Further changes are likely when the 2013 Wetlands Supplement Guidance is implemented, but this is the subject of a current UK research project.

Estimates of emissions and removals for the first commitment period (2008-2012) have now been accounted and cannot be changed. In addition, the basis for accounting from Forest Management has now changed and can only be reported for 2013 onwards, as this is the period to which the Forest Management Reference Level applies. Therefore, the numbers in the table are provided for information only. Details of the changes are given in **Table 11.3**.

Table 11.3 Recalculations of 2012 emissions/removals in the 2015 KP-LULUCF submission

IPCC Category	Source Name (2015)	Source Name (2014)	2014 Submission 2012	2015 Submission 2012	Units	Comment/Justification
KP.A.1	Afforestation and Reforestation	Afforestation and Reforestation	-2,956.74	-2,956.80	Gg CO_2	Minor improvements to the CARBINE model and input data.
KP.A.1/4(KP-II)1	Direct and indirect N_2O emissions from N fertilization	Direct N_2O emissions from N fertilization	0.0044	0.0044	Gg N_2O	The GWP for N_2O has changed (2006 AFOLU change)
KP.A.1/4(KP-II)2	CH_4 and N_2O emissions from drained and rewetted organic soils	N_2O emissions from drainage of soils	NA	0.015	Gg N_2O	Only reported for B.1 Forest Management in first commitment period.
KP.A.1/4(KP-II)3	N_2O emissions from N mineralization	N_2O emissions from disturbance associated with land use conversion to cropland	NA	0.012	Gg N_2O	Only reported for A.2 Deforestation in first commitment period. Emissions from artificially drained mineral soils now reported here (2006 AFOLU change)
KP.A.1/4(KP-II)4	GHG emissions from biomass burning	GHG emissions from biomass burning	39.24	44.33	Gg CO_2	Updated information on burnt areas and biomass densities. The GWP for N_2O and CH_4 has changed (2006 AFOLU change)
			0.1362	0.1538	Gg CH_4	
			0.0075	0.0085	Gg N_2O	

IPCC Category	Source Name (2015)	Source Name (2014)	2014 Submission 2012	2015 Submission 2012	Units	Comment/Justification
KP. C	HWP from AR land	NA	NA	-84.06	Gg CO_2	Not reported for first commitment period as instantaneous oxidation was assumed.
KP.A.2	Deforestation	Deforestation	701.38	488.61	Gg CO_2	Post-2000 deforestation areas have been updated.
KP. A.2/4(KP-II)3	N_2O emissions from N mineralization	N_2O emissions from disturbance associated with land use conversion to cropland	0.0003	0.0170	Gg N_2O	Emissions from deforestation to grassland and settlement are now included and the GWP for N_2O has changed (2006 AFOLU change)
KP.A.2/5(KP-II)4	NA	Carbon emissions from lime application.	0.0153	NA	Gg C	No longer included in KP-LULUCF (2006 AFOLU change)
KP.A.2/4(KP-II)4	GHG emissions from biomass burning	GHG emissions from biomass burning	343.54	240.63	Gg CO_2	Post-2000 deforestation areas have been updated and the GWP for N_2O and CH_4 has changed (2006 AFOLU change)
			1.49	1.03	Gg CH_4	
			0.0107	0.0076	Gg N_2O	
KP.B.1	Forest Management	Forest Management	-14,812.88	-14,851.18	Gg CO_2	Update of post-2000 deforestation areas will affect forest management areas and carbon stock changes.
KP.B.1/4(KP-II)2	CH_4 and N_2O emissions from drained and	N_2O emissions from drainage of soils	0.1253	0.0635	Gg N_2O	Estimated areas of drained soils updated to ensure consistency in forest areas on different soil types. The

IPCC Category	Source Name (2015)	Source Name (2014)	2014 Submission 2012	2015 Submission 2012	Units	Comment/Justification
	rewetted organic soils					GWP for N_2O has changed (2006 AFOLU change)
KP. B.1/4(KP-II)3	N_2O emissions from N mineralization	N_2O emissions from disturbance associated with land use conversion to cropland	NA	0.0628	Gg N_2O	Only reported for A.2 Deforestation in first commitment period. Emissions from artificially drained mineral soils now reported here (2006 AFOLU change)
KP.B.1/5(KP-II)5	GHG emissions from biomass burning	GHG emissions from biomass burning	186.82	203.38	Gg CO_2	Updated information on burnt areas and biomass densities. The GWP for N_2O and CH_4 has changed (2006 AFOLU change)
			0.6483	0.7058	Gg CH_4	
			0.0359	0.0390	Gg N_2O	

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 3.4**) 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 30% for Article 3.3 Afforestation/Reforestation and Article 3.4 will be used (as estimated for UNFCCC category 4A) 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 clear-felled 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

Natural disturbances.

The UK will confirm the natural disturbances and the background level it wishes to include in its 2015 Initial Report. Any excluded emissions will be reported in subsequent inventory submissions. Areas and emissions from wildfires on forest land are included in the KP-LULUCF inventory (see **Chapter 6** and **Annex 3.4** for further details). Wildfires are not assumed to result in a permanent change in land use.

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 2013

In 2013, 12.376 kha of land were afforested and 2.257 kha of forest land were deforested.

11.4 ARTICLE 3.3

11.4.1 Information that demonstrates that activities began on or after 1 January 2013 and before 31 December 2020 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 the whole of 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 0**. Information on new planting and restocking are published as separate figures for both state and private woodlands. New planting can be from planting, seeding or natural colonisation. Data come from administrative systems (state forests) and grant schemes (other woodland) (Forestry Statistics 2014). 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 collated from multiple sources (unconditional felling licences granted, differences between the NFI and NIWT maps, analysis of the forest sub-compartment database, information on open habitat restoration (see **Annex 3.4.4** for details)), all 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.

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. New data sources (post-2000) have been used that clearly identify the post-deforestation land use.

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 2002a). 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 0**.

11.5.2 Information relating to Article 3.4 activities, if elected, for the base year

The UK has elected three additional Article 3.4 activities: Cropland Management, Grazing Land Management and Wetland Drainage and Rewetting. We are not yet in a position to report emissions and removals from these activities and the relevant tables are filled in with the notation key NE. The UK is putting in place a research and methodological development programme for these activities to enable full reporting by the end of the commitment period.

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 2014, 1377 kha of woodland in the UK (44%) was certified under the FSC scheme (Forestry Statistics 2014). 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 2014). 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, 2002b). 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 2013 Kyoto Protocol Supplement **Section 2.3.6**. The numbers have been compared with key category analysis for the latest reported year (2013) based on level of emissions (including LULUCF).

Article 3.3 Afforestation and Reforestation (CO_2): The associated UNFCCC category 4A (-17, 298 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 (-3,134 Gg CO_2) is greater than the smallest UNFCCC key category (1A3b DERV: N_2O). 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 (4B, 4C and 4E) are key categories (12,150, -5,897 and 5,877 Gg CO_2 respectively). The Deforestation category contribution (776 Gg CO_2) to these UNFCCC categories is also larger than the smallest UNFCCC key category (1A3b DERV: N_2O).

Article 3.4 Forest Management (CO_2): The associated UNFCCC category 4A is a key category (-17,298 Gg CO_2). The Forest Management category contribution (-14,348 Gg CO_2) is also greater than other categories in the UNFCCC key category analysis.

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 2014 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 in file:

SEF_RREG1_GB_2014.xls

12.2 SUMMARY OF INFORMATION REPORTED IN THE SEF TABLES

At the end of 2014, there were 3,301,544,569 AAUs in the UK registry of which 2,377,012,562 were in the party holding account, 2,201,691 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 81,980,966 CERs and 39,038,875 ERUs.

In total for 2014, the UK Registry received 1,547,486 AAUs, 15,992,493 ERUs, and 17,966,019 CERs. Conversely, 5,998,615 AAUs, 42,078,448 ERUs, and, 29,991,680 CERs were externally transferred to other national registries.

24,987,379 CERs and 18,871,468 ERUs were retired in 2014. No replacements were made.

Information on legal entities authorised to participate in mechanisms under Articles 6, 12 and 17 of the Kyoto Protocol can be found on the UK Emissions Registry website in the Kyoto Protocol Public Reports area at

https://ets-registry.webgate.ec.europa.eu/euregistry/GB/public/reports/publicReports.xhtml

Annual Submission Item	Reporting Guidance
15/CMP.1 annex I.E paragraph 11: Standard electronic format (SEF)	UK's Standard Electronic Format report for 2014 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_RREG1_GB_2014.xlsx The contents of the SEF report (R1) can also be found in Annex 5 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 2014-GB v1.0.xls The contents of the Report R2 can also be found in Annex 5 of this document.
15/CMP.1 annex I.E paragraph 13 & 14: List of CDM notifications	No CDM notifications occurred in 2014. Refer to Separate Electronic Attachment "SIAR Reports 2014-GB v1.0.xls" Worksheet R3. The contents of the Report R3 can also be found in Annex 5 of this document.
15/CMP.1 annex I.E paragraph 15: List of non-replacements	No non-replacements occurred in 2014. Refer to Separate Electronic Attachment "SIAR Reports 2014-GB v1.0.xls" Worksheet R4. The contents of the Report R4 can also be found in Annex 5 of this document.
15/CMP.1 annex I.E paragraph 16: List of invalid units	No invalid units exist as at 31 December 2014. Refer to Separate Electronic Attachment "SIAR Reports 2014-GB v1.0.xls" Worksheet R5. The contents of the Report R5 can also be found in Annex 5 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 usually available via the homepage of the UK registry via the Kyoto Protocol Public Reports link at https://ets-registry.webgate.ec.europa.eu/euregistry/GB/public/reports/publicReports.xhtml 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) In line with the data protection requirements of Regulation (EC) No 45/2001 and Directive 95/46/EC and in accordance with Article 110 and Annex XIV of Commission Regulation (EU) no 389/2013, the information on account representatives, account holdings, account numbers, all transactions made and carbon unit identifiers, held in the EUTL, the Union Registry and any other KP registry (required by paragraph 45) is considered 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 reports page https://ets-registry.webgate.ec.europa.eu/euregistry/GB/public/reports/publicReports.xhtml 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 110 of Commission Regulation (EU) 389/2013, provides that "Information, including the holdings of all accounts, all transactions made, the unique unit identification code of the allowances and the unique numeric value of the unit serial number of the Kyoto units held or affected by a transaction, held in the EUTL, the Union Registry and any other KP registry shall be considered confidential except as otherwise required by Union law, or by provisions of national law that pursue a legitimate objective compatible with this Regulation and are proportionate.." Paragraph 47c The United Kingdom is not hosting domestic JI projects as per paragraph 46 above.

Annual Submission Item	Reporting Guidance
	Paragraph 47e The United Kingdom is currently not participating in any LULUCF projects for 2014. 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 ERUs and CERs have been retired in 2014. Details can be found on Table 2A of SEF_RREG1_GB_2104.xlsx Paragraph 47k Although we have now entered a new commitment period, no previous commitment period carry over transactions have yet taken place. This will be completed as part of the true up process. Account holders authorised to hold Kyoto units in their account (Paragraph 48) In line with the data protection requirements of Regulation (EC) No 45/2001 and Directive 95/46/EC and in accordance with Article 110 and Annex III of the Commission Regulation (EU) no 389/2013, the legal entity contact information (required by paragraph 48) is considered confidential.

12.5 CALCULATION OF THE COMMITMENT PERIOD RESERVE (CPR)

The calculation of the commitment period reserve has not been included as this is a submission under the UNFCCC and not the Kyoto Protocol.

13 Information on Changes to the National System

13.1 CHANGES TO THE NATIONAL SYSTEM

Key roles within the National Inventory System are 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 therefore occurred in 2014.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(a) Change of name or contact	No change of name or contact occurred during the reported 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 under the Standard Independent Assessment Report (SIAR). Versions of the CSEUR released after 6.1.7.1 (the production version at the time of the last Chapter 14 submission) introduced changes in the structure of the database. These changes 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 since version 6.1.7.1 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 will be carried out in February 2015 and the test report will be submitted. thereafter 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	No change to the list of publicly available information occurred during the reporting period.
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 since version 6.1.7.1 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 under the SIAR. Annex H testing was carried out in February 2015 and the test report is available alongside this document.

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 2015 NIR submission. Substantive changes include:

- An update on the Climate and Development Knowledge Network in 15.2.5
- A description of the Building Resilience and Adaptation to Climate Disasters programme in 15.2.8
- A description of the Climate Development for Africa programme in 15.2.8
- General information on current activities in capacity building in 15.2.8
- An update on Green Africa Power in 15.2.4
- An update on The World Bank's Partnership for Readiness in 15.2.4
- An update on the Scaling Up Renewable Energy Programme in 15.2.4
- An update on the Energy Market Reform policy being implemented by the UK in 15.2.9

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, working in collaboration with a number of other organisations, has built a Global Calculator, which enables 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 (http://uncached-site.globalcalculator.org/).

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[42].
- In 2013 the Department of Transport published a report on the sustainability of feedstock[43].

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[44].

This year's output from the monitoring, which is published in the Official Statistics Release, can be found online[45].

[42] http://www.dft.gov.uk/publications/regional-level-actions-to-avoid-iluc

[43] https://www.gov.uk/government/publications/biofuel-research

[44] 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

[45] http://www.defra.gov.uk/statistics/environment/green-economy/scptb01-ems/

15.2.2 Within the EU

The UK is an active participant within the EU and played a leading role in achieving agreement on the 2030 EU climate and energy policy framework to cut domestic EU greenhouse gas emissions (GHG) by at least 40% on 1990 levels by 2030. The EU now has the most ambitious climate pledge of any major economy and has the option to increase this further in the context of a comprehensive global climate deal at the Paris Conference Of Parties (COP) in December 2015. The GHG target keeps the EU on the least-cost path to meeting its 2050 goal of reducing EU emissions by between 80-95% on 1990 levels, which is consistent with a global transition to limiting average temperature increases to under 2°C.

The 2030 framework also contains a 27% renewables target, which is binding at EU level, and an indicative EU level energy efficiency target of 27%. The UK successfully argued for the inclusion in the framework of a guarantee that these goals will not be translated into nationally-binding targets. This gives EU Member States the flexibility to use the full range of low and lower carbon technologies and find the most cost-effective path to decarbonising their economies. The 2030 framework builds upon the EU2020 package, agreed by EU leaders in 2007 and enacted in 2009, which agreed climate and energy targets for 2020.

EU policies and measures for limiting emissions include the following:

- The EU Emissions Trading System (EU ETS) is the EU's main vehicle for reducing CO_2 emissions from the power, industrial and aviation sectors. The UK is a leading proponent of reform of the EU ETS, through a strengthening of the European Commission's proposal for a Market Stability Reserve (MSR), to ensure that the system can continue to deliver emissions reductions as cost effectively as possible.
- The EU Effort Sharing Decision (ESD) set targets for 2020 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%. Following the EU2030 agreement, the UK is pushing for the EU to agree Member States' effort share for the period 2021-2030 as soon as possible.
- The EU energy efficiency framework includes a number of directives spanning all sectors of the economy. The directives include the Energy Performance of Buildings Directive, Energy Efficiency Directive, Ecodesign and Energy Labelling directives, as well as vehicle emission performance standards. These legislative requirements drive progress towards the EU's non-binding target to reduce primary energy consumption by 20% by 2020 which was agreed as part of the EU2020 package. The UK is currently on track to over-achieve against the 2020 target and the supplementary targets established by the Energy Efficiency Directive.

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

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[46]. 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 to major private sector investors that climate friendly investments in developing countries are financially viable. By investing in new renewable installations and technologies the initiative is expected to contribute to deploying approximately 2,1000 megawatts of clean, reliable energy and create up to 34,000 jobs. Across a range of investments CP3 is expected to contribute to GHG emission savings of at least 53 million tonnes of CO_2e over the lifetime of the project..

The UK will invest £98 million into Green Africa Power (GAP), £95 million of which will be used to capitalise a facility established under the Private Infrastructure Development Group (PIDG). GAP will invest in renewable energy projects in sub-Saharan Africa. It aims to demonstrate the long-term viability of renewable energy in Africa to attract private developers and investors and encourage future projects. £3 million will be used to set up the project, monitor and evaluate these impacts and capture and disseminate this knowledge. GAP aims to co-finance approximately 270MW of new renewable energy generation capacity, saving 12.97m tonnes of emissions and demonstrating the commercial and technical feasibility of private sector renewable energy projects in Africa.

A £15m grant over 2012-2016 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 5.7MtCO_2e over an 8 year period (with 2MtCO_2e attributable to the UK), and create a strategy for increasing the use of SPS in Colombia and beyond.

The UK has also contributed £7m to the World Bank's Partnership for Market Readiness (PMR) to help developing countries design market-based mechanisms, such as emissions trading

[46] https://www.gov.uk/government/policies/taking-international-action-to-mitigate-climate-change/supporting-pages/international-climate-fund-icf

systems, for reducing their greenhouse gas emissions. This will foster increased investment in green technologies across the world and help stimulate private sector low carbon investment opportunities. The PMR aims to increase the number of developing countries implementing market-based schemes, with a minimum of 5 developing countries testing and piloting new market schemes by 2020; and create a forum to enable experts from different countries and organisations to share experience and knowledge. The UK has contributed £7m to the World Bank and has offered developing countries its expertise in designing and running trading systems.

To date the UK has contributed an estimated £1.8 billion to the Climate Investment Funds. These funds include 4 key programmes that help 63 developing countries pilot low-emission and climate resilient development. Scaling up Renewable Energy Program (SREP) is an example of 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. SREP will contribute towards increased energy access for over 37m people, and increased renewable energy capacity of an additional 901.6MW. For example in Mali, investment in small hydro-power improves modern and affordable energy services for 160,000 people.

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, Indonesia and Mexico 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 £75 million to the NAMA Facility with the German government matching the UK's contribution. 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 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:

- The UK is providing £33m of support for Climate Innovation Centres (CICs) in developing countries. These centres support innovation in and deployment of climate-friendly technologies, providing business development support to SMEs; the provision of technological and office facilities, R&D grants and seed capital investments; links to local universities; local financiers and government and conducting market analysis and research within that country. This support includes the Global Network of Climate Technology Innovation Centres which has established 9 new CICs which 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 and Vietnam closely following. Scoping work is also underway in other countries.

- Climate and Development Knowledge Network (CDKN) provides £140m to developing countries to share knowledge and build the capacity building of developing country decision-makers to design and deliver climate compatible development policies and programmes. The CDKN does this by providing access to high quality, demand-led technical assistance, and channelling the best available knowledge on climate change and development to support policy and implementation processes at the country and regional level. CDKN has four priority thematic areas which helps prioritise its work across its three focus regions (Africa, Asia and Latin America). These are:
    - Climate compatible development (CCD) strategies and plans
    - Improving developing countries access to climate finance
    - Strengthening resilience through climate-related disaster risk management (DRM)
    - Supporting climate negotiators from the Least Developed 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 raise the level of understanding of CCS within emerging economies – including China, South Africa, Indonesia and Mexico – leading to the establishment of necessary policy frameworks, technical know-how and incentive structures to support CCS demonstration and ultimately accelerate the deployment of CCS. The UK will support a range of capacity building projects, including: i) preparation and implementation of early-stage full scale integrated CCS pilot demonstration projects by financing CCS planning & pre-investment, capital costs for CCS units and components, and CCS related post-completion & operation activities; ii) development of geological site characterisation intended for integrated full scale CCS projects, both at the pilot and commercial demonstration scales to maximise knowledge on both near-term and future storage capacities; and iii) pilot and demonstration activities aimed at reducing the cost of the technology application across the CCS chain. It is expected that the UK's funding will lead to full scale demonstration projects in developing countries, and ultimately accelerate the deployment of CCS.

The UK continues to jointly lead with Australia the CCUS initiative under the Clean Energy Ministerial, 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.

15.2.8 Capacity building projects on adapting to climate change

The UK Government is working to ensure that UK climate support addresses both the causes and effects of climate change. The world's poorest people are hit hardest by the impacts of climate change with crops lost to floods and drought, 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, in part due to weak capacity to identify and implement practical climate adaptation resposnes. Alongside practical on-the-ground support the UK is therefore building climate response capacity in vulnerable countries.

Examples include:

- Building Resilience and Adaptation to Climate Extremes and Disasters (BRACED) is a £140m programme to support countries that are at most risk of climate extremes (e.g. droughts, storms, floods and landslides), will focuses on the Sahel – Senegal, Burkina Faso, Chad, Mali, Mauritania and Niger - and DFID focal countries identified as at most risk, including: Burma, Nepal Ethiopia, South Sudan, Sudan, Uganda, and Kenya. £30m of the programme is dedicated to developing capacity on response to climate related disasters and improve policies and institutions on DRR, and climate adaptation.
- £10m Climate Development for Africa (ClimDev) is another programme deisgned to build capacity and expertise to tackle climate change. ClimDev is Africa's first regional climate information services programme, with ICF support focused on the establishment and operations of the Africa Climate Policy Centre based at the UN Economic Commission for Africa (UNECA) in Addis Ababa, In addition ICF country programmes all have capacity building components to help developing countries effectively plan and implement climate strategies. For example the £15 million Strategic Climate Institutions Programme (SCIP) builds organisational capacity within the Ethiopian Government, civil society and the private sector to strengthen Ethiopia's capacity to manage climate risks and opportunities.In Nepal the £25m Climate Change Support Programme (NCCSP) provide capacity building support to central ministries and has a particular focus on strengthening local government capacity, as key implmenters of climate change adaptation responses.

15.2.9 Energy Market Reforms – 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 greener energy and reliable supplies that the country needs, while minimising costs for consumers in the long term. It will transform the UK electricity sector to one in which low-carbon generation can compete with conventional, fossil-fuel generation – ensuring we build a cleaner, more sustainable energy mix. 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 has now delivered, with the first capacity auction held in December 2014 and outcome of the allocation under contracts for difference (CFDs) published this February.

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 and biological treatment of solid waste.
Brown, Peter	Author and report manager: sector overviews, waste-water, general reviewing and general support of main authors.
Buys, Gwen[47]	Main author of LULUCF Cpt 6, Cpt 11, Annex 3.5 and sections in Cpt 1 and Cpt 2
Cardenas, Laura[48]	Sector expert for agriculture; author of all sections on agriculture. Compilation of Sector 3 of the CRF
MacCarthy, Joanna	Project Manager for the UK Greenhouse Gas Inventory with overall responsibility for the NIR and the CRF[49]. Author of chapter 1, the Executive Summary and chapter 10. Contributor and reviewer for all sections.
Murrells, Tim	NAEI transport manager. Technical Director of NAEI Programme. Contributing author to all sections on transport
Pang, Yvonne	Author of the road transport methodology, responsible for road transport data compilation and assistance with inventory QA/QC, uncertainties and key category analysis.
Passant, Neil	Author of selected sections on energy, industry and waste; 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 7.
Thistlethwaite, Glen	Compilation of emission estimates, in particular the offshore sector and cement. Main author of chapters and annexes for 1B and much of 1A, co-author of sections relating to waste-water treatment, EU ETS, and the reference approach. Knowledge leader responsible for final review of this report.

47 Centre for Ecology and Hydrology

48 Rothamsted Research

49 The UK greenhouse gas inventory is part of the UK National Atmospheric Emissions Inventory contract. The UK National Atmospheric Emissions Inventory is funded by the UK Department for Environment, Food & Rural Affairs and the Department of Energy and Climate Change and is contracted to a consortium led by Ricardo Energy & Environment.

Person	Technical work area and responsibility
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Gilhespy, Sarah[48]	Contributions to agriculture inventory compilation and text
Glendining, Margaret	Contributions to agriculture inventory compilation and text
Gluckman, Ray[50]	UK F-gas sector expert providing input and review of methodologies and activity data.
Goodwin, Justin[51]	Contribution to text on QA/QC plan.
Henshall, Paul[54]	CARBINE modelling for LULUCF inventory for 4A Forestry, 4G Harvested Wood Products and KP, contributions to text for sections in Cpt 6, Cpt 11 and Annex 3.5.
Hobson, Melanie[52]	Compilation of rail emissions estimates and text for this sector
Levy, Peter[54]	Responsible for uncertainty analysis of LULUCF inventory
Webb, Nicola	Project Manager for the UK Greenhouse Gas Inventory until June 2014.
Malcolm, Heath[47]	Land Use and Ecosystem Modelling Group Leader, CEH. Contribution to LULUCF data analysis
Manning, Alistair[52]	Verification of the UK greenhouse gas inventory (Annex 6)
Matthews, Robert[53]	CARBINE modelling for LULUCF inventory for 4A Forestry, 4G Harvested Wood Products and KP, contributions to text sections in Cpt 6, Cpt 11 and Annex 3.5
Miles, Stephanie[47]	Responsible for compiling LULUCF emissions for soil liming, peat extraction, OTs and CDs. Updating text for sections in Cpt 6 and Annex 3.5. Updating LULUCF text for Cpt 1 and Cpt2. Graphs of LULUCF data for text. Carrying out inventory QA/QC
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Moxley, Janet[48]	Responsible for compiling LULUCF emissions for wildfires and the Falklands islands, contributions to text for sections in Cpt 6 and Annex 3.5. Carrying out LULUCF inventory QA/QC
Pearson, Ben	Methodological development of the Monte Carlo model, and contributions to Annex 2.
Salisbury, Emma[52]	Responsible for compilation of emission estimates for the OTs and CDs, and report text relating to this
Sussams, Julia	Review of the draft NIR and contributions regarding National Inventory System. Author of Chapter 15
Wakeling, Daniel	General support of main authors and author of Annex 8 and chapter 2.
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

50 SKM Enviros

51 Aether

52 The Met Office

53 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 statistics; 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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