# UK Greenhouse Gas Inventory, 1990 to 2008

## Annual Report for Submission under the Framework Convention on Climate Change

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# Preface

This is the United Kingdom's National Inventory Report (NIR) submitted in April 2010 to the United Nations Framework Convention on Climate Change (UNFCCC). It contains national greenhouse gas emission estimates for the period 1990-2008, and the descriptions of the methods used to produce the estimates. The report is prepared in accordance with decision 18/CP.8[1] and follows the structure outlined in the document FCCC/SBSTA/2006/9[2]. This submission constitutes the UK's submission under the Kyoto Protocol. A Compact Disk on the inside of the back flap of this report contains tabular data in the Common Reporting Format (CRF) covering the United Kingdom's greenhouse gas emissions for the same period.

The greenhouse gas inventory (GHGI) is based on the same data sets used by the UK in the National Atmospheric Emissions Inventory (NAEI) for reporting atmospheric emissions under other international agreements. The GHGI is therefore consistent with the NAEI where they overlap.

The greenhouse gas inventory is compiled on behalf of the UK Department of Energy and Climate Change (DECC) Climate and Energy: Science and Analysis Division, by AEA. We acknowledge the positive support and advice from DECC throughout the work, and we are grateful for the help of all those who have contributed to this NIR. A list of the contributors can be found in **Chapter 18**.

The GHGI is compiled according to IPCC 1996 Revised Guidelines and Good Practice Guidance (IPCC, 1997; 2000 and 2003), with reference to the new 2006 IPCC Guidelines (IPCC, 2006). Each year the inventory is updated to include the latest data available. Improvements to the methodology are backdated as necessary to ensure a consistent time series. Methodological changes are made to take account of new data sources, or new guidance from IPCC, relevant work by CORINAIR, and new research, sponsored by DECC or otherwise.

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

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

# Units and Conversions

Emissions of greenhouse gases presented in this report are given in Gigagrammes (Gg), Million tonnes (Mt) and Teragrammes (Tg). GWP weighted emissions are also provided. To convert between the units of emissions, use the conversion factors given below.

Prefixes and multiplication factors

| Multiplication factor | Abbreviation | Prefix | Symbol |
|---|---|---|---|
| | | | |
| 1,000,000,000,000,000 | $10^{15}$ | peta | P |
| 1,000,000,000,000 | $10^{12}$ | tera | T |
| 1,000,000,000 | $10^{9}$ | giga | G |
| 1,000,000 | $10^{6}$ | mega | M |
| 1,000 | $10^{3}$ | kilo | k |
| 100 | $10^{2}$ | hecto | h |
| 10 | $10^{1}$ | deca | da |
| 0.1 | $10^{-1}$ | deci | d |
| 0.01 | $10^{-2}$ | centi | c |
| 0.001 | $10^{-3}$ | milli | m |
| 0.000,001 | $10^{-6}$ | micro | $\mu$ |

1 kilotonne (kt)=$10^{3}$ tonnes=1,000 tonnes
1 Mega tonne (Mt)=$10^{6}$ tonnes=1,000,000 tonnes

1 Gigagramme (Gg)   =   1 kt
1 Teragramme (Tg)=1 Mt

## Conversion of carbon emitted to carbon dioxide emitted

To covert emissions expressed in weight of carbon, to emissions in weight of carbon dioxide, multiply by 44/12.

## Conversion of Gg of greenhouse gas emitted into Gg $CO_2$ equivalent

Gg (of GHG) * GWP = Gg $CO_2$ equivalent.

The GWP is the Global Warming Potential of the greenhouse gas. The GWPs of greenhouse gases used in this report are given in Table 1.1 of Chapter 1.

# Abbreviations for Greenhouse Gases and Chemical Compounds

| Type of greenhouse gas | Formula or abbreviation | Name |
|---|---|---|
| | | |
| Direct | $CH_4$ | Methane |
| Direct | $CO_2$ | Carbon dioxide |
| Direct | $N_2O$ | Nitrous oxide |
| | | |
| Direct | HFCs | Hydrofluorocarbons |
| Direct | PFCs | Perfluorocarbons |
| Direct | $SF_6$ | Sulphur hexafluoride |
| | | |
| Indirect | CO | Carbon monoxide |
| Indirect | NMVOC | Non-methane volatile organic compound |
| Indirect | $NO_X$ | Nitrogen oxides (reported as nitrogen dioxide) |
| Indirect | $SO_2$ | Sulphur oxides (reported as sulphur dioxide) |

HFCs, PFCs and $SF_6$ are collectively known as the 'F-gases'.

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

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

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

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

In April 2009 the UK Government announced the levels of the first three five-year carbon budgets, starting in 2008, requiring the UK to cut emissions by 34% on 1990 levels by 2020. The UK's Low Carbon Transition Plan, published in July 2009, sets out the route-map to achieving that 34% reduction in GHG emissions by 2020.

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

www.decc.gov.uk
www.defra.gov.uk/environment/climatechange

## ES.1.2 Background information on greenhouse gas inventories

The UK ratified the United Nations Framework Convention on Climate Change (UNFCCC) in December 1993, and the Convention came into force in March 1994.  Parties to the Convention are committed to develop, publish and regularly update national emission inventories of greenhouse gases (GHGs).

This is the UK's National Inventory Report (NIR) submitted in April 2010.  It contains GHG emissions estimates for the period 1990 to 2008, and describes the methodology on which the estimates are based.  This report and the attached Common Reporting Format (CRF) have been compiled in accordance with UNFCCC reporting guidelines on annual inventories contained in document FCCC/CP/2002/8 and Decision 18/CP8 of the Conference of Parties.

The UK's GHG inventory is compiled under contract to the UK Department for Energy and Climate Change (DECC) by AEA.  AEA also compiles the UK's National Atmospheric Emissions Inventory on behalf of the UK Department for the Environment, Food and Rural Affairs (Defra), used for reporting emissions to other international agreements.  Most of the

underlying information is held in common databases and this helps ensure consistency between the inventories. Emissions from the agricultural sector (Sector 4) are provided by Defra's Farming and Food Science Team via a contract with North Wyke Research (NWRes), and estimates for Land Use, Land Use Change and Forestry (LULUCF) (Sector 5) are produced on behalf of DECC by the Centre for Ecology and Hydrology (CEH). DECC and Defra also fund research contracts to provide improved emissions estimates for certain sources such as fluorinated gases, landfill methane, and to provide estimates for sources such as methane emissions from closed coal mines, which first appeared in the 2005 NIR.

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

- Carbon dioxide;
- Methane ;
- Nitrous oxide ;
- Hydrofluorocarbons (HFCs) ;
- Perfluorocarbons (PFCs) ; and
- Sulphur hexafluoride ($SF_6$).

These gases contribute directly to climate change owing to their positive radiative forcing effect. Also reported are four indirect greenhouse gases:

- Nitrogen oxides (reported as $NO_2$);
- Carbon monoxide;
- Non-Methane Volatile Organic Compounds (NMVOC); and
- Sulphur oxides (reported as $SO_2$).

The structure of this report is as follows:
- Chapter 1 of the report provides an introduction and background information on greenhouse gas inventories.
- Chapter 2 provides a summary of the emission trends for aggregated greenhouse gas emissions by source and gas.
- Chapters 3 to 9 discuss each of the main source categories in detail.
- Chapter 10 presents information on recalculations, improvements and a summary of responses to review processes.
- Chapter 11 details KP-LULUCF reporting
- Chapter 12 contains information on accounting of Kyoto units
- Chapters 13 and 14 contain information regarding changes to the National System and the National Registry
- Chapter 15 contains information on the minimisation of adverse impacts in accordance with Article 3, paragraph 14.

There are also Annexes to provide key source analysis and other detailed information as set out in the Guidelines.
Unless otherwise indicated, percentage contributions and changes quoted refer to net emissions (i.e. emissions minus removals), based on the full coverage of UK emissions including all relevant Overseas Territories and Crown Dependencies, consistent with the UK's submission to the UNFCCC.

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

1. Domestic goals for $CO_2$ are based on the UK only, excluding all emissions from the UK's Crown Dependencies and Overseas Territories;
2. The Kyoto commitment extends coverage to the UK's Crown Dependencies (Guernsey, Jersey and the Isle of Man) and Overseas Territories that have ratified the Kyoto Protocol (the Cayman Islands, the Falkland Islands, Bermuda, Monserrat and Gibraltar);
3. The UK's commitments under the EU Monitoring Mechanism, which has been set up to enable the EU to meet its Kyoto Protocol target, only includes the parts of the UK which are also parts of the EU (the UK and Gibraltar, excluding all Crown Dependencies and other Overseas Territories).

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

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

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

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

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

## ES.2.1 GHG Inventory

**Table ES2.1:** **Emissions of GHGs in terms of carbon dioxide equivalent emissions including all estimated GHG emissions from the Crown Dependencies and relevant Overseas Territories, 1990-2008. (Mt CO$_2$ Equivalent)**

| Table ES2.1 | Mt CO$_2$ Equivalent | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
| CO$_2$ (Including net LULUCF) | 594.1 | 601.4 | 584.2 | 569.2 | 563.2 | 554.4 | 576.6 | 552.9 | 555.0 | 544.6 |
| CO$_2$ (Excluding net LULUCF) | 591.2 | 598.6 | 582.0 | 568.1 | 562.3 | 553.2 | 575.7 | 552.3 | 555.0 | 544.8 |
| CH$_4$ (Including net LULUCF) | 104.6 | 103.8 | 102.3 | 99.3 | 92.3 | 91.4 | 89.0 | 83.8 | 79.5 | 74.3 |
| CH$_4$ (Excluding net LULUCF) | 104.6 | 103.8 | 102.3 | 99.2 | 92.3 | 91.4 | 89.0 | 83.8 | 79.4 | 74.3 |
| N$_2$O (Including net LULUCF) | 65.1 | 65.1 | 58.5 | 53.8 | 55.0 | 53.6 | 53.5 | 54.5 | 54.0 | 43.3 |
| N$_2$O (Excluding net LULUCF) | 65.1 | 65.1 | 58.5 | 53.8 | 55.0 | 53.6 | 53.5 | 54.5 | 54.0 | 43.3 |
| HFCs | 11.4 | 11.9 | 12.3 | 13.1 | 14.1 | 15.5 | 16.7 | 19.0 | 16.8 | 10.0 |
| PFCs | 1.4 | 1.2 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 |
| SF$_6$ | 1.0 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 | 1.3 | 1.2 | 1.3 | 1.4 |
| Total (Emissions including net GHG from LULUCF) | 777.6 | 784.5 | 759.0 | 737.1 | 726.1 | 716.6 | 737.5 | 711.9 | 706.9 | 674.0 |
| Total (Emissions excluding net GHG from LULUCF) | 774.7 | 781.6 | 756.8 | 735.9 | 725.2 | 715.3 | 736.6 | 711.2 | 706.8 | 674.2 |

| Table ES2.1 | Mt CO$_2$ Equivalent | | | | | | | | | % Change |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 1990-2008 |
| CO$_2$ (Including net LULUCF) | 552.7 | 564.2 | 546.6 | 558.4 | 558.0 | 555.7 | 553.3 | 545.6 | 534.7 | -10% |
| CO$_2$ (Excluding net LULUCF) | 553.1 | 564.7 | 547.7 | 559.4 | 559.8 | 557.6 | 555.1 | 547.5 | 536.7 | -9% |
| CH$_4$ (Including net LULUCF) | 69.7 | 63.7 | 60.6 | 54.6 | 52.9 | 51.7 | 50.7 | 49.5 | 48.9 | -53% |
| CH$_4$ (Excluding net LULUCF) | 69.7 | 63.6 | 60.6 | 54.6 | 52.9 | 51.7 | 50.7 | 49.5 | 48.9 | -53% |
| N$_2$O (Including net LULUCF) | 42.3 | 39.9 | 38.1 | 37.5 | 38.1 | 36.9 | 35.3 | 34.8 | 34.0 | -48% |
| N$_2$O (Excluding net LULUCF) | 42.3 | 39.9 | 38.1 | 37.5 | 38.1 | 36.9 | 35.3 | 34.8 | 34.0 | -48% |
| HFCs | 8.7 | 9.3 | 9.8 | 10.5 | 9.7 | 10.5 | 10.8 | 11.0 | 11.2 | -1% |
| PFCs | 0.5 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | -85% |
| SF$_6$ | 1.8 | 1.4 | 1.5 | 1.3 | 1.1 | 1.1 | 0.9 | 0.8 | 0.7 | -31% |
| Total (Emissions including net GHG from LULUCF) | 675.7 | 678.9 | 657.0 | 662.7 | 660.2 | 656.2 | 651.3 | 641.9 | 629.8 | -19% |
| Total (Emissions excluding net GHG from LULUCF) | 676.0 | 679.4 | 658.0 | 663.7 | 662.0 | 658.1 | 653.1 | 643.8 | 631.8 | -18% |

1. One Mt equals one Tg, which is $10^{12}$ g (1,000,000,000,000 g) or one million tonnes
2. Net Emissions are reported in the Common Reporting Format
3. Geographical coverage of this table includes the Crown Dependencies Jersey, Guernsey and the Isle of Man, and the Overseas Territories which have joined the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol. These are the Cayman Islands, Falkland Islands, Bermuda, Montserrat and Gibraltar.

Table ES2.1 presents the UK Greenhouse Gas Inventory totals by gas, both including and excluding net emissions from LULUCF. The largest contribution to total emissions is $CO_2$, which contributed 85% to total net emissions in 2008. Methane emissions account for the next largest share (8%), and $N_2O$ emissions make up a further 5%. Emissions of all gases have decreased since 1990, contributing to an overall decrease of 19%.

## ES.2.2 KP-LULUCF activities
KP-LULUCF activities relate to estimated emissions and removals from:

- **Article 3.3**, the net emissions or removals of Aforestation, Reforestation and Deforestation (ARD) since 1990;
- **Article 3.4**, the net flux due to forest management since 1990 (the UK has elected forest management from the choices of: cropland management, grassland management, forest management and revegetation); and
- **Article 3.7**, emissions in 1990 only from deforestation, added to the base year for Kyoto reporting (only applicable for countries where there is a net LULUCF emission in 1990, which is the case for the UK).

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

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

| Table ES 2.2 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Article 3.3** | -0.6 | -0.6 | -0.6 | -0.9 | -1.1 | -1.3 | -1.5 | -1.7 | -1.9 | -2.1 |
| **Article 3.4 (capped at -0.37 MtC)** | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 |
| **Article 3.7** | | | | | | | | | | |

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

## ES.3.1 GHG Inventory

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

**Table ES3.1:** **Aggregated emission trends per source category, including all estimated GHG emissions from the Crown Dependencies and selected relevant Overseas Territories (Mt CO$_2$ equivalent).**

| Table ES2.2 | Aggregated emission trends per source category (Mt CO$_2$ equivalent) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Source Category | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
| 1. Energy | 612.1 | 622.0 | 605.6 | 590.0 | 577.0 | 568.5 | 589.1 | 564.6 | 565.5 |
| 2. Industrial Processes | 54.0 | 52.3 | 46.9 | 43.7 | 46.1 | 46.4 | 48.2 | 50.6 | 48.7 |
| 3. Solvents and Other Product Use[a] | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4. Agriculture | 55.6 | 55.1 | 53.3 | 52.6 | 53.5 | 53.4 | 53.7 | 54.0 | 53.1 |
| 5. LULUCF | 2.9 | 2.8 | 2.2 | 1.1 | 0.9 | 1.2 | 1.0 | 0.7 | 0.1 |
| 6. Waste | 52.9 | 52.2 | 51.0 | 49.6 | 48.6 | 47.1 | 45.6 | 41.9 | 39.5 |
| **Total (net emissions)** | **777.6** | **784.5** | **759.0** | **737.1** | **726.1** | **716.6** | **737.5** | **711.9** | **706.9** |

| Table ES3.1 | Aggregated emission trends per source category (Mt CO$_2$ equivalent) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Source Category | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
| 1. Energy | 553.4 | 560.5 | 572.7 | 555.7 | 563.7 | 563.2 | 559.7 | 557.1 | 546.9 | 536.3 |
| 2. Industrial Processes | 32.0 | 30.9 | 29.1 | 26.9 | 28.4 | 28.6 | 28.7 | 27.9 | 29.6 | 28.8 |
| 3. Solvents and Other Product Use[a] | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4. Agriculture | 52.5 | 50.4 | 47.4 | 47.6 | 46.9 | 46.9 | 46.7 | 45.2 | 44.3 | 43.8 |
| 5. LULUCF | -0.2 | -0.3 | -0.5 | -1.0 | -1.0 | -1.8 | -1.9 | -1.8 | -1.9 | -2.0 |
| 6. Waste | 36.2 | 34.2 | 30.2 | 27.8 | 24.7 | 23.2 | 23.0 | 23.0 | 22.9 | 22.8 |
| **Total (net emissions)** | **674.0** | **675.7** | **678.9** | **657.0** | **662.7** | **660.2** | **656.2** | **651.3** | **641.9** | **629.8** |

**Footnotes:**

[a] Solvents and other product use emissions occur as NMVOC and so do not appear in this Table which covers direct greenhouse gases

Geographical coverage of this table includes the Crown Dependencies Jersey, Guernsey and the Isle of Man, and the Overseas Territories which have joined, or are likely to join, the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol. These are the Cayman Islands, Falkland Islands, Bermuda, Montserrat and Gibraltar.

The largest contribution to greenhouse gas emissions arises from the energy sector. In 2008 this contributed 85% to the total emissions including relevant OTs. Emissions of CO$_2$, CH$_4$ and N$_2$O all arise from this sector. Since 1990, emissions from the energy sector have declined by about 12%.

The second largest source of greenhouse gases is the agricultural sector. Emissions from this sector arise for both CH$_4$ and N$_2$O. Since 1990, emissions from this sector have declined by 21%, due to a decline in emissions from enteric fermentation and agricultural waste disposal (related to lower livestock numbers) and agricultural soils (due to changes in agricultural

practices, including a decline in emissions from enteric fermentation, and a decline in the emissions from the use of synthetic fertiliser).

Industrial processes make up the third largest source of greenhouse gases in the UK, contributing 5% to the national total in 2008. Emissions of all six direct greenhouse gases occur from this sector.

Land Use, Land-use Change and Forestry contains sinks as well as sources of $CO_2$ emissions. LULUCF is a net sink in 2008. Emissions from this source occur for $CO_2$, $N_2O$ and $CH_4$.

The remaining source that contributes to direct greenhouse gas totals is waste. In 2008 this contributed around 4% to the national total. Emissions arise for $CO_2$, $CH_4$ and $N_2O$, with emissions occurring from waste incineration, solid waste disposal on land and wastewater handling. Emissions from this sector have steadily declined and in 2008 are 57% below 1990 levels.

Total net emissions have decreased by 19% since 1990.

## ES.3.2 KP-LULUCF Activities

ES.3.2 provides the time series of the UK Kyoto basket of emissions (UNFCCC geographical coverage), and ES.3.3 presents the equivalent values for the EU coverage of the UK inventory. The tables show the emissions making up the base year and subsequent years, and also estimated emissions and removals from:

- **Article 3.3**, the net emissions or removals of Aforestation, Reforestation and Deforestation (ARD) since 1990;
- **Article 3.4**, the net flux due to forest management since 1990 (the UK has elected forest management from the choices of: cropland management, grassland management, forest management and revegetation); and
- **Article 3.7**, emissions in 1990 only from deforestation, added to the base year for Kyoto reporting (only applicable for countries where there is a net LULUCF emission in 1990, which is the case for the UK).

The Base Year for emissions of carbon dioxide, methane and nitrous oxide is 1990. The Base Year for emissions of fluorinated gases (F-gases) is 1995.

The tables include two Base Year totals. The first (in the Kyoto Protocol Total row) is the 'Base Year' calculated from the 2008 inventory, based on the totals calculated for each sector this year, together with Article 3.7, and including any recalculations made since the previous inventory. The 'Fixed Base Year' is the base year total calculated from the 2004 Inventory, which has been used to calculate the UK's Assigned Amount, and in table ES.3.3, the UK's contribution to the EU's Assigned Amount. This has been reviewed during an In Country Review of the UK inventory in March 2007 and agreed by the UNFCCC. This is the total that the UK's progress towards its Kyoto Protocol target will be judged against.

**Table ES3.2:** **Kyoto basket of emissions, and emissions associated with Articles 3.3, 3.4 and 3.7, 1990-2008 (in Mt $CO_2$ equivalent) – UNFCCC Coverage.**

| Table ES3.2 | Mt $CO_2$ Equivalent | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Base Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
| $CO_2$ | 591.2 | 591.2 | 598.6 | 582.0 | 568.1 | 562.3 | 553.2 | 575.7 | 552.3 | 555.0 | 544.8 |
| $CH_4$ | 104.6 | 104.6 | 103.8 | 102.3 | 99.2 | 92.3 | 91.4 | 89.0 | 83.8 | 79.4 | 74.3 |
| $N_2O$ | 65.1 | 65.1 | 65.1 | 58.5 | 53.8 | 55.0 | 53.6 | 53.5 | 54.5 | 54.0 | 43.3 |
| HFCs | 15.5 | 11.4 | 11.9 | 12.3 | 13.1 | 14.1 | 15.5 | 16.7 | 19.0 | 16.8 | 10.0 |
| PFCs | 0.5 | 1.4 | 1.2 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 |
| $SF_6$ | 1.2 | 1.0 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 | 1.3 | 1.2 | 1.3 | 1.4 |
| **Grand Total** | 778.1 | 774.7 | 781.6 | 756.8 | 735.9 | 725.2 | 715.3 | 736.6 | 711.2 | 706.8 | 674.2 |
| Article 3.3 | | 0.4 | 0.6 | 0.6 | 0.5 | 0.4 | 0.1 | -0.1 | -0.3 | -0.5 | -0.6 |
| Article 3.4 (capped at -0.37 MtC) | | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 |
| Article 3.7 | 0.3 | | | | | | | | | | |
| **Kyoto Protocol Total** | 778.7 | 773.8 | 780.8 | 756.0 | 735.1 | 724.2 | 714.1 | 735.1 | 709.6 | 705.0 | 672.2 |
| **Fixed Base Year** | 779.9 | | | | | | | | | | |

| Table ES3.2 | Mt $CO_2$ Equivalent | | | | | | | | | % Changes | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 1990-2008 | Base Year - 2008 |
| $CO_2$ | 553.1 | 564.7 | 547.7 | 559.4 | 559.8 | 557.6 | 555.1 | 547.5 | 536.7 | -9% | -9% |
| $CH_4$ | 69.7 | 63.6 | 60.6 | 54.6 | 52.9 | 51.7 | 50.7 | 49.5 | 48.9 | -53% | -53% |
| $N_2O$ | 42.3 | 39.9 | 38.1 | 37.5 | 38.1 | 36.9 | 35.3 | 34.8 | 34.0 | -48% | -48% |
| HFCs | 8.7 | 9.3 | 9.8 | 10.5 | 9.7 | 10.5 | 10.8 | 11.0 | 11.2 | -1% | -27% |
| PFCs | 0.5 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | -85% | -55% |
| $SF_6$ | 1.8 | 1.4 | 1.5 | 1.3 | 1.1 | 1.1 | 0.9 | 0.8 | 0.7 | -31% | -43% |
| **Grand Total** | 676.0 | **679.4** | **658.0** | **663.7** | **662.0** | **658.1** | **653.1** | **643.8** | **631.8** | **-18%** | **-19%** |
| Article 3.3 | -0.6 | -0.6 | -0.9 | -1.1 | -1.3 | -1.5 | -1.7 | -1.9 | -2.1 | | |
| Article 3.4 (capped at -0.37 MtC) | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | | |
| Article 3.7 | | | | | | | | | | | |
| **Kyoto Protocol Total** | 674.1 | **677.4** | **655.8** | **661.2** | **659.3** | **655.2** | **650.0** | **640.5** | **628.3** | **-18%** | **-19%** |
| **Fixed Base Year** | | | | | | | | | | | -19% |

**Footnotes:**

[1] The Fixed Base Year is taken from the UK's Assigned Amount report. This report was submitted in 2006, based on emissions reported in the 1990-2004 Greenhouse Gas Inventory, and was subject to an official review in 2007, which concluded that this figure was correct. This base year is now fixed, and is the value that the UK will be assessed against for its Kyoto Protocol target.

Emissions and removals associated with LULUCF enter the table only through the rows labelled Article 3.3, Article 3.4 and Article 3.7. The UK has chosen to account only for forest management under Article 3.4.

Geographical coverage of this table includes the Crown Dependencies Jersey, Guernsey and the Isle of Man, and the Overseas Territories which have joined the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol. These are the Cayman Islands, Falkland Islands, Bermuda, Montserrat and Gibraltar.

**Table ES3.3:** **Kyoto basket of emissions, and emissions associated with Articles 3.3, 3.4 and 3.7, 1990-2008 (in Mt $CO_2$ equivalent) – EUMM Coverage.**

| Table ES3.3 | Mt $CO_2$ Equivalent | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Base Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
| $CO_2$ | 588.7 | 588.7 | 596.0 | 579.4 | 565.5 | 559.6 | 550.5 | 572.8 | 549.3 | 551.9 | 541.8 |
| $CH_4$ | 104.1 | 104.1 | 103.4 | 101.8 | 98.8 | 91.8 | 90.9 | 88.5 | 83.3 | 79.0 | 73.8 |
| $N_2O$ | 65.1 | 65.1 | 65.0 | 58.4 | 53.7 | 54.9 | 53.5 | 53.4 | 54.4 | 53.9 | 43.2 |
| HFCs | 15.5 | 11.4 | 11.9 | 12.3 | 13.1 | 14.0 | 15.5 | 16.7 | 19.0 | 16.8 | 9.9 |
| PFCs | 0.5 | 1.4 | 1.2 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 |
| $SF_6$ | 1.2 | 1.0 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 | 1.3 | 1.2 | 1.3 | 1.4 |
| **Grand Total** | 775.0 | 771.7 | 778.5 | 753.7 | 732.8 | 722.1 | 712.0 | 733.2 | 707.7 | 703.1 | 670.6 |
| Article 3.3 | | 0.4 | 0.6 | 0.6 | 0.5 | 0.4 | 0.1 | -0.1 | -0.3 | -0.5 | -0.6 |
| Article 3.4 (capped at -0.37 MtC) | | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 |
| Article 3.7 | 0.3 | | | | | | | | | | |
| **Kyoto Protocol Total** | 775.4 | 770.8 | 777.7 | 752.9 | 732.0 | 721.1 | 710.8 | 731.7 | 706.0 | 701.3 | 668.6 |
| **Fixed Base Year** | 776.3 | | | | | | | | | | |

| Table ES3.3 | Mt $CO_2$ Equivalent | | | | | | | | | % Changes | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 1990-2008 | Base Year - 2008 |
| $CO_2$ | 550.2 | 561.9 | 544.9 | 556.7 | 557.1 | 554.8 | 552.1 | 544.3 | 533.7 | -9% | -9% |
| $CH_4$ | 69.2 | 63.2 | 60.2 | 54.2 | 52.6 | 51.3 | 50.3 | 49.1 | 48.5 | -53% | -53% |
| $N_2O$ | 42.2 | 39.8 | 38.0 | 37.5 | 38.0 | 36.8 | 35.2 | 34.7 | 33.9 | -48% | -48% |
| HFCs | 8.6 | 9.3 | 9.7 | 10.5 | 9.6 | 10.4 | 10.8 | 10.9 | 11.2 | -2% | -28% |
| PFCs | 0.5 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | -85% | -55% |
| $SF_6$ | 1.8 | 1.4 | 1.5 | 1.3 | 1.1 | 1.1 | 0.9 | 0.8 | 0.7 | -31% | -43% |
| **Grand Total** | 672.6 | **676.0** | **654.7** | **660.5** | **658.7** | **654.7** | **649.6** | **640.0** | **628.2** | **-19%** | **-19%** |
| Article 3.3 | -0.6 | -0.6 | -0.9 | -1.1 | -1.3 | -1.5 | -1.7 | -1.9 | -2.1 | | |
| Article 3.4 (capped at -0.37 MtC) | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | -1.4 | | |
| Article 3.7 | | | | | | | | | | | |
| **Kyoto Protocol Total** | 670.6 | **674.0** | **652.4** | **658.0** | **656.0** | **651.8** | **646.5** | **636.8** | **624.8** | **-19%** | **-19%** |
| **Fixed Base Year[1]** | | | | | | | | | | | -20% |

**Footnotes:**

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

Emissions and removals associated with LULUCF enter the table only through the rows labelled Article 3.3, Article 3.4 and Article 3.7. The UK has chosen to account only for forest management under Article 3.4.

Geographical coverage of this table includes the UK and Gibraltar only.

# ES.4 - OTHER INFORMATION

ES.4 lists the indirect greenhouse gases for which the UK has made emissions estimates. Nitrogen oxides, carbon monoxide and NMVOCs are included in the inventory because they can produce increases in tropospheric ozone concentrations and this increases radiative forcing. Sulphur oxides are included because they contribute to aerosol formation.

**Table ES4.1:** **Emissions of Indirect Greenhouse Gases in the UK, 1990-2008 (in kt).**

| Gas | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|---|
| $NO_x$ | 2,756 | 2,709 | 2,597 | 2,450 | 2,365 | 2,259 | 2,188 | 2,052 | 2,011 |
| CO | 9,043 | 9,253 | 8,845 | 8,501 | 8,040 | 7,527 | 7,578 | 7,081 | 6,792 |
| NMVOC | 2,573 | 2,510 | 2,450 | 2,335 | 2,270 | 2,090 | 1,998 | 1,925 | 1,794 |
| $SO_2$ | 3,731 | 3,628 | 3,449 | 3,120 | 2,676 | 2,366 | 2,045 | 1,666 | 1,636 |

| Gas | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|
| $NO_x$ | 1,914 | 1,881 | 1,837 | 1,737 | 1,755 | 1,711 | 1,685 | 1,657 | 1,561 | 1,406 |
| CO | 6,421 | 5,660 | 5,277 | 4,647 | 4,177 | 3,876 | 3,479 | 3,271 | 3,052 | 2,828 |
| NMVOC | 1,614 | 1,491 | 1,394 | 1,319 | 1,202 | 1,129 | 1,072 | 1,030 | 1,013 | 943 |
| $SO_2$ | 1,224 | 1,238 | 1,111 | 984 | 973 | 817 | 692 | 674 | 599 | 516 |

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

Since 1990, emissions of all indirect gases have decreased. The largest source of emissions for all the indirect gases is the energy sector. For $NO_x$, CO and $SO_2$, over 90% of emissions arise from activities within this sector. For NMVOC, 44.6% of emissions are energy related, with other significant contributions from both the industrial processes and solvent sectors.

# Contacts

This work is part of the Climate and Energy: Science and Analysis (CESA) Research Programme of the Department for Energy and Climate Change. The Land Use Change and Forestry estimates were provided by the Centre for Ecology and Hydrology (CEH) Edinburgh (Contract CPEG 1). North Wyke Research (NWRes) provide the estimates of agricultural emissions.

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

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# List of Tables and Figures

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**Tables** (in the main report)

## Document Revision History

| Issue | Revision History |
|---|---|
| | |
| **Issue - Draft** | Reviewed by DECC |
| **Issue 1** | Submission to the EUMM, incorporates comments from DECC |
| **Issue 2** | Submission to the UNFCCC.  Includes updates to Chapter 12, Chapter 14 and Annex 6, and a new Annex of final user emissions (Annex 13). |
| **Issue 3** | Submission to the UNFCCC.  Includes further updates to Annex 6 and Chapter 12. |

# 1      Introduction

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

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

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

## 1.1      BACKGROUND INFORMATION ON GREENHOUSE GAS INVENTORIES, CLIMATE CHANGE

### 1.1.1      Background information on Climate Change

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

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

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

The UK has set itself even more stringent domestic targets, including an emission reduction target of 34% by 2020 on 1990 levels. This target is included in the *Climate Change Act.*
The UK's Climate Change Programme published in March 2006, described measures to ensure that the UK delivers its legally binding target under the Kyoto Protocol to reduce

emissions of the basket of the six greenhouse gases to 12.5% below base year levels over the first commitment period 2008-2012, and to move the UK towards its domestic goal of a 20% reduction in carbon dioxide emissions below 1990 levels by 2010.   The Climate Change Programme formed the basis of the UK's Fourth National Communication to the UNFCCC.

The Climate Change Act became UK Law on the 26th November 2008. This legislation introduced a new, more ambitious and legally binding target for the UK to reduce GHG emissions to 80% below base year by 2050, with legally binding five year GHG budgets. The independent Committee on Climate Change (CCC) was set up to advise the UK Government on the scope and level of UK carbon budgets. The CCC published its first advice to the UK Government on the 1st December 2008.

In response to the CCC's recommendations, in April 2009 the UK Government announced the levels of the first three five-year carbon budgets, starting in 2008, requiring the UK to cut emissions by 34% on 1990 levels by 2020. More recently, in July 2009, the UK Government released its Low Carbon Transition Plan, which plots out the route-map to achieving that 34% reduction in GHG emissions by 2020.

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

www.decc.gov.uk
www.defra.gov.uk/environment/climatechange

## 1.1.2     Background information on Greenhouse Gas Inventories

### 1.1.2.1     Reporting of the UK Greenhouse Gas Inventory

The UK ratified the United Nations Framework Convention on Climate Change (UNFCCC) in December 1993 and the Convention came into force in March 1994.   Parties to the Convention are committed to develop, publish and regularly update national emission inventories of greenhouse gases (GHGs).

The UK's National Inventory Report (NIR) is prepared in accordance with decision 18/CP.8[3] and follows the structure outlined in the document FCCC/SBSTA/2006/9[4].   In addition to this, the UK also reports GHG emissions by sources and removals by sinks in the Common Reporting Format (CRF) tables.   The estimates are consistent with the IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories (IPCC, 1997a, b, c) and Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000, 2003).

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[3] FCCC Decision 18/CP.8.   Guidelines for the preparation of national communications by Parties included in Annex I to the Convention, part I:UNFCCC reporting guidelines on annual inventories.   Report of the Conference of the Parties on its Eighth Session, held at New Delhi from 23 October to 1 November 2002. FCCC/CP/2002/7/Add.2 28 March 2003.

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

This report and corresponding CRF tables provide annual emission estimates submitted by the UK to the UNFCCC for the period 1990 to 2008. Estimates for emissions from Energy, Industrial Processes, Solvents and Waste are compiled by AEA, under contract to the Department of Energy and Climate Change (DECC). Emissions and removals from land use change and forestry are provided by the Centre of Ecology and Hydrology (CEH) under contract to DECC and agricultural emissions by North Wyke Research, under contract to the Department of Environment, Food and Rural Affairs (Defra).

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

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

The main part of the report presents greenhouse gas emissions for the years 1990-2008, and discusses the reasons for the trends and any changes in the estimates due to revisions made since the last inventory. The Annexes provide supplementary detail of the methodology of the estimates, and explain how the Greenhouse Gas Inventory relates to the IPCC Guidelines and the NAEI. It contains mappings between IPCC, NAEI source categories and fuel types as well as some emission factors and references to the technical literature. The Annexes also include sections on the estimation of uncertainties and atmospheric verification of the inventory, and additional detail of the methods used to estimate emissions of GHGs. The IPCC Good Practice Guidance (IPCC, 2000) requires that certain sets of activity data are reported as well as the Common Reporting Format Tables. These datasets are included on a CD ROM attached to this report.

The CRF consists of a series of detailed spreadsheets, with one set for each year. The CRF reports much more detail than the IPCC Sectoral Tables, in that it contains additional tables of activity data as well as updated versions of the IPCC Sectoral Tables. A copy of the CRF for each reported geographical coverage accompanies this report on a CD ROM.

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

A major source of activity data for the UK inventory is provided by UK DECC through their publication the Digest of UK Environmental Statistics (DUKES) (see **Table** 1.6), and the geographical coverage of DUKES helps define the geographical coverage of the inventory.

DECC advises that the geographical coverage of the statistics is the United Kingdom (DECC, 2009). Shipments to the Channel Islands and the Isle of Man from the United Kingdom are not classed as exports, and supplies of solid fuel and petroleum to these islands are therefore included as part of the United Kingdom inland consumption or deliveries.

The definition of the UK used by DECC accords with that of the "economic territory of the United Kingdom" used by the UK Office for National Statistics, which in turn accords with the definition required to be used under the European System of Accounts (ESA95).

The geographical coverage of the UK inventory presented in this NIR has been extended to include emissions from the UK's Crown Dependencies (CDs) and the UK's Overseas Territories (OTs)[5] who have joined, or are likely to join, the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol.

The UK has two types of associated territories, which are as follows:

- Crown Dependencies (CDs)
  The Crown Dependencies are the Isle of Man and the Channel Islands. They are not part of the United Kingdom, and are largely self-governing with their own legislative assemblies and systems of law. The British Government, however, is responsible for their defence and international relations. The Crown Depedencies are not members of the European Union.

- Overseas Territories (OTs, formerly called Dependent Territories)
  The Overseas Territories are constitutionally not part of the United Kingdom. They have separate constitutions, and most Overseas Territories have elected governments with varying degrees of responsibilities for domestic matters. The Governor, who is appointed by, and represents, Her Majesty the Queen, retains responsibility for external affairs, internal security, defence, and in most cases the public service. The OTs include the Sovereign Bases (SBs) as a subset.

Details of the methods used to disaggregate the fuel use in the CDs from the UK totals presented in DUKES are detailed in Annex 3.9

### 1.1.2.3    Greenhouse Gases Reported in the UK Inventory
The greenhouse gases reported are:

*Direct Greenhouse Gases*
- Carbon dioxide($CO_2$)
- Methane($CH_4$)
- Nitrous oxide($N_2O$)
- Hydrofluorocarbons(HFCs)
- Perfluorocarbons(PFCs)
- Sulphur hexafluoride($SF_6$)

*Indirect Greenhouse Gases*
- Nitrogen oxides($NO_x$, as $NO_2$)
- Carbon monoxide(CO)
- Non-Methane Volatile Organic Compounds(NMVOC)
- Sulphur dioxide($SO_2$)

---

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

These indirect gases have indirect effects on radiative forcing and are requested by the UNFCCC guidelines.

Emissions estimates are made using methodologies corresponding mostly to the detailed sectoral Tier 2/3 methods in the IPCC Guidelines.

Most sources are reported in the detail required by the CRF. The main exceptions are the emissions of individual halocarbon species, which cannot always be reported individually because some of these are considered commercially sensitive data. Consequently, emissions data have been aggregated to protect this information. It is however possible to report the total global warming potential of these gases and hence the total global warming potential of all UK greenhouse gases.

### 1.1.2.4    Global Warming Potentials of the Greenhouse Gases

The direct greenhouse gases have different effectiveness in radiative forcing. The Global Warming Potential (GWP) is a means of providing a simple measure of the relative radiative effects of the emissions of the various gases. The index is defined as the cumulative radiative forcing between the present and a future time horizon caused by a unit mass of gas emitted now, expressed relative to that of $CO_2$. It is necessary to define a time horizon because the gases have different lifetimes in the atmosphere. **Table 1.1** shows GWPs defined on a 100-year horizon (IPCC, 1996). These are the GWP values required by FCCC/CP/2002/8, consistent with Decision 2/CP3.

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

| Gas | GWP |
|---|---|
| | |
| Carbon dioxide | 1 |
| Methane | 21 |
| Nitrous oxide | 310 |
| HFCs | 140-11,700 |
| PFCs | 6,500-9,200 |
| $SF_6$ | 23,900 |

A range of GWP values is shown for HFCs and PFCs because these refer to a number of species, each with its own GWP. By weighting the emission of a gas with its GWP it is possible to estimate the total contribution to global warming of UK greenhouse gas emissions.

GWPs of certain greenhouse gases have been updated in the IPCC Third and Fourth Assessment Reports (IPCC, 2001; IPCC, 2007). However, it has been agreed internationally that these will not apply to the Kyoto targets under the first commitment period. All calculations and inventory submissions throughout this period will be based on the GWPs given in the Second Assessment Report (IPCC, 1996).

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

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

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

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

| Reporting Element | Background Information |
|---|---|
| Supplementary inventory information for activities under Article 3, Paragraphs 3 and 4 | The reporting of KP-LULUCF is carried out by the Centre for Ecology and Hydrology (CEH) on behalf of DECC.  The UK has chosen to elect Forest Management (FM) as an activity under Article 3.4.  The calculations follow the same method and use the same models as the UNFCCC estimates for LULUCF, which are also prepared by CEH.  Further information can be found in Chapter 11. |
| Information on Kyoto Protocol units | The UK National Registry is operated and maintained by the Environment Agency on behalf of DECC.  Information on accounting of Kyoto Protocol units, including a summary of information reported in the standard electronic format (SEF) tables is provided in Chapter 12. SEF tables including information for the period 01.01.2009 to 31.12.2009 can be found in Annex 6 of this report. |
| Changes in National Systems | The UK national system is managed and maintained by DECC, who are the Single National Entity.  Changes to the national System are reported in Chapter 13 of this report. |
| Changes in National Registry | The UK National Registry is operated and maintained by the Environment Agency on behalf of DECC. The national registry currently sits outside of the national system for the inventory, but is represented on the National Inventory Steering Committee. There were 3 upgrades to the UK registry in 2009, predominantly addressing reliability and performance issues. 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 |

| Reporting Element | Background Information |
|---|---|
|  | be addressed. We have supported several capacity building projects via our Foreign and Commonwealth Office promoting energy efficiency and deployment of renewable energy. We are also engaging with five major economies (Brazil, South Africa, China, India and Mexico) in sustainable dialogues. Further details on the UK's efforts to minimise adverse impacts is provided in Chapter 15. |

## 1.2    INSTITUTIONAL ARRANGEMENTS FOR INVENTORY PREPARATION

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

The UK Greenhouse Gas Inventory is compiled and maintained by AEA of AEA Technology plc – the **Inventory Agency** - under contract with the Climate, Energy, Science and Analysis (CESA) Division in the UK Department of Energy and Climate Change (DECC).  AEA is directly responsible for producing the emissions estimates for CRF categories Energy (CRF sector 1), Industrial Processes (CRF sector 2), Solvent and Other Product Use (CRF sector 3), and Waste (CRF Sector 6).  AEA is also responsible for inventory planning, data collection, QA/QC and inventory management and archiving.  Agricultural sector emissions (CRF sector 4) are produced by the Defra's Farming and Food Science Team by means of a contract with North Wyke Research.

Land-Use Change and Forestry emissions (CRF sector 5) are calculated by the UK Centre for Ecology and Hydrology (CEH), under separate contract to CESA (DECC).  The KP-LULUCF information is also produced by CEH.  The mechanism for generating the KP-LULUCF data and the quality control and assurance procedures applied are an integral part of the UK's National System.

#### 1.2.1.1    The UK Greenhouse Gas National Inventory System (UK NIS)

The Marrakesh Accords of the Kyoto Protocol (Decision 20/CP7) define the requirements for National Inventory Systems (NIS), including the need to establish legal, procedural and institutional arrangements to ensure that all parties to the Protocol estimate and report their GHG emissions in accordance with relevant decisions of the COP, facilitate UNFCCC Reviews and improve the quality of their inventories.  Under related EU legislation set out in Decision 280/2004/EC the UK was required to have in place its NIS by 31st December 2005.  The development of more formal agreements between DECC and Key Data Providers (KDPs) within the NIS is ongoing and will specify the framework of data supply e.g. data quality, format, timeliness and security to underpin the GHG inventory.

**Figure 1.1** shows the main elements the UK National Inventory System, including provision of data to the European Union under the terms of the EU Monitoring Mechanism.  DECC is the **Single National Entity** responsible for submitting the UK's greenhouse gas inventory (GHGI) to the UNFCCC.  The Inventory Agency is AEA, who are responsible for compiling

the GHGI on behalf of DECC.  Key Data Providers include other Government Departments such as Department for Environment, Food and Rural Affairs (Defra) and Department for Transport (DfT), Non-Departmental Public Bodies such as the Environment Agency for England and Wales (EA) and the Scottish Environmental Protection Agency (SEPA), private companies such as Corus, and business organisations such as UK Petroleum Industry Association (UKPIA) and UK Offshore Oil Association (UKOOA).  **Figure 1.2** Summarises the key organisational structure of the UK National Inventory System and Section 1.2.2 includes further detailed information on the roles and responsibilities of each of the key organisations.

**Figure 1.1**     **Main elements for the preparation of the UK greenhouse gas inventory**
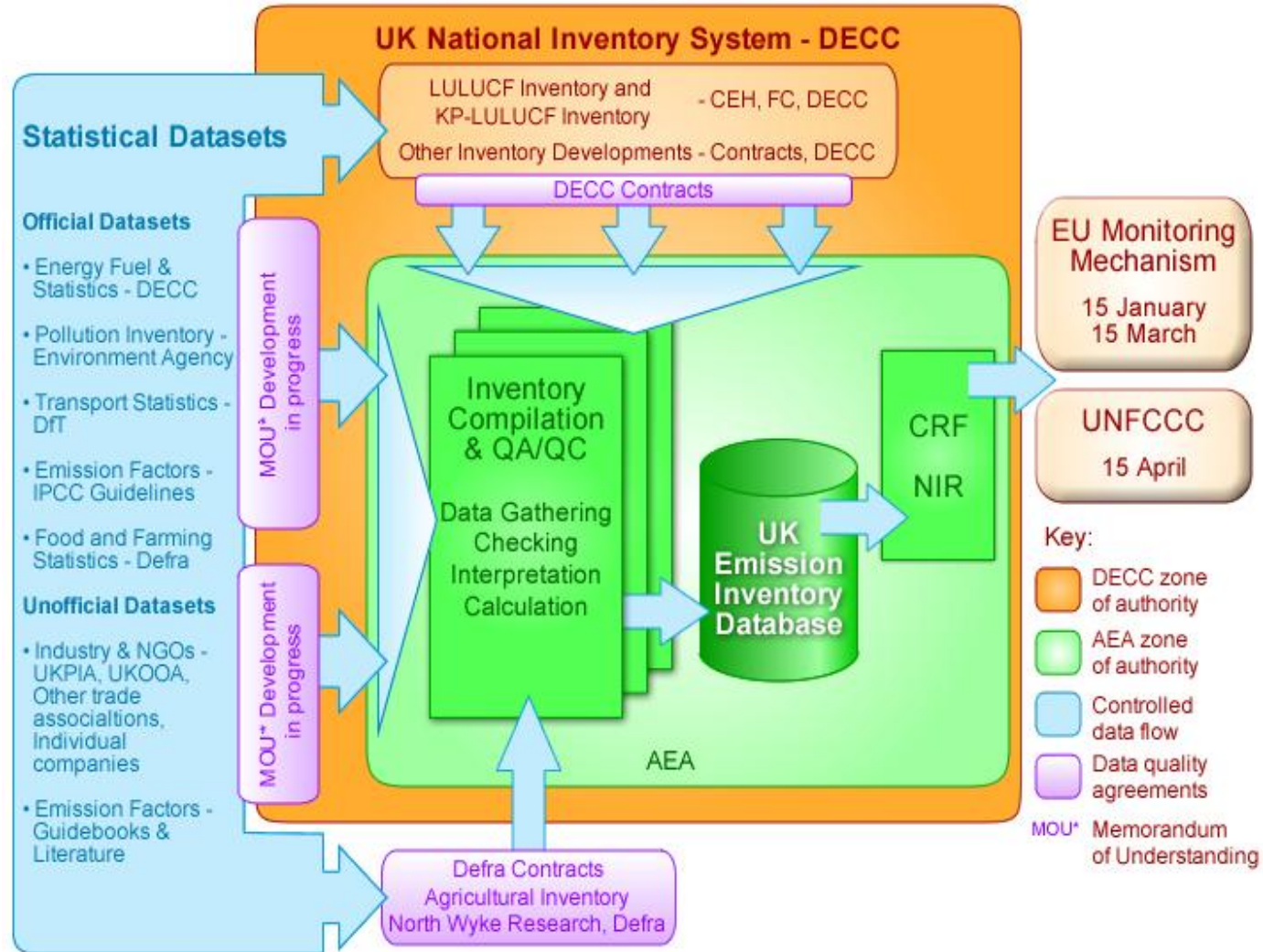
**Figure 1.2    Key organisational structure of the UK National Inventory System**
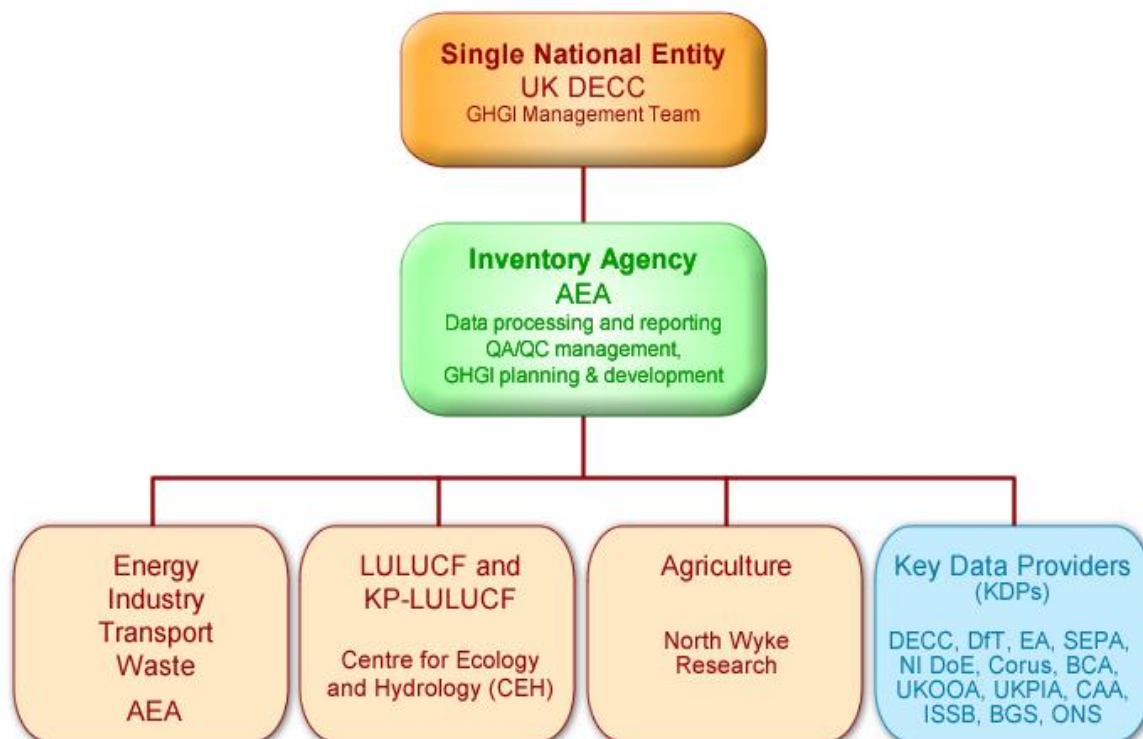


Key Organisations

## 1.2.1.2   Legal Framework

The UK GHGI has been reported annually since 1994, and historically the acquisition of the data required has been based on a mixture of existing environmental and energy legislation and informal arrangements with industry contacts and trade associations.

The legislation relied upon has been set up for other purposes, such as:

- Integrated Pollution Prevention and Control (IPPC) regulations (industrial point source emission data from UK environmental regulatory agencies); and
- Statistics of Trade Act (UK energy statistics from DECC).

Recognising the fact that such a system of data collection might not meet the standards required under the Kyoto Protocol, the UK has introduced new legislation specifically for national inventory purposes which took effect from November 2005[6]. 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

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

includes penalties for failure to comply, and authority for entry to premises to obtain information required or verify information provided.

To ensure that the system works most effectively as it currently stands and to minimise the need for legislative action, DECC is in the process of introducing data supply agreements with relevant organisations to build upon existing relationships with data suppliers. These agreements will formalise the acquisition of data and clarify the main requirements of quality, format, security and timely delivery of data for the national inventory.

## 1.2.2    Overview of inventory planning

As summarised in Section 1.2.1, the UK has designated authorities with clear roles and responsibilities.  The following sections summarise the roles and responsibilities of key stakeholders in the UK NIS.

### 1.2.2.1    Single National Entity – DECC

Since its creation in October 2008, the UK Government Department of Energy and Climate Change (DECC) has been appointed as the Single National Entity for the UK and this has been confirmed in writing to the UN Executive Secretary.  DECC has overall responsibility for the UK Greenhouse Gas Inventory and the UK National System and carries out this function on behalf of Her Majesty's Government and the Devolved Administrations (Wales, Scotland and Northern Ireland).  DECC is responsible for the institutional, legal and procedural arrangements for the national system and for the strategic development of the national inventory.

Within DECC, the Climate, Energy, Science and Analysis (CESA) Division administers this responsibility.  CESA coordinates expertise from across Government and manages research contracts to ensure that the UK Greenhouse Gas Inventory meets international standards set out in the UNFCCC reporting guidelines, the Kyoto Protocol and the IPCC 1996 Guidelines and IPCC Good Practice Guidance.

As the designated Single National Entity for the UK GHG NIS, DECC has the following roles and responsibilities:

*National Inventory System Management & Planning*
- Overall control of the NIS development & function;
- Management of contracts & delivery of GHG inventory; and
- Definition of performance criteria for NIS key organisations.

*Development of Legal & Contractual Infrastructure*
- Review of legal & organisational structure; and
- Implementation of legal instruments and contractual developments as required to meet guidelines.

## 1.2.2.2    Inventory Agency - AEA

AEA under contract to DECC performs the role of Inventory Agency and is responsible for all aspects of national inventory preparation, reporting and quality management.  AEA prepares the national atmospheric emissions inventory (NAEI) which is the core air emissions database from which the greenhouse gas inventory (GHGI) is extracted to ensure consistency in reporting across all air emissions for different reporting purposes (UNFCCC, UNECE etc). Activities include: collecting and processing data from a wide range of sources; selecting appropriate emission factors and estimation methods according to IPCC guidance; compiling the inventory; managing all aspects of inventory QA/QC including QC of raw data and data management tools, documentation and archiving, prioritisation of methodology and raw data improvements; carrying out uncertainty assessments; delivering the NIR (including CRF tables) by deadlines set to the EU Monitoring Mechanism (EUMM) and the UNFCCC on behalf of DECC (formerly Defra); assisting with Article 8 reviews.

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

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

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

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

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

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

North Wyke, under contract to Defra, is responsible for the preparation and development of the agriculture inventory. North Wyke conducts specific research in the agriculture sector and provide finalised GHG emissions data to AEA for inclusion within the UK inventory dataset.

### 1.2.2.3    Key Data Providers and Reference Sources

The organisations that provide the raw data to the UK GHGI include a wide range of Government Departments, non-Departmental public bodies and Government Agencies, private companies and industrial trade associations.

Within the UK GHG National Inventory System, organisations that are Key Data Providers have the following roles and responsibilities:

*Data Quality, Format, Timeliness, Security*
- Delivery of source data in appropriate format and in time for inventory compilation, allowing for all required QA/QC procedures;
- Assessment of their data acquisition, processing & reporting systems, taking regard for QA/QC requirements;
- Identification of any required organisational or legal development and resources to meet more stringent NIS data requirements, notably the security of data provision in the future; and
- Communication with DECC, AEA and their peers / members to help to disseminate information regarding the GHG inventory and National System.

Energy statistics required for compilation of the GHGI are obtained from the Digest of UK Energy Statistics (DUKES).  DUKES is compiled and published annually by UK DECC.

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

a) The Environment Agency's Pollution Inventory for England & Wales;
b) The Scottish Environmental Protection Agency's European Pollution Emissions Register; and
c) The Northern Ireland Department of Environment Inventory of Statutory Releases.

Reporting to these UK inventories for the purposes of environmental regulation is a statutory requirement for industries covered by IPPC.  The data from these inventory sources is also used to quality check data provided voluntarily by companies directly to AEA.

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

The Centre for Ecology and Hydrology (CEH) compiles estimates of emissions and removals from LULUCF using land-use data and information on forestry from the Forestry Commission (a non-departmental public body), Government Departments and from other sources.

### 1.2.2.4    Inventory Development - Roles and Responsibilities & Process for official consideration and approval of the UK GHGI

The national inventory is planned, prepared and managed according to the information provided in the annual National Inventory Report which is submitted to the EUMM and UNFCCC each year.

UN Expert Review Team reports in recent years all indicate that the UK submissions generally conform to international standards, although some of the recommended best practice is not yet established in the UK system, such as the performance of a pre-submission review of inventory data by a review group independent of the main GHG inventory compilation process. This area is currently under consideration by DECC.

To meet the detailed requirements of a National System, as described within the Marrakesh Accords and to address some of the identified gaps in best practice, DECC has established a formal cross-Government Steering Committee tasked with the official consideration and approval of the national inventory prior to submission to the UNFCCC. The role of the Committee is to assist in the review and improvement of the UK inventory and facilitate better communication between inventory stakeholders including Government Departments and Agencies. Special Advisors to the Steering Committee include the Inventory Agency team at AEA, other contractors, plus appropriate sector, legal and economic experts. These experts are responsible for reviewing methodologies, activity data, emission factors and emission estimates at a sectoral level and report their findings and recommendations to the steering committee on a regular basis. The committee is responsible for ensuring that the inventory meets international standards of quality, accuracy and completeness, and is delivered on time each year to the EU Monitoring Mechanism and the UNFCCC.

**Table 1.3** and **Table 1.4** below shows the main organisations engaged in the UK national system, and their roles and responsibilities in relation to the preparation and development of the national inventory. These tables include organisations from the following categories, many of which are classed as key data providers:

- Government Departments;
- Government Agencies (e.g. environmental regulators);
- Industry bodies or associations; and
- Consultants.

The development of the inventory is driven through the National Inventory Steering Committee (NISC). The NISC meet twice a year to discuss the development of the inventory and the prioritisation of tasks. The Key Category Analysis and the uncertainty analysis, as well as recommendations from reviews of the UK GHG inventory are used as guidance to help the members of the NISC make decisions on which improvements are the most important. Key categories with high uncertainty are given priority over non-key categories or categories with a low uncertainty. The official reviews from the UNFCCC are also used to help guide decisions in improvements.

DECC organised a workshop in September 2009 to remind all NISC members of their roles and responsibilities, to encourage them to actively participate in the NISC, and to remind them of the importance their input in the process of inventory review and approval.

**Table 1.3      UK GHG National Inventory Steering Committee**

| Organisation | Role in relation to NISC | Key NISC responsibilities |
|---|---|---|
| DECC<br><br>Climate Energy Science and Analysis | • GHG inventory manager<br>• Manager of GHG research contracts<br>• DECC annual climate change statistics and indicators | • Administer functions of Single National Entity for the UK National Inve<br>• Overall responsibility for inventory development, compilation and reporting;<br>• Manage GHG inventory research contracts<br>• Act as NISC Chair<br>• Ensure that UK GHGI conforms to EU and UN international standards and requirements |
| Defra – Air Quality and Industrial Pollution (AQIP) | • AQ inventory manager<br>• Manager of AQ research contracts | • Ensure that UK AQ inventory conforms to EU and UN international standards and requirements<br>• Overall responsibility for AQ inventory development, compilation and reporting |
| Defra | • Liason between Defra and NISC | • Provide an analytical overview of all relevant Defra sectors<br>• Provide link with Defra climate change mitigation team |
| DECC – National Climate Change | • UK Climate Change Programme<br>• Climate Change Act<br>• Carbon budgets | • Inform NISC of UK programme developments<br>• Explore links between inventory and carbon budgets and potential requirements for either area |
| DECC – National Climate Change, Carbon Markets | • EU ETS<br>• EU ETS Registry<br>• EC Effort Share Decision | • Provide EU ETS fuel use and fuel characterisation datasets for determining industrial fuel use statistics and GHG emission from combustion sources<br>• Provide updates of developments on the Effort Share Decision and EU ETS and any implications for future reporting requirements<br>• Improve links between EU ETS registry and GHG inventory |
| DECC – International Climate Change and Energy (ICCE) | • International negotiations<br>• EUMM<br>• UNFCCC | • Feed international emissions inventory expectations back to the NISC to ensure the UK complies and develops the inventory accordingly<br>• Provide information on future international developments and changes to expectations<br>• Provide advice on the implications of domestic changes to the inventory in an international arena |

| Organisation | Role in relation to NISC | Key NISC responsibilities |
|---|---|---|
| DECC – International Climate Change and Energy (ICCE) – LULUCF | • LULUCF Inventory manager | • Provide LULUCF inventory data that conforms to EU and UNFCCC international standards and requirements<br>• 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<br>• Work with the NISC to ensure highest quality data |
| Defra – Water policy | • Waste water | • To provide water policy expertise to the inventory<br>• To assist in improving waste water data quality |
| Defra – Waste | • Waste | • To provide waste policy expertise to the inventory, including landfill waste<br>• To assist in improving landfill waste data quality |
| DECC – Energy Statistics (DUKES) | • Energy statistics | • Annual publication of Digest of UK Energy Statistics<br>• Providing energy statistics to inform the UK inventory |
| Regulators:<br>• Environment Agency for England and Wales<br>• Scottish Environment Protection Agency<br>• Environment and Heritage Service in Northern Ireland | • Pollution inventory<br>• EU ETS Registry | • Management, compilation, QA/QC and reporting of pollutant emission inventories/registers under IPCC regulations, and EU ETS annual emission reporting<br>• 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<br>• Collate information in annual emission reports for EU ETS |
| DECC<br><br>Offshore Regulator | • Offshore oil & gas | • Providing offshore oil & gas industry (via the trade association, Oil & Gas UK) annual activity and emission data to inform the UK inventory<br>• Regulation of the offshore oil & gas industry, including management of the EEMS reporting system of environmental emissions from that sector |
| Department for Communities and Local Government (CLG) | • Housing statistics<br>• Local Government issues | • Publication of housing statistics each year; coordination of technical requirements of local authorities to assist in action on climate change<br>• Providing housing statistics to inform the UK inventory |

| Organisation | Role in relation to NISC | Key NISC responsibilities |
|---|---|---|
| Department for Transport (DfT) | • Transport | • Publication of transport statistics each year<br>• 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<br>• Review aspects of the UK GHG inventory that correspond to devolved issues, ensuring the integration of local datasets and specific research where appropriate. |
| GHG inventory contractor (AEA | • UK greenhouse gas inventory compilation and development | • Contractor responsible for UK GHG inventory; activity data, methods, emission factors, emissions estimation, reporting and archiving<br>• Deliver annual NIR and CRF submission to the UN and EU<br>• Participate in sectoral expert panels as required |
| Agricultural inventory contractor (North Wyke) | • Agriculture Inventory compilation and development | • Contractor responsible for agriculture inventory; activity data, methods, emission factors and emission estimation<br>• Prepare and develop agricultural inventory and deliver on time for incorporation into nation inventory<br>• 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<br>• Prepare and develop LULUCF inventory of emissions and removals and deliver on time for incorporation into the national inventory<br>• Participate in sectoral expert panels as required |
| DECC – Energy Analysis | • Energy modelling and projections | • Produce UK $CO_2$ projections |

**Table 1.4 Special Advisors to the UK GHG National Inventory Steering Committee[7]**

| Organisation | Role in relation to NISC | Key NISC responsibilities |
|---|---|---|
| Met Office/Bristol University | • Atmospheric measurements and interpretation at Mace Head, Ireland | • Provide atmospheric measurements and interpretation of data collected at Mace Head, for use in inventory data verification<br>• 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, UKOOA, Corus, Electricity Supply Industry, Transco |

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

### 1.2.2.5 Work to improve the accuracy and transparency of the inventory

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

In 2009 DECC reminded the NISC members of their roles and responsibilities, and the NISC reviewed and agreed updated Terms of Reference and membership. The NISC reviewed the Inventory Improvement Programme in 2009, to ensure it established a clear plan for prioritising and driving forward improvements in the UK GHG inventory. The NISC advised and agreed the priority areas for inventory improvement, which are pursued by identified 'leads' for each improvement task.

Both DECC and Defra currently fund research contracts to provide emissions estimates for certain sources such as fluorinated gases, landfill methane and to provide estimates for previously unreported sub-sectors such as methane from abandoned coal mines, included for the first time in the UK's inventory submitted in 2005. The work programme to develop the inventory is guided by the uncertainty analysis (Approach 1 and Approach 2), and is informed by recent scientific developments in areas relevant to the inventory.

DECC initiated an improvement programme in 2008 to increase the accuracy of the historic and projected estimates of F-gas emissions, and to improve the transparency of reporting by speciating the F-gas emissions. A component of this work programme concentrated on improving the accuracy of the HFC emissions. This work is currently undergoing peer review and will be published soon. Work to speciate the F-gas emissions is being progressed through the inventory improvement plan. The first component of this work is now complete, and speciated emissions should be included in the 2011 submission of the UK's GHG inventory.

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

The improvement plan comprises:
1) Restructuring the inventory to improve spatial and temporal disaggregation and incorporation of Tier 2 methodology in those areas where both measurement and activity data are available. Also to allow the inventory to reflect the effect of mitigation strategies (DEFRA project AC0112).
2) Data mining to collate and review existing experimental agricultural data to deliver a set of country specific (Tier 2) emission factors and supporting farm practice data to enable an improved mapping of nitrous oxide and methane emissions for the United Kingdom with an assessment of uncertainty (DEFRA project AC0114).
3) Measurements at field scale of $CH_4$ emissions from enteric fermentation to develop Tier 2 methodology (DEFRA project AC0115).
4) Measurements at field scale of direct $N_2O$ emissions at a range of UK sites to develop new country specific emission factors for inorganic N fertiliser, manure applications

and urine and dung deposition by grazing livestock (EF1, EF3) (DEFRA project AC0116). In addition, measurements of indirect $N_2O$ losses are planned at three sites where drainage is collected and the $N_2O$ loss from leached/drained N is quantified ($EF_5$)

5) Measurements at field scale of $NH_3$ emissions from manure management systems (DEFRA project AC0112).
6) Development of emission factors for $N_2O$ from animal manure management systems from existing data (DEFRA project AC0112).
7) Assessment of the effect of mitigation strategies, specifically the use of nitrification inhibitors and optimising fertiliser timing on $N_2O$ emission from soils

As part of the UK GHGI improvement programme, a detailed review of the GHG inventory data (including estimation methods, source data, emission factors, assumptions) used to prepare the sub-UK Devolved Administration GHG emission inventories was commissioned and reported in summer 2009. This review has led to the implementation of a more comprehensive annual review and improvement programme for the UK and DA inventories, including the recent commissioning of a series of sector-specific studies to target the sources of greatest uncertainty that the review identified. Although the review was aimed at the DA GHG inventories, it has helped to identify areas of research that will also lead to improvements in the UK GHGI.

## 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 Defra. The UK for this purpose comprises England, Wales, Scotland, Northern Ireland, Offshore installations and Gibraltar. The Environment Agency is a Government Agency.

Responsibilities of the Environment Agency include:

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

The relationship between DECC and the Environment Agency will be controlled by a memorandum of understanding.

## 1.3    PROCESS OF INVENTORY PREPARATION

### 1.3.1    GHG Inventory and KP- LULUCF Inventory

The present UK GHG inventory for the period 1990-2008 was compiled in accordance with the IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories (IPCC, 1997a, b, c) and Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000, 2003).  As already highlighted in this Chapter, the KP-LULUCF is prepared by CEH, who also prepare Sector 5 LULUCF emission estimates.

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

**Figure 1.3** outlines the main elements of the data collection system used in the UK inventory. The data acquisition task provides the fundamental activity data from which the GHG inventory is constructed.  Starting in June, requests for data are issued.  A database of contacts is used to track progress of the data acquired.

**Figure 1.3**         Data collection for the UK greenhouse gas inventory
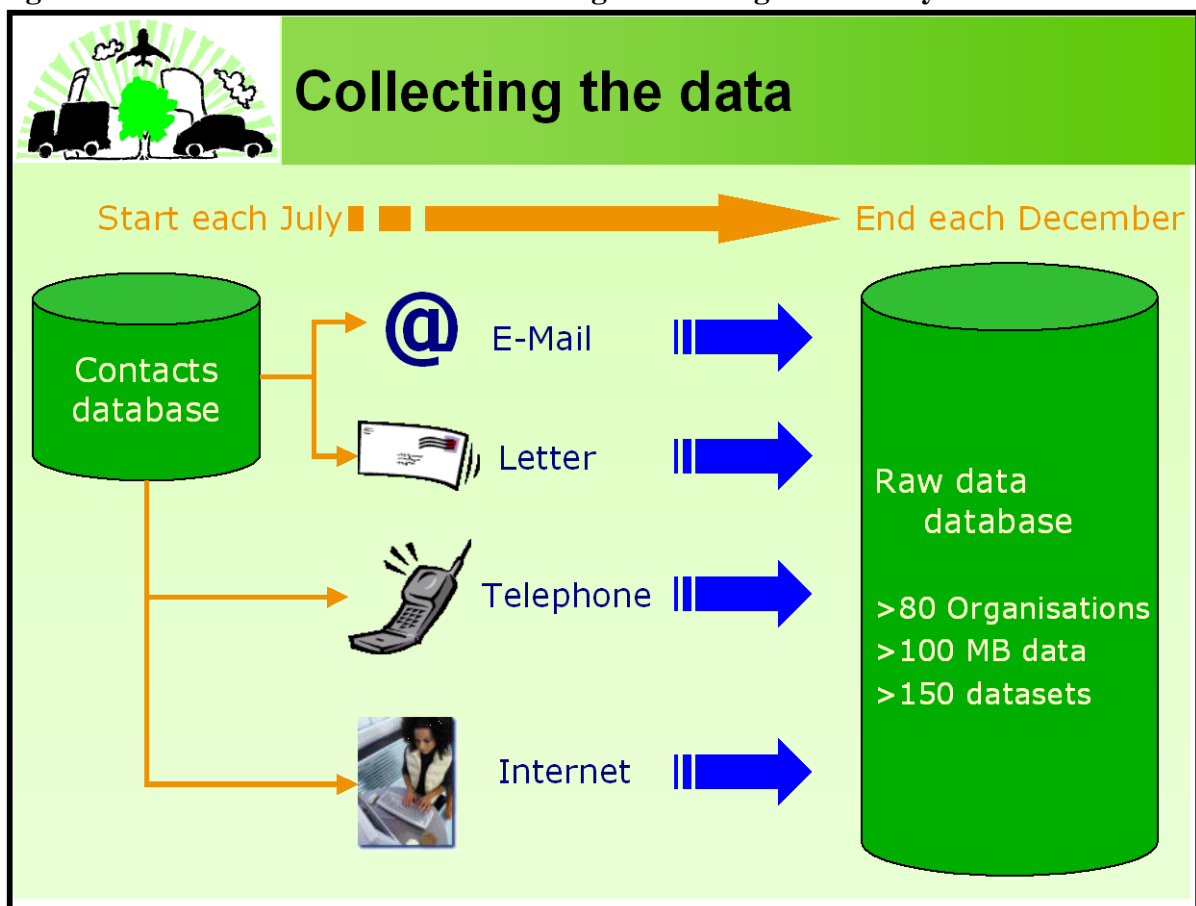


The following activities are carried out each year, in order, as the inventory is compiled, as follows:

- *Method Improvement*

  Improvements to calculation methods are normally implemented before the inventory is compiled. These improvements are in part based on recommendations of UNFCCC (In Depth Reviews, In Country Reviews), peer reviews and relevant research sponsored by Defra or other organisations.

- *Data Request*

  Requests for activity data and background data are issued to a wide range of data suppliers. Each request is issued with a unique code, and a database is used to track the request and the data supplied from that request.

- *Data Verification*

  Activity data received are examined. Anomalies are investigated, such as time series discrepancies, or large changes in values from the previous to the current inventory year.

- *Data Processing*

  Data are prepared to allow emissions of direct and indirect GHG to be estimated.

- *Emission Estimation*

  Provisional emissions are estimated using the most recent activity data available.

- *Emissions Review*

  A series of internal reviews are carried out to detect anomalies in the estimates (time series variations and year to year changes). Errors and omissions are then rectified.

- *Emissions Reporting (including background data)*

  Estimates of emissions are prepared for the various reporting formats (e.g. IPCC, UNECE etc.).

- *Report Generation*

  Draft reports are written to satisfy the reporting criteria of the various agencies, e.g. the IPCC.

- *Report Review*

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

- *Report Publication*

  Final reports and data sets are then submitted and published in print and on publicly available web sites.

- *Data archiving*

  At the end of each inventory cycle, all data, spreadsheets, databases and reports are archived, allowing all data to remain traceable, should it be needed in future years.

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

North Wyke Research and CEH, who are the sector experts for Agriculture and LULUCF (including KP LULUCF), respectively have their own systems in place for data collection. As the Inventory Agency responsible for compiling the overall inventory estimates, AEA receive completed emission estimates from these organisations as part of the annual data collection process.

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

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

## 1.4    METHODOLOGIES AND DATA SOURCES

### 1.4.1    GHG Inventory

The methods used to estimate emissions are described in detail in the relevant sections of this report.  The direct and indirect GHGs reported are estimated using methodologies which mostly correspond to the detailed sectoral Tier 2/3 methods in the IPCC Guidelines.  **Figure** 1.4 below shows the data flow through the UK GHG inventory.

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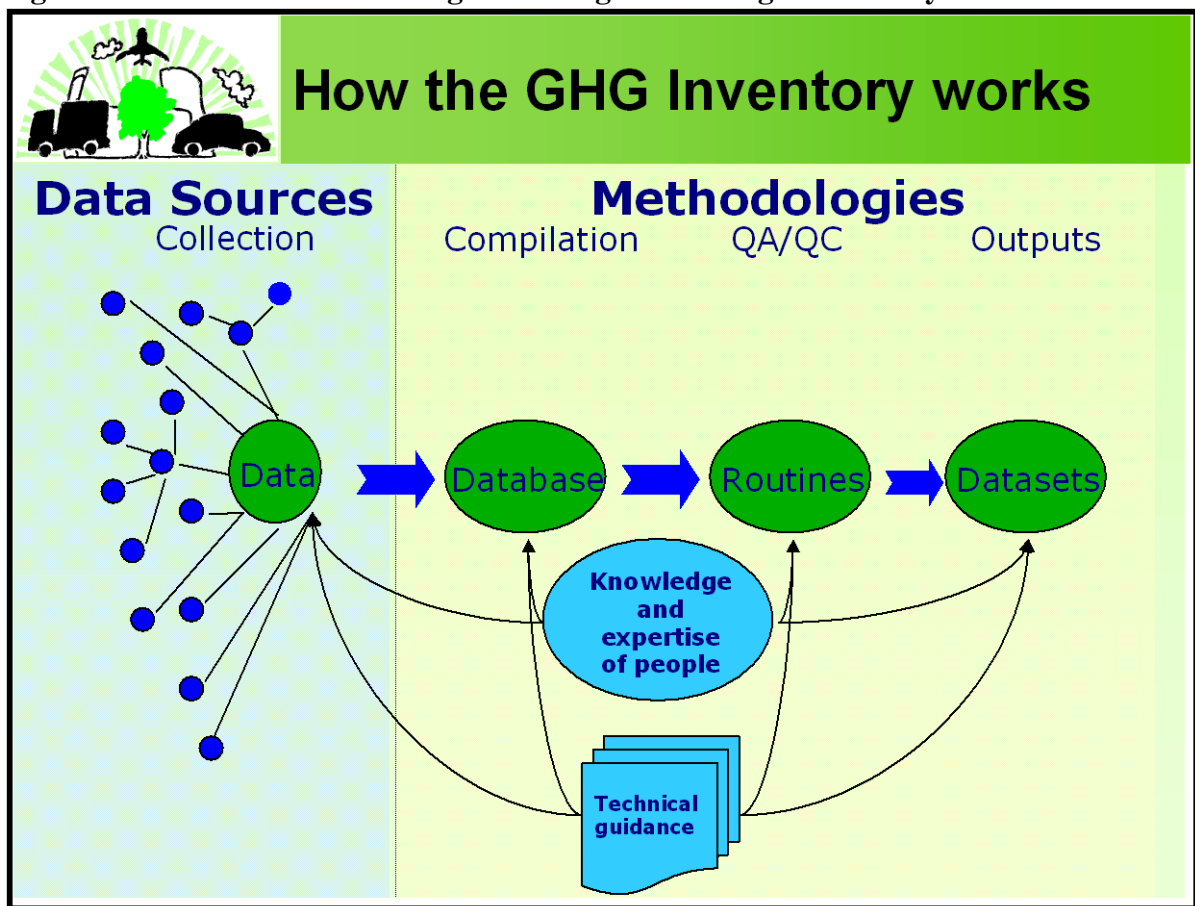


**Table 1.5** provides a brief summary of the methods used to estimate UK GHG emissions, which are described in more detail in the subsequent Chapters and Appendices.

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

| CRF sector | Comments on methods |
|---|---|
| 1A | • Basic combustion module (see **Annex 3**, **Section A3.3.1**); and <br> • Transport model (see **Annex 3**, **Section A3.3.5**). |
| 1B | • Carbon Balance approach (See **Annex 3**, **Section A3.3.8.1.2**); <br> • UKOOA EEMS inventory (See **Annex 3**, **Section A3.3.8.2**); and <br> • Gas leakage data from network operators (See **Annex 3**, **Section A3.3.8.2.6**). |
| 2A | • Cement production: IPCC Tier 2 approach (see **Chapter 4**, **Section 4.2.2**). |
| 2B | • Emissions calculated based on data from industry and the Pollution Inventory; and <br> • Carbon emissions from certain non-energy uses (NEU) of fuel reported here. |
| 2C | • Iron and Steel - 2 stage carbon balance (see Annex 3, Section A3.3.3.3 and A3.4.3.1); and <br> • Spreadsheet model to estimate emissions of F-gases. |
| 2D | • Emissions calculated based on USEPA Compilation of Air Emission Factors; and <br> • Emissions calculated based on Industry and Government data sources. |
| 2E, 2F | • Spreadsheet model to estimate emissions of F-gases. |
| 3A | • (No direct GHGs emitted from this sector). |
| 3B | • (No direct GHGs emitted from this sector). |
| 3C | • (No direct GHGs emitted from this sector). |
| 3D | • (No direct GHGs emitted from this sector). |
| 4A | • Emissions calculated based on animal population data and appropriate Efs. |
| 4B | • Emissions calculated based on animal population data and appropriate Efs. |
| 4D | • IPCC recommended methodology. |
| 4F | • Emissions calculated based on IPCC methodologies and USEPA Efs. |
| 5 | • Spreadsheet model to estimate emissions from LULUCF. |
| 6A | • The new MELmod model. |
| 6B | • IPCC default method and the Hobson model |
| 6C | • Uses country specific emission factors, partially based on Pollution Inventory data. |

The sources of data used are documented in the relevant sections of this NIR though much of the activity data are taken from the key publications listed in Table 1.6. All sources are updated annually.

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

| Source (and publisher) | Relevant activity data contained in the source |
|---|---|
| **Digest of UK Energy Statistics** (UK Department of Energy and Climate Change) | • Energy statistics for the UK (imports, exports, production, consumption, demand) of liquid, solid and gaseous fuels; and <br>• Calorific values of fuels and conversion factors. |
| **Transport Statistics GB** (UK Department for Transport) | • Vehicle km according to vehicle type and road type: <br>• Vehicle licensing statistics (split in vehicle km by fuel type); and <br>• Selected domestic and international civil aviation aircraft km flown. |
| **Northern Ireland Department of the Environment** | • Traffic count and vehicle km data for Northern Ireland; and <br>• Information on regulated processes in NI. |
| **Civil Aviation Authority** | • Detailed domestic and international civil aviation aircraft km flown. |
| **Pollution Inventory** (Environment Agency) | • Information on emissions from regulated processes in England and Wales. |
| **Scottish Environmental Protection Agency** | • Information on regulated processes in Scotland. |
| **United Kingdom Petroleum Industry Association** | • Refinery emissions; <br>• Lead and sulphur contents of fuels, benzene content of petrol, RVP of petrol. |
| **United Kingdom Offshore Operators Association** | • Detailed inventory of oil & gas emissions. |
| **Iron and Steel Statistics Bureau** | • Energy production and consumption in the Iron and Steel industry; and <br>• Other statistics regarding the Iron and Steel industry. |
| **United Kingdom Minerals Yearbook** (British Geological Society) | • Statistical data on minerals production, consumption and trade. |
| **Annual Abstract of Statistics** (Office for National Statistics) | • Population data. |

## 1.4.2     KP- LULUCF inventory

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

## 1.5      DESCRIPTION OF KEY SOURCE CATEGORIES

### 1.5.1      GHG Inventory (including and excluding LULUCF)

Key categories are defined as the sources of emissions that have a significant influence on the inventory as a whole, in terms of the absolute level of the emissions, the trend, or both.  **Table 1.7**, **Table** 1.8**,** and **Table 1.9**, **Table** 1.10 summarise the key source categories, for 2008 (the latest reported year), and the base year, derived from the IPCC Approach 1 uncertainty analysis.  Tables are included for the analysis with and without LULUCF.  Details of the key source category analysis are given in **Annex 1**, including an analysis of key source categories in the base year.  A trend cannot be calculated for the base year alone, and so the tables for the base year only contain key source categories identified by level.

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

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

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

| IPCC source category | Fuel/Activity | GHG | Reason |
|---|---|---|---|
| 4D | Agricultural Soils | $N_2O$ | Level |
| 6A | Solid Waste Disposal | $CH_4$ | Level |
| 1A(stationary) | Oil | $CO_2$ | Level |
| 4B | Manure Management | $N_2O$ | Level |
| 1A1&1A2&1A4&1A5 | Other Combustion | $N_2O$ | Level |
| 2B | Nitric Acid Production | $N_2O$ | Level |
| 5B | 5B LUCF | $CO_2$ | Level |
| 1A3b | Auto Fuel | $CO_2$ | Level |
| 5C | 5C LUCF | $CO_2$ | Level |
| 6B | Wastewater Handling | $N_2O$ | Level |
| 4A | Enteric Fermentation | $CH_4$ | Level |
| 5E | 5E LUCF | $CO_2$ | Level |

| IPCC source category | Fuel/Activity | GHG | Reason |
|---|---|---|---|
| 2B | Adipic Acid Production | N2O | Level |
| 5A | 5A LUCF | $CO_2$ | Level |
| 2 | Industrial Processes | HFC | Level |
| 1A | Coal | $CO_2$ | Level |
| 1B1 | Mining & Solid Fuel Transformation | $CH_4$ | Level |
| 1A3b | Auto Fuel | $N_2O$ | Level |

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

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

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

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

## 1.5.2    KP-LULUCF Inventory

A separate uncertainty analysis has been completed for the Key Categories for Land Use, Land-Use Change and Forestry Activities under the Kyoto Protocol.  The full details of this analysis are given in Table NIR 3, reproduced in **Table A1.2.1** in **Annex 1**.  This analysis

indicates the key categories of emissions and removals are (KP category, gas, associated UNFCCC category):

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

## 1.6 QA/QC PLAN

This section presents the general QA/QC plan for the UK GHGI, including verification and treatment of confidentiality issues. The current system complies with the Tier 1 procedures outlined in the Good Practice Guidance (IPCC, 2000). The system is being developed and the range of activities extended so that the system complies with Tier 2.

Source specific QA/QC details are discussed in the relevant sections of this NIR. Where there is currently insufficient detail available to provide source specific QA/QC, more general information is given in the relevant section of the NIR.

### 1.6.1 Description of the QA/QC current system

The National Atmospheric Emissions Inventory and the UK Greenhouse Gas Inventory are compiled and maintained by AEA, part of AEA Technology plc. The data compilation and reporting for some source sectors of the UK inventory are performed by other contractors (i.e. North Wyke compile the agriculture sector, CEH compile the land use, land use change and forestry sector), but AEA is responsible for co-ordinating inventory-wide QA/QC activities.

UK emission estimates are prepared via a central database of activity data and emission factors, from which the UK emissions are extracted and reported in CRF format. The QC within this system has evolved over many years, and is illustrated in **Figure 1.5** below.

Numerous QA/QC procedures are built into the data processing system. These include checks before data are entered into the national database of GHG emissions, and when data are extracted from the database. The database contains activity data and emission factors for all the sources necessary to construct the UK GHG inventory.

The Inventory has been subject to ISO 9000 since 1994 and is now subject to BS EN ISO 9001:2008. It is audited by Lloyds and the AEA Technology internal QA auditors. The NAEI has been audited favourably by Lloyds on three occasions in the last ten years. The emphasis of these audits was on authorisation of personnel to work on inventories, document control, data tracking and spreadsheet checking, and project management. As part of the Inventory management structure there is a nominated officer responsible for the QA/QC system – *the QA/QC Co-ordinator*. AEA is currently accredited to BS EN ISO 9001:2008, and was last audited in October 2009 by Lloyds.

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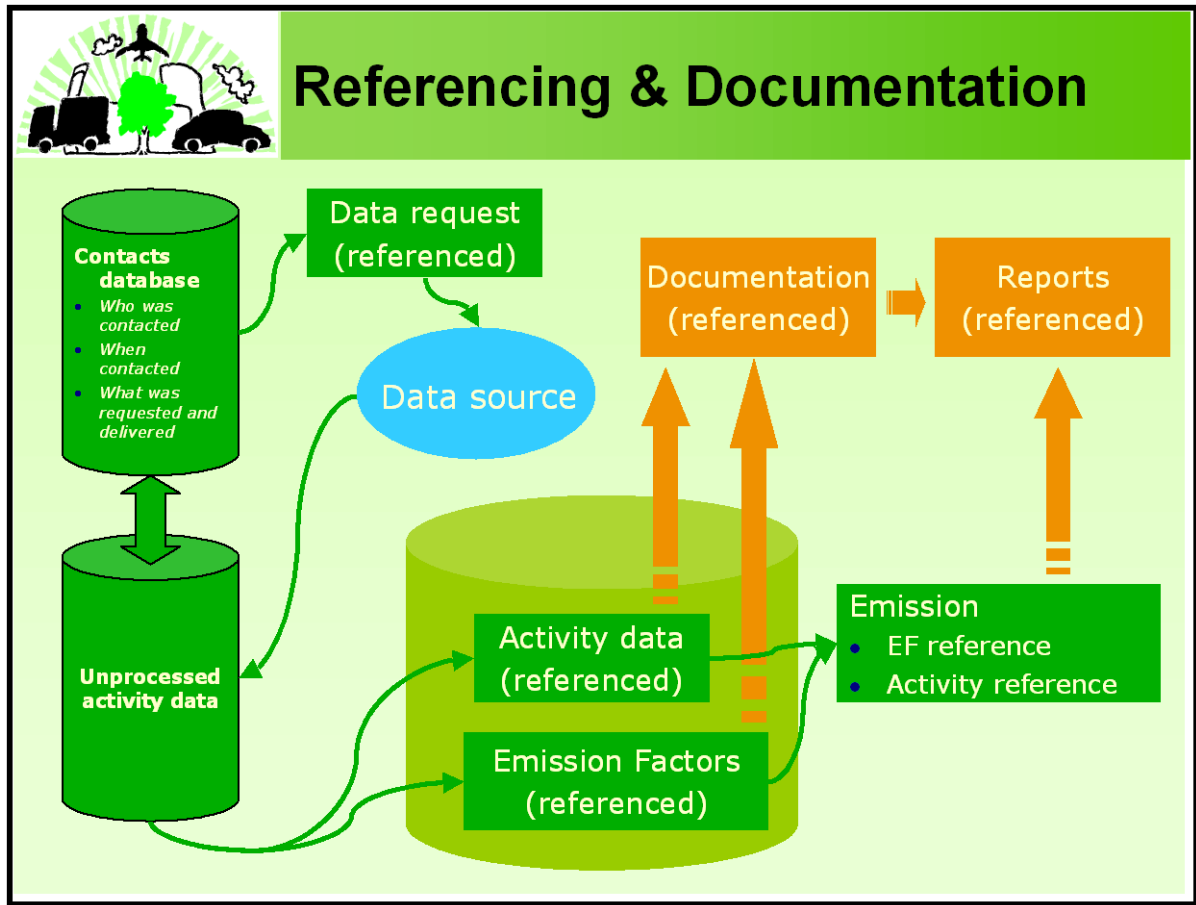


The system incorporates the following activities (see **Figure 1.5**), which are carried out each year as the inventory is compiled:

*1.* ***Documentation***
- Source data received by AEA are logged, numbered and are traceable back to their source from anywhere in the system, using a contacts database, spreadsheet notes and automated system of data referencing within the main NAEI database of activity data and emission factors;

- A database provides the mechanism by which all incoming and outgoing data from the inventory is logged and referenced in a transparent way that enables data flows to be traced back to source from any part of the data pathway. This database provides the central hub for data referencing and archiving and also provides a detailed record of data required for inventory compilation and the data source contacts, thereby ensuring both transparency of inventory data flows and consistency in source data acquisition across inventory cycles;
- Data processing spreadsheets each include a QA sheet in a standard format. This QA sheets provides summary details of source data, data processing activities for each sheet, the scope of activity and emission factor data outputs, relationships with other processing spreadsheets (where inter-dependencies exist), links to

internal consistency checks, plus records of authorship, version control and checking procedures;

- The inventory is held as a database of activity data and emission factors. Within the database these data fields are referenced to both the data source and the spreadsheet used to process source data. The database is populated via an automated system of querying specific spreadsheets, and data may only be uploaded to the database once it meets specified QAQC criteria of data checking, completion and consistency. The automation routines help to minimise potential human data transcription errors, and are also checked as part of the QA system; and

- Annual reports to UNFCCC and UNECE provide full details of inventory estimation methodologies by source sector, and these reports include summaries of key data sources and significant revisions to methods and historic data, where appropriate.

*2. Database*
- A consistency check between IPCC output and CORINAIR formatted output is made;

- Each activity or emission factor data point in the database includes the following information: origin processing sheet, date entered, the person uploading the data (which all ensure traceability and version control), source category, activity category, units (to ensure correct calculation), a code to indicate where there has been a revision from previous inventory versions (which ensures that recalculations of historic data can be easily traced and summarised); and

- Data extracted from the NAEI database and entered into the CRF Reporter tool are finally checked against the direct database output totals to ensure that any inconsistencies are identified and rectified prior to the CRF submission.

*3. Checking*
- AEA's QA/QC system requires that spreadsheet calculations are checked and the checks applied are described. Also the data sources used for calculations must be referenced on the spreadsheet;

- All spreadsheets are subject to second-person checking prior to data uploading to the NAEI database;

- Source data used for calculations are referenced on the spreadsheet QA page with more detailed references (e.g. to a specific table within a referenced publication) noted throughout the processing spreadsheets to ensure transparency of data flows and consistency of inventory compilation;

- Mass balance checks are made to ensure that the total fuel consumptions in the GHG inventory are in accordance with those published in the official UK Energy Statistics from DECC;

- Database output comparisons between different inventory cycles enable the investigation of the effects of recalculations and help identify any data processing errors. A designated auditor identifies sources where there have been significant changes or new sources. Inventory compilers are then required to explain these changes to satisfy the auditor; and

- A final check is made on the inventory comparing the emissions of the latest year with those of the previous year (within the same version), and a complete time-series check is also conducted for selected key sources. A designated checker identifies sources where there have been significant changes. Inventory staff are required to explain these changes in the inventory to satisfy the checker. This is somewhat more detailed than the recalculation explanations required by Table 8 in the CRF, as it is based on the more disaggregated source sectors used in the NAEI database.

*4.* ***Recalculation***
- Where changes are made to inventory estimation methodologies, or where source data are revised or errors in previous inventories identified, then the full time-series of emissions are recalculated. Where this occurs (or where a new source is added to the inventory), the database entries of activity and/or emission factors are labelled with a specific change code as appropriate.

*5.* ***Uncertainties***
- Estimates are made of the uncertainties in the estimates according to Approach 1 (error propagation) and Tier 2 procedures set out in the IPCC GPG; and

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

*6.* ***Archiving***
- At the end of each reporting cycle, all the database files, spreadsheets, on-line manuals, electronic source data, paper source data, output files are in effect frozen and archived. An annual report outlining the methodology of the inventory and data sources is produced. Electronic information is stored on hard disks that are regularly backed up. Paper information is being archived in a Lektreiver® or Roller Racking system and there is a simple database of all items in the archive.

The system outlined in the text above complies with the Approach 1 (error propagation) procedures outlined in Table 8.1 of the Good Practice Guidance (IPCC, 2000). A review of the QA/QC procedures was carried out in 2001 (Salway, 2001) and each year work continues to refine the procedures used.

**Figure 1.6** **Summary of the system of data checks used within the UK greenhouse gas inventory**

(The yellow vertical bars symbolise 'gates' through which data should not pass until the appropriate checks have been performed)
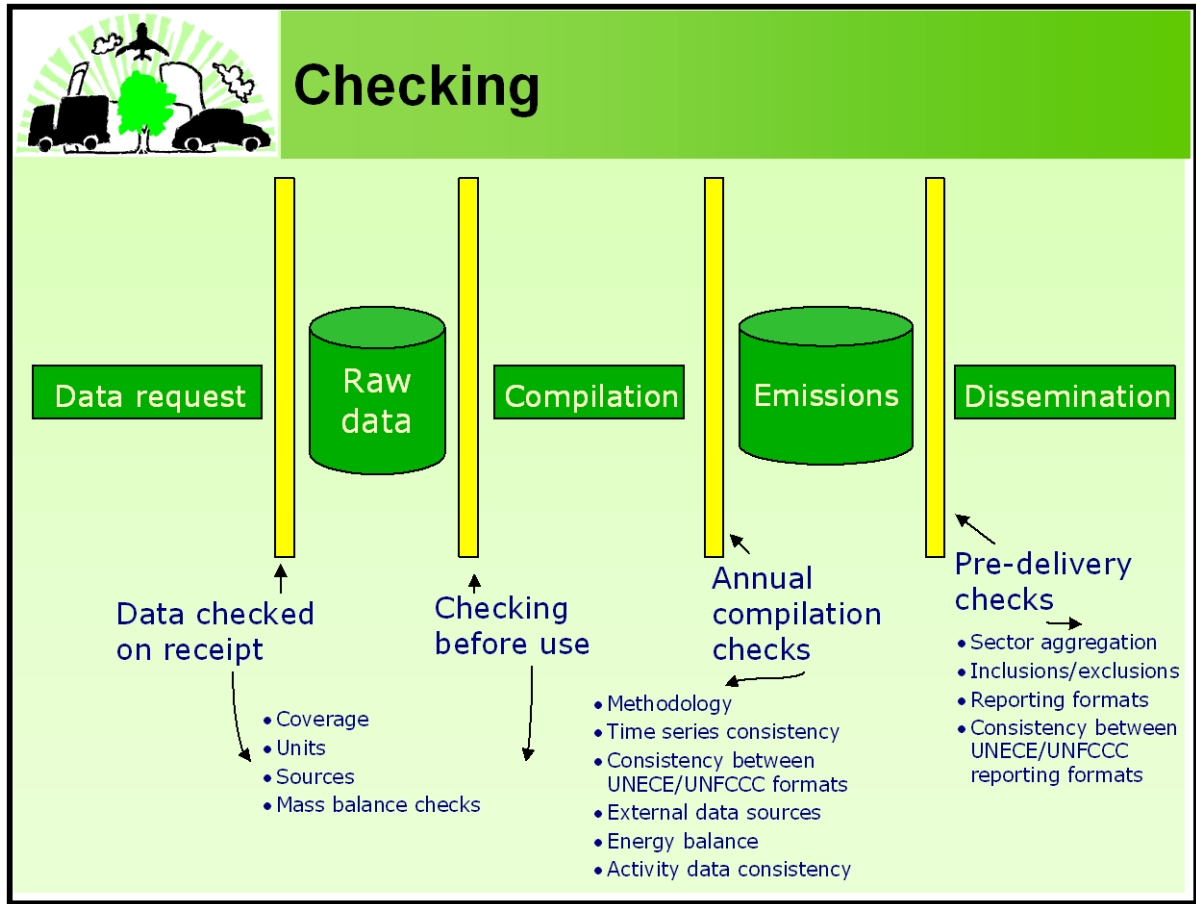


### 1.6.1.1 Special QA/QC activities undertaken in 2009-2010

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

*Stakeholder Consultation with Key Data Providers*
We have continued to have one-to-one meetings or engage in detailed discussions with Key Data Providers to help ensure that the inventory is using the best available data. This programme of stakeholder consultation has included:

- Meeting with natural gas transmission network operators to review processes for gas analysis and local/regional gas consumption data, leakage data and gas quality issues such as methane content.
- Consultation with DECC DUKES and the regulators of the EU ETS data collection and reporting systems to determine sector-specific and fuel-specific quality parameters for the UK, and to resolve any data inconsistencies between published UK energy statistics and the EU ETS data for the latest year.
- Consultation with several stakeholder organisations with the water industry in the UK including OFWAT (independent industry watchdog), Water UK (trade association representing the water companies in the UK) and UKWIR (water industry research

- body) to determine the most appropriate actions for development of improved emission factors for non-$CO_2$ GHG emissions from water sector activities.
- Meetings with sector experts from the environmental regulatory agencies in the UK (EA, SEAP, NIEA) to explore site-specific and sector-wide issues to address source-specific emission factor uncertainties and obtain up to date information regarding site-specific activities, abatement and so on.
- Consultation with the UK refinery trade association to resolve energy data reporting inconsistencies from specific refinery operators.
- Consultation with DECC Oil & Gas to resolve data gaps and inconsistencies within reported EEMS data.

### 1.6.1.2    Future Development of the QA/QC System

The programme of UK inventory improvement was reviewed by the UK GHG Inventory Steering Group Committee in 2009. This programme will again be reviewed in 2010 and inventory QA/QC priorities and improvements will be updated/derived.

### 1.6.1.3    Compliance of National Statistical Agencies

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

### 1.6.1.4    Documentation and Review

The inventory is documented in the National Inventory Report. The NIR describes the methods used to estimate emissions and presents underlying activity and emission factor data. The Good Practice Guidance highlights the need for review of methodologies during inventory compilation. A list collating and prioritising improvements identified by the Inventory Agency, and from Expert and Peer Reviews, is maintained by the Inventory Agency. This information provides a key contribution to the inventory improvement programme, which ensures that improvements to the inventory are implemented as necessary.

### 1.6.1.5    Bilateral reviews, External Peer Review and Internal Reviews

*Bilateral Reviews*

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

The current inventory work-plan includes similar bilateral reviews for other sectors, covering Industry, Transport and Waste. The UK intends to take part in another bilateral review in 2010/2011.

*External Peer Reviews*
Tier 2 of the Good Practice Guidance requires that key sources should be subjected to external peer review. During 2002, the UK implemented a programme of peer reviews by experts outside of the organisation responsible for the estimates. The first peer review on $CO_2$ emissions from fossil fuel has been completed (Simmons, 2002). Recommendations from this Peer Review, which have now been implemented, include: an improved method for estimating emissions from domestic and international civil aviation; a review of the carbon emission factors used in the UK GHG inventory; and a review of the proportion of recycled lubricants burnt.

The second Peer Review on agriculture was carried out in March 2005. The external reviewers were Prof. Ulrich Daemmgen (Institute of Agroecology, Germany) and Ulrike Doering (Federal Environmental Agency, Germany). Both Prof. Ulrich Daemmgenm and Ulrike Doering are internationally recognised experts in the technical area of agriculture. The review team also included the GHG agricultural expert from UK IGER (Lorna Brown) and John Watterson and Chris Dore from AEA (representing the Inventory Agency). The review covered: the methods used to estimate agricultural emissions, including emissions from agricultural soils ($N_2O$), manure management ($N_2O$) and enteric fermentation ($CH_4$); the underlying activity data and emission factors; uncertainties; and the QA/QC of the emission estimates. The recommendations of the review will be used to help improve the accuracy of the emission estimates from the agricultural sector.

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

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

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

## 1.6.2   Verification
Verification is covered as part of the QA/QC checks and by the background research undertaken by DECC. In addition, DECC contributes support and analysis of the continuous high-frequency observations of the Kyoto gases at the Mace Head Atmospheric Research

Station on the Atlantic Ocean coastline of Ireland. The UK Met Office employs the Lagrangian dispersion model NAME (Numerical Atmospheric dispersion Modelling Environment) driven by 3D synoptic meteorology from the Unified Model to sort the observations made at Mace Head into those that represent northern hemisphere baseline air masses and those that represent regionally-polluted air masses arriving from Europe. The Lagrangian dispersion model is then used to estimate the magnitude and spatial distribution of the European emissions that best support the observations. The technique has been applied to 2-yearly rolling subsets of the data.

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

### 1.6.3    Treatment of Confidentiality

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

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

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

## 1.7    GENERAL UNCERTAINTY EVALUATION

### 1.7.1    GHG Inventory

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

Approach 2 (Monte Carlo simulation) suggests that the uncertainty in the combined GWP weighted emissions of all the greenhouse gases is 15% in 1990 and 14% in 2008. The trend in the total GWP weighted emissions expressed as the fall between 1990 and 2008 is -19%, with 95% of the values found to lie within the range -21% to -17%. The source making the major contribution to the overall uncertainty is 4D – Agricultural soils.

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

## 1.7.2      KP – LULUCF Inventory

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

## 1.8      GENERAL ASSESSMENT OF COMPLETENESS

## 1.8.1      GHG Inventory

The UK GHG inventory aims to include all anthropogenic sources of GHGs.  **Annex 5** shows sources of GHGs that are not estimated in the UK GHG inventory, and the reasons for those sources being omitted.

## 1.8.2      KP – LULUCF Inventory

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

# 2 Trends in Greenhouse Gas Emissions

## 2.1 EMISSION TRENDS FOR AGGREGATED GREENHOUSE GAS EMISSIONS

As already described in **Chapter 1**, there are six direct greenhouse gases, each with different global warming potentials.  In 2008, the total direct greenhouse gas net emissions (including LULUCF emissions) in the UK were estimated to be 629.8 Mt $CO_2$ equivalent (based on full UNFCCC coverage).  This was some 19% below the 1990 level.

The following sections summarise the emission trends between 1990-2008 for the aggregated greenhouse gases, both by gas and by source.  Unless otherwise indicated, percentages quoted are relative to net emissions (i.e. emissions including removals from LULUCF).  The geographical coverage used for calculating all figures is full UNFCCC coverage – i.e. UK including Crown Dependencies and Overseas Territories.

The percentage changes presented in this chapter are calculated from emission estimates held at full precision within a database.

## 2.2 EMISSION TRENDS BY GAS

The largest contributor to global warming is carbon dioxide at 85% of the weighted emission.  Methane contributes 8% and nitrous oxide 5%.  In spite of their high GWPs the contribution of halocarbons is small at around 1.9% of the total.  This is because their mass emissions are very small.  Overall the total weighted emission has fallen by 19.0% since 1990.

### 2.2.1 Carbon Dioxide

In 2008, $CO_2$ emissions were 534.7 Mt $CO_2$ equivalent, 10% below the 1990 level.  The trend in $CO_2$ emissions is illustrated in **Figure 2.1,** which shows that the total emissions are dominated by the energy sector, which is the main driver for the declining trend in emission.

**Figure 2.1        UK CO$_2$ Emissions Trend by Source**



Trends in CO$_2$ Emissions By Sector
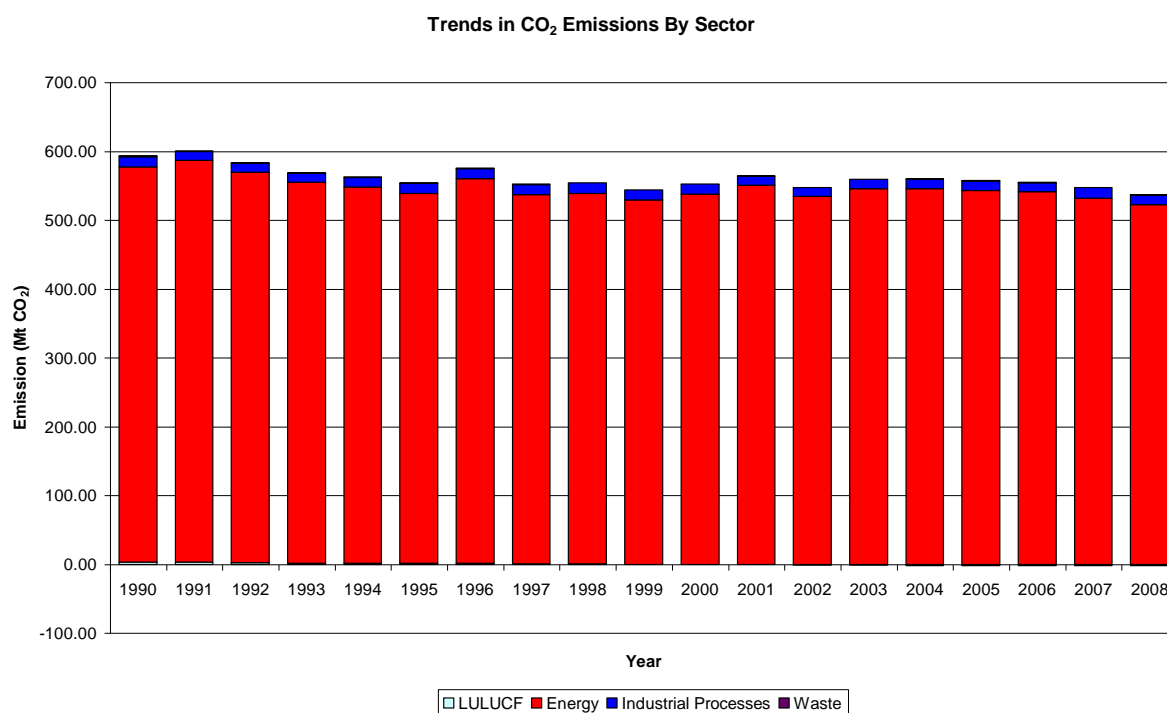
## 2.2.2    Methane

**Figure 2.2** illustrates the trend in emissions of methane, broken down by source.  Methane is the second most significant greenhouse gas in the UK after CO$_2$.  In 2008, methane emissions were 48.9 Mt CO$_2$ equivalent.

Unlike most of the other major pollutants in the Greenhouse Gas Inventory, fuel combustion is not the predominant source of methane.  The major sources are agriculture, waste disposal, leakage from the gas distribution system and coal mining.  Emissions from all these sources have declined since 1990, and the main reasons for these are:

- In the energy sector, reduced coal mining activity, and improvements to the gas distribution network have contributed to an overall decrease in emissions of 70% since 1990.  Decreases in this sector have contributed 40% to the total decrease in methane emissions.
- Total emissions in the waste sector have decreased by 58% due to increased implementation of methane recovery systems at landfill sites. The reduction in emissions in this sector is responsible for 53% of the total decrease in methane emissions since 1990.
- Emissions from agriculture have decreased by 18% since 1990, following the trend of decreasing livestock numbers.

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

**Figure 2.2          UK Trends in CH₄ Emissions by Sector**

**Trends in CH₄ Emissions By Sector**
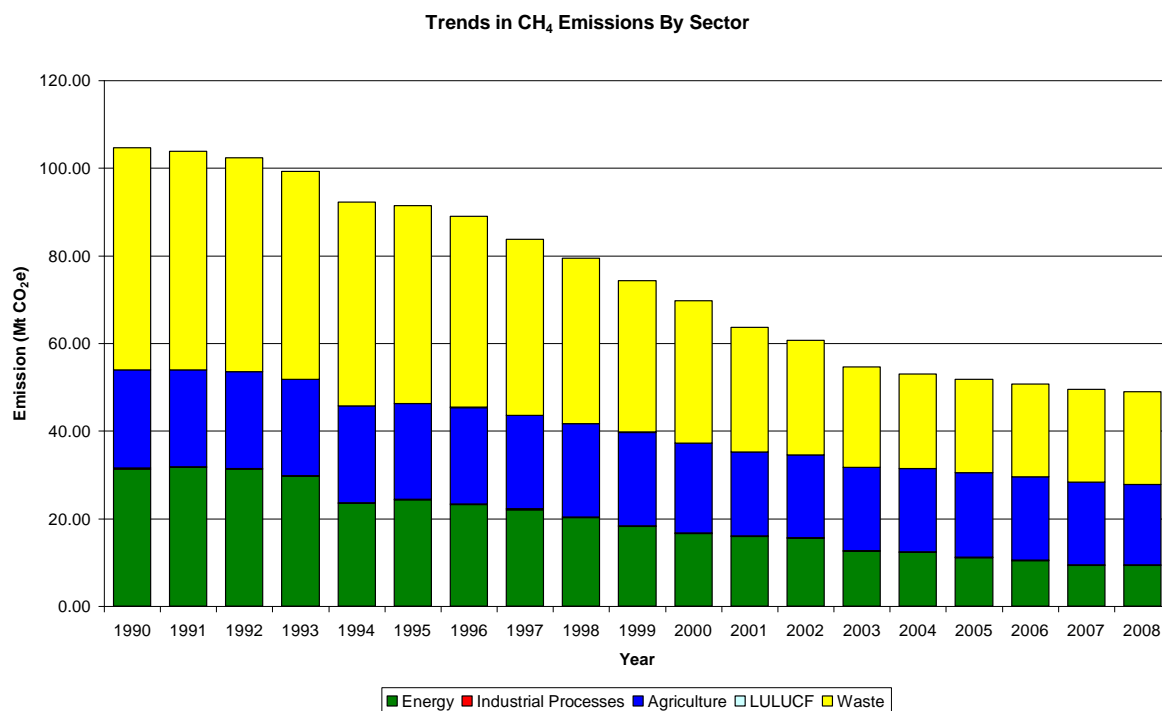


### 2.2.3    Nitrous Oxide

**Figure 2.3** illustrates the trend in emissions of nitrous oxide.  The main anthropogenic sources are agriculture, transport, industrial processes, and coal combustion.  In 2008, emissions of nitrous oxide were 34.0 Mt $CO_2$ equivalent.  Emissions have declined 48% since 1990, and the main reasons for this reduction are:

- The agriculture sector is a major source of $N_2O$ emissions, contributing 75% to total emissions of $N_2O$.  Emissions from this sector have decreased by 23% since 1990, mostly due to a decrease in emissions from sector 4D, agricultural soils, driven by a fall in synthetic fertiliser application.
- Although the total emission is dominated by agriculture, the trend in emissions across the time series is driven by a significant reduction in emissions from Industrial Processes.  In 1990, nitric and adipic acid production were both significant sources of $N_2O$, contributing 38% to total $N_2O$ emissions.  In 2008, these sources accounted for only 7%.  This has been a result of plant closures combined with the installation of abatement equipment at the adipic acid plant in 1998 (the effect of this can be seen in **Figure 2.3**).  Emissions from Industrial Processes have decreased by 90% since 1990, contributing 71% to the total decline in $N_2O$ emissions.
- Fuel combustion is also a significant $N_2O$ source, with total emissions from the energy sector contributing 14% to total $N_2O$ emissions in 2008.  Emissions from this sector have decreased by 22% since 1990.  The most significant sources within this sector are road transport, industrial combustion and power generation.   Both industrial combustion and power generation have shown decreases in emissions since 1990.  Road transport emissions increased steadily from 1990 to 1995 due to the increase in cars with 3-way catalysts in the fleet.  From 2000 onwards, however, emissions from

this source have started to decrease due to the improvements in catalyst technology in newer vehicles.  Emissions in 2008 are now 9% lower than emissions in 1990.

**Figure 2.3       UK Trends in $N_2O$ Emissions by Sector**

Trends in $N_2O$ Emissions By Sector
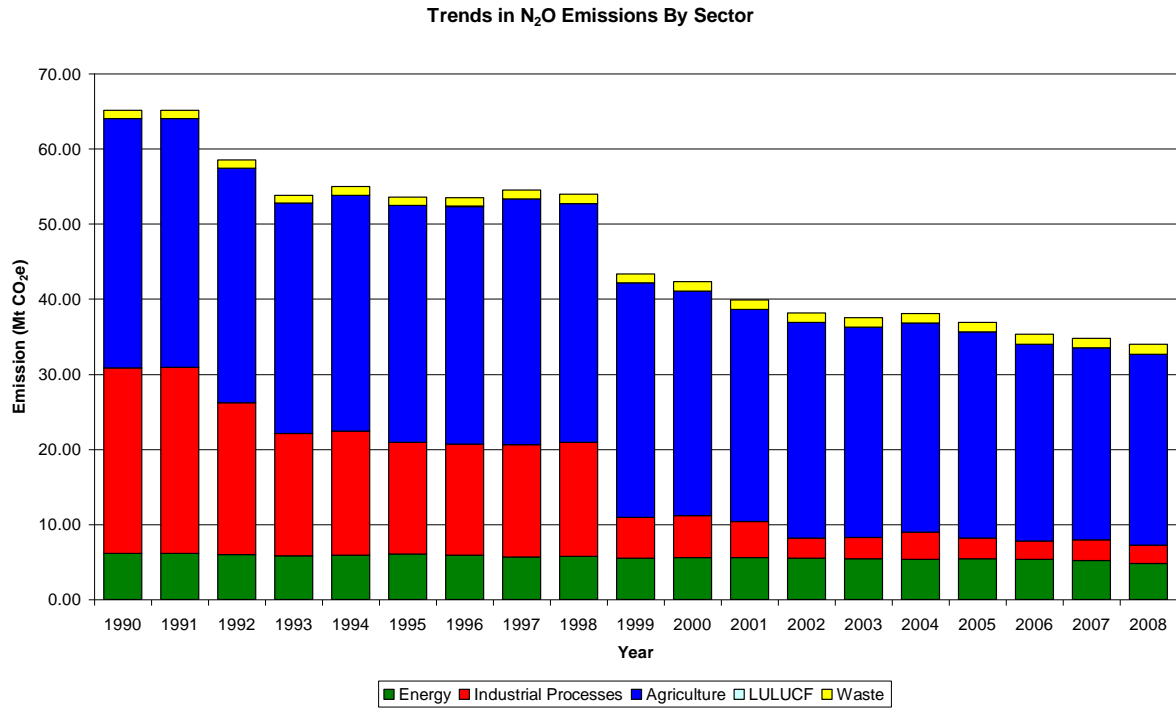


## 2.2.4    Fluorinated-Gases

Emissions of the F-gases (HFCs, PFCs, and $SF_6$) totalled 12.2 Mt $CO_2$ equivalent in 2008. Since 1990 the overall decrease in their emissions has been 12%, due mainly to the fall in emissions from F-Gas manufacture, due to the installation of abatement equipment at two of the three manufacturers.

**Figure 2.4** **UK emissions of F-gases by sector**

Trends in F-Gas Emissions By Sector
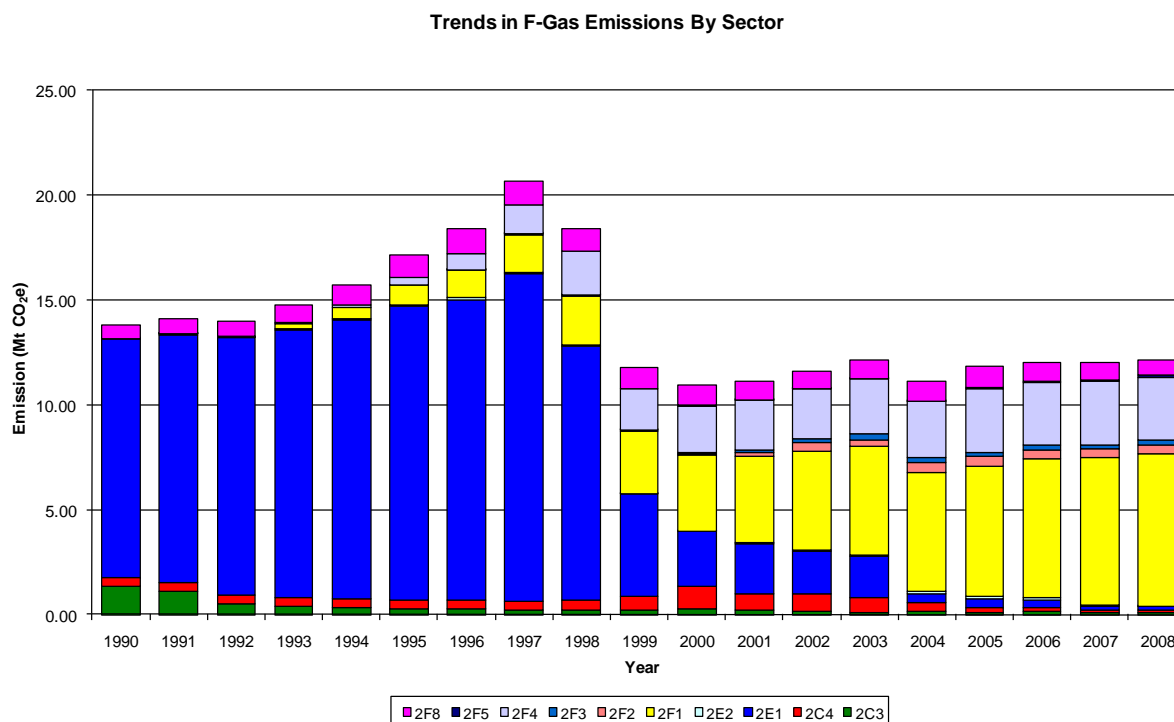


## 2.3 EMISSION TRENDS BY CATEGORY

Total greenhouse gas emissions broken down by sector are shown in Figure 2.6. The largest contribution is from the energy sector, which contributes some 85% to the total emissions. Within this category the largest contributions arise from the energy industries and transport. Category 1A4 (other sectors) and 1A2 (Manufacturing, Industry and construction) also have a significant impact on the emissions of this sector. Energy sector emissions have declined by about 12% since 1990, primarily due to fuel switching to less carbon-intensive energy sources (e.g. coal to gas in the power sector) and reduced energy intensity of the economy.

The next largest contribution comes from the agricultural sector. This contributes approximately 7% to the total emissions. The emissions from this sector have shown an overall decrease of 21% since 1990, reflecting trends in livestock numbers and emissions from fertiliser application.

The industrial processes sector (IPCC Sector 2) contributes 5% to total greenhouse gas emissions. Emissions from this sector include non-energy related emissions from mineral products, chemical industry and metal production as well as emissions from the F-gases. Since 1990, this category has seen a decline in emissions, mostly due to changes in the emissions from the chemical production and metal processing industries.

Land Use, Land-use Change and Forestry contains sinks as well as sources of $CO_2$ emissions. LULUCF has been a net sink since 1999. Emissions from this source occur for $CO_2$, $N_2O$ and $CH_4$.

Emissions from the waste sector contributed 4% to greenhouse gas emission in 2008. Emissions consist of $CO_2$, $N_2O$ and $CH_4$ from waste incineration, and $CH_4$ and $N_2O$ from both solid waste disposal on land and wastewater handling. Overall emissions from the waste sector have decreased by 57% since 1990 and this is mostly due to the implementation of methane recovery systems at UK landfill sites.

## 2.4     EMISSION TRENDS FOR INDIRECT GREENHOUSE GASES AND SO2

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

The main source of $NO_x$ in the UK is fuel combustion. These emissions are complex as the nitrogen can be derived from both the fuel and the combustion air. Emissions also depend on the conditions of combustion, which can vary considerably. In 2008, the total emissions were 1406 Gg, with 99.7% of these emissions arising from the energy sector. Since 1990, emissions have decreased by 49%, mostly as a result of abatement measures on power stations, three-way catalytic converters fitted to cars and stricter emission regulations on trucks.

Carbon monoxide arises from incomplete fuel-combustion. In 2008, the total emissions were 2828 Gg, of which 93% were from the energy sector. Since 1990, emissions of CO have decreased by 69%. Significant reductions are due to the cessation of agricultural stubble burning since 1993.

In 2008, total emissions of NMVOCs were 943 Gg, of which 45% were from the energy sector, with other significant contributions from solvent and other product use and industrial processes. The development of an accurate emission inventory for NMVOCs is complex. The diversity of processes emitting NMVOC is large. Often emissions from sources are small individually, but important collectively. A good example of this is leakage from valves, flanges and other connections in petrochemical plants. Since 1990, overall emissions of NMVOCs have decreased by 63%. This decrease in emissions can, in part, be attributed to the increased use of catalytic converters on cars as well as the switching from petrol to diesel cars. Further reductions have occurred due to control of emissions from most industrial sources of NMVOCs.

Total $SO_2$ emissions in 2008 were 516 Gg. Of this, 94% of emissions were from the energy sector, with the remaining emissions arising from the industrial processes sector and a small proportion from the waste sector. Since 1990, emissions of $SO_2$ from the energy sector have decreased by 87%. The decrease has been as a result of the increase in the proportion of electricity generated in nuclear plant and the use of Combined Cycle Gas Turbine (CCGT)

stations and other gas fired plant, as well as the application of Flue Gas Desulphurisation abatement equipment on several of the largest coal-fired power stations in the UK.

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



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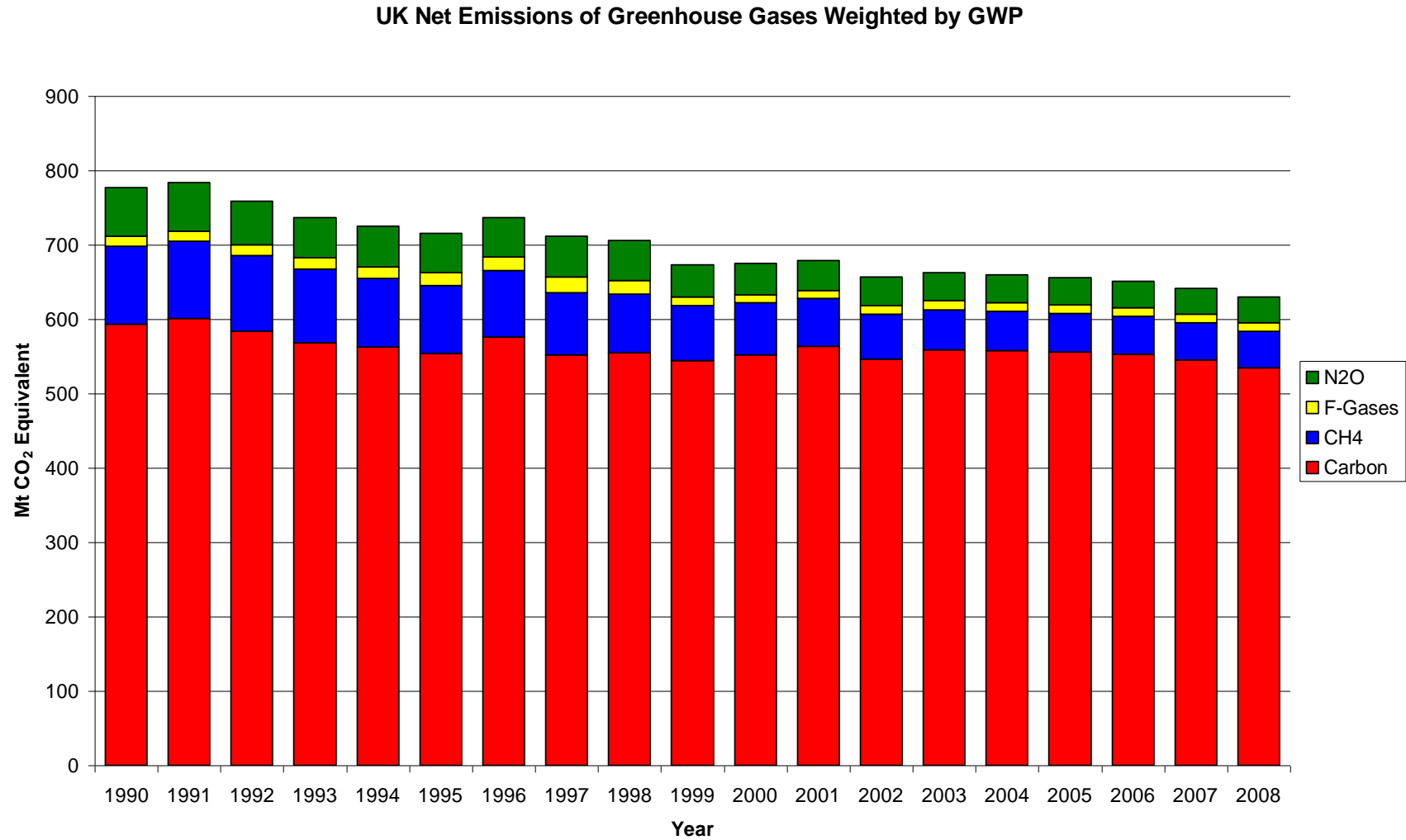
**Figure 2.6** **UK Net Emissions of Greenhouse Gases by Source**



UK Net Emissions of Greenhouse Gases by Source
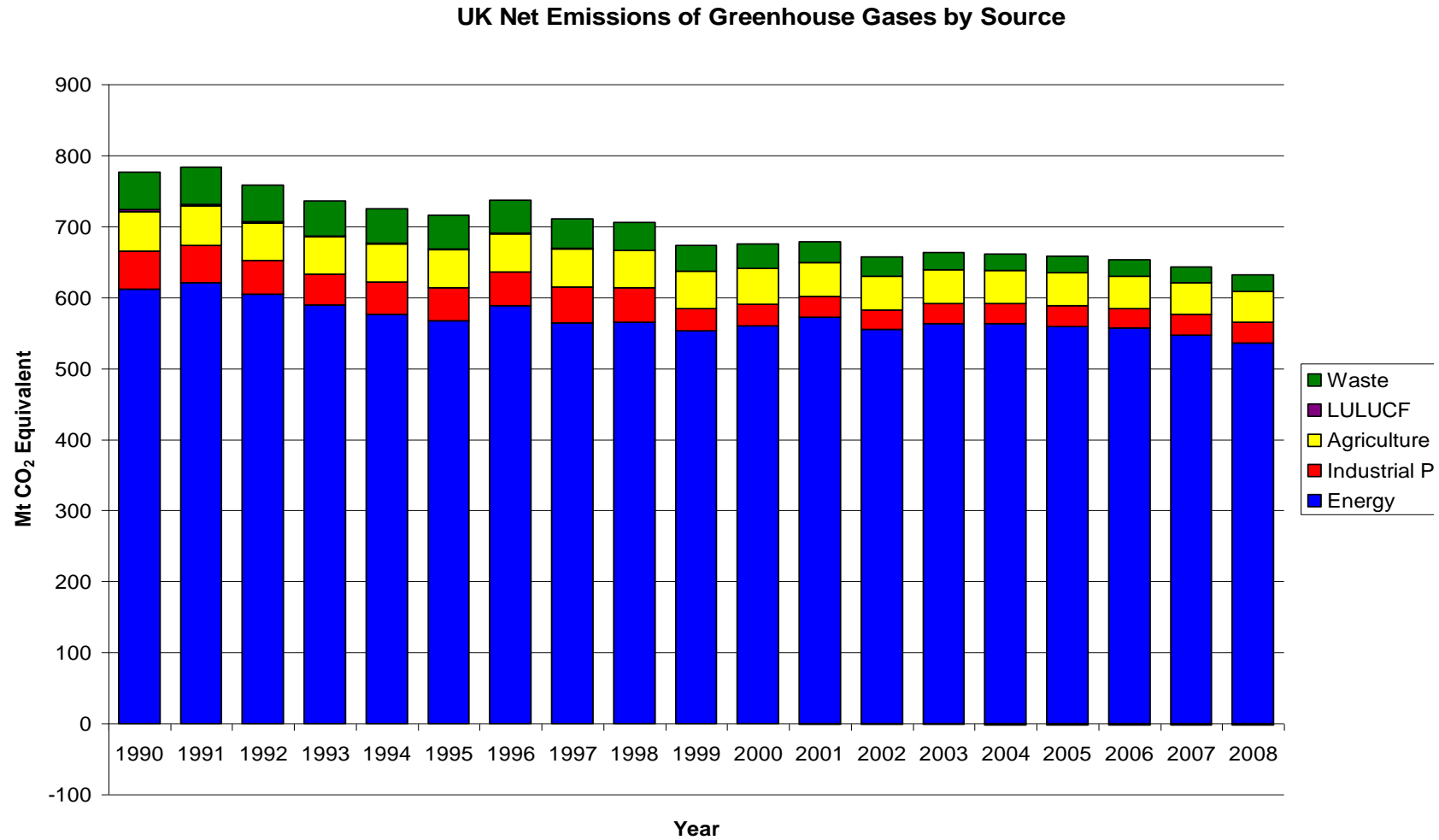
'Solvent and Other Product Use' is not shown in Figure 2.2 as it has zero emissions for all years.

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

**UK Net Emissions of Indirect Greenhouse Gases**
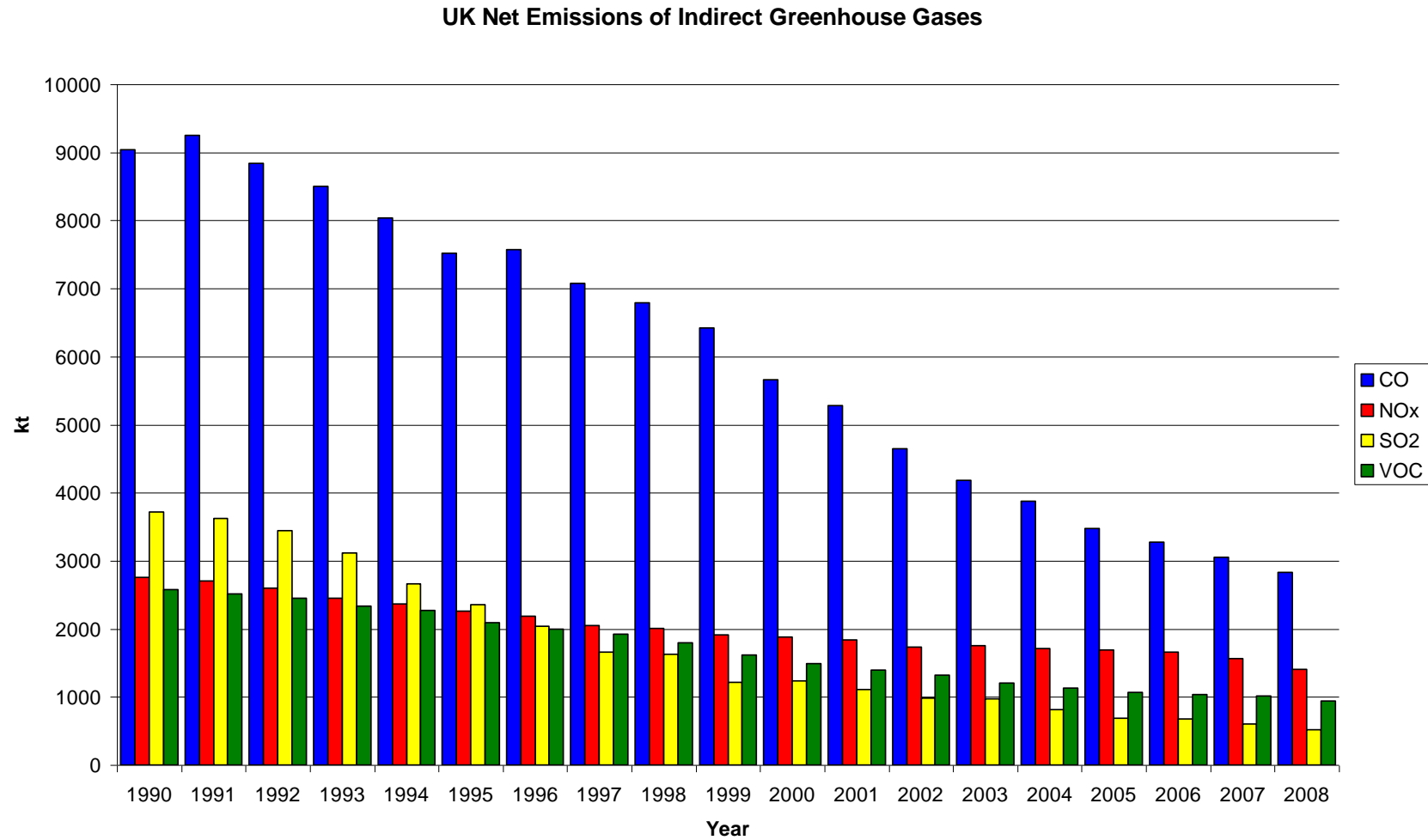
## 2.5 EMISSION TRENDS FOR KP-LULUCF INVENTORY IN AGGREGATE AND BY ACTIVITY, AND BY GAS

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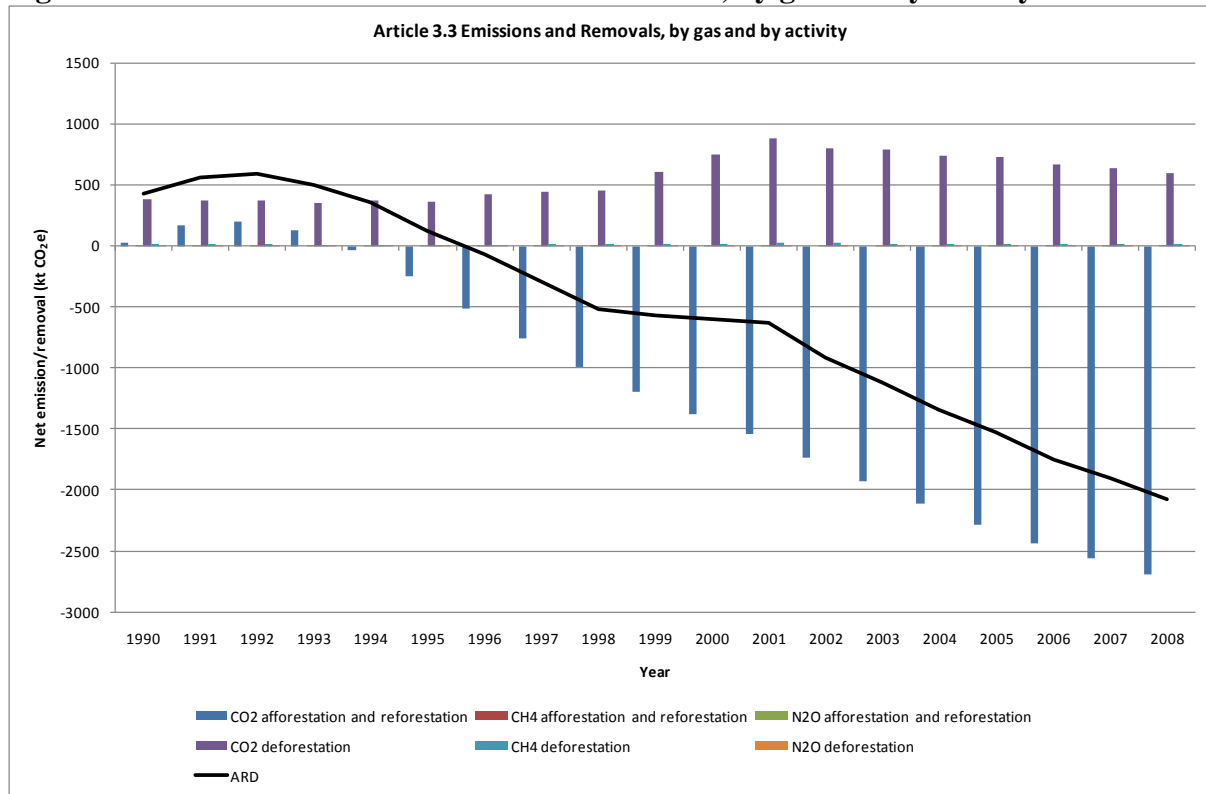


**Figure 2.8** above shows net emissions/removals from afforestation, reforestation and deforestation activities (Article 3.3). These activities were a net source of emissions in 1990, and are now a net sink. The total net emission/removal is dominated by $CO_2$ from afforestation and reforestation.

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



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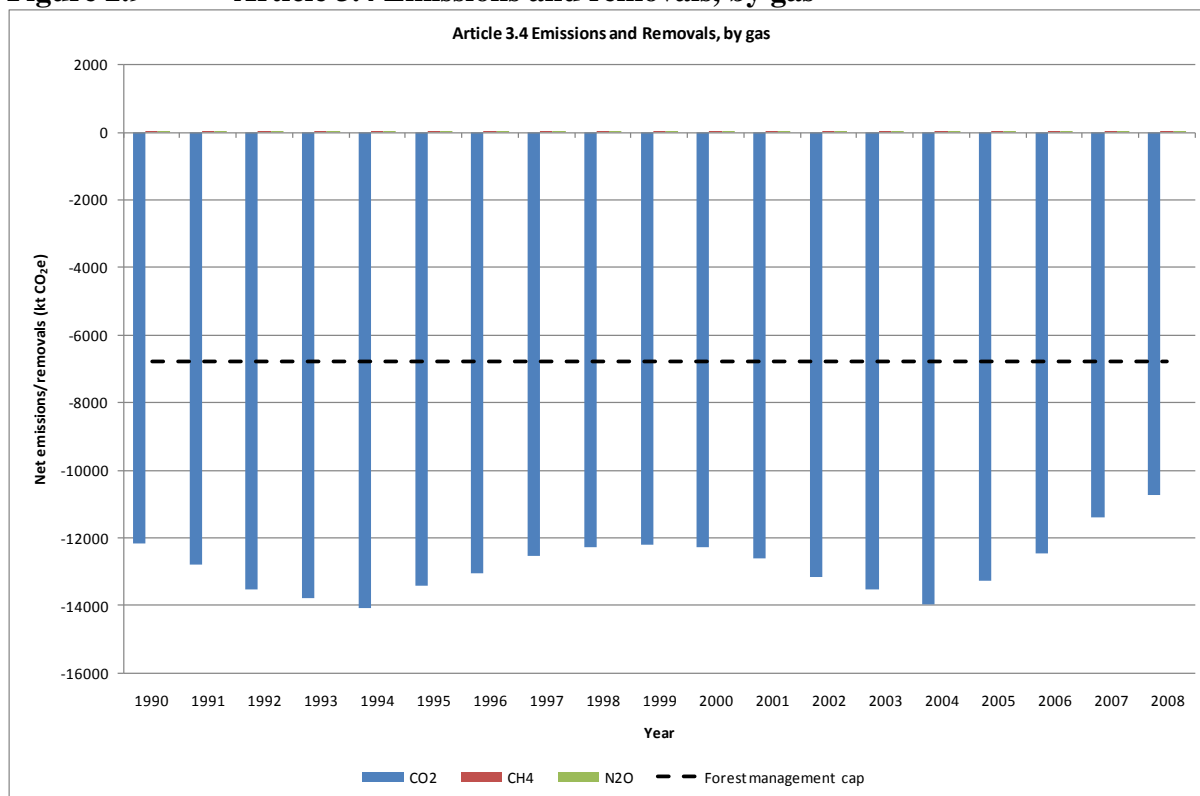
**Figure 2.9** shows the net emissions and removals of greenhouse gases from forest management activities (Article 3.4).  In accordance with the Annex to Decision 16/CMP.1, credits from Forest Management are capped in the first commitment period. For the UK the cap is a relatively modest 0.37 MtC (1.36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

# 3      Energy (CRF Sector 1)

## 3.1      OVERVIEW OF SECTOR

The energy sector is the largest emitter of greenhouse gases in the U.K.  As noted in **Section 2.3**, in 2008, 85% of direct greenhouse gas emissions came from this sector.  Major sources include power stations, road transport, combustion from industrial sources and provision of building services. Fugitive emissions are also accounted for in this sector.  These are emissions that arise from the production, extraction of coal, oil and natural gas, and their storage, processing and distribution.

**Annex 3.3** contains more detailed descriptions of the methods used to estimate emissions in this sector.

## 3.2      FUEL COMBUSTION (CRF 1.A)

### 3.2.1      Comparison of Sectoral and Reference approaches

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

Summary Table 7B includes the IPCC Reference Inventory total for carbon dioxide.  This is a -'top-down'- inventory calculated from national statistics on production, imports, exports and stock changes of fossil fuels.   All other Sectoral Tables report emissions of pollutants estimated using a -'bottom-up'- approach with emissions estimated from activity statistics (mostly fuel consumption) in the various economic sectors and processes.

In principle the IPCC Reference Total can be compared with the IPCC Table 1A Total plus the emissions arising from fuel consumption in 1B1 Solid Fuel Transformation and Table 2 Industrial Processes (Iron and Steel and Ammonia Production).  The IPCC Reference totals range between 1% lower to 3% higher than the comparable bottom up totals, largely because they are based on a different set of statistics.  Reasons for the differences between the two estimates are discussed in **Annex 4**.

Over the period (1990 to 2008), emissions estimated by the Reference Approach have fallen by 7.4% compared with 9.9% for the sectoral approach.  A more detailed discussion of the reasons for this difference is given in **Annex 4**.

A detailed comparison between the IPCC Reference Inventory, the UK Greenhouse Gas Inventory and the UK Inventory based on the IPCC Default Methodology is given by Salway (1998a).

### 3.2.2      International Bunker Fuels (memo item)

International bunker emissions (international aviation and shipping) are not included in the national total but are reported separately.  In 2008, the shipping emission contributed 18% to total bunker emissions, with aviation contributing the remaining 82%.  Since 1990, estimated emissions from international aviation have more than doubled.

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

### 3.2.3    Feedstocks and non-energy use of Fuels
Natural gas is used as a feedstock for the manufacture of ammonia (for fertiliser), methanol and acetic acid.  This process is described in **Section 4.9.1**.

### 3.2.4    Capture and storage of $CO_2$ from Flue gases
Currently in the UK, $CO_2$ emitted from flue gases is not captured and stored.

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

### 3.2.6    Source Category 1A1 – Energy Industries

#### 3.2.6.1    Source Category Description
This source category includes: electricity generation, the use of fossil fuels for petroleum refining, and the production of coke and solid smokeless fuels.

The main fossil fuels used by the UK electricity supply industry are bituminous coal and natural gas.  Approximately 46 Mtonnes of coal were burnt at 17 power stations during 2008, while approximately 11,600 Mtherms of natural gas were consumed at 38 large power stations and 10 small (<50MWth) regional stations (mostly Combined-Cycle Gas Turbines, CCGTs). Heavy fuel oil was the main fuel at 3 large facilities, and gas oil or burning oil was used by 4 large and 13 small power stations.

Bio-fuels are burnt at an increasing number of power generation sites to help electricity generators meet Government targets for renewable energy production. Four established sites use poultry litter as the main fuel, another site burns straw, yet another burns wood, whilst many coal-fired power stations have increased the use of biofuels such as short-rotation coppice to supplement the use of fossil fuels.  $CO_2$ emissions associated with biofuel combustion are estimated and reported as memo items, but not included in national totals. Emissions of other greenhouse gases are estimated and included.  This is in accordance with IPCC advice in the treatment of biofuels.

Electricity is also generated at 22 Energy from Waste plant (EfW) plant in the UK.  Formerly referred to as municipal solid waste (MSW) incinerators, all such plant are now required to be fitted with boilers to raise power and heat, and their emissions are therefore reported under CRF source category 1A1 (electricity generation) and 1A4 (heat generation), rather than 6C (Waste Incineration).  This has been the case since 1997; prior to that year at least some MSW was burnt in older plant without energy recovery.

The UK has 12 oil refineries, 3 of these being small specialist refineries employing simple processes such as distillation to produce solvents or bitumens only.  The remaining 9 complex refineries are much larger and produce a far wider range of products including refinery gases, petrochemical feedstocks, transport fuels, gas oil, fuel oils, lubricants, and petroleum coke. The crude oils processed, refining techniques, and product mix will differ from one refinery to

another and this will influence the level of emissions from the refinery, for example by dictating how much energy is required to process the crude oil.

Most UK coke is produced at coke ovens associated with integrated steelworks, although one independent coke manufacturer also exists.  At the end of 2008, there were four coke ovens at steelworks and one independent coke oven.  A further three coke ovens have closed in the last six years, due to closure of associated steelworks or closure of other coke consumers.  Solid smokeless fuels (SSF) can be manufactured in various ways but only those processes employing thermal techniques are included in the inventory since these give rise to significant emissions.  Currently, there are two sites manufacturing SSF using such processes.

### 3.2.6.2    Methodological Issues

Most emissions are estimated from information such as fuel consumption data and estimates for a particular source sector are calculated by applying an emission factor to an appropriate statistic (see **Annex 3**, **Section A3.3** for details).  This method is applied to estimating emissions from this sector for direct greenhouse gases.  General fuel consumption statistics taken from DUKES (DECC, 2009) are applied to emission factors to give an estimation of the emission.  Some emissions of indirect greenhouse gases are also estimated in this way (see **Table 3.1** for details).

Some alterations are made to the basic fuel consumption statistics available from DUKES.  This is done in order to ensure consistency between the GHGI and fuel usage data reported by certain process operators.  Overall fuel consumption in the GHGI is, however, still consistent with DUKES.

One reallocation concerns oils consumed in power stations.  DUKES reports less fuel burnt by power producers than is reported by operators either directly to AEA or via the EU Emissions Trading Scheme (EUETS).  Therefore fuel oil, gas oil, and burning oil are reallocated from industry to power stations to ensure consistency with operator data.

For some sectors, emissions data are available for individual sites, either from the Environment Agency for England and Wales (EA, 2009), via the Pollution Inventory (PI); from the Scottish Environment Protection Agency (SEPA, 2009), via the Scottish Pollutant Release Inventory (SPRI); or from the Inventory of Statutory Releases (ISR) of the Department of the Environment in Northern Ireland (DOENI, 2009).  In such cases, the emission for a particular sector can be calculated as the sum of the emissions from these point sources.  However, in order to make an estimate of emissions from non-point sources in the sector, an independent estimate of fuel consumption associated with these point sources needs to be made, to ensure no double counting occurs (See **Annex 3**, **Section A3.3**).  This method is applied to emissions of indirect greenhouse gases for sectors as shown in **Table 3.1**.  Detailed tables of emission factors for both direct and indirect greenhouse gases can be found in **Annex 3**, **Tables A3.3.1–A3.3.4** and **A3.3.6**.

Carbon emission factors for coal, fuel oil and natural gas use in power stations and fuel oil use in refineries are based on data reported to the EU Emissions Trading Scheme (EU ETS) for the years 2005-2008.  These data are of high quality, and available for all significant UK plant - some very small power stations e.g. on remote islands will not report to EU ETS but their

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

Data from the EU ETS are also used to estimate carbon emissions from combustion of petroleum coke at refineries. This petroleum coke is in the form of carbon deposits that build up on catalysts used in cracking processes. The deposits must be removed periodically or they reduce the effectiveness of the catalyst, and so a catalyst regeneration section is included in the catalytic cracking unit. The carbon deposits both form and are burnt off in the cracking unit, so quantifying the mass of petroleum coke burnt has relied upon estimation to a greater extent than for other fuels, which can be directly measured. For the years 2005-2008 however, carbon emissions from catalyst regeneration are available from the EU ETS. The emissions are quantified by site operators within EU ETS using either a mass balance approach or, increasingly, by monitoring carbon dioxide emitted in the flue gases from the catalyst regenerator. Data are available for all UK refineries. The carbon emissions available from the EU ETS are not consistent with estimates of petroleum coke consumption given in UK energy statistics, but are used because they are the best data available. This decision was agreed in close consultation with the UK energy statistics team in DECC, as it is a deviation from reported UK energy statistics on refinery petroleum coke use. Before 2005, emissions are calculated using the activity data given in UK energy statistics and the emission factor proposed in Baggott et al, 2004. Further revision of the approach for the earlier part of the time series may be necessary. If further revision is necessary, it will be added to the UK improvements programme list and prioritised accordingly.

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

**Table 3.1      Methods used for deriving emission estimates for direct and indirect greenhouse gases for CRF Source Category 1A1**

| Pollutant | CO$_2$ | CH$_4$ | N$_2$O | CO | NOx | SO$_2$ | NMVOC |
|-----------|--------|--------|--------|----|----|--------|-------|
|           |        |        |        |    |    |        |       |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Power Stations | F | F | F | R | R | R | R |
| MSW incineration | F | F | F | R | R | R | R |
| Refineries | F | F | F | F/R | F/R | F/R | F |
| Coke ovens | F | F | F | F/R | F/R | R | F/R |
| SSF Manufacture | F | F | F | R | R | F | F |

**Key:**

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

### 3.2.6.3    Uncertainties and Time-Series Consistency

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

Most of the core activity data for this source category is derived from the DECC publication the Digest of UK Energy Statistics.  **Section 3.5** provides further general information about the time series consistency of activity data in this publication, and provides more general comments on the approaches used to ensure time series consistency in source category 1A.

Combustion emissions from the NAEI category 'Gas separation plant' are reported under category 1A1c (see **Annex 3**, **Table A3.2.1**).  Background energy data for the calculation of these emissions are taken from the most up to date version of the Digest of UK Energy Statistics.  In the DUKES published in 2002, DECC (formally DTI) stopped collecting the activity data about oil and gas extraction previously used to estimate these emissions. Therefore, for data from 2001 onwards, the amount of propane and ethane has been extrapolated from historical data, as advised through discussions with DECC.

**Table 3.2        Time series consistency of emission factors (EFs) of direct GHGs used in source category 1A1**

| GHGs | Source category | Fuel types | Comments on time series consistency |
|---|---|---|---|
| | | | |
| Carbon | 1A1 | All fuels | • EFs vary somewhat across the time series based on comprehensive carbon factor review in 2004 and EUETS data for some fuels from 2005 onwards<br>• Key sources of carbon EF data include: UKPIA, Association of Electricity Producers, Powertech, Transco, EU-ETS |
| $CH_4$, $N_2O$ | 1A1 | All fuels | • Nearly all EFs are constant over the entire time series, with limited use of time-varying EFs due to fuel variability or technological developments.<br>• Increased availability of data from emissions of combustion of poultry litter has resulted in variable EFs across the time-series for both $CH_4$ and $N_2O$. |

### 3.2.6.4    Source Specific QA/QC and Verification

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

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The core publication for Activity Data is the annual DECC publication *-The Digest of UK Energy Statistics-* which is produced in accordance with QA/QC requirements stipulated within the UK Government's *-National Statistics Code of Practice-* and as such is subject to regular QA audits and reviews.

Where emissions data are provided by plant operators to the UK environmental regulatory agencies (EA, SEPA, DOENI) and reported via their respective inventories of pollutant releases (and then used in the UK's GHG emission inventory) the data is subject to audit and review within established QA systems. Within England & Wales, the operator emission estimates are initially checked & verified locally by their main regulatory contact (Site Inspector), and then passed to a central Pollution Inventory team where further checks are conducted prior to publication. Specific checking procedures include: benchmarking across sectors, time-series consistency checks, checks on estimation methodologies and the use and applicability of emission factors used within calculations. Similar systems are being developed by SEPA and DOENI, with some routine checking procedures already in place.

### 3.2.6.5    Source Specific Re-calculations
The method for estimating emissions from refinery use of petroleum coke has been revised for 2005 onwards.  Due to a lack of suitable data, it is not possible to use the same methodology for previous years, and the existing methodology was therefore retained for those years. Details of the method are given in **Section 3.2.6.2**.

### 3.2.6.6    Recalculation by Gas
The following section describes the main changes that have occurred in sector 1A1 per pollutant since the publication of the 2007 inventory (2009 NIR).  Comparisons are made between the current inventory (1990-2008) and the previous inventory (1990-2007) for the year 2007.

#### 3.2.6.6.1  *Carbon Dioxide (CO$_2$)*
- Overall there has been an increase in estimated emissions for 2007 of 1067 Gg CO$_2$ from sector 1A1.  This has been caused by both energy statistics revisions and emission factor changes.  The more major causes of this increase are described below;
- There has been an increase of 793 Gg CO$_2$ from petroleum coke burnt in refineries due to a revision to the emission factor presented in the EU-ETS data.
- Emissions from natural gas used in power stations have  increased by 471 Gg CO2 due to a revision in the activity statistics reported in DUKES (DECC, 2009).
- There has been an increase of 300 Gg CO$_2$ from OPG in refineries, due to a revision in the activity statistics reported in DUKES (DECC, 2009).
- There has been a decrease of 321 Gg CO$_2$ in estimated emissions from fuel oil use at refineries due to a revision in activity statistics reported in DUKES (DECC, 2009).
- There has been a decrease in the reported fuel use of fuel oil from power stations in DUKES (DECC, 2009), leading to a decrease in estimated emissions of 153 Gg CO$_2$.

#### 3.2.6.6.2  *Methane (CH4)*
- Overall there has been an increase in estimated emissions for 2007 of 0.28 Gg CH$_4$ from sector 1A1, with an increase in the estimated emissions from gas production in 1A1c contributing 0.27Gg CH$_4$ towards this increase.  The increase in estimated

emissions from gas production were due to an increase in the reported use of natural gas for this sector in DUKES (DECC, 2009).

### 3.2.6.6.3 *Nitrous oxide (N2O)*
- Overall there has been an increase in estimated emissions for 2007 of 0.10 Gg $N_2O$ from sector 1A1;
- A major cause of this increase was the revision to petroleum coke fuel usage reported in DUKES (DECC, 2009) for refineries. This cause an increase of 0.09 Gg $N_2O$.
- A revision to natural gas from gas production (reported in DUKES) caused and increase in emission from 1A1c of 0.01 Gg $N_2O$.

### 3.2.6.6.4 *Nitrogen Oxides (NOX)*
- There have been no significant recalculations for this version of the inventory.

### 3.2.6.6.5 *Carbon Monoxide (CO)*
- There has been some re-allocation of  CO emitted by coal-fired power stations from coal (-10 Gg) to petroleum coke (+10 Gg) and liquid bio-fuels (+1 Gg). This is due to updating of the activity data rather than any change in the basic methodology and overall emissions are unchanged.

### 3.2.6.6.6 *Sulphur Dioxide (SO2)*
- There have been no significant recalculations for this version of the inventory.

### 3.2.6.6.7 *Volatile Organic Compounds (VOC)*
- There have been no significant recalculations for this version of the inventory.

## 3.2.6.7  Source Specific Planned Improvements
Emission factors and activity data are kept under review. Fuel characterisation data from verified Emission Trading Scheme datasets will be considered in future GHGI cycles. Further refinement of emission estimates for indirect gases will concentrate on improving the transparency of the methodology used for the years 1990-1996 for minor fuels.

## 3.2.7  Source Category 1A2 – Manufacturing Industries and Construction

## 3.2.7.1  Source Category Description
This source category covers the use of fossil fuels by industrial processes, including the use of fuels to generate electricity in cases where the generation of electricity is not the principal activity of the process operator (autogenerators). The GHGI separately reports emissions from autogenerators, cement clinker manufacture, lime manufacture, and iron & steel processes. Only those iron & steel industry emissions from the use of fossil fuels in boilers and heat treatment or melting furnaces, the use of coke in sinter plant and the use of coke oven gas, blast furnace gas and natural gas in the hot stoves used to heat air for blast furnaces are reported under 1A2. Other sources such as emissions of carbon from basic oxygen furnaces are reported under 2C1. The allocation of activities and emissions between combustion and process source categories for iron and steel and other "contact industries" in the UK GHGI are as consistent as possible with data provided directly from operators (e.g. Corus integrated

steelworks data), UK energy statistics and EU ETS (where process emissions are reported separately from combustion emissions)

Emissions from fuel used by other industrial sectors (e.g. chemicals, non-ferrous metals, food & drink) are reported as 'other industry'.

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

### 3.2.7.2    Methodological Issues

Emissions of direct greenhouse gases are estimated using the principles of the basic combustion model, as described in **Annex 3**, **Section A3.3.1**. The DUKES publication is used to obtain relevant activity statistics, as well as data collected from industry. There are a number of sources of emission factors and these can be found in **Annex 3**, **Tables A3.3.1– A3.3.4**. Methods used to calculate emission estimates for both direct and indirect gases are summarised in **Table 3.3**.

**Table 3.3        Methods for calculation of direct and indirect greenhouse gas emission from 1A2**

| Sector/pollutant | $CO_2$ | $CH_4$ | $N_2O$ | CO | $NO_x$ | $SO_2$ | NMVOC |
|---|---|---|---|---|---|---|---|
| Cement Fuel Combustion | Emission factors and fuel consumption data. | | | No emissions reported. | | | |
| Cement Clinker production | No emissions reported. | | | Emissions data reported by process operators to regulators. | | | |
| Lime Manufacture | Emission factors and fuel consumption data. | | | Emissions data from regulators | | Emission factors and fuel consumption data | |
| Autogenerators[1] | Emission factors and fuel consumption data. | | | | | | |
| Other Industry | Emission factors and fuel consumption data[2.] | | | | | | |
| Sinter Plant | Emission factors and fuel consumption data. | | | Emissions estimates for individual sites provided by process operators. | | | |

[1]For the largest coal fired autogenerator, emissions data from the Pollution Inventory is used for CO, $NO_x$, $SO_2$
[2]Emission estimated for $NO_x$ based on a combination of reported data for large combustion plant and literature based emissions factors and fuel consumption for small plant.

### 3.2.7.3    Uncertainties and Time Series Consistency

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

Most of the core activity data for this source category is derived from the DECC publication the Digest of UK Energy Statistics. **Section 3.5** provides further general information about the time series consistency of activity data in this publication, and provides more general comments on the approaches used to ensure time series consistency in source category 1A.

**Table 3.4** summarises the time series consistency of emission factors used in source category 1A2.

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**Table 3.4**    **Time series consistency of emission factors of direct GHGs used in source category 1A2**

| GHGs | Source category | Fuel types | Comments on time series consistency |
|---|---|---|---|
| Carbon | 1A2 | All fuels | EFs vary somewhat across time series based on comprehensive carbon factor review in 2004, with UKPIA providing new CEF data for many fuels used in this sector. Emission factors for coal use by autogenerators for 2005 to 2008 are now based on EU ETS data. |
| CH$_4$, N$_2$O | 1A2 | All fuels | Nearly all EFs are constant over the entire time series, with limited use of time-varying EFs due to fuel variability or technological developments. |

### 3.2.7.4    Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Allocations of fuel use are primarily derived from DECC publications that are subject to established QA/QC requirements, as required for all UK National Statistics. For specific industry sectors (iron & steel, cement, lime, autogeneration) the quality of these data are also checked by the Inventory Agency through comparison against operator-supplied information and unverified Emission Trading Scheme baseline datasets (covering 1998 to 2003). As discussed above, there have been instances where such information has lead to amendments to fuel allocations reported by DECC (through fuel re-allocations between sectors).

### 3.2.7.5    Source Specific Re-calculations

No source specific recalculations.

### 3.2.7.6    Recalculation by Gas

The following section describes the main changes that have occurred in sector 1A2 per pollutant since the publication of the 2007 inventory (2009 NIR). Comparisons are made between the current inventory (1990-2008) and the previous inventory (1990-2007) for the year 2007.

3.2.7.6.1 *Carbon Dioxide (CO$_2$)*
- Estimated emissions of CO$_2$ from 1A2 have decreased by 279 Gg CO$_2$. The main reasons for this decrease are given below;
- There has been an increase in emissions of 99 Gg CO$_2$ due to a revision to the reported fuel oil use in DUKES (DECC, 2009) in the iron and steel industry, reported in 1A2a.
- There has been an increase of 118 Gg CO2 from coal used in 1A2f. This increase was due to a revision in the reported use of coal in DUKES (DECC, 2009), mainly for autogeneration and other industry.
- There has been a decrease in estimated emissions of 406 Gg CO$_2$ from other industry fuel oil use in 1A2f, due to a revision in the reported statistics in DUKES (DECC, 2009).
- A decrease of 219 Gg CO$_2$ occurred from natural gas usage in 1A2f. This was due to a revision in the reported activity statistics for autogeneration and other industry in DUKES (DECC, 2009).

- There has been an increase of 98 Gg $CO_2$ in emissions from gas oil use in 1A2f, caused by revisions to activity statistics presented in DUKES (DECC, 2009).

### 3.2.7.6.2 *Methane (CH₄)*

- There was an overall increase in emissions of 0.04 Gg $CH_4$. The reasons for this change are given below;
- There was a small revision in fuel oil use for other industry in DUKES (DECC, 2009) which caused a decrease of 0.01 Gg $CH_4$ from 1A2f.
- There were small revisions in activity data for natural gas use in autogeneration, other industry and lime production in 1A2f, causing a decrease of 0.02 Gg $CH_4$.
- There was an increase of 0.05 Gg $CH_4$ in emissions from petrol use in 1A2f sue to revisions in activity statistics and emission factors for off road machinery.
- Due to a change in activity data reported in DUKES (DECC, 2009) for wood used in other industry, emissions from 1A2f increased by 0.03Gg $CH_4$.

### 3.2.7.6.3 *Nitrous Oxide (N₂O)*

- There has been an overall increase of 0.04 Gg $N_2O$ from 1A2. This was mainly caused by revision to emission factors and activity data for gas oil use and coal use in 1A2f.

### 3.2.7.6.4 *Nitrogen Oxides (NOₓ)*

- There have been a series of recalculations to estimated emissions from natural gas combustion by industrial plant due to revisions to emission factors so that the estimates decrease by 5 Gg. Emission factors for combustion of LPG have also been revised, decreasing emissions by 1 Gg.
- Emission estimates for industrial off-road vehicles increase by 13 Gg due to revisions to both the emission factor and activity data.

### 3.2.7.6.5 *Carbon Monoxide (CO)*

- Estimated emissions from industrial combustion of wood have increased by 4 Gg due to use of updated activity data.
- Emission estimates for industrial off-road vehicles increase by 16 Gg due to revisions to both the emission factors and activity data.

### 3.2.7.6.6 *Sulphur Dioxide (SO2)*

- Estimated emissions from industrial combustion of coal have risen by 1 Gg, while emissions from industrial combustion of fuel oil fall by 1 Gg following various minor updates to data.

### 3.2.7.6.7 *Volatile Organic Compounds (VOC)*

- Emission estimates for industrial off-road vehicles increase by 2 Gg due to revisions to both the emission factors and activity data.

## 3.2.7.7 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

## 3.2.8    Source Category 1A3 – Transport

### 3.2.8.1    Source Category Description

This source category reports the emissions of pollutants from transport.  Emissions from aviation, railways, road transport, and shipping are covered by this category.  Aircraft support vehicles are also covered under 1A3e.  Road transport is by far the largest contributor to transport emissions and estimations are made for a wide variety of vehicle types using both petrol and diesel fuel and LPG.

The UK GHGI reports emissions from both stationary and mobile sources for railways. Stationary emissions are reported under category 1A4a.  Mobile emissions, which are reported under 1A3c cover estimates from diesel trains as freight, intercity and regional.

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

Emissions from gaseous fuels are not estimated as no activity data are available and emissions from these sources are believed to be very small.

Emissions of methane and nitrous oxide from LPG use in road transport are not estimated as there are no suitable emission factors available.  Further detail is included in the response to review queries in Chapter 10.  Emissions of methane and $N_2O$ from lubricant use for coastal shipping are not estimated since a suitable emission factor has not been identified, and emissions are believed to be negligible.

### 3.2.8.2    Methodological Issues

The IPCC requires an estimate of emissions from 1A3ai International Aviation and 1A3Aii Domestic to include emissions from the cruise phase of the flight as well as the LTO[8]. Emissions from aviation comprise emissions from the landing and take-off phases and the cruise phase of the flight.  A technique following the IPCC Tier 3 method to estimate emissions and fuel use for civil aircraft in the UK has been developed and is used.   The method estimates emissions from both domestic and international aviation. Details can be found in **Annex 3**, **Section A3.3.5.1.**

Emissions from road transport are calculated either from a combination of total fuel consumption data and fuel properties or from a combination of drive cycle related emission factors and road traffic data.  Details are discussed in **Annex 3**, **Section 3.3.5.3**.

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

Emission estimates for coastal shipping are estimated according to the base combustion module (**Annex 3**, **Section A3.3.1**) using emission factors given in **Table A3.3.1**. For International marine, fuel consumption data are assumed to be the marine bunkers total minus the naval consumption.  Emission factors are used from **Table A3.3.1**

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

### 3.2.8.3    Uncertainties and Time Series Consistency

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

Some of the core activity data for this source category are derived from DECC publication the Digest of UK Energy Statistics. **Section 3.5** provides further general information about the time series consistency of activity data in this publication, and provides more general comments on the approaches used to ensure time series consistency in source category 1A.

Other important sources of activity data are UK Department for Transport publication Transport Statistics Great Britain and fuel consumption data supplied by the Ministry of Defence (Defence Fuels Group). Transport Statistics Great Britain is an established publication and the compilers of the activity data strive to use consistent methods to produce the activity data.

**Table 3.5        Time series consistency of emission factors of direct GHGs used in source category 1A3**

| GHGs | Source category | Fuel types | Time series consistency |
|------|-----------------|------------|-------------------------|
| Carbon | 1A3 | Liquid fuels and gaseous fuels | Time-series of EFs used based on carbon content of UK fuels available for each year from 1990 from UK sources and so appropriate for the UK. |
| $CH_4$, $N_2O$ | 1A3 | Fuel types used in the UK | For road transport and off-road machinery, time varying EFs used appropriate to emission standards in force and age profile of vehicle/machinery fleet. |

### 3.2.8.4    Source Specific QA/QC and Verification

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

### 3.2.8.5    Source Specific Re-calculations

These are detailed in section 3.2.8.6.

### 3.2.8.6    Recalculation by Gas

The following section describes the main changes that have occurred in sector 1A3 per pollutant since the publication of the 2007 inventory. Comparisons are made between the current inventory (1990-2008) and the previous inventory (1990-2007) for the year 2007.

#### 3.2.8.6.1    *Carbon Dioxide (CO2)*

- Emissions from 1A3 Transport have increased overall by 125 Gg $CO_2$, due to changes in estimates for road transport, rail and civil aviation.
- Estimated emissions from category 1A3a Aviation increased by 153 Gg $CO_2$ This was primarily due to improvements in assumptions on thrust settings during take-off and climb-out and a more detailed methodology used in calculating non AMT flights and air-taxi.
- A small change in total road transport emissions is due to revised fuel consumption figures in DUKES, a change in the fuel consumption figures in the Crown

- Dependencies and a change in the estimates of total road fuels used by off-road machinery.
- Although there has been very little overall change in total $CO_2$ emissions from road transport in the UK, there are revisions in the allocation between vehicle types due to revisions in the fuel consumption factors used for different vehicle types, use of new data from DfT on fuel efficiency of local buses and use of a new normalisation technique to reconcile the calculated fuel consumption with fuel sales figures in DUKES.
- Estimated emissions from rail decreased by 71 Gg $CO_2$ due to updated estimates of passenger and freight rail activities reported for 2007 in the National Rail Trends 2008-2009 Yearbook.

### 3.2.8.6.2 *Methane (CH$_4$)*
Among the transport sectors, methane emissions are dominated by road transport. There were significant changes in emissions from individual vehicle types due to the use of new emission factors, but these largely cancelled each other out (increases for buses and motorcycles, decreases in cars) leaving very little overall change.

### 3.2.8.6.3 *Nitrous oxide (N$_2$O)*
Among the transport sectors, $N_2O$ emissions are dominated by road transport. There was a very small (0.08 Gg) decrease in emissions from this sector due to minor changes in the data used to calculated the effect of accumulated mileage on emissions and changes to catalyst failure rate assumptions for cars. Emissions of $N_2O$ from road transport are lower in 2008 compared with 2007 due to increased penetration of lower emitting petrol cars. There were also small decreases in estimates of emissions from rail and from military aircraft and shipping due to revised activity data for these sectors.

### 3.2.8.6.4 *Nitrogen Oxides (NOx)*
Emission estimates for road transport in 2007 increased by 58 Gg. This was mainly due to changes in catalyst failure rate assumptions for petrol cars. Emissions are lower in 2008 than 2007 due to increased penetration of cleaner vehicles.

### 3.2.8.6.5 *Carbon Monoxide (CO)*
Emission estimates for road transport in 2007 increased by 919 Gg due to changes in emission factors for different vehicle types and changes in catalyst failure rate assumptions for petrol cars. Emissions are lower in 2008 than 2007 due to increased penetration of cleaner vehicles.

### 3.2.8.6.6 *Non-Methane Volatile Organic Compounds (NMVOC)*
Emission estimates for road transport in 2007 increased by 63 Gg due to changes in emission factors for different vehicle types and changes in catalyst failure rate assumptions for petrol cars. Emissions are lower in 2008 than 2007 due to increased penetration of cleaner vehicles.

## 3.2.8.7   Source Specific Planned Improvements
Emission factors and activity data are continuously kept under review. If appropriate, fuel characterisation data from verified Emission Trading Scheme datasets will be considered in future GHGI cycles.

## 3.2.9    Source Category 1A4 – Other Sources

### 3.2.9.1    Source Category Description
The emissions that are included in this source category arise from the following sectors:

- *Commercial/Institutional* – emissions from fuel combustion in commercial and institutional buildings;
- *Residential* – emissions from fuel combustion in households; and
- *Agriculture/Forestry/Fishing* – emissions from fuel combustion in these sectors.

Emissions from the burning of municipal solid waste (MSW) to generate heat are reported under CRF source category 1A4. Emissions from stationary railway sources are reported under 1A4a Commercial/Institutional.  Stationary railway sources include emissions from the combustion of burning oil, fuel oil and natural gas used by the railway sector.

### 3.2.9.2    Methodological Issues
A correction has been made for the estimate of consumption of petroleum coke as a fuel by the domestic sector during 2007.

The inventory methodology includes a reallocation of gas oil from the industrial, commercial and public sectors to off-road vehicles and mobile machinery.  However, the GHGI still maintains consistency with the total UK consumption of gas oil/DERV reported in DUKES.

The methodology used for emissions from the burning of MSW to generate heat is identical to that used for burning of MSW to generate electricity (see **Section 3.2.6.2**) and the emission factors are therefore the same.

Emissions of both direct and indirect greenhouse gases for other sources are primarily calculated using national activity data, taken from DUKES, and emission factors. Emissions from off-road mobile sources including agricultural and other machinery are estimated based on recent research by AEA, which includes some minor modifications to fuel use allocations from DUKES. See **Section A.3.3.7** for further details.

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

Most of the core activity data for this source category is derived from the DECC publication the Digest of UK Energy Statistics.  **Section 3.5** provides further general information about the time series consistency of activity data in this publication, and provides more general comments on the approaches used to ensure time series consistency in source category 1A.

**Table 3.6** summarises the time series consistency of emission factors used in source category 1A4.

**Table 3.6**       **Time series consistency of emission factors of direct GHGs used in source category 1A4**

| GHGs | Source category | Fuel types | Comments on time series consistency |
|------|-----------------|------------|-------------------------------------|
| Carbon | 1A4 | All fuels | EFs vary somewhat across time series based on the UK carbon factor review in 2004. |
| $CH_4$, $N_2O$ | 1A4 | All fuels | Nearly all EFs are constant over the entire time series, with limited use of time-varying EFs due to fuel variability or technological developments. |

### 3.2.9.4    Source Specific QA/QC and Verification

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

### 3.2.9.5    Source Specific Re-calculations

Recalculations in this sector are detailed by individual gas below.

### 3.2.9.6    Recalculation by Gas

The following section describes the main changes that have occurred in sector 1A4 per pollutant since the publication of the 2007 inventory (2009 NIR). Comparisons are made between the current inventory (1990-2008) and the previous inventory (1990-2007) for the year 2007.

3.2.9.6.1 *Carbon Dioxide ($CO_2$)*
- Overall $CO_2$ emissions from 1A4 increased by 598 Gg $CO_2$. The main reasons for these changes are highlighted below;
- 1A4a emissions from gas oil decreased by -29 Gg $CO_2$ due to revisions in national energy statistics
- 1A4a emissions from natural gas decreased by -23 Gg $CO_2$ due to revisions in national energy statistics.
- 1A4b emissions from natural gas increased by 582 Gg $CO_2$ due to a change in reported natural gas consumption (DUKES, DECC 2009) for the domestic sector.
- 1A4b emissions from petroleum coke increased by 41 Gg $CO_2$ due to a revision to activity reported in DUKES (DECC, 2009) for the domestic sector.
- 1A4c emissions from gas oil increased by 22 Gg $CO_2$ due to a small revision in statistics reported for gas oil use for agricultural mobile machinery.

3.2.9.6.2 *Methane ($CH_4$)*
- There was an overall increase in emissions from 1A4 of 0.09 Gg $CH_4$. The main reasons for this change are highlighted below;
- There was an increase of 0.06 Gg CH4 from the domestic sector (1A4b). This was caused by an increase in the reported consumption of natural gas in DUKES (DECC, 2009)
- There was an increase in emissions of 0.36 Gg CH4 caused by the burning of peat in the domestic sector.

- There was a decrease in emissions of 0.33 Gg CH4 caused by a revision to the reported usage of wood in the domestic sector (DUKES, DECC 2009).

### 3.2.9.6.3 *Nitrous Oxide (N$_2$O)*
- The overall change in 1A4 was an increase of 0.06 Gg N$_2$O which was due to the revision of the gas oil emission factor used for agricultural mobile machinery

### 3.2.9.6.4 *Nitrogen Oxides (NOx)*
- Emission estimates for gas combustion by the miscellaneous industrial/commercial sector and the public sector each rose by 1 Gg due to minor updates to input data.
- Updated raw data leads to a 3 Gg increase in emissions from agricultural machinery.

### 3.2.9.6.5 *Carbon Monoxide (CO)*
- Changes to estimated emissions of CO from domestic combustion of wood (-6 Gg), peat (+6 Gg) and petroleum coke (+2 Gg) occur as a result of revision to activity estimates.
- A revision to the emission factor for CO from domestic anthracite fires leads to an increase in estimates of 1 Gg.
- Emission estimates for garden equipment decrease by 3 Gg due to revisions to both the emission factors and activity data, while emissions from agricultural equipement increase by 1 Gg.

### 3.2.9.6.6 *Sulphur Dioxide (SO$_2$)*
- Estimated emissions of CO from domestic combustion of petroleum coke increase by 2 Gg as a result of revision to activity estimates.

### 3.2.9.6.7 *Volatile Organic Compounds (VOC)*
- Changes to estimated emissions of VOC from domestic combustion of wood (-2 Gg) and peat (+2 Gg) occur as a result of revision to activity estimates.

## 3.2.9.7   Source Specific Planned Improvements
Emission factors and activity data will be kept under review.

## 3.2.10   Source Category 1A5 – Other

## 3.2.10.1   Source Category Description
This category includes emissions from military aircraft and naval vessels. Both are reported under category 1A5b: mobile emissions.

## 3.2.10.2   Methodological Issues
Methods of estimation for both military aircraft and naval vessel emissions are discussed in the transport section of **Annex 3** (**Section A3.3.5**).

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

Military fuel consumption data are supplied by the Ministry of Defence Fuels Group. The MOD has supplied a time-series of fuel consumption data since 1990 and we believe the time series consistency of the fuel use data is good and was improved in the current version of the inventory by new time-series data provided back to 2003.

**Table 3.7        Time series consistency of emission factors of direct GHGs used in source category 1A5**

| GHGs | Source category | Fuel types | Comments on time series consistency |
|------|-----------------|------------|-------------------------------------|
| Carbon | 1A5 | All fuels | EFs vary somewhat across time series based on the UK carbon factor review in 2004. |
| $CH_4$, $N_2O$ | 1A5 | All fuels | EFs are constant over the entire time series |

### 3.2.10.4   Source Specific QA/QC and Verification
This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

### 3.2.10.5   Source Specific Re-Calculations
Recalculations by gas are described in **Section 3.2.10.6**.

### 3.2.10.6   Recalculation by Gas
Emissions for military aviation and naval shipping were re-calculated using revised fuel consumption data provided by the MoD back to 2003.  This revision caused a decrease in emissions for $CO_2$ of 614 $GgCO_2$.  Methane emissions decreased 0.02 Gg $CH_4$ and nitrous oxide also decreased by 0.02 Gg $N_2O$.

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

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

## 3.3.1      Source category 1B1 – Solid Fuels

### 3.3.1.1   Source Category Description
This source category covers emissions which occur during the production, transportation or use of solid fuels but which are not due to the combustion of those fuels to support of a productive activity.  These emissions will include the release of methane contained within coal and emissions of carbon and organic compounds during the transformation of coal into coke and solid smokeless fuels.  Emissions will also occur from the flaring of any waste gases from coke or SSF manufacture.

### 3.3.1.2    Methodological Issues

Carbon emissions from coke ovens are based on a carbon balance approach (discussed in **Annex 3**, **Section A3.3.8.1.2**) with calculations arranged so that the total carbon emission, plus carbon in products and wastes, corresponds to the carbon content of the input fuels. For process emissions from coke ovens for other pollutants, emissions are estimated either on the basis of total production of coke or the coal consumed. Emission factors are provided in **Annex 3**, **Table A3.3.30**.

Emissions of carbon from Solid Smokeless Fuel (SSF) production are also based on a carbon balance approach, as discussed in **Annex 3**, **Section A3.3.8.1.2**. For other pollutants, estimates are either made based on operators' reported emissions or on production data and emission factors as provided in **Table A3.3.29**.

Methane emissions from closed coal mines are accounted for within Sector 1B1a of the UK inventory, with estimates based on consultation with the author of a recent study funded by Defra (Kershaw, UK Coal, 2007). The original study into closed coal mine emissions was conducted during 2005.

The estimation method for both historic and projected methane emissions from UK coal mines comprised two separate sets of calculations to estimate emissions from (1) coal mines that had been closed for some years, and (2) methane emissions from mines that had recently closed or were forecast to close over 2005 to 2009. The 2005 study derived emission estimates for the years 1990 to 2050 using a relationship between emissions and the quantity of the underlying methane gas within the abandoned mine workings, including site-specific considerations of the most appropriate decay model for the recently closed mines. Consultation with the author has confirmed the actual mine closure programme in the UK and has thus provided updated estimates for 2005 and 2006. More details of the estimation methodology are provided in **Annex 3, Section A3.3.8.1.1.**

### 3.3.1.3    Uncertainties and Time Series Consistency

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

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

**Section 3.5** provides further general information about the time series consistency of activity data in this publication, and provides more general comments on the approaches used to ensure time series consistency in source category 1B.

The time series consistency of emission factors used in this source category is discussed in **Annex 3, Section A3.3.8.1**.

### 3.3.1.4    Source Specific QA/QC and Verification

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

### 3.3.1.5 Source Specific Re-Calculations

There were no significant changes.

### 3.3.1.6 Re-Calculation by Gas

There were no significant changes.

### 3.3.1.7 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

## 3.3.2 Source category 1B2 – Oil and Natural Gas

### 3.3.2.1 Source Category Description

This source category covers emissions which occur during the production, transportation, or use of liquid and gaseous fuels but which are not due to the combustion of those fuels to support a productive activity.

Emissions occur from oil and gas production facilities, gas and oil terminals, gas processing facilities, oil refineries, gas transmission networks, and storage and distribution of petrol.

Oil & gas production facilities are sources of $CO_2$, $CH_4$, CO, $N_2O$, $NO_x$, $SO_2$, and VOC. Organic pollutants are emitted as a result of venting from processes for reasons of safety and from leakages from process plant. Flaring of waste streams gives rise to emissions of all seven pollutants. Most of the UK's oil and gas production occurs offshore but there are a number of mostly small onshore production sites as well.

Offshore oil and gas has to be transported to processing plant and pipelines are used for gas and a proportion of the oil produced. The remaining oil is transferred to shore using marine tankers and emissions of $CH_4$ and VOC occur during loading of oil into the ship's tanks. Some oil transported to shore by pipeline is subsequently reloaded into marine tankers for distribution to refineries and emissions of $CH_4$ and VOC will occur during this loading stage as well. Emissions of VOC occur from storage tanks located at oil terminals.

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

Emissions of carbon, $CH_4$, CO, $N_2O$, $NO_x$, $SO_2$, and VOC occur at refineries due to venting of process plant for reasons of safety, from flaring of waste products, leakages from process plant, evaporation of organic contaminants in refinery wastewater, regeneration of catalysts by burning off carbon fouling, and storage of crude oil, intermediates, and products at refineries.

Petrol distribution begins at refineries where petrol may be loaded into rail or road vehicles. Petrol is distributed to approximately 60 petrol terminals where it is stored prior to loading into road tankers for distribution to petrol stations. At petrol stations it is stored and then dispensed into the fuel tanks of road vehicles. Emissions of VOC occur from each storage stage and from each transfer stage.

Emissions from 1B2bv(i) and (ii) are currently reported as not estimated. Further work is planned during the next inventory cycle to confirm the scope of the gas leakage estimates reported by the network operators, to determine whether leaks at the point of use are included; if such losses are not within the current estimates then separate estimates for emissions under 1B2bv "Other Leakage" will be made in the next inventory.

### 3.3.2.2    Methodological Issues

Emission estimates for the offshore oil & gas industry are based on data provided by the trade organisation, Oil and Gas UK, through their annual emissions reporting mechanism to the UK regulatory agency (the Department of Energy & Climate Change), called the Environmental Emissions Monitoring System (EEMS). This system provides a detailed inventory of point source emissions estimates, based on operator returns for the years 1995-2008. Additional data on $CO_2$ emissions from some offshore combustion processes has become available via the National Allocation Plan and annual operator emission estimates for sites participating in the EU Emission Trading Scheme. In recent years these EU ETS data have been used by operators to update their EEMS emission estimates for combustion processes, ensuring consistency between EEMS and EU ETS, and by the Inventory Agency as a useful Quality Check on time-series consistency of carbon emission factors.

For years prior to 1995 (i.e. pre-EEMS), emission totals are based on an internal Oil and Gas UK summary report produced in 1998. The 1990-1994 detailed estimates are based on (1) total emission estimates and limited activity data (for 1990-1994) from the 1998 UKOOA summary report, and (2) the detailed split of emissions from the 1997 EEMS dataset.

The 1998 UKOOA report presents data from detailed industry studies in 1991 and 1995 to derive emission estimates for 1990 from available operator estimates. Emission estimates for 1991-1994 are then calculated using production-weighted interpolations. Only limited data are available from operators in 1990-1994, and emission totals are only presented in broadly aggregated sectors of: drilling (offshore), production (offshore), loading (offshore) and total emissions onshore. Estimates of the more detailed oil & gas processing source sectors for 1990-1994 are therefore based on applying the fraction of total emissions derived from the 1997 data from EEMS (as gaps and inconsistencies within the 1995 and 1996 datasets indicate that these early years of the EEMS dataset are somewhat unreliable).

Emission estimates for onshore oil and gas terminals are also based on annual emissions data reported by process operators under the EEMS system, regulated by DECC. These onshore sites also report emissions data to the UK environmental regulatory agencies (the Environment Agency of England & Wales and the Scottish Environmental Protection Agency) under IPC/IPPC regulations. Emissions data for Scottish plant are available for 2002 and 2004 onwards, whilst in England & Wales the Pollution Inventory of the EA holds emissions data from industrial plant from around 1995 onwards. For some terminals, occasional data gaps are evident in the EEMS data, most notably for methane and NMVOC emissions from oil loading

activities. In these instances, the emission estimates reported under IPC/IPPC are used to provide an indication of the level of emissions in that year, but the longer time-series of the EEMS data for Scottish sites has led the Inventory Agency to use the EEMS data as the primary data source for these terminals.

For the EEMS reporting cycle for 2006 data, a new online system of operator reporting was implemented by DECC. However, due to teething problems of this new system the operator emissions data provided to the Inventory Agency was incomplete for several sources including drilling and well testing (all activity data and emissions data), onshore loading (missing NMVOC emissions for several sites), onshore fugitive emission sources (missing methane data for some sites), and onshore own gas use data ($CO_2$ emissions for some sites).

In the 2007 and 2008 datasets, many of these problems have been resolved, as the DECC Oil & Gas team of regulators has engaged with several operators to identify and resolve reporting gaps and inconsistencies. One or two non-reporting sites for some sources are still evident, however.

To resolve these data gaps, the Inventory Agency agreed the following actions with DECC (Furneaux, 2009):

- Onshore & offshore loading: Three sites had omitted to report in 2008, and data have been extrapolated from earlier years;
- Onshore Fugitive sources: Several sites had omitted to report the quite minor fugitive emissions data estimates in 2008, and all of these were estimated based on extrapolation of previous data and comparison against PI/SPRI data;
- Onshore Own Gas use, flaring and fugitive emissions: One site had omitted to report in 2008; activity data were obtained and the emission factors from 2007 data used to provide the 2008 emission estimates.
- Direct Process emissions: One offshore site reported emissions that were identified as erroneous by the inventory agency. Consultation with the operator resolved this matter and led to revisions of the 2008 data from EEMS.

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

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

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

There remains a limitation on the transparency and detail of the inventory reporting, as the available information on emission sources does not enable emission estimates from the production of gas to be derived separately from the emissions from the production of oil. There are many sites and processes where production of gas and oil together lead to emissions reported in EEMS, but separate estimates cannot be derived. As a consequence, the emissions from gas exploration (1B2bi) and gas production / processing (1B2bii) are included within the equivalent reporting categories for oil exploration (1B2ai) and oil production / processing (1B2aii). Some progress has been made to allocate sites to "oil " or "gas" upstream exploration and production, via consultation with the DECC Oil & Gas team that regulate the industry and manage the EEMS dataset. More work is needed, however, to complete this process, and this is therefore an item on the UK GHGI improvement plan for consideration by DECC during the next inventory cycle.

Emission estimates for all pollutants from the nine complex UK refineries (see **Section 3.2.1**) are provided annually by the UK Petroleum Industry Association (UKPIA, 2009) and are incorporated directly into the GHGI.  The UKPIA estimates are compiled by the refinery operators using agreed industry standard methods.

Emission estimates from the natural gas distribution network in the UK are provided by the gas network operators: Transco, UKD, Scotia Gas, Northern Gas Networks, Wales and West, Phoenix gas. Natural gas compositional analysis is provided by the gas network operators and emissions of methane and NMVOCs from leaks are included within the inventory. In addition, following a recommendation from the ERT, emissions of $CO_2$ from natural gas leakage are also now included (following the same method as for methane and NMVOCs).  The estimates are derived from industry models that calculate the leakages from:

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

Further work is planned during the next inventory cycle to confirm the scope of the gas leakage estimates reported by the network operators, to determine whether leaks at the point of use are included; if such losses are not within the current estimates then separate estimates for emissions under 1B2bv "Other Leakage" will be made in the next inventory.

Petrol distribution emissions are calculated using petrol sales data taken from the Digest of UK Energy Statistics and emission factors calculated using the UK Institute of Petroleum's protocol on estimation of emissions from petrol distribution.  This protocol requires certain

other data such as average temperatures, Reid Vapour Pressure (RVP) of petrol and details of the level of abatement in place.

Central England Temperature (CET) data, obtained from the Met Office, is used for the temperature data, while UKPIA supply RVP estimates for summer and winter blend petrol and estimates of the level of control are based on statistics given in the Institute of Petroleum's annual petrol retail survey.

For further details on all processes covered under 1B2 including emission factors and detailed methodological descriptions, see **Annex 3**, **Section 3.3.8.2**.

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

The emission estimates for the offshore industry are based on the Oil and Gas UK EEMS dataset for 1995-2008. Emission estimates from 1990-1994 (i.e. pre-EEMS) are estimated from specific Oil and Gas UK studies of 1991 and 1998, using production data as a basis for interpolation of data between 1990 and 1995. The dataset provided in 2009 by DECC and Oil and Gas UK provides a more consistent time-series of data for the range of activities within this sector. However, whilst the EEMS data quality appears to be improving over recent years, the completeness of emissions reported via the EEMS reporting system is still subject to uncertainty as reporting gaps for some sites are still evident. The Inventory Agency continues to work with the regulatory agency, DECC, in the continued development of emission estimates from this sector. Full details are given in **Annex 3 A3.3.8.2**.

### 3.3.2.4    Source Specific QA/QC and Verification
This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Oil and Gas UK provides emission estimation guidance for all operators to assist in the completion of EEMS and EU-ETS returns to the UK environmental regulators, including the provision of appropriate default emission factors for specific activities, where installation-specific factors are not available.

The data gaps & inconsistencies evident within the latest (2008) data submission indicate that there is still some further improvement to the QA/QC of the source data by operators regulators alike, but improvements are evident compared to the 2006 dataset, since the implementation of  a new electronic reporting system for 2007 and 2008 data.

There are inconsistencies evident from oil and gas terminal submissions to different reporting mechanisms. For example different NMVOC and methane emission totals have been reported by terminal operators under IPPC compared to those submitted under the EEMS system. It is unclear whether these reporting inconsistencies are due to a different scope of operator activities being reported via these two systems, or due to operator errors.

DECC have commissioned a study to review the scope of reporting through EEMS and IPPC; this work is ongoing during winter and spring 2010, to reduce uncertainties prior to the next inventory cycle.

### 3.3.2.5    Source Specific Re-Calculations

A number of recalculations have been made due to new data becoming available for 2007 in the oil & gas exploration and production sector, or new estimates based on interpolation and extrapolation of existing data. (See **Section A3.3.8** for details).

### 3.3.2.6    Recalculation by Gas

The following section describes the main changes that have occurred in sector 1B2 per pollutant since the publication of the 2007 inventory. Comparisons are made between the current inventory (1990-2008) and the previous inventory (1990-2007) for the year 2007.

#### 3.3.2.6.1   *Carbon Dioxide (CO$_2$)*

- Total emissions of CO$_2$ from category 1B2 have decreased by 13.9 Gg CO$_2$
- Estimated emissions from category 1B2c (flaring) have decreased by 23 Gg CO$_2$, due primarily to revised estimates from three offshore platforms (Marathon Brae) and two onshore terminals (TOTAL Miller and Frigg), partly offset by a small reported increase from one other onshore terminal (BP CATS).
- This decrease has been partially offset by the inclusion of emissions of CO$_2$ (9.7 Gg CO$_2$) from natural gas leakage, following a recommendation from the ERT. This recalculation affects the whole time series.

#### 3.3.2.6.2   *Methane (CH4)*

- Overall, emissions of methane from category 1B2 have been revised up slightly by 0.6 Gg.
- There has been a small increase in estimated methane emissions from 1B2a of 0.2 Gg, which is due to small increases in emission estimates of methane emitted by process and fugitive sources at one onshore terminal (BP CATS) and three offshore platforms (Marathon Brae);
- Emissions from 1B2c (flaring) increased by 0.21 Gg CH$_4$, due to increased estimates of emissions from one onshore terminal (BP CATS), whilst emissions from 1B2c (venting) also increased by 0.15 Gg CH$_4$ due to increased estimates of emissions from three offshore platforms (Marathon Brae).
- Emissions from 1B2b (natural gas leakage) have been revised up by 0.02 Gg, following the inclusion of leakage data from Northern Ireland.

#### 3.3.2.6.3   *Carbon Monoxide (CO)*

- Very small increases in emissions in 1B2a are due to new reported emissions from one onshore terminal.

#### 3.3.2.6.4   *Non Methane Volatile Organic Compounds (NMVOCs)*

- Emissions from 1B2a have increased by 10.7 Gg, due to revised estimates of emissions from oil loading at three offshore platforms;
- Revisions to emissions from flaring for several sites have led to decreases of 0.55 Gg NMVOC, whilst venting emissions have been revised upwards by a total of 0.17 Gg NMVOC.

### 3.3.2.7    Source Specific Planned Improvements

The significant revisions undertaken through consultation with DECC and Oil & Gas UK in the 1990-2007 inventory compilation cycle helped to resolve a number of errors evident in the dataset; evidence from the 2008 data indicates that some data gaps and inconsistencies remain. In order to address data reporting inconsistencies between the EEMS and IPPC systems, there is ongoing research to compare the reported emissions and the scope of reported activities between the two systems for oil and gas terminals. In addition, some data gaps in 2008 have been filled through extrapolation of historic data, in consultation with DECC, and these sites will be prioritised for further contact during 2010.

## 3.4    GENERAL COMMENTS ON QA/QC

## 3.4.1    DECC Energy Balance Data

DECC provides the majority of the energy statistics required for compilation of the NAEI and the GHGI.  These statistics are obtained from the DECC publication – *The Digest of UK Energy Statistics* – which is produced in accordance with QA/QC requirements stipulated within the UK Government's – *National Statistics Code of Practice (ONS, 2002)* – and as such is subject to regular QA audits and reviews.

DECC include a number of steps to ensure the energy statistics are reliable. At an aggregate level, the energy balances are the key quality check with large statistical differences used to highlight areas for further investigation.  Prior to this, DECC tries to ensure that individual returns are as accurate as possible.  A two-stage process is used to achieve this. Initially the latest data returns are compared with those from previous months or quarters to highlight any anomalies. Where data are seasonal, comparison is also made with corresponding data for the same month or quarter in the previous year.  DECC also uses an energy balance approach to verify that individual returns are sensible.  Any queries are followed up with the reporting companies.  DECC depends on data from a range of companies, and work closely with these reporting companies to ensure returns are completed as accurately as possible and in good time for the annual publications of statistics.

The data collection system used by DECC to collect and calculate sector-specific estimates of the use of petroleum-based fuels has been changed, and since January 2005 a new electronic system of reporting has been introduced.  This development should lead to more consistent returns from petroleum industries, reducing mis-allocations and transcription errors that may have occurred under the previous paper-based system.  Improvements are evident in DUKES 2006 onwards.

## 3.4.2    Industrial Point-Source Emissions Data

Where emissions data are provided by plant operators to the Environment Agency's Pollution Inventory and then used in the UK's GHG emission inventory, the data is subject to audit and review within the Agency's QA procedures.

The operator emission estimates are initially checked & verified locally by their main regulatory contact (Site Inspector), and then passed to a central Pollution Inventory team where further checks are conducted prior to publication. Specific checking procedures

include: benchmarking across sectors, time-series consistency checks, checks on estimation methodologies and the use and applicability of emission factors used within calculations.

Sector-specific guidance regarding estimation of annual emissions by plant operators are under development by the Environment Agency. A rolling programme of guidance publication for different sectors has now been completed, and it is anticipated that this will lead to a gradual improvement of the consistency and accuracy of operator returns to the Pollution Inventory. The development of the SEPA and NI DoE reporting systems is anticipated to adopt these QA/QC mechanisms.

## 3.5 GENERAL COMMENTS ON ENERGY SECTOR TIME SERIES CONSISTENCY

The UK GHG inventory seeks to ensure time series consistency of its emission estimates. In general, the time series consistency of emissions will depend on:

- Consistency in the techniques used to compile activity data;
- Correct choice of source and fuel specific emission factors for each year of the inventory; and
- Consistency in the techniques used to estimate emissions from the activity data and emission factors.

Much of the core activity data for the sources reported in CRF sector 1 (Energy) is derived from the DECC publication the Digest of UK Energy Statistics. This is a long running publication and the compilers of the activity data for DUKES strive to use consistent methods to produce the activity data. This helps to ensure good time series consistency. Revisions of activity data may be made up to two years behind the latest reported year, but such revisions are clearly noted in DUKES and are incorporated into the GHG inventory when the inventory is updated each year. Where activity data other than that presented in DUKES are required for a source category, we have made quantitative and qualitative comments about the quality of the time series if possible.

The emission factors used are typically fuel- and source-specific, and any comments on the time series consistency of the emission factors are made in the sections on uncertainties and time-series consistency in this chapter. Comments are restricted to the emission factors of the direct greenhouse gases.

In nearly all cases in the UK GHGI, a single method is used to estimate a time series of emissions from a specific source category. The technique of splicing two or more methods is rarely used. If a more sophisticated method is used to replace a simpler one, the entire time series of emissions is updated using the new method. Occasionally, there are insufficient data to produce a complete time series of emissions from the chosen method. Here, extrapolations and interpolations, use of surrogate data, and use of constant estimates of emission factors or activity data may be used to provide a complete time series.

The same options can be used when splicing methodologies, and in addition, it may also be necessary to overlap of methodologies (Rypdal *et al.,* 2000).

# 4 Industrial Processes (CRF Sector 2)

## 4.1 OVERVIEW OF SECTOR

UK industry includes many processes that give rise to direct or indirect greenhouse gases. Important sectors include cement and lime production, glass manufacture, steel production, secondary non-ferrous metal production, chemicals manufacture and food and drink manufacture. Primary non-ferrous metal production is now limited to the production of primary aluminium at three sites and the UK paper and pulp industry is relatively small compared with many other Northern European countries.

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

**Annex 3.4** contains more detailed descriptions of the methods used to estimate emissions in this sector.

## 4.2 SOURCE CATEGORY 2A1 – CEMENT PRODUCTION

### 4.2.1 Source Category Description

Cement is produced by grinding a mixture of calcium carbonate ($CaCO_3$), silica, alumina and iron oxides, either in a wet or dry process, and then heating the ground material in a kiln. In the kiln, the calcium carbonate breaks down into calcium oxide (CaO) and carbon dioxide (a process known as calcination). The calcium oxide subsequently reacts with the other raw materials to form clinker. The clinker is cooled and, after addition of other raw materials, ground to make cement.

Emissions of carbon dioxide result both from calcination of the calcium carbonate, but also from fuels burnt to provide the heat for calcination and clinkering. Fuels used include coal, petroleum coke and waste materials plus small quantities of oil. Emissions of $CO_2$ from fuel combustion are reported under CRF source category 1A2f while emissions from calcination are reported under category 2A1.

Fuel combustion also gives rise to emissions of $NO_x$ and $N_2O$ which are reported under 1A2f. Finally, emissions of methane, NMVOC, $SO_2$ and CO also occur, both due to fuel combustion but also due to the evaporation of organic or sulphurous components present in the raw materials. The current GHGI methodology for estimating emissions of these pollutants does not allow emissions from fuels and emissions from raw materials to be quantified separately and so all emissions of these four pollutants are reported under 1A2f.

The UK had 14 sites producing cement clinker during 2008, although 3 sites were closed or mothballed during the year.

## 4.2.2    Methodological Issues

The methodology used for estimating $CO_2$ emissions from calcination is to use data provided by the British Cement Association (2009), which in turn is based on data generated by UK cement clinker producers for the purposes of reporting to the EU Emission Trading Scheme. The data are available for 2005 to 2008 only, and so the value for 2005 has been applied to earlier years as well. Previously, estimates had been based on the IPCC Tier 2 approach (IPCC, 2000), yielding an emission factor of 137.6 t C/kt clinker. The revised emission factors are about 10% higher than this figure and the reasons for this disparity are that the previous emission factor:

- Slightly underestimated the CaO content of clinker produced; and
- Failed to take account of $CO_2$ emitted from dolomite (i.e. the method assumed a zero MgO content, which was not correct).

## 4.2.3    Uncertainties and Time Series Consistency

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

The activity data show a peak production of clinker in 1990, followed by a sharp decline by 1992/1993 (production in 1992 was just 75% of the figure in 1990). Following this slump, production increased again and remained fairly consistent until 2000, after which time production again decreased, with a particularly large decrease between 2007 and 2008. Average production in the years 2001-2008 has been about 90% of the average level during the period 1994-2000. The initial large drop in clinker production can be explained by a sharp drop in construction activity and hence a decline in the need for cement (confirmed by statistics available for the construction industry). The less pronounced decline in production over the period 1994-2007 may, in part, be due to increased use of slag cement, the production of which is likely to have risen sharply over the same period. The sharp decrease in production in 2008 is linked to the recession, which caused a decline in construction and therefore demands for cement. A number of cement kilns were closed or mothballed during 2008, and further closures occurred in 2009.

## 4.2.4    Source Specific QA/QC and Verification

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

## 4.2.5    Source Specific Re-Calculations

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

## 4.2.6    Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

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## 4.3    SOURCE CATEGORY 2A2 – LIME PRODUCTION

### 4.3.1    Source Category Description

Lime (CaO) is manufactured by the calcination of limestone ($CaCO_3$) and dolomite ($CaCO_3MgCO_3$) in kilns fired by coal, coke or gas.  The calcination results in the evolution of carbon dioxide.

It is necessary to distinguish between processes where lime is produced for use off-site and where carbon dioxide is emitted to atmosphere, and those processes where lime is produced so that the carbon dioxide and lime can be used on-site in the process.  In these processes, which include sugar refining and the production of sodium carbonate using the Solvay process, most of the carbon dioxide is not emitted to atmosphere.

Lime was produced at 14 UK sites during 2008.  Two of these produce lime for use on-site in the Solvay process and four produce lime for use on-site in sugar manufacturing.

### 4.3.2    Methodological Issues

The UK bases estimation of lime production on limestone and dolomite consumption data, which are readily available (British Geological Survey, 2009).  The use of consumption data rather than production data is simpler and probably more reliable since it is not necessary to consider the different types of lime produced.  An emission factor of 120 t carbon/kt limestone was used, based on the stoichiometry of the chemical reaction and assuming pure limestone.  For dolomite, an emission factor of 130t carbon/kt dolomite would have been appropriate; however dolomite calcination data are not given separately by the British Geological Survey, but included in the limestone data.  The use of the limestone factor for this dolomite calcination will cause a small under-estimate of emissions.  Dolomite calcination is believed to be a small proportion of the total hence the underestimate is unlikely to be significant.  The limestone calcination data exclude limestone calcined in the chemical industry since a large proportion of this is used in the Solvay process, which does not release $CO_2$.  The calcination of limestone in the sugar industry is also excluded for the same reason.

### 4.3.3    Uncertainties and Time Series Consistency

Uncertainty in both the activity data and emission factor used for this source are judged to be low.  The use of an emission factor applicable to limestone calcination for estimating emissions of both limestone and dolomite will lead to a slight underestimate in emissions. The exclusion of limestone used by the chemicals industry and sugar production will also lead to a small underestimate since not all $CO_2$ is consumed by the processes and, in the case of chemicals, some lime may be used in processes other than the Solvay process.  Time-series consistency of activity data is very good due to the continuity in data provided by the British Geological Survey.

The British Geological Survey data for 2004-2008 do not include an estimate of the quantity of limestone used by the chemical industry, thus this has had to be estimated by AEA.  This means that the estimates for these years are somewhat more uncertain than estimates for other years.  Should BGS data continue to omit these data, then additional data sets may need to be sought in order to avoid an increasing level of uncertainty in emission estimates for this sector.

### 4.3.4    Source-specific QA/QC and Verification
This source category is covered by the general QA/QC of the greenhouse gas inventory in
**Section 1.6**.

### 4.3.5    Source Specific Re-Calculations
In the previous version of the inventory, activity data were not available for 2007, and so the
2006 value was used.  For this version, 2007 data are now available and are used instead.
This leads to an increase in the estimated emissions of 187 Gg of $CO_2$.

### 4.3.6    Source Specific Planned Improvements
**Section 4.3.3** describes possible areas for improvement, though the impact on the trend is
likely to be relatively small.

## 4.4    SOURCE CATEGORY 2A3 – LIMESTONE & DOLOMITE USE

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

Use of limestone and dolomite in sinter production, basic oxygen furnaces, and glass
manufacture all result in the evolution of carbon dioxide, which is emitted to atmosphere.
Limestone is also used in flue-gas desulphurisation (FGD) plant used to abate $SO_2$ emissions
from combustion processes.  The limestone reacts with the $SO_2$ present in flue gases, being
converted to gypsum, with $CO_2$ being evolved.

The UK had three operational steel-making sites during 2008 and approximately 20 large
glassworks manufacturing soda-lime type glasses.  FGD was operational on five UK power
stations by the end of 2008.

### 4.4.2    Methodological Issues
Emissions are calculated using emission factors of 120 t carbon/kt limestone and
130 t carbon/kt dolomite, in the case of glass processes involving calcination, and 69 t
carbon/kt gypsum produced in the case of FGD processes.  These factors are based on the
assumption that all of the carbon dioxide is released to atmosphere.  The British Geological
Survey has previously been the source of data on the consumption of limestone and dolomite
by the glass industry.  However, the data available for the last ten years are very incomplete
and show surprising year on year variations that do not fit well with estimates of glass
production.  An alternative approach has therefore been adopted this year. This is based on a
detailed survey of raw material usage, carried out in 2006 (GTS, 2008), and this yields
estimates of dolomite and limestone use by sector.  These data are extrapolated to other years

between 1999 and 2008. Data on the usage of limestone and dolomite for steel production are available from the Iron & Steel Statistics Bureau (2009). Gypsum produced in FGD plant is available from the British Geological Survey (2009).

Corus UK Ltd has provided analytical data for the carbon content of limestone and dolomite used at their steelworks (Corus, 2005), and these have been used to generate emission factors of 111 t carbon/kt limestone and 123 t carbon/kt dolomite for sintering and basic oxygen furnaces.

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

Uncertainty in both the activity data and emission factor used for this source are judged to be low. Time-series consistency is also very good due to the continuity in data provision by the British Geological Survey and the Iron & Steel Statistics Bureau.

### 4.4.4    Source Specific QA/QC and Verification
This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

### 4.4.5    Source Specific Re-Calculations
The revision to the methodology used to estimate limestone and dolomite use by the glass industry leads to increases in the emission estimates of 62 and 42 Gg $CO_2$ respectively in 2007.

### 4.4.6    Source Specific Planned Improvements
Emission factors and activity data will be kept under review.


## 4.5    SOURCE CATEGORY 2A4 – SODA ASH USE

### 4.5.1    Source Category Description
Soda ash (sodium carbonate, $Na_2CO_3$) is used in the manufacture of soda-lime glasses. The soda ash decomposes in the melt to $Na_2O$, which is incorporated into the glass, and $CO_2$, which is released to atmosphere. Other uses of soda ash can also result in the emission of $CO_2$, including use in food and drink manufacture and pharmaceuticals, however the consumption of soda ash for these applications is small. Only the emissions from soda-lime glasses are reported in 2A4.

The UK has approximately 20 large glassworks manufacturing soda-lime type glasses.

Soda ash in the UK is manufactured at two sites using the Solvay process. These processes involve the use of coke to calcine limestone, thereby producing lime and $CO_2$. The $CO_2$ resulting from combustion of the coke is reported under 1A2f, while the $CO_2$ resulting from

the decarbonisation of the limestone is assumed to be consumed in the subsequent production of soda ash.  Some emissions of CO do occur from the process and are reported under 2A4.

## 4.5.2    Methodological Issues

Emission estimates are based on an assumption that the consumption of soda ash in the production of soda-lime glass is 20% of the mass of glass produced - a figure which is based on data provided by the glass industry (British Glass, 2001).   Glass production data are available on an annual basis for container glass only (British Glass, 2009), and production of other types of glass has to be estimated based on data for single years (EIPPCB, 2000), extrapolated to other years on the basis of estimated plant capacity.  The glass production data are corrected for the amount of recycled glass (cullet) and the soda ash consumption is therefore estimated as 20% of the new glass melted and not total glass melted.  The estimate of soda ash consumption is based on the production of container glass, flat glass and domestic glass.  Other types of glass, such as glass fibres, glass wool and special glasses are not soda-lime glasses and do not involve the use of large quantities of soda ash.

An emission factor of 113 kt carbon/Mt soda ash, based on the stoichiometric relationship between carbon and soda ash is used.

Emissions of CO from soda ash production are estimated based on emissions data reported in the Pollution Inventory (Environment Agency, 2009).

## 4.5.3    Uncertainties and Time Series Consistency

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

The calculation of soda ash consumption is subject to uncertainties linked to:

- Glass production data, which are themselves estimates subject to moderate uncertainty; and
- Estimate of the rate of soda ash production per tonne of glass, which is an approximate figure.

The emission factor is based on the stoichiometry of the chemical reaction undergone by the soda ash and will be accurate.  The time-series required some interpolation of data from year to year.

## 4.5.4    Source Specific QA/QC and Verification

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

## 4.5.5    Source Specific Re-Calculations

Some minor revisions to the estimates of glass production lead to a downward revision in the $CO_2$ emission estimate of 22 Gg for 2007.

## 4.5.6    Source-specific planned improvements

Estimates for this sector could be improved either through collection of actual soda ash consumption data or through more detailed estimation of soda ash consumption at sub-sector level (e.g. separately for flat glass, container glass etc. using glass composition data.) Currently the sector is probably not a priority for further improvements, since emissions are relatively minor compared to the UK total.

## 4.6    SOURCE CATEGORY 2A5 – ASPHALT ROOFING

Emissions of $CO_2$ are not estimated from this source as there is no methodology available. Emissions from this source category are likely to be extremely small in relation to national emissions.

## 4.7    SOURCE CATEGORY 2A6 – ROAD PAVING WITH ASPHALT

### 4.7.1    Source Category Description

Bitumen is used in the preparation of road surfaces.  Different types of surface dressing are used and some contain kerosene as well as bitumen.  The kerosene partially evaporates and is emitted to atmosphere.  Emissions are reported under 2A6.

### 4.7.2    Methodological Issues

Emissions of $CO_2$ are not estimated from this source, as there is no methodology available. Emissions from this source category are likely to be extremely small in relation to national emissions.

The inventory reports emissions of NMVOC from the use of bitumen emulsions, cut-back bitumens, and cut-back fluxes used in road construction using emission factors of 7, 87.5 and 700 kg NMVOC/ tonne for each component respectively (Refined Bitumen Association, 1990).  These estimates are based on the assumption that only 70% of the kerosene is emitted, the remainder being fixed in the road material.  Estimates of the usage of these surface dressings are based on a set of consumption data for one year only, provided by the Transport and Road Research Laboratory (1989) and are extrapolated to other years using data for annual bitumen consumption given in the Digest of UK Energy Statistics (DECC, 2009).

### 4.7.3    Uncertainties and Time Series Consistency

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

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

### 4.7.4    Source Specific QA/QC and Verification

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

### 4.7.5    Source Specific Re-Calculations

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

### 4.7.6    Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

## 4.8    SOURCE CATEGORY 2A7 – OTHER MINERAL PRODUCTS

### 4.8.1    Source Category Description

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

At the start of 2008, Fletton bricks were being manufactured at three works in Southern England using the Lower Oxford Clay, however one of these brickworks closed in February 2008. The Lower Oxford Clay contains a high level of carbonaceous material, which acts as a fuel during firing, leading to emissions of carbon dioxide, carbon monoxide, methane, and NMVOC. The clay also contains sulphurous material, which can result in $SO_2$ emissions as well.

Glass fibres were manufactured at one site in the UK during 2008, and glass wool was manufactured at ten sites. Both process types involve the attenuation of molten glass into fine fibres, which are then cooled and coated with organic materials. The coating processes give rise to some emissions of NMVOC.

Coated roadstone is produced at numerous sites. The stone is quarried, crushed and then coated with bitumen. Emissions of NMVOC from these processes are relatively trivial.

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

### 4.8.2    Methodological Issues

Emissions data for Fletton brickworks during recent years are available from the Pollution Inventory (Environment Agency, 2009). These data include emissions both from the burning of the carbonaceous and sulphurous material in the clay but also from the burning of coal and gas used as support fuel. Emissions from the clay materials were estimated by estimating the likely emissions from coal and gas combustion in the manufacture of the bricks and then subtracting these estimates, which are included in source category 1A2f, from the emissions reported in the Pollution Inventory.

The recent emissions data are extrapolated back using estimates of Fletton brick production. The sole company involved in the manufacture of Fletton bricks has been approached previously but has not provided any additional data; this necessitated extrapolation which will have increase the uncertainty of the estimates of emissions from earlier years.

Emissions of NMVOC from glass fibre and glass wool processes in recent years are also available from the Pollution Inventory, although these do not include the two glass wool producers located in Scotland.  The Pollution Inventory data are used to calculate emission factors, based on estimates of glass production and emissions can then be calculated both to include all processes and, by extrapolation, to include other years.

Emissions of NMVOC during manufacture of coated roadstone are estimated using production data from TSO, 2008 and an emission factor of 8.73 g/t coated roadstone, which is the average of emission factors given by US EPA, 2007 for various types of batch roadstone coating plant.

### 4.8.3 Uncertainties and Time Series Consistency

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

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

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

### 4.8.4 Source Specific QA/QC and Verification

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

### 4.8.5 Source Specific Re-Calculations

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

### 4.8.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

## 4.9 SOURCE CATEGORY 2B1 – AMMONIA PRODUCTION

### 4.9.1 Source Category Description

Ammonia is produced using the Haber process, which starts with the steam reforming of natural gas to make hydrogen.  The simplified reactions are:

$CH_4 + H_2O \Leftrightarrow CO + 3H_2$
$CO + H_2O \Leftrightarrow CO_2 + H_2$
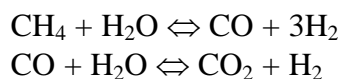
The hydrogen is then reacted with nitrogen from air to form ammonia.

$N_2 + 3H_2 \Leftrightarrow 2NH_3$
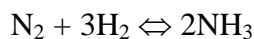
If there is no use of the by-products CO and $CO_2$ formed, then these are emitted to atmosphere. Ammonia plants can be integrated with methanol and/or acetic acid manufacture for greater efficiency. Thus, hydrogen formed as a by-product from acetic acid manufacture is used as the feedstock for ammonia manufacture. Some carbon monoxide and carbon dioxide from the reforming process is used to manufacture methanol:

$CO + 2H_2 \Leftrightarrow CH_3OH$
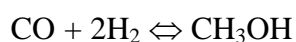
One ammonia plant sells $CO_2$ to the food industry and nuclear industry. Because this $CO_2$ is still ultimately emitted to atmosphere, it is included in the emissions reported here. This is considered more reliable than trying to identify carbon emissions at the point of final use since $CO_2$ will also be emitted from other processes such as fermentation.

Ammonia was being produced at four UK sites by the end of 2008, one of which also produced acetic acid. Methanol production, which was carried out at a different UK site, ceased in 2001.

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

## 4.9.2    Methodological Issues

Emissions from ammonia production and the associated production of methanol and acetic acid are reported under two inventory source categories. The first category is reserved for emissions of $CO_2$ from natural gas used as a feedstock in the ammonia and other processes. The second category includes emissions of $CO_2$ and other pollutants from the combustion of natural gas to produce the heat required by the reforming process.

Emissions of $CO_2$ from feedstock use of natural gas are calculated by combining reported data on $CO_2$ produced, emitted and sold by the various ammonia processes. Where data are not available, they have been calculated from other data such as plant capacity or natural gas consumption. The ammonia plant utilising hydrogen by-product from acetic acid manufacture does not need to be included since there are no process emissions of $CO_2$.

A correction has to be made for $CO_2$ produced at one site where some of this $CO_2$ is subsequently 'recovered' through sequestration in methanol. This carbon is calculated from methanol capacity data based on the stoichiometry of the chemical reaction. This only applies to estimates for 1990-2001, after which this correction is not required as the methanol plant ceased operation. Methanol is used as a chemical feedstock and also as a solvent, and emissions of volatile organic compounds resulting from these uses are reported predominantly under 2B5 and 3D respectively.

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

    a) Natural gas equivalent to carbon sequestrated in methanol (see above);
    b) Natural gas equivalent to the $CO_2$ emitted from ammonia manufacture; and
    c) Natural gas usage of the acetic acid plant, available from the process operator.

For the first two parts of the calculation, the default carbon emission factor for natural gas is used to convert between carbon and natural gas. The total feedstock use of natural gas is estimated as the sum of items 1-3 and a $CO_2$ emission factor can be calculated from the $CO_2$ emission estimate already generated.

Emissions of $CO_2$ and other pollutants from natural gas used as a fuel are calculated using estimates of natural gas usage as fuel supplied by the operators and emission factors. Factors for $NO_x$ are back-calculated from reported $NO_x$ emissions data, while emission factors for carbon, methane, CO, $N_2O$ and NMVOC are default emission factors for industrial gas combustion.

## 4.9.3    Uncertainties and Time Series Consistency

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

A consistent time series of activity data has been reported from the manufacturers of ammonia, and this results in good time series consistency of emissions. For 2001 to 2006, no new ammonia production data were received from one plant operator. Production estimates from 2000 and annual plant emissions data from the Environment Agency Pollution Inventory have been used to estimate production & emissions from this plant in 2001-2006.

## 4.9.4    Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6** and the source emissions data from plant operators is subject to the QA/QC procedures of the Environment Agency's Pollution Inventory.

## 4.9.5    Source Specific Re-Calculations

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

## 4.9.6    Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

## 4.10    SOURCE CATEGORY 2B2 – NITRIC ACID PRODUCTION

### 4.10.1   Source Category Description

Nitric acid is produced by the catalytic oxidation of ammonia:

$4NH_3 + 5O_2 \Rightarrow 4NO + 6H_2O$
$2NO + O_2 \Leftrightarrow 2NO_2$
$3NO_2 + H_2O \Leftrightarrow 2HNO_3 + NO$
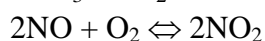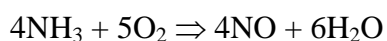
Nitrous oxide is also formed by oxidation of ammonia:

$$4NH_3 + 3O_2 \Rightarrow 2N_2O + 6H_2O$$
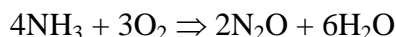
Nitrous oxide is emitted from the process as well as a small percentage of the $NO_x$. Nitric acid was being manufactured at 4 UK sites at the end of 2008. One of the sites has NOx/nitrous oxide abatement fitted to all nitric acid process plant since commissioning (all pre-1990). The three other sites have no nitrous oxide abatement fitted to any units.

## 4.10.2    Methodological Issues

Across the 1990-2008 time-series, the availability of emissions and production data for UK Nitric Acid (NA) plant is inconsistent, and hence a range of methodologies have had to be used to provide estimates and derive emission factors for this sector.

For plant in England, emissions data from plant operators are available for all sites from 1998 onwards from the EA's Pollution Inventory. For the plant (now closed) in Northern Ireland, emissions data from plant operators became available from 2001.

Site-specific production estimates are largely based on production capacity reported directly by the plant operators. This approach may overestimate actual production. No data are available for two sites operating between 1990 and 1994, and production at these sites is calculated based on the difference between estimates of total production and the sum of production at the other sites.

Emission estimates for $N_2O$ are derived for each NA site using:

a) Emissions data provided by the process operators directly or via the Pollution Inventory (1998 onwards for plant in England, 2001 onwards for plant in N Ireland);
b) Site-specific emission factors derived from reported emissions data for the same site for another year (1990-1997 for some plant in England, 1994-1997 for other plant in England, 1990-2000 for plant in N Ireland); and
c) A default emission factor of 6 ktonnes $N_2O$ /Mt 100% acid produced in cases where no emissions data are available for the site (some sites in England, 1990-1993). This default factor is the average of the range quoted in IPCC Guidelines (IPCC, 1997) for medium pressure plant

Emissions of $NO_x$ are derived for each nitric acid site using emissions data provided by the process operators directly or via the Pollution Inventory. No emissions data are available before 1994 and so a default $NO_x$ emission factor of 3.98 tonne $NO_x$ / ktonne of 100% acid produced and nitric acid production data (CIS, 1991) is used up to 1988 with emissions between 1989 and 1993 being calculated by linear interpolation.

The default emission factor is an aggregate factor based on CORINAIR (1989) emission factors for the different types of processes ranging from 3-12 t/kt of 100% acid produced. The aggregate factor is based on data on UK manufacturing plant provided by the Nitric Acid Association for the year 1985 (Munday, 1990).

Some nitric acid capacity is associated with a process that manufactures adipic acid. For the years 1990-1993, its emissions are reported combined with those from the adipic acid plant (see **Section 3.10**) but emissions from 1994 onwards are reported separately. This causes some inconsistency in between reporting categories, although total emissions are not affected.

### 4.10.3    Uncertainties and Time Series Consistency

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

Emissions from nitric acid production are estimated based on a combination of emission factors and reported emissions data. The methodology used to estimate $N_2O$ for this sector does vary through the time-series depending upon the availability of data. The calculated $N_2O$ EF for UK nitric acid production facilities varies quite significantly across the time series, and this may be a reflection of the lack of availability of a consistent time-series of emissions data. However, the variable $N_2O$ EF for this sector is also a reflection of nitric acid production patterns across UK sites that utilise different process conditions with only one plant fitted with $N_2O$ abatement.

For all plants in England, emissions of $N_2O$ used in the GHG inventory are taken from emissions reported in the Pollution Inventory data from 1998 onwards. For the plant in Northern Ireland, reported emission data became available from 2001 onwards. Prior to these years in England, emissions of $N_2O$ are estimated using either plant-specific EFs (in terms of plant capacity) based on 1998 PI data and applied to known historic plant capacity, or by applying a default emission factor of 6 ktonnes $N_2O$ /Mt 100% acid produced for some plant in 1990-1993. A similar approach has been used for the nitric acid plant in Northern Ireland prior to 2001.

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

### 4.10.4    Source Specific QA/QC and Verification

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

### 4.10.5    Source Specific Re-Calculations

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

### 4.10.6    Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

## 4.11    SOURCE CATEGORY 2B3 – ADIPIC ACID PRODUCTION

### 4.11.1    Source Category Description
Adipic acid is manufactured in a multi-stage process from cyclohexane via oxidation with nitric acid.  Nitrous oxide is produced as a breakdown product from the nitric acid.  A single company produces adipic acid in the UK.

### 4.11.2    Methodological issues
Production data and emission estimates have been estimated based on data provided by the process operator (Invista, 2009).  The emission estimates are based on the use of plant-specific emission factors for unabated flue gases, which were determined through a series of measurements on the plant, combined with plant production data and data on the proportion of flue gases that are unabated. In 1998 an $N_2O$ abatement system was fitted to the plant.  The abatement system is a thermal oxidation unit and is reported by the operators to be 99.99% efficient at $N_2O$ destruction. In 2004 it was operational 92.6 % of the time (when compared to plant operation).  Variation in the extent to which this abatement plant is operational, account for the large variations in emission factors for the adipic acid plant since 1999.

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

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

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

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

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

### 4.11.4    Source Specific QA/QC and Verification
This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. During summer 2005, consultation between Defra, AEA, plant operators and the UK Meteorological Office was conducted to discuss factors affecting emissions from the

adipic acid plant, including: plant design, abatement design, abatement efficiency and availability, emission measurement techniques, historic stack emission datasets and data to support periodic fluctuations in reported emissions. These discussions were intended to clarify the relationship between annual emission totals reported by the plant operators and emissions verification work conducted by the Met Office using ambient $N_2O$ concentration measurements from the Mace Head observatory in Ireland. The meeting prompted exchange of detailed plant emissions data and recalculation of back-trajectory emission models.

### 4.11.5   Source Specific Re-Calculations
No recalculations have been made for emission estimates in this category

### 4.11.6   Source Specific Planned Improvements
Emission factors and activity data will be kept under review.

## 4.12      SOURCE CATEGORY 2B4 – CARBIDE PRODUCTION

This category does not occur in the UK.

## 4.13      SOURCE CATEGORY 2B5 – OTHER

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

$CO_2$ emissions can occur direct from chemical processes, and estimates are made in the case of production of ammonia (see **Section 4.9**).  It is possible that other chemical processes also result in direct $CO_2$ emissions but none have been identified.  Chemical processes can result indirectly in emissions if wastes from the process are subsequently used as fuels and emission estimates for this type of source have been included in the inventory.

Chemical manufacturing processes are a significant source of NMVOC emissions.  Due to the complexity of the sector and the difficulty of separating emissions from different chemical processes, almost all emissions are reported using a single, general, category.

Emissions of the remaining pollutants are less significant compared with national totals but are reported in more detail.

Methane emissions are reported separately for production of ethylene and production of methanol, these chemicals being suggested as sources by the IPCC Guidelines for National Greenhouse Gas Inventories.  Ethylene was manufactured on four sites at the end of 2008 while the only methanol plant closed in 2001.

The IPCC Guidelines also suggested that methane might be emitted from manufacture of carbon black, styrene and dichloroethylene, however no evidence of any emissions of methane from these processes in the UK has been found and no estimates have been made. However, methane is emitted from other UK chemical processes and these emissions are reported as third, general, source category.

Emissions of other pollutants are reported under the following source categories:

- Chemical industry  - CO, $SO_2$, NMVOC;
- Chemical industry (carbon black) - CO, $SO_2$;
- Chemical industry (nitric acid use) - $NO_x$;
- Chemical industry (pigment manufacture) - $SO_2$;
- Chemical industry (reforming) – CO;
- Chemical industry (soda ash) – CO;
- Chemical industry (sulphuric acid use) - $SO_2$;
- Chemical industry (titanium dioxide) – CO;
- Coal, tar and bitumen processes – NMVOC;
- Solvent and oil recovery – NMVOC;
- Ship purging – NMVOC; and
- Sulphuric acid production - $SO_2$.

The first source listed is the general category used where emissions occur from processes which do not fit elsewhere. The remaining categories are specific and often relate to small numbers of sites. Carbon black was being produced at two sites at the end of 2008, although both then closed in 2009. The carbon black is manufactured by partially burning petroleum feedstocks to produce finely divided soot. The categories 'chemical industry (nitric acid use) and 'chemical industry (sulphuric acid use) refer to processes using these acids and emitting $NO_X$ and $SO_2$ respectively. Manufacture of nitric acid (see **Section 4.10**) and sulphuric acid are treated separately from use. Sulphuric acid was being produced at three sites at the end of 2008. Pigment manufacture relates to a single plant where sulphur is burnt as part of the manufacturing process. The sulphur oxides produced are largely consumed in the process, although some emissions do occur.

Reforming processes convert natural gas or other light hydrocarbons into hydrogen and carbon monoxide for use in further chemical processes, and can result in emissions of CO. Soda ash manufacture also results in some emissions of CO, which is formed during the lime manufacturing stage and then passes through the chemical processes before being emitted. These emissions are not included in the inventory category 'Lime (combustion)'. Titanium dioxide is manufactured by two routes in the UK, but one involves the use of coke as a reductant and is carried out on two sites. Carbon monoxide is emitted to atmosphere from the process. The remaining three source categories are reserved for minor sources of NMVOC. Processes involving coal-based chemicals and bitumen-based products are reported under 'coal, tar & bitumen processes', the recovery of solvents and other organic chemicals by distillation is reported under 'oil & solvent recovery', and the venting of chemical vapours from ships' tanks where cross-contamination of cargoes must be avoided, is reported under 'ship purging'.

## 4.13.2   Methodological Issues

The quantity of waste recovered for use as a fuel is estimated based on analysis of data reported to the Environment Agency for the years 1998-2002 and contained in the Pollution Inventory data supplied in 2005. The average mass of waste recovered for use as a fuel over these five years was 183 ktonnes. This figure was assumed applicable for all years.  The wastes were characterised only as either 'special' or 'non-special' so no details were available which would allow the carbon content to be calculated.  Previously, the carbon content was assumed to be the same as for waste oils used as a fuel but this is likely to have overestimated the carbon emissions.  For this version of the inventory, a carbon emission factor for waste solvents used in the cement industry has been applied instead and results in significantly lower estimates of emissions.

In the case of other pollutants, emissions data for chemical processes located in England and Wales are available in the Pollution Inventory (Environment Agency, 2009).  Reporting generally started in 1994 or 1995, and few data exist for the years prior to 1994.  Data for ethylene production processes in Scotland and additional data for some of the methane-emitting processes in England and Wales have been obtained from process operators and from the Scottish Pollutant Release Inventory (SEPA, 2009).  The Scottish Environment Protection Agency has also, on previous occasions, supplied some data on emissions of NMVOC from individual Scottish chemical processes and additional NMVOC data for processes located in both Scotland and Northern Ireland have been obtained from process operators.  Additional data on Northern Ireland's only major chemical works is provided by DoE NI (2009).  The National Sulphuric Acid Association (NSAA, 2003) have provided historical emissions data for sulphuric acid production processes.  Emissions from ship purging are based on a single estimate given by Rudd *et al* (1996), which is applied to all years.

All of the data available are in the form of emission estimates, usually generated by the process operators and based on measurements or calculated based on process chemistry. Emission factors and activity data are not required, although emission factors are back-calculated in the process of extrapolation of emissions back to the years prior to 1994.  The extrapolation is usually linked to changes in the level of output from the chemicals manufacturing sector as measured by the 'index of output' figures published by the Office of National Statistics (2009).  In a few cases, such as the figures for methane from ethylene production and $SO_2$ from sulphuric acid production, actual emissions data are available or can be estimated for individual plant based on actual plant capacities.

Some gaps exist in the reported data.  For example, emissions from a given process will be reported for some years but not others, even though the process is known to have been operating.  These gaps are presumably due to the fact that either the process operator was not required to submit emissions data or that emissions data was not or could not be supplied when requested.  Most of the gaps occur in the early years of the Pollution Inventory.  These gaps have been filled by copying emissions data from the nearest year for which emissions data were reported.

## 4.13.3   Uncertainties and Time Series Consistency

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

Emission estimates for 1994 onwards are mostly based on data reported by process operators and might therefore be considered accurate. However, in the absence of any detailed assessment of the methods used by individual process operators to estimate emissions, it is not possible to come to a definite conclusion. Emission estimates for NMVOC are more uncertain than the estimates for other pollutants because of the way in which these emissions are reported in the Pollution Inventory. As a result, the data have to be interpreted using expert judgement.

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

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

### 4.13.4    Source Specific QA/QC and Verification

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

### 4.13.5    Source Specific Re-Calculations

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

- Changes to the emissions data given in the Pollution Inventory and other sources; and
- The influence of emissions data for 2008, available for the first time, with subsequent changes to the extrapolations necessary for filling 'gaps' in the data (for example, gaps in reported data for 2007 might previously been filled using emissions reported for 2006, whereas now the mean of the 2006 and 2008 emissions would be used).

The various re-calculations have usually resulted in very small changes in emissions from these sources compared with values in the last version of the inventory. The most significant change is for NMVOC, where estimated emissions have decreased by 1 Gg.

### 4.13.6    Source Specific Planned Improvements

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

## 4.14   SOURCE CATEGORY 2C1 – IRON AND STEEL PRODUCTION

### 4.14.1   Source Category Description

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

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

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

Blast furnaces are used to reduce the iron oxides in iron ore to iron. They are continuously charged with a mixture of sinter, fluxing agents such as limestone, and reducing agents such as coke. Hot air is blown into the lower part of the furnace and reacts with the coke, producing carbon monoxide, which reduces the iron ore to iron.

Gas leaving the top of the blast furnace has a high heat value because of the residual CO content, and is used as a fuel in the steelworks. Molten iron and liquid slag are withdrawn from the base of the furnace. Subsequent cooling of the slag with water can cause emissions of $SO_2$. The most significant greenhouse gas emissions to occur directly from the blast furnace process are the combustion gases from the 'hot stoves' used to heat the blast air.

These generally use blast furnace gas, together with coke oven gas and/or natural gas as fuels. These emissions are reported under CRF category 1A2. Gases emitted from the top of the blast furnace are collected and emissions should only occur when this gas is subsequently used as fuel. These emissions are allocated to the process using them. However, some blast furnace gas is lost and the carbon content of this gas is reported under CRF category 2C1.

Pig iron has a high carbon content derived from the coke used in the blast furnace. A substantial proportion of this must be removed to make steel and this is done in the basic oxygen furnace. Molten pig iron is charged to the furnace and oxygen is blown through the metal to oxidise carbon and other contaminants. As a result, carbon monoxide and carbon dioxide are emitted from the furnace and are collected for use as a fuel. As with blast furnace gases, some losses occur and these losses are reported with blast furnace gas losses under CRF category 2C1.

Electric arc furnaces produce steel from ferrous scrap, using electricity to provide the high temperatures necessary to melt the scrap. Emissions of carbon dioxide occur due to the breakdown of the graphite electrodes used in the furnace and $NO_x$ is formed due to oxidation of nitrogen in air at the high temperatures within the furnace. Emissions of NMVOC and CO

occur due to the presence of organic contaminants in the scrap, which are evaporated and partially oxidised. Emissions from electric arc furnaces are reported under CRF category 2C1.

The inventory contains estimates of NMVOC emissions from rolling mills. Lubricants are needed and contain organic material, some of which evaporates. These emissions are reported under 2C1. A more significant emission from rolling mills and other downstream processing of steel are those emissions from use of fuels to heat the metal. These emissions are reported under 1A2.

## 4.14.2  Methodological Issues

The methodology for the prediction of carbon dioxide emissions from fuel combustion, fuel transformation, and processes at integrated steelworks is based on a detailed carbon balance (this methodology is described in more detail within the section on CRF sector 1A2a). Carbon emissions from electric arc furnaces are calculated using an emission factor provided by Corus (2005). For other pollutant emissions from blast furnaces, emissions are partly based on the methodology described in IPCC (1997), with some revisions made to the $SO_2$ factors based on data available from industry. Details of all methodologies are provided in **Annex 3**, **Section A3.4.3**, which also provides details on emissions from electric arc furnaces. Energy related emissions from foundries are included in category 1A2a but any process emissions from foundries of direct GHGs are likely to be very small and are not estimated.

Emissions from integrated steelworks are split between 1A2a, 1B1b, and 2C1. The allocation of emissions to these three categories will be reviewed before the next version of the inventory to ensure that this is done in accordance with IPCC guidance.

## 4.14.3  Uncertainties and Time Series Consistency

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

Much of the activity data used to estimate emissions from this source category come from the Iron and Steel Statistics Bureau (ISSB) and DECC publication DUKES. Time-series consistency of these activity data are very good due to the continuity in data provided in these two publications.

## 4.14.4  Source Specific QA/QC and Verification

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

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

### 4.14.5    Source Specific Re-Calculations

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

### 4.14.6    Source Specific planned Improvements

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

## 4.15    SOURCE CATEGORY 2C2 – FERROALLOYS PRODUCTION

This category is not relevant to the UK since the early 1990s.  Prior to then, some ferroalloys were produced however emissions are likely to have been trivial.

## 4.16    SOURCE CATEGORY 2C3 – ALUMINIUM PRODUCTION

### 4.16.1    Source Category Description

Aluminium is produced by the electrolytic reduction of alumina, currently at two sites in the UK.  A third site closed during 2009, and a fourth process closed in mid 2000.  All of the operational sites use the pre-baked anode process, whereas the plant that closed in 2000 used the Soderberg Cell process.  This distinction is important because of large differences in emission rates for some pollutants.

Both process types make use of carbon anodes and these anodes are consumed as the process proceeds, resulting in emissions of $CO_2$, CO, NMVOC and $SO_2$.  The high temperatures necessary in the process mean that $NO_x$ is also emitted.  Finally, the PFC species tetrafluoromethane ($CF_4$) and hexafluoroethane ($C_2F_6$) are formed if the alumina content of the electrolyte falls too low.  Computerised control of alumina addition to the cells is a feature of modern plant and has helped to reduce PFC emissions from aluminium production.

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

### 4.16.2    Methodological Issues

Emissions of carbon were estimated based on the production of aluminium for each type of process and emission factors.  The carbon emission factors reflect current practice, and higher emission factors were used for earlier years.

All emissions of PFCs occur during the aluminium smelting process.  The estimates were based on actual emissions data provided by the aluminium-smelting sector. There are two main aluminium smelting operators in the UK.

One operator uses a Tier 2 methodology Smelter-specific relationship between emissions and operating parameters based on default technology-based slope and over-voltage coefficients, using the default factors for the CWPB (Centre Worked Prebaked) plant.  The other operator

uses a Tier 3b methodology (as outlined in the IPCC guidance) Smelter-specific relationship between emissions and operating parameters based on field measurements. Emissions estimates were based on input parameters, including frequency and duration of anode effects, and number of cells operating. Emission factors were then used to derive the type of PFC produced. All emissions occur during manufacturing. These emissions were provided directly by the operators.

The type of smelter design has a large effect on the rate of PFC emissions. The UK industry has previously made major investment to improve their technology and all UK plants now use point feeder prebake. A more detailed description of the methodology used to calculate emission estimates for this sector is provided in AEAT (2004).

For other pollutants, some emissions data are available from the Environment Agency's Pollution Inventory for the two largest processes in England & Wales, whilst data for the plant located in Scotland were obtained by direct contact with the plant operators, derived from emission factors calculated from the England & Wales plant emissions, or obtained from the Scottish Pollutant Release Inventory, produced by the Scottish Environmental Protection Agency (SEPA).

Activity data are taken from BGS data sets for all years except 2005, 2007 and 2008 where production data available directly from the operators of each site did not agree with the BGS figure, the sum of the site-specific data being slightly higher. The BGS data was therefore replaced by the site-specific data for these years.

### 4.16.3    Uncertainties and Time Series Consistency

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

The source of activity data is almost always from data compiled by the British Geological Survey (production of primary aluminium). This is a long running publication and the compilers of the activity data strive to use consistent methods to produce the activity data. This helps to ensure good time series consistency of the emission estimates. The alternative data used for 2005 and 2007 is only slightly higher (<0.4%) than the BGS number and supports the view that the BGS data are reliable, although the discrepancy in the 2008 data is larger (3.4%).

### 4.16.4    Source Specific QA/QC and Verification

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

### 4.16.5    Source Specific Re-Calculations

Emissions of PFCs and $CO_2$ in 2007 have been revised, based on updated data from one of the plant operators. This has led to a decrease in emissions of 1.8 and 0.3Gg $CO_2$eq, respectively.

### 4.16.6    Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

## 4.17 SOURCE CATEGORY 2C4 – SF$_6$ USED IN ALUMINIUM AND MAGNESIUM FOUNDRIES

### 4.17.1 Source Category Description

SF$_6$ is used in the magnesium alloy and casting industry as a cover gas, to prevent molten magnesium oxidising when exposed to air. All SF$_6$ used in this way is released to the atmosphere unless capture/recycle technologies are employed. SF$_6$ is non-flammable and non-toxic, and is therefore a safe gas to use. In the UK, SF$_6$ has been used as an alternative cover gas to SO$_2$ in magnesium alloy production and sand and die-casting since the early 1990s. Magnesium alloy production and casting are therefore significant emitters of SF$_6$ in the UK.

In the UK, there is one large magnesium alloy producer and six smaller casting operators (three die-casting and 3 sand-casters (two of which have now closed)). Alloy production involves the use of primary magnesium ingots, recycled scrap material and second-generation magnesium materials (i.e. material already made into alloys) for the production of different alloys. Both die and sand casters use these magnesium alloys to produce specific components for a wide range of industries. For the casting industry, SF$_6$ is used for casting specific magnesium alloys where other cover gases, such as argon, are not suitable.

### 4.17.2 Methodological Issues

For magnesium alloy production, emissions from 1998-2008 were estimated based on the emission data reported by the company to the UK's Pollution Inventory. These data are considered reasonably robust whilst earlier data (pre-1998) are estimated based on consultation with the manufacturer. In 2004, for the first time, one of the main industry users has implemented a cover gas system using HFC134a as a cover gas for some of its production capacity. There has not been a complete switch to HFC 134a, although the operator is considering this on an ongoing basis depending on suitability for the different alloys produced. In addition to having a significantly lower GWP than SF$_6$ (and thus reducing emissions on a CO$_2$ equivalent basis), use of HFC134a is further advantageous in that a significant fraction of it is destroyed by the high process temperatures thus reducing the fraction of gas emitted as a fugitive emission. It is assumed 90% of the used HFC cover gas is destroyed in the process (CSIRO 2005). In 2008, for the first time, emissions of HFCs have been reported in the Pollution Inventory, and therefore this figure has been used for 2008.

As part of a recent study to update the F-gas inventory, castings operators were re-contacted to provide activity data for recent years (the previous survey was conducted in 2004). Some of the operators provided new data, while for others assumed values for SF$_6$ use were used based on the data provided for other years.

SF$_6$ can also be used as a cover gas in aluminium foundries, although no emissions are currently reported by any of the operating plants in the Pollution Inventory, and therefore this is not thought to be occurring in the UK.

Note that actual emissions of SF$_6$ for this sector are reported for practical reasons under 2C5 'Other metal production'. This is because the CRF Reporter does not allow reporting of HFC emissions under the 2C4 sector category.

### 4.17.3   Uncertainties and Time Series Consistency

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

The following information on uncertainty associated with time-series data for this sector should not be confused with the formal IPCC uncertainty analysis in **Annex 7**.

For the period 1990-1997, the estimated uncertainty in the time series data was +/- 30%. The main area of uncertainty is regarding emissions of $SF_6$ from casting based on discussions with the sector Trade Association. Data from the main magnesium alloy producer is also uncertain for this period.

For the period 1998-2008, the uncertainty of the time-series emissions is estimated to be significantly lower (+/- 10%). Data received from the main magnesium alloy producer are considered to be reasonably robust and accurate.

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

### 4.17.4   Source Specific QA/QC and Verification

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

### 4.17.5   Source Specific Re-Calculations

There have been to re-calculations to this sector.

### 4.17.6   Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

## 4.18    SOURCE CATEGORY 2C5 – OTHER METAL PRODUCTION

### 4.18.1   Source Category Description

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

The primary lead/zinc process, the secondary copper process, and some of the secondary lead processes involve the use of coke as a reductant and emissions from these processes are reported under 2C5. Currently, emissions of carbon from use of this coke are included with estimates for other industrial combustion (see **Section A3.4.3**). Two of the secondary lead producers also emit $SO_2$ from the automotive batteries that they recover lead from. Copper wire rod plants use natural gas burners to create a slightly reducing atmosphere in the melting

furnace, which helps to maintain a high conductivity product. This leads to elevated emissions of CO. A few other non-ferrous metal plants have very minor emissions of CO as well.

Carbon monoxide is used as a reagent by the only UK nickel refinery and is produced by reforming of butane. Emissions from this process have been included in the NAEI estimates for chemical industry reforming processes and are reported under 2B5.

As described in the preceding section, (2C4 'SF$_6$ used in Aluminium and Magnesium Foundries') actual emissions of SF$_6$ and HFC134a for this sector are reported under 2C5 'Other metal production' for practical reasons, as the CRF Reporter does not allow reporting of HFC emissions under the 2C4 sector category. Separate estimates for category 2C5 are not available.

### 4.18.2    Methodological Issues

Emission estimates for these processes are derived from emissions data available from the Pollution Inventory (Environment Agency, 2009). For earlier years, where no emissions data are available, emission estimates are made by extrapolation based on production of the relevant type of metal.

### 4.18.3    Uncertainties and Time Series Consistency

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

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

### 4.18.4    Source Specific QA/QC and Verification

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

### 4.18.5    Source Specific Re-Calculations

No significant re-calculations have been made.

### 4.18.6    Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

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

### 4.19.1    Source Category Description

The UK paper industry is mainly confined to the production of pulp from recycled material and the production of papers using either imported virgin pulp, recycled pulp or a combination of the two. Production of virgin pulp is limited to a few processes producing mechanical or

neutral sulphite semi-chemical pulp.  Emissions from UK paper processes consist largely of emissions from the associated combustion processes, which supply steam and power to the papermaking processes.  These emissions are reported under CRF category 1A2.  Other atmospheric emissions of greenhouse gases from UK paper and pulp processes will be minor and are currently not estimated.

Emissions of NMVOC from the manufacture of chipboard, fibreboard and oriented strand board (OSB) are reported under 2D1.  These products differ in the type of wood material that is made into board.  Chipboard is made from assorted wood shavings, dust & chippings etc., while fibreboard is made from mechanically pulped wood fibres and OSB is made from long, thin wafers of wood with fairly uniform dimensions.  All three processes involve steps for drying of the wood particles and hot pressing of the formed board and both steps give rise to some NMVOC emissions.

### 4.19.2   Methodological Issues

Emissions are estimated using emission factors derived from those available in the USEPA Compilation of Air Emission Factors (USEPA, 2009).  Production of the wood products is estimated from data published by the Office of National Statistics (2009).  These data are given as areas or volumes of product depending upon the type of product and must be converted to a mass basis by making assumptions about the thickness and/or density of the products.

### 4.19.3   Uncertainties and Time Series Consistency

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

### 4.19.4   Source Specific QA/QC and Verification

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

### 4.19.5   Source Specific Re-Calculations

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

### 4.19.6   Source Specific Planned improvements

Emission factors and activity data will be kept under review.

## 4.20     SOURCE CATEGORY 2D2 – FOOD AND DRINK

### 4.20.1   Source Category Description

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

6 large grain distilleries and approximately 90 smaller malt distilleries. There is a single small whisky distillery in Wales and a large whiskey distillery in Northern Ireland. Scotland and England also produce other distilled spirits such as gin and vodka, with production being concentrated in Scotland.

Malt production also creates emissions of NMVOC. Malting is occasionally carried out by distilleries but most malt, both for distillers and breweries, is produced by specialist maltsters. Brewing processes such as fermentation and wort boiling and fermentation for production of cider and wine are all very minor sources of NMVOC.

Bread manufacture involves fermentation reactions and ethanol is released as a result. Most bread in the UK is made in large mechanised bakeries, of which there are about 70. The remainder is made in small –'craft bakeries'. Some other baked products include a fermentation stage and also emit ethanol. Heating of food products can cause reactions that produce organic emissions, and so processes such as drying of vegetable matter, preparation of compounded animal foods and cooking of meat and fish can cause NMVOC emissions. Finally, the processing of oils and fats is also a source of emissions, although emissions of hexane, a solvent used to extract vegetable oil from rape and other oilseeds is included in estimates of solvent use rather than as a food industry emission.

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

### 4.20.2 Methodological Issues

Emissions of NMVOC from food and drink manufacture are all calculated using emission factors and activity data obtained from either industry or Government sources. In the case of whisky maturation, data are available for volumes of whisky in storage at the end of each year from the Scotch Whisky Association (2009), and so emissions can be calculated by applying an annual emission rate factor with the average volume of whisky in storage for each year. This is more accurate than using an overall emission factor applied to whisky production since whiskies are stored for varying lengths of time and stock levels will rise or fall depending upon production, demand and changes in the length of maturation required.

### 4.20.3 Uncertainties and Time Series Consistency

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

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

### 4.20.4 Source Specific QA/QC and Verification

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

### 4.20.5 Source Specific Re-Calculations

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

### 4.20.6   Source Specific Planned improvements
Emission factors and activity data will be kept under review.

## 4.21    SOURCE CATEGORY 2E – PRODUCTION OF HALOCARBONS AND SF$_6$

### 4.21.1   Source Category Description
Emissions arise from the UK manufacture of HFCs, PFCs and HCFC 22.  There are two single manufacturers of HFCs and PFCs respectively in the UK, and two companies were operating HCFC 22 plants, one of which closed in 2008, and the second closed at the end of 2009.  Species data from these sectors have been aggregated to protect commercial confidentiality.  There is no UK production of SF$_6$.

In terms of their global warming impact (expressed as kt $CO_2$ eq.), HFC 23 emissions are responsible for the substantial majority of emissions from this manufacturing sector.  It has a high GWP, and traditionally is emitted at levels of 3-5% of the amount of HCFC 22 produced.  The market for HCFC 22 is presently made up of three elements:

- End user markets, refrigerants for refrigeration and air-conditioning equipment (subject to phasing out under the Montreal Protocol);
- Export markets; and
- Feedstock for production of certain plastic products, especially PTFE.

### 4.21.2   Methodological Issues
A full description of the emission model and associated methodology used for this sector is contained in AEA (2008).  Within the model, manufacturing emissions from UK production of HFCs, PFCs and HFC 23 (by-product of HCFC 22 manufacture) are estimated from reported data from the respective manufacturers. Manufacturers have reported both production and emissions data, but only for certain years, and for a different range of years for different manufacturers.  Therefore the emissions model is based on implied emission factors, and production estimates are used to calculate emissions in those years for which reported data was not available.  Two of the three manufacturers were members of the UK greenhouse gas Emissions Trading Schemes.  As a requirement of participation in the scheme, their reported emissions are verified annually via external and independent auditors.  All three now report their emissions to the Environment Agency's Pollution Inventory and these reported emissions have been used to calculate total emissions in later years for two of the operating plant, where full speciated emissions data were provided by one of the operators for most of the time series.

Under an agreement on confidentiality, the three UK manufacturers have provided speciated data for certain years on the condition that only aggregated data are reported.  As described in **Section 4.21.1**, there is only one UK manufacturer of HFCs, a different sole manufacturer of PFCs and two manufacturers of HCFC 22.  The UK inventory team will continue to investigate to establish whether it will be possible to report emissions by species in future.

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

### 4.21.3   Uncertainties and Time-Series Consistency

The Approach 1 (error propagation) uncertainty analysis in Annex 7, shown in **section A7.6**, provides estimates of uncertainty according to IPCC source category and fuel type.

There is a significant decrease in HFC emissions in 1998/1999. This step-change in emissions is due to the installation of thermal oxider pollution abatement equipment at one of the UK manufacturing sites. Fugitive HFC emissions from both an HCFC22 plant and HFC manufacturing plant (run by the same operator) are treated using the same thermal oxidiser unit. Emissions also decrease in 2004, reflecting the installation of a thermal oxider at the second of the UK's HCFC22 manufacturing sites. This was installed in late 2003, and became fully operational in 2004.

A significant increase in PFC emissions from the production of halocarbons is observed from 1992 to 1996 (with the trend changing after 1996). The increase in emissions was due to increasing production levels at the single UK manufacturing plant during this period. Since 1996, the level of emissions have changed each year which broadly reflects the demand (and hence production levels) for PFCs. In 2004 and 2005, emissions reported by the company increased compared with the preceding 3 years of fairly stable emission levels 2001-2003.

### 4.21.4   Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**, and details of verification of emissions of HFC-134a and HFC-152a are given in **Annex 9**. Additionally, as described above in **Section 4.21.2**, two of the UK manufacturing plants also had their emissions externally validated as part of the requirements of the UK Emissions Trading Scheme.

### 4.21.5   Source Specific Re-Calculations

There have been no re-calculations to emissions from this sector.

### 4.21.6   Source Specific Planned Improvements

The F-gas inventory was reviewed and updated in 2008 (AEA, 2008). Further work in this area is also planned. Emission factors and activity data will be kept under review.

## 4.22    SOURCE CATEGORY 2F1 – REFRIGERATION AND AIR CONDITIONING EQUIPMENT

### 4.22.1   Source Category Description

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

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

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

- Domestic refrigeration (including refrigerators, chest freezers, upright freezers and fridge-freezers);
- Other small hermetic refrigeration units (including through the wall air-conditioners, retail equipment, drinking water coolers etc);
- Small commercial distributed systems (including pub cellar coolers, small chill and cold stores);
- Supermarket systems;
- Industrial systems;
- Building air conditioning systems (direct use of refrigerant);
- Building air-conditioning chillers (indirect use of refrigerant);
- Refrigerated transport (refrigerated lorries, containers etc) using conventional refrigeration technology; and
- Mobile air conditioning (air-conditioning systems for cars and other vehicles).

## 4.22.2    Methodological Issues

A full description of the emissions and associated methodology used for this sector is contained in AEA (2010). The general methodology used was based on that of March (1999). The calculation methodology within the model is considered to provide a relatively conservative approach to the estimation of emissions. The bank of fluid is estimated by considering the consumption of fluid in each sector, together with corrections for imports, exports, disposal and emissions. Once the size of the bank in a given year is known, the emission can be estimated by application of a suitable emission factor. Emissions are also estimated from the production stage of the equipment and during disposal. The methodology corresponds to the IPCC Tier 2 -'bottom-up'- approach. Data are available on the speciation of the fluids used in these applications; hence estimates were made of the global warming potential of each fluid category.

Emissions from the domestic refrigeration sector were estimated based on a bottom-up approach using UK stock estimates of refrigerators, fridge-freezers, chest-freezers and upright freezers from the UK Market Transformation Programme (MTP, 2002).

For the commercial and industrial refrigeration sub-sectors, emission estimates are now based on refrigerant fluid sales data, from the British Refrigeration Association. This allowed the previous estimates within the model to be verified against real data, and adjusted accordingly.

Emissions of HFCs from mobile air conditioning systems were also derived based on a bottom-up analysis using UK vehicle statistics obtained from the UK Society of Motor Manufacturers and Traders, and emission factors determined in consultation with a range of stakeholders. A full account of the assumptions and data used to derive emission estimates for the MAC sub-sector is in AEAT (2004) and AEA (2008).

## 4.22.3    Uncertainties and Time-Series Consistency

Estimates of the uncertainties associated with time-series data for this sector were made in AEA (2008), based on an understanding of the uncertainties within the sector and from discussion with industry.  An uncertainty range of +/- 20% was estimated for the aggregated time-series emissions from the domestic and commercial refrigeration sectors, and +/- 10% for the mobile air conditioning sector.  Uncertainty data from this study have been used in the uncertainty analysis presented in **Annex 7**.

## 4.22.4    Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Details of verification of emissions of HFC-134a and HFC-152a are given in **Annex 9**.

## 4.22.5    Source Specific Re-Calculations

The model used to calculate emissions from this sector has undergone a number of significant changes and improvements.  These are:

- Refrigerant fluids have been speciated at the input stage of the model, rather than speciating the emissions output.  This has changed the time profile of the GWP weighted emissions.
- The model has been checked for internal consistency and adjusted accordingly.
- Refrigerant fluid input into the model has been separated out, into the amount filled into new units, and the amount used for topping up existing units.  The previous model did not explicitly contain data on the amount used to top up units.
- Input data (refrigerant fluid filled into new products, and used for topping up existing products) has been verified against sales data.  The previous estimates were based on consultation and expert judgement, and therefore the use of sales data is considered to be a significant improvement to the estimates.

These changes have led to an overall change in emissions of +1.4Mt $CO_2$e in 2007.

## 4.22.6    Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

## 4.23    SOURCE CATEGORY 2F2 – FOAM BLOWING

### 4.23.1    Source Category Description

Prior to the Montreal Protocol, a wide range of foams was produced using CFC blowing agents.  As use of these chemicals was banned, the industry moved to alternatives including HCFCs.  For applications such as packaging and cushioning, the use of HCFCs was banned under the EC Regulation on Substances that Deplete the Ozone Layer (EC 3093/94) and these sectors moved to blowing agents such as water or $CO_2$.  Use of HCFC was still permitted in rigid insulating foams and integral skin foams for safety applications, but a new EC Regulation on Substances that Deplete the Ozone Layer  (EC 2037/2000) has now banned all HCFC use in these remaining sectors.

Emissions of HFCs from foams can occur as follows:
- During the manufacturing process;
- Over the lifetime of the foam; rigid foams are closed cell foams and the blowing agent is designed to remain in the foam and contributes to its performance.  Loss of HFCs is undesirable as it may affect the performance of the foam but is estimated to occur, albeit at a low rate; and
- At disposal of the foam.

Emissions at each point vary according to the type of foam.  Typically, of the HFC used in the production process, less than 10% is emitted during manufacture (although emissions may be as high as 40 to 45 % for some types of foam), less than 1% per year over the useful lifetime of the product and the remainder on disposal.

### 4.23.2    Methodological Issues

A full description of the emissions and associated methodology used for this sector is contained in AEA (2008).  The emissions for the years 1990 to 2002 are based on data from March (1999).  Emissions data for recent years (2003 onward) were obtained from UK industry experts. The methodology used estimates the bank of fluid used by considering the consumption of fluid in each foam sub-sector, together with corrections for imports, exports, disposal and emissions.  Once the size of the bank in a given year is known, the emission can be estimated by application of a suitable emission factor.  Emissions are also estimated from the production stage of the equipment and during disposal.  The methodology corresponds to the IPCC Tier 2 'bottom-up' approach.

### 4.23.3    Uncertainties and Time-Series Consistency

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

Estimates of the uncertainties associated with time-series data for this sector were made in AEA (2008), based on an understanding of the uncertainties within the sector and from discussion with industry.  Time-series data was estimated to have an uncertainty range of +/- 30% for this sector.  Uncertainty data from this study have been used in the uncertainty analysis presented in **Annex 7**.

### 4.23.4    Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Details of verification of emissions of HFC-134a and HFC-152a are given in **Annex 9**.

### 4.23.5    Source Specific Re-Calculations

Data from 2003 onwards has been recalculated to reflect more up to date data and experience of the emissions from this source.

### 4.23.6    Source Specific Planned improvements

Emission factors and activity data will be kept under review.

## 4.24     SOURCE CATEGORY 2F3 – FIRE EXTINGUISHERS

### 4.24.1    Source Category Description

In the UK, manufacturers of fixed suppression systems for fire fighting have been using HFCs as an alternative to Halons for the past 12-13 years. Fluorocarbons currently take up a significant proportion of the market that would have previously been covered by Halons. This is primarily due to the specific requirements of certain industries where the use of HFCs is seen as necessary to reduce fire risks. Such systems have much faster discharge and suppression times, and do not damage equipment.

The systems are also compact and take up minimal space. The HFCs themselves are non-toxic. It is the combination of speed, space and safety that makes HFCs important alternatives to Halon in those applications where these properties are required. HFC-based systems are used for the protection of electronic and telecommunications equipment, and in military applications, records offices, bank vaults and oil production facilities.

The main HFC used in UK fixed systems is HFC 227, with some use of HFC 23 and HFC 125. The majority of emissions of HFCs will occur when the system is discharged, either when triggered accidentally or during a fire. Minimal emissions may also occur during filling or maintenance of the systems. The rest of the market for fixed system applications uses inert gases or non-gaseous agents, such as water mist, and non-extinguishing early warning systems.

As well as HFCs being used to replace halon-based systems in the mid-1990s, a small quantity of PFC (mainly $C_4F_{10}$) was imported by a US company into the EU to be used as an alternative fluid in fire fighting fixed systems. The main application of these PFC-based fixed systems is for fire protection of flooding closed rooms (e.g. control rooms). Imports for new systems stopped in 1999, as this application of PFCs was not regarded as an essential use. For purposes of recharge, PFCs are still supplied. By 2010 there will probably be no fixed systems using PFCs in the EU.

Portable extinguishers have moved away from Halons, with most manufacturers using water, dry powder and carbon dioxide as the replacement. A small number of niche applications use HFCs, but emissions from such applications are thought to be insignificant.

### 4.24.2    Methodological Issues

Emissions for this sector were calculated using the same emission model as used for the UK's previous submission, updated based on the findings of a recent study (AEA, 2008). Emissions estimates were obtained from March (1999) for years 1990-1996 and for subsequent years from the representative UK trade organisation, the Fire Industry Council (FIC) and from ASSURE. The emissions data are based on estimates of installed capacity and an annual emission rate of approximately 5% per annum until 2000 and decreasing to 2.6% by 2005 (an assumption based discussion with industry representatives). There are no emissions from HFC prior to 1995. A full description of the associated methodology used is contained in AEA (2008).

### 4.24.3   Uncertainties and Time Series Consistency

Estimates of the uncertainties associated with time-series data for this sector were made in AEA (2008), based on an understanding of the uncertainties within the sector and from discussion with industry.   Uncertainties in emissions over the 1990-2005 period were estimated to be +/- 10%, and estimates from 2005 onwards are thought to be more uncertain (around 20%) since these are based on projections and anecdotal evidence.  Uncertainty data from this study have been used in the uncertainty analysis presented in **Annex 7**.

### 4.24.4   Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Details of verification of emissions of HFC-134a and HFC-152a are given in **Annex 9**.

### 4.24.5   Source Specific Re-Calculations

A review of the PFC emissions from this sector indicated that the previous assumption that emissions ceased in 2001 may have led to an underestimate of emissions from this sector. The model has been updated and emissions from this source are now included to 2008.

### 4.24.6   Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

## 4.25     SOURCE CATEGORY 2F4 – AEROSOLS/ METERED DOSE INHALERS

### 4.25.1   Source Category Description

In the UK, HFCs are generally used as propellants in specific aerosols where the use of HFCs is considered critical, i.e. where safe alternative propellants are not available.  Historically many types of aerosols were formulated with CFCs as propellants.  However, for the vast majority of aerosols, the use of CFCs ceased at the end of 1989 on account of concerns regarding their role in ozone destruction.  Aerosol manufacturers could then choose between a number of options to replace CFCs, including hydrocarbons, dimethyl ether (DME), compressed gases or HFCs.

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

now banned, from July 2009, under the EC Regulation on fluorinated greenhouse gases (EC 842/2006).

Metered dose inhalers (MDIs) are used to deliver certain pharmaceutical products as an aerosol. For patients with respiratory illnesses, such as asthma and chronic obstructive pulmonary disease (COPD), medication needs to be delivered directly to the lungs. MDIs are one of the preferred means of delivering inhaled medication to patients with these illnesses. MDIs originally used CFC propellants but, as with industrial aerosols, concern over ozone destruction led to attempts to replace CFCs with HFCs. HFCs have been identified as the only viable replacement for CFCs in MDIs as no other compound has met the stringent criteria for a medical gas to be used for inhalation by patients. Criteria include the need for the gas to be non-flammable, non-toxic, liquefied, chemically stable, compatible with range of medicines, acceptable to patients, and to have appropriate density and solvent properties. This switch from CFCs to HFCs has resulted in increasing emissions of HFCs from this sector (although a saving in terms of $CO_2$ equivalent).

## 4.25.2   Methodological Issues

A full description of the emissions and associated methodology used for this sector is contained in AEA (2008). Aerosol HFC emission estimates have been derived on the basis of fluid consumption data provided by BAMA. Estimates of emissions from HFC-filled aerosols were derived by estimating the amount of fluid used annually in their manufacture. An average product lifetime of one year for all aerosols containing HFC has been assumed, based on discussions with BAMA, although this may be shorter or longer depending on the specific aerosol application. The number of HFC-based aerosols that are used in the UK is derived from data from BAMA, based on assumptions concerning imports and exports. It is estimated that 1% of HFC emissions from aerosols occur during manufacture. The majority is released during the product lifetime (97%), with end of life emissions accounting for the other 2%. These emission factors are the same as those estimated in previous work by March (1999). The lifetime and end of life emissions are calculated after import and exports have been taken into account.

The MDI methodology was based on a Tier 2 bottom-up analysis, deriving the number of units (inhalers) used annually and estimating the amount of HFC in each inhaler. Although the amount of HFC in each inhaler differs between manufacturers, an average amount was assumed. MDIs were assumed to emit 96% of total HFC contained during the lifetime usage: 2% of emissions occur during manufacture and 2% at end-of-life. Import and export levels have been based on data provided by manufacturers, and estimates of the UK market for MDI usage.

## 4.25.3   Uncertainties and Time Series Consistency

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

Estimates of the uncertainties associated with time-series data for this sector were made in AEA (2008), based on an understanding of the uncertainties within the sector and from discussion with industry. The uncertainty for aerosol emissions was estimated to be  +/- 15-

20%, based on uncertainties surrounding the estimation of import and export markets, and reliance on estimates from previous work (March 1999).

For MDIs, the uncertainty was estimated to be +/- 30-40%, a relatively high uncertainty due to the use of approximations of the use of HFCs in MDIs for research work, and assumptions that had to be made concerning the import / export market, domestic market and number of doses used in the UK annually. Uncertainty data from this study have been used in the uncertainty analysis presented in **Annex 7**.

### 4.25.4    Source Specific QA/QC and Verification
This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Details of verification of emissions of HFC-134a and HFC-152a are given in **Annex 9**.

### 4.25.5    Source Specific Re-Calculations
No recalculations were made to emissions from aerosols or MDI.

### 4.25.6    Source Specific Planned Improvements
Activity data and emission factors will be kept under review.


## 4.26    SOURCE CATEGORY 2F5 – SOLVENTS

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

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

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

Estimates of the uncertainties associated with time-series data for this sector were made in AEAT (2004), based on an understanding of the uncertainties within the sector and from discussion with industry.

There is a relatively high uncertainty estimated for emissions from this sector (+/- 25%). Uncertainty data from this study have been used in the uncertainty analysis presented in **Annex 7**.

### 4.26.4   Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.  Details of verification of emissions of HFC-134a and HFC-152a are given in **Annex 9**.

### 4.26.5   Source Specific Re-Calculations

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

### 4.26.6   Source Specific Planned Improvements

Activity data and emission factors will be kept under review.


## 4.27     SOURCE CATEGORY 2F6 – SEMICONDUCTOR MANUFACTURE

### 4.27.1   Source Category Description

PFCs and $SF_6$ are released from activities in this source sector.

Emissions of PFCs from semiconductor manufacturing are combined with emissions from training shoes in source category 2F8b for reasons of commercial confidentiality.  This source category is described in **Section 4.30**.

Emissions of $SF_6$ from semiconductor manufacturing are combined with emissions from training shoes and electrical insulation in source category 2F8b for reasons of commercial confidentiality.  This source category is described in **Section 4.30**.


## 4.28     SOURCE CATEGORY 2F7 – ELECTRICAL EQUIPMENT

### 4.28.1   Source Category Description

$SF_6$ is released from activities in this source sector.

Emissions of $SF_6$ from electrical equipment (insulation in electrical transmission and distribution – e.g. switchgear) are combined with emissions from training shoes and semiconductor manufacture in source category 2F8b for reasons of commercial confidentiality.  This source category is described in **Section 4.30**.

## 4.29    SOURCE CATEGORY 2F8A – ONE COMPONENT FOAMS

### 4.29.1    Source Category Description

One Component Foams (OCFs) are used by tradesmen (and in the home improvement sector, to a lesser extent) to mount doors and windows and to insulate different types of open joints and gaps.  As an insulator, OCF helps improve energy efficiency, due to the insulating properties of the PU foam and because the foam adheres to the building materials providing air tightness.  Therefore, use of OCFs could contribute to savings of $CO_2$ through improved energy efficiency.  When used as an OCF propellant, HFC (134a, 152a) is blended with various flammable gases.  HFC escapes from the foam on application, leaving small residues, which remain in the hardened foam for up to a year.  These products are not manufactured in the UK, although they are imported.  The use of HFCs in OCFs has been banned under the EC Regulation on fluorinated greenhouse gases (EC 842/2006) from July 4th 2008, except for where their use is safety critical.

### 4.29.2    Methodological Issues

A full description of the emissions and associated methodology used is contained in AEA (2008).  UK estimates of emissions from this source were based on a recent European evaluation of emissions from this sector (Harnisch and Schwarz, 2003), subsequently disaggregated by GDP to provide a top-down UK estimate.

### 4.29.3    Uncertainties and Time-Series Consistency

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

Estimates of the uncertainties associated with time-series data for this sector were made in AEAT (2004), based on an understanding of the uncertainties within the sector and from discussion with industry.  Emissions from this sector are estimated to fall within an uncertainty range of 10-25%.  Uncertainty data from this study have been used in the uncertainty analysis presented in **Annex 7**.

### 4.29.4    Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Details of verification of emissions of HFC-134a and HFC-152a are given in **Annex 9**.

### 4.29.5    Source Specific Re-Calculations

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

### 4.29.6    Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

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

### 4.30.1    Source Category Description

$SF_6$ has been used as a cushioning agent in sports-shoes. It is well suited to this application because it is chemically and biologically inert and its high molecular weight means it cannot easily diffuse across membranes. This means the gas is not released until the training shoe is destroyed at the end of its useful life. $SF_6$ has also been used for filling tennis balls, but this practice has now ceased.

$SF_6$ has been used in electrical transmission and distribution high and medium voltage switchgear and transformers since the mid-1960s because the physical properties of the gas make it very effective as an arc-quenching medium and as an insulator. Consequently it has gradually replaced equipment using older technologies, namely oil filled and air blast equipment.

The electronics industry is one of the largest sources of PFC emissions in the UK. The main uses of PFCs are as follows:

- Cleaning of chambers used for chemical vapour deposition (CVD) processes;
- Dry plasma etching;
- Vapour phase soldering and vapour phase blanketing;
- Leak testing of hermetically sealed components; and
- Cooling liquids, e.g. in supercomputers or radar systems.

In addition $SF_6$ is used in etching processes for polysilicon and nitrite surfaces, and there is some usage of $CHF_3$ and $NF_3$. The first two of these processes (cleaning and etching during semiconductor manufacture) account for the majority of emissions from the sector, with cleaning accounting for around 70% and etching 30%.

### 4.30.2    Methodological Issues

Emissions from these sectors have been combined for reasons of commercial confidentiality. A full description of the emissions and associated methodology used is contained in AEAT (2004) and AEA (2008). Estimates of emissions from sports-shoes were based on a bottom-up Tier 2 estimate, using activity data supplied in confidence by the manufacturer.

$SF_6$ emission from electrical transmission and distribution were based on industry data from BEAMA (for equipment manufacturers) and the Electricity Association (for electricity transmission and distribution), who provided emission estimates based on Tier 3b methodology, but only for recent years. Tier 3a estimates were available for the electricity distribution and transmission industry for 1995. In order to estimate a historical time series and projections, these emission estimates together with fluid bank estimates provided by the utilities were extrapolated using the March study methodology (March, 1999).

This involved estimating leakage factors based on the collected data and using the March model to estimate the time series. Emissions prior to 1995 used the March $SF_6$ consumption data to extrapolate backwards to 1990 from the 1995 estimates.

Emissions of PFC and $SF_6$ emissions from electronics are based on data supplied by UK MEAC – the UK Microelectronics Environmental Advisory Committee. UK MEAC gave total PFC consumption for the UK electronics sector based on purchases of PFCs as reported by individual companies. Emissions were then calculated using the IPCC Tier 1 methodology, which subtracts the amount of gas left in the shipping container (10%), the amount converted to other products (between 20% and 80% depending on the gas) and the amount removed by abatement (currently assumed to be zero). Emissions for previous years were extrapolated backwards assuming an annual 15% growth in the production of semiconductors in the UK up until 1999.

### 4.30.3   Uncertainties and Time Series Consistency

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

Estimates of the uncertainties associated with time-series data for this sector were made in AEAT (2004) and reviewed in AEA (2008), based on an understanding of the uncertainties within the sector and from discussion with industry. Estimated uncertainties in individual sectors: sports-shoes: +/- 20-50%, electronics +/- 30-60%, and electrical transmission and distribution +/- 20%. Uncertainty data from this study have been used in the uncertainty analysis presented in **Annex 7**.

### 4.30.4   Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Details of the verification of the greenhouse gas inventory are given in **Annex 9**.

### 4.30.5   Source Specific Re-Calculations

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

### 4.30.6   Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

# 5 Solvent and Other Product Use (CRF Sector 3)

## 5.1 OVERVIEW OF SECTOR

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

## 5.2 SOURCE CATEGORY 3A – PAINT APPLICATION

### 5.2.1 Source Category Description

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

**Table 5.1        Paints and their applications in the UK**

| Type of paint | Application |
|---|---|
| Decorative paint:<br>  Retail decorative<br>  Trade decorative | 'DIY' decorative coatings mainly sold directly to the public<br>'Professional' decorative coatings mainly sold to decorating contractors |
| Industrial coatings:<br>  ACE | Coatings for agricultural, construction and earthmoving equipment |
|   Aircraft | Coatings for aircraft & aircraft components |
|   Coil | Coatings for steel and aluminium coil |
|   Commercial vehicles | Coatings for new, non-mass produced vehicles |
|   Drum | Coatings for new and reclaimed metal drums |
|   High performance | Coatings for large structures such as bridges, offshore installations etc. |
|   Marine | Coatings for the exteriors and interiors of ships and yachts including both new and old vessels |
|   Metal and plastic | Coatings for metal and plastic substrates not covered elsewhere |
|   Metal packaging | Coatings for food and beverage cans and other small metal packaging |
|   OEM | Coatings for new mass-produced road vehicles |
|   Vehicle refinishing | Coatings for the refinishing of road vehicles |
|   Wood | Coatings for wooden substrates |

## 5.2.2    Methodological Issues

Emission estimates for most types of coatings are based on annual consumption data and emission factors provided by the British Coatings Federation (BCF, 2009).  Emission estimates for drum coatings, metal packaging and OEM coatings are estimated instead using a combination of consumption data and emission factors and estimates made on a plant by plant basis using information supplied by the Metal Packaging Manufacturers Association (MPMA, 2000) and the regulators of individual sites.

## 5.2.3    Uncertainties and Time- Series Consistency

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

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

## 5.2.4    Source Specific QA/QC and Verification

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

## 5.2.5    Source Specific Re-Calculations

No significant recalculations have occurred for this version of the inventory.

## 5.2.6    Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

## 5.3    SOURCE CATEGORY 3B – DEGREASING & DRY CLEANING

## 5.3.1    Source Category Description

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

Chlorinated solvents, including trichloroethene, tetrachloroethene and dichloromethane are widely used in industry to clean metallic, plastic and other surfaces, often using the process of vapour degreasing.  Objects to be cleaned are suspended above boiling solvent.  Solvent vapour condenses on the object and removes grease and other surface contamination.  Cooling tubes at the top of the tank minimise emissions but some solvent is emitted.  Cold cleaning is also used with objects being dipped in cold solvent and larger objects may be hand cleaned with solvent-soaked cloths.  Historically, 1,1,1-trichloroethane was also used as a cleaning solvent but this was prohibited due to this solvent's contribution to ozone depletion

and use ceased by 1999.  Hydrocarbons and oxygenated solvents are also used as cleaning solvents, generally being used for hand cleaning or cold cleaning of objects.

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

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

## 5.3.2    Methodological Issues

Emission estimates for surface cleaning processes are based on estimates of annual consumption and emission factors.  Consumption estimates are based on data from UK industry sources and UK and European trade associations, together with some published data.  Some extrapolation of data is necessary, using Index of Output data produced annually by the Office for National Statistics (ONS, 2009), although this is not expected to introduce significant uncertainty into the estimates.  Emission factors assume that all hydrocarbon and oxygenated solvent is emitted, while emission factors for chlorinated solvents are lower, reflecting the fact that some solvent is sent for disposal rather than emitted.

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

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

## 5.3.3    Uncertainties and Time-Series Consistency

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

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

## 5.3.4    Source Specific QA/QC and Verification

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

## 5.3.5    Source Specific Re-Calculations

No significant recalculations were necessary for this sector.

### 5.3.6     Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

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

### 5.4.1     Source Category Description

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

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

Film coating includes the manufacture of photographic film, data storage films, hot stamping films and other specialist products.  Processes manufacturing hot stamping films can use particularly large quantities of solvents.

Leather is generally coated with products that are waterborne, although more solvent borne coatings were used historically.  Coatings are used to provide protection or to enhance the appearance by improving colour or glossiness.

Textile coating processes can include the application of waterproof or fire-proof coatings to textiles and coating of textiles with rubber.

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

### 5.4.2     Methodological Issues

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

Emissions from coating manufacture are calculated from the solvent contained in coatings produced in the UK, by assuming that an additional 2.5% of solvent was lost during manufacture.

Emissions from the manufacture of rubber goods other than tyres are based on solvent consumption estimates provided by the British Rubber Manufacturers Association (BRMA, 2001), which are extrapolated to other years on the basis of the Index of Output figures for the rubber industry which are published each year by the ONS.

### 5.4.3     Uncertainties and Time Series Consistency

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

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

### 5.4.4    Source Specific QA/QC and Verification

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

### 5.4.5    Source-specific recalculations

No significant recalculations were necessary for this sector.

### 5.4.6    Source Specific Planned Improvements

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

## 5.5    SOURCE CATEGORY 3D - OTHER

### 5.5.1    Source Category Description

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

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

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

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

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

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

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

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

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

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

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

### 5.5.2    Methodological issues
Emission estimates are based on one of three approaches:

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

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

Estimates for sources covered by source category 3D are estimating using a consistent methodology with relatively little extrapolation of data. Some extrapolation of activity data is required for some sources included in source category 3D as this will limit the accuracy of

emission estimates for these sources e.g. industrial adhesives, other solvent use. Other sources included in 3D, including emission estimates for printing and paper coating are likely to be comparable in quality to the estimates for paint application or chemical products (source categories 3A and 3C). Overall, however, the estimate for source category 3D is likely to be more uncertain than those for 3A, 3B and 3C.

### 5.5.4    Source-specific QA/QC and verification

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

### 5.5.5    Source-specific recalculations

Two minor recalculations have been made for the printing sector. Estimated emissions from flexible packaging printing decrease by 1 Gg following the updating of emissions data, while estimated emissions from overprint varnishes increase by 2 Gg, following revision to the activity data.

### 5.5.6    Source-specific planned improvements

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

# 6    Agriculture (CRF sector 4)

## 6.1    OVERVIEW OF SECTOR

Sector 4 includes all anthropogenic emissions from agriculture, except for emissions from fuel combustion, sewage and liming of land. These emissions are included in Energy 1A and Waste 6B and LULUCF 5 respectively. Emissions from enteric fermentation, manure management, and agricultural soils are included in this CRF sector. Historical emissions from the field burning of agricultural residues are included here also, but field burning ceased in the UK in 1993.

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

## 6.2    SOURCE CATEGORY 4A – ENTERIC FERMENTATION

### 6.2.1    Source category description
Methane is produced as a by-product of enteric fermentation. Enteric fermentation is a digestive process whereby carbohydrates are broken down by micro-organisms into simple molecules. Both ruminant animals (e.g. cattle and sheep), and non-ruminant animals (e.g. pigs and horses) produce $CH_4$, although ruminants are the largest source per unit of feed intake.

### 6.2.2    Methodological issues
A more detailed description of the method used and emission factors can be found in **Annex 3**, **Section A3.6.1**.

Emissions from enteric fermentation are calculated from animal population data collected in the June Agricultural Census and the appropriate emission factors. Data for earlier years are often revised so information was taken from the Defra agricultural statistics database.

Apart from cattle, lambs and deer, the methane emission factors are IPCC Tier 1 defaults (IPCC, 1997) and do not change from year to year. The dairy cattle emission factors are estimated following the IPCC Tier 2 procedure (IPCC, 1997) and vary from year to year. For dairy cattle, the calculations are based on the population of the 'dairy breeding herd' rather than 'dairy cattle in milk'. The former definition includes 'cows in calf but not in milk'. In the current inventory the dairy cattle weights are derived from slaughter weight data; see **Table A3.6.3** in **Annex 3** for further details.

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

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

The emission factor for lambs is assumed to be 40% of that for adult sheep (Sneath *et al.* 1997).

In using the animal population data, it is assumed that the reported number of animals are alive for that whole year. The exception is the treatment of sheep where it is normal practice to slaughter lambs and other non-breeding sheep after 6 to 9 months. Hence it is assumed that breeding sheep are alive the whole year but that lambs and other non-breeding sheep are only alive 6 months of a given year (based on Smith and Frost, 2000). These assumptions for lamb can not be improved at the present time as there are no direct measurements of methane emission by lambs in the UK.

### 6.2.3    Uncertainties and time-series consistency
The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.2.1** and **Table A7.2.2**, provides estimates of uncertainty according to IPCC source category.

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

### 6.2.4    Source-specific QA/QC and verification
This source category is covered by the general QA/QC procedures, which are discussed in **Section 6.9**.

### 6.2.5    Source-specific recalculations
The following sections summarise the changes in the parameters.

*Cattle weights*
In the 2007 inventory, dairy cattle weights were derived from the following sources:

- 1990 to 2004; Steve Walton, Defra, pers. comm.
- 2005, and 2006; Helen Mason, Defra, pers. comm.
- 2007 was the average of the weights of the previous 5 years

In the current 2008 inventory the dairy cattle weights were replaced with slaughter weight data provided by Sarah Thompson, Defra. There is an increase in slaughter weights from 2004 (238kg) to 2005 (343kg). This increase was a result of the lifting of the Over Thirty Month rule[9], which is a measure to control the exposure of humans to the disease BSE; see **Table A3.6.3** in **Annex 3** for further details. A footnote to this table also includes the description of the method used to estimate live weight from slaughter weights.

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[9] To be able to slaughter cattle aged over 30 months (OTM), abattoirs must be OTM approved by the Meat Hygiene Service (MHS). In the UK, it is an offence to slaughter OTM cattle in a non-OTM approved abattoir. It is also an offence to slaughter cattle which were born or reared in the UK before 1 August 1996 for human consumption in any abattoir.

The impact on the change of cattle weight data source on the emissions was an increase between 1990 and 1996 and 2005 and 2007. Emissions decreased between 1997 and 2004.

*Animal numbers*
The national cattle numbers have been changed to agree with the sum of the regional data (for the four constituent countries of the UK) for years 2005, 2006, 2007. The type of cattle whose number have been corrected (beef or dairy) depends on the year. The difference on average is not greater than 1.2%. There is agreement in animal numbers between the national and regional inventories for the rest of the years.

In previous methane inventories, the time series of deer numbers used to estimate emissions had not been updated. Therefore, deer numbers used to estimate the methane emissions in 1996, 97, 98 were corrected to be consistent with the regularly updated numbers used to estimate emissions of $N_2O$. Deer numbers in the 2008 methane inventory for 1996, 97, 98 are lower compared with the 2007 inventory, and so this has resulted in a decline in methane emissions. The sharp decrease in emissions from deer between 1993 and 1994 is due to a large decrease in deer numbers in 1994.

*Milk yield*
The calculation of milk yield for leap years was changed from dividing the total by 365 instead of 366. Values of milk production were corrected by dairy herd to match values from regional totals.

*Emission factors*
Up to the 2007 inventory, the enteric fermentation emission factors for beef cattle were almost identical to the IPCC Tier 1 default so the default was used. In the 2008 inventory the Tier 2 methodology was introduced for the calculation of the emissions from beef (backdated to 1990), but a time series of cattle weights were not available and so a constant weight was assumed of 500 kg. The emissions were back calculated to 1990 producing an increase in emissions in most years across the time series (except in 2006).

## 6.2.6    Source-specific planned improvements
Emission factors and activity data will be kept under review. The Tier 2 structure will be incorporated for all animal categories and calculations included when activity data are available.

## 6.3    SOURCE CATEGORY 4B – MANURE MANAGEMENT

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

## 6.3.2 Methodological issues

### 6.3.2.1 Methane emissions from animal manures
A more detailed description of the method used and emission factors can be found in **Annex 3**, **Section A3.6**.

Methane is produced from the decomposition of manure under anaerobic conditions. When manure is stored or treated as a liquid in a lagoon, pond or tank it tends to decompose anaerobically and produce a significant quantity of methane. When manure is handled as a solid or when it is deposited on pastures, it tends to decompose aerobically and little or no methane is produced. Hence the system of manure management used affects emission rates. Emissions of methane from animal manures are calculated from animal population data (Defra, 2009a) in the same way as the enteric emissions.

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

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

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

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

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

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

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

The IPCC (1997) method for calculating emissions of $N_2O$ from animal waste management is followed.

The methodology assumes that 20% of the total manure N applied to soil volatilises as $NO_x$ and $NH_3$ and therefore does not contribute to $N_2O$ emissions from AWMS. This is because in the absence of a more detailed split of $NH_3$ losses at the different stages of the manure handling process it has been assumed that $NH_3$ loss occurs prior to major $N_2O$ losses.

The conversion of excreted N into $N_2O$ emissions is determined by the type of manure management system used. The distributions used were revised for cattle and poultry in the 2000 Inventory. The change related to the way that data on 'no significant storage capacity' of farmyard manure (FYM) were allocated. This could have a large effect on emissions because it amounted to around 50% of manure and the 'Daily spread (DS)' category has an emission factor of zero, compared to 0.02 for the 'Solid storage and dry lot (SSD)' category. Assigning this 'stored in house' manure to 'daily spread' is acceptable only if emissions from the housing phase are thought to be very small. Calculations were performed with the $N_2O$ Inventory of Farmed Livestock to compare housing and storage phases (Sneath *et al.* 1997). For pigs and poultry, the emission factor for housing is the same as or greater than that of storage. It would therefore lead to significant underestimation to use the daily spread emission factor. The FYM in this case has therefore been re-allocated to SSD or 'other' as appropriate.

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

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

### 6.3.3    Uncertainties and time-series consistency

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

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

### 6.3.4    Source-specific QA/QC and verification

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

### 6.3.5    Source-specific recalculations

Changes to cattle numbers (dairy and beef) as described in Section 6.2.5 also apply to this source sector.

The wrong correction for N volatilisation had been applied to all excreta up to the 2007 inventory (the removal of volatilised N had been applied to total excreted N). This has been corrected in the 2008 inventory submission and backdated to 1990, so now only the N applied to soil is corrected for volatilisation as the IPCC guidelines recommend. This has resulted in an increase of emissions in each year from animal waste management systems. In 2007 this increase was 25%.

### 6.3.6    Source-specific planned improvements

Emission factors and activity data will be kept under review including the use of more detailed emission factors and activity data to allow estimation of the effect of future mitigation policies. The Tier 2 structure will be incorporated when activity data are available.

## 6.4      SOURCE CATEGORY 4C – RICE CULTIVATION

This source is not relevant in the UK.

## 6.5      SOURCE CATEGORY 4D – AGRICULTURAL SOILS

### 6.5.1    Source category description

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

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

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

- (vii)   Emission of $N_2O$ from atmospheric deposition of agricultural $NO_x$ and $NH_3$
- (viii)  Emission of $N_2O$ from leaching of agricultural nitrate and runoff

Descriptions of the methods used are described in **Section 6.5.2**. A nitrogen cycle is included to describe the sources of $N_2O$ from agriculture (Figure 6.1).

**Figure 6.1     Simplified Nitrogen cycle highlighting the steps affecting the production of N$_2$O from agriculture.**
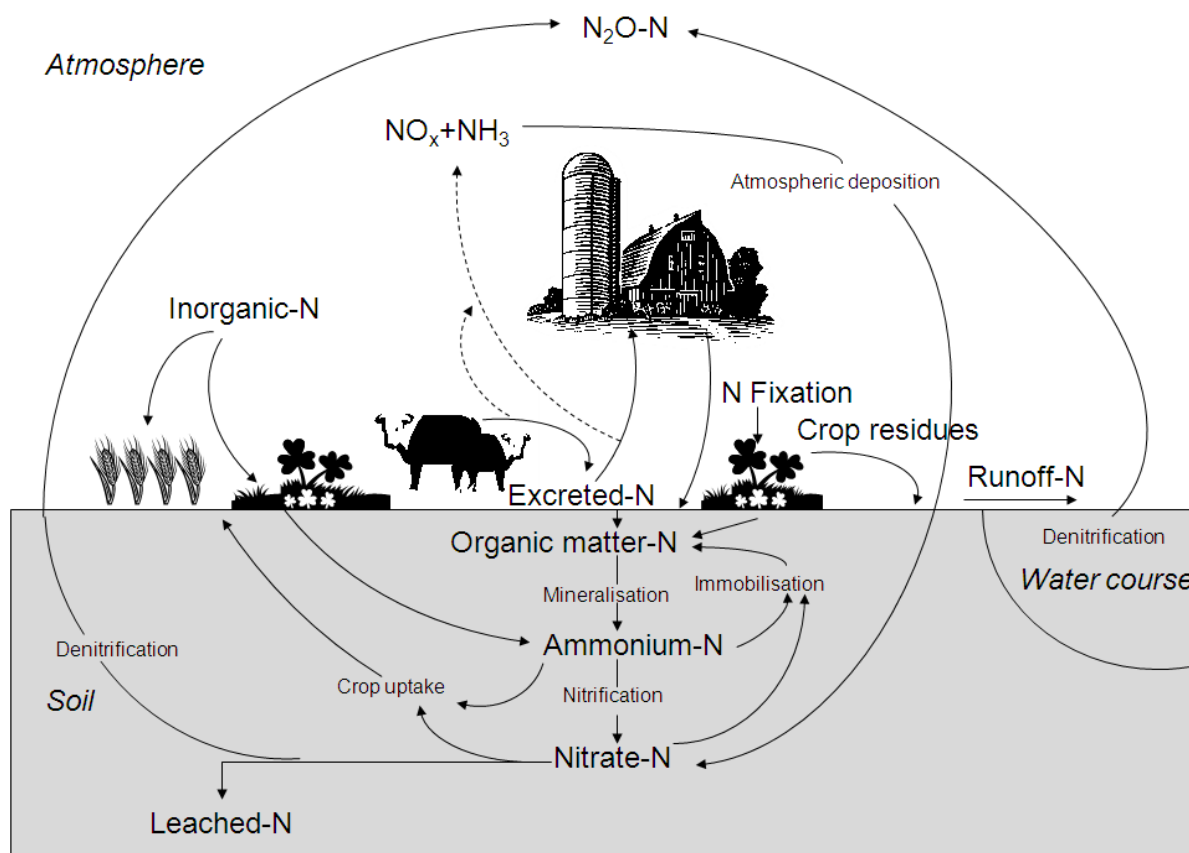


## 6.5.2     Methodological issues

A more detailed description of the method used and emission factors can be found in **Annex 3**, **Section A3.6.3**.

### 6.5.2.1     Inorganic Fertiliser

Emissions from the application of inorganic fertilizer are calculated using the IPCC (1997) methodology and IPCC default emission factors.

Annual consumption of synthetic fertilizer is estimated based on crop areas (Defra, 2009a) and fertilizer application rates (BSFP, 2009).

### 6.5.2.2     Biological Fixation of Nitrogen by crops

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

The data for the ratio residue/crop are default values found under Agricultural Soils or derived from Table 4.17 in Field Burning of Agricultural Residues (IPCC, 1997).  Crop production data are taken from Defra (2009a, 2009b). The total nitrous oxide emission reported also includes a contribution from improved grass calculated using a fixation rate of 4 kg N/ha/year (Lord, 1997). For this source the calculation of the emission requires estimating the amount of N that is fixed and then the emission factor is applied to this value previously with the result that the Implied Emission Factor reported in the old CRF, which was derived from the ratio

$N_2O$ emission: dry matter, was different from the IPCC default value (0.013). In the new CRF this has been modified and the IEF coincides with the IPCC default value.

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

Production data of crops are taken from Defra (2009a, 2009b).  Field burning has largely ceased in the UK since 1993.  For years prior to 1993, field-burning data were taken from the annual MAFF Straw Disposal Survey (MAFF, 1995).  Dry matter content of crops data from Burton (1982), Nix (1997), PGRE (1998), BLRA (1998).

### 6.5.2.4    Histosols
Emissions from histosols were estimated using the IPCC (2000) default factor of 8 kg $N_2O$-N/ha/yr.  The area of cultivated histosols is assumed to be equal to that of eutric organic soils in the UK and is based on a FAO soil map figure supplied by the Soil Survey and Land Research Centre (SSLRC) (now National Soil Resources Institute (NSRI).

### 6.5.2.5    Grazing Animals
Emissions from manure deposited by grazing animals are reported under agricultural soils by IPCC.  The method of calculation is the same as that for AWMS (**Section 6.3.2.2**), using factors for pasture range and paddock. However the value for the fraction of livestock N excreted and deposited onto soil during grazing is a country specific value of 0.52, much larger than the IPCC recommended value (0.23), based on country specific data.

### 6.5.2.6    Organic Fertilizers
Emissions from animal manures and slurries used as organic fertilizers are reported under agricultural soils by IPCC.  The calculation involves estimating the amount of nitrogen applied to the land and applying IPCC emission factors.

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

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

### 6.5.2.7    Atmospheric deposition of $NO_X$ and $NH_3$
Indirect emissions of $N_2O$ from the atmospheric deposition of ammonia and $NO_x$ are estimated according to the IPCC (1997) methodology but with corrections to avoid double counting N.  The sources of $NH_3$ and $NO_x$ considered are synthetic fertiliser application and animal manures applied as fertiliser.

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

### 6.5.2.8    Leaching and runoff

Indirect emissions of $N_2O$ from leaching and runoff are estimated according the IPCC methodology but with corrections to avoid double counting N.  The sources of nitrogen considered, are synthetic fertiliser application and animal manures applied as fertiliser.

## 6.5.3    Uncertainties and time-series consistency

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

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

## 6.5.4    Source-specific QA/QC and verification

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

## 6.5.5    Source-specific recalculations

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

The wrong correction for N volatilisation had been applied to all excreta up to the 2007 inventory (the removal of volatilised N had been applied to total excreted N).  This has been corrected in the 2008 inventory submission and backdated to 1990, so now only the N applied to soil is corrected for volatilisation as the IPPC guidelines recommend.

## 6.5.6    Source-specific planned improvements

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

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

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

## 6.6    SOURCE CATEGORY 4E – PRESCRIBED BURNING OF SAVANNAS

This source is not relevant in the UK.

## 6.7    SOURCE CATEGORY 4F – FIELD BURNING OF AGRICULTURAL RESIDUES

### 6.7.1    Source category description

This sector covers the emissions of non-$CO_2$ greenhouse gases from the burning (in the field) of crop residue and other agricultural waste on site.

### 6.7.2    Methodological issues

The National Atmospheric Emissions Inventory reports emissions from field burning under the category agricultural incineration.   The estimates are derived from emission factors calculated according to IPCC (1997) and from USEPA (1997).

The estimates of the masses of residue burnt of barley, oats, wheat and linseed are based on crop production data (e.g. Defra, 2009a) and data on the fraction of crop residues burnt (MAFF, 1995; ADAS, 1995b).  Field burning ceased in 1993 in England and Wales.  Burning in Scotland and Northern Ireland is considered negligible, so no estimates are reported from 1993 onwards.  The carbon dioxide emissions are not estimated because these are part of the annual carbon cycle.

### 6.7.3    Uncertainties and time-series consistency

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

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

### 6.7.4    Source-specific QA/QC and verification

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

### 6.7.5    Source-specific recalculations

There have been no recalculations.

### 6.7.6    Source-specific planned improvements

Emission factors and activity data will be kept under review.

## 6.8    SOURCE CATEGORY 4G - OTHER

There are no emissions reported in the UK under this category

## 6.9    GENERAL COMMENTS ON QA/QC

The livestock activity data used for constructing the inventory are supplied annually from the June census by the Defra Economics and Statistics Group, who follow documented QA procedures. Activity data on mineral fertiliser are calculated using application rates from Defra's annual British Survey of Fertiliser Practice (BSFP, 2009) multiplied by crop areas in Defra's Survey of Farming Incomes (June Census). Data from the June Census, in the form of *.PDF files, can be downloaded from the Defra website ([www.defra.gov.uk](http://www.defra.gov.uk)) and incorporated into inventory spreadsheets without the need for manual data entry, eliminating the need for double entry procedures. Annual comparisons of emission factors and other coefficients used are made by contractors compiling the inventory on behalf of Defra and by Defra itself. Any changes are documented in the spreadsheet and in the accompanying chapter of the National Inventory Report. Hardcopies of the submitted inventories, associated emails and copies of activity data are filed in Government secure files adhering to Government rules on document management.

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

The animal number and crop areas activity data used to be sourced separately from each of the four Devolved Administrations. These data are now provided by the Centre for Ecology and Hydrology (U. Dragotsis) for England, Scotland and Northern Ireland but not Wales. The welsh data we obtain from the welsh agriculture statistics. These data are also used to generate the NH3 inventory.

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

## 7.1 OVERVIEW OF SECTOR

Sector 5 includes carbon stock changes, emissions of greenhouse gases ($CO_2$, $CH_4$ and $N_2O$) by sources and removals of $CO_2$ by sinks from land use, land use change and forestry activities. Emissions from agriculture are included in Sector 4 Agriculture. Removals of carbon dioxide are conventionally presented as negative quantities. The sector has been a net sink since 1999, with a net removal in 2008 of -1.97 Mt $CO_2$ equivalent (

**Figure** 7.1).

**Figure 7.1         LULUCF emissions and removals 1990-2008**
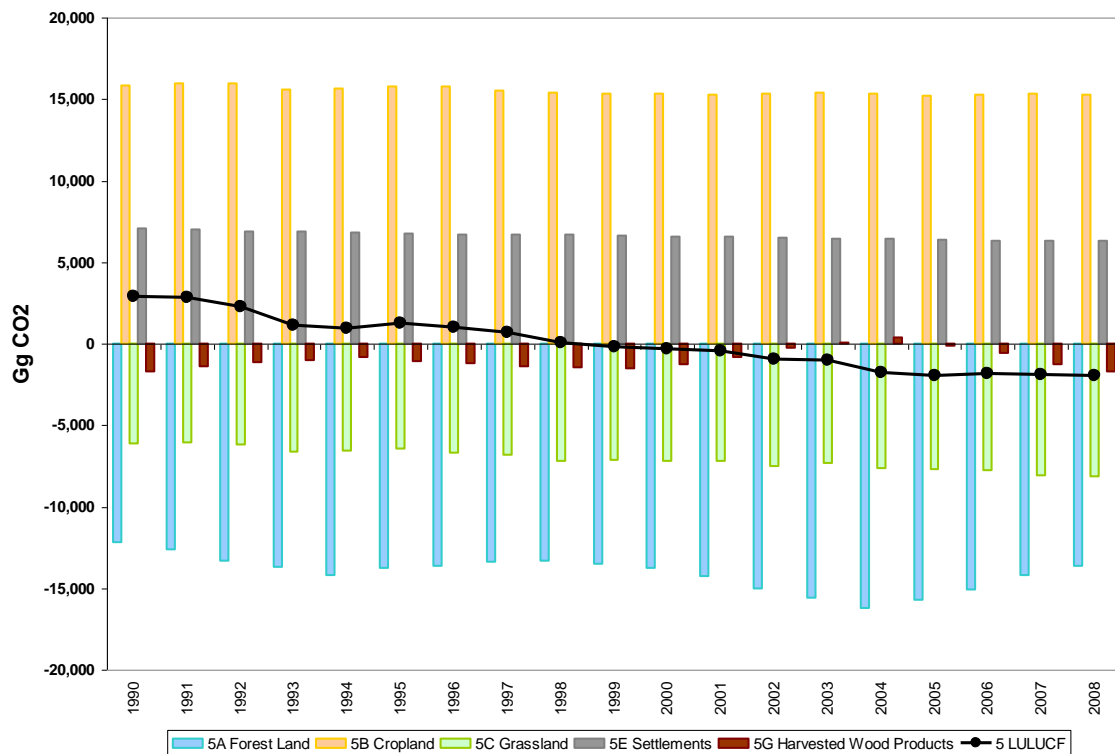


Net emissions in 1990 are estimated to be 2929 Gg $CO_2$ (the same as in the 2007 National Inventory Report). For 2007 a net removal of -1886 Gg $CO_2$ is estimated here compared to a net removal of -1815 Gg $CO_2$ in the 2007 Inventory. These differences are due to revisions in the deforestation activity data and the updating of 2007 activity data for liming and peat extraction that were not available for inclusion with the 2007 inventory.

There have been minor revisions of the data used for this Sector and no significant changes in methods. The text of this chapter and Annex 3.7 has been revised to improve the clarity and transparency of inventory reporting and to integrate Chapter 11 on Kyoto Protocol LULUCF

reporting (included in this NIR for the first time). Supplementary information on LULUCF and KP-LULUCF inventory reporting has been made available at http://www.edinburgh.ceh.ac.uk/ukcarbon/.

Activities under Article 3.3 and Article 3.4 of the Kyoto Protocol are reported in Chapter 11. Annex 3.7 contains more detailed descriptions of the methods used to estimate emissions in this Sector. Each section will discuss carbon stock changes and then GHG emissions. Planned improvements to the inventory are described in the relevant category.

### 7.1.1    The land use transition matrix

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

Areas of land use and land use change are compiled from various sources. 1990 areas for Cropland, Grassland and Settlements come from the 1990 Countryside Survey (Barr *et al*. 1993) and 1990 areas for Forest Land come from the Forestry Commission[10]. Wetlands are not reported as a separate category: wetland areas are included under Grassland or Other land, depending on habitat type. Other Land includes land not identified within the other categories and also takes account of the discrepancy between the forest areas in the Countryside Survey and the Forestry Commission forest areas (Howard *et al*. 2003). Areas of land use change to Forest (afforestation) come from planting data provided by the Forestry Commission, areas of land use change from Forest (deforestation) come from Forestry Commission data and the Department for Communities and Local Government. Other land use change data comes from the changes between the 1990 and the 1998 Countryside Surveys (Barr *et al*. 1993, Haines-Young *et al*. 2000), rolled forward to 2008.

The annual land use transition matrices for 1990-1991 and 2007-2008 for the UK are shown here (**Table 7.1** and **Table 7.2**). The full set of annual matrices for the UK and its individual countries are available at the LULUCF inventory website (www.edinburgh.ceh.ac.uk/ukcarbon ). The off-diagonal items (land use change data from the Countryside Survey, forest planting and deforestation datasets) in the matrix are used to estimate the land use change fluxes in the LULUCF inventory. The diagonal items (land remaining in the same use, in italics) are included for information but will not match the areas reported in the CRF.

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[10] The area of total productive woodland in 1999 (conifer and broadleaf high forest plus coppice) was used as a baseline (Forestry Commission 1999) and areas in 1990 calculated by subtracting total planting in 1991-1999 and taking account of woodland loss. This approach was undertaken with the help of the Forestry Commission but preceded full availability of the National Inventory of Woodland and Trees 1995-99.

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

| From:<br>To: | Forest | Cropland | Grassland | Wet-lands | Settlements | Other Land | Total (final) |
|---|---|---|---|---|---|---|---|
| **Forest** | *2,236,629* | 1,633 | 18,717 | 0 | 759 | 0 | **2,257,739** |
| **Cropland** | 0 | *5,458,672* | 95,948 | 0 | 942 | 0 | **5,555,562** |
| **Grassland** | 212 | 83,447 | *14,162,804* | 0 | 4,663 | 0 | **14,251,126** |
| **Wetlands** | 0 | 0 | 0 | *0* | 0 | 0 | 0 |
| **Settlements** | 644 | 2,475 | 13,462 | 0 | *2,004,786* | 0 | **2,021,368** |
| **Other Land** | 0 | 0 | 0 | 0 | 0 | *1,673,188* | **1,673,188** |
| **Total (initial)** | **2,237,485** | **5,546,227** | **14,290,932** | **0** | **2,011,151** | **1,673,188** | *25,758,983* |

**Table 7.2     Land use transition matrix, kha, for the UK in 2007-2008**

| From:<br>To: | Forest | Cropland | Grassland | Wet-lands | Settlements | Other Land | Total (final) |
|---|---|---|---|---|---|---|---|
| **Forest** | *2,496,123* | 973 | 8,720 | 0 | 497 | 0 | **2,506,313** |
| **Cropland** | | *5,617,950* | 95,948 | 0 | 942 | 0 | **5,714,841** |
| **Grassland** | 625 | 83,447 | *13,584,155* | 0 | 4,662 | 0 | **13,672,889** |
| **Wetlands** | 0 | 0 | 0 | *0* | 0 | 0 | 0 |
| **Settlements** | 445 | 2,475 | 13,462 | 0 | *2,175,370* | 0 | **2,191,752** |
| **Other Land** | 0 | 0 | 0 | 0 | 0 | *1,673,188* | **1,673,188** |
| **Total (initial)** | **2,497,193** | **5,704,845** | **13,702,285** | **0** | **2,181,472** | **1,673,188** | *25,758,983* |

These matrices have changed from previous years, as an error in compilation meant that Northern Ireland areas had been omitted. The total area of the UK is now reported as 25 758 983 hectares. This is 104% of the Standard Area Measurement reported for the UK (Office for National Statistics 2007). This difference is due to the way that areas of sea are dealt with in the land use change calculations: it should be possible to resolve this issue when new data is incorporated in the coming year. There is not thought to be any bias in the estimation of land use areas.

A new Countryside Survey was undertaken in 2007 in both Great Britain and Northern Ireland (Carey *et al*. 2008). This will provide new information on areas of land use and land use change from 1998 to 2007: we are in discussion with the Countryside Survey team about analysis of the raw data that would produce information for the inventory.

## 7.2     CATEGORY 5A – FOREST LAND

### 7.2.1     Description

This category is divided into Category 5.A.1 Forest remaining Forest Land and Category 5.A.2 Land converted to Forest Land. Reporting of carbon stock changes is disaggregated between the four geographical areas of England, Scotland, Wales and Northern Ireland. Reporting in category 5.A.2 is also split between two time periods, pre- and post-1990, to facilitate comparison with Kyoto Protocol reporting.

Forest Land is the biggest land use sink in the UK but the category also includes carbon stock losses and GHG emissions from forest management. All UK forests are classified as temperate and about 67% of these have been planted since 1921 on land that had not been forested for many decades.

The UK reports carbon stock changes in all forests planted since 1921 (when the first national survey of forests was undertaken). Forest surveys have been intermittent in the UK and there is not a network of permanent sample plots as exists in other European countries. As a consequence, estimates of carbon stock gains and losses for biomass and soils are modelled based on planting history and yield classes. According to the modelled results, the soil carbon under afforested land has not yet reached equilibrium so all land afforested since 1921 is reported under 5.A.2 Land converted to Forest (as permitted under the IPCC Good Practice Guidance for LULUCF).

No carbon stock changes are reported under 5.A.1 as all forest in this category was established before 1921 and is assumed to be in carbon balance (see section 7.2.6 for justification of this assumption). The area of forest reported under this category from 1990 to 2008 is adjusted to take account of forest land converted to other land use categories (see Chapter 11, section 1.3).

Nitrogen fertilizers are not generally applied to native woodlands, mature forests or re-planted forests in the UK, so emissions of $N_2O$ from N fertilization of forests (Table 5(I)) are reported as Not Occurring.

Reporting of non-$CO_2$ emissions from forest drainage (Table 5(II)) are not mandatory under the IPCC Good Practice Guidance for LULUCF, and there is currently no activity data for this activity, which is reported as Not Estimated. Work is planned in this area (section 7.2.8) Controlled burning (for example for habitat management) does not take place in the UK. Wildfires do occur but the activity data is not sufficient to split between 5.A.1 and 5.A.2. Therefore emissions of greenhouse gases from wildfires are all reported under 5.A.2 in Table 5(V).

Carbon stock changes in forest biomass (gains and losses), dead organic matter and soils due to land use change to Forest Land since 1921 are reported under 5.A.2. Land use change from Cropland, Grassland and Settlements are considered and mineral and organic soils are reported separately.

In the UK it is recommended that nitrogen fertilizers are only applied to forest when it is absolutely necessary. This is assumed to comprise first rotation forests on 'poor' soils, e.g. reclaimed slag heaps, impoverished brown field sites and upland organic soils. In terms of the inventory, this means that N fertilization is assumed for areas of Settlements converted to Forest Land and Grassland converted to Forest Land on organic soils. $N_2O$ emissions from this fertilization are reported under 5.A.2 in Table 5(I).

Emissions from wildfires on Forest Land in the UK are reported in Table 5(V). As mentioned above, all emissions from forest wildfires are reported under 5.A.2.

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

The UK uses Approach 2 (IPCC 2006) for the representation of land use areas in the inventory, and compiles several different data sources into a non-spatially-explicit land use

conversion matrix. The data sources are available at the individual country level (England, Scotland, Wales and Northern Ireland).

The state agencies responsible for forests in the UK are the Forestry Commission (England, Scotland and Wales) and the Forest Service (Northern Ireland). The areas of forest planted annually are published in Forest Statistics (described below) and the Forestry Commission also provide us with a more detailed breakdown of the published numbers. The allocation of land use change between Cropland, Grassland and Settlement is based on the proportional changes in the land use change matrices from the Countryside Survey (although we do not use the areas for conversion to forest from these matrices).

Forestry Statistics is an annual compendium Forestry Commission publication, published each September as a web-only publication accessible from 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. The NS outputs also include annual statistics for woodland area for each country, again using operational data for the FC/FS estates, with non-FC woodland based on the 1995-99 National Inventory, adjusted for new planting and sales of FC woodland; at present no adjustment is made for woodland converted to another land use. The sources and methodologies are described in more detail in the Sources section of the publication (section 11.1 of Forestry Statistics 2009).

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

The new National Forest Inventory (NFI) for Great Britain comprises a digital woodland map based on comprehensive aerial photography, a field survey using one-hectare sample squares and a survey of small woods and trees. The digital map and main woods survey now cover all woodland areas down to half a hectare, while the core field survey sample has been reduced to around 0.5% of area. An initial digital woodland map will be published in 2010. The field survey started in 2009 and should be completed in 2014. Interim results will be used for the softwood production forecast in 2011.

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

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

Statistics move to using the new NFI, the statistics may switch to using 0.5 hectares as minimum area.

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

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

## 7.2.4    Methodological Issues

In the draft ARR of the previous inventory submission the review team asked the UK to provide evidence to support the assumption of carbon balance in forest established before 1921. Simulations of UK forest conditions using the C-Flow and Forest Research CARBINE carbon accounting models have shown that, in the longer term, carbon stocks neither increase nor decrease. Rather, stocks fluctuate around a long term average value (Dewar, 1990, 1991; Dewar and Cannell, 1992; Thompson and Matthews, 1989). Typically in the UK, the long-term average stock is approached in <100 years after the time of woodland creation. This outcome is observed whether woodlands are left to grow undisturbed to achieve 'old growth' conditions or managed for production (Forest Research, recent unpublished model results). The assumption that woodlands in existence before 1921 *collectively* do not exhibit significant long-term changes in biomass stock in reporting periods relevant to the current inventory is consistent with these long-standing results. However, it is recognised that this may be a conservative assumption, which is only valid if the management of stands in the UK is not subject to long-term change (e.g. a general trend away from clearfell management towards 'continuous cover' management in stands).

The carbon uptake by the forests planted since 1920 is calculated by a carbon accounting model, C-Flow, as the net change in the pools of carbon in standing trees, litter, soil and products from harvested material for conifer and broadleaf forests.  The method can be described as Tier 3, as defined in the Good Practice Guidance for LULUCF (IPCC 2003).  The model calculates the masses of carbon in the pools of new even-aged plantations that were clear-felled and then replanted at the time of Maximum Area Increment.  The C-Flow model produces separate gains and losses for Carbon stock change in living biomass, rather than net

change. A detailed description of the method used can be found in Annex 3.7 for biomass, dead organic matter and soil.

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

## 7.2.5    Uncertainties and Time-Series Consistency

The Approach 1 (error propagation) uncertainty analysis in the Annexes provides estimates of uncertainty according to the GPG source category and gas. 5A Forest Land is estimated to have an uncertainty of 25% for net emissions in 1990 and 2008.

No measures of statistical uncertainty can be associated with the planting statistics. They mostly come from operational systems, for grants and FC planting. The grant-aided planting is allocated by date of payment, so all the recorded planting should have taken place. The new National Forest Inventory (NFI) map due in 2010 should provide better information on the reliability of the planting statistics. This comparison is likely to be limited to woods over 2 hectares, to enable like-with-like comparisons with the previous NIWT map.

The wildfire activity data are estimated to have an uncertainty of 50% for 1990-2004 and 100% for 2005-2008, as these have been extrapolated. The IPCC default of 70% uncertainty is used for the emission factors.

Considerable work on assessing the uncertainty in the Tier 3 approach to modelling carbon stock changes in forests has been undertaken as part of the LULUCF project in the past three years. This is described in **Chapter 11, Section 11.3.1.5.**

In terms of time series consistency:

- For forest carbon stock changes and N fertilization of forests, time series consistency is good as activity data are obtained consistently from the same national forestry sources.

- For emissions from wildfires, data have been collated from several published sources but all originate from the state forestry agencies so there is good time series consistency for 1990-2004. Data have been extrapolated for 2005-2008.

## 7.2.6    Category-Specific QA/QC and Verification

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

The first NFI output will be a new map, currently scheduled for June 2010, which will be used to assess estimates of total woodland area. The woodland field survey will provide direct assessment of woodland growing stock including species composition, stand structure, tree age (distribution) productivity indices, numbers of trees, and diameter and height distribution. Standing biomass (and carbon) in trees will be derived from these assessments using GB-specific conversion factors and allometric equations. A complete 5-year cycle of ground survey should be completed in 2014, at which point direct verification of tree forest carbon stocks should be possible. The ground survey also includes more qualitative assessments of

deadwood biomass which should be sufficient to enable checks on reported estimates. The possibility for the ground survey to also include some form of soil assessments is under consideration but, at the present time, this is not planned as part of the NFI scope. The full National Forest Inventory results are expected to be published in 2015.

Research undertaken as part of the inventory project (Levy and Clark 2009, Bellamy and Rivas-Casado 2009) on the impact of afforestation on soil carbon stocks has produced results that suggest net losses of soil carbon following afforestation rather than the net gains estimated using the inventory methodology (Hargreaves *et al*. 2003). These results are based on a limited number of experimental sites but bear further investigation. Meta-analyses of the impact of afforestation on soil carbon (Post and Kwon 2000; Guo and Gifford 2002) have found both positive and negative effects, with no clear conclusion.

### 7.2.7 Category-Specific Re-Calculations

The area of Forest remaining Forest (5.A.1) is adjusted to take account of losses due to deforestation. The updating of the deforestation estimates and revisions to the adjustment methodology led to changes in the estimated area between 2000 and 2007 but there was no impact on emissions/removals as this category is estimated to be in carbon balance.

The estimates of emissions and removals due to afforestation (5.A.2) were updated with planting statistics for 2008 provided by Forestry Statistics. A minor error in the area planted in Northern Ireland in 2007 (overestimated by 65 ha) was corrected, which lead to an increase in the carbon flux of 0.0685 Gg C.

### 7.2.8 Category-Specific Planned Improvements

The area reported under 5.A.1 Forest remaining Forest will be reviewed to ensure consistency with current Forestry Commission statistics.

We also plan to explore reporting Forest carbon stock changes using the IPCC default 20 year period, as recommended in the draft ARR of the last inventory submission. This will improve compatibility of the UK's reporting with the European Union. This would mean that much of the carbon stock change currently reported under 5.A.2 would move to 5.A.1 although the total net emissions would not change. The C-Flow model would have to be adapted and there may be other impacts on reporting. This would also remove the discrepancy between the UNFCCC approach and the Kyoto Protocol approach (see Chapter 11 section 1.3) on the adjustment of forest areas to take account of deforestation (necessary because national forest statistics do not currently capture forest conversion to other land uses).

The compilation of spatially disaggregated planting series (20x20km squares) back to 1990 is now complete although some final work is required to make this process fully operational for inventory production. Further details and mapped results will be made available on the project website www.edinburgh.ceh.ac.uk/lulucf. An investigation of the impact of forest management (species planting mix, thinning, harvest age) on forest carbon stocks and fluxes is also under way, enabled by access to more detailed forest datasets and associated model representations. This exercise encompasses:

- A reconciliation of forestry planting statistics with data on area by age class reported in existing forest inventories.

- Reference to data from successive forest inventories (and Forestry Commission woodland databases) on tree species composition and growth rates.
- Compilation of dispersed data and anecdotal accounts of the historical development of forest management practices, as well as drivers for ongoing long-term changes in approaches to forest management. This will contribute to the reporting of growth and removals due to forest management under Article 3.4.

Forest Research is exploring the possibility of obtaining data or anecdotal information on the spatial distribution of drainage of soils and nitrogen fertilization. These activities are known to have been common practice at certain times in particular localities in the UK; however, quantitative records on their extent are not readily available. This work is still at an early scoping stage.

Non-$CO_2$ GHG fluxes and changes associated with drainage of soils are also being investigated by Forest Research. A desk review of existing research literature is being undertaken to identify whether better information exists for the specification of emissions factors. In the medium term, research is continuing to improve understanding of the GHG dynamics in drained soils, as well as soils in which drainage is reversed. This involves direct monitoring of fluxes in a large scale trial site exploring the impacts of both soil drainage and restoration of the original water table.

An investigation by Forest Research is planned of the fate of forest carbon following harvesting interventions in woodlands. This should serve the dual purpose of checking the carbon dynamics associated with thinning and felling events as simulated by the C-Flow and CARBINE forest carbon accounting models and, if and where needed, informing the refinement of the representation of carbon dynamics of harvesting events in these models.

## 7.3 CATEGORY 5B – CROPLAND

### 7.3.1 Description
The category is disaggregated into 5.B.1 Cropland remaining Cropland and 5.B.2 Land converted to Cropland. Reporting of carbon stock changes is disaggregated between the four geographical areas of England, Scotland, Wales and Northern Ireland. Reporting in category 5.B.2 is also split between two time periods, pre- and post-1990, to facilitate comparison with Kyoto Protocol reporting.

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

- Non-forest biomass from yield improvements:  This is the annual increase in the biomass of cropland vegetation in the UK that is due to yield improvements (from improved species strains or management, rather than fertilization or nitrogen deposition).
- Fenland drainage (England only). Fenland areas of England were drained many decades ago for agriculture (although there was no land use change).  The soils in these areas are still emitting $CO_2$, i.e. there is an ongoing change in soil carbon stock.

Burning of agricultural residues (cereal straw or stubble) is not permitted in England and Wales and strongly discouraged in Scotland and Northern Ireland (NetRegs 2010). Therefore, emissions of non-$CO_2$ gases from biomass burning of cropland are not currently reported. Emissions of carbon dioxide from the application of limestone, chalk and dolomite to cropland are reported in Table 5(IV). The amount of agricultural lime applied relates to all areas of Cropland, therefore it will include areas in 5B1 and 5B2.

Carbon stock changes in non-forest biomass and soil due to land use change to Cropland are reported under 5B2. All forms of land use change, including deforestation, are considered and both mineral and organic soils are included.

$N_2O$ emissions from disturbance associated with land use conversion to cropland (Table 5(III)) are not currently estimated. The UK does not think that the method of estimation recommended in the Good Practice Guidance is suitable and it would therefore seem prudent to await an alternative approach to estimating $N_2O$ emissions due to land use change before including any data in the inventory. This is discussed in Annex 3.7 in more detail.

The conversion of Forestland to Cropland since 1990, which would result in some emissions from biomass burning, has been assessed as negligible (<0.4% of land use change). This will be re-assessed when the latest Countryside Survey data and the new National Forest Inventory map become available (due summer 2010). There is no activity data for wildfires on non-forest land in the UK.

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

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

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

Decadal matrices of land use change from 1950 have been developed from the Monitoring Landscape Change project dataset (using a sample survey of aerial photographs in 1947 and 1980) (MLC 1986) and the ITE/CEH Countryside Surveys of 1984, 1990 and 1998 (Barr *et al*. 1993; Haines-Young *et al*. 2000; Cooper and McCann 2002), which are based on repeated sample field surveys. A new Countryside Survey was undertaken in 2007 (Carey *et al*. 2008; Cooper *et al*. 2009) but the detailed data has not yet been assimilated into the inventory. Case studies of land use matrix development for Scotland and Wales are described in the ECOSSE report (Smith *et al*. 2007), and the same approach has been used to develop matrices for England. Data for Northern Ireland before 1990 is limited but matrices have been developed using agricultural census and forestry data (Cruickshank and Tomlinson 2000): a combination of IPCC Approaches 1 and 2.

The areas of Cropland receiving lime are estimated from the cropland (tillage + bare fallow) area reported in the annual June Agricultural Census and the proportions of arable areas receiving lime reported in the British Survey of Fertiliser Practice (2009).

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

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

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

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

### 7.3.4 Methodological Issues

Detailed descriptions of the methods and emission factors used for estimating carbon stock changes and emissions from Cropland can be found in Annex 3.7.

Changes in biomass and soil carbon due to land use change are estimated using a land use matrix approach. The development of the land use change matrices have been described in the previous sections and in Annex 3.7.

A dynamic model of carbon stock change is used with the land use change matrices to estimate soil carbon stock changes due to land use change. This uses a database of soil carbon density for the UK (Milne and Brown 1997; Cruickshank *et al*. 1998; Bradley *et al*. 2005) which has been constructed based on information on soil type, land cover and carbon content of soil cores. These densities included carbon to a depth of 1 m or to bedrock, whichever was the shallower, for mineral and peaty/mineral soils. Deep peat in the North of Scotland was identified separately and depths to 5 m are included.

In the dynamic model of soil carbon stock change, the change in equilibrium soil carbon density from the initial to the final land use during a transition is required. These are calculated for each land use category as averages for Scotland, England, Northern Ireland and Wales. The rate of loss or gain of soil carbon is dependent on the type of land use transition. A

Monte Carlo approach is used to vary the rate of change, the area activity data and the values for soil carbon equilibrium (under initial and final land use) for all countries in the UK. The mean soil carbon flux for each region resulting from these imposed random choices was then reported as the estimate for the Inventory. A detailed description of the method is found in Annex 3.7. An adjustment is made to these calculations for each country to remove increases in soil carbon due to afforestation, as the C-Flow model used in 5A2 is used to estimate these fluxes.

The activity data on liming for 2008 was published too late to include the most recent data in the inventory. The data for 2008 was extrapolated from the time series of previous values and will be recalculated in the next inventory submission.

As mentioned in **Section 7.3.1** we do not currently report $N_2O$ emissions from the conversion of Forest Land to Cropland. More detail is given in Annex 3.7. Work is planned in this area (see **Section 7.2.8**).

## 7.3.5   **Uncertainties and Time-Series Consistency**

The Approach 1 (error propagation) uncertainty analysis in the Annexes provides estimates of uncertainty according to the GPG source category and gas. 5B Cropland is estimated to have an uncertainty of 45% for net emissions in 1990 and an uncertainty of 50% for net emissions in 2008.

Recent work on quantifying uncertainties in the inventory has focussed on forest modelling (see **Chapter 11, Section 11.3.1.5**). Two recent COST Actions (603 and 639) have compiled the different datasets, methods and models of uncertainty analysis in Europe but have not reached any conclusions. A proposed new COST Action would produce a recommended method for comprehensive uncertainty analysis of Tier 3 approaches, which could be applied in the UK.

For liming, uncertainty in both the activity data and emission factor are judged to be low. The main source of uncertainty in the estimates is caused by non-publication of some data due to commercial restrictions although these are not judged to be very significant.

In terms of time series consistency:

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

## 7.3.6    Category-Specific QA/QC and Verification

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

A resampling of the 1980-based National Soil Inventory (NSI) in England and Wales in 1995-2003 found large losses of soil carbon across all land use types (Bellamy *et al*. 2005). As part of the supporting research for the LULUCF inventory project, Bellamy and Rivas-Casado (2009) attempted to identify NSI sites where there was sufficient land management information to determine the relationship between changes in soil carbon and differences in land management. Unfortunately, there was insufficient co-incident data (for example, none of 1314 Countryside Survey sample sites were closer than 1.9 km to a resampled NSI site) to allow these relationships to be investigated except at Forest Land sites (see section 7.2.6). Further work by Kirk and Bellamy (in review) has concluded that past changes (i.e. before the first NSI measurements in 1980) in land use and management are probably dominant in the observed losses of soil carbon, with climate warming only a small contributor (Smith *et al*. 2007).

Experimental work to detect the effect of cultivation (i.e. Grassland converted to Cropland) on $CO_2$, $CH_4$ and $N_2O$ fluxes and on soil carbon stocks was undertaken as part of a research project in support of the LULUCF inventory (Levy *et al*. 2009).  The results showed that, contrary to expectation, loss of carbon was greatest in the uncultivated control plots. However, the ground surface of all plots were kept bare during the experiment (to remove the influence of variation in litter input) so the comparability of these results to real agricultural land use changes is questionable, and there are likely to be important differences when a crop canopy is maintained on the soil surface. The implication of these results is that cultivation does not directly accelerate the decomposition of soil organic matter, and may actually impede it. This does not impinge on the empirical calculations used in the LULUCF inventory, but does have implications for mitigation policies based on changes to tillage practices.

## 7.3.7    Category-Specific Re-calculations

The 2007 emissions due to liming were estimated using the 2006 data on production of lime for agricultural use (ONS 2007 and BGS personal communication) as the data for 2007 was not published in time for inclusion in the inventory. Therefore values were assumed to be equal to those for the 2006 inventory.  The lime production data for 2007 has since been published (ONS 2008) and the estimates for liming emissions from Cropland in 2007 updated accordingly. This recalculation resulted in an increase in emissions of 16.96 Gg C.

## 7.3.8    Category-Specific Planned Improvements

A review of data sources is currently in progress: this will be used to assess whether there are additional data sources that could be used in the inventory or contribute to uncertainty estimates. The review will also assess other models that could potentially be used, although a full methods comparison is beyond the intended scope of the review.

The latest Countryside Survey data (2007) needs to be assimilated to update the land use change matrices. Discussions with the Countryside Survey team (also part of CEH) have taken place and the work should happen during this summer (2010). This will involve revision of

the methods used to produce the land use change matrices but the overall approach will remain the same. Any methodological revisions will be reported in the next submission.

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

Reporting of soil carbon stock changes in 5B1 Cropland remaining Cropland are currently limited to fenland drainage. Development of this section of the inventory at Tier 2 level would enable the effects of land management policies to be better reflected in the inventory. An assessment of the availability and quality of activity data and country-specific emission factors is necessary before this development can be implemented.

We also plan to explore moving to the IPCC 20-year default period for land remaining in the Land converted to Cropland category. This would also allow the discrepancies between the CRF areas and **Table 7.2** to be resolved.

## 7.4 Category 5C – GRASSLAND

### 7.4.1 Description
The category is disaggregated into 5.C.1 Grassland remaining Grassland and 5.C.2 Land converted to Grassland. Reporting of carbon stock changes is disaggregated between the four geographical areas of England, Scotland, Wales and Northern Ireland. Reporting in category 5.C.2 is also split between two time periods, pre- and post-1990, to facilitate comparison with Kyoto Protocol reporting. Carbon stock changes and biomass burning emissions due to conversion of Forest Land to Grassland are reported for all of the UK from 1990 onwards (emissions occur in the same year as the land use conversion).

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

Carbon stock changes in soil as a result of peat extraction for horticultural use are reported under 5.C.1. Emissions due to peat extraction for fuel use are reported in the Energy Sector of the GHGI. The inventory does not currently account for on-site emissions during ground preparation and extraction or for emissions from abandoned extraction sites.

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

Carbon stock changes in non-forest biomass and soil due to land use change to Grassland are reported under 5C2. All forms of land use change, including deforestation, are considered and both mineral and organic soils are included.

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

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

The approaches used for representing land use areas in the inventory are described in **Section 7.3.2**. The areas of Grassland receiving lime are estimated from the grassland (short term (<5 years old) and permanent (>5 years old)) area reported in the annual June Agricultural Census and the proportion of grassland receiving lime reported in the British Survey of Fertiliser Practice (2009). Areas of Grassland where peat extraction occurs are estimated from emissions, using an emission factor of 11.436 Gg C kha$^{-1}$ for Great Britain and 22.227 Gg C kha$^{-1}$ for Northern Ireland, as emissions are calculated from volume activity data rather than areas. Areas of Forest Land converted to Grassland (deforestation) are estimated from data compiled by the Forestry Commission on unconditional felling licences (felling licences granted without a requirement to restock) in England 1990-2002 and Great Britain 1999-2001. Areas of converted land for all of Great Britain are extrapolated from the English data for 1990-2002 (based on the 1999-2001 ratios for Great Britain). No recent data has been collected so rates of conversion for 2003-2008 are extrapolated from the rate for the previous ten years using an autoregressive model.

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

Grassland is defined in accordance with the Good Practice Guidance (IPCC 2003). Grazing is the pre-dominant land use, so areas of wetland habitat, such as bogs, are also included in the Grassland category. For pre-1980 land use matrices grassland is the sum of the following land cover types in the Monitoring Landscape Change project (MLC 1986): upland heath, upland smooth grass, upland coarse grass, blanket bog, bracken, lowland rough grass, lowland heather, gorse, neglected grassland, marsh, improved grassland, rough pasture, peat bog, fresh marsh and salt marsh. Post-1980, grassland is the sum of the following Broad Habitat types in the Countryside Survey: improved grassland, neutral grassland, calcareous grassland, acid grassland, bracken, dwarf shrub heath, fen/marsh/swamp, bogs and montane (**Table 7.3**).

**Table 7.3**  **Definitions of Broad Habitat types within the Grassland category (from Haines-Young *et al*. 2000, Appendix A).**

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

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

### 7.4.4    Methodological Issues

Detailed descriptions of the methods and emission factors used for the activities in this Category can be found in Annex 3.7.

The activity data on liming and peat extraction for 2008 was published too late to include the most recent data in the inventory. The data for 2008 was extrapolated from the time series of previous values and will be recalculated in the next inventory submission.

### 7.4.5    Uncertainties and Time-Series Consistency

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

In terms of time series consistency:
- For peat extraction (5C1), activity data come from several sources so the time series consistency is medium.
- For liming (5C) there is good time series consistency as there has been continuity in the published data sources.
- For changes in non-forest biomass and soil carbon stocks due to land use change (5C2) the data sources for Great Britain have separate good internal consistency, but there is poorer consistency between these sources and with the data for Northern Ireland.
- For emissions due to biomass burning after conversion of Forest Land to Grassland, the time series consistency is medium as the two constituent data series are not both available for each year and the values for much of the period are partially derived from data in one region.

## 7.4.6    Category-Specific QA/QC and Verification

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

## 7.4.7    Category-Specific Re-Calculations

The 2007 emissions due to liming and peat extraction were estimated using the 2006 data on production of horticultural peat and of lime for agricultural use (ONS 2007 and BGS personal communication) as the data for 2007 was not published in time for inclusion in the inventory. Therefore values were assumed to be equal to those for the 2006 inventory.  The production data for 2007 has since been published (ONS 2008) and the estimates for emissions from Grassland in 2007 updated accordingly. This recalculation resulted in a difference in emissions of 6.18 Gg C from liming on Grassland and a difference of 41.05 GgC from peat extraction.

The dataset on deforestation to Settlement was revised for 2000-2007, which resulted in a re-allocation of areas in the land use change matrix. This resulted in minor changes in estimates of net carbon stock change in soils between 2002 and 2007 of between +0.03 and -0.99 GgC.

## 7.4.8    Category-Specific Planned Improvements

The review and other planned improvements described in **Section 7.3.8** are also relevant to this section. Input activity data for deforestation remain a problem but outputs from the National Forest Inventory and map may help to resolve this (see the Forest Land section for further information). The initial focus involves the comparison of 'snapshot' woodland area maps from the Forestry Commission's NIWT (1995-1999) and the new NFI map. In principle, it should be possible to derive provisional deforestation estimates from such a comparison, however technical issues concerning the methods used to prepare the two maps are still being addressed. The intention is that eventually deforestation estimates should be obtained directly from periodic National Forest Inventories (NFIs), as results from these become available.

There has been work on soils in Northern Ireland which will be incorporated into the inventory for the next submission. A repeat survey of peat extraction (for fuel and horticultural use) in Northern Ireland has been undertaken (Tomlinson 2009) and the new results will be incorporated. The Tellus project (Jordan *et al*. 2009) has used airborne geophysical survey to map the extent and depth of peat in Northern Ireland. This project is

still in progress and the results will be used to derive an updated soil carbon inventory for Northern Ireland.

It is planned to move the reporting of emissions from peat extraction from this category to the 5D Wetlands category, in keeping with the IPCC 2006 Guidelines. At the same time, we will investigate including other emissions associated with peat extraction (from ground preparation, the extraction process and abandoned extraction sites) using Tier 1 approaches. The availability of suitable activity data will need to be assessed, so this may not be completed before the next inventory submission.

We also plan to explore moving to the IPCC 20-year default period for land remaining in the Land converted to Grassland category. This would also allow the discrepancies between the CRF areas and **Table 7.2** to be resolved.

## 7.5 CATEGORY 5D – WETLANDS

### 7.5.1 Description
According to the IPCC (2006), Wetlands include any land that is covered or saturated by water for all or part of the year, and that does not fall into the Forest Land, Cropland, or Grassland categories. In the UK, saturated land (based on the Countryside Survey Broad Habitat classification) such as bogs or marshes will fall into the Grassland category (as it is principally managed for grazing). Land covered by open water (e.g. lakes, rivers, reservoirs) is included in the Other Land category. Table 5.D. (Wetlands) is therefore completed with 'IE' (Included Elsewhere).

### 7.5.2 Category-specific planned improvements
As discussed in **Section 7.4.8**, there is a plan to move the reporting of emissions from peat extraction from the Grassland category to this category, in keeping with the IPCC 2006 Guidelines. The guidelines also suggest that emissions from peat extraction for energy use should be reported here, rather than in the Energy sector, as previously recommended. The area of land converted to permanently Flooded Land is assumed to be small in the UK but activity data will be sought.

We also plan to start reporting areas of open water in this category (rather than as part of the Other Land category). It is assumed that there are no emissions associated with such areas.

## 7.6 CATEGORY 5E – SETTLEMENTS

### 7.6.1 Description
This category is disaggregated into 5.E.1 Settlements remaining Settlements and 5.E.2 Land converted to Settlements. The area of Settlements in Category 5.E.1 is considered not to have long term changes in carbon stock. Reporting of carbon stock changes is disaggregated between the four geographical areas of England, Scotland, Wales and Northern Ireland. Reporting in category 5.C.2 is also split between two time periods, pre- and post-1990, to

facilitate comparison with Kyoto Protocol reporting. Carbon stock changes and biomass burning emissions due to conversion of Forest Land to Settlements are reported for all of the UK from 1990 onwards (emissions occur in the same year as the land use conversion).

Carbon stock changes in non-forest biomass and soil due to land use change to Settlement are reported under 5E2. All forms of land use change, including deforestation, are considered and both mineral and organic soils are included.

Emissions of $CO_2$, $CH_4$ and $N_2O$ from the burning of forest biomass when Forest Land is converted to Settlement are reported under Table 5(V).

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

The approaches used for representing land use areas in the inventory are described in **Section 7.3.2**. Activity data on areas of Forest Land converted to Settlement (deforestation) is extrapolated from data for England held by the Department of Communities and Local Government (DCLG). They obtain this information from the Ordnance Survey (the national mapping agency) which makes an annual assessment of land use change from the data it collects for map updating. Areas of Forest Land conversion to Settlement are calculated as the sum of all forest land use categories to urban land use categories. (Note that this data set is not thought to be reliable for forest conversion in rural areas because the resurveying frequency is too low).

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

Settlement is defined in accordance with the Good Practice Guidance (IPCC 2003). For pre-1980 land use matrices Settlement land is the sum of the Built-up, Urban open, Transport, Mineral workings and Derelict land cover types in the Monitoring Landscape Change project (MLC 1986). Post-1980, Settlement land corresponds to the Built-up and Gardens Broad Habitat type in the Countryside Survey (Haines-Young *et al*. 2000, Appendix A), defined as:

"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."

### 7.6.4    Methodological Issues

Detailed descriptions of the methods and emission factors used for the activities in this Category can be found in Annex 3.7.

### 7.6.5    Uncertainties and Time-Series Consistency

The uncertainty analysis in the Annexes provides estimates of uncertainty according to the GPG source category and gas. 5E Settlement is estimated to have an uncertainty of 35% for net emissions in 1990 and an uncertainty of 50% for net emissions in 2008. The discussion of recent work on uncertainty in **Section 7.3.5** is also applicable.

In terms of time series consistency:

- For changes in non-forest biomass and soil carbon stocks due to land use change (5E2) the data sources for Great Britain have separate good internal consistency, but there is poorer consistency between these sources and with the data for Northern Ireland.

- For emissions due to biomass burning after conversion of Forest Land to Settlement, there is good time series consistency as there has been continuity in the activity data source.

### 7.6.6 Category-Specific QA/QC and Verification

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

### 7.6.7 Category-Specific Re-Calculations

The dataset on deforestation to Settlement was revised for 2000-2005. A five-year moving average has been applied on the recommendation of the data suppliers (Department of Communities and Local Government). The area of deforestation in 2006 to 2008 has been estimated by extrapolation from earlier years. These revisions have resulted in changes in the estimates of carbon stock changes in living biomass and soils and in emissions from biomass burning between 2000 and 2007. The carbon stock change in living biomass changed by -0.02 to -0.1  between 2000 and 2004, and by 1.72 to 2.31 Gg C between 2005 and 2007. The carbon stock change in soils changed by -0.03 to 0.99 GgC between 2000 and 2007. Estimates of emissions from biomass burning changed by 0.06 to -1.34 Gg C (and emissions of non-$CO_2$ gases in proportion).

### 7.6.8 Category-Specific Planned Improvements

The review and other planned improvements described in section 7.3.8 are also relevant to this section. Input activity data for deforestation remain a problem but outputs from the National Forest Inventory and map may help to resolve this (see the Forest Land section for further information).

We also plan to explore moving to the IPCC 20-year default period for land remaining in the Land converted to Settlement category. This would also allow the discrepancies between the CRF areas and **Table 7.2** to be resolved.

## 7.7    CATEGORY 5F – OTHER LAND

### 7.7.1    Description

No emissions or removals are reported in this category. It is assumed that there are very few areas of land of other types that become bare rock or water bodies, which make up the majority of this type. Therefore Table 5.F. (Other Land) is completed with 'NO' (Not Occurring).

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

The approaches used for representing land use areas in the inventory are described in **Section 7.3.2**.

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

Other Land is defined as areas that do not fall into the other land use categories. For pre-1980 land use matrices Other Land is the sum of the Bare rock, Sand/shingle, Inland water and Coastal water land cover types in the Monitoring Landscape Change project (MLC 1986). Post-1980, Other Land is the sum of the Inland rock, Standing water and Canals and Rivers and Streams Broad Habitat types in the Countryside Survey (**Table 7.4**).

**Table 7.4          Definitions of Broad Habitat types included in Other Land (Haines-Young *et al*. 2000, Appendix A)**

| Broad habitat type | Definitions |
|---|---|
| Inland rock | Habitat types that occur on both natural and artificial exposed rock surfaces, such as inland cliffs, caves, screes and limestone pavements, as well as various forms of excavations and waste tips, such as quarries and quarry waste. |
| Standing Waters and Canals | This Broad Habitat category includes lakes, meres and pools, as well as man-made water bodies such as reservoirs, canals, ponds, gravel pits and water-filled ditches. |
| Rivers and Streams | This category includes rivers and streams from bank top to bank top; where there are no distinctive banks or banks are never overtopped, it includes the extent of the mean annual flood. |

### 7.7.4    Category-specific planned improvements

We plan to start reporting areas in the CRF Table for this category. As discussed in **Section 7.5.2**, areas of open water will be reported in the Wetlands category.

## 7.8      CATEGORY 5G – OTHER

### 7.8.1    Description

Changes in stocks of carbon in harvested wood products (HWP) are reported here. These HWP stocks result from normal forest management processes (thinning and harvesting) and from conversion of Forest Land to Grassland or Settlements (deforestation).

The UK includes direct GHG emissions in its GHGI from those 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.Net LULUCF emissions from the UK's Overseas Territories and Crown Dependencies are currently included in sector 5G. This is due to a technical CRF reporting issue which AEA are pursuing with the

CRF Helpdesk. We hope to have resolved this issue in time for the next inventory submission. Data for the Crown Dependencies of Jersey, Guernsey and the Isle of Man and the Overseas Territory of the Falkland Islands are reported.

## 7.8.2    Methodological Issues

A description of the method used to account for changes in stocks of carbon in HWP is in Annex 3.7. The carbon accounting model (C-Flow) is used to calculate the net changes in carbon stocks of harvested wood products, in the same way as it is used to estimate carbon stock changes in 5.A. Changes in carbon stocks from HWP arising from deforestation (conversion of Forest Land to Grassland or Settlement) are estimated using a look-up table of annual HWP stock changes generated by C-Flow.

The availability of data for the different OTs and CDs is very variable, so that emission estimates can only be made for the Isle of Man, Guernsey, Jersey and the Falkland Islands. These four comprise over 95% of the area in all the OTs and CDs. Gibraltar wished to produce their own inventory: their LULUCF net emissions/removals are likely to be extremely small, given the size of the country (6km$^2$), and will have little impact on overall numbers. A lack of suitable data for the Caribbean territories (discussed in the 1990-2006 NIR) makes it impossible to create inventories for them at the present time.

Information on the area of each IPCC land category, dominant management practices, land use change, soil types and climate types were compiled for each OT/CD from statistics and personal communications from their government departments and global land/soil cover databases. This allowed Tier 1 level inventories to be constructed for the four OT/CDs already mentioned, and a Tier 3 approach for Forest Land on the Isle of Man (using the C-Flow model also used for the UK). The estimates have high uncertainty and probably do not capture all relevant activities, in particular land use change to Settlement from land uses other than Forest Land (there are no default IPCC methods for these transitions).

## 7.8.3    Uncertainties and Time-Series Consistency

The uncertainty analysis in the Annexes  provides estimates of uncertainty according to IPCC source category and gas. 5G is estimated to have an uncertainty of 30% for net emissions in 1990 and 2008.

Activity data (areas planted and consequently harvested) are obtained consistently from the same national forestry sources, which helps ensure time series consistency of estimated removals.

The estimates for the Overseas Territories and Crown Dependencies have high uncertainties (expert estimate of 100%).

## 7.8.4    Category-Specific QA/QC and Verification

This source category is covered by the general QA/QC procedures, which are discussed in section 7.9 Work is currently being undertaken to verify the modelled Harvested Wood Products estimates by comparison with the Forestry Commission model forecasts.

### 7.8.5    Category-Specific Re-Calculations

Revisions in the deforestation to Settlement dataset resulted in changes in the pool of harvested wood products (from additions from deforestation). This resulted in changes in carbon stocks in this category of between 0.1 and -2.19 Gg C between 2000 and 2007.

Net emissions from LULUCF for the Overseas Territories and Crown Dependencies were calculated for the 1990 to 2006 inventory. These estimates have not been updated and have been rolled forward from the 2006 values.

### 7.8.6    Category-Specific Planned Improvements

The emission factors and activity data for harvested wood products will be kept under review. A watching brief on the development of methods of HWP estimation has been maintained (Matthews 2009). It is too early to proceed with full implementation of any specific method and preparation of estimates until methodologies have been agreed by the IPCC.

The technical issue over where to report the estimates for the Overseas Territories and Crown Dependencies should be resolved by the time of the next submission. Methods and emission factors for net emissions from the Overseas Territories and Crown Dependencies will be reviewed and updated for the next submission. The Global FRA 2010 country reports for each territory will then be available which will provide updated activity data for category 5A.

## 7.9      GENERAL COMMENTS ON QA/QC

CEH (the inventory compiler for the LULUCF sector) has adopted the quality assurance principles set out in the Joint Code of Practice for Research issued by the Biotechnology and Biological Sciences Research Council, the Department for Environment, Food and Rural Affairs, the Food Standards Agency and the Natural Environment Research Council.  Quality Assurance is reported to Executive Board as appropriate.  In addition projects are managed through Prince2 protocols. The CEH Policy Statement is given below.

- CEH is dedicated to achieving and maintaining the highest possible standards of quality in order to meet the needs of its work programmes and the needs of internal and external customers
- In pursuit of its quality aims, CEH strives to create a working situation that enables all staff to contribute to the continuous and meaningful improvement of a Quality Management System through competence and effective communication
- It is the aim to ensure that all staff at CEH understand and are committed to their individual and collective responsibilities for quality
- To achieve these objectives, the suitability of working practices and the training needs for existing and new members of staff will be appraised by management.

In 2009 the LULUCF inventory project was audited by an independent CEH team to confirm compliance with the Joint Code of Practice, where the project was praised for its high standards.

In addition to internal quality assurance procedures the submitted inventory data is also checked by AEA (the national inventory compilers) and the European Commission).

The project maintains a publicly available website, www.edinburgh.ceh.ac.uk/ukcarbon where the inventory reports and tables are made available. There is a plan to make more use of this website for providing access to additional information relating to the inventory. The inventory data will also be available via the CEH Information Gateway http://gateway.ceh.ac.uk/ . Technical information on the inventory methods is documented in a 'wiki' available to team members, ensuring continuity. Issue management software is used for project management and tracking issues such as requests for data from stakeholders and external parties.

# 8　　Waste (CRF Sector 6)

## 8.1　　OVERVIEW OF SECTOR

Emissions of GHGs from this sector occur from the disposal and treatment of waste. Solid wastes can be disposed of through landfilling and treated through recycling, composting, incineration and waste-to-energy. The most important GHG produced in this sector is methane, which is produced as organic wastes decay in the airless conditions of landfills.

Emissions of carbon dioxide derived from fossil carbon by waste incineration are covered, together with other greenhouse gases, under category 6C (Waste incineration) or 1A if there is energy recovery.

Sector 6B covers wastewater treatment which produces methane and nitrous oxide. Emissions of non-methane volatile organic compounds are also covered under sector 6B.

## 8.2　　SOURCE CATEGORY 6A – SOLID WASTE DISPOSAL ON LAND

### 8.2.1　　Source category description

Methane is the most important greenhouse gas produced in this sector. It is formed during the anaerobic decomposition of organic waste disposed in solid waste disposal sites (SWDS), which also produces an equivalent amount of carbon dioxide  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 carbon dioxide from SWDS are not considered further. Non-methane volatile organic compounds (NMVOCs) are also produced at SWDS. These are estimated using an emission factor relating the NMVOC to the amount of methane formed. An emission factor of 0.01 t non-methane volatile organic compounds /t methane produced, is equivalent to 5.65g non-methane volatile organic compounds /m$^3$ landfill gas (Passant, 1993), has been used. Nitrous oxide emissions from landfill are believed to be negligible and are not considered under this sector 6A.

The NAEI category Landfill maps directly on to IPCC category 6A1 Landfills (managed waste disposal on land) for methane emissions. Emissions are reported from managed landfills only, as open dumps and unmanaged landfills (unmanaged waste disposal sites) are not significant sources in the UK.

Emissions for $CO_2$ are reported as NE as they are considered to be biogenic and therefore do not contribute to the total emissions.

### 8.2.1.1    UK Waste Management Disposal to Land Legislation and Guidance

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

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

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

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

The Environmental Permit specifies the emission limits for relevant pollutants and operating conditions, based on recognised Best Available Techniques (BAT), taking into account the technical characteristics of the installation, its geographic location and local environmental conditions.

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

The Landfill Directive aims to improve standards of landfilling across Europe by setting specific requirements for the design and operation of landfills, and for the types of waste that can be accepted in landfills. All landfills are required to comply with the Directive's requirements, although a transitional period is allowed for landfills in existence at 16 July 2001.  In accordance with the Article 4 of the Directive, landfills are classified on the basis of the types of waste they are licensed to receive, namely Hazardous, Non-Hazardous or Inert waste.  Most biodegradable waste landfilled in the UK is categorised as non-hazardous, and so Non-Hazardous landfills accounts for nearly all the methane emitted from UK landfills, with negligible amounts from Inert and Hazardous waste landfills.

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

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

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

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

## 8.2.2    Methodological issues

The UK method uses a first order decay (Tier 2) methodology based on estimates and historical data on waste quantities, composition and disposal practices over several decades. "First-order decay" is simply the assumption that biodegradable carbon in the waste decays to methane with a reaction rate that is proportional to the amount of carbon remaining in the waste. The IPCC Guidelines define the overall approach for calculating methane emission from landfill as the amount of methane generated in the waste, *minus* the amount of methane recovered (for flaring or other combustion process), correcting for the amount of remaining methane that is oxidised to carbon dioxide. This is represented by the following equation:

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

which is represented by equation 3.1 in the 2006 Guidelines, where

$CH_4$ emissions = $CH_4$ emitted in year T, Gg
T=inventory year
x=waste category or type of material
$R_T$=recovered $CH_4$ in year T, Gg
$OX_T$=oxidation factor in year T (fraction).

Only the methane remaining after subtraction of methane recovered is available for oxidation. Mass units used are Giga grams (Gg, $10^9$ grams): one Gg is equivalent to one kilotonne (kt). All sites in the UK are managed, and therefore have a methane correction factor of 1.0.

The IPCC FOD methodology is based on the premise that Degradable Organic Carbon compounds (DOC) 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. DOC) present at any given time. This means that as the reactant is used up, the rate of reaction slows down also. The decomposition process is characterised by an exponential rate constant, k, with dimensions of reciprocal time (units in this case are year$^{-1}$). The rate constant is related to the half-life ($T_{0.5}$) of the reaction, namely the time taken for the concentration of the reactant to halve, as shown by the following equation:

$$(2) T_{0.5} = \ln(2)/k$$

where ln(2) is the natural logarithm of 2.

The AEA Technology model of methane generation from landfill sites was used until 2002 (Brown *et al*, 1999). This was updated and revised for Defra by the consultants Land Quality Management (LQM, 2003). Further revision of the LQM version of the model was made in 2005 by the consultants Golder Associates (Golder, 2005) and the 2006 and 2007 NIR. and CRF contains results from this model.

The UK method is based on Equations 4 and 5 in the Revised 1996 IPCC guidelines (IPCC, 1997) (pp 6.10-6.11), which are compatible with Equations 5.1 and 5.2 in the Good Practice Guidance (IPCC, 2000). A slightly modified version of Equation 5.1 is used, which takes into account the fact that the model uses a finite time interval (one year). The full derivation of the equations used is given in Appendix 6 of Golder (2005).

The UK revised the model used to estimate emissions from the managed waste disposal on land in 2008. The new model (MELMod-UK) offers considerable advantages to the user in terms of transparency of approach, utility and ease of use. An additional landfill type has been added that may be useful for modelling new developments in landfill practices. MELMod-UK is based on the first-order decay (FOD) methodology described in the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. The model has been tested against the previous national assessment model and the two models yield identical results from the same input data. MELMod-UK allows the use of the updated modelling approach for estimating methane generation described in the 2006 IPCC Guidelines and this avoids the small errors in integrating the exponential decay curve inherent in the approach described in previous editions of the Guidelines.

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

The model uses waste disposal data from 1945 to the present, a period equivalent to over four half lives for the slowly degrading waste (i.e. with a decay rate of 0.046 year$^{-1}$, equivalent to a half life 15 years). This lies within the range of 3 to 5 half-lives recommended by the Good Practice Guidance.

The model takes account of changes in landfill practice over past decades that reflect improvements in landfill gas collection for utilisation and disposal by flaring, as described below.

The estimates of historical MSW waste disposal and composition data are based on various data sources, described fully in Brown et al. (1999), LQM (2003) and Golder (2005). Between 1945 and 1994 the waste arisings data are the same as that used for the AEA model (Brown et al., 1999) and are based on waste surveys in the UK using actual data combined with landfilled volume estimates, household waste composition surveys and population data to interpolate where necessary. From 1995 to 2000, data are based on a new study carried out by ERM for input to the LQM (2003) using England and Wales arisings derived from Defra's Municipal Waste Management Survey for the year 1999/00. Years between 1995 and 1998 inclusive are calculated by linear interpolation between 1994 and 1999. From 2001 the model uses a scenario of waste disposal from the Local Authority Waste Recycling Recovery and Disposal (LAWRRD) model (AEA Technology, 2005; Brown et al., 2006). The LAWRRD model provides arisings for England and so the data have been scaled up to the UK on the basis of population, assuming that England represents 83% of the UK's total population. A comparison between the LAWRRD data and actual waste arisings for 2002 and 2003 showed a discrepancy of 2% and 4%, respectively. These differences are considered insignificant in comparison with greater uncertainties elsewhere in the methodology and so the LAWRRD model data were taken to be representative of the current situation.

As recommended in the Good Practice Guidance, the estimates of waste disposal quantities include commercial and industrial waste, demolition and construction waste, sewage sludge disposal to landfill as well as municipal waste. There is greater uncertainty in both the amounts and composition of industrial and commercial wastes than in MSW. Arisings for these categories from 1945 to 1998 were determined by Brown *et al.* (1999), primarily based on the Aitchison et al. (1996) model and on national estimates from a 1995 survey. Commercial waste arisings for 1993 were derived from the Department of Environment Digest of Environmental Statistics for 1994. They estimated that this value (15Mt) was subject to an uncertainty of +/- 5Mt. Industrial waste arisings for 1993 were from two sources (Pearce et al., 1993 and Bellingham et al., 1994). Industrial arisings amounted to 68Mt in 1993, of which the methane-producing fractions included 10Mt of general industrial wastes, believed to be similar in nature to commercial wastes, and 20Mt of food production wastes. Historical data were scaled using employment rates in the industries concerned.

In the Golder (2005) model, commercial and industrial arisings have been based on Environment Agency data; for 2002. Estimates for commercial and industrial waste for the years between 1997 (the last year of estimates given by Brown *et al* (1999) and 2002 were estimated by linear interpolation between these years. After 2002, the commercial and industrial waste arisings were assumed to remain constant. The composition of commercial and industrial waste, based on the Strategic Waste Management Assessment, and in the absence of better data, has been assumed to be constant from 1999.

As part of the improvement of the UK assessment model, a review of waste arisings data was completed. This review found that 2002 data for commercial and industrial waste arisings given by Golders was based on England and Wales only, rather than the UK as a whole, and that this error consequently affected estimates for commercial and industrial waste from 1998 onwards. This was corrected in the last reported year (2007). This resulted in an increase of 7.46 Mt of waste to landfill in 2007, and a corresponding increase in methane emitted, from 919 to 963 Mt that year. Prior to 1998 arisings from commercial and industrial were determined according to Brown *et al.* (1999). Commercial and industrial waste arising from Brown *et al.* (1999) included the whole of the UK and therefore data for commercial and industrial waste before 1998 has been unaffected.

Methane and carbon dioxide produced in landfilled waste originates from degradable organic carbon (DOC). DOC is assumed to consist only of cellulose and hemi-cellulose in the waste, in accordance with the previous methodology (Golder, 2005). Cellulose and hemicellulose make up approximately 91% of the degradable fraction, whilst other potential degradable fractions which make a small contribution (such as proteins and lipids) are ignored (LQM, 2003). The proportion of cellulose and hemi-cellulose in each waste component and the degradability of these fractions were based on a study by Barlaz *et al.* (1997). Moisture content was derived from the National Household Waste Analysis Project (1994).

Each waste component (paper, food, etc) was assigned a DOC value based on the cellulose and hemi-cellulose content. The component was then allocated into four fractions: rapidly degrading, moderately degrading, slowly degrading and inert, each of which was assigned the appropriate degradation rate. For example, paper was taken to be 25% moderately degrading and 75% slowly degrading. The DOC value, applied to both components, was assumed to be equal to the percentage by weight of cellulose and hemi-cellulose multiplied by a factor of 72/162 (to account for the carbon content). This was around 22% for household paper waste. Further details are provided in Annex 3, section A3.8.

In addition to DOC, we also need to know how much of the DOC is converted into methane and carbon dioxide (i.e. is dissimilated), as opposed to being converted into other carbon compounds that are retained in the landfill. This dissimilated fraction of DOC is referred to as $DOC_F$. $DOC_F$ is also derived from an analysis of the laboratory study by Barlaz *et al.* (1997). It varies from 35% (newspaper) to 98% (white office paper) depending on the particular component in the waste. The majority of the waste components are between 50% and 64% degradable. The IPCC recommended range quoted in the guidance is 50-60%.

The volume (and also molar) fraction of $CH_4$ in landfill gas (*F*) is generally taken to be 50% for modern landfills, which is in line with the Guidance. For old shallow sites it is taken to be 30% to reflect a higher degree of oxidation.

The fraction of methane recovered was derived from a survey of statistics on gas use for power generation, and a survey of installed flare capacity. Flares (other than those used to back up power generation, which are assumed to operate only when needed) are taken to have a load factor of 85% (i.e. 15% downtime), and 7% of flares are assumed to be replaced every year, so that the flare lifetime is 15 years. This approach was taken because suitable metering data were not available. In 2005 the estimates were that 32% of generated methane was utilised and 38% was flared. Further details are provided in section A3.8 of the NIR.

The oxidation factor was based on a model developed by LQM (2003) (which distinguishes between passage of methane through fissures and through the intact cap) until the 2005 inventory. Since the 2006 inventory submission, the recommended IPCC Guidance value of 0.1 has been adopted. This was following a reassessment in response to previous UNFCCC reviews. Recovered methane is subtracted before applying the oxidation factor. This is in line with the IPCC Guidance.

Emissions from electricity generation are considered under Power Stations and emissions from heat generation are included under Miscellaneous and are discussed in **Annex 3**.
As mentioned above, carbon dioxide from waste decomposition in landfills originates from contemporary sources of biomass and so can be omitted from the inventory, according to current guidance.

### 8.2.3    Uncertainties and time-series consistency

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.2.1** and **Table A7.2.2**, provides estimates of uncertainty according to IPCC source category and gas. There are many uncertainties in estimating methane emissions from landfill sites. The model is particularly sensitive to the values assumed for the degradable organic carbon (DOC) present in different fractions of waste, and the amount of this that is dissimilable (i.e. is converted to methane and carbon dioxide), as well as to the oxidation factor. Both of these parameters are poorly understood, and field and experimental observations exhibit wide variation, so uncertainties are inevitably high, and the uncertainty estimates in **Annex 7** are intended to reflect this as well as uncertainties in the other data and model parameters.

The estimates for all years have been calculated from the MELmod model and thus the methodology is consistent throughout the time series. Estimates of waste composition and quantities have been taken from different sources – prior to 1995 they are from Brown *et al.* (1999), prior to 2000 they are based on the LQM (2003) study and from 2000 they are based on modelled data from the Golder (2005) study. This has resulted in a relatively stable background trend of an annual increase of around 1 million tonnes per year. Similarly, due to the difference sources, estimates of industrial and commercial waste arisings increase rapidly from 108 million tonnes in 1995 to 169 million tonnes by 1999 (assuming a linear increase over this period). Arisings are roughly constant in the years before 1995 and after 1999; the values for 2002 are based on Environment Agency and SEPA data and are assumed constant thereafter.

### 8.2.4    Source-specific QA/QC and verification

The IPCC Tier 2 Solid Waste Disposal from Land model from the 2006 Inventory Guidelines (which are agreed by IPCC but still under consideration by UNFCCC) has been used for

purposes of quality control. The model was used to compare emissions to the Golder (2005) model. A comparison of the results is shown in **Table 9.2**. Although the Golder model uses country specific DOC, $DOC_F$ and K (half-life) values, the way they are implemented against rapidly-, moderately- and slowly-degrading fractions of waste means that they are capable of changing with time through each waste stream.

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

MELmod takes another approach which allows the UK specific factors to be modelled with the IPCC model. It does this by calculating the amount of DOC, $DOC_F$ the UK produces and applies this to the IPCC calculation. The activity data, the methane correction factor, the fraction of methane, the oxidation factor and the amount recovered were identical between the two model runs which therefore show the effect of country specific values for DOC, $DOC_F$ and K (half-life). The results in Table 8.1 show that there is negligible difference between the UK estimation of methane generated based on IPCC Guidelines 2000 (Calculation engine 1) and that given by the 2006 IPCC model methodology (Calculation engine 2). It is therefore considered MELmod is validated and has therefore been used in the compilation of this inventory.

**Table.8.1          Amount of methane generated compared with the IPCC Tier 2 model.**

| Year | Mass of waste landfilled (Mt) | | | Mass of waste landfilled as reported in CRF* Excluding inorganic industrial waste (Mt) | UK MELmod v1.11 Calculation Engine 1 | IPCC MELmod v1.11 Calculation Engine 2 | Difference (%) |
|---|---|---|---|---|---|---|---|
| | MSW | C&I | Combined waste streams | | Methane generated (kt) | Methane generated (kt) | |
| **1990** | 18.19 | 81.83 | 100.02 | 75.65 | 2947 | 2954 | 0.21 |
| **1991** | 18.84 | 81.77 | 100.61 | 76.57 | 3024 | 3030 | 0.20 |
| **1992** | 19.47 | 81.72 | 101.19 | 77.49 | 3098 | 3104 | 0.19 |
| **1993** | 20.09 | 81.66 | 101.76 | 78.39 | 3170 | 3175 | 0.18 |
| **1994** | 20.71 | 81.61 | 102.32 | 79.28 | 3240 | 3246 | 0.17 |
| **1995** | 23.83 | 81.56 | 105.39 | 82.69 | 3294 | 3298 | 0.13 |
| **1996** | 24.76 | 78.17 | 102.93 | 74.00 | 3330 | 3333 | 0.09 |
| **1997** | 26.14 | 72.86 | 99.00 | 67.19 | 3352 | 3354 | 0.06 |
| **1998** | 25.94 | 74.01 | 99.95 | 64.62 | 3389 | 3392 | 0.09 |
| **1999** | 27.03 | 71.99 | 99.02 | 64.49 | 3425 | 3428 | 0.09 |
| **2000** | 27.54 | 69.98 | 97.51 | 63.78 | 3461 | 3463 | 0.08 |

| Year | Mass of waste landfilled (Mt) | | | Mass of waste landfilled as reported in CRF* Excluding inorganic industrial waste (Mt) | UK MELmod v1.11 Calculation Engine 1 | IPCC MELmod v1.11 Calculation Engine 2 | Difference (%) |
|------|-----|-----|-----|-----|-----|-----|-----|
| | MSW | C&I | Combined waste streams | | Methane generated (kt) | Methane generated (kt) | |
| **2001** | 26.87 | 67.96 | 94.82 | 61.89 | 3492 | 3495 | 0.08 |
| **2002** | 27.18 | 65.94 | 93.13 | 61.00 | 3523 | 3525 | 0.07 |
| **2003** | 26.41 | 65.94 | 92.35 | 60.22 | 3551 | 3553 | 0.07 |
| **2004** | 25.48 | 65.94 | 91.43 | 59.29 | 3577 | 3579 | 0.06 |
| **2005** | 24.19 | 65.94 | 90.13 | 58.00 | 3600 | 3601 | 0.05 |
| **2006** | 21.69 | 65.94 | 87.63 | 55.50 | 3617 | 3619 | 0.04 |
| **2007** | 20.06 | 65.94 | 86.00 | 53.87 | 3631 | 3632 | 0.03 |
| **2008** | 18.31 | 65.94 | 84.25 | 54.87 | 3642 | 3643 | 0.02 |
| **Total** | | | | | **63,360** | **64,423** | |

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

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

New landfill data were included for Guernsey.

## 8.2.6 Source-specific planned improvements

Emission factors, model parameters, and activity data will be kept under review including the possible use of weighbridge returns to improve activity data. DECC and the environmental regulatory agencies in the UK are funding new research to test landfill methane measurement, which may in time provide more information to enable more accurate determination of landfill waste emissions in the UK.

## 8.3 SOURCE CATEGORY 6B – WASTEWATER HANDLING

## 8.3.1 Source Category Description

Emissions from this category cover those released from wastewater handling. Emissions are included for industrial, domestic and commercial wastewater.

Methane and nitrous oxide are produced from anaerobic decomposition of organic matter by bacteria in sewage facilities and from food processing and other industrial facilities during wastewater handling. Nitrous oxide may also be released from wastewater handling and human waste.

Emissions of nitrous oxide and methane from industrial wastewater are reported as not estimated as no suitable data are available. Most waste water is treated in the public system so emissions are assumed to be captured within the estimates for 6B2.

Emissions of nitrous oxide from domestic and commercial wastewater treatment (excluding human sewage) are not estimated as no data are available. Emissions are believed to be small.

## 8.3.2    Methodological Issues

The NAEI category Sewage is mapped on to the IPCC category 6B2 Domestic and Commercial Wastewater.

The NAEI estimate is based on the work of Hobson *et al* (1996) who estimated emissions of methane for the years 1990-95. Subsequent years are extrapolated on the basis of population. Sewage disposed to landfill is included in landfill emissions.

The methodology of the UK model differs in some respects from the IPCC default methodology. The main differences are that it considers wastewater and sewage together rather than separately. It also considers domestic, commercial and industrial wastewater together rather than separately. Emissions are based on empirical emission factors derived from the literature expressed in kg $CH_4$/tonne dry solids rather than the BOD default factors used by IPCC. The model complies with the IPCC Good Practice Guidance as a national model (IPCC, 2000).

The basic activity data are the throughput of sewage sludge through the public system. The estimates are based on the UK population connected to the public sewers and estimates of the amount of sewage per head generated. From 1995 onwards the per capita production is a projection (Hobson *et al*, 1996). The main source of sewage activity data is the UK Sewage Survey (DOE, 1993). Emissions are calculated by disaggregating the throughput of sewage into 14 different routes. The routes consist of different treatment processes each with specific emission factors. The allocation of sludge to the treatment routes is reported for each year on the CRF tables attached to this report as a CD and on the NAEI website.

For more details on methodology, including work to improve the methodology, and coverage of the Hobson model, see **Section A.3.8.3**.

Nitrous oxide emissions from the treatment of human sewage are based on the IPCC (1997c) default methodology. The most recent average protein consumption per person is based on the Expenditure and Food Survey (Defra, 2009). This is a household survey and may omit some consumption, but it is not thought that the effect on emissions would be significant.

## 8.3.3    Uncertainties and Time-Series Consistency

The Approach 1 (error propagation) uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and gas. The same methodology has been used to estimate emissions for all years. The population data needed to estimate emissions are provided by the Office of National Statistics (ONS). The time-series consistency of these activity data is very good due to the continuity in data provided by the ONS.

The most recent average protein consumption per person is based on the Expenditure and Food Survey (Defra, 2009); see **TableA 3.8.6**. Between 1996 and 1997 there is a step change in the reported protein consumption data. This is because Defra revised their publication

(formally National Food Survey) and in doing so revised the method used to calculate protein consumption. The new method only provides data back to 1997 and so a step change occurs.

### 8.3.4    Source Specific QA/QC and Verification

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

### 8.3.5    Source Specific Re-Calculations

- Methane emissions decreased by 0.01 $GgCH_4$ due to a small revision to the estimate for the Isle of Man.
- Nitrous oxide emissions decreased by 0.07 $GgN_2O$ due to a revision to statistics for protein consumption.

### 8.3.6    Source Specific Planned improvements

The methodology of the UK model is based on research, surveys and reports from the early 1990s. Significant changes to sewage treatment systems have been implemented in the intervening years, and hence the UK is evaluating whether the current estimation methodology needs to be revised. In summer 2005, UK water companies adopted a new GHG emissions calculation system (developed by UK Water Industry Research) and in future may be required to submit annual emission estimates to the industry regulator, OFWAT. The Inventory Agency continues to make efforts to review these estimates of emissions and underlying factors and activity data, and has attended meetings with UKWIR. Further details of work to improve the methodology are given in **Section A.3.8.3**.

## 8.4    SOURCE CATEGORY 6C – WASTE INCINERATION

### 8.4.1    Source Category Description

This source category covers the incineration of wastes, excluding waste-to-energy facilities. For the UK, this means that all current MSW incineration is excluded, being reported under CRF source category 1A instead. Incineration of chemical wastes, clinical wastes, sewage sludge and animal carcasses is included here. In-situ burning of agricultural waste e.g. crop residue burning is reported under category 4F.

There are approximately 70 plant incinerating chemical or clinical waste or sewage sludge and approximately 2600 animal carcass incinerators. Animal carcass incinerators are typically much smaller than the incinerators used to burn other forms of waste.

This source category also includes emissions from crematoria.

Emissions of $CO_2$ and $N_2O$ from accidental vehicle fires are not estimated as there are no suitable emission factors available.

$N_2O$ emissions from chemical waste incineration are not estimated as this is a high temperature combustion process and therefore emissions are considered insignificant.

## 8.4.2    Methodological Issues

Emissions of carbon, CO, $NO_x$, $SO_2$, and VOC from chemical waste incinerators are estimated based on analysis of data reported to the Pollution Inventory (Environment Agency, 2009). This only covers England and Wales, but there are not thought to be any significant emissions from plant 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 plant but the need for extrapolation of data may contribute to significant variations in the quality of the estimates.  New activity data for this source have been provided by the Environment Agency.

Emissions of $CH_4$, CO, $N_2O$, $NO_x$, $SO_2$ and VOC from sewage sludge incinerators are estimated from a combination of data reported to the Environment Agency's Pollution Inventory, supplemented with the use of literature-based emission factors for those pollutants where the Pollution Inventory does not give information sufficient to derive estimates. Emissions of $NO_x$ are estimated using Pollution Inventory data while emissions of all other direct and indirect greenhouse gases are estimated from literature-based emission factors.  The factor for $N_2O$ is the default factor given in the IPCC good practice guidance for UK sewage sludge incineration.  Emission factors for other pollutants are taken from the EMEP/CORINAIR Emission Inventory Guidebook.  The quantity of waste burnt annually is estimated, these estimates being based on estimates given in the literature.

Emissions of carbon, $CH_4$, CO, $N_2O$, $NO_x$, $SO_2$, and VOC from clinical waste incinerators are estimated using literature-based emission factors.  The factor for carbon is the default factor given in the IPCC good practice guidance, while the factor for $N_2O$ is the default for UK MSW incineration given in the same source.  Emission factors for other pollutants are largely taken from the EMEP/CORINAIR Emission Inventory Guidebook.  The quantity of waste burnt annually is also estimated, these estimates being based on information given in literature sources.

Emission estimates for animal carcass incinerators are taken directly from a Defra-funded study (AEA Technology, 2002) and are based on emissions monitoring carried out at a cross section of incineration plant.  No activity data are available and so the emission estimates given in this report are assumed to apply for all years.
Emissions of CO, $NO_x$, $SO_2$ and VOC from crematoria are based on literature-based emission factors, expressed as emissions per corpse, and taken from US EPA (2008).  Data on the annual number of cremations is available from the Cremation Society of Great Britain (2009).

All UK plant used to incinerate municipal solid waste (MSW) are now required to be fitted with boilers to raise power and heat, and their emissions are therefore reported under CRF source category 1A1 (electricity generation) and 1A4 (heat generation), rather than 6C (Waste Incineration).  This has been the case since 1997; prior to that year at least some MSW was burnt in older plant without energy recovery. Emissions from these incinerators are reported under 6C and are generally based on Pollution Inventory data for the period 1993-1997 with use of literature factors generally for the period 1990-1992 to reflect the higher emissions likely from UK MSW incinerators in that period before plant shutdowns and upgrades occured in the 1993-1995 period.

### 8.4.3    Uncertainties and Time-Series Consistency

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

### 8.4.4    Source Specific QA/QC and Verification

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

### 8.4.5    Source Specific Re-Calculations

- There was an increase of 3.1 Gg $CO_2$ due to the provision of new activity data supplied by the Environment Agency.
- There was a small decrease in estimated emissions from methane due to an update to statistics for vehicle fires (previously the estimate was provisional as it was based on 2006 data).

### 8.4.6    Source Specific Planned improvements

Emission estimates for chemical waste incineration currently do not include the burning of chemical wastes in flares and it is unclear whether these emissions might be included in the estimates reported in 2B5. 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.

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[i] The decay rate constant for inert waste is of course zero.

# 9     Other (CRF Sector 7)

## 9.1     OVERVIEW OF SECTOR

Emissions from LULUCF activities in the Overseas Territories and Crown Dependencies are reported in Sector 7 of the CRF.  This is because there was not a suitable category within Sector 5 to report these emissions.  Technical issues with the CRF reporting software have meant that it is not possible to add a category under Sector 5G.

# 10    Re-Calculations and Improvements

This section of the report summarises the recalculations and improvements made to the UK GHG inventory since the 2009 NIR (2007 inventory) was issued, including responses to reviews of the inventory. It summarises material that has already been presented and discussed in more detail in **Chapter 3** to **Chapter 9**. Table 8(b) of the CRF for each year also contains a summary of the recalculations since the previous inventory was submitted. For a quantitative discussion of emissions estimated in the 2008 GHG inventory, please see **Annex 9**.

Each year, the UK greenhouse inventory is as follows:

- *Updated*    Existing activity data and/or emissions factors may be revised; and
- *Extended*    The inventory includes a new inventory year.

*Updating* often entails revision of emission estimates, most commonly because of revision to the core energy statistics presented in the Digest of UK Energy Statistics (DUKES). The inventory also makes use of other datasets (see **Table 1.3** for a summary), and these too may also be revised. Updating will also reflect adoption of revised methodologies. Updating, particularly involving revised methodologies, may affect the whole time series, so estimates of emissions for a given year may differ from estimates of emissions for the same year reported previously. Therefore comparisons between submissions should take account of whether there have been changes to the following:

- The methodology used to estimate emissions; and/or
- The base activity data.

The time series of the inventory is *extended* by including a new inventory year - for example, the previous report covered the years up to and including 2007; this report gives emission estimates for 2007, and includes estimates for the year 2008 also.

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

## 10.1    EXPLANATIONS AND JUSTIFICATIONS FOR RE-CALCULATIONS

**Table 10.1** and **Table 10.2** summarise the recalculations that have occurred in estimates of the direct GHGs since the 2009 NIR (2007 inventory) was issued.

It contains brief comments on the reasons behind the recalculations, and shows if a revision of the entire time series has occurred.  The changes in emissions are net changes (the sum of any increases and decreases) in the source category, for the year 2007 (**Table 10.1**) and the base year (**Table 10.2**).

Table 8(a) s1 and Table 8 (a) s2 of the CRF also present details of recalculations of emissions between the current and the previous inventory.  The emissions are expressed as GWP emissions, but are not shown to the same level of sectoral detail in **Table 10.1 or Table 10.2**.

The percentage change, due to re-calculation with respect to the previous submission, is calculated as follows:

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

Where
LS = Latest Submission (2008 inventory; 2010 NIR); and
PS = Previous Submission (2007 inventory, 2009 NIR).

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

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

**Table 10.1:** **Re-Calculations of direct GHG emissions for the year 2007 in the UK 2010 NIR (2008 inventory).**

| Source category and GHG | Change in emissions (GgCO$_2$eq) (Emissions in 2008 inventory minus emissions in 2007 inventory) | Change in emissions (%) (Percentage change relative to the 2007 inventory) | Brief description of reasons for Re-Calculation |
|---|---|---|---|
| **1A1** | | | |
| CO$_2$ | 1066.6 | 1% | Significant revisions to energy statistics for natural gas in power stations and other energy industries, and OPG in refineries. Revision to the emission factor used for offshore natural gas use, based on operator reported data. Revised method for petroleum coke use in refineries, to ensure consistency with the reported emissions under EU ETS. |
| CH$_4$ | 5.9 | 2% | Significant revisions to energy statistics for natural gas in power stations and other energy industries, and OPG in refineries. Revised emission factors for fuel oil and gas oil based on revised GCVs. Revision to the emission factor used for offshore natural gas use, based on operator reported data. Revised method for petroleum coke use in refineries, to ensure consistency with the reported emissions under EU ETS. |
| N$_2$O | 31.6 | 2% | Significant revisions to energy statistics for natural gas in power stations and other energy industries, and OPG in refineries. Revised emission factors for coal and fuel oil based on revised GCVs. Revision to the emission factor used for offshore natural gas use, based on operator reported data. Revised method for petroleum coke use in refineries, to ensure consistency with the reported emissions under EU ETS. |
| **1A2** | | | |
| CO$_2$ | -279.2 | 0% | Improvements to the method for off road mobile machinery. Revisions to emission factors for fuels used by the cement industry to use data supplied by the BCA. Revisions to DUKES activity statistics, and to the data for autogenerators. Improvements to the method for lime production. Correction to fuel allocation for the Cayman Islands water desalination plant. |
| CH$_4$ | 0.9 | 0% | Improvements to the method for off road mobile machinery. Revisions to DUKES activity statistics, and to the data for autogenerators. Improvements to the method for lime production. Correction to fuel allocation for the Cayman Islands water desalination plant. Revisions to emission factors for fuel oil and gas oil based on revised GCV data. |

| Source category and GHG | Change in emissions (GgCO$_2$eq)<br><br>(Emissions in 2008 inventory minus emissions in 2007 inventory) | Change in emissions (%)<br><br>(Percentage change relative to the 2007 inventory) | Brief description of reasons for Re-Calculation |
|---|---|---|---|
| N$_2$O | 13.0 | 1% | Improvements to the method for off road mobile machinery.<br>Revisions to DUKES activity statistics, and to the data for autogenerators.<br>Improvements to the method for lime production.<br>Correction to fuel allocation for the Cayman Islands water desalination plant.<br>Revised emission factor for N2O for coal based on revised GCV. |
| **1A3** | | | |
| CO$_2$ | 125.2 | 0% | Improvements to the aviation model have led to changes in the split of fuel use between domestic and international flights. (based on the outcomes of the Project for the Sustainable Development of Heathrow).<br>Improvements to the off road mobile machinery model have led to increased fuel consumption for aircraft support vehicles<br>New data has been incorporated into the estimates for rail. |
| CH$_4$ | -0.2 | 0% | New road transport emission factors used, in addition to revised vehicle km statistics, catalytic failure assumption and survival rates.<br>Improvements to aviation model (based on the outcomes of the Project for the Sustainable Development of Heathrow).<br>Improvements to off road mobile machinery model have led to changes in methane emissions. |
| N$_2$O | -35.9 | -2% | Road transport emissions model improved to contain revised vehicle km statistics for Northern Ireland, the effects of accumalative mileage on vehicles with petrol engines, catalytic failure rates, and survival rates.<br>Improvements to aviation model (based on the outcomes of the Project for the Sustainable Development of Heathrow).<br>Improvements to off road mobile machinery model have led to changes in methane emissions. |
| **1A4** | | | |
| CO$_2$ | 598.1 | 1% | Main change is a revision energy statistics for natural gas used in the domestic sector.<br>Smaller changes have also occurred as a result of the changes to the off road mobile machinery model, and the use of new energy statistics for the Isle of Man. |
| CH$_4$ | 1.9 | 0% | The majority of this recalculation is due to the replacement of a provisional estimate (based on 2006 data) for peat use in the domestic sector with finalised 2007 data.<br>Other changes have arisen from the revision to the energy statistics for natural gas use in the domestic sector, improvements to the off road mobile machinery model, and the use of new energy statistics for the Isle of Man. |
| N$_2$O | 20.0 | 3% | The majority of this recalculation is as a result of the improvements to the off road mobile machinery model.<br>Changes also arise due to the revised natural gas use statistics for the domestic sector, and the update to the peat use figure. |

| Source category and GHG | Change in emissions (GgCO$_2$eq) (Emissions in 2008 inventory minus emissions in 2007 inventory) | Change in emissions (%) (Percentage change relative to the 2007 inventory) | Brief description of reasons for Re-Calculation |
|---|---|---|---|
| **1A5** | | | |
| CO$_2$ | -614.0 | -18% | Revised activity statistics provided by the defence fuels group for both naval shipping and military aircraft |
| CH$_4$ | -0.5 | -23% | Revised activity statistics provided by the defence fuels group for both naval shipping and military aircraft |
| N$_2$O | -6.4 | -19% | Revised activity statistics provided by the defence fuels group for both naval shipping and military aircraft |
| **1B2** | | | |
| CO$_2$ | -13.9 | 0% | Emissions from flaring have been revised down, based on revisions to reported data from the operators. An estimate of emissions from natural gas leakage has been included following a recommendation from the ERT. |
| CH$_4$ | 12.3 | 0% | Revised reported emissions form process and fugitive sources based on operator reported data. Revised emissions from venting and flaring based on revisions to data reported to the operator. Inclusion of estimated emissions from natural gas leakage in Northern Ireland for the first time to ensure that emissions from this source are complete. |
| N$_2$O | 0.2 | 1% | Revised emissions from flaring based on revisions to data reported by the operators. |
| **2A** | | | |
| CO$_2$ | 270.0 | 3% | For lime production, provisional estimates based on 2006 data have been updated to reflect 2007 activity statistics. A revision to the method for calculating emissions from limestone and dolomite use by the glass industry has led to an increase in the estimated emission. Revised glass production statistics have led to a decrease in emisisons from soda ash use. |
| **2B** | | | |
| CO$_2$ | -2.7 | 0% | Minor revision to the statistics for detergent use. |
| **2C** | | | |
| CO$_2$ | 1.7 | 0% | Minor revision to the estimate for blast furnace gas flaring. Revised data for emissions from primary aluminium production supplied by one of the operators. |
| PFC | 1.8 | 2% | Revised data for emissions from primary aluminium production supplied by one of the operators. |
| **2F** | | | |
| HFC | 1397.0 | 15% | Major improvement to the model for estimating emissions from refrigeration. The model now incorporates sales data of HFC and PFC based fluids within the refrigeration sector, replacing older assumptions. The model for HFC emissions from foams has also been reviewed and updated. |

| Source category and GHG | Change in emissions (GgCO$_2$eq) (Emissions in 2008 inventory minus emissions in 2007 inventory) | Change in emissions (%) (Percentage change relative to the 2007 inventory) | Brief description of reasons for Re-Calculation |
|---|---|---|---|
| PFC | 3.7 | 5% | Major improvement to the model for estimating emissions from refrigeration. The model now incorporates sales data of HFC and PFC based fluids within the refrigeration sector, replacing older assumptions. The model for PFC emissions from firefighting has also been reviewed and updated. The previous inventory did not incorporate the full time series of emissions estimates. |
| SF6 | -0.2 | 0% | Minor updates to emissions for Overseas Territories and Crown Dependencies. |
| **4A** | | | |
| CH$_4$ | 344.4 | 2% | Cattle weight data, used within the Tier 2 calculation for dairy cattle, updated based on slaughter weight data. Tier 2 method now used for beef cattle. |
| **4B** | | | |
| CH$_4$ | 55.2 | 2% | Cattle weight data, used within the Tier 2 calculation for dairy cattle, updated based on slaughter weight data. |
| N$_2$O | 435.3 | 25% | N2O from animal wastes revised to use nitrogen excretion rates not corrected for volatilisation. This followed the recommendations of the ERT. |
| **4D** | | | |
| N$_2$O | 41.7 | 0% | Decreased emissions from Farm Animal Wastes, due to changes in the method to calculate emissions from AWMS |
| **5A** | | | |
| CO$_2$ | -0.2 | 0% | Correction of an error in the conifer afforestation rate |
| N$_2$O | 0.0 | 0% | Correction of an error in the conifer afforestation rate |
| CH$_4$ | 0.0 | 0% | Correction of an error in the conifer afforestation rate |
| **5B** | | | |
| CO$_2$ | 62.2 | 0% | Provisional estimates based on 2006 data for liming replaced with finalised 2007 data. |
| **5C** | | | |
| CO$_2$ | -124.3 | 2% | Provisional estimates based on 2006 data for liming and peat extraction replaced with finalised 2007 data. Update to activity data for forest land converted to settlements for 2000-2005. |
| **5E** | | | |
| CO$_2$ | -17.2 | 0% | Update to activity data for forest land converted to settlements for 2000-2005. |
| CH$_4$ | -0.5 | -7% | Update to activity data for forest land converted to settlements for 2000-2005. |
| N$_2$O | 0.0 | -7% | Update to activity data for forest land converted to settlements for 2000-2005. |

| Source category and GHG | Change in emissions (GgCO$_2$eq) (Emissions in 2008 inventory minus emissions in 2007 inventory) | Change in emissions (%) (Percentage change relative to the 2007 inventory) | Brief description of reasons for Re-Calculation |
|---|---|---|---|
| **5G** | | | |
| CO$_2$ | -91.9 | 7% | The estimates of emissions and removals have changed due to an update in the activity data on Forest Land converted to Settlement 2000-2005. This has affected the amount of products from deforestation that enter the HWP pool. Correction to Overseas Territories LULUCF. There was an error in the inclusion of this source in the database for the 2009 submission |
| **6A** | | | |
| CH$_4$ | 93.5 | 0% | Inclusion of new data for landfilled waste in Guernsey |
| **6B** | | | |
| CH$_4$ | -0.1 | 0% | Small revision to estimate for Isle of Man |
| N$_2$O | -20.3 | -2% | Revision to statistics for protein consumption. |
| **6C** | | | |
| CO$_2$ | 3.1 | 1% | Method improvement for chemical waste incineration based on revised activity data supplied by the Environment Agency. |
| CH$_4$ | -0.1 | -2% | Provisional estimates based on 2006 data for accidental vehicle fires replaced with 2007 statistics. |

**Table 10.2:** **Re-Calculations of direct GHG emissions for the base year in the UK 2010 NIR (2008 inventory).**

| Source category and GHG | Change in emissions (GgCO$_2$eq) (Emissions in 2008 inventory minus emissions in 2007 inventory) | Change in emissions (%) (Percentage change relative to the 2007 inventory) | Brief description of reasons for Re-Calculation |
|---|---|---|---|
| **1A1** | | | |
| CO$_2$ | 9.7 | 0% | Minor revisions to estimated power station fuel consumption in the Crown Dependencies, based on new data for the Isle of Man |
| CH$_4$ | -0.3 | 0% | Revised emission factors for fuel oil, gas oil, naphtha and miscellaneous refinery fuels |

| Source category and GHG | Change in emissions (GgCO$_2$eq) (Emissions in 2008 inventory minus emissions in 2007 inventory) | Change in emissions (%) (Percentage change relative to the 2007 inventory) | Brief description of reasons for Re-Calculation |
|---|---|---|---|
| N$_2$O | 0.9 | 0% | Main change is revision to emission factor for coal (based on revised GCV). Smaller changes to emission factors for fuel oil and gas oil (also due to revised GCVs). |
| **1A2** | | | |
| CO$_2$ | -40.8 | 0% | Improvements to the method for off road mobile machinery. Improvements to the method for lime production. Correction to fuel allocation for the Cayman Islands water desalination plant. |
| CH$_4$ | 0.4 | 0% | Improvements to the method for off road mobile machinery. Improvements to the method for lime production. Correction to fuel allocation for the Cayman Islands water desalination plant. |
| N$_2$O | -3.3 | 0% | Improvements to the method for off road mobile machinery. Improvements to the method for lime production. Correction to fuel allocation for the Cayman Islands water desalination plant. |
| **1A3** | | | |
| CO$_2$ | -48.7 | 0% | Improvements to the aviation model have led to changes in the split of fuel use between domestic and international flights. Improvements to the off road mobile machinery model have led to increased fuel consumption for aircraft support vehicles (based on the outcomes of the Project for the Sustainable Development of Heathrow). New data has been incorporated into the estimates for rail. |
| CH$_4$ | -58.8 | -8% | New road transport emission factors used, in addition to revised vehicle km statistics, catalytic failure assumption and survival rates. Improvements to aviation model (based on the outcomes of the Project for the Sustainable Development of Heathrow). Improvements to off road mobile machinery model have led to changes in methane emissions. |
| N$_2$O | -14.5 | -1% | Road transport emissions model improved to contain revised vehicle km statistics for Northern Ireland, the effects of accumalative mileage on vehicles with petrol engines, catalytic failure rates, and survival rates. Improvements to aviation model (based on the outcomes of the Project for the Sustainable Development of Heathrow). Improvements to off road mobile machinery model have led to changes in methane emissions. |
| **1A4** | | | |
| CO$_2$ | -7.2 | 0% | Adjustments to gas oil use estimates for public and commercial sectors, to account for increased gas oil use for off road mobile machinery. Improvements to the method for off road mobile machinery. |

| Source category and GHG | Change in emissions (GgCO$_2$eq) (Emissions in 2008 inventory minus emissions in 2007 inventory) | Change in emissions (%) (Percentage change relative to the 2007 inventory) | Brief description of reasons for Re-Calculation |
|---|---|---|---|
| CH$_4$ | 8.1 | 1% | Adjustments to gas oil use estimates for public and commercial sectors, to account for increased gas oil use for off road mobile machinery. Improvements to the method for off road mobile machinery. Change to emission factor for domestic peat consumption. The methane factor is based on the emission factor for domestic wood combustion, and has been updated to reflect the most up to date emission factor for this source. |
| N$_2$O | 18.2 | 2% | Adjustments to gas oil use estimates for public and commercial sectors, to account for increased gas oil use for off road mobile machinery. Improvements to the method for off road mobile machinery. Change to emission factor for domestic peat consumption. The methane factor is based on the emission factor for domestic wood combustion, and has been updated to reflect the most up to date emission factor for this source. Revised emission factor for coal, based on revised GCV value. |
| **1B2** | | | |
| CO$_2$ | 17.8 | 0% | Inclusion of CO2 emissions from natural gas leakage, following a recommendation from the ERT. |
| **2F** | | | |
| HFC | -107.9 | -7% | Major improvement to the model for estimating emissions from refrigeration. The model now incorporates sales data of HFC and PFC based fluids within the refrigeration sector, replacing older assumptions. |
| PFC | -8.8 | -8% | Major improvement to the model for estimating emissions from refrigeration. The model now incorporates sales data of HFC and PFC based fluids within the refrigeration sector, replacing older assumptions. |
| **4A** | | | |
| CH$_4$ | 138.9 | 1% | Cattle weight data, used within the Tier 2 calculation for dairy cattle, updated based on slaughter weight data. Tier 2 method now used for beef cattle. |
| **4B** | | | |
| CH$_4$ | 19.3 | 1% | Cattle weight data, used within the Tier 2 calculation for dairy cattle, updated based on slaughter weight data. |
| N$_2$O | 538.2 | 24% | N2O from animal wastes revised to use nitrogen excretion rates not corrected for volatilisation. This followed the recommendations of the ERT. |
| **4D** | | | |
| N$_2$O | -8.1 | 0% | Decreased emissions from Farm Animal Wastes, due to changes in the method to calculate emissions from AWMS |
| **5G** | | | |
| CO$_2$ | -53.6 | 3% | Correction to Overseas Territories LULUCF. There was an error in the inclusion of this source in the database for the 2009 submission |

### 10.1.1 KP-LULUCF Inventory
This is the first official submission of Article 3.3 and Article 3.4 estimates, so any recalculations will be reported from the next submission onwards, as appropriate.

## 10.2      IMPLICATIONS FOR EMISSION LEVELS

### 10.2.1 GHG Inventory
The implications for emission levels in the year 2007 are summarised by sector in **Table 10.1**, and the overall effect for individual years is shown in **Figure 10.2**.

### 10.2.2 KP-LULUCF Inventory
This is the first official submission of Article 3.3 and Article 3.4 estimates, so any recalculations will be reported from the next submission onwards, as appropriate.

## 10.3      IMPLICATIONS FOR EMISSION TRENDS, INCLUDING TIME SERIES CONSISTENCY

### 10.3.1 GHG Inventory
The effects of the re-calculations and improvements made in the 2008 inventory are summarised in this section in a series of charts.  The charts show the changes in the time series of emissions, or percentage changes in emissions, since the 2007 inventory.

**Figure 10.1** summarises the effect of the recalculations in the 2010 NIR (2008 inventory) in terms of the time series of GWP emissions.  The chart shows the time series of differences in the annual GWP emissions of the basket of the 6 Kyoto GHGs between the inventories of 2007 and 2008, according to IPCC source sector.  A negative difference indicates a decline in GWP emission between the inventory presented in the 2010 NIR (2008 inventory), and the inventory presented in the 2009 NIR (2007 inventory).  The LULUCF totals are presented as net emissions.

**Figure 10.2** summarises the effect of the recalculations in the 2010 NIR in terms of the following:

- Changes in the time series of total net UK GWP emissions (sum of emissions and removals); and
- Percentage changes in the time series of GWP emissions.

The chart shows the time series of changes in the basket of the 6 Kyoto GHGs between the inventories of 2007 and 2008.

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

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

Where
LS = Latest Submission (2008 inventory; 2010 NIR); and
PS = Previous Submission (2007 inventory, 2009 NIR).

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

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

For later years, totals have also been affected by significant revisions to national fuel use statistics (DECC, 2009). The changes in the time series of GWP emissions in **Figure 10.2** reflect these enhancements. A summary of the key reasons for the changes are given below. More detailed information is given in the sections describing the source-specific recalculations given in **Chapters 3 to 8**.

*Reasons for changes in GWP emissions in the base year*
- Re-calculations in the base year have led to a net increase in emissions of 399.5 Gg $CO_2$ eq;
- The largest single change to emissions in the base year was an increase of 538 Gg $CO_2$ eq of $N_2O$ in IPCC sector 4B. This follows a change to the method for calculating $N_2O$ emissions from animal wastes, following a recommendation from the ERT.
- Emissions from enteric fermentation have increased by 139 Gg $CO_2$ eq for $CH_4$ following revisions to the dairy cattle weight data.
- Emissions of HFCs from refrigeration have been revised down by 108 Gg $CO_2$ eq following improvements to the refrigeration model.

*Reasons for changes in GWP emissions in 2007*
- Re-calculations in 2007 have led to an increase in emissions of 3,377.5 Gg $CO_2$ eq;
- The most significant revision occurred in sector 2F. HFC emissions from this sector increased by 1397 Gg $CO_2$ eq which was mostly driven by the improvements made to the refrigeration model.
- Fuel combustion emissions have increased by 927 Gg $CO_2$ eq overall, mostly due to revisions in national energy statistics and revised data from the defence fuels group.
- There was an increase of 435.3 Gg $CO_2$ eq for $N_2O$ in IPCC sector 4B. This follows a change to the method for calculating $N_2O$ emissions from animal wastes, following a recommendation from the ERT.
- Emissions from enteric fermentation have increased by 344 Gg $CO_2$ eq for $CH_4$ following revisions to the dairy cattle weight data.
- Emissions from both 2A and 5C have been revised following the publication of new lime production and peat extraction data, which replaced the provisional 2007 estimates in the previous inventory (which were based on 2006 data).

**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.**



Changes in GWP emissions (2008 minus 2007 inventory estimates) according to IPCC source sector
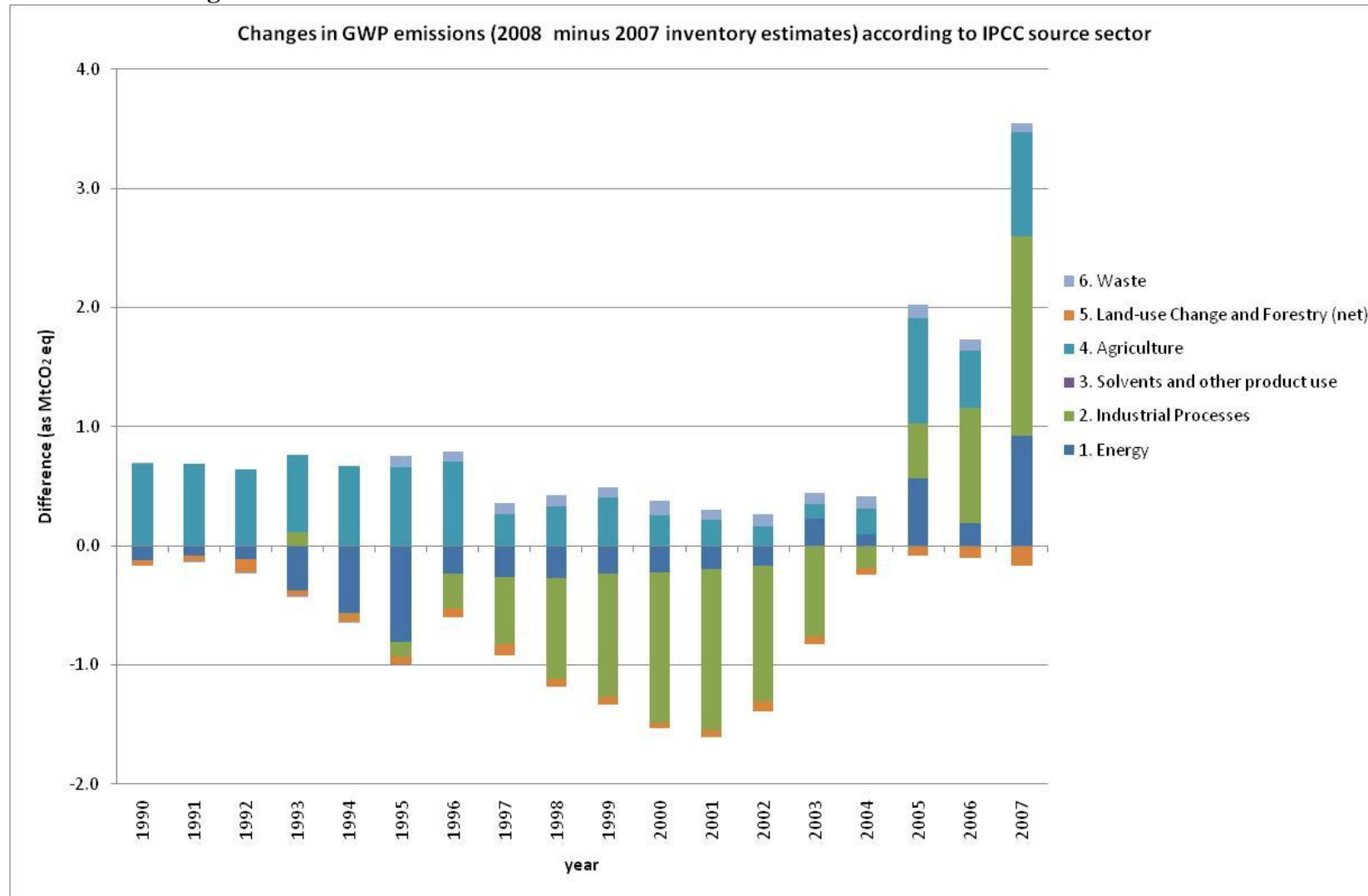
**Figure 10.2:** **Time series of changes in total net GWP emissions, and percentage changes in total net GWP emissions, between the inventory presented in the current and the previous NIR.**



Difference and percentage change (2008 relative to 2007 inventory estimates) in total GWP net emissions
(Basket of 6 Kyoto GHGs)
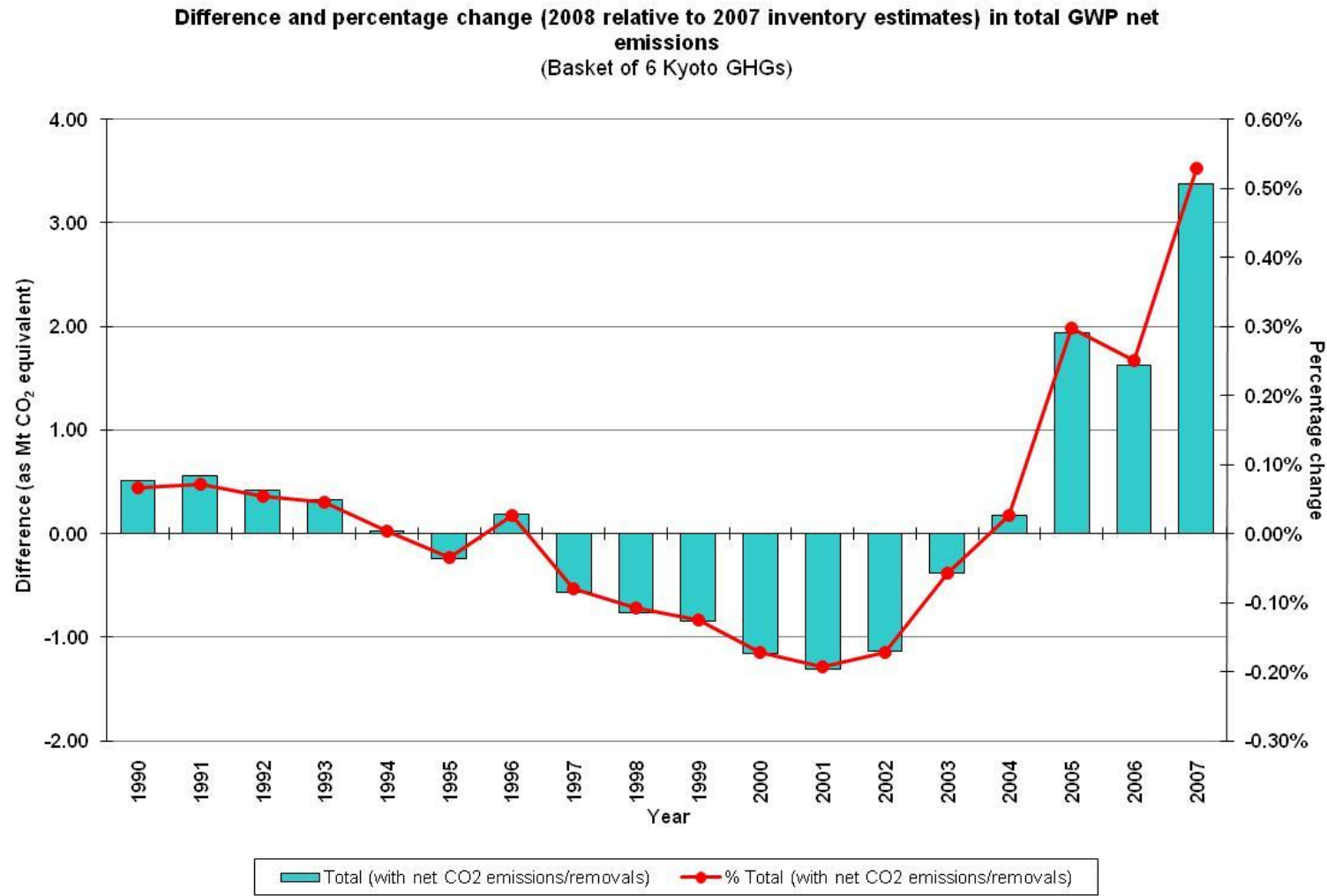
### 10.3.2 KP-LULUCF Inventory

This is the first official submission of Article 3.3 and Article 3.4 estimates, so any recalculations will be reported from the next submission onwards, as appropriate.

## 10.4 RESPONSE TO THE REVIEW PROCESS

### 10.4.1 GHG Inventory

There has been one review of the UKs GHG inventory since the publication of the 2009 NIR.

The UNFCCC conducted a Centralised Review of the 2009 greenhouse gas inventory submission in accordance with decision 22/CMP.1. This review took place from 14-19 September 2009 in Bonn, Germany. The review follows on from the Centralised Review conducted on the 2007 and 2008 greenhouse gas inventory submissions in September 2008 and the In-Country review of the 2006 greenhouse gas inventory (London, 12-17 March 2007).

**Table 10.3** provides an overview of the actions taken to improve the NIR and the inventory in response to the comments made by UNFCCC Expert Review Teams. The table concentrates on the improvements that have been made to methods used to estimate emissions from the Key Categories and the steps taken to improve transparency of reporting from those Key Categories. This table includes improvements made in response to reviews which were carried out up to 2008. Reviews carried out during 2009 and the corresponding comments are detailed in Table 10.4.

**Table 10.3: Brief Details of Improvements to the NIR and the Inventory in response to FCCC Reviews.**

| ERT comment | Actions |
|---|---|
| | |
| *Third Centralised Review* | |
| Include in NIR description of how AD and emissions data reported by companies are verified (e.g. description of QA of Pollution Inventory data) | A programme of meetings involving the Key Data Providers, Defra and the Inventory Agency continues. The aim of these meetings is understand QA/QC activities in place and suggest improvements where necessary. |
| Comment on lime production - data based on assumption that all lime is quicklime and that calcination of dolomite is minimal - review, confirm, improve text in NIR - provide documented evidence of assumptions. | Our best information at present is that the use of dolomite is small or negligible. This is still under review as it is proving difficult to obtain the necessary data.<br><br>There is potential for the EU ETS to provide the data in the near future when the lime producers, who are not currently part of the ETS, will soon be required to be. Should the EU ETS returns not provide the necessary data, then we will contact the lime producers again directly. |
| | |

| ERT comment | Actions |
|---|---|
| *Fourth Centralised Review* | |
| Further explanations of the revised EFs used from enteric fermentation in the NIR. | Work is currently underway with the agricultural sector experts to improve the transparency of reporting for this sector. |
| Provide quantitative results and qualitative discussions of the sources of uncertainty in individual source categories in the sectoral chapters of the NIR | The collation of this information has taken longer than expected, but the UK National Inventory Compiler has reminded the sectoral experts of this requirement. Additional information has been provided in this NIR. This task is still ongoing. |
| Review assumption that 20 per cent of the total nitrogen emitted by livestock volatilizes as nitrogen oxide and ammonia and therefore does not contribute to $N_2O$ emissions from AWMS | The UK is looking into improving the link between the $NH_3$ and GHG inventories, and incorporating $NO_x$ in a study (desk/experimental) will review the current assumption of 20% of N lost as $NH_3$ and $NO_x$. |
| | |
| *In Country Review March 2007* | |
| *Cross cutting* - Add a commentary about the reasons for the changes in the base year emissions | A new table, Table 10.2 *Recalculations of direct GHG emissions for the base year* , has been added to Chapter 10. |
| *Cross cutting* - Alter the pagination of the UK NIR, so that the cover page was page 1 and other pages followed on sequentially from this. | The pagination has been amended. |
| *Cross cutting* - Improve the transparency of the nomenclature used to identify the type of uncertainty analysis used | We now use the nomenclature in the 2006 IPPC guidelines to identify the type of uncertainty analysis performed – Approach 1 (error propagation analysis) and Approach 2 (Monte Carlo model). |
| *Cross cutting* - Key Category analysis includes only categories that add up to a cumulative total of more than 94 per cent. | The Key Categories presented are summed together in descending order of magnitude, and add up to over 95 per cent of the "level" or "trend" parameter. |
| *Cross cutting* - The ERT recommended adding a Key Category analysis for the base year. | This NIR contains a Key Category analysis for the base year. |
| *Cross cutting* - Consistency: Reporting in the NIR and CRF table Summary 3 do not always correspond. | We have tried to improve the consistency between the NIR and the CRF. |
| *Cross cutting* - Recalculations: Provide in CRF table 8(a) | The reasons for recalculations are now provided in the CRF tables for all years. They were omitted because of problems with the installation of the CRF Reproter software. Reasons for recalculations for 2005, and the base year, are also provides in Chapter 10 of the NIR. |
| *Cross cutting* - General comments on consistency within the NIR and between the NIR and the CRF | We have asked sector experts to review their sections in the NIR and to review the consistency of the NIR with the CRF. |
| *Cross cutting* - Transparency of reporting of emissions from the Crown Dependencies and the Overseas Territories. | Additional information has been provided in this NIR including information on improvements to methodologies used for emission estimates. |
| *Energy* - Large inter-annual changes in IEFs, caused by changes in annual derived CEFs. Consider applying regression analysis to avoid these inter-annual changes | We have considered this and discussed with UK DECC. For the moment, the UK continues to update CEFs on an annual basis because it considers that this approach provides the most accurate estimates of carbon emissions in a given year. |
| *Energy* - Fugitive emissions: Activity data incorrectly reported in CRF | The time series of activity data is now correctly reported in the CRF submission, and was corrected in the 2007 CRF submission also. |
| *Industrial Processes* - Cement ($CO_2$) – 25% decrease between 90-92 due to downturn in construction activity | An enhanced explanation has been included in the chapter on Industrial Processes. |

| ERT comment | Actions |
|---|---|
| *Industrial Processes* - Nitric Acid production (N$_2$O): Recommendation that the Party tries to reduce the uncertainty in this source by reviewing the assumptions used and investigating if other industrial data could be used as the basis for more accurate estimates of emissions. | The emissions of N$_2$O from nitric acid production, particularly between 1990 and 1994, are associated with a higher level of uncertainty than in later years of the time series. The higher uncertainty arises because some production data between 1990 and 1994 is unknown and has to estimated from surrogate parameters. We are trying to reduce the uncertainty in this source by reviewing the assumptions used and investigating if other industrial data could be used as the basis for more accurate estimates of emissions. No changes have been made to the estimates of emissions reported in this NIR. |
| *Agriculture* - The methodologies applied tend to utilize highly aggregated activity data. Given the range of quality data that are available, the United Kingdom is encouraged to develop methodologies that use more disaggregated data for its inventory in future. | Noted. The current methodology is based on the most disaggregated data we can obtain. However, we are starting a new project to improve the inventory methodology and this will disaggregate the input data , so as information becomes available this disaggregated data can be used |
| *Agriculture* – Suggestion of implementing a Tier 2 approach for beef cattle. | In the new project (mentioned above) Tier 2 will be implemented in all possible categories including beef cattle. |
| *Agriculture* – Calculation of the Tier 2 emission factors for beef cattle – suggestion that some additional background information could have been provided in the NIR. | Noted. This information has been provided in this NIR. |
| *LULUCF* - The United Kingdom explained that LULUCF emissions were not estimated for Overseas Territories and Crown Dependencies as there was not sufficient information available. | A time series of estimates of LULUCF emissions have now been made for the Overseas Territories and Crown Dependencies and are included in this NIR. |
| *LULUCF* - The NIR does not provide the comprehensive information on land use and land-use change in the country in the form of a land-use matrix as described in the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry | The LULUCF chapter now contains a land use matrix. |
| *LULUCF* - Emissions of the Overseas Territories and Crown Dependencies are not included in the estimates but seem to be negligible. The ERT encourages the United Kingdom to collect data to address these gaps. | The UK inventory now contains estimates of net emissions from Overseas Territories and Crown Dependencies. |
| *LULUCF* - The LULUCF inventory does not include separate estimates of N$_2$O from fertilization of forests, from disturbance of soils, or from wildfires. The ERT encourages the United Kingdom to collect data to address these gaps. | The UK inventory now includes these estimates separately. |
| *LULUCF* - The United Kingdom's countryside survey does not distinguish wetland from other types of land. Wetland types are mainly included in the grassland, or in the case of open water in the category other land. Table 5.D is reported as "included elsewhere" ("IE"). Grassland converted to other land is reported in table 5 as "not occurring" ("NO"), whereas in tables 5.A, 5.B and 5.E grassland conversion is reported. | Noted. |

| ERT comment | Actions |
|---|---|
| *LULUCF* - The area affected by land-use change is reported under the "land converted to" subdivisions. A distinction is made between land converted before 1990 and after 1990. According to the IPCC good practice guidance for LULUCF, land converted from one land-use category to another should be kept in the conversion state for 20 years. Although after 20 years the equilibrium in soil carbon content is not reached, the management practice of the new land use may have a significant influence on the carbon stock in the soil. Hence a subdivision of land remaining in the same category would be more in accordance with the IPCC good practice guidance for LULUCF. The ERT invites the United Kingdom to consider the duration of the conversion status. | Noted. |
| *LULUCF* - The United Kingdom uses a model approach, described as a tier 3 method as defined in the IPCC good practice guidance for LULUCF, to estimate emissions and removals from forests, afforestation and deforestation. The model provides net changes of all three carbon pools – living biomass, dead organic matter, and carbon stock of soils – as well as of wood products harvested from forests in the United Kingdom. No data are provided in the columns "Increase" and "Decrease" of carbon stock changes in living biomass in table 5.A. | The UK now reports Increases and Decreases of carbon stock changes in living biomass in Table 5.A. |
| *LULUCF* - The United Kingdom experts further informed the ERT that they are working on the issues of afforested drained peat land, $N_2O$ emission from drainage, and carbon stock change of organic soils, and that they intend to provide this information in the Party's next NIR. | This is still work in progress. Carbon stock changes on organic soils as a result of afforestation are now reported in table 5.A. |
| *LULUCF* - No estimates are reported for wildfires. The United Kingdom experts explained that there are almost no wildfires but that they would check whether data are available. | The UK now reports estimates for forest wildfires. |
| *LULUCF* - The United Kingdom reports a net emission of 618.82 Gg $CO_2$ from harvested wood products in Table 5 but there is little explanation in the NIR as to how this sink is calculated. The United Kingdom is encouraged to improve the transparency of this calculation by addressing these issues in the NIR of its future submissions. | The text has been updated to improve the transparency of reporting. |
| *Waste* - Check the time series consistency of $N_2O$ emissions from human sewage. | We have examined the time series consistency of these emissions. Between 1996 and 1997 there is a step change in the reported protein consumption data. This is because Defra revised their publication (National Food Survey) and in doing so revised the method used to calculate protein consumption. The new method only provides data back to 1997 and so a step change occurs. |

| ERT comment | Actions |
|---|---|
| *Waste* - The ERT recommended the United Kingdom to explain more clearly in the NIR how it obtained the AD for solid waste disposal on land. | The UK is currently preparing text to include in a later NIR. This will follow on from a review of the model that is used to estimate emission from the disposal of waste to landfill. |
| *Waste* - The ERT recommended the United Kingdom provide more information on how national policies and measures influence the reduction of the quantities of landfilled wastes and the CH4 emissions. | A new section has been added in the main section of the NIR "UK Waste Management Disposal to Land Legislation and Guidance" which explains the UK regulatory framework. |
| *Waste* - The ERT recommends the United Kingdom to clarify how it has obtained such high recovery rates of $CH_4$ in recent years (2000–2004) compared with other European countries. | This NIR contains extra information in Table 3.8.3 on the total quantities of gas flared and utilised. The UK is currently preparing text to include in a later NIR. This will follow on from a review of the model that is used to estimate emission from the disposal of waste to landfill. |
| *Waste* – $N_2O$ and $CH_4$ emissions from industrial waste water are not included due to lack of activity data and of information on processes, which makes it likely that they would be underestimated. The ERT recommends the Party to include these emissions in its future inventories. | The UK has continues with its efforts to estimate emissions from this source. The UK identified has asked the UK Environment Agency to prepare a list of on-site industrial waste water treatment works. This will cover treatment plants in the England and Wales. |
| *Waste* – The United Kingdom uses country-specific EFs for estimating $CO_2$ emissions for waste incineration. The NIR does not provide sufficient clarity on how the biogenic portions of municipal solid waste incinerated were handled for estimating the country-specific EFs. | Additional information has been provided in the Annex 3 of the NIR. In the UK, emissions from MSW are reported under category 1A1a. |
| ***EUMM uncertainty review for EC 2007 NIR*** | |
| *Industrial processes*. 2B Chemical industry. $N_2O$. uncertainty estimate. Emission factor uncertainty value seems to be comparatively high (in relation to those used by other Member States). | Nitric acid and adipic acid manufacture are both key categories in the UK GHG inventory. The uncertainties assigned to the AD and EFs are: 2B2 Nitric acid production, AD 10%, EF 230%; 2B3 Adipic acid production, AD 0.5%, EF 15%. The uncertainties associated with N2O emissions released from nitric acid production dominate the overall uncertainty in $N_2O$ emissions in sector 2B. The uncertainty assigned to the EF of nitric acid production was taken from a study commissioned by UK Defra (Salway, 1998) and the uncertainty in the EF for nitric acid production was estimated from a range of values in the available literature - the reference in the report indicates the main source was the 1996 IPCC guidelines. The UK has not reviewed the uncertainties associated with nitric and adipic acid for some time. The UK stated that it would review the uncertainties with the manufacturers during the compilation of the 2008 NIR but has not altered the uncertainty parameters following this review. Work continues to refine the uncertainty from this source. |

| ERT comment | Actions |
|---|---|
| *4B Manure management*.  N$_2$O EF uncertainty. Uncertainty value seems to be comparatively high (in relation to those used by other Member States). | Manure management is a key category in the UK GHG inventory.  The emissions of N$_2$O from manure management are currently approximately 20 times smaller than those from agricultural soils.  The uncertainties assigned to the AD and EFs are: 4B Manure management, AD 1%, EF ~400%.  Emissions from this source are highly uncertain.  The uncertainties ascribed were derived from the study complete by Salway et al. (1998).  For the purpose of the uncertainty simulation in that study, the much smaller source manure management was included in the agricultural soil total. This was because no separate information on the uncertainty of emissions from manure management was available.  In the GHG uncertainty analysis, the uncertainty associated with manure management was assigned by expert judgement.  The uncertainty ascribed to the EF was reviewed during the agrcultural peer review of the 2004 and 2005 NIRs (Dämmgen and Döring, 2005).  No change was recommended to the ascribed uncertainty as no better country specific data could be identifed.  UK Defra continues to fund research to improve the scientific understanding of emissions from manure management. |
| *4D Agricultural soils*.  N$_2$O EF uncertainty. Uncertainty value seems to be comparatively high (in relation to those used by other Member States). | Agricultural soils is a key category in the UK GHG inventory.  The uncertainties assigned to the AD and EFs are: 4D Agricultural soils, AD 1%, EF ~400%. Emissions from this source are highly uncertain. Current research in the UK indicates that emission factors (kg per hectare per year) are likely to range over two orders of magnitude.  This will be determined by a complex combination of variability (i.e. as influenced by climate, agricultural practice and soil type) and uncertainty (reflecting the difficulty in quantifying the release for any single set of conditions).  As the quality of the activity information (e.g. numbers of animals, fertiliser consumption, crop areas) is generally very high compared to that which is used to quantify the emission factors, uncertainties in the activity data were ignored in the analysis (set to 1% as a mathematical device), and the uncertainties in emissions ascribed solely to those in emission factors (Salway, 1998).  The distribution in emissions from agricultural soil in the UK is represented using a log-normal distribution, with the 95th percentile set to be 100 times larger than the corresponding 5th percentile (Salway et al., 1998).  The uncertainties ascribed to the EF were reviewed during the agrcultural peer review of the 2004 and 2005 NIRs (Dämmgen and Döring, 2005).  No change was recommended to the ascribed uncertainty as no better country specific data could be identifed.  UK Defra continues to fund research to improve the scientific understanding of emissions from agricultural soils. |

| ERT comment | Actions |
|---|---|
| *Centralised Review – September 2008* | |
| *NB These are the responses to the Draft Report, as of 3rd March 2009 and therefore may change before final submission to the UNFCCC on 23rd March* | |
| *Cross Cutting*: Provide more information in the NIR on Quality Assurance procedures and the external review of the inventory | Noted |
| *NIR:* Insufficient trend analysis in Chp2. Recommend that UK present in detail in the appropriate chapter of the NIR the general trend analysis for overall GHG emissions (including explanation for trend variations by gas and by sector) | Chapter 2 has been extended |
| *NIR:* Minor inconsistencies between data in the NIR and CRF summary table 3 (especially agriculture). Address these in the next submission | Noted. |
| *Energy & LULUCF*: Several categories not estimated and insufficient information provided in CRF table 9(a) and annex 5 of the NIR.  Estimate and report in next annual submission the emissions from categories currently reported as NE, giving priority to the largest sources. | Noted |
| *CRF:* Table 9 not populated.  Provide complete information on the categories reported as IE in both the CRF and NIR | Noted |
| *Transparency:* Transparency could be further improved by enhancing the explanation and justification for the allocation of AD and the adoption of new EFs, in particular where these do not result in a recalculation of the entire time-series | Noted |
| *Verification and QA/QC* : Provide more information on QA activities in the NIR in next submission | Noted |
| *Follow up from previous reviews*: Noted that the following recommendations from previous reviews not yet implemented:<br>• Reporting F-gas emissions by species<br>• Including explanations on CO2 emissions from cement production in the NIR<br>• Including the estimation of CH4 and N2O emissions from industrial wastewater in the NIR | - DECC requested not to specify F gases<br>- We are unsure of what is required regarding the cement production.  There is an explanation in the NIR regarding time series variation<br>- Industrial waste water is under review in conjunction with DECC.  It is not clear yet as to what will be done regarding this sector. |
| *Areas for further improvement – cross cutting:*<br>• Information on QA procedures and the external review of the inventory should be more detailed in the NIR<br>• General trend analysis for the overall GHG emissions should be presented in detail in the relevant chapter of the NIR<br>• Consistency between NIR and CRF should be further improved | Noted – see comments in appropriate sections above |
| *Feedstocks and non-energy use:* NG used as a feedstock for manufacture of  ammonia, methanol and acetic acid.  Provide detailed background information in the NIR together with a full description o f the fractions of carbon stored for the fuels listed in CRF table 1.A.(d) | Noted.   We will try to incorporate this in the 2010 submission. |

| ERT comment | Actions |
|---|---|
| *Feedstocks and non-energy use:* Assess whether the default values for the fractions of carbon stored correspond to its national circumstances given the significant differences in apparent energy consumption and CO2 emissions between sectoral and reference approaches | Noted. |
| *Stationary Combustion*: Compare facility level data with activity data received from the EUETS and with activity data received from facilities temporarily excluded from emissions trading. Address any discrepancies found and provide detailed background information on the reallocation issue in next submission | Noted |
| *Stationary Combustion*; CO2 IEFs – provide the explanation in the NIR which was given during the review, along with information on the CO2 EF for MSW and the disaggregated fuel consumption data for OTs (all fuels), CDs (MSW) and scrap tyres | From the 2009 submission this will no longer be relevant because OT fuel use will be included in the categories in which it occurs |
| *Stationary Combustion:* Solid fuels in manufacturing industries and construction – all emissions currently reported under other. Should be reported in correct sub-categories in future submissions as this will increase transparency | Noted |
| *Fugitive Emissions:* Currently no documentation in the NIR describing the methodology for fugitive CO2 emissions from oil production. Recommend providing a description of the estimation methodology for these sources in next submission | Noted. There has been a thorough review of the data available for this sector, with further information supplied in this NIR report. |
| *QA/QC*: Carry out an evaluation of the EA's QA/QC procedures and report results in next annual submission. Also make use of the contacts database and cite personal communication when justifying key assumptions | It is not appropriate for AEA to evaluate a Governments QA/QC programme. We would recommend that this comment is altered. We can ask the EA for an update on their QA/QC procedures and report these findings in the NIR in 2010, but we can not evaluate them. |
| *F-gases:* Recommends reporting F-gas emissions by species in metric tonnes, the unit used in the sectoral background data tables | Noted. This may be possible in the 2010 submission |
| *Solvent use:* Reported as NE. Encouraged to provide estimates for these gases | Noted. |
| *Adipic Acid*: Major revision carried out to the estimation of emissions from adipic acid production, but the document on which the revision was based was not included in the list of references in the NIR. Increase the transparency of reporting by justifying the change to a lower EF in the NIR in the next submission | Information was provided during the review so can this be included in the NIR |
| *F-gases*: Document the recalculation transparency regarding the new model in the NIR. Assess the effect of the change in methodology on the overall consumption patterns of HFCs in different applications | The work incorporated as a result of the F-gas review is documented in the 2009 submission |
| *Chemical Industry:* Waste chemicals burnt. During the review we provided references for old and new EFs and an explanation as to the rationale behind the changes. Add these references together with explanations to the NIR | Noted. We will try to include this information in the 2009 submission |

| ERT comment | Actions |
|---|---|
| *Al Production (PFCs);* Document recalculation transparently.  Include explanation of how time-series consistency has been maintained following the introduction of a new data source that replaces the PI data | Noted.  This was a mistake in the 2008 submission.  It is fixed in the 2009 submission. |
| *Landfill;* Provide detailed info on any improvements | The 2009 submission details improvements made to the waste model. |
| *Landfill* Recommend the collection of updated survey data according to IPCC GPG to avoid overestimation of the amount of recovery | Noted. |
| *Wastewater Handling*: Inconsistency in time series in emissions from human sewage, due to different data sources being used for per capita protein consumption.  Recommend reviewing assumption and providing an explanation for the difference between what is used and the figures provided by the UK to the Food and Agriculture Organisation of the UN | Noted.  There is a comment under 6B in the 2009 NIR |
| *Wastewater Handling*; Emissions from industrial waste water reported as NE due to lack of AD.  Recommend including these emissions in future submissions | Noted.  We will try to follow this up  through stakeholder consultation and report progress in the 2010 NIR |
| *Wastewater Handling*; Emissions from industrial waste water reported as NE due to lack of AD.  Recommend including these emissions in future submissions | Noted.  We will try to follow this up  through stakeholder consultation and report progress in the 2010 NIR |
| *Waste Incineration*; UK uses country-specific EFs for estimating CO2 emissions from waste incineration.  Not enough clarity on geographical coverage.  Recommend that the UK estimate emissions from incinerators in Scotland and NI. | During the review we provided information explaining that currently there are no large incinerators in Scotland or NI but minor ones may exist.  We will try to pick up with stakeholder consultation budget and report on progress in the 2010 NIR. |
| *National System;* ERT encourages the UK to secure the formal agreements between Defra and key data providers and to provide information in the NIR | Noted.  AEA and DECC are working together to try to finalise the Data Supply Agreements. |
| *Commitment Period Reserve*; Recommend that the UK include information on its commitment period reserve in next annual submission | Noted.  We have highlighted this recommendation to DECC who are responsible for reporting the Commitment Period Reserve information |

In response to a request from the EUMM, the UK has revised this table for the 2009 centralised review and EC review to include further detail about where changes can be found in the inventory submission.  Table 10.4 provides details of the comments received from the review teams, the UK response and an update, including NIR references where applicable.

**Table 10.4:** **Brief Details of Improvements to the NIR and the Inventory in response to FCCC Reviews in response to the 2009 reviews.**

| CRF category/issue | Comment from review team | UK response & action | NIR reference |
|---|---|---|---|
| *Centralised Review – September 2009 – please note that the final report has not yet been released* | | | |
| All | Ensure, to the extent possible that categories currently reported as NE and for which methods exist are estimated, or reasons as to why not included in NIR | Noted | See completeness table in Annex 5 of the 2010 NIR |
| All | Provide more detailed info in CRF table 9(a) on categories reported as not estimated and IE | Noted. The UK will look at the information in this table and try to provide a complete set of information | See CRF tables included with this NIR submission. |
| All | Include all rationale for recalculations made in CRF table 8(b) | Noted. The UK endeavours to provide information for all recalculations | See tables 10.1 and 10.2 of the NIR |
| Cross-cutting issue | Include a complete description on how the uncertainty analysis is used to prioritise further improvements in the inventory | Noted. The UK will look at the current description in the NIR and amend if necessary | See Chapter 1 of the NIR |
| Cross-cutting issue | Include detailed discussion on completeness and uncertainty analysis in main body of NIR | Noted. Completeness and uncertainty analysis are provided in the NIR. The UK will look into this recommendation and amend if appropriate | Uncertainty analysis is presented in Annex 7 and cross referenced throughout the main body of the text. Completeness table is provided in Annex 5. |
| Cross-cutting issue | Include more detailed description of the QA procedures implemented and the planning of external peer review activities | Noted. The UK will look into this during the update of the 2010 NIR | See Chapter 1 for description of QA/QC procedures. |
| Cross-cutting issue | Conclude formal MoUs with data providers | DECC are currently preparing formal MOUs for agreement with data providers. | Nothing further to note. |
| Energy | Report fuel consumption and emissions from direct flights between UK and OTs under domestic aviation | The UK is currently reviewing this request and until the outcome of the review is completed, it is not certain that the UK will change future submissions. | Nothing further to note. |
| LULUCF | Include emissions from LULUCF from CDs and OTs in the LULUCF sector and not sector 7 | This is not possible to do at present due to technical issues with the CRF reporter.  It is not possible to add | Nothing further to note. |

| CRF category/issue | Comment from review team | UK response & action | NIR reference |
|---|---|---|---|
| | | additional categories to accommodate the CDs and OTs in sector 5.  The only place that it is currently possible to add LULUCF for these categories is in Sector 7. The UK will be raising this with the CRF helpdesk. | |
| Registry | Further improve measures in place in national registry with a view to minimising operator errors and ensuring interoperability with other registry systems | A new windows service has been introduced to improve and simplify the logical design of the system. This service is designed to provide one single framework for the processing of incoming and outgoing messages, in time allowing to concentrate all logic concerning messaging in one part of the system. This creates a robust basis to start improving messaging reliability, efficiency and the capacity of the registry as a result.

The functionality allowing to initiate transfers has been improved by using a smarter data integrity algorithm. This change increases robustness of the system when several users are trying to initiate transfers from the same account.

Together with the above improvements to the registry system, automated load and performance testing was introduced for system testing. With this, it was possible to test more and to better performance test the system. | For changes in the National Registry see Chapter 14. |

| CRF category/issue | Comment from review team | UK response & action | NIR reference |
|---|---|---|---|
| | | | |
| Registry | Take appropriate actions to reduce the number of out-of-sequence messages sent by its registry | The asynchronous processing of incoming messages is now performed in sequence as opposed to in parallel. These changes have increased the robustness of message processing and resource efficiency, hereby further increasing the capacity of the registry. | For changes in the National Registry see Chapter 14. |
| Registry | Enhance the user interface of the registry | Version 4.3 of the UK registry will provide a new reporting service, which is currently under development. This service will make available a revised set of public reports to satisfy UN requirements. They are expected for release to the registry on 5 April 2010. | For changes in the National Registry see Chapter 14 |
| Issues of completeness paper | | | |
| $CH_4$ and $N_2O$ from LPG in road transportation (1.A.3.b) | Currently reported as NE, but IPCC methodology available for estimating emissions | The UK has no firm data on the number of vehicles running on LPG which would be required to estimate CH4 and N2O emissions from available emission factors. Vehicle licensing data suggest the number of vehicles to be around 0.1% of the car fleet, but it is not clear whether the vehicles running on LPG are cars or vans. Energy statistics indicate 0.3% of all road fuels sold in the UK was LPG, and it is from this that we are able to make an estimate of CO2 emissions, but this cannot be allocated to any specific vehicle class. Since the UK's inventory for CH4 and N2O is based on vehicle km information split by petrol and diesel fuel types, then it would be the | Road transport is discussed in Chapter 3 |

| CRF category/issue | Comment from review team | UK response & action | NIR reference |
|---|---|---|---|
| | | case that emissions from vehicles running on LPG are being captured in the inventories, but as emissions from vehicles running on either of these two fuels instead.<br><br>Light duty vehicles emit around 0.2% of total UK emissions of CH4 in 2007. Although emissions of CH4 from vehicles running on LPG are 2-3 times higher than those running on petrol and diesel, the incorrect assignment of 0.3% of the light duty vehicle fleet using LPG to petrol or diesel would have an extremely small impact on the UK's inventory for CH4.<br><br>Light duty vehicles emit around 2.6% of total UK emissions of N2O in 2007. Emissions of N2O from vehicles running on LPG are 3-5 times higher than their petrol counterparts, but 2-3 times lower than diesel equivalents.  If all the vehicles running on LPG are being incorrectly assigned to petrol cars with a lower emission factor for N2O than LPG then it is estimated that the N2O inventory for road transport would be underestimated by a maximum of 0.4% and the total UK inventory for N2O underestimated by a maximum of 0.01%. | |
| $CO_2$, $CH_4$ and $N_2O$ from gaseous fuels in road transportation (1.A.3.b) | Currently reported as NE, but IPCC methodology available for estimating emissions | UK energy statistics (DUKES) are not able to give the amount of gas used as transport fuels.  An extremely small number of vehicles run on natural gas in | Road transport is discussed in Chapter 3 |

| CRF category/issue | Comment from review team | UK response & action | NIR reference |
|---|---|---|---|
| | | the UK, but the numbers given by licensing statistics are ambiguous as they refer to both dedicated gas and gas bi-fuel vehicles.  Together these constitute 0.06% of all cars, but it is not possible to estimate what fraction of these are running on just gas. | |
| $CO_2$ from fugitive emissions from natural gas (1.B.2.b i-iv) | Currently reported as NE, but IPCC methodology available for estimating emissions | An estimate has been included in the 2010 submission | See Chapter  3, Section 3.3.2.2 |
| $CH_4$ from other leakage of natural gas (1.B.2.b v) | Currently reported as NE, but IPCC methodology available for estimating emissions | We will look into it during the inventory cycle next year (2010-2011). Our gas leakage model includes estimates from the high pressure transmission system, above ground installations and the low pressure supply network to consumers, and as such we consider that the leakage model is comprehensive, but we will re-visit through discussions with the gas network operators." | See Chapter 3, Section 3.3.2.2 |
| $N_2O$ and $CH_4$ emissions from drainage of soils from 5.A forest land (organic and mineral soils). | Currently reported as NE, but IPCC methodology available for estimating emissions | Reporting of non-CO2 emissions from drainage of forest soils is not mandatory (methods are given in an appendix to the Good Practice Guidance) so the UK does not currently prepare estimates. We have requested our UK forest agency partners to look into this matter, and if possible to prepare activity data and emission factors for future reporting. | LULUCF is discussed in Chapter 7 |
| $N_2O$ from disturbance of soils associated to 5.B.2, land use conversion to cropland (in particular 5.B.2.1 forest land | Currently reported as NE, but IPCC methodology available for estimating emissions | This matter was discussed in the UK's 1990-2006 NIR. Estimates were made of N2O emissions after land use change | LULUCF is discussed in Chapter 7 |

| CRF category/issue | Comment from review team | UK response & action | NIR reference |
|---|---|---|---|
| converted to cropland). | | disturbance using the LULUCF GPG methodology default emission factors and C:N ratio. Estimated emissions in 1990 from Forest Land conversion to Cropland were 1.24 Gg CO2-e (0.004 Gg N2O) and from Grassland to Cropland 1548.45 Gg CO2-e (4.995 Gg N2O). These estimated emissions would increase net emissions from the UK's LULUCF sector in 1990 by over 50% (with similar impacts in other years). Given the magnitude of the impact it is important that the methodology used is scientifically sound and we are not confident that this is the case (see the 1990-2006 NIR for further discussion). It would seem prudent to await an alternative approach to estimating N2O emissions due to land use before reporting estimates in table 5(III), given that there is not currently sufficient information to develop Tier 2 methods.. | |
| Industrial wastewater – CH$_4$ | Currently reported as NE, but IPCC methodology available for estimating emissions | At present, the UK does not have suitable data available to make estimates from industrial wastewater.  We are working with the Environment Agency to identify suitable data sources.  A proportion of industrial waste water in the UK is treated at sewage treatment works and therefore is captured in the inventory. We will report progress on estimating emissions from this category in the 2010 NIR. | Industrial wastewater is discussed in Chapter 8. |

| CRF category/issue | Comment from review team | UK response & action | NIR reference |
|---|---|---|---|
| *EC Internal Review of the 2009 UK GHGI Submission* | | | |
| Industrial Processes | Report $CO_2$ emissions from glass production under 2A7 instead of 2A3/2A4 | Our interpretation of the IPCC guidelines is that we should report process emissions from limestone and dolomite use in 2A3, and process emissions from soda ash use in 2A4, and then "other mineral process emissions" in 2A7. This is what we the UK does currently. To change our reporting of all glass industry emissions to 2A7 would be a less detailed reporting approach than we currently take.  This issue has not been picked up by the ERT reviews and if we were to move to a less detailed reporting, we may be subject to criticism from review teams.   The UNFCCC have confirmed that reporting under 2A3 and 2A4 is acceptable and in line with IPCC guidelines. | |
| Industrial Processes | 2C1 - Reconsider allocation of process and energy emissions and explain the reasoning if the allocation cannot be improved | We will review the GLs and make any changes necessary.  The allocation of emissions between combustion and process sources is open to some degree of interpretation within "contact" processes such as Iron & Steel and cement manufacture.  There are some sources currently reported within 1A2a that could arguably be reported within 2C1.  The overall emissions are correct and we work closely with Corus to ensure that our UK carbon balance approach provides emissions by source that are consistent with industry estimates. | |

| CRF category/issue | Comment from review team | UK response & action | NIR reference |
|---|---|---|---|
| Industrial Processes | 2C4, 2E1, 2E4 - Check if F-gases from these categories still need to be kept confidential: | The UK require more time to consider each of these sources in detail and work out where new data (from ePRTR) may impact on the data compilation. It should be noted that additional data from ePRTR may be of limited additional use as we have good quality data from the UK Pollution Inventory for major installations. With regards to reporting, there are still confidentiality issues for some sectors. At present there is limited scope for more detailed reporting as the CRF and related automated systems for populating the CRF would need a significant revision to enable reporting. At present this is not something which is factored into the inventory cycle. | |
| Industrial Processes | 2F -Reconsider reporting of unspeciated mix of F gases instead of single gas emissions | See response provided above regarding F-gas reporting. | |
| Industrial Processes | 2F - Include unspeciated mix of f gas emissions in 2F at least in the subcategory where they are emitted | In most cases, emissions are reported in the correct subcategory. Emissions are only aggregated to disguise commercially confidential data. | |
| Industrial Processes | 2A6 - Check if $CO_2$ emissions from road paving with asphalt can be estimated | This requires investigation. We can add this to the list that the UK discusses at the NISC meetings and request further investigation. Note that estimates are likely to be small and very uncertain. | |
| Industrial Processes | 2C41 - Check if $SF_6$ emissions from Al foundries occur and can be estimated | Nothing is reported in the Pollution Inventory. | |
| Industrial Processes | 2C5 - Check if Si metal production exists and check if $CO_2$ emissions from non-ferrous metal production is included in the inventory | We are not aware of any significant production of Si metal in the UK. To the best of our knowledge, all CO2 emissions from non-ferrous metal | |

| CRF category/issue | Comment from review team | UK response & action | NIR reference |
|---|---|---|---|
| | | production is included in the inventory | |
| Industrial Processes | 2F9 - Do $SF_6$ emissions occur from double glazing and if so, are they estimated | This requires investigation. Again we will add it to the list for discussion at a NISC meeting. | |

## 10.4.2 Major Improvements to the Current Inventory

The data and compilation methods used in the UK GHGI are reviewed annually and where appropriate the estimation methodologies are revised and improved. The main methodological changes in the UK inventory during the latest compilation cycle are summarised below. Further details can be found in the appropriate sections of this report.

1)Sector: Road Transport

Revised fuel consumption factors
- New TRL fuel consumption speed-related functions for cars, LGVs and motorcycles
- HGVs – average miles per gallon fuel efficiency (DfT) used in conjunction with new TRL speed-related functions to define the variation in fuel consumption with speed
- Buses – new information from Bus Service Operating Grant (BSOG) used to define fuel efficiency, combined with new TRL speed-related functions

How are GHGs affected?
- Total fuel consumption is unchanged, so the overall change in carbon emissions is zero, but the distribution of emissions by vehicle type has been revised.

Revised Emission Factors: methane
- New TRL emission factors adopted

How are GHGs affected?
- Methane emissions have been revised across the whole time series

Activity Data:Vehicle km data revised
- Slight revision to vkm time series due to new information from the Northern Ireland Department for Regional Development

How are GHGs affected?
- Affects the split of $CO_2$ between vehicle types, and also has led to small revisions to methane and nitrous oxide estimates for recent years.

Other Road Transport Assumptions
- New assumptions surrounding accumulative mileage, catalytic failure and survival rate

How are GHGs affected?
- Accumulative mileage assumptions have led to revisions of nitrous oxide emissions from petrol vehicles.
- Revisions to catalytic failure rates affect emissions of both methane and nitrous oxide.
- Revisions to the survival rate affects estimates of all pollutants by vehicle type.

2)Sector: Aviation
- Incorporation of recommendations from the Project for the Sustainable Development of Heathrow (PSDH) across all UK airports regarding thrust setting at take-off and climb-out as well as revised cut-back height (previously only incorporated for Heathrow);
- Scaling of emissions on an airport by airport basis to account for non ATM and air-taxi prior to fuel reconciliation;
- Revised fuel use data for military aviation.

3)Sector: Industrial Processes - F-Gases
- Revision to the refrigeration model for HFCs and PFCs

4)Other Revisions
- Revised methodology for calculating use of limestone/dolomite in the glass industry due to concerns about the existing data
- Updated the calculation of the production of various types of glass
- Added liquid biofuels as a power station fuel (very minor source)
- EU ETS data are now used in preference to UK energy statistics for petroleum coke use in the refinery sector for 2006 onwards.

## 10.4.3   KP-LULUCF Inventory

This is the first year that the UK has officially reported the KP-LULUCF and so there are not any recalculations to report.

# 11 KP-LULUCF

## 11.1 GENERAL INFORMATION

### 11.1.1 Definition of forest

The UK has chosen the following definition of forest and single minimum values (also in table NIR.1).

A definition of 'forest' as agreed with the Forestry Commission comprising:

- a minimum area of 0.1 hectares;
- a minimum width of 20 metres;
- tree crown cover of at least 20 per cent, or the potential to achieve it;
- a minimum height of 2 metres, or the potential to achieve it.

This definition includes felled areas awaiting restocking and integral open space (open areas up to 1 hectare) (Forestry Statistics 2009, section 11.1).

These single minimum values are used for reporting UK forestry statistics (Forestry Commission, 2009) and the UK's greenhouse gas inventory submitted under the UNFCCC. The definitions are consistent with information provided by the UK to the FAO. However, if an international enquiry uses a different minimum definition, for example 0.5 ha in the Global Forest Resource Assessment 2005, the UK areas are adjusted (explicitly or implicitly) to this different definition (FAO, 2005).

### 11.1.2 Elected activities under Article 3, paragraph 4 of the Kyoto Protocol

The UK has chosen to elect Forest Management (FM) as an activity under Article 3.4. In accordance with the Annex to Decision 16/CMP.1, credits from Forest Management are capped in the first commitment period. For the UK the cap is a relatively modest 0.37 MtC (1.36 $MtCO_2$) per year, or 6.78 $MtCO_2$ for the whole commitment period.

### 11.1.3 Description of how the definitions of each activity under Article 3.3 and each elected activity under Article 3.4 have been implemented and applied consistently over time

The areas of forest land reported for AR and FM under the Kyoto protocol are broadly equivalent to the area reported under 5A2 (Land converted to Forest Land) in the UNFCCC greenhouse gas inventory. Definitions are consistent with those used in the UNFCCC GHGI. The Afforestation/Reforestation area is land that has been converted to forested land since 1990 (inclusive). However, the Forestry Commission (the state forestry agency) report new planting by 'planting years', which run from 1st April to 31st March. In order to be compatible with the requirement to demonstrate that activities under Article 3.3 began on or after 1st January 1990, it is necessary to adjust the planting figures (Forestry Commission, pers.

comm.). For example, 1990 will contain planting reported in 1990 (1<sup>st</sup> April 1989-31<sup>st</sup> March 1990) and 1991 (1<sup>st</sup> April 1990-31<sup>st</sup> March 1991). Therefore, the area reported for Article 3.3 Afforestation/Reforestation in 1990 is the sum of 25% of 1990 planting and 75% of 1991 planting, and so on to the present. The numbers reported in the UNFCCC GHGI are not adjusted (**Figure 11.1**): in 2008 the area of forest established since 1990 was 294,710 ha in the UNFCCC GHGI and 283,115 ha under Article 3.3 Afforestation.

**Figure 11.1**     **UK afforestation since 1990 in the UNFCCC GHGI (by planting year) and in Article 3.3 (adjusted by calendar year)**
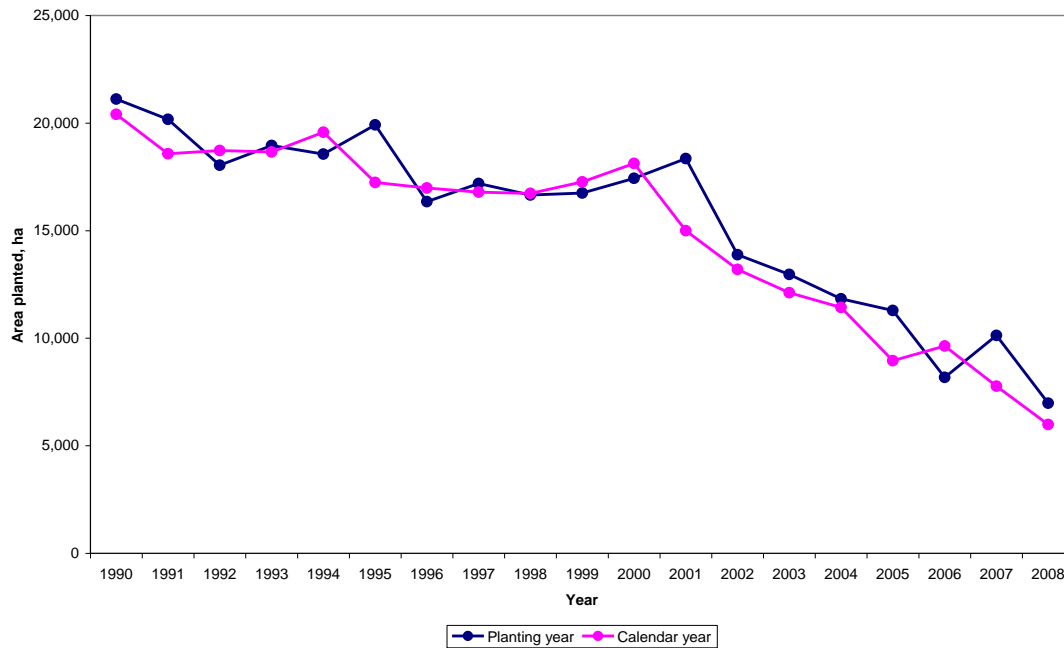


Deforestation since 1990 is taken to be the land area permanently converted from forest land to either grassland or settlement (conversion to cropland since 1990 is estimated to be negligible based on land use surveys). Areas of annual forest conversion are reported in the UNFCCC GHGI, and the cumulative total 1990-2008 matches the area reported under Article 3.3 Deforestation.

The Forest Management area is the area converted to forest land between 1921 and 1989 (1,394.49 kha), adjusted to reflect losses from deforestation 1990-2008 (19.76 kha), giving a total of 1375.66 kha in 2008. In the UNFCCC GHGI the deforestation area is currently deducted from the Forest remaining Forest Land area (established before 1920) (emissions from and carbon stock changes in soils and biomass due to deforestation are fully accounted for in the GHGI). We hope to resolve the differences between the deforestation and forest planting datasets before the next inventory, to allow these reporting differences to be removed.

The afforestation/reforestation datasets are provided by the Forestry Commission and the Forest Service of Northern Ireland (the national forestry agencies) and are consistent with the definition of forest given above. New planting can use planting/seeding or natural colonisation. Data come from administrative systems (state forests) and grant schemes (other woodland) (Forestry Statistics 2009). Areas of planting that are not state-owned or grant-aided (i.e. whether these woodlands are explicitly managed is unknown) are not included in the

GHGI or Article 3.3 AR. It is estimated that these contribute less than 0.4 kha annually (possibly an underestimate due to incomplete reporting, according to the Forestry Commission).

There is an assumption of restocking after harvesting, although open habitat can make up 13-20% of stand area on restocking. Therefore, Afforestation and Reforestation under Article 3.3 can be considered together. Thinning is considered to be part of the normal forest management regime. A felling license is required for felling outside the national forest estate; there is a legal requirement to restock under such a license unless an unconditional felling license is granted (in which case this would be formally reported as deforestation). Information on deforestation activities is assembled from data provided by the Forestry Commission and by the Ordnance Survey (the national cartographic agency) through the UK government (see Chapter 7). To the best of knowledge, these definitions have been applied consistently over time, although larger uncertainties are associated with deforestation estimates compared with afforestation estimates.

### 11.1.4   Precedence conditions and hierarchy among Art. 3.4 activities

Not applicable, as only Forest Management has been elected under Article 3.4.

## 11.2   LAND-RELATED INFORMATION

### 11.2.1   Spatial assessment unit used for determining the area of the units of land under Article 3.3

The spatial assessment units used are the four countries of the UK: England, Scotland, Wales and Northern Ireland (GPG LULUCF Reporting Method 1). There is sufficiently detailed data to allow carbon stock changes for Article 3.3 AR and Article 3.4 FM land to be reported for 20x20km units, but not for the reporting of other emissions or Article 3.3 Deforestation carbon stock changes. Further information on the detailed mapping of AR and FM carbon stock changes will be made available at http://www.edinburgh.ceh.ac.uk/ukcarbon.

### 11.2.2   Methodology used to develop the land transition matrix

The land transition matrix is shown in Table NIR 2. The same data sources are used for the UNFCCC greenhouse gas inventory and emissions/removals under Articles 3.3 and 3.4. National planting statistics from 1921 to the present are provided by the Forestry Commission and the Northern Ireland Forest Service for each of the countries in the UK. Areas planted since 1990 in this dataset are used in Article 3.3 Afforestation/ Reforestation (**Figure 11.2**). There is currently no detailed information on the age and type of forests subject to deforestation so it is assumed that areas that have been afforested since 1990 will not have been deforested during this period. Estimates of areas in Article 3.3 Deforestation (**Figure 11.3**) are made using Unconditional Felling Licences and the Land Use Change Statistics (LUCS), a survey of land converted to developed use. Further information on these data sources is in Chapter 7 and a summary is given in Table 11.1. The area of Article 3.4 Forest Management land is the area of forest planted between 1921 and 1990, adjusted to take account of the area lost by deforestation (**Figure 11.4**). The area of Other Land in table NIR 2

is balanced so that the total area adds up to the land area reported for the UK in Table 7.2 (25,758.98 kha) and is constant for all years.

**Figure 11.2       Forest area planted since 1990 in the countries of the United Kingdom**
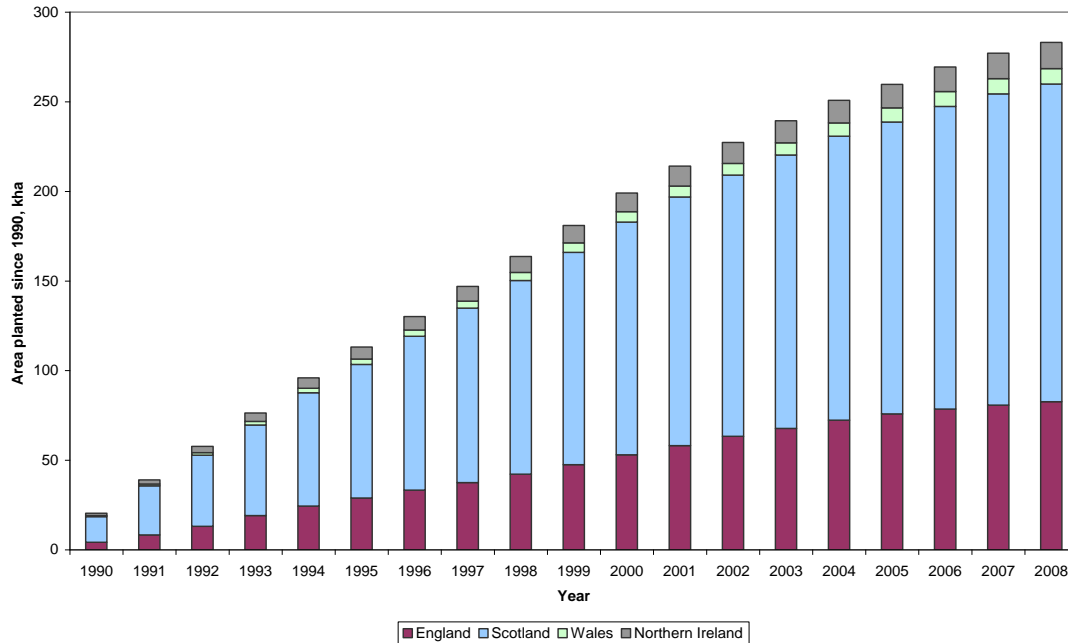


**Figure 11.3       Area deforested since 1990 in the countries of the United Kingdom (note different scale from previous figure)**
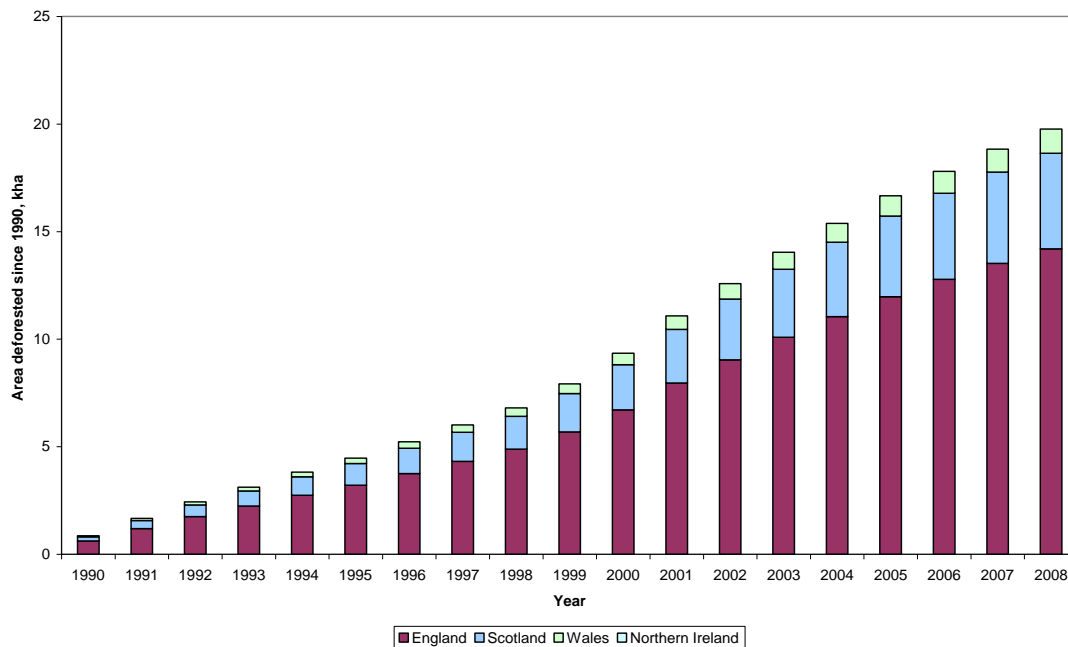
**Figure 11.4**     **Area of Forest Management land 1990-2008 in the countries of the United Kingdom**



■ England ■ Scotland □ Wales □ Northern Ireland
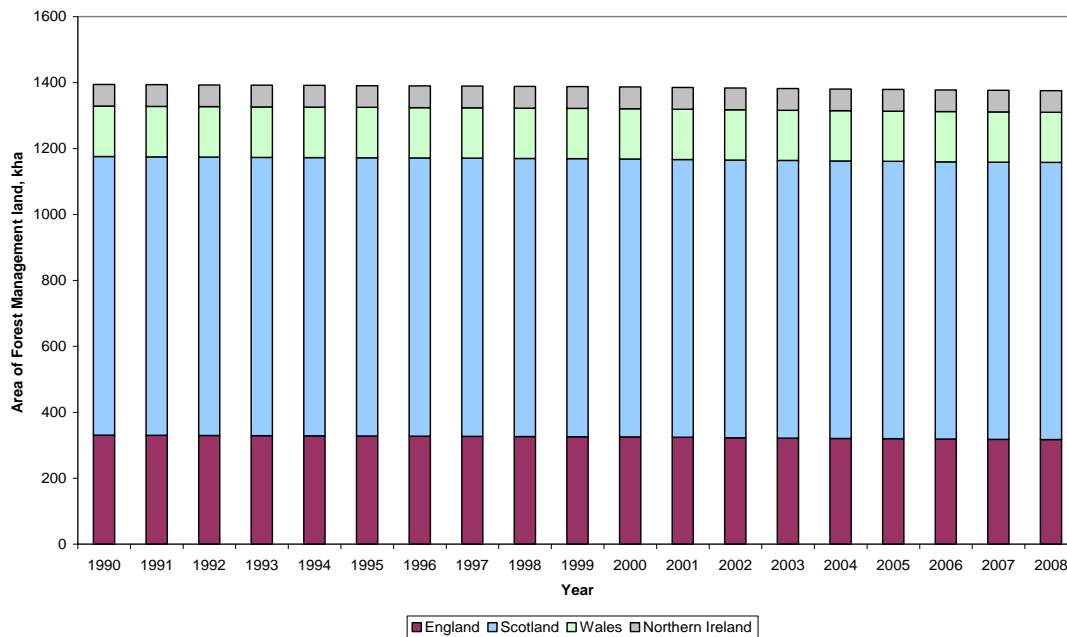
**Table 11.1**     **Data sources on ARD and FM activities**

| Activity | Dataset | Available scale | Time period | Details |
|---|---|---|---|---|
| AR & FM | Annual planting statistics | Country (England, Scotland, Wales, Northern Ireland) | 1921-present | New planting on previously non-forested land. Updated annually. Categorized into conifer and broadleaved woodland. |
| D | Forestry Commission Unconditional Felling Licence data | England/Great Britain | 1990-2002 (England only), 1999-2001 (Great Britain) | Unconditional Felling Licences are issued for felling without restocking. Used to estimate deforestation in rural areas (primarily for heathland restoration). English data is extrapolated to GB scale and to current reporting year. Omits felling for development purposes, e.g. construction of wind turbines. |
| D | Land Use Change Statistics (survey of land converted to developed uses) | England only | 1990-2005 (updated in 2008) | Estimates of the conversion of forest to urban/developed land use. Based on Ordnance Survey map updates, identifying changes through aerial surveys and other reporting, expected to capture most changes within five years. English data is extrapolated to GB scale and to current reporting year. |

### 11.2.3 Maps and database to identify the geographical locations, and the system of identification codes for the geographical locations

The individual countries of the United Kingdom have been used as the geographical units for reporting (**Figure 11.5**). The Forestry Commission and Forest Service maintain administrative systems that allow areas of land to be tracked within each country (sub-compartment databases for state forests and grant scheme data for other woodland).

**Figure 11.5    Spatial units used for reporting Kyoto protocol LULUCF activities**
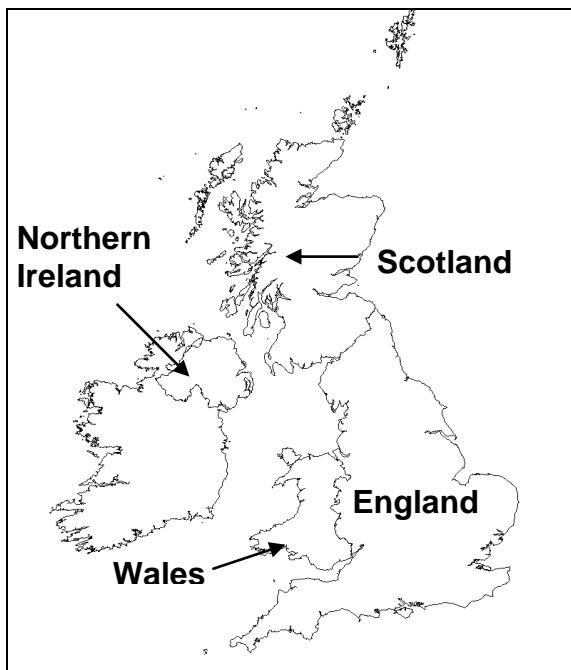


## 11.3    ACTIVITY-SPECIFIC INFORMATION

### 11.3.1 Methods for carbon stock change and GHG emission and removal estimates

#### 11.3.1.1 Description of the methodologies and the underlying assumptions used

Methods for estimating carbon stock changes in forests (for Article 3.3 Afforestation/Reforestation and Article 3.4 Forest Management) are the same as those used for the UNFCCC greenhouse gas inventory: details are given in annex 3.7. A carbon accounting model, C-Flow, is used to estimate the net change in pools of carbon in living biomass, litter and soil in conifer and broadleaved forests. In the KP CRF tables changes in carbon stock are reported for: above-ground biomass (gains and losses), litter (net changes) and soils (net changes in mineral and organic soils). Carbon stock changes in below-ground biomass and dead wood are reported as Included Elsewhere: below-ground biomass is calculated as part of the above-ground biomass pool (not the soils pool as reported in the CRF) and dead wood is calculated as part of the litter pool.

Annual data on forest planting is provided by the Forestry Commission (at a higher precision than that published in the annual Forestry Statistics and with non-grant-aided planting separated out). Information on state afforestation is stored in the Forestry Commission Sub-Compartment Database (SCDB): this is the stand management database for state-owned and managed forest, containing information on species, age, yield class and management. Non-state forest information comes from the grant schemes by which the government encourages planting and management of private woodland. These schemes cover almost all private woodland planting since 1995: there is a small amount of non-grant aided woodland (mostly in England) which is assumed to be broadleaved natural regeneration but we have no further information on the management or permanence of this area. Areas included are those for which new planting grants have been paid and the planting has actually been completed. The FC will not pay grants prior to the planting taking place so it can be assumed the areas are therefore stocked.

Estimates for carbon stock changes as a result of Article 3.3 Deforestation use the same methods as the UNFCCC greenhouse gas inventory (annex 3.7). During deforestation, 40% of the above-ground biomass is burnt and emissions of $CO_2$, $CH_4$ and $N_2O$ are reported in Table 5(KP-II)5. The remaining carbon stock change in biomass is assumed to be immediately lost. This loss (in Gg C) is calculated as:

Stock change = C fraction * % of biomass removed * (area * available biomass) * 0.001
where
*carbon fraction = 0.5*
*proportion of biomass removed = 60%*
*area = area deforested, ha*
*available biomass = 240 t/ha (mature broadleaved forest assumed)*

Carbon stock changes in soils as a result of deforestation are calculated using the dynamic model of carbon stock change discussed in Annex 3.7. It is not possible to report changes in mineral and organic soils separately (no separate activity data). Estimates of deforestation are made for England, Scotland and Wales. There is no activity data available for deforestation in Northern Ireland.

Carbon stock changes due to Forest Management are estimated using the C-Flow model, as described in Annex 3.7. However, it is assumed that all deforestation occurs on Forest Management land, so the area of FM land and carbon stock changes need to be 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 11.4**), and the resulting areas multiplied by the implied carbon stock changes per unit area to give total carbon stock changes.

Greenhouse gas emissions (rather than carbon stock changes) from LULUCF activities under the Kyoto Protocol are reported in Tables 5(KP-II)1-5.

*Table 5(KP-II)1. Direct $N_2O$ emissions from N fertilization*

The method used to estimate emissions is the same as that used in the UNFCCC greenhouse gas inventory and described in Annex 3.7. It is assumed that nitrogen fertilizer is only applied to newly planted forests in the UK (see Chapter 7 for more information)

*Table 5(KP-II)2. $N_2O$ emissions from drainage of soils*

According to the Good Practice Guidance, reporting of these emissions is not mandatory so no estimates have been made. There is further discussion on this matter in Chapter 7 and Annex 3.7. Work is planned for this area.

*Table 5(KP-II)3. $N_2O$ emissions from disturbance associated with land use conversion to cropland.*

Deforestation to Cropland in the UK since 1990 has been estimated to be negligible, based on land use surveys. New data (from Countryside Survey 2007 and possibly from the Forestry Commission's forest map) will become available in 2010. This will enable this assumption to be re-examined and new estimates to be produced if necessary.

*Table 5(KP-II)4. Carbon emissions from lime application*

No lime is applied to UK forests (Forestry Commission, pers. comm.). It is difficult and economically unviable to apply lime at the heavy rates required (Taylor 1991).

*Table 5(KP-II)5. GHG emissions from biomass burning*

The method used to estimate emissions is the same as that used in the UNFCCC greenhouse gas inventory and described in Annex 3.7. There is no information on the location of wildfires in forests in the UK, so it is not possible to split burning between Afforestation/Reforestation land and Forest Management land. Therefore, emissions from wildfires are all reported under Forest Management. Wildfires would only affect a very small area of Afforestation/Reforestation land area (less than 1% since 1990) if the burnt areas are distributed in proportion to forest area. As described above, it is assumed that 40% of the standing biomass undergoes controlled burning during deforestation and emissions from that burning are reported in this table.

## 11.3.1.2 Justification for omitting any carbon pool or GHG emissions/removals from activities under Article 3.3 and elected activities under Article 3.4

*Table 5(KP-I)A.1.2 Article 3.3 activities: Afforestation and Reforestation. Units of land harvested since the beginning of the commitment period*

It is assumed that no areas that have been afforested since 1990 have been harvested in the period 1990-2008, so carbon stock changes in this table are reported as NO (not occurring). There is an assumption that the species planted are managed so that they reach maturity (40 years or more) before harvesting.

*Table 5(KP-I)A.1.3 Article 3.3 activities: Afforestation and Reforestation. Units of land otherwise subject to elected activities under Article 3.4 (information item)*

Only Forest Management has been elected under Article 3.4.

*Table 5(KP-I)A.2 Article 3.3 activities: Deforestation*

There is no activity data on deforestation in Northern Ireland and carbon stock changes are reported as Not Occurring.

*Table 5(KP-I)A.2.1 Article 3.3 activities: Deforestation. Units of land otherwise subject to elected activities under Article 3.4 (information item)*

Only Forest Management has been elected under Article 3.4. As Deforestation is a permanent loss of forest cover, any unit of land that has been deforested under Article 3.3 cannot also be subject to Forest Management under Article 3.4.

*Table 5(KP-II)1. Direct $N_2O$ emissions from N fertilization*

It is assumed that nitrogen is only applied to newly planted forests in the UK, therefore no N fertilization occurs on Forest Management land. It is assumed that no areas that have been afforested since 1990 have been harvested in the period 1990-2008 so emissions for A.1.2 are reported as Not Occurring.

*Table 5(KP-II)2. $N_2O$ emissions from drainage of soils*

Reporting of these emissions is not mandatory so no estimates are made. There is no activity data on the extent of drainage under Forest Management areas but this is currently under investigation and a report on progress will be made in the next NIR submission.

*Table 5(KP-II)3. $N_2O$ emissions from disturbance associated with land use conversion to cropland.*

Deforestation to Cropland in the UK since 1990 has been estimated to be negligible, based on land use surveys, and reported as Not Occurring. New data (from Countryside Survey 2007 and possibly from the Forestry Commission's forest map) will become available in 2010, providing an activity dataset. This will enable this assumption to be re-examined and new estimates to be produced if necessary.

*Table 5(KP-II)4. Carbon emissions from lime application*

No lime is applied to UK forests (Forestry Commission, pers. comm.), so emissions are reported as Not Occurring.

*Table 5(KP-II)5. GHG emissions from biomass burning*

There is no controlled burning in UK forests, so this is reported as Not Occurring under Afforestation/Reforestation and Forest Management. There is no information on the location of wildfires in forests in the UK, so it is not possible to split burning between Afforestation/Reforestation land and Forest Management land. Therefore, emissions from wildfires are all reported under Forest Management. There is no activity data collected on wildfires on non-forest land in the UK at present, therefore emissions from wildfires on deforested land cannot be estimated. It is assumed that wildfires on forested land do not result in a permanent loss of forest cover and burnt areas will undergo replanting or natural regeneration.

### 11.3.1.3 Information on whether or not indirect and natural GHG emissions and removals have been factored out

The UK inventory approach to estimating forest carbon stock changes is based on modelled growth data rather than national-scale measurements of forest annual volume increments. The CFlow model is based on yield class tables, and in principle assumes constant weather and management conditions. Therefore 'factoring out' of climate change effects is not required. Work has been undertaken to model the impact of climate, $CO_2$ and land use change on the carbon balance of terrestrial ecosystems in Great Britain (Levy and Clark 2009) and interaction between these factors. This suggested that interactions are small and the effects of these environmental factors are additive (and so could be 'factored in' in future). Nitrogen dynamics were not considered in this work: the extent to which enhanced nitrogen deposition affects forest carbon sequestration remains contentious (Magnani *et al* 2007; Sutton *et al* 2008). Much of the United Kingdom's forest area was established during the 20th century, and forests are still in their first or second rotation. The dynamic effects of the age structure as a result of this planting pattern have not been 'factored out' of carbon stock changes in Article 3.4 Forest Management, but this is taken account of by the FM cap.

### 11.3.1.4 Changes in data and methods since the previous submission (recalculations)

This is the first official submission of Article 3.3 and Article 3.4 estimates, so any recalculations will be reported from the next submission onwards, as appropriate.

### 11.3.1.5 Uncertainty estimates

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

*Uncertainty from model inputs.*

The IPCC Tier 2 approach for uncertainty quantification recommends quantifying the uncertainties associated with individual input factors by expressing them as probability distribution functions (PDFs). Sampling from the PDFs propagates input uncertainty through the model to the outputs. However, 'knowledge about parameters is generally incomplete; they interact and uncertainty may propagate non-linearly in the calculations. If the only source of information utilized for the PDFs is direct measurement or expert opinion, the resulting output may be overly high' (van Oijen and Thomson, submitted.). Bayesian techniques (van Oijen *et al*. 2005, Patenaude *et al*, 2008) have been used in this uncertainty assessment to reduce input uncertainties where possible.

CFlow requires input data on the afforestation rate (ha yr$^{-1}$) and yield class (mean wood volume production, m$^3$ ha$^{-1}$ yr$^{-1}$) for different forest types and regions in the UK. CFlow has near-linearity with respect to the yield class input, i.e. the use of yield class 12 m$^3$ ha$^{-1}$ yr$^{-1}$ for conifers (used in CFlow) produces a carbon flux time series that closely approximates the mean of yield classes 8,10,12,14 and 16 m$^3$ ha$^{-1}$ yr$^{-1}$ (van Oijen 2008). The average annual

flux over 100 years since first planting for yield class 12 is 1.53 Mg C ha$^{-1}$ yr$^{-1}$ (biomass+litter+soil), with values for other yield classes ranging from 1.18 Mg C ha$^{-1}$ yr$^{-1}$ (-23%, yield class 8) to 1.97 Mg C ha$^{-1}$ yr$^{-1}$ (+29%, yield class 16). However, very large uncertainties can arise when assessing carbon sequestration for specific calendar years with different yield classes as harvesting produces a large flux (Figure 11.6 B and C). However, when categories 5A and 5G (Forest Land and Harvested Wood Products) are considered together the combined uncertainty is much smaller (Figure 11.6 A) because of the opposite effect that harvesting has on these two stock pools. It should also be noted that these graphs show the fluxes from a single instance of planting: when spatio-temporal patterns across the UK are combined together these inter-year uncertainties are cancelled out to a large extent.

**Figure 11.6** **Comparison of flux time series since first planting from CFlow for Sitka spruce yield class 6,8…16. The default curve (YC12) is shown in bold blue. Lower yield classes are in red-green, higher yield classes in blue-magenta.**
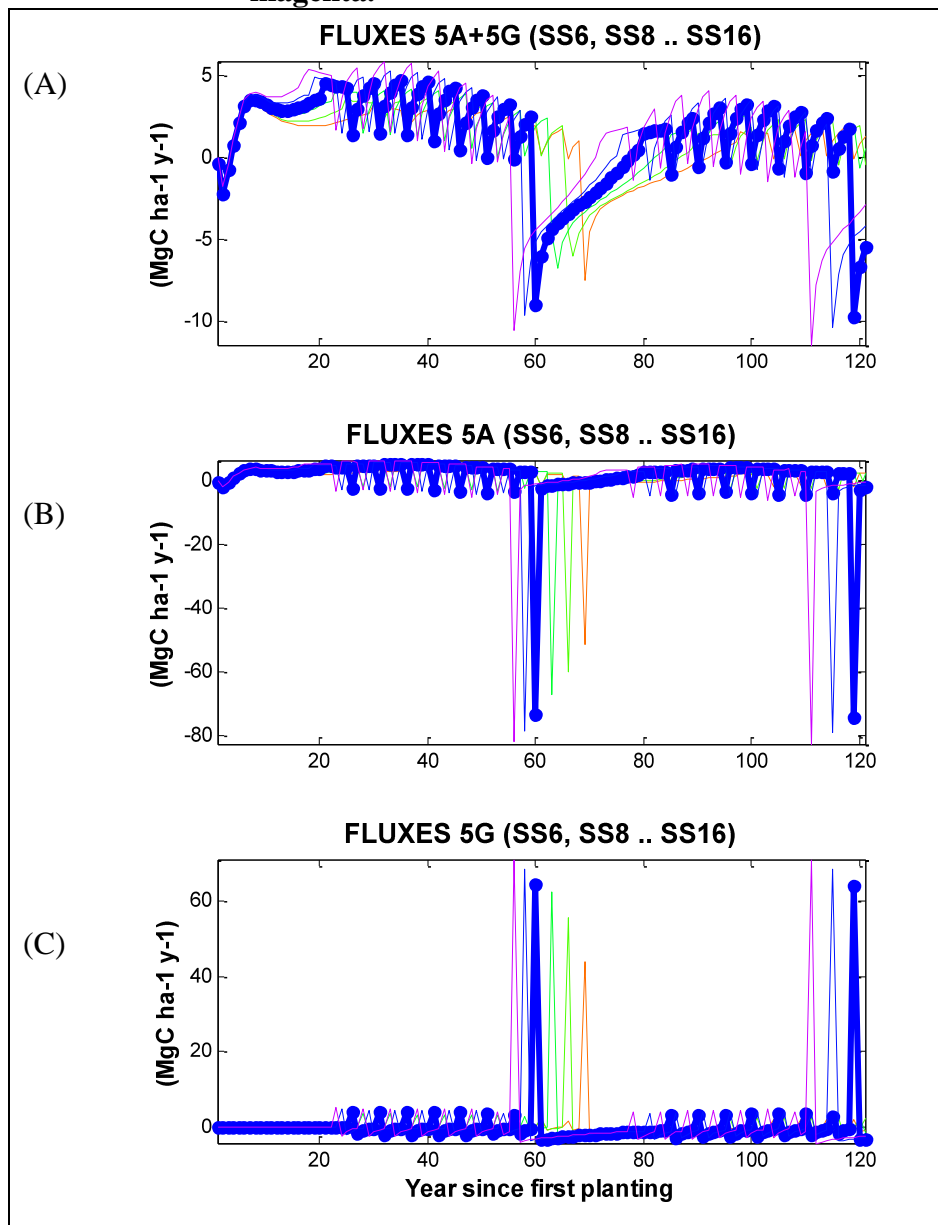
No measures of statistical uncertainty can be associated with the planting statistics because they come from administrative systems not surveys (Forestry Commission, pers. comm.). It should be possible to derive better information on the reliability of the planting statistics when the new National Forest Inventory (NFI) map becomes available in mid-2010: the NFI team are scheduled to produce gross and net change statistics based on the new map during 2010/11, although details have not yet been finalised. We are particularly looking to this new source to improve our estimates of woodland loss, but it should also provide information about woodland planting that is non-FC and non-grant aided.

*Uncertainty from model parameters*

Dewar and Cannell (1992) include a sensitivity analysis of CFlow's parameters. The processes and parameters that were most uncertain or variable were: the fractions of woody biomass in branches and woody roots, litter and soil organic matter decomposition rates and the rate of fine root turnover. Other parameters were known to reasonable accuracy and/or had a small impact on carbon storage.

Additional sensitivity analysis was presented in van Oijen (2009). The sensitivity of the biomass expansion factor and turnover rate parameters (controlling the carbon partitioning between trees, litter and soil) were modelled with 30% uncertainty about the default parameters under a uniform distribution (**Figure 11.7**). Changes in parameters do not affect the overall time pattern of carbon sequestration due to afforestation. Of particular relevance to Kyoto Protocol reporting is that there are only minor differences between sink strength in any given year and a reference year, e.g. 1990.

**Figure 11.7** **Sensitivity analysis (SA) of 5A+5G to changes in parameters. Top row: changes in expansion factors. Bottom row: changes in turnover rates. Blue lines: default parameterisation. Black lines: sample of 20 parameter vectors from a multivariate uniform distribution where every individual parameter has a range from 0.7 to 1.3 times its default.**
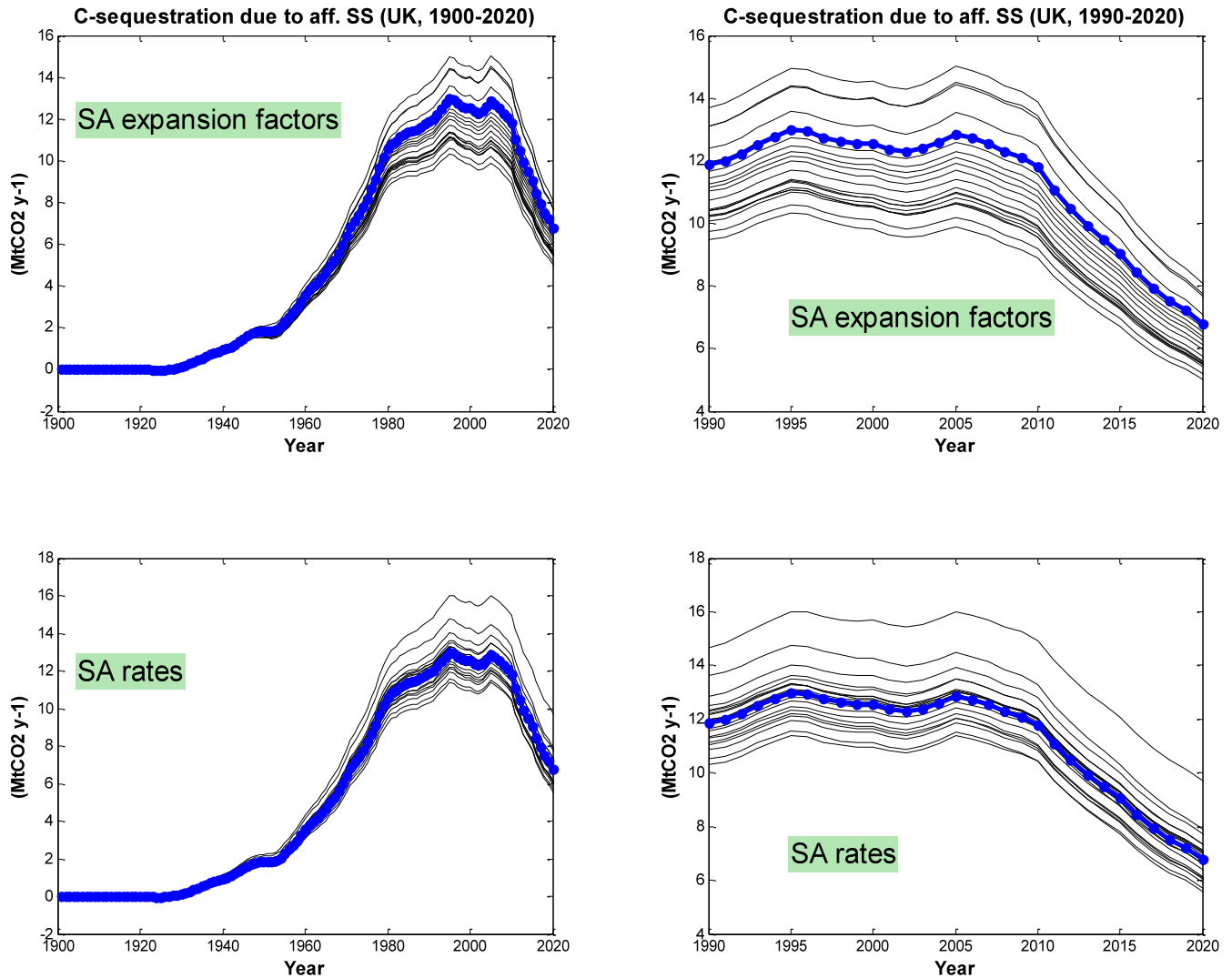


*Uncertainty from model structure*

Van Oijen (2009) also examined the inclusion of certain processes within CFlow: the gradual loss of pre-existing soil carbon due to planting disturbance and carbon removal by ground vegetation before canopy closure (based on Hargreaves *et al*. 2003). The assumptions regarding the dynamics of these processes do not affect the general pattern of carbon stock change over time but do affect the magnitude of that stock change (**Figure 11.8**). The implementation of both processes was based on a limited amount of empirical information, so the reliability of the current model is to some extent uncertain. However, the existence of these processes is not in doubt- their magnitude and change over time are (so the graphs over-estimate the uncertainty regarding these processes).

**Figure 11.8** **Total carbon stock change due to U.K. afforestation (5A+5G). Left: 1900-2020, right: 1990-2020. Blue line: actual inventory method. Red: no emissions from pre-existing soil carbon. Green: no removal by grass growth. Yellow: neither process (i.e. "Red+Green").**
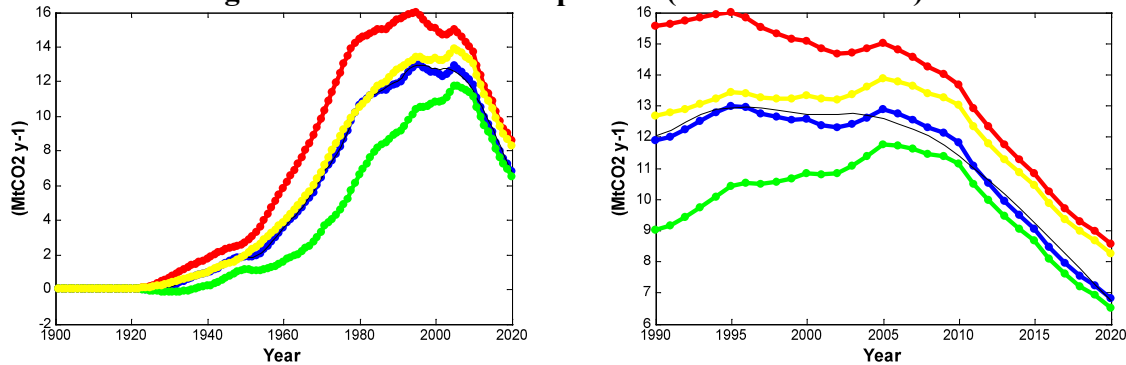


Work using a more complex process-based carbon flow model (BasFor) discovered that uncertainties showed distinct spatial trends across the UK, as a result of heterogeneous environmental conditions (van Oijen and Thomson submitted). This suggests that a simple approach to forestry-related uncertainty (i.e. assuming uncertainty to be a fixed percentage of the absolute flux rate) is not applicable.

This work has not yet produced a simple uncertainty estimate for reporting, so work is continuing in this area. In the interim, an uncertainty of 25% for Article 3.3 Afforestation/Reforestation and Article 3.4 will be used (as estimated for UNFCCC category 5A) and an uncertainty of 50% for Article 3.3 Deforestation (based on expert judgement).

### 11.3.1.6 Information on other methodological issues

*Disturbances.* Data is available on fire damage to state-managed forests and extrapolated to privately-managed forests (see Chapter 7 and Annex 3.7 for further details). There is no data available on the type of forest burnt by wildfires (species or age) or wildfire locations within each country of the UK. Wildfires are not assumed to result in a permanent change in land use. Damage from windblow is not reported in the UNFCCC inventory, although it does occur in the UK (FAO, 2005; Forestry Commission, 2002). There are currently insufficient data to include the effects of these disturbances in the inventory. If a storm causing extensive, widespread forest destruction occurred (as in the 1987 storm in southern England) then this would be taken account of on an *ad hoc* basis.

*Inter-annual variability.* The method used to estimate emissions and removals from AR and FM is based on the C-Flow model. This model is not sensitive to inter-annual variation in environmental conditions so these will not affect the annual growth and decay rates. There is an ongoing research project to look at the variation in management conditions across the UK forest estate and over time. The area burnt in wildfires does show inter-annual variation and this is included in the emissions methodology. Where data is missing from the annual time series a Burg regression equation is used to extrapolate the trend from the previous ten years.

**11.3.1.7 The year of the onset of an activity, if after 2008**

Not applicable for this submission.

## 11.4 ARTICLE 3.3

### 11.4.1 Information that demonstrates that activities began on or after 1 January 1990 and before 31 December 2012 and are directly human-induced

Under the current methodology, the Forestry Commission and the Forest Service of Northern Ireland provide annual data on new planting (on land that has not previously been forested). This information is provided for each country in the UK and the time series extends back before 1990. Data are provided by 'planting' year and then adjusted to calendar years as described in section 11.1.3. Information on new planting and restocking are published as separate figures for both state and private woodlands. New planting can use planting/seeding or natural colonisation. Data come from administrative systems (state forests) and grant schemes (other woodland) (Forestry Statistics 2009). Areas of planting that are not state-owned or grant-aided (i.e. whether these woodlands are explicitly managed is unknown) are not included in the GHGI or Article 3.3 AR.

Information on deforestation is assembled from felling licences for deforestation to other rural land uses and information on the conversion of forests to settlement land uses, both of which can thereby be shown to be directly human-induced. The time series of activity data is not sufficiently detailed to demonstrate the exact date of deforestation within a year at present.

### 11.4.2 Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation

The data sources used for estimating Deforestation do not allow for confusion between harvesting or forest disturbance and deforestation. The unconditional felling licences used for the estimation of rural deforestation are only given when no restocking will occur, and the survey of land converted to developed use describes the conversion of forest land to the settlement category, which precludes re-establishment. A new national forest inventory will be partially completed by the end of the commitment period and will be used to verify deforestation estimates made using these data sources.

### 11.4.3 Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforested

Restocking is assumed for forest areas that have lost forest cover through harvesting or forest disturbance, unless there is deforestation as described above. As such, information on the size and location of forest areas that have lost forest cover is not explicitly collected on an annual basis. The area of felled forest awaiting restocking was reported in the National Inventory of Woodland and Trees in the mid-late 1990s: this was 1.4% of the total forest area in England (15,100 ha), 1.8% in Scotland (22,979 ha) and 3.1% in Wales (8,961 ha) (Forestry Commission 2002). A comparable inventory was not available for Northern Ireland but in

2002 410 ha of Forest Service land was awaiting replanting (0.5% of the state forest area) (Forest Service 2002).

## 11.5 ARTICLE 3.4

### 11.5.1 Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human-induced

All managed forests (planted between 1921 and 1989) are included in Article 3.4 Forest Management. The C-Flow model is used to calculate emissions from this forest area after 1990 that have arisen from thinning, harvesting and restocking. The area under Forest Management is adjusted to reflect losses from deforestation, as recorded in section 11.1.3.

### 11.5.2 Information relating to Cropland Management, Grazing Land Management and Revegetation, if elected, for the base year

These activities were not elected by the United Kingdom.

### 11.5.3 Information relating to Forest Management

#### 11.5.3.1 That the definition of forest for this category conforms with the definition in item 11.1 above

Data used for estimating emissions from Forest Management is supplied by the Forestry Commission and complies with their definition of forest land, which is the one used for Article 3.3 and 3.4 activities (**Section 11.6.1**).

#### 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 2009, 1283 kha of woodland in the UK (45%) was certified under the FSC scheme (Forestry Statistics 2009). The management practices in certified woodlands are reviewed annually. All state-owned forests are certified and an increasing proportion of non-state-owned woodlands are becoming certified (23% in 2009). This does not include all woodland that is managed in a sustainable manner, such as smaller or non-timber producing woodlands where certification is not considered worthwhile. In particular, it may omit many broadleaved woodlands even though they are managed for their social and environmental benefits (Forestry Commission, 2002). In the UK's country report to the Global Forest Resource Assessment 2005 (FAO, 2005) 83% of UK forests are managed for production, 18% are managed for conservation of biodiversity (these have protected status) and 55% have a social service function (public access).

## 11.6    OTHER INFORMATION

### 11.6.1    Key category analysis for Article 3.3 activities and any elected activities under Article 3.4

Three categories are considered to be key: Article 3.3 Afforestation and Reforestation ($CO_2$), Article 3.3 Deforestation ($CO_2$) and Article 3.4 Forest Management ($CO_2$). These have been assessed according to the IPCC good practice guidance for LULUCF section 5.4.4. The numbers have been compared with Table A 1.1.5 Key category analysis for the latest reported year (2008) based on level of emissions (including LULUCF).

*Article 3.3 Afforestation and Reforestation ($CO_2$)*: The associated UNFCCC category 5A (-13,627 Gg $CO_2$e) is a key category although the AR component (forest planted since 1990) is not key on its own (i.e. its category contribution (-2,766 Gg $CO_2$e) is smaller than the smallest UNFCCC key category (1A Coal)). Removals from this category are also predicted to increase over time as a result of tree planting schemes partially focussed on climate change mitigation.

*Article 3.3 Deforestation ($CO_2$)*: The associated UNFCCC categories (5C and 5E) are key categories (-8,156 and 6,280 Gg $CO_2$e respectively). However, the Deforestation category contribution (615 Gg $CO_2$e) to these UNFCCC categories is smaller than the smallest UNFCCC key category (1A Coal). The data used in the calculation of deforestation emissions are the most uncertain of the data sources in the KP-LULUCF inventory and are a priority for improvement.

*Article 3.4 Forest Management ($CO_2$)*: The associated UNFCCC category 5A is a key category (-13,627 Gg $CO_2$e). The Forest Management category contribution (-10,698 Gg $CO_2$e) is also greater than other categories in the UNFCCC key category.

These categories are the priority for improvement in the KP-LULUCF inventory, and there is ongoing development (described in Chapter 7).

### 11.6.2    Information relating to Article 6

Not applicable in the United Kingdom.

# 12 Information on accounting of Kyoto units

## 12.1 BACKGROUND INFORMATION

The UK Greenhouse Gas Registry is operated and maintained by the Environment Agency on the behalf of DECC. A full description of the UK Registry system is presented in the UK's Initial Report under the Kyoto Protocol.[11] The standard electronic format tables are included in the submission for the second time. The SEF tables include information on the AAU, ERU, CER, t-CER, l-CER and RMU in the UK registry from 01.01.2009 to 31.12.2009 as well as information on transfers of the units in 2009 to and from other Parties of the Kyoto Protocol.

The UK's Standard Electronic Format report for 2009 containing the information required in paragraph 11 of the annex to decision 15/CMP.1 and adhering to the guidelines of the SEF has been submitted to the UNFCCC Secretariat electronically – SEF_GB_2010_2_18-8-40 27-4-2010.xls.

## 12.2 SUMMARY OF INFORMATION REPORTED IN THE SEF TABLES

At the end of 2009, there were 3,456,620,292 AAUs in the UK registry of which 2,956,145,800 were in the party holding account, 239,617,021 in the entity holding account, 2497 in other cancellation accounts and 260,854,974 in the retirement account. The registry also contained a total of 24,730,924 CERs and 762,472 ERUs.

In total for 2009, the UK Registry received 625,404,135 AAUs, 1,356,648 ERUs and 128,934,348 CERs. Conversely, 622,175,066 AAUs, 594,176 ERUs and 129,572,000 CERs were externally transferred to other national registries. Account holders voluntarily cancelled 2417 AAUs and 265,170 CERS. There were no transactions of any kind involving RMUs, tCERs or lCERs.

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

## 12.3 DISCREPANCIES AND NOTIFICATIONS

Information regarding discrepancies and notifications is summarised in **Table 12.1.**

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

**Table 12.1        Summary of discrepancies and notifications**

| Annual Submission Item | Reporting Guidance |
|---|---|
| 15/CMP.1 annex I.E paragraph 12:<br><br>List of discrepant transactions | The list of discrepant transactions is listed in the table named "R2" in the Excel file included with this submission with the name "SIAR Reports 2009-GB v1.0.xls".<br><br>The contents of the Report R2 can also be found in Annex 6 of this document. |
| 15/CMP.1 annex I.E paragraph 13 & 14:<br><br>List of CDM notifications | No CDM notifications occurred in 2009.<br><br>Refer to Separate Electronic Attachment "SIAR Reports 2009-GB v1.0.xls" Worksheet R3.<br><br>The contents of the Report R3 can also be found in Annex 6 of this document. |
| 15/CMP.1 annex I.E paragraph 15:<br><br>List of non-replacements | No non-replacements occurred in 2009.<br><br>Refer to Separate Electronic Attachment  "SIAR Reports 2009-GB v1.0.xls" Worksheet R4.<br><br>The contents of the Report R4 can also be found in Annex 6 of this document. |
| 15/CMP.1 annex I.E paragraph 16:<br><br>List of invalid units | No invalid units exist as at 31 December 2009.<br><br>Refer to Separate Electronic Attachment "SIAR Reports 2009-GB v1.0.xls" Worksheet R5.<br><br>The contents of the Report R5 can also be found in Annex 6 of this document. |
| 15/CMP.1 annex I.E paragraph 17<br><br>Actions and changes to address discrepancies | Actions and changes are addressed in Chapter 14: Information on Changes to National Register under section Previous Annual Review recommendations for the National Registry. |

## 12.4    PUBLICLY ACCESSIBLE INFORMATION

Information on legal entities authorised to participate in mechanisms under Articles 6, 12 and 17 of the Kyoto Protocol can be found on the Emissions registry website at http://emissionsregistry.environment-agency.gov.uk/ .    Further details are summarised in Table 12.2 below.

**Table 12.2        Details of publicly accessible information**

| Annual Submission Item | Reporting Guidance |
| --- | --- |
| 15/CMP.1 annex I.E<br><br>Publicly accessible information | The following information is now deemed publicly accessible and as such is available via the homepage of the UK registry – http://emissionsregistry.environment-agency.gov.uk/<br><br>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) and Account holders authorised to hold Kyoto units in their account (Paragraph 48)**<br>In light of the forthcoming amendments introduced by Article 78 of the revised Registries Regulation (due to come into force in August 2010) and for security reasons, it is considered that the representative identification information as required in paragraph 45 and paragraph 48 is held as confidential.<br><br>JI projects in UK (Paragraph 46)<br>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.<br><br>Paragraph 47 a/d/f - Holding and transaction information of units<br>Holding and transaction information is provided on a holding type level, due to more detailed information being declared confidential by EU Regulation.<br><br>Article 10 of EU Regulation 2216/2004/EC, provides that "All information, including the holdings of all accounts and all transactions made, held in the registries and the Community independent transaction log shall be considered confidential for any purpose other than the |

| Annual Submission Item | Reporting Guidance |
|---|---|
| | implementation of the requirements of this Regulation, Directive 2003/87/EC or national law." <br><br> Paragraph 47c <br> The United Kingdom is not hosting domestic JI projects as per paragraph 46 above. |
| | Paragraph 47e <br> The United Kingdom is currently not participating in any LULUCF projects for 2009. <br><br> Paragraph 47g <br> No ERUs, CERs, AAUs and RMUs have been cancelled on the basis of activities under Article 3, paragraphs 3 and 4 to date. <br><br> Paragraph 47h <br> 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. <br><br> Paragraph 47j <br> No ERUs, CERs, AAUs nor RMUs have been retired to date. <br><br> Paragraph 47k <br> There is no previous commitment period to carry ERUs, CERs, and AAUs over from. |

## 12.5    CALCULATION OF THE COMMITMENT PERIOD RESERVE (CPR)

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

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

Either
90% of the UK's assigned amount – see above
= 0.9 x 3,412,080,630 tonnes $CO_2$ equivalent
= 3,070,872,567 tonnes $CO_2$ equivalent.
or
100% of 5 x most recently reviewed inventory (2006, submitted in 2008)
= 5 x 655,786,725 tonnes $CO_2$ equivalent
= 3,278,933,627 tonnes $CO_2$ equivalent

The 2008 inventory submission has been taken as the most recently reviewed inventory, because there are still outstanding comments on the final report of the 2009 inventory submission review.  This calculation has been revised since the 2009 NIR submission to exclude emissions from LULUCF.

The lower of the two numbers is that calculated as 90 per cent of the UK's assigned amount. The UK's Commitment Period Reserve is therefore **3,070,872,567 tonnes of $CO_2$ equivalent (or assigned amount units)**.


## 12.6     KP-LULUCF ACCOUNTING


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

# 13 Information on changes in national system

## 13.1 CHANGES TO THE NATIONAL SYSTEM

DECC organised a workshop in September 2009 to remind all NISC members of their roles and responsibilities, to encourage them to actively participate in the NISC, and to remind them of the importance their input in the process of inventory review and approval. As part of this workshop, membership to the NISC was reviewed and some new groups were added to the committee.

New organisations or groups to the NISC include:
- DECC – National Climate change, Carbon Markets
- Defra – Air Quality and Industrial Pollution
- DECC – International Climate Change and Energy
- Defra – Water policy
- Defra – Waste
- DECC – Energy Analysis

# 14 Information on changes in national registry

## 14.1 CHANGES TO THE UK'S REGISTRY SYSTEM

Changes to the UK registry system are detailed in Table 14.1, below.

**Table 14.1        Changes to the UK's registry system**

| Reporting Item | |
|---|---|
| 15/CMP.1 annex II.E paragraph 32.(a)<br><br>Change of name or contact | Addition of contact details:<br><br>**Mr. Kevin Williams**<br><br>Environment Agency<br>Richard Fairclough House<br>Knutsford Road<br>Warrington<br>UK<br>WA4 1HG<br>Email: KevinJ.williams@environment-agency.gov.uk<br>Telephone: +44 1925 542517<br><br>Any previous contact details should be removed. |
| 15/CMP.1 annex II.E paragraph 32.(b)<br>Change of cooperation arrangement | No change of the cooperation arrangement itself occurred during the 2009 reporting period.<br><br>However the GRETA collective of Registries (of which UK is a licensee) changed IT supplier from Siemens Services and Solutions Ltd. to SFW Ltd. due to the end of a framework contract.<br><br>Development and support has been taken over by SFW Ltd. as of 9 February 2009. |
| 15/CMP.1 annex II.E paragraph 32.(c)<br>Change to database or the capacity of National Registry | The changes to UK's registry in 2009 cover changes to software as detailed below. |

| Reporting Item | |
|---|---|
| **Software Changes** | |

A general description of functional changes to the UK GRETA Registry in 2009 is as follows:

Version 4.0: This new release enabled Operators to surrender Certified Emission Reduction Units (CERs) and Emission Reduction Units (ERUs) and to set CER/ERU percentage surrender limits for individual installations within their operating zone, in line with EU and national policy.

Version 4.1: This new release enabled Registry Administrators and thus Member States, perform a new EUA Conversion and Retirement Process (as specified in the EU Registry Regulations) as part of their EU annual compliance requirements.

Version 4.2: This new release implemented a number of significant performance and reliability improvements to the internal and external transfer functions to allow an intense period of high-value contract settlements to be performed and to provide a lower burden of local and central support calls.

Each new release also includes a 'maintenance' element whereby high-priority legacy bugs are also resolved.

Thus, in 2009 two registry software version updates have been implemented, namely to GRETA Version 4.1 in June 2009 and Version 4.2 in October 2009. Please note that GRETA Version 4.1 included the changes made in Version 4.0:

Both upgrades (V4.1 and V4.2) have incorporated changes that increased the capacity of the Registry. The following capacity improving measures have been implemented compared to the previously used version.

Update from Version 3.0.84 to Version 4.1
Internal database procedures have been improved to increase resource efficiency.

Update from Version 4.1 to Version 4.2
A new windows service has been introduced to improve and simplify the logical design of the system. This service is designed to provide one single framework for the processing of incoming and outgoing messages, in time allowing to concentrate all logic concerning messaging in one part of the system. This creates a robust basis to start improving messaging reliability, efficiency and the capacity of the registry as a result.

Most checks on incoming messages are now performed asynchronously instead of synchronously, hereby considerably decreasing the time needed to create the synchronous response. This change has eliminated time-out errors in processing incoming messages.

The asynchronous processing of incoming messages is now performed in sequence as opposed to in parallel. These changes have increased the robustness of message processing and resource efficiency, hereby further increasing the capacity of the registry.

| Reporting Item | |
|---|---|
| The functionality allowing the initiation of transfers has been improved by using a smarter data integrity algorithm. This change increases robustness of the system when several users are trying to initiate transfers from the same account. This further increases the capacity of the registry for outgoing transfers.<br><br>Together with the above improvements to the registry system, automated load and performance testing was introduced for system testing. With this, it was possible to test more and to better performance test the system.<br><br>Testing has proven that the system is now able to process in and outgoing messages containing 2500 unit blocks without problems on mainstream hardware. Calculations have been made suggesting the system is able to process messages containing up to 9000 unit blocks. This limit is likely imposed by network delays external to the system.<br><br>Please consult the attached release notes (Annex 6) for details on the changes compared to GRETA Version 3.0.84 used in 2008. Please note that GRETA Version 4.1 included the changes made in Version 4.0:<br><br>- Release Notes version 4.0.16<br>- Release Notes version 4.1.16<br>- Release Notes version 4.2.21<br><br>The following test reports are also attached in Annex 6:<br>- Test Report Version 4.1<br>- Test Report Version 4.2 | |
| 15/CMP.1 annex II.E paragraph 32.(d)<br>Change of conformance to technical standards | No change in the registry's conformance to technical standards occurred for the 2009 reporting period. |
| 15/CMP.1 annex II.E paragraph 32.(e) Change of procedures | No changes were made to the procedures to prevent and/or resolve discrepancies during the 2009 reporting period. |
| 15/CMP.1 annex II.E paragraph 32.(f)<br>Change of Security | No change of security occurred during the reporting period |

## 14.2   CHANGES IN RESPONSE TO REVIEW RECOMMENDATIONS

The centralised review of the UK's GHG Inventory in September 2009 identified some recommendations for the national registry. A response to each recommendation is provided below in Table 14.2 and responses are also noted in Chapter 10 of this report.

**Table 14.2      Changes in response to review centralised review recommendations**

| UNFCCC centralised review recommendation | UK response and action |
|---|---|
| **(j) Further improve the measures in place in its national registry with a view to minimizing operator errors and ensuring reliable interoperability with other registry systems, including the ITL, in accordance with paragraph 115 of the annex to decision 22/CMP.1 and paragraph 25 of the annex to decision 24/CP.8 and with a view to reporting in its next annual submission on the changes made to the registry following the successful implementation and testing of those measures, including any relevant test plans and test reports** | A new windows service has been introduced to improve and simplify the logical design of the system. This service is designed to provide one single framework for the processing of incoming and outgoing messages, in time allowing to concentrate all logic concerning messaging in one part of the system. This creates a robust basis to start improving messaging reliability, efficiency and the capacity of the registry as a result.<br><br>The functionality allowing to initiate transfers has been improved by using a smarter data integrity algorithm. This change increases robustness of the system when several users are trying to initiate transfers from the same account.<br><br>Together with the above improvements to the registry system, automated load and performance testing was introduced for system testing. With this, it was possible to test more and to better performance test the system. |
| **(k) Take appropriate actions to reduce the number of out-of-sequence messages sent by its registry;** | The asynchronous processing of incoming messages is now performed in sequence as opposed to in parallel. These changes have increased the robustness of message processing and resource efficiency, hereby further increasing the capacity of the registry. |
| **(l) Enhance the user interface of the registry by providing the public information referred to in paragraphs 45, 46 and 48 of the annex to decision 13/CMP.1, and report, in its next annual submission, on any changes made to that public information.** | Version 4.3 of the UK registry will provide a new reporting service, which is currently under development. This service will make available a revised set of public reports to satisfy UN requirements. They are expected for release to the registry on 5 April 2010. |

# 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 provide parties with social, economic and sutainable development opportunities, but we acknowlegde that it also plays a role on the vulnerabilities. We need to ensure that transition to a low carbon economy supports sustainable development processes in all countries, but 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.

## 15.2 ACTIONS TO MINIMIZE 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, and how they could be addressed. We supported several capacity building projects via our Foreign and Commonwealth Office promoting energy efficiency and deployment of renewable energy. We are also engaging with five major economies (Brazil, South Africa, China, India and Mexico) in sustainable dialogues. These dialogues pull a number of different themes together, from agriculture to natural resource management; from sustainable consumption and production to environmental law enforcement; and from sustainable urban development to sustainable tourism. Many of the projects implemented under the Dialogues contribute to climate change mitigation and/or adaptation.

### 15.2.1 Research/Review/Analysis

DECC has commissioned "*An Assessment of the Literature on the Effects of Climate Change Mitigation Policies on Non-Annex 1 Countries*". This paper draws together the existing literature on the response measures of climate change mitigation policy action. It focuses on the impact that climate change mitigation policies have on:

- Fossil fuel importing economies
- Tourism reliant economies
- Economies reliant on food exports

*The Gallagher Review* was set up to look into concerns around the sustainability of biofuels. It concluded that increases in GHGs could not be ruled out unless effects arising from indirect land use change are taken into account. The report also concluded that biofuels expansion was likely to have had a modest upward impact on food prices.  As a result, the UK Government is taking a more cautious stance towards biofuels targets and has legislated to slow the increase in biofuels to allow more time to make sure that sustainability issues are addressed.

Within the EU – The UK negotiated hard to get binding sustainability criteria included as part of the Renewable Energy Directive. The list of agreed criteria does not include the indirect effects of biofuel production. The UK was instrumental in getting a specific requirement into the Directive for the Commission to submit a report and (if appropriate) proposals to the European Parliament and the Council on impacts of indirect land use change on greenhouse gas emissions by December 2010 (Article 19(6)).

In the UK - The rate of increase in the UK's Renewable Transport Fuel Obligation has been slowed, taking the level to 5% by volume by 2013/14, instead of by 2010/11, as originally required. This was enacted through the Renewable Transport Fuel Obligations.

*Food Miles:* There is a danger that steps taken by consumers in the UK to reduce their contribution to carbon emissions may lead them to avoid buying produce from developing countries in the mistaken belief that air-freighted food and flowers necessarily have a higher carbon footprint. We believe that consumers need accurate information about the way products have been grown as well as transported.

Current evidence suggests that environmental labelling in itself actually has limited impact on consumer choice at present, partly because of the complex factors behind choice and behaviour and because labels may run the risk of confusing rather than helping consumers. However the Government agreed this needs to be explored in more detail and the Department for Environment Food and Rural Affairs have just commissioned a research project to look at the practicality and effectiveness of environmental labelling of food as a mechanism to promote behavioural change in order to reduce the negative environmental impacts of food production and consumption. The study will also compare the pros and cons of different labelling formats, including omni-labels, and will investigate the potential burden, particularly costs, that introducing such a label would have on industry,  including food producers and exporters.
The Department for International Development (DFID) has also commissioned the following studies:

- Implications for developing countries of an increasingly carbon-constrained global economy (*Growth in a Carbon Constrained Global Economy*, work still underway by the Overseas Development Institute). Objective: understand how mitigation measures undertaken by A1 (and developing) countries would affect the growth prospects for

developing countries. Focus is on both opportunities and risks. The study (still underway) has been exploring the likely impact of the following developed country policy measures on developing countries through a number of scenarios:

- Carbon taxes
- Emission trading schemes
- Border tax adjustments
- CMD & its reform
- REDD+
- Liberalisation of trade in environmental goods & services
- Carbon labelling
- Technology transfer mechanisms

Key messages are that

- the impact of an increasingly carbon-constrained global economy will differ by country (whether net oil exporter or importer, current carbon intensity of production, etc);
- middle income countries and low income countries do not always have the same interests;
- each of the A1 policy measures will offer some countries opportunities as well as pose risks. How developing countries choose respond will therefore be important.

- Concept paper at request of Government of South Africa on Developing South Africa's Economic Policies for a Low Carbon World (work undertaken by AccountAbility). Objective: a short report to provide a framework for understanding the industrial policy implications for RSA of the emerging global transition to a low-carbon economy and to pilot this in a couple of industrial sectors. Findings:
    - RSA (given its industrial policy objective of diversifying its industrial base):
        - Diversifying the energy mix could enable opportunities to develop new energy & industrial value chains
        - By demonstrating responsiveness to the climate agenda it could create opportunities for export industries to strengthen their export competitiveness
    - Climate change and low carbon competition (inaction) pose economic & broader threats to South Africa
        - Direct climate impacts
        - Trade barriers, in form of carbon border tariffs and the commercial application of private standards
        - Investment constraints if investors are nervous of countries that are failing to respond to climate challenges
    - The balance of risks and opportunities vary between sectors

- The study then sets out elements of an economic strategy for South Africa and proposes a South African Renewables Initiative.

## 15.2.2 Examples of projects from the Sustainable Development Dialogues

- In Mexico City: public transport more sustainable through contributing to work on the development of a "zero emissions corridor".
- In Brazil we funded a Brazilian NGO (IPAM – Amazon Environmental Research Institute) to assist in the development of state plans to reduce deforestation.
- India: Two 2-day conferences: *Building a Sustainable Energy Future for India: Scaling Up Local Sustainable Energy Models*.

## 15.2.3 Capacity Building projects on Renewables & Energy Efficiency

In addition to the capacity building projects undertaken in the Kingdom of Saudi Arabia, already mentioned in Chapter 1 of this report, the UK Foreign and Commonwealth Office (FCO) funded the following projects in South Africa, India and Kazakhstan:

*SOUTH AFRICA: Clean Energy in the Western Cape – In progress*

Objective: to institutionalise and gazette a comprehensive sustainable energy policy for the Western Cape Province.

Key Outputs:
- The White Paper is in its final stages of development and when adopted it will establish a provincial team/council to set policy and practices and encourage the uptake of renewable energy by municipalities.
- The project has already resulted in the development of an energy strategy by Gauteng and Eastern Cape Provinces.
- A key outcome, underlining buy-in from the municipality is their recruitment of an Advisor on energy policy development to steer the White Paper, and subsequently follow it through until the Act is adopted.

*INDIA: Standardised Baselines for Renewable Energy Clean Development Mechanism Projects*

This project has developed "ready to use" standardised baselines for each of the 5 regional power grids in India. The availability of these baselines assists the small scale renewable energy projects by reducing the transaction costs of developing CDM projects for all grid-connected projects

*KAZAKHSTAN: creation of a unified set of energy efficiency, renewables and alternative (nuclear) energy policies that will accelerate Kazakhstan's progress towards a high growth, low-carbon economy.*

Project implementer has become involved in developing the key pieces of legislation intended to underpin Kazakhstan's journey towards becoming a low carbon economy.

Specifically:

- Involved in consultation with EBRD and consultants (MVV Decon / Kolumbus) engaged in drafting/critiquing Law on Energy Efficiency
- Part of official Kazakhstan delegation to UNFCCC meeting in Bonn during August
- Supporting Ministry of Environment Protection with Kyoto Protocol implementation steps, specifically around Workstream 3 – Commercial Implications
- Engaged in developing capabilities in GHG foot printing using accredited international methodologies and coefficients adapted for local conditions
- Supported the preparation of the English language version of the 2nd National Communication to UNFCCC

## 15.2.4    Other UK Initiatives

*Trading*: The UK is still strongly committed to provide Aid for Trade to developing countries, and especially the poorest amongst them, to help build their capacity to trade, integrate into global markets while also addressing any adjustment costs that might arise from more liberalisation, within the context of sustainable development. The UK is stepping up support and will provide £1 billion per year over the next three years towards trade and growth.

*UK's Position on CAP Reform and Development:* At the EU level, the 2003 reform of the Common Agricultural Policy (CAP) established some important principles, including the decoupling of farm subsidy from production and a stronger focus on delivering environmental benefits.

The UK wants reforms of the CAP to go further since we believe that the CAP has exacerbated the problems posed by food security issues, by distorting markets and undermining the ability of other countries, including developing countries to produce and trade agricultural goods.

The UK is therefore committed to the Doha Development Agenda of trade talks (DDA) as it has the potential to significantly reduce trade distorting domestic support globally and to eliminate all export subsidies by 2013.  Both of these outcomes are consistent with the UK's Vision for CAP Reform which will ultimately foster an internationally competitive industry without reliance on subsidy or protection and one which is non-distorting of international trade and the world economy. Net welfare benefits to developing countries from CAP reform alone are estimated to range between $US 24 - 43 billion annually. The World Bank estimate that liberalisation would result in increased growth in farm output in most of the world (annual output growth of around 5-6% in SSA 2005-15) while marginally declining in the EU and Japan.

## 15.2.5 Within the EU Communities

Many of our diversified response measure are addressed in the EC 5th national communications. They include emission trading (EU ETS) and action to encourage CCS.

*EU ETS*

The EU ETS - Through the ETS and the linking directive that allows European facilities to engage in the CDM as a way of meeting their commitments, the EU has increased investments in renewable energy and energy efficiency in developing countries making an important contribution to diversifying the energy mix in those countries.

*Integration of the aviation sector in the EU ETS*

A study was conducted by consultants to analyse the impact of this policy on different actors in this sector. This study showed, inter alia, that the policy itself could have a far lesser impact on the transport of perishables than other factors, like the increase in market prices for oil.

*Clean coal technologies (including CCS)*

The EU's "Seventh Framework Programme" is composed of a number of areas, including "cooperation and inviting developing countries to participate in EU-funded programmes". Cooperation areas include the development and demonstration of clean coal technologies, including carbon capture and storage. The European Community has already allocated 7 million Euros for the investigation of CCS demonstration in China and is working on the financing of the additional cost of the project which may amount to 300 million Euros. Also proposed for the 2009 budget to allocate 70 million Euros for the Global Climate Change Alliance and clean carbon technology transfer including CCS.

*Diversification of economic activities*

Capacity building is essential to support the diversification of economic activities and reduce over-reliance on vulnerable sectors. Several EU member states are involved in supporting energy sector reforms in developing countries, especially with a view to increasing energy security and diversify the energy resources.

*Renewable energy/ biofuels*

EU drafted the proposal on the promotion of renewable energy sources. Concerns were raised about the possible impact of biofuels development on food prices. In this context, this proposal is laying down a set of sustainability criteria for biofuels and other bioliquids, including GHG performance, biodiversity, and high carbon stock areas. The sustainability criteria should take into account the negative spill over effects generated by certain types of biofuels.

# 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.

## 17.1 CHAPTER 1 [INTRODUCTION]

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# 18    Acknowledgements

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**Table 18.1          Contributors to this National Inventory Report and the CRF**

| Person | Technical work area and responsibility |
|---|---|
| *Main authors* | |
| Brophy, Nicola | Author of Annex 8 and Annex 9 |
| Choudrie, Sarah | Project Manager for the UK Greenhouse Gas Inventory with overall responsibility for the NIR and the CRF[12].  Contributions to most chapters, co-author of energy sector text, author of Chapter 1, Annex 4 and 5. |
| Cardenas, Laura | Sector expert for agriculture; author of all sections on agriculture. Compilation of Sector 4 of the CRF. |
| MacCarthy, Joanna | Manager of NIR and CRF submission, co-author of Chapter 10, F-gases sector expert, lead author of Annex 7, Final Users expert, manager of Overseas Territories and Crown Dependencies inventory compilation. |
| Mobbs, Deena | Co-author of all sections on Land Use Change and Forestry; compilation of Sector 5 of the CRF. |
| Murrells, Tim | NAEI transport manager.  Contributing author to all sections on transport. |
| Passant, Neil | Author of selected sections on energy and industry; contributions to most chapters. Developments to the methods used to estimate GHG emissions from the non-energy use of fuels and stored carbon.  Author of Annex 11. |
| Thistlethwaite, Glen | Compilation of emission estimates, in particular the offshore sector and cement.  Main author of chapters and annexes for 1B |
| Thomas, Jenny | Sector expert for Source Category 6a – Solid Waste Disposal On Land; responsible for the CRF and report for this source category.  Author of Chapter 2.  Report co-ordinator. |
| Thomson, Amanda | Co-author of all sections on Land Use Change and Forestry.  Compilation of Sector 5 of the CRF. |
| Watterson, John | Co-author of Uncertainties Chapter and Key Category Analysis.  Author of Waste water treatment sections.  Development of the inventory. |
| *Contributors* | |
| Brown, Keith | Contributions to landfill sections of report and the development of the MELmod model |
| Dagnet, Yamide[13] | Author of Chapter 15 |
| Gilhespy, Sarah [14] | Contributions to agriculture inventory compilation and text |
| Gillam, Simon[15] | Contributions to the LULUCF sections |
| Li, Yvonne | Approach 1 (error propagation) uncertainty analysis.  Responsible for road transport data compilation. |
| Manning, Alistair | Verification of the UK greenhouse gas inventory. |
| Matthews, Robert[16] | Contributions to LULUCF sections |

| Person | Technical work area and responsibility |
|---|---|
| Misselbrook, Tom | Contributions to agriculture inventory compilation and text |
| Pierce, Martin | Development of off road machinery emissions estimate |
| Sneddon, Stuart | Compilation of rail emissions estimates and text for this sector |
| Wagner, Anne | Assistance with QC of the time series consistency. |
| Walker, Charles | Sector expert for aviation in the NAEI. |
| *Additional assistance* | |
| Aston, Clare | Data acquisition |
| Champion, Helen[17] | Suggestions and improvements to draft versions of the NIR |
| Mackintosh, John[18] | Suggestions and improvements to draft versions of the NIR |

**Table 18.2      Key Data Providers to the Greenhouse Gas Inventory**

| Company |
|---|
| UKPIA |
| UKOOA |
| Environment Agency |
| DECC |
| Defra |
| PowerTech |
| British Cement Association |
| UK Gas Distribution Networks |
| Corus |
| DfT |
| NIDoE |
| SEPA |

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