Annexes

Table of Tables:

ANNEX 1: Key Categories

This annex contains the key category analysis for the latest GHG inventory[1]. It contains:

- A description of the methodology used for identifying key categories
- Information on the level of disaggregation
- Information to fulfil the reporting requirements of Tables 4.2 and 4.3 of Volume 1 of the 2006 IPCC Guidelines, including and excluding land use, land-use change and forestry (LULUCF).

The annex also contains information relevant to the requirements of reporting under the Kyoto Protocol. The table below contains the additional KP information that Annex 1 needs to contain, and the locations of this information in the Annex[2].

Requirements	**Locations of the relevant information in this Annex**
Description of methodology used for identifying key categories, *including KP-LULUCF*	See sections immediately below including "*General approach used to identify Key Categories*" and "*Approach used to identify KP-LULUCF Key Categories*".
Reference to the key category tables in the CRF	This Annex of the NIR presents detailed tables of information of the data derived from the key category analysis. These data are used to create the key category tables (Table 7) in the CRF.
Reference to the key category tables in the CRF, *including in the KP-LULUCF CRF tables*	This Annex of the NIR presents detailed tables of information of the data derived from the key category analysis. These data are used to create the key category KP-LULUCF tables (Table NIR 3) in the CRF.
Information on the level of disaggregation	The tables in this Annex contain information on the level of disaggregation used. The level of disaggregation follows IPCC 2006 Guidelines.
Tables 4.2 to 4.4 of Volume 4 the 2006 IPCC guidelines	The data requested in the 2006 Guidelines tables, including and excluding LULUCF, are provided in **Table A 1.3.1** to **Table A 1.4.6** and **Table 1.7** to **Table 1.10**.
Table NIR.3, as contained in the annex to decision 6/CMP.3	A facsimile of Table NIR 3, provided in the CRF, is given in **Table A 1.7.1**.

A 1.1 GENERAL APPROACH USED TO IDENTIFY KEY CATEGORIES

In the UK inventory, certain source categories are particularly significant in terms of their contribution to the overall uncertainty of the inventory. These key source categories have been identified so that

[1] Following the requirements to report information about uncertainties as set out in FCCC/CP/2013/10/Add.3. Report of the Conference of the Parties on its nineteenth session, held in Warsaw from 11 to 23 November 2013. Addendum Part two: Action taken by the Conference of the Parties at its nineteenth session.

[2] The information in this table has been taken directly from the UNFCCC document "Annotated outline of the National Inventory Report including reporting elements under the Kyoto Protocol".

the resources available for inventory preparation may be prioritised, and the best possible estimates prepared for the most significant source categories.

The UK completes both quantitative and qualitative Key Category Analyses (KCAs).

The UK has used the method set out in Section 4.3.1 and Section 4.3.2 of the 2006 IPCC Guidelines Volume 1 General Guidance and Reporting (*Approach 1 to identify key categories,* and *Approach 2 to identify key categories* respectively) to quantitatively determine the key source categories.

The method used in the qualitative KCA is described below, and further descriptions of the methods the UK uses to quantitatively determine key categories are given later in this section.

A 1.2 QUALITATIVE ANALYSIS USED TO IDENTIFY KEY CATEGORIES

Following IPCC good practice, a qualitative analysis of the inventory has been made to identify any additional key source categories, which may not have been identified using the quantitative analysis. The approach set out in Section 4.3.3 of the IPCC 2006 Guidelines has been applied, using the four criteria set out in the guidance, to judge whether a category is a key category. The criteria are:

1. (Use of) mitigation techniques and technologies;
2. Emissions growth (increase or decrease);
3. No quantitative assessment of uncertainties performed;
4. Completeness (examine qualitatively potential key categories that are not yet estimated quantitatively by applying the qualitative considerations above).

In addition, additional criteria have also been taken in account

5. High uncertainty (links to point 3 above);
6. Unexpectedly low or high emissions;
7. External recommendation has also been used as an additional criterion to identify key categories.

The results of the qualitative analysis did not identify any categories that were not already identified by the quantitative key category analysis.

A 1.3 QUANTITATIVE APPROACH 1 KCA FOLLOWING IPCC 2006 GUIDELINES

A key category analysis has been completed for both level and trend. This KCA has been created using the 2006 IPCC Guidelines Approach 1 methodology. The factors that make a source a key category are:

- A high contribution to the level of emissions; and
- A high contribution to the trend;

For example, transport fuel (1A3b) is a key category for carbon dioxide because it is a large source of emissions and nitric acid production (2B2) because it shows a significant trend.

The category groupings are largely aligned to those suggested in Tables 4.5 and 4.6 in Volume 1, Chapter 4 of the 2006 IPCC guidelines, although we deviate in a number of cases, in particular:

- Agriculture and LULUCF. In the 2006 guidelines a different nomenclature for categorising agriculture and LULUCF sources and sinks was used compared to the adopted nomenclature, which means that it would be challenging and confusing to retain this categorisation when sources are grouped differently in the adopted nomenclature. The agriculture categories are analysed at the level of mostly 3 digit IPCC codes, whilst analysis for LULUCF sources and sinks is more aggregated. The UK inventory agency considers that the level of aggregation used in the UK method for the KCA is sufficiently detailed to target inventory improvements (e.g. consideration of the more important livestock types under agriculture) whilst not introducing unnecessary computational difficulties (e.g. use of "miscellaneous" categories to mop up the remainder within a sector). Further, the level of source/sink category aggregations in the KCA are aligned to how individual methods or models are used to derive the UK inventory estimates, and are therefore at an appropriate level of detail for the UK inventory

- Fugitive Emissions. The suggested categories are at a much more granular level (e.g. 1B2aii) than other sectors. We considered that this would lead to an undue diminishing of these sectors, decreasing their likelihood of being considered key, so have adopted a level of aggregation more consistent with other sectors
- Miscellaneous emissions. The suggested approach was to group a large number of small sources into one category. We considered that this would lead to an undue increase in the significance of these sources, increasing their likelihood of being considered key, so have adopted a level of aggregation more consistent with other sectors

The results of the key category analysis with and without LULUCF, for the base year and the latest reported year and for both Approaches 1 and 2 KCA, are summarised by sector and gas in **Section 1.5.1**. The tables indicate whether a key category arises from the level (L1) assessment or the trend (T1) assessment.

The results of the **level assessment** (based on Approach 1) with and without LULUCF for the base year and the latest reported year are shown **Table A 1.3.1** to **Table A 1.3.4.** The key source categories are highlighted by the shaded cells in the table. The source categories (i.e. rows of the table) were sorted in descending order of magnitude based on the results of the "Level Parameter", and then the cumulative total was included in the final column of the table. The key source categories are those whose contributions add up to 95% of the sum of the level parameters in the final column after this sorting process, which according to the 2006 IPCC guidelines, should account for 90% of the uncertainty in level.

The results of the **trend assessment** (based on Approach 1) with and without LULUCF for the base year to the latest reported year are shown in **Table A 1.3.5** and **Table A 1.3.6.** The key source categories are highlighted by the shaded cells in the table. The trend parameter was calculated using the absolute value of the result; an absolute function is used since Land Use, Land Use Change and Forestry contains negative sources (sinks) and the absolute function is necessary to produce positive uncertainty contributions for these sinks. The source categories (i.e. rows of the table) were sorted in descending order of the "Trend parameter", and then the cumulative total was included in the final column of the table. The key source categories are those whose contributions add up to 95% of the sum of the trend parameters in the final column after this sorting process, which according to the 2006 IPCC guidelines, should account for 90% of the uncertainty in trend.

Note that the tables in chapter 1 of the NIR summarise the key categories from both the approach 1 and approach 2 key categories analyses and the aggregations used are slightly different for the two approaches. The category "3A" is therefore total emissions from category 3A, whilst categories 3A1 and 3A2 have also been identified as key categories in their own right. Category "2B Chemical industries - CO2" is total CO_2 emissions from category 2B.

Table A 1.3.1 Approach 1 Key Category Analysis for the base year based on level of emissions (including LULUCF)

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A1	Energy industries: solid fuels	CO_2	185,492.23	185,492.23	0.2169	0.2169
1A3b	Road transportation: liquid fuels	CO_2	108,568.67	108,568.67	0.1270	0.3439
1A4	Other sectors: gaseous fuels	CO_2	70,373.19	70,373.19	0.0823	0.4262
5A	Solid waste disposal	CH_4	60,432.98	60,432.98	0.0707	0.4969
1A1	Energy industries: liquid fuels	CO_2	40,865.08	40,865.08	0.0478	0.5447
1A2	Manufacturing industries and construction: solid fuels	CO_2	38,484.26	38,484.26	0.0450	0.5897
1A2	Manufacturing industries and construction: liquid fuels	CO_2	29,831.66	29,831.66	0.0349	0.6246
1A2	Manufacturing industries and construction: gaseous fuels	CO_2	27,334.85	27,334.85	0.0320	0.6566
1B1	Coal mining and handling	CH_4	21,826.68	21,826.68	0.0255	0.6821
3A1	Enteric fermentation from Cattle	CH_4	20,572.07	20,572.07	0.0241	0.7061
2B3	Adipic acid production	N_2O	19,934.61	19,934.61	0.0233	0.7295
1A4	Other sectors: solid fuels	CO_2	19,868.96	19,868.96	0.0232	0.7527
1A4	Other sectors: liquid fuels	CO_2	19,364.29	19,364.29	0.0226	0.7753
2B9	Fluorochemical production	HFCs PFCs SF_6 and NF_3	17,793.94	17,793.94	0.0208	0.7961
4A	Forest land	CO_2	-17,445.77	17,445.77	0.0204	0.8166
4B	Cropland	CO_2	15,023.23	15,023.23	0.0176	0.8341
3D	Agricultural soils	N_2O	13,762.28	13,762.28	0.0161	0.8502
1B2	Oil and gas extraction	CH_4	12,345.03	12,345.03	0.0144	0.8647
1A1	Energy industries: gaseous fuels	CO_2	9,236.91	9,236.91	0.0108	0.8755
4C	Grassland	CO_2	-7,756.55	7,756.55	0.0091	0.8845
1A3d	Domestic Navigation: liquid fuels	CO_2	7,611.13	7,611.13	0.0089	0.8934
2A1	Cement production	CO_2	7,295.26	7,295.26	0.0085	0.9020
4E	Settlements	CO_2	6,901.20	6,901.20	0.0081	0.9100
1B2	Oil and gas extraction	CO_2	5,777.92	5,777.92	0.0068	0.9168
2C1	Iron and steel production	CO_2	5,591.54	5,591.54	0.0065	0.9233
1A5	Other: liquid fuels	CO_2	5,293.44	5,293.44	0.0062	0.9295
3A2	Enteric fermentation from Sheep	CH_4	5,102.88	5,102.88	0.0060	0.9355

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
2B8	Petrochemical and carbon black production	CO_2	4,536.66	4,536.66	0.0053	0.9408
5D	Wastewater treatment and discharge	CH_4	4,219.05	4,219.05	0.0049	0.9457
2B2	Nitric acid production	N_2O	3,860.26	3,860.26	0.0045	0.9502
3B1	Manure management from Cattle	CH_4	3,544.12	3,544.12	0.0041	0.9544
3B1	Manure management from Cattle	N_2O	2,473.92	2,473.92	0.0029	0.9573
2B1	Ammonia production	CO_2	1,895.00	1,895.00	0.0022	0.9595
1A3a	Domestic aviation: liquid fuels	CO_2	1,837.04	1,837.04	0.0021	0.9616
1B1	Coal mining and handling solid fuels	CO_2	1,698.56	1,698.56	0.0020	0.9636
4G	Harvested wood products	CO_2	-1,614.71	1,614.71	0.0019	0.9655
2A2	Lime production	CO_2	1,462.05	1,462.05	0.0017	0.9672
1A3c	Railways: liquid fuels	CO_2	1,455.18	1,455.18	0.0017	0.9689
5C	Incineration and open burning of waste	CO_2	1,363.29	1,363.29	0.0016	0.9705
2C6	Zinc production	CO_2	1,358.83	1,358.83	0.0016	0.9721
1A3b	Road transportation: liquid fuels	N_2O	1,312.32	1,312.32	0.0015	0.9737
1A4	Other sectors: solid fuels	CH_4	1,264.97	1,264.97	0.0015	0.9751
1A3b	Road transportation: liquid fuels	CH_4	1,246.71	1,246.71	0.0015	0.9766
3B3	Manure management from Swine	CH_4	1,091.12	1,091.12	0.0013	0.9779
1A1	Energy industries: solid fuels	N_2O	1,023.18	1,023.18	0.0012	0.9791
4B	Cropland	N_2O	1,019.85	1,019.85	0.0012	0.9803
3G	Liming	CO_2	1,015.18	1,015.18	0.0012	0.9814
1A2	Manufacturing industries and construction: liquid fuels	N_2O	912.10	912.10	0.0011	0.9825
5D	Wastewater treatment and discharge	N_2O	783.59	783.59	0.0009	0.9834
2G1	Electrical equipment	HFCs PFCs SF_6 and NF_3	747.79	747.79	0.0009	0.9843
2F4	Aerosols	HFCs PFCs SF_6 and NF_3	663.00	663.00	0.0008	0.9851
2A4	Other process uses of carbonates	CO_2	640.93	640.93	0.0007	0.9858

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A4	Other sectors: liquid fuels	N_2O	607.11	607.11	0.0007	0.9865
4E	Settlements	N_2O	584.71	584.71	0.0007	0.9872
2D	Non-energy products from fuels and solvent use	CO_2	553.12	553.12	0.0006	0.9879
2G3	N_2O from product uses	N_2O	552.57	552.57	0.0006	0.9885
3B3	Manure management from Swine	N_2O	535.72	535.72	0.0006	0.9891
2F1	Refrigeration and air conditioning	HFCs PFCs SF_6 and NF_3	531.19	531.19	0.0006	0.9898
1A4	Other sectors: peat	CO_2	488.50	488.50	0.0006	0.9903
4D	Wetlands	CO_2	486.95	486.95	0.0006	0.9909
3B4	Manure management from Other livestock	N_2O	465.12	465.12	0.0005	0.9914
2C3	Aluminium production	CO_2	450.32	450.32	0.0005	0.9920
2A3	Glass production	CO_2	405.54	405.54	0.0005	0.9924
4	Indirect N_2O emissions from LULUCF	N_2O	401.41	401.41	0.0005	0.9929
2C4	Magnesium production	HFCs PFCs SF_6 and NF_3	387.17	387.17	0.0005	0.9934
2C3	Aluminium production	HFCs PFCs SF_6 and NF_3	333.43	333.43	0.0004	0.9938
3H	Urea application to land	CO_2	327.53	327.53	0.0004	0.9941
3A4	Enteric fermentation from Other livestock	CH_4	294.61	294.61	0.0003	0.9945
3A3	Enteric fermentation from Swine	CH_4	283.28	283.28	0.0003	0.9948
2G2	SF_6 and PFCs from other product use	HFCs PFCs SF_6 and NF_3	278.70	278.70	0.0003	0.9951
1A4	Other sectors: solid fuels	N_2O	241.66	241.66	0.0003	0.9954
2B7	Soda ash production	CO_2	231.55	231.55	0.0003	0.9957
4A	Forest land	N_2O	230.75	230.75	0.0003	0.9960
1A1	Energy industries: other fuels	CO_2	228.01	228.01	0.0003	0.9962
1A3e	Other transportation: liquid fuels	CO_2	224.74	224.74	0.0003	0.9965

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A1	Energy industries: gaseous fuels	N_2O	198.91	198.91	0.0002	0.9967
3F	Field burning of agricultural residues	CH_4	186.57	186.57	0.0002	0.9969
2B10	Other Chemical Industry	CH_4	185.65	185.65	0.0002	0.9972
2F2	Foam blowing agents	HFCs PFCs SF_6 and NF_3	184.42	184.42	0.0002	0.9974
1A4	Other sectors: gaseous fuels	CH_4	157.18	157.18	0.0002	0.9976
1A2	Manufacturing industries and construction: solid fuels	N_2O	147.70	147.70	0.0002	0.9977
1A1	Energy industries: liquid fuels	N_2O	139.85	139.85	0.0002	0.9979
5C	Incineration and open burning of waste	CH_4	137.63	137.63	0.0002	0.9981
3B2	Manure management from Sheep	CH_4	134.31	134.31	0.0002	0.9982
3B4	Manure management from Other livestock	CH_4	110.89	110.89	0.0001	0.9983
2B6	Titanium dioxide production	CO_2	104.63	104.63	0.0001	0.9985
1A3d	Domestic Navigation: liquid fuels	N_2O	103.71	103.71	0.0001	0.9986
1A1	Energy industries: gaseous fuels	CH_4	92.30	92.30	0.0001	0.9987
1A4	Other sectors: biomass	CH_4	81.01	81.01	0.0001	0.9988
1A2	Manufacturing industries and construction: other fuels	CO_2	76.94	76.94	0.0001	0.9989
3F	Field burning of agricultural residues	N_2O	57.66	57.66	0.0001	0.9990
1A4	Other sectors: liquid fuels	CH_4	57.49	57.49	0.0001	0.9990
1A5	Other: liquid fuels	N_2O	56.12	56.12	0.0001	0.9991
1A1	Energy industries: solid fuels	CH_4	49.29	49.29	0.0001	0.9991
5C	Incineration and open burning of waste	N_2O	47.47	47.47	0.0001	0.9992
1A2	Manufacturing industries and construction: solid fuels	CH_4	47.37	47.37	0.0001	0.9993
1A2	Manufacturing industries and construction: liquid fuels	CH_4	44.28	44.28	0.0001	0.9993
3B2	Manure management from Sheep	N_2O	43.39	43.39	0.0001	0.9994
1A1	Energy industries: liquid fuels	CH_4	43.12	43.12	0.0001	0.9994
2G4	Other product manufacture and use	N_2O	41.00	41.00	0.0000	0.9995
1B2	Oil and gas extraction	N_2O	40.75	40.75	0.0000	0.9995

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A4	Other sectors: gaseous fuels	N_2O	37.47	37.47	0.0000	0.9995
2C1	Iron and steel production	CH_4	36.89	36.89	0.0000	0.9996
1A4	Other sectors: peat	CH_4	34.56	34.56	0.0000	0.9996
2A4	Other process uses of carbonates	CH_4	31.11	31.11	0.0000	0.9997
1A3e	Other transportation: liquid fuels	N_2O	27.86	27.86	0.0000	0.9997
2B8	Petrochemical and carbon black production	CH_4	27.83	27.83	0.0000	0.9997
2F6	Other product uses as substitutes for ODS	HFCs PFCs SF_6 and NF_3	27.61	27.61	0.0000	0.9998
2C1	Iron and steel production	N_2O	17.74	17.74	0.0000	0.9998
1A3a	Domestic aviation: liquid fuels	N_2O	17.39	17.39	0.0000	0.9998
1A2	Manufacturing industries and construction: biomass	N_2O	15.84	15.84	0.0000	0.9998
1A2	Manufacturing industries and construction: gaseous fuels	N_2O	14.54	14.54	0.0000	0.9998
1A3c	Railways: liquid fuels	N_2O	13.75	13.75	0.0000	0.9999
1A1	Energy industries: other fuels	CH_4	13.47	13.47	0.0000	0.9999
1A2	Manufacturing industries and construction: gaseous fuels	CH_4	12.20	12.20	0.0000	0.9999
1A4	Other sectors: biomass	N_2O	12.10	12.10	0.0000	0.9999
4C	Grassland	N_2O	10.36	10.36	0.0000	0.9999
4C	Grassland	CH_4	10.00	10.00	0.0000	0.9999
1A2	Manufacturing industries and construction: biomass	CH_4	9.97	9.97	0.0000	0.9999
2E1	Integrated circuit or semiconductor	HFCs PFCs SF_6 and NF_3	9.56	9.56	0.0000	0.9999
1A1	Energy industries: other fuels	N_2O	5.91	5.91	0.0000	1.0000
5B	Biological treatment of solid waste	CH_4	5.48	5.48	0.0000	1.0000
4D	Wetlands	N_2O	4.13	4.13	0.0000	1.0000
1A3a	Domestic aviation: liquid fuels	CH_4	4.13	4.13	0.0000	1.0000
5B	Biological treatment of solid waste	N_2O	3.92	3.92	0.0000	1.0000
1A3d	Domestic Navigation: liquid fuels	CH_4	3.66	3.66	0.0000	1.0000
1A5	Other: liquid fuels	CH_4	3.56	3.56	0.0000	1.0000

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
4E	Settlements	CH_4	3.05	3.05	0.0000	1.0000
4A	Forest land	CH_4	2.92	2.92	0.0000	1.0000
1A3c	Railways: liquid fuels	CH_4	2.46	2.46	0.0000	1.0000
2B8	Petrochemical and carbon black production	N_2O	2.10	2.10	0.0000	1.0000
1A4	Other sectors: peat	N_2O	1.92	1.92	0.0000	1.0000
2F3	Fire protection	HFCs PFCs SF_6 and NF_3	1.41	1.41	0.0000	1.0000
1A1	Energy industries: biomass	CH_4	0.47	0.47	0.0000	1.0000
1A2	Manufacturing industries and construction: other fuels	N_2O	0.38	0.38	0.0000	1.0000
2B1	Ammonia production	N_2O	0.31	0.31	0.0000	1.0000
1A3e	Other transportation: liquid fuels	CH_4	0.29	0.29	0.0000	1.0000
2B1	Ammonia production	CH_4	0.26	0.26	0.0000	1.0000
1A1	Energy industries: biomass	N_2O	0.25	0.25	0.0000	1.0000
1A2	Manufacturing industries and construction: other fuels	CH_4	0.16	0.16	0.0000	1.0000
1B1	Coal mining and handling biomass	CH_4	0.10	0.10	0.0000	1.0000
4B	Cropland	CH_4	0.09	0.09	0.0000	1.0000
1B1	Coal mining and handling solid fuels	N_2O	0.09	0.09	0.0000	1.0000
1B1	Coal mining and handling solid fuels	CH_4	0.07	0.07	0.0000	1.0000
Total			**801,412.67**	**855,046.74**	**1.0000**	

Table A 1.3.2 Approach 1 Key Category Analysis for the base year based on level of emissions (excluding LULUCF)

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A1	Energy industries: solid fuels	CO_2	185,492.23	185,492.23	0.2308	0.3660
1A3b	Road transportation: liquid fuels	CO_2	108,568.67	108,568.67	0.1351	0.3660
1A4	Other sectors: gaseous fuels	CO_2	70,373.19	70,373.19	0.0876	0.4535
5A	Solid waste disposal	CH_4	60,432.98	60,432.98	0.0752	0.5287
1A1	Energy industries: liquid fuels	CO_2	40,865.08	40,865.08	0.0509	0.5796

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A2	Manufacturing industries and construction: solid fuels	CO_2	38,484.26	38,484.26	0.0479	0.6275
1A2	Manufacturing industries and construction: liquid fuels	CO_2	29,831.66	29,831.66	0.0371	0.6646
1A2	Manufacturing industries and construction: gaseous fuels	CO_2	27,334.85	27,334.85	0.0340	0.6986
1B1	Coal mining and handling	CH_4	21,826.68	21,826.68	0.0272	0.7258
3A1	Enteric fermentation from Cattle	CH_4	20,572.07	20,572.07	0.0256	0.7514
2B3	Adipic acid production	N_2O	19,934.61	19,934.61	0.0248	0.7762
1A4	Other sectors: solid fuels	CO_2	19,868.96	19,868.96	0.0247	0.8009
1A4	Other sectors: liquid fuels	CO_2	19,364.29	19,364.29	0.0241	0.8250
2B9	Fluorochemical production	HFCs PFCs SF_6 and NF_3	17,793.94	17,793.94	0.0221	0.8472
3D	Agricultural soils	N_2O	13,762.28	13,762.28	0.0171	0.8643
1B2	Oil and gas extraction	CH_4	12,345.03	12,345.03	0.0154	0.8797
1A1	Energy industries: gaseous fuels	CO_2	9,236.91	9,236.91	0.0115	0.8912
1A3d	Domestic Navigation: liquid fuels	CO_2	7,611.13	7,611.13	0.0095	0.9006
2A1	Cement production	CO_2	7,295.26	7,295.26	0.0091	0.9097
1B2	Oil and gas extraction	CO_2	5,777.92	5,777.92	0.0072	0.9169
2C1	Iron and steel production	CO_2	5,591.54	5,591.54	0.0070	0.9239
1A5	Other: liquid fuels	CO_2	5,293.44	5,293.44	0.0066	0.9304
3A2	Enteric fermentation from Sheep	CH_4	5,102.88	5,102.88	0.0064	0.9368
2B8	Petrochemical and carbon black production	CO_2	4,536.66	4,536.66	0.0056	0.9424
5D	Wastewater treatment and discharge	CH_4	4,219.05	4,219.05	0.0053	0.9477
2B2	Nitric acid production	N_2O	3,860.26	3,860.26	0.0048	0.9525
3B1	Manure management from Cattle	CH_4	3,544.12	3,544.12	0.0044	0.9569
3B1	Manure management from Cattle	N_2O	2,473.92	2,473.92	0.0031	0.9600
2B1	Ammonia production	CO_2	1,895.00	1,895.00	0.0024	0.9623
1A3a	Domestic aviation: liquid fuels	CO_2	1,837.04	1,837.04	0.0023	0.9646
1B1	Coal mining and handling solid fuels	CO_2	1,698.56	1,698.56	0.0021	0.9667
2A2	Lime production	CO_2	1,462.05	1,462.05	0.0018	0.9686
1A3c	Railways: liquid fuels	CO_2	1,455.18	1,455.18	0.0018	0.9704

IPCC Code	IPCC Category	GHG	Base year emissions ($Gg\ CO_2e$)	Absolute value of Base year emissions ($Gg\ CO_2e$)	Level Assessment	Cumulative Total
5C	Incineration and open burning of waste	CO_2	1,363.29	1,363.29	0.0017	0.9721
2C6	Zinc production	CO_2	1,358.83	1,358.83	0.0017	0.9738
1A3b	Road transportation: liquid fuels	N_2O	1,312.32	1,312.32	0.0016	0.9754
1A4	Other sectors: solid fuels	CH_4	1,264.97	1,264.97	0.0016	0.9770
1A3b	Road transportation: liquid fuels	CH_4	1,246.71	1,246.71	0.0016	0.9785
3B3	Manure management from Swine	CH_4	1,091.12	1,091.12	0.0014	0.9799
1A1	Energy industries: solid fuels	N_2O	1,023.18	1,023.18	0.0013	0.9811
3G	Liming	CO_2	1,015.18	1,015.18	0.0013	0.9824
1A2	Manufacturing industries and construction: liquid fuels	N_2O	912.10	912.10	0.0011	0.9835
5D	Wastewater treatment and discharge	N_2O	783.59	783.59	0.0010	0.9845
2G1	Electrical equipment	HFCs PFCs SF_6 and NF_3	747.79	747.79	0.0009	0.9855
2F4	Aerosols	HFCs PFCs SF_6 and NF_3	663.00	663.00	0.0008	0.9863
2A4	Other process uses of carbonates	CO_2	640.93	640.93	0.0008	0.9871
1A4	Other sectors: liquid fuels	N_2O	607.11	607.11	0.0008	0.9878
2D	Non-energy products from fuels and solvent use	CO_2	553.12	553.12	0.0007	0.9885
2G3	N_2O from product uses	N_2O	552.57	552.57	0.0007	0.9892
3B3	Manure management from Swine	N_2O	535.72	535.72	0.0007	0.9899
2F1	Refrigeration and air conditioning	HFCs PFCs SF_6 and NF_3	531.19	531.19	0.0007	0.9905
1A4	Other sectors: peat	CO_2	488.50	488.50	0.0006	0.9911
3B4	Manure management from Other livestock	N_2O	465.12	465.12	0.0006	0.9917
2C3	Aluminium production	CO_2	450.32	450.32	0.0006	0.9923
2A3	Glass production	CO_2	405.54	405.54	0.0005	0.9928

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
2C4	Magnesium production	HFCs PFCs SF_6 and NF_3	387.17	387.17	0.0005	0.9933
2C3	Aluminium production	HFCs PFCs SF_6 and NF_3	333.43	333.43	0.0004	0.9937
3H	Urea application to land	CO_2	327.53	327.53	0.0004	0.9941
3A4	Enteric fermentation from Other livestock	CH_4	294.61	294.61	0.0004	0.9945
3A3	Enteric fermentation from Swine	CH_4	283.28	283.28	0.0004	0.9948
2G2	SF_6 and PFCs from other product use	HFCs PFCs SF_6 and NF_3	278.70	278.70	0.0003	0.9952
1A4	Other sectors: solid fuels	N_2O	241.66	241.66	0.0003	0.9955
2B7	Soda ash production	CO_2	231.55	231.55	0.0003	0.9957
1A1	Energy industries: other fuels	CO_2	228.01	228.01	0.0003	0.9960
1A3e	Other transportation: liquid fuels	CO_2	224.74	224.74	0.0003	0.9963
1A1	Energy industries: gaseous fuels	N_2O	198.91	198.91	0.0002	0.9966
3F	Field burning of agricultural residues	CH_4	186.57	186.57	0.0002	0.9968
2B10	Other Chemical Industry	CH_4	185.65	185.65	0.0002	0.9970
2F2	Foam blowing agents	HFCs PFCs SF_6 and NF_3	184.42	184.42	0.0002	0.9972
1A4	Other sectors: gaseous fuels	CH_4	157.18	157.18	0.0002	0.9974
1A2	Manufacturing industries and construction: solid fuels	N_2O	147.70	147.70	0.0002	0.9976
1A1	Energy industries: liquid fuels	N_2O	139.85	139.85	0.0002	0.9978
5C	Incineration and open burning of waste	CH_4	137.63	137.63	0.0002	0.9980
3B2	Manure management from Sheep	CH_4	134.31	134.31	0.0002	0.9981
3B4	Manure management from Other livestock	CH_4	110.89	110.89	0.0001	0.9983
2B6	Titanium dioxide production	CO_2	104.63	104.63	0.0001	0.9984

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A3d	Domestic Navigation: liquid fuels	N_2O	103.71	103.71	0.0001	0.9985
1A1	Energy industries: gaseous fuels	CH_4	92.30	92.30	0.0001	0.9987
1A4	Other sectors: biomass	CH_4	81.01	81.01	0.0001	0.9988
1A2	Manufacturing industries and construction: other fuels	CO_2	76.94	76.94	0.0001	0.9988
3F	Field burning of agricultural residues	N_2O	57.66	57.66	0.0001	0.9989
1A4	Other sectors: liquid fuels	CH_4	57.49	57.49	0.0001	0.9990
1A5	Other: liquid fuels	N_2O	56.12	56.12	0.0001	0.9991
1A1	Energy industries: solid fuels	CH_4	49.29	49.29	0.0001	0.9991
5C	Incineration and open burning of waste	N_2O	47.47	47.47	0.0001	0.9992
1A2	Manufacturing industries and construction: solid fuels	CH_4	47.37	47.37	0.0001	0.9992
1A2	Manufacturing industries and construction: liquid fuels	CH_4	44.28	44.28	0.0001	0.9993
3B2	Manure management from Sheep	N_2O	43.39	43.39	0.0001	0.9994
1A1	Energy industries: liquid fuels	CH_4	43.12	43.12	0.0001	0.9994
2G4	Other product manufacture and use	N_2O	41.00	41.00	0.0001	0.9995
1B2	Oil and gas extraction	N_2O	40.75	40.75	0.0001	0.9995
1A4	Other sectors: gaseous fuels	N_2O	37.47	37.47	0.0000	0.9996
2C1	Iron and steel production	CH_4	36.89	36.89	0.0000	0.9996
1A4	Other sectors: peat	CH_4	34.56	34.56	0.0000	0.9996
2A4	Other process uses of carbonates	CH_4	31.11	31.11	0.0000	0.9997
1A3e	Other transportation: liquid fuels	N_2O	27.86	27.86	0.0000	0.9997
2B8	Petrochemical and carbon black production	CH_4	27.83	27.83	0.0000	0.9997
2F6	Other product uses as substitutes for ODS	HFCs PFCs SF_6 and NF_3	27.61	27.61	0.0000	0.9998
2C1	Iron and steel production	N_2O	17.74	17.74	0.0000	0.9998
1A3a	Domestic aviation: liquid fuels	N_2O	17.39	17.39	0.0000	0.9998
1A2	Manufacturing industries and construction: biomass	N_2O	15.84	15.84	0.0000	0.9998
1A2	Manufacturing industries and construction: gaseous fuels	N_2O	14.54	14.54	0.0000	0.9999

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A3c	Railways: liquid fuels	N_2O	13.75	13.75	0.0000	0.9999
1A1	Energy industries: other fuels	CH_4	13.47	13.47	0.0000	0.9999
1A2	Manufacturing industries and construction: gaseous fuels	CH_4	12.20	12.20	0.0000	0.9999
1A4	Other sectors: biomass	N_2O	12.10	12.10	0.0000	0.9999
1A2	Manufacturing industries and construction: biomass	CH_4	9.97	9.97	0.0000	0.9999
2E1	Integrated circuit or semiconductor	HFCs PFCs SF_6 and NF_3	9.56	9.56	0.0000	1.0000
1A1	Energy industries: other fuels	N_2O	5.91	5.91	0.0000	1.0000
5B	Biological treatment of solid waste	CH_4	5.48	5.48	0.0000	1.0000
1A3a	Domestic aviation: liquid fuels	CH_4	4.13	4.13	0.0000	1.0000
5B	Biological treatment of solid waste	N_2O	3.92	3.92	0.0000	1.0000
1A3d	Domestic Navigation: liquid fuels	CH_4	3.66	3.66	0.0000	1.0000
1A5	Other: liquid fuels	CH_4	3.56	3.56	0.0000	1.0000
1A3c	Railways: liquid fuels	CH_4	2.46	2.46	0.0000	1.0000
2B8	Petrochemical and carbon black production	N_2O	2.10	2.10	0.0000	1.0000
1A4	Other sectors: peat	N_2O	1.92	1.92	0.0000	1.0000
2F3	Fire protection	HFCs PFCs SF_6 and NF_3	1.41	1.41	0.0000	1.0000
1A1	Energy industries: biomass	CH_4	0.47	0.47	0.0000	1.0000
1A2	Manufacturing industries and construction: other fuels	N_2O	0.38	0.38	0.0000	1.0000
2B1	Ammonia production	N_2O	0.31	0.31	0.0000	1.0000
1A3e	Other transportation: liquid fuels	CH_4	0.29	0.29	0.0000	1.0000
2B1	Ammonia production	CH_4	0.26	0.26	0.0000	1.0000
1A1	Energy industries: biomass	N_2O	0.25	0.25	0.0000	1.0000
1A2	Manufacturing industries and construction: other fuels	CH_4	0.16	0.16	0.0000	1.0000
1B1	Coal mining and handling biomass	CH_4	0.10	0.10	0.0000	1.0000
1B1	Coal mining and handling solid fuels	N_2O	0.09	0.09	0.0000	1.0000

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1B1	Coal mining and handling solid fuels	CH_4	0.07	0.07	0.0000	1.0000
Total			**803,551.05**	**803,551.05**	**1.0000**	

Table A 1.3.3 Approach 1 Key Category Analysis for the latest reported year based on level of emissions (including LULUCF)

IPCC Code	IPCC Category	GHG	2016 emissions (Gg CO_2e)	Absolute value of 2016 emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A3b	Road transportation: liquid fuels	CO_2	113,363.37	113,363.37	0.2098	0.2098
1A4	Other sectors: gaseous fuels	CO_2	76,440.96	76,440.96	0.1415	0.3513
1A1	Energy industries: gaseous fuels	CO_2	63,108.62	63,108.62	0.1168	0.4681
1A1	Energy industries: solid fuels	CO_2	27,845.72	27,845.72	0.0515	0.5197
4A	Forest land	CO_2	-24,050.29	24,050.29	0.0445	0.5642
1A2	Manufacturing industries and construction: gaseous fuels	CO_2	22,955.13	22,955.13	0.0425	0.6067
3A1	Enteric fermentation from Cattle	CH_4	17,434.85	17,434.85	0.0323	0.6389
1A1	Energy industries: liquid fuels	CO_2	15,975.45	15,975.45	0.0296	0.6685
1A2	Manufacturing industries and construction: liquid fuels	CO_2	14,150.47	14,150.47	0.0262	0.6947
5A	Solid waste disposal	CH_4	14,016.99	14,016.99	0.0259	0.7207
1A2	Manufacturing industries and construction: solid fuels	CO_2	13,358.05	13,358.05	0.0247	0.7454
1A4	Other sectors: liquid fuels	CO_2	12,973.46	12,973.46	0.0240	0.7694
2F1	Refrigeration and air conditioning	HFCs PFCs SF_6 and NF_3	12,649.02	12,649.02	0.0234	0.7928
4B	Cropland	CO_2	11,504.76	11,504.76	0.0213	0.8141
3D	Agricultural soils	N_2O	11,349.08	11,349.08	0.0210	0.8351
4C	Grassland	CO_2	-9,371.91	9,371.91	0.0173	0.8525
4E	Settlements	CO_2	6,422.08	6,422.08	0.0119	0.8643
1A3d	Domestic Navigation: liquid fuels	CO_2	5,424.06	5,424.06	0.0100	0.8744
1B2	Oil and gas extraction	CH_4	4,863.35	4,863.35	0.0090	0.8834
2A1	Cement production	CO_2	4,553.32	4,553.32	0.0084	0.8918
1B2	Oil and gas extraction	CO_2	4,115.18	4,115.18	0.0076	0.8994

IPCC Code	IPCC Category	GHG	2016 emissions (Gg CO_2e)	Absolute value of 2016 emissions (Gg CO_2e)	Level Assessment	Cumulative Total
3A2	Enteric fermentation from Sheep	CH_4	4,047.67	4,047.67	0.0075	0.9069
1A1	Energy industries: other fuels	CO_2	3,600.84	3,600.84	0.0067	0.9136
3B1	Manure management from Cattle	CH_4	3,466.94	3,466.94	0.0064	0.9200
5D	Wastewater treatment and discharge	CH_4	3,421.01	3,421.01	0.0063	0.9263
2B8	Petrochemical and carbon black production	CO_2	2,767.26	2,767.26	0.0051	0.9315
1A4	Other sectors: solid fuels	CO_2	2,624.01	2,624.01	0.0049	0.9363
2C1	Iron and steel production	CO_2	2,408.19	2,408.19	0.0045	0.9408
3B1	Manure management from Cattle	N_2O	2,048.05	2,048.05	0.0038	0.9446
1A3c	Railways: liquid fuels	CO_2	1,959.26	1,959.26	0.0036	0.9482
1A3a	Domestic aviation: liquid fuels	CO_2	1,813.18	1,813.18	0.0034	0.9515
2F4	Aerosols	HFCs PFCs SF_6 and NF_3	1,726.32	1,726.32	0.0032	0.9547
1A5	Other: liquid fuels	CO_2	1,547.07	1,547.07	0.0029	0.9576
2B1	Ammonia production	CO_2	1,442.28	1,442.28	0.0027	0.9603
1A3b	Road transportation: liquid fuels	N_2O	1,072.47	1,072.47	0.0020	0.9623
5B	Biological treatment of solid waste	CH_4	1,070.53	1,070.53	0.0020	0.9642
2A2	Lime production	CO_2	1,021.20	1,021.20	0.0019	0.9661
3G	Liming	CO_2	928.72	928.72	0.0017	0.9679
4G	Harvested wood products	CO_2	-844.44	844.44	0.0016	0.9694
5D	Wastewater treatment and discharge	N_2O	719.86	719.86	0.0013	0.9707
1A2	Manufacturing industries and construction: liquid fuels	N_2O	675.37	675.37	0.0013	0.9720
5B	Biological treatment of solid waste	N_2O	657.72	657.72	0.0012	0.9732
2G3	N_2O from product uses	N_2O	641.81	641.81	0.0012	0.9744
3B3	Manure management from Swine	CH_4	632.80	632.80	0.0012	0.9756
1A2	Manufacturing industries and construction: other fuels	CO_2	612.46	612.46	0.0011	0.9767
1A4	Other sectors: biomass	CH_4	586.94	586.94	0.0011	0.9778
4E	Settlements	N_2O	526.89	526.89	0.0010	0.9788
1A4	Other sectors: liquid fuels	N_2O	523.84	523.84	0.0010	0.9797

IPCC Code	IPCC Category	GHG	2016 emissions (Gg CO_2e)	Absolute value of 2016 emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A3e	Other transportation: liquid fuels	CO_2	514.72	514.72	0.0010	0.9807
3B4	Manure management from Other livestock	N_2O	507.66	507.66	0.0009	0.9816
1B1	Coal mining and handling	CH_4	502.79	502.79	0.0009	0.9826
4B	Cropland	N_2O	476.64	476.64	0.0009	0.9834
3A4	Enteric fermentation from Other livestock	CH_4	463.97	463.97	0.0009	0.9843
2F2	Foam blowing agents	HFCs PFCs SF_6 and NF_3	425.72	425.72	0.0008	0.9851
2A4	Other process uses of carbonates	CO_2	391.24	391.24	0.0007	0.9858
3H	Urea application to land	CO_2	365.57	365.57	0.0007	0.9865
2A3	Glass production	CO_2	360.75	360.75	0.0007	0.9872
2D	Non-energy products from fuels and solvent use	CO_2	352.37	352.37	0.0007	0.9878
2F3	Fire protection	HFCs PFCs SF_6 and NF_3	331.73	331.73	0.0006	0.9884
4D	Wetlands	CO_2	319.71	319.71	0.0006	0.9890
3B3	Manure management from Swine	N_2O	306.47	306.47	0.0006	0.9896
2G2	SF_6 and PFCs from other product use	HFCs PFCs SF_6 and NF_3	301.96	301.96	0.0006	0.9901
2G1	Electrical equipment	HFCs PFCs SF_6 and NF_3	298.25	298.25	0.0006	0.9907
5C	Incineration and open burning of waste	CO_2	283.37	283.37	0.0005	0.9912
1A1	Energy industries: gaseous fuels	N_2O	270.94	270.94	0.0005	0.9917
1B1	Coal mining and handling solid fuels	CO_2	253.13	253.13	0.0005	0.9922
4	Indirect N_2O emissions from LULUCF	N_2O	248.33	248.33	0.0005	0.9926
2G4	Other product manufacture and use	N_2O	185.65	185.65	0.0003	0.9930

IPCC Code	IPCC Category	GHG	2016 emissions (Gg CO_2e)	Absolute value of 2016 emissions (Gg CO_2e)	Level Assessment	Cumulative Total
3A3	Enteric fermentation from Swine	CH_4	182.59	182.59	0.0003	0.9933
1A1	Energy industries: biomass	N_2O	180.81	180.81	0.0003	0.9937
1A4	Other sectors: solid fuels	CH_4	179.49	179.49	0.0003	0.9940
2B9	Fluorochemical production	HFCs PFCs SF_6 and NF_3	178.70	178.70	0.0003	0.9943
2B6	Titanium dioxide production	CO_2	169.48	169.48	0.0003	0.9946
1A4	Other sectors: gaseous fuels	CH_4	168.25	168.25	0.0003	0.9950
1A1	Energy industries: solid fuels	N_2O	157.13	157.13	0.0003	0.9952
4A	Forest land	N_2O	152.39	152.39	0.0003	0.9955
2B7	Soda ash production	CO_2	143.51	143.51	0.0003	0.9958
3B4	Manure management from Other livestock	CH_4	127.80	127.80	0.0002	0.9960
1A1	Energy industries: gaseous fuels	CH_4	119.41	119.41	0.0002	0.9963
1A1	Energy industries: biomass	CH_4	114.76	114.76	0.0002	0.9965
3B2	Manure management from Sheep	CH_4	108.64	108.64	0.0002	0.9967
1A3b	Road transportation: liquid fuels	CH_4	101.43	101.43	0.0002	0.9969
1A1	Energy industries: other fuels	CH_4	96.93	96.93	0.0002	0.9970
1B1	Coal mining and handling liquid fuels	CO_2	95.50	95.50	0.0002	0.9972
1A4	Other sectors: biomass	N_2O	92.22	92.22	0.0002	0.9974
1A1	Energy industries: other fuels	N_2O	87.00	87.00	0.0002	0.9975
1A1	Energy industries: liquid fuels	N_2O	86.83	86.83	0.0002	0.9977
2F5	Solvents	HFCs PFCs SF_6 and NF_3	78.62	78.62	0.0001	0.9978
2C4	Magnesium production	HFCs PFCs SF_6 and NF_3	77.51	77.51	0.0001	0.9980
2C3	Aluminium production	CO_2	73.28	73.28	0.0001	0.9981
1A2	Manufacturing industries and construction: biomass	N_2O	72.96	72.96	0.0001	0.9983
1A3d	Domestic Navigation: liquid fuels	N_2O	68.57	68.57	0.0001	0.9984

IPCC Code	IPCC Category	GHG	2016 emissions (Gg CO_2e)	Absolute value of 2016 emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A3e	Other transportation: liquid fuels	N_2O	63.73	63.73	0.0001	0.9985
2B10	Other Chemical Industry	CH_4	62.77	62.77	0.0001	0.9986
2F6	Other product uses as substitutes for ODS	HFCs PFCs SF_6 and NF_3	53.74	53.74	0.0001	0.9987
1A2	Manufacturing industries and construction: biomass	CH_4	45.91	45.91	0.0001	0.9988
5C	Incineration and open burning of waste	N_2O	41.33	41.33	0.0001	0.9989
1A4	Other sectors: gaseous fuels	N_2O	40.11	40.11	0.0001	0.9990
4C	Grassland	N_2O	37.62	37.62	0.0001	0.9990
1B2	Oil and gas extraction	N_2O	36.06	36.06	0.0001	0.9991
1A3c	Railways: solid fuels	CO_2	35.72	35.72	0.0001	0.9992
1A2	Manufacturing industries and construction: solid fuels	N_2O	33.71	33.71	0.0001	0.9992
1A4	Other sectors: solid fuels	N_2O	33.51	33.51	0.0001	0.9993
3B2	Manure management from Sheep	N_2O	33.47	33.47	0.0001	0.9993
1A4	Other sectors: liquid fuels	CH_4	32.87	32.87	0.0001	0.9994
1A2	Manufacturing industries and construction: liquid fuels	CH_4	29.90	29.90	0.0001	0.9995
2B2	Nitric acid production	N_2O	24.73	24.73	0.0000	0.9995
4C	Grassland	CH_4	23.63	23.63	0.0000	0.9996
2E1	Integrated circuit or semiconductor	HFCs PFCs SF_6 and NF_3	19.74	19.74	0.0000	0.9996
1A3c	Railways: liquid fuels	N_2O	18.49	18.49	0.0000	0.9996
1A3a	Domestic aviation: liquid fuels	N_2O	17.16	17.16	0.0000	0.9997
1A1	Energy industries: liquid fuels	CH_4	17.15	17.15	0.0000	0.9997
1A5	Other: liquid fuels	N_2O	16.37	16.37	0.0000	0.9997
2C3	Aluminium production	HFCs PFCs SF_6 and NF_3	14.27	14.27	0.0000	0.9997
1A2	Manufacturing industries and construction: solid fuels	CH_4	12.35	12.35	0.0000	0.9998
1A2	Manufacturing industries and construction: gaseous fuels	N_2O	12.05	12.05	0.0000	0.9998

IPCC Code	IPCC Category	GHG	2016 emissions (Gg CO_2e)	Absolute value of 2016 emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A2	Manufacturing industries and construction: other fuels	N_2O	11.67	11.67	0.0000	0.9998
2C1	Iron and steel production	CH_4	10.69	10.69	0.0000	0.9998
4E	Settlements	CH_4	10.66	10.66	0.0000	0.9998
1A2	Manufacturing industries and construction: gaseous fuels	CH_4	10.10	10.10	0.0000	0.9999
2B8	Petrochemical and carbon black production	CH_4	10.00	10.00	0.0000	0.9999
5C	Incineration and open burning of waste	CH_4	9.89	9.89	0.0000	0.9999
1A1	Energy industries: solid fuels	CH_4	7.62	7.62	0.0000	0.9999
1A2	Manufacturing industries and construction: other fuels	CH_4	7.16	7.16	0.0000	0.9999
2C1	Iron and steel production	N_2O	6.36	6.36	0.0000	0.9999
1A4	Other sectors: peat	CO_2	6.34	6.34	0.0000	1.0000
1A3d	Domestic Navigation: liquid fuels	CH_4	6.04	6.04	0.0000	1.0000
2A4	Other process uses of carbonates	CH_4	5.99	5.99	0.0000	1.0000
1B1	Coal mining and handling biomass	CH_4	3.76	3.76	0.0000	1.0000
1A3c	Railways: liquid fuels	CH_4	1.95	1.95	0.0000	1.0000
2B8	Petrochemical and carbon black production	N_2O	1.48	1.48	0.0000	1.0000
1A3a	Domestic aviation: liquid fuels	CH_4	1.31	1.31	0.0000	1.0000
1A5	Other: liquid fuels	CH_4	1.02	1.02	0.0000	1.0000
1A3c	Railways: solid fuels	CH_4	0.94	0.94	0.0000	1.0000
1A4	Other sectors: peat	CH_4	0.45	0.45	0.0000	1.0000
4A	Forest land	CH_4	0.40	0.40	0.0000	1.0000
1A3e	Other transportation: liquid fuels	CH_4	0.38	0.38	0.0000	1.0000
2B1	Ammonia production	N_2O	0.30	0.30	0.0000	1.0000
4D	Wetlands	N_2O	0.30	0.30	0.0000	1.0000
2B1	Ammonia production	CH_4	0.25	0.25	0.0000	1.0000
1A3c	Railways: solid fuels	N_2O	0.09	0.09	0.0000	1.0000
4B	Cropland	CH_4	0.05	0.05	0.0000	1.0000
1A4	Other sectors: peat	N_2O	0.02	0.02	0.0000	1.0000
1B1	Coal mining and handling solid fuels	N_2O	0.02	0.02	0.0000	1.0000
1B1	Coal mining and handling solid fuels	CH_4	0.02	0.02	0.0000	1.0000
Total			**471,726.43**	**540,259.71**	**1.0000**	

Table A 1.3.4 Approach 1 Key Category Analysis for the latest reported year based on level of emissions (excluding LULUCF)

IPCC Code	IPCC Category	GHG	2016 emissions (Gg CO_2e)	Absolute value of 2016 emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A3b	Road transportation: liquid fuels	CO_2	113,363.37	113,363.37	0.2331	0.2331
1A4	Other sectors: gaseous fuels	CO_2	76,440.96	76,440.96	0.1572	0.3903
1A1	Energy industries: gaseous fuels	CO_2	63,108.62	63,108.62	0.1298	0.5201
1A1	Energy industries: solid fuels	CO_2	27,845.72	27,845.72	0.0573	0.5774
1A2	Manufacturing industries and construction: gaseous fuels	CO_2	22,955.13	22,955.13	0.0472	0.6246
3A1	Enteric fermentation from Cattle	CH_4	17,434.85	17,434.85	0.0359	0.6604
1A1	Energy industries: liquid fuels	CO_2	15,975.45	15,975.45	0.0329	0.6933
1A2	Manufacturing industries and construction: liquid fuels	CO_2	14,150.47	14,150.47	0.0291	0.7224
5A	Solid waste disposal	CH_4	14,016.99	14,016.99	0.0288	0.7512
1A2	Manufacturing industries and construction: solid fuels	CO_2	13,358.05	13,358.05	0.0275	0.7787
1A4	Other sectors: liquid fuels	CO_2	12,973.46	12,973.46	0.0267	0.8054
2F1	Refrigeration and air conditioning	HFCs PFCs SF_6 and NF_3	12,649.02	12,649.02	0.0260	0.8314
3D	Agricultural soils	N_2O	11,349.08	11,349.08	0.0233	0.8547
1A3d	Domestic Navigation: liquid fuels	CO_2	5,424.06	5,424.06	0.0112	0.8659
1B2	Oil and gas extraction	CH_4	4,863.35	4,863.35	0.0100	0.8759
2A1	Cement production	CO_2	4,553.32	4,553.32	0.0094	0.8852
1B2	Oil and gas extraction	CO_2	4,115.18	4,115.18	0.0085	0.8937
3A2	Enteric fermentation from Sheep	CH_4	4,047.67	4,047.67	0.0083	0.9020
1A1	Energy industries: other fuels	CO_2	3,600.84	3,600.84	0.0074	0.9094
3B1	Manure management from Cattle	CH_4	3,466.94	3,466.94	0.0071	0.9166
5D	Wastewater treatment and discharge	CH_4	3,421.01	3,421.01	0.0070	0.9236
2B8	Petrochemical and carbon black production	CO_2	2,767.26	2,767.26	0.0057	0.9293
1A4	Other sectors: solid fuels	CO_2	2,624.01	2,624.01	0.0054	0.9347
2C1	Iron and steel production	CO_2	2,408.19	2,408.19	0.0050	0.9396
3B1	Manure management from Cattle	N_2O	2,048.05	2,048.05	0.0042	0.9438
1A3c	Railways: liquid fuels	CO_2	1,959.26	1,959.26	0.0040	0.9479

IPCC Code	IPCC Category	GHG	2016 emissions (Gg CO_2e)	Absolute value of 2016 emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A3a	Domestic aviation: liquid fuels	CO_2	1,813.18	1,813.18	0.0037	0.9516
2F4	Aerosols	HFCs PFCs SF_6 and NF_3	1,726.32	1,726.32	0.0036	0.9551
1A5	Other: liquid fuels	CO_2	1,547.07	1,547.07	0.0032	0.9583
2B1	Ammonia production	CO_2	1,442.28	1,442.28	0.0030	0.9613
1A3b	Road transportation: liquid fuels	N_2O	1,072.47	1,072.47	0.0022	0.9635
5B	Biological treatment of solid waste	CH_4	1,070.53	1,070.53	0.0022	0.9657
2A2	Lime production	CO_2	1,021.20	1,021.20	0.0021	0.9678
3G	Liming	CO_2	928.72	928.72	0.0019	0.9697
5D	Wastewater treatment and discharge	N_2O	719.86	719.86	0.0015	0.9712
1A2	Manufacturing industries and construction: liquid fuels	N_2O	675.37	675.37	0.0014	0.9726
5B	Biological treatment of solid waste	N_2O	657.72	657.72	0.0014	0.9739
2G3	N_2O from product uses	N_2O	641.81	641.81	0.0013	0.9753
3B3	Manure management from Swine	CH_4	632.80	632.80	0.0013	0.9766
1A2	Manufacturing industries and construction: other fuels	CO_2	612.46	612.46	0.0013	0.9778
1A4	Other sectors: biomass	CH_4	586.94	586.94	0.0012	0.9790
1A4	Other sectors: liquid fuels	N_2O	523.84	523.84	0.0011	0.9801
1A3e	Other transportation: liquid fuels	CO_2	514.72	514.72	0.0011	0.9812
3B4	Manure management from Other livestock	N_2O	507.66	507.66	0.0010	0.9822
1B1	Coal mining and handling	CH_4	502.79	502.79	0.0010	0.9832
3A4	Enteric fermentation from Other livestock	CH_4	463.97	463.97	0.0010	0.9842
2F2	Foam blowing agents	HFCs PFCs SF_6 and NF_3	425.72	425.72	0.0009	0.9851
2A4	Other process uses of carbonates	CO_2	391.24	391.24	0.0008	0.9859
3H	Urea application to land	CO_2	365.57	365.57	0.0008	0.9866
2A3	Glass production	CO_2	360.75	360.75	0.0007	0.9874
2D	Non-energy products from fuels and solvent use	CO_2	352.37	352.37	0.0007	0.9881

IPCC Code	IPCC Category	GHG	2016 emissions (Gg CO_2e)	Absolute value of 2016 emissions (Gg CO_2e)	Level Assessment	Cumulative Total
2F3	Fire protection	HFCs PFCs SF_6 and NF_3	331.73	331.73	0.0007	0.9888
3B3	Manure management from Swine	N_2O	306.47	306.47	0.0006	0.9894
2G2	SF_6 and PFCs from other product use	HFCs PFCs SF_6 and NF_3	301.96	301.96	0.0006	0.9900
2G1	Electrical equipment	HFCs PFCs SF_6 and NF_3	298.25	298.25	0.0006	0.9906
5C	Incineration and open burning of waste	CO_2	283.37	283.37	0.0006	0.9912
1A1	Energy industries: gaseous fuels	N_2O	270.94	270.94	0.0006	0.9918
1B1	Coal mining and handling solid fuels	CO_2	253.13	253.13	0.0005	0.9923
2G4	Other product manufacture and use	N_2O	185.65	185.65	0.0004	0.9927
3A3	Enteric fermentation from Swine	CH_4	182.59	182.59	0.0004	0.9931
1A1	Energy industries: biomass	N_2O	180.81	180.81	0.0004	0.9934
1A4	Other sectors: solid fuels	CH_4	179.49	179.49	0.0004	0.9938
2B9	Fluorochemical production	HFCs PFCs SF_6 and NF_3	178.70	178.70	0.0004	0.9942
2B6	Titanium dioxide production	CO_2	169.48	169.48	0.0003	0.9945
1A4	Other sectors: gaseous fuels	CH_4	168.25	168.25	0.0003	0.9949
1A1	Energy industries: solid fuels	N_2O	157.13	157.13	0.0003	0.9952
2B7	Soda ash production	CO_2	143.51	143.51	0.0003	0.9955
3B4	Manure management from Other livestock	CH_4	127.80	127.80	0.0003	0.9957
1A1	Energy industries: gaseous fuels	CH_4	119.41	119.41	0.0002	0.9960
1A1	Energy industries: biomass	CH_4	114.76	114.76	0.0002	0.9962
3B2	Manure management from Sheep	CH_4	108.64	108.64	0.0002	0.9964
1A3b	Road transportation: liquid fuels	CH_4	101.43	101.43	0.0002	0.9967

IPCC Code	IPCC Category	GHG	2016 emissions (Gg CO_2e)	Absolute value of 2016 emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A1	Energy industries: other fuels	CH_4	96.93	96.93	0.0002	0.9969
1B1	Coal mining and handling liquid fuels	CO_2	95.50	95.50	0.0002	0.9970
1A4	Other sectors: biomass	N_2O	92.22	92.22	0.0002	0.9972
1A1	Energy industries: other fuels	N_2O	87.00	87.00	0.0002	0.9974
1A1	Energy industries: liquid fuels	N_2O	86.83	86.83	0.0002	0.9976
2F5	Solvents	HFCs PFCs SF_6 and NF_3	78.62	78.62	0.0002	0.9978
2C4	Magnesium production	HFCs PFCs SF_6 and NF_3	77.51	77.51	0.0002	0.9979
2C3	Aluminium production	CO_2	73.28	73.28	0.0002	0.9981
1A2	Manufacturing industries and construction: biomass	N_2O	72.96	72.96	0.0002	0.9982
1A3d	Domestic Navigation: liquid fuels	N_2O	68.57	68.57	0.0001	0.9984
1A3e	Other transportation: liquid fuels	N_2O	63.73	63.73	0.0001	0.9985
2B10	Other Chemical Industry	CH_4	62.77	62.77	0.0001	0.9986
2F6	Other product uses as substitutes for ODS	HFCs PFCs SF_6 and NF_3	53.74	53.74	0.0001	0.9987
1A2	Manufacturing industries and construction: biomass	CH_4	45.91	45.91	0.0001	0.9988
5C	Incineration and open burning of waste	N_2O	41.33	41.33	0.0001	0.9989
1A4	Other sectors: gaseous fuels	N_2O	40.11	40.11	0.0001	0.9990
1B2	Oil and gas extraction	N_2O	36.06	36.06	0.0001	0.9991
1A3c	Railways: solid fuels	CO_2	35.72	35.72	0.0001	0.9991
1A2	Manufacturing industries and construction: solid fuels	N_2O	33.71	33.71	0.0001	0.9992
1A4	Other sectors: solid fuels	N_2O	33.51	33.51	0.0001	0.9993
3B2	Manure management from Sheep	N_2O	33.47	33.47	0.0001	0.9993
1A4	Other sectors: liquid fuels	CH_4	32.87	32.87	0.0001	0.9994
1A2	Manufacturing industries and construction: liquid fuels	CH_4	29.90	29.90	0.0001	0.9995
2B2	Nitric acid production	N_2O	24.73	24.73	0.0001	0.9995

IPCC Code	IPCC Category	GHG	2016 emissions (Gg CO_2e)	Absolute value of 2016 emissions (Gg CO_2e)	Level Assessment	Cumulative Total
2E1	Integrated circuit or semiconductor	HFCs PFCs SF_6 and NF_3	19.74	19.74	0.0000	0.9996
1A3c	Railways: liquid fuels	N_2O	18.49	18.49	0.0000	0.9996
1A3a	Domestic aviation: liquid fuels	N_2O	17.16	17.16	0.0000	0.9996
1A1	Energy industries: liquid fuels	CH_4	17.15	17.15	0.0000	0.9997
1A5	Other: liquid fuels	N_2O	16.37	16.37	0.0000	0.9997
2C3	Aluminium production	HFCs PFCs SF_6 and NF_3	14.27	14.27	0.0000	0.9997
1A2	Manufacturing industries and construction: solid fuels	CH_4	12.35	12.35	0.0000	0.9998
1A2	Manufacturing industries and construction: gaseous fuels	N_2O	12.05	12.05	0.0000	0.9998
1A2	Manufacturing industries and construction: other fuels	N_2O	11.67	11.67	0.0000	0.9998
2C1	Iron and steel production	CH_4	10.69	10.69	0.0000	0.9998
1A2	Manufacturing industries and construction: gaseous fuels	CH_4	10.10	10.10	0.0000	0.9999
2B8	Petrochemical and carbon black production	CH_4	10.00	10.00	0.0000	0.9999
5C	Incineration and open burning of waste	CH_4	9.89	9.89	0.0000	0.9999
1A1	Energy industries: solid fuels	CH_4	7.62	7.62	0.0000	0.9999
1A2	Manufacturing industries and construction: other fuels	CH_4	7.16	7.16	0.0000	0.9999
2C1	Iron and steel production	N_2O	6.36	6.36	0.0000	0.9999
1A4	Other sectors: peat	CO_2	6.34	6.34	0.0000	1.0000
1A3d	Domestic Navigation: liquid fuels	CH_4	6.04	6.04	0.0000	1.0000
2A4	Other process uses of carbonates	CH_4	5.99	5.99	0.0000	1.0000
1B1	Coal mining and handling biomass	CH_4	3.76	3.76	0.0000	1.0000
1A3c	Railways: liquid fuels	CH_4	1.95	1.95	0.0000	1.0000
2B8	Petrochemical and carbon black production	N_2O	1.48	1.48	0.0000	1.0000
1A3a	Domestic aviation: liquid fuels	CH_4	1.31	1.31	0.0000	1.0000
1A5	Other: liquid fuels	CH_4	1.02	1.02	0.0000	1.0000
1A3c	Railways: solid fuels	CH_4	0.94	0.94	0.0000	1.0000
1A4	Other sectors: peat	CH_4	0.45	0.45	0.0000	1.0000

IPCC Code	IPCC Category	GHG	2016 emissions (Gg CO_2e)	Absolute value of 2016 emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A3e	Other transportation: liquid fuels	CH_4	0.38	0.38	0.0000	1.0000
2B1	Ammonia production	N_2O	0.30	0.30	0.0000	1.0000
2B1	Ammonia production	CH_4	0.25	0.25	0.0000	1.0000
1A3c	Railways: solid fuels	N_2O	0.09	0.09	0.0000	1.0000
1A4	Other sectors: peat	N_2O	0.02	0.02	0.0000	1.0000
1B1	Coal mining and handling solid fuels	N_2O	0.02	0.02	0.0000	1.0000
1B1	Coal mining and handling solid fuels	CH_4	0.02	0.02	0.0000	1.0000
Total			**486,269.62**	**486,269.62**	**1.0000**	

Table A 1.3.5 Approach 1 Key Category Analysis based on trend in emissions (from base year to latest reported year, including LULUCF)

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
1A1	Energy industries: solid fuels	CO_2	185,492.23	27,845.72	0.0951	0.2134	0.2134
1A1	Energy industries: gaseous fuels	CO_2	9,236.91	63,108.62	0.0674	0.1513	0.3647
1A3b	Road transportation: liquid fuels	CO_2	108,568.67	113,363.37	0.0578	0.1297	0.4944
1A4	Other sectors: gaseous fuels	CO_2	70,373.19	76,440.96	0.0410	0.0919	0.5863
5A	Solid waste disposal	CH_4	60,432.98	14,016.99	0.0252	0.0565	0.6428
1B1	Coal mining and handling	CH_4	21,826.68	502.79	0.0144	0.0324	0.6752
2F1	Refrigeration and air conditioning	HFCs PFCs SF_6 and NF_3	531.19	12,649.02	0.0144	0.0324	0.7076
2B3	Adipic acid production	N_2O	19,934.61	-	0.0137	0.0308	0.7383
2B9	Fluorochemical production	HFCs PFCs SF_6 and NF_3	17,793.94	178.70	0.0120	0.0270	0.7654
1A2	Manufacturing industries and construction: solid fuels	CO_2	38,484.26	13,358.05	0.0109	0.0244	0.7897

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
1A4	Other sectors: solid fuels	CO_2	19,868.96	2,624.01	0.0106	0.0238	0.8135
1A1	Energy industries: liquid fuels	CO_2	40,865.08	15,975.45	0.0094	0.0212	0.8347
1A2	Manufacturing industries and construction: gaseous fuels	CO_2	27,334.85	22,955.13	0.0080	0.0180	0.8527
3A1	Enteric fermentation from Cattle	CH_4	20,572.07	17,434.85	0.0062	0.0140	0.8667
1A1	Energy industries: other fuels	CO_2	228.01	3,600.84	0.0041	0.0091	0.8758
1A2	Manufacturing industries and construction: liquid fuels	CO_2	29,831.66	14,150.47	0.0040	0.0089	0.8847
3D	Agricultural soils	N_2O	13,762.28	11,349.08	0.0038	0.0085	0.8933
4B	Cropland	CO_2	15,023.23	11,504.76	0.0031	0.0070	0.9002
1B2	Oil and gas extraction	CH_4	12,345.03	4,863.35	0.0028	0.0063	0.9065
4E	Settlements	CO_2	6,901.20	6,422.08	0.0028	0.0062	0.9127
2B2	Nitric acid production	N_2O	3,860.26	24.73	0.0026	0.0059	0.9186
4C	Grassland	CO_2	-7,756.55	-9,371.91	0.0018	0.0041	0.9228
1A4	Other sectors: liquid fuels	CO_2	19,364.29	12,973.46	0.0018	0.0041	0.9269
1A5	Other: liquid fuels	CO_2	5,293.44	1,547.07	0.0018	0.0041	0.9310
4G	Harvested wood products	CO_2	-1,614.71	-844.44	0.0017	0.0038	0.9348
3B1	Manure management from Cattle	CH_4	3,544.12	3,466.94	0.0016	0.0036	0.9384
2F4	Aerosols	HFCs PFCs SF_6 and NF_3	663.00	1,726.32	0.0016	0.0035	0.9419
1A3c	Railways: liquid fuels	CO_2	1,455.18	1,959.26	0.0013	0.0029	0.9448
5B	Biological treatment of solid waste	CH_4	5.48	1,070.53	0.0012	0.0028	0.9476
3A2	Enteric fermentation from Sheep	CH_4	5,102.88	4,047.67	0.0012	0.0027	0.9503
1A3d	Domestic Navigation: liquid fuels	CO_2	7,611.13	5,424.06	0.0011	0.0025	0.9528

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
5D	Wastewater treatment and discharge	CH_4	4,219.05	3,421.01	0.0011	0.0025	0.9553
2C1	Iron and steel production	CO_2	5,591.54	2,408.19	0.0010	0.0023	0.9576
2C6	Zinc production	CO_2	1,358.83	-	0.0009	0.0021	0.9597
1B1	Coal mining and handling solid fuels	CO_2	1,698.56	253.13	0.0009	0.0020	0.9616
1A3a	Domestic aviation: liquid fuels	CO_2	1,837.04	1,813.18	0.0009	0.0019	0.9636
1B2	Oil and gas extraction	CO_2	5,777.92	4,115.18	0.0008	0.0019	0.9654
5B	Biological treatment of solid waste	N_2O	3.92	657.72	0.0008	0.0017	0.9672
1A3b	Road transportation: liquid fuels	CH_4	1,246.71	101.43	0.0007	0.0017	0.9688
3B1	Manure management from Cattle	N_2O	2,473.92	2,048.05	0.0007	0.0016	0.9704
4A	Forest land	CO_2	-17,445.77	-24,050.29	0.0007	0.0015	0.9719
1A2	Manufacturing industries and construction: other fuels	CO_2	76.94	612.46	0.0007	0.0015	0.9734
1A4	Other sectors: solid fuels	CH_4	1,264.97	179.49	0.0007	0.0015	0.9748
1A4	Other sectors: biomass	CH_4	81.01	586.94	0.0006	0.0014	0.9763
5C	Incineration and open burning of waste	CO_2	1,363.29	283.37	0.0006	0.0014	0.9776
1A1	Energy industries: solid fuels	N_2O	1,023.18	157.13	0.0005	0.0012	0.9788
1A3e	Other transportation: liquid fuels	CO_2	224.74	514.72	0.0004	0.0010	0.9798
3G	Liming	CO_2	1,015.18	928.72	0.0004	0.0009	0.9807
2F3	Fire protection	HFCs PFCs SF_6 and NF_3	1.41	331.73	0.0004	0.0009	0.9815
2B1	Ammonia production	CO_2	1,895.00	1,442.28	0.0004	0.0009	0.9824

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
2F2	Foam blowing agents	HFCs PFCs SF_6 and NF_3	184.42	425.72	0.0004	0.0008	0.9832
2G3	N_2O from product uses	N_2O	552.57	641.81	0.0004	0.0008	0.9840
1A3b	Road transportation: liquid fuels	N_2O	1,312.32	1,072.47	0.0004	0.0008	0.9848
3A4	Enteric fermentation from Other livestock	CH_4	294.61	463.97	0.0003	0.0008	0.9856
1A4	Other sectors: peat	CO_2	488.50	6.34	0.0003	0.0007	0.9863
2A1	Cement production	CO_2	7,295.26	4,553.32	0.0003	0.0007	0.9870
5D	Wastewater treatment and discharge	N_2O	783.59	719.86	0.0003	0.0007	0.9877
3B4	Manure management from Other livestock	N_2O	465.12	507.66	0.0003	0.0006	0.9883
2C3	Aluminium production	CO_2	450.32	73.28	0.0002	0.0005	0.9888
4E	Settlements	N_2O	584.71	526.89	0.0002	0.0005	0.9893
2C3	Aluminium production	HFCs PFCs SF_6 and NF_3	333.43	14.27	0.0002	0.0005	0.9898
1A1	Energy industries: biomass	N_2O	0.25	180.81	0.0002	0.0005	0.9902
3H	Urea application to land	CO_2	327.53	365.57	0.0002	0.0005	0.9907
1A4	Other sectors: liquid fuels	N_2O	607.11	523.84	0.0002	0.0004	0.9911
2G4	Other product manufacture and use	N_2O	41.00	185.65	0.0002	0.0004	0.9916
2A2	Lime production	CO_2	1,462.05	1,021.20	0.0002	0.0004	0.9920
1A1	Energy industries: gaseous fuels	N_2O	198.91	270.94	0.0002	0.0004	0.9924
2C4	Magnesium production	HFCs PFCs SF_6 and NF_3	387.17	77.51	0.0002	0.0004	0.9928

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
2G1	Electrical equipment	HFCs PFCs SF_6 and NF_3	747.79	298.25	0.0002	0.0004	0.9931
1A2	Manufacturing industries and construction: liquid fuels	N_2O	912.10	675.37	0.0002	0.0004	0.9935
2G2	SF_6 and PFCs from other product use	HFCs PFCs SF_6 and NF_3	278.70	301.96	0.0002	0.0004	0.9939
4B	Cropland	N_2O	1,019.85	476.64	0.0001	0.0003	0.9942
2A3	Glass production	CO_2	405.54	360.75	0.0001	0.0003	0.9945
1A1	Energy industries: biomass	CH_4	0.47	114.76	0.0001	0.0003	0.9948
3F	Field burning of agricultural residues	CH_4	186.57	-	0.0001	0.0003	0.9951
1A4	Other sectors: solid fuels	N_2O	241.66	33.51	0.0001	0.0003	0.9954
2B6	Titanium dioxide production	CO_2	104.63	169.48	0.0001	0.0003	0.9957
2B8	Petrochemical and carbon black production	CO_2	4,536.66	2,767.26	0.0001	0.0003	0.9959
1B1	Coal mining and handling liquid fuels	CO_2	-	95.50	0.0001	0.0003	0.9962
1A1	Energy industries: other fuels	CH_4	13.47	96.93	0.0001	0.0002	0.9964
1A4	Other sectors: biomass	N_2O	12.10	92.22	0.0001	0.0002	0.9966
1A1	Energy industries: other fuels	N_2O	5.91	87.00	0.0001	0.0002	0.9969
2F5	Solvents	HFCs PFCs SF_6 and NF_3	-	78.62	0.0001	0.0002	0.9971
1A4	Other sectors: gaseous fuels	CH_4	157.18	168.25	0.0001	0.0002	0.9973
5C	Incineration and open burning of waste	CH_4	137.63	9.89	0.0001	0.0002	0.9974
1A1	Energy industries: gaseous fuels	CH_4	92.30	119.41	0.0001	0.0002	0.9976

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
1A2	Manufacturing industries and construction: biomass	N_2O	15.84	72.96	0.0001	0.0002	0.9978
3B4	Manure management from Other livestock	CH_4	110.89	127.80	0.0001	0.0002	0.9979
1A2	Manufacturing industries and construction: solid fuels	N_2O	147.70	33.71	0.0001	0.0001	0.9981
1A3e	Other transportation: liquid fuels	N_2O	27.86	63.73	0.0001	0.0001	0.9982
2B10	Other Chemical Industry	CH_4	185.65	62.77	0.0001	0.0001	0.9983
1A2	Manufacturing industries and construction: biomass	CH_4	9.97	45.91	0.0000	0.0001	0.9984
2F6	Other product uses as substitutes for ODS	HFCs PFCs SF_6 and NF_3	27.61	53.74	0.0000	0.0001	0.9985
1A3c	Railways: solid fuels	CO_2	-	35.72	0.0000	0.0001	0.9986
3F	Field burning of agricultural residues	N_2O	57.66	-	0.0000	0.0001	0.9987
4D	Wetlands	CO_2	486.95	319.71	0.0000	0.0001	0.9988
4C	Grassland	N_2O	10.36	37.62	0.0000	0.0001	0.9989
3B2	Manure management from Sheep	CH_4	134.31	108.64	0.0000	0.0001	0.9990
2D	Non-energy products from fuels and solvent use	CO_2	553.12	352.37	0.0000	0.0001	0.9990
1A1	Energy industries: solid fuels	CH_4	49.29	7.62	0.0000	0.0001	0.9991
1A4	Other sectors: peat	CH_4	34.56	0.45	0.0000	0.0001	0.9991
1A4	Other sectors: gaseous fuels	N_2O	37.47	40.11	0.0000	0.0000	0.9992
4C	Grassland	CH_4	10.00	23.63	0.0000	0.0000	0.9992
1A5	Other: liquid fuels	N_2O	56.12	16.37	0.0000	0.0000	0.9993
4A	Forest land	N_2O	230.75	152.39	0.0000	0.0000	0.9993
3A3	Enteric fermentation from Swine	CH_4	283.28	182.59	0.0000	0.0000	0.9994

IPCC Code	IPCC Category	GHG	Base year emissions ($Gg\ CO_2e$)	2016 emissions ($Gg\ CO_2e$)	Trend Assessment	Contribution to Trend	Cumulative Total
1A2	Manufacturing industries and construction: solid fuels	CH_4	47.37	12.35	0.0000	0.0000	0.9994
2E1	Integrated circuit or semiconductor	HFCs PFCs SF_6 and NF_3	9.56	19.74	0.0000	0.0000	0.9994
2A4	Other process uses of carbonates	CO_2	640.93	391.24	0.0000	0.0000	0.9995
5C	Incineration and open burning of waste	N_2O	47.47	41.33	0.0000	0.0000	0.9995
2A4	Other process uses of carbonates	CH_4	31.11	5.99	0.0000	0.0000	0.9995
1B2	Oil and gas extraction	N_2O	40.75	36.06	0.0000	0.0000	0.9996
4	Indirect N_2O emissions from LULUCF	N_2O	401.41	248.33	0.0000	0.0000	0.9996
1A2	Manufacturing industries and construction: other fuels	N_2O	0.38	11.67	0.0000	0.0000	0.9996
2C1	Iron and steel production	CH_4	36.89	10.69	0.0000	0.0000	0.9997
1A3c	Railways: liquid fuels	N_2O	13.75	18.49	0.0000	0.0000	0.9997
3B3	Manure management from Swine	CH_4	1,091.12	632.80	0.0000	0.0000	0.9997
4E	Settlements	CH_4	3.05	10.66	0.0000	0.0000	0.9997
3B3	Manure management from Swine	N_2O	535.72	306.47	0.0000	0.0000	0.9998
1A1	Energy industries: liquid fuels	CH_4	43.12	17.15	0.0000	0.0000	0.9998
3B2	Manure management from Sheep	N_2O	43.39	33.47	0.0000	0.0000	0.9998
1A3d	Domestic Navigation: liquid fuels	N_2O	103.71	68.57	0.0000	0.0000	0.9998
2B7	Soda ash production	CO_2	231.55	143.51	0.0000	0.0000	0.9999

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
1A2	Manufacturing industries and construction: other fuels	CH_4	0.16	7.16	0.0000	0.0000	0.9999
1A3a	Domestic aviation: liquid fuels	N_2O	17.39	17.16	0.0000	0.0000	0.9999
2B8	Petrochemical and carbon black production	CH_4	27.83	10.00	0.0000	0.0000	0.9999
1A1	Energy industries: liquid fuels	N_2O	139.85	86.83	0.0000	0.0000	0.9999
2C1	Iron and steel production	N_2O	17.74	6.36	0.0000	0.0000	0.9999
1A3d	Domestic Navigation: liquid fuels	CH_4	3.66	6.04	0.0000	0.0000	0.9999
1A2	Manufacturing industries and construction: liquid fuels	CH_4	44.28	29.90	0.0000	0.0000	0.9999
1B1	Coal mining and handling biomass	CH_4	0.10	3.76	0.0000	0.0000	1.0000
1A2	Manufacturing industries and construction: gaseous fuels	N_2O	14.54	12.05	0.0000	0.0000	1.0000
1A2	Manufacturing industries and construction: gaseous fuels	CH_4	12.20	10.10	0.0000	0.0000	1.0000
4D	Wetlands	N_2O	4.13	0.30	0.0000	0.0000	1.0000
4A	Forest land	CH_4	2.92	0.40	0.0000	0.0000	1.0000
1A3a	Domestic aviation: liquid fuels	CH_4	4.13	1.31	0.0000	0.0000	1.0000
1A4	Other sectors: peat	N_2O	1.92	0.02	0.0000	0.0000	1.0000
1A5	Other: liquid fuels	CH_4	3.56	1.02	0.0000	0.0000	1.0000
1A4	Other sectors: liquid fuels	CH_4	57.49	32.87	0.0000	0.0000	1.0000
1A3c	Railways: solid fuels	CH_4	-	0.94	0.0000	0.0000	1.0000
1A3c	Railways: liquid fuels	CH_4	2.46	1.95	0.0000	0.0000	1.0000
2B8	Petrochemical and carbon black production	N_2O	2.10	1.48	0.0000	0.0000	1.0000
1A3e	Other transportation: liquid fuels	CH_4	0.29	0.38	0.0000	0.0000	1.0000

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
2B1	Ammonia production	N_2O	0.31	0.30	0.0000	0.0000	1.0000
2B1	Ammonia production	CH_4	0.26	0.25	0.0000	0.0000	1.0000
1A3c	Railways: solid fuels	N_2O	-	0.09	0.0000	0.0000	1.0000
1B1	Coal mining and handling solid fuels	N_2O	0.09	0.02	0.0000	0.0000	1.0000
1B1	Coal mining and handling solid fuels	CH_4	0.07	0.02	0.0000	0.0000	1.0000
4B	Cropland	CH_4	0.09	0.05	0.0000	0.0000	1.0000
Total			**801,412.67**	**471,726.43**	**0.4458**	**1.0000**	

Table A 1.3.6 Approach 1 Key Category Analysis based on trend in emissions (from base year to latest reported year, excluding LULUCF)

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
1A1	Energy industries: solid fuels	CO_2	185,492.23	27,845.72	0.0951	0.2186	0.2186
1A1	Energy industries: gaseous fuels	CO_2	9,236.91	63,108.62	0.0674	0.1550	0.3735
1A3b	Road transportation: liquid fuels	CO_2	108,568.67	113,363.37	0.0578	0.1329	0.5064
1A4	Other sectors: gaseous fuels	CO_2	70,373.19	76,440.96	0.0410	0.0941	0.6005
5A	Solid waste disposal	CH_4	60,432.98	14,016.99	0.0252	0.0579	0.6584
1B1	Coal mining and handling	CH_4	21,826.68	502.79	0.0144	0.0332	0.6916
2F1	Refrigeration and air conditioning	HFCs PFCs SF_6 and NF_3	531.19	12,649.02	0.0144	0.0331	0.7247
2B3	Adipic acid production	N_2O	19,934.61	-	0.0137	0.0315	0.7563
2B9	Fluorochemical production	HFCs PFCs SF_6 and NF_3	17,793.94	178.70	0.0120	0.0277	0.7839
1A2	Manufacturing industries and construction: solid fuels	CO_2	38,484.26	13,358.05	0.0109	0.0250	0.8089

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
1A4	Other sectors: solid fuels	CO_2	19,868.96	2,624.01	0.0106	0.0244	0.8333
1A1	Energy industries: liquid fuels	CO_2	40,865.08	15,975.45	0.0094	0.0217	0.8550
1A2	Manufacturing industries and construction: gaseous fuels	CO_2	27,334.85	22,955.13	0.0080	0.0184	0.8734
3A1	Enteric fermentation from Cattle	CH_4	20,572.07	17,434.85	0.0062	0.0143	0.8877
1A1	Energy industries: other fuels	CO_2	228.01	3,600.84	0.0041	0.0093	0.8971
1A2	Manufacturing industries and construction: liquid fuels	CO_2	29,831.66	14,150.47	0.0040	0.0092	0.9062
3D	Agricultural soils	N_2O	13,762.28	11,349.08	0.0038	0.0087	0.9149
1B2	Oil and gas extraction	CH_4	12,345.03	4,863.35	0.0028	0.0065	0.9214
2B2	Nitric acid production	N_2O	3,860.26	24.73	0.0026	0.0060	0.9274
1A4	Other sectors: liquid fuels	CO_2	19,364.29	12,973.46	0.0018	0.0042	0.9317
1A5	Other: liquid fuels	CO_2	5,293.44	1,547.07	0.0018	0.0042	0.9359
3B1	Manure management from Cattle	CH_4	3,544.12	3,466.94	0.0016	0.0037	0.9396
2F4	Aerosols	HFCs PFCs SF_6 and NF_3	663.00	1,726.32	0.0016	0.0036	0.9432
1A3c	Railways: liquid fuels	CO_2	1,455.18	1,959.26	0.0013	0.0030	0.9462
5B	Biological treatment of solid waste	CH_4	5.48	1,070.53	0.0012	0.0029	0.9490
3A2	Enteric fermentation from Sheep	CH_4	5,102.88	4,047.67	0.0012	0.0028	0.9518
1A3d	Domestic Navigation: liquid fuels	CO_2	7,611.13	5,424.06	0.0011	0.0025	0.9544
5D	Wastewater treatment and discharge	CH_4	4,219.05	3,421.01	0.0011	0.0025	0.9569
2C1	Iron and steel production	CO_2	5,591.54	2,408.19	0.0010	0.0024	0.9593
2C6	Zinc production	CO_2	1,358.83	-	0.0009	0.0021	0.9614

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
1B1	Coal mining and handling solid fuels	CO_2	1,698.56	253.13	0.0009	0.0020	0.9634
1A3a	Domestic aviation: liquid fuels	CO_2	1,837.04	1,813.18	0.0009	0.0020	0.9654
1B2	Oil and gas extraction	CO_2	5,777.92	4,115.18	0.0008	0.0019	0.9673
5B	Biological treatment of solid waste	N_2O	3.92	657.72	0.0008	0.0018	0.9691
1A3b	Road transportation: liquid fuels	CH_4	1,246.71	101.43	0.0007	0.0017	0.9708
3B1	Manure management from Cattle	N_2O	2,473.92	2,048.05	0.0007	0.0016	0.9723
1A2	Manufacturing industries and construction: other fuels	CO_2	76.94	612.46	0.0007	0.0015	0.9739
1A4	Other sectors: solid fuels	CH_4	1,264.97	179.49	0.0007	0.0015	0.9754
1A4	Other sectors: biomass	CH_4	81.01	586.94	0.0006	0.0014	0.9768
5C	Incineration and open burning of waste	CO_2	1,363.29	283.37	0.0006	0.0014	0.9782
1A1	Energy industries: solid fuels	N_2O	1,023.18	157.13	0.0005	0.0012	0.9794
1A3e	Other transportation: liquid fuels	CO_2	224.74	514.72	0.0004	0.0010	0.9805
3G	Liming	CO_2	1,015.18	928.72	0.0004	0.0009	0.9813
2F3	Fire protection	HFCs PFCs SF_6 and NF_3	1.41	331.73	0.0004	0.0009	0.9822
2B1	Ammonia production	CO_2	1,895.00	1,442.28	0.0004	0.0009	0.9831
2F2	Foam blowing agents	HFCs PFCs SF_6 and NF_3	184.42	425.72	0.0004	0.0009	0.9840
2G3	N_2O from product uses	N_2O	552.57	641.81	0.0004	0.0009	0.9848
1A3b	Road transportation: liquid fuels	N_2O	1,312.32	1,072.47	0.0004	0.0008	0.9856

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
3A4	Enteric fermentation from Other livestock	CH_4	294.61	463.97	0.0003	0.0008	0.9864
1A4	Other sectors: peat	CO_2	488.50	6.34	0.0003	0.0008	0.9872
2A1	Cement production	CO_2	7,295.26	4,553.32	0.0003	0.0007	0.9879
5D	Wastewater treatment and discharge	N_2O	783.59	719.86	0.0003	0.0007	0.9885
3B4	Manure management from Other livestock	N_2O	465.12	507.66	0.0003	0.0006	0.9892
2C3	Aluminium production	CO_2	450.32	73.28	0.0002	0.0005	0.9897
2C3	Aluminium production	HFCs PFCs SF_6 and NF_3	333.43	14.27	0.0002	0.0005	0.9902
1A1	Energy industries: biomass	N_2O	0.25	180.81	0.0002	0.0005	0.9907
3H	Urea application to land	CO_2	327.53	365.57	0.0002	0.0005	0.9911
1A4	Other sectors: liquid fuels	N_2O	607.11	523.84	0.0002	0.0004	0.9916
2G4	Other product manufacture and use	N_2O	41.00	185.65	0.0002	0.0004	0.9920
2A2	Lime production	CO_2	1,462.05	1,021.20	0.0002	0.0004	0.9924
1A1	Energy industries: gaseous fuels	N_2O	198.91	270.94	0.0002	0.0004	0.9929
2C4	Magnesium production	HFCs PFCs SF_6 and NF_3	387.17	77.51	0.0002	0.0004	0.9933
2G1	Electrical equipment	HFCs PFCs SF_6 and NF_3	747.79	298.25	0.0002	0.0004	0.9936
1A2	Manufacturing industries and construction: liquid fuels	N_2O	912.10	675.37	0.0002	0.0004	0.9940
2G2	SF_6 and PFCs from other product use	HFCs PFCs SF_6 and NF_3	278.70	301.96	0.0002	0.0004	0.9944
2A3	Glass production	CO_2	405.54	360.75	0.0001	0.0003	0.9947

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
1A1	Energy industries: biomass	CH_4	0.47	114.76	0.0001	0.0003	0.9950
3F	Field burning of agricultural residues	CH_4	186.57	-	0.0001	0.0003	0.9953
1A4	Other sectors: solid fuels	N_2O	241.66	33.51	0.0001	0.0003	0.9956
2B6	Titanium dioxide production	CO_2	104.63	169.48	0.0001	0.0003	0.9959
2B8	Petrochemical and carbon black production	CO_2	4,536.66	2,767.26	0.0001	0.0003	0.9962
1B1	Coal mining and handling liquid fuels	CO_2	-	95.50	0.0001	0.0003	0.9964
1A1	Energy industries: other fuels	CH_4	13.47	96.93	0.0001	0.0002	0.9967
1A4	Other sectors: biomass	N_2O	12.10	92.22	0.0001	0.0002	0.9969
1A1	Energy industries: other fuels	N_2O	5.91	87.00	0.0001	0.0002	0.9971
2F5	Solvents	HFCs PFCs SF_6 and NF_3	-	78.62	0.0001	0.0002	0.9973
1A4	Other sectors: gaseous fuels	CH_4	157.18	168.25	0.0001	0.0002	0.9975
5C	Incineration and open burning of waste	CH_4	137.63	9.89	0.0001	0.0002	0.9977
1A1	Energy industries: gaseous fuels	CH_4	92.30	119.41	0.0001	0.0002	0.9979
1A2	Manufacturing industries and construction: biomass	N_2O	15.84	72.96	0.0001	0.0002	0.9981
3B4	Manure management from Other livestock	CH_4	110.89	127.80	0.0001	0.0002	0.9982
1A2	Manufacturing industries and construction: solid fuels	N_2O	147.70	33.71	0.0001	0.0001	0.9984
1A3e	Other transportation: liquid fuels	N_2O	27.86	63.73	0.0001	0.0001	0.9985
2B10	Other Chemical Industry	CH_4	185.65	62.77	0.0001	0.0001	0.9986

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
1A2	Manufacturing industries and construction: biomass	CH_4	9.97	45.91	0.0000	0.0001	0.9987
2F6	Other product uses as substitutes for ODS	HFCs PFCs SF_6 and NF_3	27.61	53.74	0.0000	0.0001	0.9988
1A3c	Railways: solid fuels	CO_2	-	35.72	0.0000	0.0001	0.9989
3F	Field burning of agricultural residues	N_2O	57.66	-	0.0000	0.0001	0.9990
3B2	Manure management from Sheep	CH_4	134.31	108.64	0.0000	0.0001	0.9991
2D	Non-energy products from fuels and solvent use	CO_2	553.12	352.37	0.0000	0.0001	0.9992
1A1	Energy industries: solid fuels	CH_4	49.29	7.62	0.0000	0.0001	0.9992
1A4	Other sectors: peat	CH_4	34.56	0.45	0.0000	0.0001	0.9993
1A4	Other sectors: gaseous fuels	N_2O	37.47	40.11	0.0000	0.0000	0.9993
1A5	Other: liquid fuels	N_2O	56.12	16.37	0.0000	0.0000	0.9994
3A3	Enteric fermentation from Swine	CH_4	283.28	182.59	0.0000	0.0000	0.9994
1A2	Manufacturing industries and construction: solid fuels	CH_4	47.37	12.35	0.0000	0.0000	0.9995
2E1	Integrated circuit or semiconductor	HFCs PFCs SF_6 and NF_3	9.56	19.74	0.0000	0.0000	0.9995
2A4	Other process uses of carbonates	CO_2	640.93	391.24	0.0000	0.0000	0.9995
5C	Incineration and open burning of waste	N_2O	47.47	41.33	0.0000	0.0000	0.9996
2A4	Other process uses of carbonates	CH_4	31.11	5.99	0.0000	0.0000	0.9996
1B2	Oil and gas extraction	N_2O	40.75	36.06	0.0000	0.0000	0.9996
1A2	Manufacturing industries and construction: other fuels	N_2O	0.38	11.67	0.0000	0.0000	0.9997

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
2C1	Iron and steel production	CH_4	36.89	10.69	0.0000	0.0000	0.9997
1A3c	Railways: liquid fuels	N_2O	13.75	18.49	0.0000	0.0000	0.9997
3B3	Manure management from Swine	CH_4	1,091.12	632.80	0.0000	0.0000	0.9997
3B3	Manure management from Swine	N_2O	535.72	306.47	0.0000	0.0000	0.9998
1A1	Energy industries: liquid fuels	CH_4	43.12	17.15	0.0000	0.0000	0.9998
3B2	Manure management from Sheep	N_2O	43.39	33.47	0.0000	0.0000	0.9998
1A3d	Domestic Navigation: liquid fuels	N_2O	103.71	68.57	0.0000	0.0000	0.9998
2B7	Soda ash production	CO_2	231.55	143.51	0.0000	0.0000	0.9999
1A2	Manufacturing industries and construction: other fuels	CH_4	0.16	7.16	0.0000	0.0000	0.9999
1A3a	Domestic aviation: liquid fuels	N_2O	17.39	17.16	0.0000	0.0000	0.9999
2B8	Petrochemical and carbon black production	CH_4	27.83	10.00	0.0000	0.0000	0.9999
1A1	Energy industries: liquid fuels	N_2O	139.85	86.83	0.0000	0.0000	0.9999
2C1	Iron and steel production	N_2O	17.74	6.36	0.0000	0.0000	0.9999
1A3d	Domestic Navigation: liquid fuels	CH_4	3.66	6.04	0.0000	0.0000	0.9999
1A2	Manufacturing industries and construction: liquid fuels	CH_4	44.28	29.90	0.0000	0.0000	1.0000
1B1	Coal mining and handling biomass	CH_4	0.10	3.76	0.0000	0.0000	1.0000
1A2	Manufacturing industries and construction: gaseous fuels	N_2O	14.54	12.05	0.0000	0.0000	1.0000

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
1A2	Manufacturing industries and construction: gaseous fuels	CH_4	12.20	10.10	0.0000	0.0000	1.0000
1A3a	Domestic aviation: liquid fuels	CH_4	4.13	1.31	0.0000	0.0000	1.0000
1A4	Other sectors: peat	N_2O	1.92	0.02	0.0000	0.0000	1.0000
1A5	Other: liquid fuels	CH_4	3.56	1.02	0.0000	0.0000	1.0000
1A4	Other sectors: liquid fuels	CH_4	57.49	32.87	0.0000	0.0000	1.0000
1A3c	Railways: solid fuels	CH_4	-	0.94	0.0000	0.0000	1.0000
1A3c	Railways: liquid fuels	CH_4	2.46	1.95	0.0000	0.0000	1.0000
2B8	Petrochemical and carbon black production	N_2O	2.10	1.48	0.0000	0.0000	1.0000
1A3e	Other transportation: liquid fuels	CH_4	0.29	0.38	0.0000	0.0000	1.0000
2B1	Ammonia production	N_2O	0.31	0.30	0.0000	0.0000	1.0000
2B1	Ammonia production	CH_4	0.26	0.25	0.0000	0.0000	1.0000
1A3c	Railways: solid fuels	N_2O	-	0.09	0.0000	0.0000	1.0000
1B1	Coal mining and handling solid fuels	N_2O	0.09	0.02	0.0000	0.0000	1.0000
1B1	Coal mining and handling solid fuels	CH_4	0.07	0.02	0.0000	0.0000	1.0000
Total			**803,551.05**	**486,269.62**	**0.4353**	**1.0000**	

A 1.4 QUANTITATIVE APPROACH 2 KCA FOLLOWING IPCC 2006 GUIDELINES

Following the 2006 IPCC Guidelines, the UK has also completed an Approach 2 KCA for both level and trend, which takes into account uncertainties, using the Approach 1 method for uncertainty estimates. This analysis has been performed using the data shown in **Table A 1.4.1** to **Table A 1.4.4** using the same categorisation and the same estimates of uncertainty.

The results of the level assessment (based on Approach 2) with and without LULUCF for the base year and the latest reported year are shown in **Table A 1.4.1** to **Table A 1.4.4**. The key source categories are highlighted by the shaded cells in the table. The source categories (i.e. rows of the table) were sorted in descending order of magnitude based on the results of the “Level Parameter”, and then the cumulative total was included in the final column of the table. The key source categories are those whose contributions add up to 90% of the sum of the level parameter in the final column after this sorting process, which accounts for 90% of the uncertainty in level.

The results of the trend assessment (based on Approach 2) with and without LULUCF for the base year to the latest reported year to the latest reported year, are shown in **Table A 1.4.5** to **Table A 1.4.6**

The key source categories are highlighted by the shaded cells in the table. The trend parameter was calculated using the absolute value of the result; an absolute function is used since Land Use, Land Use Change and Forestry contains negative sources (sinks) and the absolute function is necessary to produce positive uncertainty contributions for these sinks. The source categories (i.e. rows of the table) were sorted in descending order of magnitude based on the results of the trend parameter, and then the cumulative total was included in the final column of the table. The key source categories are those whose contributions add up to 90% of the sum of the level parameter in the final column after this sorting process, which accounts for 90% of the uncertainty in trend.

Any methodological improvements to the uncertainty analysis are discussed in **Annex 2**.

Table A 1.4.1 Approach 2 Level Assessment for Base year (including LULUCF) with Key Categories Shaded in Grey

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
5A	5A_Solid Waste Disposal	CH_4	60432.98	60432.98	0.2231	0.2231
2B3	2B3_Adipic Acid Production	N_2O	19934.61	19934.61	0.1522	0.3753
3D	3D_Agricultural Soils	N_2O	13762.28	13762.28	0.0560	0.4313
1A	1A_Coal	CO_2	243845.45	243845.45	0.0536	0.4849
4B	4B_Cropland	CO_2	15033.60	15033.60	0.0516	0.5365
4A	4A Forest Land	CO_2	-17445.77	17445.77	0.0466	0.5831
1A	1A_(Stationary)_Oil	CO_2	95348.82	95348.82	0.0463	0.6295
1B1	1B1_Coal Mining	CH_4	21826.78	21826.78	0.0335	0.6629
2B2	2B2_Nitric Acid Production	N_2O	3860.26	3860.26	0.0296	0.6925
4C	4C_Grassland	CO_2	-7756.55	7756.55	0.0296	0.7222
3A	3A_Enteric Fermentation	CH_4	26252.83	26252.83	0.0275	0.7497
4E	4E Settlements	CO_2	6901.20	6901.20	0.0263	0.7760
3B	3B_Manure Management	N_2O	3518.14	3518.14	0.0183	0.7943
1A	1A_Natural Gas	CO_2	106944.95	106944.95	0.0160	0.8102
1B2	1B2_Natural Gas Transmission	CH_4	10168.33	10168.33	0.0157	0.8259
1A1 & 1A2 & 1A4 & 1A5	1A1 & 1A2 & 1A4 & 1A5_Other Combustion	N_2O	3415.05	3415.05	0.0150	0.8409
5D	5D_Wastewater Handling	N_2O	783.59	783.59	0.0148	0.8558

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
2B	2B_Chemical_industry	HFCs	17680.04	17680.04	0.0135	0.8693
1A3b	1A3b_Gasoline/ LPG	CO_2	75562.72	75562.72	0.0128	0.8821
1A3d	1A3d_Marine fuel	CO_2	7611.13	7611.13	0.0104	0.8925
2B	2B_Chemical industries	CO_2	6767.84	6767.84	0.0096	0.9021
5D	5D_Wastewater Handling	CH_4	4219.05	4219.05	0.0087	0.9108
1A3b	1A3b_Gasoline/ LPG	CH_4	1157.96	1157.96	0.0066	0.9174
2G	2G_Other_Product_Manufacture_and_Use	N_2O	593.57	593.57	0.0064	0.9238
1A3b	1A3b_DERV	CO_2	33005.80	33005.80	0.0056	0.9294
1A3b	1A3b_Gasoline/ LPG	N_2O	989.41	989.41	0.0056	0.9351
4G	4G Other Activities	CO_2	-1614.71	1614.71	0.0055	0.9406
1A1 & 1A2 & 1A4 & 1A5	1A1 & 1A2 & 1A4 & 1A5_Other Combustion	CH_4	1911.40	1911.40	0.0053	0.9459
4	4_Indirect_LULUCF_Emissions	N_2O	401.41	401.41	0.0051	0.9510
4D	4D Wetland	CO_2	486.95	486.95	0.0037	0.9547
1A3b	1A3b_DERV	N_2O	322.92	322.92	0.0032	0.9579
1B2	1B2_Offshore Oil& Gas	CH_4	2176.71	2176.71	0.0031	0.9610
1B2	1B2_Oil & Natural Gas	CO_2	5777.92	5777.92	0.0030	0.9640
2C	2C_Metal_Industries	CO_2	7400.69	7400.69	0.0028	0.9668
1A3a	1A3a_Aviation Fuel	CO_2	1837.04	1837.04	0.0028	0.9696
4B	4B_Cropland	N_2O	1019.85	1019.85	0.0027	0.9723
5C	5C_Waste Incineration	CO_2	1363.29	1363.29	0.0024	0.9747
2D	2D_Non Energy Products from Fuels and Solvent Use	CO_2	553.12	553.12	0.0023	0.9770
1A3	1A3_Other diesel	CO_2	1679.92	1679.92	0.0019	0.9790
3B	3B_Manure Management	CH_4	4880.44	4880.44	0.0018	0.9807
4A	4A_Forest_land	N_2O	230.75	230.75	0.0018	0.9825
2A1	2A1_Cement Production	CO_2	7295.26	7295.26	0.0018	0.9843
3G	3G_Liming	CO_2	1015.18	1015.18	0.0016	0.9859
2F	2F_Product_Uses_as_Substitutes_for_ODS	HFCs	1407.19	1407.19	0.0013	0.9872

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
3H	3H_Urea_application_to_agriculture	CO_2	327.53	327.53	0.0012	0.9884
1A4	1A4_Peat	CO_2	488.50	488.50	0.0012	0.9896
1B1	1B1_Solid Fuel Transformation	CO_2	1698.56	1698.56	0.0010	0.9905
1A3d	1A3d_Marine fuel	N_2O	103.71	103.71	0.0009	0.9915
1A3b	1A3b_DERV	CH_4	88.75	88.75	0.0009	0.9923
5C	5C_Waste Incineration	N_2O	47.47	47.47	0.0008	0.9932
4E	4E_Settlements	N_2O	584.71	584.71	0.0007	0.9938
2A2	2A2_Lime Production	CO_2	1462.05	1462.05	0.0006	0.9944
2G	2G_Other_Product_Manufacture_and_Use	PFCs	149.16	149.16	0.0005	0.9949
5C	5C_Waste Incineration	CH_4	137.63	137.63	0.0005	0.9955
2C	2C_Metal_Industries	PFCs	333.43	333.43	0.0005	0.9960
1A3	1A3_Other diesel	N_2O	41.61	41.61	0.0004	0.9964
2G	2G_Other_Product_Manufacture_and_Use	SF_6	877.33	877.33	0.0004	0.9968
3F	3F_Field Burning	CH_4	186.57	186.57	0.0004	0.9972
2B	2B_Chemical Industry	CH_4	213.73	213.73	0.0003	0.9975
1B2	1B2_Oil & Natural Gas	N_2O	40.75	40.75	0.0003	0.9978
2A	2A_Minerals_industry	CH_4	31.11	31.11	0.0002	0.9980
1A	1A_Other (waste)	CO_2	229.09	229.09	0.0002	0.9983
2C	2C_Metal_Industries	SF_6	387.17	387.17	0.0002	0.9985
2A4	2A4_Other_process_uses_of_carbonates	CO_2	640.93	640.93	0.0002	0.9987
2C	2C_Iron & Steel	N_2O	17.74	17.74	0.0002	0.9988
1A4	1A4_Petroleum Coke	CO_2	81.64	81.64	0.0002	0.9990
2A3	2A3_Glass_production	CO_2	405.54	405.54	0.0002	0.9991
1A3a	1A3a_Aviation Fuel	N_2O	17.39	17.39	0.0001	0.9993
2C	2C_Iron & Steel Production	CH_4	36.89	36.89	0.0001	0.9994
3F	3F_Field Burning	N_2O	57.66	57.66	0.0001	0.9995
2B	2B_Chemical_industry	PFCs	113.90	113.90	0.0001	0.9996
4C	4C_Grassland	N_2O	10.36	10.36	0.0001	0.9997

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
5B	5B_Biological_treatment_of_solid_waste	CH_4	5.48	5.48	0.0000	0.9997
4C	4C_Grassland	CH_4	10.00	10.00	0.0000	0.9998
1A3d	1A3d_Marine fuel	CH_4	3.66	3.66	0.0000	0.9998
4D	4D_Grassland	N_2O	4.13	4.13	0.0000	0.9998
2E	2E_Electronics_Industry	HFCs	8.73	8.73	0.0000	0.9999
5B	5B_Biological_treatment_of_solid_waste	N_2O	3.92	3.92	0.0000	0.9999
1A3	1A3_Other diesel	CH_4	2.75	2.75	0.0000	0.9999
1A3a	1A3a_Aviation Fuel	CH_4	4.13	4.13	0.0000	1.0000
2B8	2B8_Petrochemical_and_Carbon_Black_Production	N_2O	2.10	2.10	0.0000	1.0000
4E	4E_Settlements	CH_4	3.05	3.05	0.0000	1.0000
4A	4A_Forest_Land	CH_4	2.92	2.92	0.0000	1.0000
2E	2E_Electronics_Industry	NF_3	0.83	0.83	0.0000	1.0000
2B1	2B1_Ammonia_Production	N_2O	0.31	0.31	0.0000	1.0000
2F	2F_Product_Uses_as_Substitutes_for_ODS	PFCs	0.44	0.44	0.0000	1.0000
1B1	1B1_Fugitive_Emissions_from_Solid_Fuels	N_2O	0.09	0.09	0.0000	1.0000
4B	4B_Cropland	CH_4	0.09	0.09	0.0000	1.0000
1B1	1B1_Solid Fuel Transformation	CH_4	0.07	0.07	0.0000	1.0000
1A3c	1A3c_Coal	CO_2	0.00	0.00	0.0000	1.0000
4F	4F Other Land	CO_2	0.00	0.00	0.0000	1.0000
1A3c	1A3c_Coal	CH_4	0.00	0.00	0.0000	1.0000
2D	2D_Non-energy_Products_from_Fuels_and_Solvent_Use	CH_4	0.00	0.00	0.0000	1.0000
1A3c	1A3c_Coal	N_2O	0.00	0.00	0.0000	1.0000
2D	2D_Non-energy_Products_from_Fuels_and_Solvent_Use	N_2O	0.00	0.00	0.0000	1.0000
2C	2C_Metal_Industries	HFCs	0.00	0.00	0.0000	1.0000

Table A 1.4.2 Approach 2 Level Assessment for the latest reported year (including LULUCF) with Key Categories Shaded in Grey

IPCC Code	IPCC Category	Gas	2016 emissions (Gg CO_2e)	Absolute value of 2016 emissions (Gg CO_2e)	Level Assessment	Cumulative Total
4A	4A Forest Land	CO_2	-24050.29	24050.29	0.1244	0.1244
5A	5A_Solid Waste Disposal	CH_4	14016.99	14016.99	0.1002	0.2246
3D	3D_Agricultural Soils	N_2O	11349.08	11349.08	0.0893	0.3140
4B	4B_Cropland	CO_2	11504.76	11504.76	0.0765	0.3905
4C	4C_Grassland	CO_2	-9371.91	9371.91	0.0693	0.4597
4E	4E Settlements	CO_2	6422.08	6422.08	0.0475	0.5072
1A	1A_Natural Gas	CO_2	162504.72	162504.72	0.0470	0.5542
3A	3A_Enteric Fermentation	CH_4	22129.07	22129.07	0.0449	0.5991
1A	1A_(Stationary)_Oil	CO_2	44562.54	44562.54	0.0419	0.6410
3B	3B_Manure Management	N_2O	2895.67	2895.67	0.0291	0.6701
2F	2F_Product_Uses_as_Substitutes_for_ODS	HFCs	15264.79	15264.79	0.0266	0.6967
5D	5D_Wastewater Handling	N_2O	719.86	719.86	0.0264	0.7231
1A3b	1A3b_DERV	CO_2	76795.02	76795.02	0.0254	0.7484
1A1 & 1A2 & 1A4 & 1A5	1A1 & 1A2 & 1A4 & 1A5_Other Combustion	N_2O	2294.55	2294.55	0.0195	0.7679
1A	1A_Coal	CO_2	43827.78	43827.78	0.0187	0.7866
1A3b	1A3b_DERV	N_2O	967.70	967.70	0.0186	0.8052
2G	2G_Other_Product_Manufacture_and_Use	N_2O	827.46	827.46	0.0173	0.8225
5B	5B_Biological_treatment_of_solid_waste	CH_4	1070.53	1070.53	0.0164	0.8389
1A3d	1A3d_Marine fuel	CO_2	5424.06	5424.06	0.0144	0.8533
5D	5D_Wastewater Handling	CH_4	3421.01	3421.01	0.0136	0.8669
2B	2B_Chemical industries	CO_2	4522.54	4522.54	0.0124	0.8793
1A3b	1A3b_Gasoline/ LPG	CO_2	36568.31	36568.31	0.0120	0.8914
1B2	1B2_Natural Gas Transmission	CH_4	3782.53	3782.53	0.0113	0.9027
5B	5B_Biological_treatment_of_solid_waste	N_2O	657.72	657.72	0.0092	0.9119
1A	1A_Other (waste)	CO_2	4018.69	4018.69	0.0080	0.9199

IPCC Code	IPCC Category	Gas	2016 emissions (Gg CO_2e)	Absolute value of 2016 emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A1 & 1A2 & 1A4 & 1A5	1A1 & 1A2 & 1A4 & 1A5_Other Combustion	CH_4	1430.30	1430.30	0.0077	0.9276
4	4_Indirect_LULUCF_Emissions	N_2O	248.33	248.33	0.0061	0.9336
4G	4G Other Activities	CO_2	-844.44	844.44	0.0056	0.9392
1A3	1A3_Other diesel	CO_2	2473.98	2473.98	0.0055	0.9448
1A3a	1A3a_Aviation Fuel	CO_2	1813.18	1813.18	0.0053	0.9501
4D	4D Wetland	CO_2	319.71	319.71	0.0047	0.9548
1B2	1B2_Oil & Natural Gas	CO_2	4115.18	4115.18	0.0041	0.9589
3B	3B_Manure Management	CH_4	4336.19	4336.19	0.0031	0.9620
1B2	1B2_Offshore Oil& Gas	CH_4	1080.81	1080.81	0.0030	0.9650
3G	3G_Liming	CO_2	928.72	928.72	0.0029	0.9679
2D	2D_Non Energy Products from Fuels and Solvent Use	CO_2	352.37	352.37	0.0028	0.9707
3H	3H_Urea_application_to_agriculture	CO_2	365.57	365.57	0.0027	0.9734
4B	4B_Cropland	N_2O	476.64	476.64	0.0025	0.9759
4A	4A_Forest_land	N_2O	152.39	152.39	0.0023	0.9782
2A1	2A1_Cement Production	CO_2	4553.32	4553.32	0.0021	0.9803
2C	2C_Metal_Industries	CO_2	2481.47	2481.47	0.0018	0.9821
1A3	1A3_Other diesel	N_2O	82.22	82.22	0.0016	0.9837
1B1	1B1_Coal Mining	CH_4	506.55	506.55	0.0015	0.9852
5C	5C_Waste Incineration	N_2O	41.33	41.33	0.0014	0.9866
1A3d	1A3d_Marine fuel	N_2O	68.57	68.57	0.0012	0.9878
2G	2G_Other_Product_Manufacture_and_Use	PFCs	168.48	168.48	0.0012	0.9890
4E	4E_Settlements	N_2O	526.89	526.89	0.0012	0.9901
1A3b	1A3b_Gasoline/ LPG	N_2O	104.77	104.77	0.0012	0.9913
1A4	1A4_Petroleum Coke	CO_2	278.57	278.57	0.0010	0.9923
1A3b	1A3b_Gasoline/ LPG	CH_4	90.12	90.12	0.0010	0.9933
5C	5C_Waste Incineration	CO_2	283.37	283.37	0.0010	0.9943
2A2	2A2_Lime Production	CO_2	1021.20	1021.20	0.0008	0.9950
4C	4C_Grassland	N_2O	37.62	37.62	0.0006	0.9956

IPCC Code	IPCC Category	Gas	2016 emissions (Gg CO_2e)	Absolute value of 2016 emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1B2	1B2_Oil & Natural Gas	N_2O	36.06	36.06	0.0006	0.9962
2G	2G_Other_Product_Manufacture_and_Use	SF_6	431.72	431.72	0.0004	0.9966
1B1	1B1_Solid Fuel Transformation	CO_2	348.63	348.63	0.0004	0.9969
2B2	2B2_Nitric Acid Production	N_2O	24.73	24.73	0.0004	0.9973
1A3a	1A3a_Aviation Fuel	N_2O	17.16	17.16	0.0003	0.9976
2A3	2A3_Glass_production	CO_2	360.75	360.75	0.0003	0.9978
2B	2B_Chemical_industry	PFCs	171.18	171.18	0.0003	0.9981
1A3b	1A3b_DERV	CH_4	11.31	11.31	0.0002	0.9983
2B	2B_Chemical Industry	CH_4	73.02	73.02	0.0002	0.9985
2A4	2A4_Other_process_uses_of_carbonates	CO_2	391.24	391.24	0.0002	0.9987
4C	4C_Grassland	CH_4	23.63	23.63	0.0002	0.9989
2E	2E_Electronics_Industry	HFCs	19.25	19.25	0.0001	0.9991
1A3d	1A3d_Marine fuel	CH_4	6.04	6.04	0.0001	0.9992
2C	2C_Iron & Steel	N_2O	6.36	6.36	0.0001	0.9993
1A3c	1A3c_Coal	CO_2	35.72	35.72	0.0001	0.9994
2A	2A_Minerals_industry	CH_4	5.99	5.99	0.0001	0.9995
4E	4E_Settlements	CH_4	10.66	10.66	0.0001	0.9996
2C	2C_Metal_Industries	SF_6	75.31	75.31	0.0001	0.9997
2C	2C_Iron & Steel Production	CH_4	10.69	10.69	0.0001	0.9997
5C	5C_Waste Incineration	CH_4	9.89	9.89	0.0001	0.9998
1A3	1A3_Other diesel	CH_4	2.33	2.33	0.0000	0.9998
2C	2C_Metal_Industries	PFCs	14.27	14.27	0.0000	0.9999
1A4	1A4_Peat	CO_2	6.34	6.34	0.0000	0.9999
2B8	2B8_Petrochemical_and_Carbon_Black_Production	N_2O	1.48	1.48	0.0000	0.9999
1A3c	1A3c_Coal	CH_4	0.94	0.94	0.0000	1.0000
1A3a	1A3a_Aviation Fuel	CH_4	1.31	1.31	0.0000	1.0000
2B	2B_Chemical_industry	HFCs	7.51	7.51	0.0000	1.0000
4D	4D_Grassland	N_2O	0.30	0.30	0.0000	1.0000
2C	2C_Metal_Industries	HFCs	2.20	2.20	0.0000	1.0000

IPCC Code	IPCC Category	Gas	2016 emissions (Gg CO_2e)	Absolute value of 2016 emissions (Gg CO_2e)	Level Assessment	Cumulative Total
2E	2E_Electronics_Industry	NF_3	0.48	0.48	0.0000	1.0000
4A	4A_Forest_Land	CH_4	0.40	0.40	0.0000	1.0000
2B1	2B1_Ammonia_Production	N_2O	0.30	0.30	0.0000	1.0000
1A3c	1A3c_Coal	N_2O	0.09	0.09	0.0000	1.0000
4B	4B_Cropland	CH_4	0.05	0.05	0.0000	1.0000
1B1	1B1_Fugitive_Emissions_from_Solid_Fuels	N_2O	0.02	0.02	0.0000	1.0000
1B1	1B1_Solid Fuel Transformation	CH_4	0.02	0.02	0.0000	1.0000
4F	4F Other Land	CO_2	0.00	0.00	0.0000	1.0000
2D	2D_Non-energy_Products_from_Fuels_and_Solvent_Use	CH_4	0.00	0.00	0.0000	1.0000
3F	3F_Field Burning	CH_4	0.00	0.00	0.0000	1.0000
2B3	2B3_Adipic Acid Production	N_2O	0.00	0.00	0.0000	1.0000
2D	2D_Non-energy_Products_from_Fuels_and_Solvent_Use	N_2O	0.00	0.00	0.0000	1.0000
3F	3F_Field Burning	N_2O	0.00	0.00	0.0000	1.0000
2F	2F_Product_Uses_as_Substitutes_for_ODS	PFCs	0.00	0.00	0.0000	1.0000

Table A 1.4.3 Approach 2 Level Assessment for Base year (not including LULUCF) with Key Categories Shaded in Grey

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
5A	5A_Solid Waste Disposal	CH_4	60432.98	60432.98	0.2701	0.2701
2B3	2B3_Adipic Acid Production	N_2O	19934.61	19934.61	0.1842	0.4543
3D	3D_Agricultural Soils	N_2O	13762.28	13762.28	0.0677	0.5220
1A	1A_Coal	CO_2	243845.45	243845.45	0.0649	0.5869
1A	1A_(Stationary)_Oil	CO_2	95348.82	95348.82	0.0561	0.6430
1B1	1B1_Coal Mining	CH_4	21826.78	21826.78	0.0405	0.6835
2B2	2B2_Nitric Acid Production	N_2O	3860.26	3860.26	0.0358	0.7194
3A	3A_Enteric Fermentation	CH_4	26252.83	26252.83	0.0333	0.7527

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
3B	3B_Manure Management	N_2O	3518.14	3518.14	0.0221	0.7748
1A	1A_Natural Gas	CO_2	106944.95	106944.95	0.0193	0.7941
1B2	1B2_Natural Gas Transmission	CH_4	10168.33	10168.33	0.0190	0.8131
1A1 & 1A2 & 1A4 & 1A5	1A1 & 1A2 & 1A4 & 1A5_Other Combustion	N_2O	3415.05	3415.05	0.0181	0.8312
5D	5D_Wastewater Handling	N_2O	783.59	783.59	0.0180	0.8492
2B	2B_Chemical_industry	HFCs	17680.04	17680.04	0.0163	0.8655
1A3b	1A3b_Gasoline/ LPG	CO_2	75562.72	75562.72	0.0155	0.8810
1A3d	1A3d_Marine fuel	CO_2	7611.13	7611.13	0.0126	0.8937
2B	2B_Chemical industries	CO_2	6767.84	6767.84	0.0116	0.9053
5D	5D_Wastewater Handling	CH_4	4219.05	4219.05	0.0105	0.9158
1A3b	1A3b_Gasoline/ LPG	CH_4	1157.96	1157.96	0.0080	0.9238
2G	2G_Other_Product_Manufacture_and_Use	N_2O	593.57	593.57	0.0078	0.9316
1A3b	1A3b_DERV	CO_2	33005.80	33005.80	0.0068	0.9384
1A3b	1A3b_Gasoline/ LPG	N_2O	989.41	989.41	0.0068	0.9452
1A1 & 1A2 & 1A4 & 1A5	1A1 & 1A2 & 1A4 & 1A5_Other Combustion	CH_4	1911.40	1911.40	0.0064	0.9516
1A3b	1A3b_DERV	N_2O	322.92	322.92	0.0039	0.9555
1B2	1B2_Offshore Oil& Gas	CH_4	2176.71	2176.71	0.0038	0.9592
1B2	1B2_Oil & Natural Gas	CO_2	5777.92	5777.92	0.0036	0.9629
2C	2C_Metal_Industries	CO_2	7400.69	7400.69	0.0034	0.9663
1A3a	1A3a_Aviation Fuel	CO_2	1837.04	1837.04	0.0034	0.9696
5C	5C_Waste Incineration	CO_2	1363.29	1363.29	0.0029	0.9725
2D	2D_Non Energy Products from Fuels and Solvent Use	CO_2	553.12	553.12	0.0028	0.9753
1A3	1A3_Other diesel	CO_2	1679.92	1679.92	0.0023	0.9777
3B	3B_Manure Management	CH_4	4880.44	4880.44	0.0022	0.9799
2A1	2A1_Cement Production	CO_2	7295.26	7295.26	0.0021	0.9820
3G	3G_Liming	CO_2	1015.18	1015.18	0.0020	0.9839

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
2F	2F_Product_Uses_as_Substitutes_for_ODS	HFCs	1407.19	1407.19	0.0015	0.9855
3H	3H_Urea_application_to_agriculture	CO_2	327.53	327.53	0.0015	0.9870
1A4	1A4_Peat	CO_2	488.50	488.50	0.0014	0.9884
1B1	1B1_Solid Fuel Transformation	CO_2	1698.56	1698.56	0.0012	0.9896
1A3d	1A3d_Marine fuel	N_2O	103.71	103.71	0.0011	0.9907
1A3b	1A3b_DERV	CH_4	88.75	88.75	0.0011	0.9918
5C	5C_Waste Incineration	N_2O	47.47	47.47	0.0010	0.9928
2A2	2A2_Lime Production	CO_2	1462.05	1462.05	0.0007	0.9934
2G	2G_Other_Product_Manufacture_and_Use	PFCs	149.16	149.16	0.0006	0.9941
5C	5C_Waste Incineration	CH_4	137.63	137.63	0.0006	0.9947
2C	2C_Metal_Industries	PFCs	333.43	333.43	0.0006	0.9953
1A3	1A3_Other diesel	N_2O	41.61	41.61	0.0005	0.9958
2G	2G_Other_Product_Manufacture_and_Use	SF_6	877.33	877.33	0.0005	0.9963
3F	3F_Field Burning	CH_4	186.57	186.57	0.0004	0.9968
2B	2B_Chemical Industry	CH_4	213.73	213.73	0.0004	0.9972
1B2	1B2_Oil & Natural Gas	N_2O	40.75	40.75	0.0004	0.9976
2A	2A_Minerals_industry	CH_4	31.11	31.11	0.0003	0.9978
1A	1A_Other (waste)	CO_2	229.09	229.09	0.0003	0.9981
2C	2C_Metal_Industries	SF_6	387.17	387.17	0.0003	0.9984
2A4	2A4_Other_process_uses_of_carbonates	CO_2	640.93	640.93	0.0002	0.9986
2C	2C_Iron & Steel	N_2O	17.74	17.74	0.0002	0.9988
1A4	1A4_Petroleum Coke	CO_2	81.64	81.64	0.0002	0.9990
2A3	2A3_Glass_production	CO_2	405.54	405.54	0.0002	0.9992
1A3a	1A3a_Aviation Fuel	N_2O	17.39	17.39	0.0002	0.9993
2C	2C_Iron & Steel Production	CH_4	36.89	36.89	0.0002	0.9995
3F	3F_Field Burning	N_2O	57.66	57.66	0.0001	0.9996
2B	2B_Chemical_industry	PFCs	113.90	113.90	0.0001	0.9998

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
5B	5B_Biological_treatment_of_solid_waste	CH_4	5.48	5.48	0.0001	0.9998
1A3d	1A3d_Marine fuel	CH_4	3.66	3.66	0.0000	0.9998
2E	2E_Electronics_Industry	HFCs	8.73	8.73	0.0000	0.9999
5B	5B_Biological_treatment_of_solid_waste	N_2O	3.92	3.92	0.0000	0.9999
1A3	1A3_Other diesel	CH_4	2.75	2.75	0.0000	1.0000
1A3a	1A3a_Aviation Fuel	CH_4	4.13	4.13	0.0000	1.0000
2B8	2B8_Petrochemical_and_Carbon_Black_Production	N_2O	2.10	2.10	0.0000	1.0000
2E	2E_Electronics_Industry	NF_3	0.83	0.83	0.0000	1.0000
2B1	2B1_Ammonia_Production	N_2O	0.31	0.31	0.0000	1.0000
2F	2F_Product_Uses_as_Substitutes_for_ODS	PFCs	0.44	0.44	0.0000	1.0000
1B1	1B1_Fugitive_Emissions_from_Solid_Fuels	N_2O	0.09	0.09	0.0000	1.0000
1B1	1B1_Solid Fuel Transformation	CH_4	0.07	0.07	0.0000	1.0000
1A3c	1A3c_Coal	CO_2	0.00	0.00	0.0000	1.0000
1A3c	1A3c_Coal	CH_4	0.00	0.00	0.0000	1.0000
2D	2D_Non-energy_Products_from_Fuels_and_Solvent_Use	CH_4	0.00	0.00	0.0000	1.0000
1A3c	1A3c_Coal	N_2O	0.00	0.00	0.0000	1.0000
2D	2D_Non-energy_Products_from_Fuels_and_Solvent_Use	N_2O	0.00	0.00	0.0000	1.0000
2C	2C_Metal_Industries	HFCs	0.00	0.00	0.0000	1.0000

Table A 1.4.4 Approach 2 Level Assessment for the latest reported year (not including LULUCF) with Key Categories Shaded in Grey

IPCC Code	IPCC Category	Gas	2016 emissions (Gg CO_2e)	Absolute value of 2016 emissions (Gg CO_2e)	Level Assessment	Cumulative Total
5A	5A_Solid Waste Disposal	CH_4	14016.99	14016.99	0.1520	0.1520
3D	3D_Agricultural Soils	N_2O	11349.08	11349.08	0.1355	0.2876
1A	1A_Natural Gas	CO_2	162504.72	162504.72	0.0713	0.3588

IPCC Code	IPCC Category	Gas	2016 emissions (Gg CO_2e)	Absolute value of 2016 emissions (Gg CO_2e)	Level Assessment	Cumulative Total
3A	3A_Enteric Fermentation	CH_4	22129.07	22129.07	0.0681	0.4269
1A	1A_(Stationary)_Oil	CO_2	44562.54	44562.54	0.0636	0.4905
3B	3B_Manure Management	N_2O	2895.67	2895.67	0.0442	0.5347
2F	2F_Product_Uses_as_Substitutes_for_ODS	HFCs	15264.79	15264.79	0.0403	0.5750
5D	5D_Wastewater Handling	N_2O	719.86	719.86	0.0400	0.6150
1A3b	1A3b_DERV	CO_2	76795.02	76795.02	0.0385	0.6535
1A1 & 1A2 & 1A4 & 1A5	1A1 & 1A2 & 1A4 & 1A5_Other Combustion	N_2O	2294.55	2294.55	0.0296	0.6831
1A	1A_Coal	CO_2	43827.78	43827.78	0.0283	0.7114
1A3b	1A3b_DERV	N_2O	967.70	967.70	0.0282	0.7396
2G	2G_Other_Product_Manufacture_and_Use	N_2O	827.46	827.46	0.0262	0.7658
5B	5B_Biological_treatment_of_solid_waste	CH_4	1070.53	1070.53	0.0249	0.7908
1A3d	1A3d_Marine fuel	CO_2	5424.06	5424.06	0.0218	0.8126
5D	5D_Wastewater Handling	CH_4	3421.01	3421.01	0.0206	0.8332
2B	2B_Chemical industries	CO_2	4522.54	4522.54	0.0188	0.8521
1A3b	1A3b_Gasoline/ LPG	CO_2	36568.31	36568.31	0.0182	0.8703
1B2	1B2_Natural Gas Transmission	CH_4	3782.53	3782.53	0.0171	0.8875
5B	5B_Biological_treatment_of_solid_waste	N_2O	657.72	657.72	0.0140	0.9014
1A	1A_Other (waste)	CO_2	4018.69	4018.69	0.0122	0.9136
1A1 & 1A2 & 1A4 & 1A5	1A1 & 1A2 & 1A4 & 1A5_Other Combustion	CH_4	1430.30	1430.30	0.0116	0.9253
1A3	1A3_Other diesel	CO_2	2473.98	2473.98	0.0084	0.9336
1A3a	1A3a_Aviation Fuel	CO_2	1813.18	1813.18	0.0081	0.9417
1B2	1B2_Oil & Natural Gas	CO_2	4115.18	4115.18	0.0063	0.9480
3B	3B_Manure Management	CH_4	4336.19	4336.19	0.0047	0.9527
1B2	1B2_Offshore Oil& Gas	CH_4	1080.81	1080.81	0.0045	0.9572
3G	3G_Liming	CO_2	928.72	928.72	0.0044	0.9615

IPCC Code	IPCC Category	Gas	2016 emissions (Gg CO_2e)	Absolute value of 2016 emissions (Gg CO_2e)	Level Assessment	Cumulative Total
2D	2D_Non Energy Products from Fuels and Solvent Use	CO_2	352.37	352.37	0.0043	0.9659
3H	3H_Urea_application_to_agriculture	CO_2	365.57	365.57	0.0041	0.9700
2A1	2A1_Cement Production	CO_2	4553.32	4553.32	0.0032	0.9732
2C	2C_Metal_Industries	CO_2	2481.47	2481.47	0.0028	0.9760
1A3	1A3_Other diesel	N_2O	82.22	82.22	0.0024	0.9784
1B1	1B1_Coal Mining	CH_4	506.55	506.55	0.0023	0.9806
5C	5C_Waste Incineration	N_2O	41.33	41.33	0.0021	0.9828
1A3d	1A3d_Marine fuel	N_2O	68.57	68.57	0.0018	0.9846
2G	2G_Other_Product_Manufacture_and_Use	PFCs	168.48	168.48	0.0018	0.9863
1A3b	1A3b_Gasoline/ LPG	N_2O	104.77	104.77	0.0017	0.9881
1A4	1A4_Petroleum Coke	CO_2	278.57	278.57	0.0016	0.9897
1A3b	1A3b_Gasoline/ LPG	CH_4	90.12	90.12	0.0015	0.9912
5C	5C_Waste Incineration	CO_2	283.37	283.37	0.0015	0.9926
2A2	2A2_Lime Production	CO_2	1021.20	1021.20	0.0011	0.9938
1B2	1B2_Oil & Natural Gas	N_2O	36.06	36.06	0.0008	0.9946
2G	2G_Other_Product_Manufacture_and_Use	SF_6	431.72	431.72	0.0006	0.9952
1B1	1B1_Solid Fuel Transformation	CO_2	348.63	348.63	0.0006	0.9958
2B2	2B2_Nitric Acid Production	N_2O	24.73	24.73	0.0006	0.9963
1A3a	1A3a_Aviation Fuel	N_2O	17.16	17.16	0.0004	0.9968
2A3	2A3_Glass_production	CO_2	360.75	360.75	0.0004	0.9972
2B	2B_Chemical_industry	PFCs	171.18	171.18	0.0004	0.9976
1A3b	1A3b_DERV	CH_4	11.31	11.31	0.0003	0.9979
2B	2B_Chemical Industry	CH_4	73.02	73.02	0.0003	0.9982
2A4	2A4_Other_process_uses_of_carbonates	CO_2	391.24	391.24	0.0003	0.9985
2E	2E_Electronics_Industry	HFCs	19.25	19.25	0.0002	0.9987
1A3d	1A3d_Marine fuel	CH_4	6.04	6.04	0.0002	0.9989
2C	2C_Iron & Steel	N_2O	6.36	6.36	0.0002	0.9991
1A3c	1A3c_Coal	CO_2	35.72	35.72	0.0002	0.9992

IPCC Code	IPCC Category	Gas	2016 emissions (Gg CO_2e)	Absolute value of 2016 emissions (Gg CO_2e)	Level Assessment	Cumulative Total
2A	2A_Minerals_industry	CH_4	5.99	5.99	0.0001	0.9994
2C	2C_Metal_Industries	SF_6	75.31	75.31	0.0001	0.9995
2C	2C_Iron & Steel Production	CH_4	10.69	10.69	0.0001	0.9996
5C	5C_Waste Incineration	CH_4	9.89	9.89	0.0001	0.9997
1A3	1A3_Other diesel	CH_4	2.33	2.33	0.0001	0.9998
2C	2C_Metal_Industries	PFCs	14.27	14.27	0.0001	0.9998
1A4	1A4_Peat	CO_2	6.34	6.34	0.0000	0.9999
2B8	2B8_Petrochemical_and_Carbon_Black_Production	N_2O	1.48	1.48	0.0000	0.9999
1A3c	1A3c_Coal	CH_4	0.94	0.94	0.0000	0.9999
1A3a	1A3a_Aviation Fuel	CH_4	1.31	1.31	0.0000	1.0000
2B	2B_Chemical_industry	HFCs	7.51	7.51	0.0000	1.0000
2C	2C_Metal_Industries	HFCs	2.20	2.20	0.0000	1.0000
2E	2E_Electronics_Industry	NF_3	0.48	0.48	0.0000	1.0000
2B1	2B1_Ammonia_Production	N_2O	0.30	0.30	0.0000	1.0000
1A3c	1A3c_Coal	N_2O	0.09	0.09	0.0000	1.0000
1B1	1B1_Fugitive_Emissions_from_Solid_Fuels	N_2O	0.02	0.02	0.0000	1.0000
1B1	1B1_Solid Fuel Transformation	CH_4	0.02	0.02	0.0000	1.0000
2D	2D_Non-energy_Products_from_Fuels_and_Solvent_Use	CH_4	0.00	0.00	0.0000	1.0000
3F	3F_Field Burning	CH_4	0.00	0.00	0.0000	1.0000
2B3	2B3_Adipic Acid Production	N_2O	0.00	0.00	0.0000	1.0000
2D	2D_Non-energy_Products_from_Fuels_and_Solvent_Use	N_2O	0.00	0.00	0.0000	1.0000
3F	3F_Field Burning	N_2O	0.00	0.00	0.0000	1.0000
2F	2F_Product_Uses_as_Substitutes_for_ODS	PFCs	0.00	0.00	0.0000	1.0000

Table A 1.4.5 Approach 2 Assessment for Trend (including LULUCF) with Key Categories Shaded in Grey

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Trend Assessment with Uncertainty	% Contribution to Trend Uncertainty	Cumulative Total
2B3	2B3_Adipic Acid Production	N_2O	19934.61	0.00	0.0137	22.5%	0.2247
5A	5A_Solid Waste Disposal	CH_4	60432.98	14016.99	0.0122	20.0%	0.4243
1A	1A_Coal	CO_2	243845.45	43827.78	0.0034	5.5%	0.4793
1B1	1B1_Coal Mining	CH_4	21826.78	506.55	0.0029	4.7%	0.5268
2B2	2B2_Nitric Acid Production	N_2O	3860.26	24.73	0.0026	4.3%	0.5700
1A	1A_Natural Gas	CO_2	106944.95	162504.72	0.0023	3.7%	0.6073
3D	3D_Agricultural Soils	N_2O	13762.28	11349.08	0.0020	3.3%	0.6404
2F	2F_Product_Uses_as_Substitutes_for_ODS	HFCs	1407.19	15264.79	0.0020	3.3%	0.6730
1A3b	1A3b_DERV	CO_2	33005.80	76795.02	0.0015	2.5%	0.6975
4B	4B_Cropland	CO_2	15033.60	11504.76	0.0014	2.3%	0.7204
4E	4E Settlements	CO_2	6901.20	6422.08	0.0014	2.3%	0.7430
5B	5B_Biological_treatment_of_solid_waste	CH_4	5.48	1070.53	0.0013	2.1%	0.7642
2B	2B_Chemical_industry	HFCs	17680.04	7.51	0.0012	2.0%	0.7841
1A3b	1A3b_DERV	N_2O	322.92	967.70	0.0012	1.9%	0.8035
3A	3A_Enteric Fermentation	CH_4	26252.83	22129.07	0.0011	1.8%	0.8210
4C	4C_Grassland	CO_2	-7756.55	-9371.91	0.0009	1.5%	0.8361
1A	1A_(Stationary)_Oil	CO_2	95348.82	44562.54	0.0009	1.4%	0.8502
2G	2G_Other_Product_Manufacture_and_Use	N_2O	593.57	827.46	0.0008	1.3%	0.8632
4G	4G Other Activities	CO_2	-1614.71	-844.44	0.0008	1.2%	0.8755
5D	5D_Wastewater Handling	N_2O	783.59	719.86	0.0008	1.2%	0.8878
5B	5B_Biological_treatment_of_solid_waste	N_2O	3.92	657.72	0.0007	1.2%	0.8997
3B	3B_Manure Management	N_2O	3518.14	2895.67	0.0007	1.1%	0.9105
1A	1A_Other (waste)	CO_2	229.09	4018.69	0.0006	1.0%	0.9205

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Trend Assessment with Uncertainty	% Contribution to Trend Uncertainty	Cumulative Total
1B2	1B2_Natural Gas Transmission	CH_4	10168.33	3782.53	0.0005	0.9%	0.9290
1A3b	1A3b_Gasoline/ LPG	CH_4	1157.96	90.12	0.0005	0.8%	0.9375
1A3b	1A3b_Gasoline/ LPG	N_2O	989.41	104.77	0.0004	0.7%	0.9443
5D	5D_Wastewater Handling	CH_4	4219.05	3421.01	0.0003	0.5%	0.9492
1A3	1A3_Other diesel	CO_2	1679.92	2473.98	0.0003	0.4%	0.9535
4A	4A Forest Land	CO_2	-17445.77	-24050.29	0.0002	0.4%	0.9573
1A3b	1A3b_Gasoline/ LPG	CO_2	75562.72	36568.31	0.0002	0.3%	0.9607
1A3d	1A3d_Marine fuel	CO_2	7611.13	5424.06	0.0002	0.3%	0.9639
1A1 & 1A2 & 1A4 & 1A5	1A1 & 1A2 & 1A4 & 1A5_Other Combustion	N_2O	3415.05	2294.55	0.0002	0.3%	0.9670
1A3a	1A3a_Aviation Fuel	CO_2	1837.04	1813.18	0.0002	0.3%	0.9698
5C	5C_Waste Incineration	CO_2	1363.29	283.37	0.0001	0.2%	0.9721
1A1 & 1A2 & 1A4 & 1A5	1A1 & 1A2 & 1A4 & 1A5_Other Combustion	CH_4	1911.40	1430.30	0.0001	0.2%	0.9742
2B	2B_Chemical industries	CO_2	6767.84	4522.54	0.0001	0.2%	0.9762
2C	2C_Metal_Industries	CO_2	7400.69	2481.47	0.0001	0.2%	0.9779
1A4	1A4_Peat	CO_2	488.50	6.34	0.0001	0.2%	0.9796
3H	3H_Urea_application_to_agriculture	CO_2	327.53	365.57	0.0001	0.2%	0.9813
1A3	1A3_Other diesel	N_2O	41.61	82.22	0.0001	0.1%	0.9827
3B	3B_Manure Management	CH_4	4880.44	4336.19	0.0001	0.1%	0.9841
3G	3G_Liming	CO_2	1015.18	928.72	0.0001	0.1%	0.9854
1A4	1A4_Petroleum Coke	CO_2	81.64	278.57	0.0001	0.1%	0.9865
1A3b	1A3b_DERV	CH_4	88.75	11.31	0.0001	0.1%	0.9875
1B2	1B2_Oil & Natural Gas	CO_2	5777.92	4115.18	0.0001	0.1%	0.9885
1B1	1B1_Solid Fuel Transformation	CO_2	1698.56	348.63	0.0001	0.1%	0.9894
4B	4B_Cropland	N_2O	1019.85	476.64	0.0001	0.1%	0.9902
2G	2G_Other_Product_Manufacture_and_Use	PFCs	149.16	168.48	0.0000	0.1%	0.9909

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Trend Assessment with Uncertainty	% Contribution to Trend Uncertainty	Cumulative Total
1B2	1B2_Offshore Oil& Gas	CH_4	2176.71	1080.81	0.0000	0.1%	0.9917
2C	2C_Metal_Industries	PFCs	333.43	14.27	0.0000	0.1%	0.9924
5C	5C_Waste Incineration	CH_4	137.63	9.89	0.0000	0.1%	0.9930
4C	4C_Grassland	N_2O	10.36	37.62	0.0000	0.1%	0.9937
4D	4D Wetland	CO_2	486.95	319.71	0.0000	0.1%	0.9943
5C	5C_Waste Incineration	N_2O	47.47	41.33	0.0000	0.1%	0.9949
3F	3F_Field Burning	CH_4	186.57	0.00	0.0000	0.1%	0.9954
4E	4E_Settlements	N_2O	584.71	526.89	0.0000	0.1%	0.9960
4	4_Indirect_LULUCF_Emissions	N_2O	401.41	248.33	0.0000	0.0%	0.9963
4A	4A_Forest_land	N_2O	230.75	152.39	0.0000	0.0%	0.9967
2D	2D_Non Energy Products from Fuels and Solvent Use	CO_2	553.12	352.37	0.0000	0.0%	0.9969
1B2	1B2_Oil & Natural Gas	N_2O	40.75	36.06	0.0000	0.0%	0.9972
2A	2A_Minerals_industry	CH_4	31.11	5.99	0.0000	0.0%	0.9974
2C	2C_Metal_Industries	SF_6	387.17	75.31	0.0000	0.0%	0.9976
2B	2B_Chemical Industry	CH_4	213.73	73.02	0.0000	0.0%	0.9978
2B	2B_Chemical_industry	PFCs	113.90	171.18	0.0000	0.0%	0.9980
4C	4C_Grassland	CH_4	10.00	23.63	0.0000	0.0%	0.9982
1A3d	1A3d_Marine fuel	N_2O	103.71	68.57	0.0000	0.0%	0.9984
3F	3F_Field Burning	N_2O	57.66	0.00	0.0000	0.0%	0.9985
2A1	2A1_Cement Production	CO_2	7295.26	4553.32	0.0000	0.0%	0.9987
2A2	2A2_Lime Production	CO_2	1462.05	1021.20	0.0000	0.0%	0.9989
1A3a	1A3a_Aviation Fuel	N_2O	17.39	17.16	0.0000	0.0%	0.9990
1A3c	1A3c_Coal	CO_2	0.00	35.72	0.0000	0.0%	0.9991
2E	2E_Electronics_Industry	HFCs	8.73	19.25	0.0000	0.0%	0.9993
2A3	2A3_Glass_production	CO_2	405.54	360.75	0.0000	0.0%	0.9994
2C	2C_Iron & Steel Production	CH_4	36.89	10.69	0.0000	0.0%	0.9995
2G	2G_Other_Product_Manufacture_and_Use	SF_6	877.33	431.72	0.0000	0.0%	0.9996

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Trend Assessment with Uncertainty	% Contribution to Trend Uncertainty	Cumulative Total
1A3d	1A3d_Marine fuel	CH_4	3.66	6.04	0.0000	0.0%	0.9997
4E	4E_Settlements	CH_4	3.05	10.66	0.0000	0.0%	0.9998
2C	2C_Iron & Steel	N_2O	17.74	6.36	0.0000	0.0%	0.9999
4D	4D_Grassland	N_2O	4.13	0.30	0.0000	0.0%	0.9999
1A3c	1A3c_Coal	CH_4	0.00	0.94	0.0000	0.0%	0.9999
1A3	1A3_Other diesel	CH_4	2.75	2.33	0.0000	0.0%	0.9999
4A	4A_Forest_Land	CH_4	2.92	0.40	0.0000	0.0%	1.0000
1A3a	1A3a_Aviation Fuel	CH_4	4.13	1.31	0.0000	0.0%	1.0000
2A4	2A4_Other_process_uses_of_carbonates	CO_2	640.93	391.24	0.0000	0.0%	1.0000
2B8	2B8_Petrochemical_and_Carbon_Black_Production	N_2O	2.10	1.48	0.0000	0.0%	1.0000
2C	2C_Metal_Industries	HFCs	0.00	2.20	0.0000	0.0%	1.0000
1A3c	1A3c_Coal	N_2O	0.00	0.09	0.0000	0.0%	1.0000
2F	2F_Product_Uses_as_Substitutes_for_ODS	PFCs	0.44	0.00	0.0000	0.0%	1.0000
2B1	2B1_Ammonia_Production	N_2O	0.31	0.30	0.0000	0.0%	1.0000
1B1	1B1_Fugitive_Emissions_from_Solid_Fuels	N_2O	0.09	0.02	0.0000	0.0%	1.0000
1B1	1B1_Solid Fuel Transformation	CH_4	0.07	0.02	0.0000	0.0%	1.0000
2E	2E_Electronics_Industry	NF_3	0.83	0.48	0.0000	0.0%	1.0000
4B	4B_Cropland	CH_4	0.09	0.05	0.0000	0.0%	1.0000
4F	4F Other Land	CO_2	0.00	0.00	0.0000	0.0%	1.0000
2D	2D_Non-energy_Products_from_Fuels_and_Solvent_Use	CH_4	0.00	0.00	0.0000	0.0%	1.0000
2D	2D_Non-energy_Products_from_Fuels_and_Solvent_Use	N_2O	0.00	0.00	0.0000	0.0%	1.0000

Table A 1.4.6 Approach 2 Assessment for Trend (not including LULUCF) with Key Categories Shaded in Grey

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Trend Assessment with Uncertainty	% Contribution to Trend Uncertainty	Cumulative Total
2B3	2B3_Adipic Acid Production	N_2O	19934.61	0.00	0.0137	24.4%	0.2443
5A	5A_Solid Waste Disposal	CH_4	60432.98	14016.99	0.0122	21.7%	0.4614
1A	1A_Coal	CO_2	243845.45	43827.78	0.0034	6.0%	0.5212
1B1	1B1_Coal Mining	CH_4	21826.78	506.55	0.0029	5.2%	0.5728
2B2	2B2_Nitric Acid Production	N_2O	3860.26	24.73	0.0026	4.7%	0.6199
1A	1A_Natural Gas	CO_2	106944.95	162504.72	0.0023	4.1%	0.6604
3D	3D_Agricultural Soils	N_2O	13762.28	11349.08	0.0020	3.6%	0.6964
2F	2F_Product_Uses_as_Substitutes_for_ODS	HFCs	1407.19	15264.79	0.0020	3.5%	0.7318
1A3b	1A3b_DERV	CO_2	33005.80	76795.02	0.0015	2.7%	0.7585
5B	5B_Biological_treatment_of_solid_waste	CH_4	5.48	1070.53	0.0013	2.3%	0.7816
2B	2B_Chemical_industry	HFCs	17680.04	7.51	0.0012	2.2%	0.8033
1A3b	1A3b_DERV	N_2O	322.92	967.70	0.0012	2.1%	0.8243
3A	3A_Enteric Fermentation	CH_4	26252.83	22129.07	0.0011	1.9%	0.8434
1A	1A_(Stationary)_Oil	CO_2	95348.82	44562.54	0.0009	1.5%	0.8587
2G	2G_Other_Product_Manufacture_and_Use	N_2O	593.57	827.46	0.0008	1.4%	0.8728
5D	5D_Wastewater Handling	N_2O	783.59	719.86	0.0008	1.3%	0.8861
5B	5B_Biological_treatment_of_solid_waste	N_2O	3.92	657.72	0.0007	1.3%	0.8991
3B	3B_Manure Management	N_2O	3518.14	2895.67	0.0007	1.2%	0.9108
1A	1A_Other (waste)	CO_2	229.09	4018.69	0.0006	1.1%	0.9217
1B2	1B2_Natural Gas Transmission	CH_4	10168.33	3782.53	0.0005	0.9%	0.9310
1A3b	1A3b_Gasoline/ LPG	CH_4	1157.96	90.12	0.0005	0.9%	0.9402
1A3b	1A3b_Gasoline/ LPG	N_2O	989.41	104.77	0.0004	0.7%	0.9476
5D	5D_Wastewater Handling	CH_4	4219.05	3421.01	0.0003	0.5%	0.9529

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Trend Assessment with Uncertainty	% Contribution to Trend Uncertainty	Cumulative Total
1A3	1A3_Other diesel	CO_2	1679.92	2473.98	0.0003	0.5%	0.9575
1A3b	1A3b_Gasoline/ LPG	CO_2	75562.72	36568.31	0.0002	0.4%	0.9612
1A3d	1A3d_Marine fuel	CO_2	7611.13	5424.06	0.0002	0.4%	0.9647
1A1 & 1A2 & 1A4 & 1A5	1A1 & 1A2 & 1A4 & 1A5_Other Combustion	N_2O	3415.05	2294.55	0.0002	0.3%	0.9681
1A3a	1A3a_Aviation Fuel	CO_2	1837.04	1813.18	0.0002	0.3%	0.9712
5C	5C_Waste Incineration	CO_2	1363.29	283.37	0.0001	0.3%	0.9737
1A1 & 1A2 & 1A4 & 1A5	1A1 & 1A2 & 1A4 & 1A5_Other Combustion	CH_4	1911.40	1430.30	0.0001	0.2%	0.9760
2B	2B_Chemical industries	CO_2	6767.84	4522.54	0.0001	0.2%	0.9780
2C	2C_Metal_Industries	CO_2	7400.69	2481.47	0.0001	0.2%	0.9800
1A4	1A4_Peat	CO_2	488.50	6.34	0.0001	0.2%	0.9818
3H	3H_Urea_application_to_agriculture	CO_2	327.53	365.57	0.0001	0.2%	0.9836
1A3	1A3_Other diesel	N_2O	41.61	82.22	0.0001	0.2%	0.9852
3B	3B_Manure Management	CH_4	4880.44	4336.19	0.0001	0.1%	0.9867
3G	3G_Liming	CO_2	1015.18	928.72	0.0001	0.1%	0.9881
1A4	1A4_Petroleum Coke	CO_2	81.64	278.57	0.0001	0.1%	0.9893
1A3b	1A3b_DERV	CH_4	88.75	11.31	0.0001	0.1%	0.9904
1B2	1B2_Oil & Natural Gas	CO_2	5777.92	4115.18	0.0001	0.1%	0.9914
1B1	1B1_Solid Fuel Transformation	CO_2	1698.56	348.63	0.0001	0.1%	0.9924
2G	2G_Other_Product_Manufacture_and_Use	PFCs	149.16	168.48	0.0000	0.1%	0.9932
1B2	1B2_Offshore Oil& Gas	CH_4	2176.71	1080.81	0.0000	0.1%	0.9940
2C	2C_Metal_Industries	PFCs	333.43	14.27	0.0000	0.1%	0.9948
5C	5C_Waste Incineration	CH_4	137.63	9.89	0.0000	0.1%	0.9955
5C	5C_Waste Incineration	N_2O	47.47	41.33	0.0000	0.1%	0.9962
3F	3F_Field Burning	CH_4	186.57	0.00	0.0000	0.1%	0.9967
2D	2D_Non Energy Products from Fuels and Solvent Use	CO_2	553.12	352.37	0.0000	0.0%	0.9970

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Trend Assessment with Uncertainty	% Contribution to Trend Uncertainty	Cumulative Total
1B2	1B2_Oil & Natural Gas	N_2O	40.75	36.06	0.0000	0.0%	0.9973
2A	2A_Minerals_industry	CH_4	31.11	5.99	0.0000	0.0%	0.9976
2C	2C_Metal_Industries	SF_6	387.17	75.31	0.0000	0.0%	0.9978
2B	2B_Chemical Industry	CH_4	213.73	73.02	0.0000	0.0%	0.9980
2B	2B_Chemical_industry	PFCs	113.90	171.18	0.0000	0.0%	0.9982
1A3d	1A3d_Marine fuel	N_2O	103.71	68.57	0.0000	0.0%	0.9984
3F	3F_Field Burning	N_2O	57.66	0.00	0.0000	0.0%	0.9986
2A1	2A1_Cement Production	CO_2	7295.26	4553.32	0.0000	0.0%	0.9988
2A2	2A2_Lime Production	CO_2	1462.05	1021.20	0.0000	0.0%	0.9989
1A3a	1A3a_Aviation Fuel	N_2O	17.39	17.16	0.0000	0.0%	0.9991
1A3c	1A3c_Coal	CO_2	0.00	35.72	0.0000	0.0%	0.9992
2E	2E_Electronics_Industry	HFCs	8.73	19.25	0.0000	0.0%	0.9994
2A3	2A3_Glass_production	CO_2	405.54	360.75	0.0000	0.0%	0.9995
2C	2C_Iron & Steel Production	CH_4	36.89	10.69	0.0000	0.0%	0.9996
2G	2G_Other_Product_Manufacture_and_Use	SF_6	877.33	431.72	0.0000	0.0%	0.9997
1A3d	1A3d_Marine fuel	CH_4	3.66	6.04	0.0000	0.0%	0.9998
2C	2C_Iron & Steel	N_2O	17.74	6.36	0.0000	0.0%	0.9999
1A3c	1A3c_Coal	CH_4	0.00	0.94	0.0000	0.0%	0.9999
1A3	1A3_Other diesel	CH_4	2.75	2.33	0.0000	0.0%	1.0000
1A3a	1A3a_Aviation Fuel	CH_4	4.13	1.31	0.0000	0.0%	1.0000
2A4	2A4_Other_process_uses_of_carbonates	CO_2	640.93	391.24	0.0000	0.0%	1.0000
2B8	2B8_Petrochemical_and_Carbon_Black_Production	N_2O	2.10	1.48	0.0000	0.0%	1.0000
2C	2C_Metal_Industries	HFCs	0.00	2.20	0.0000	0.0%	1.0000
1A3c	1A3c_Coal	N_2O	0.00	0.09	0.0000	0.0%	1.0000
2F	2F_Product_Uses_as_Substitutes_for_ODS	PFCs	0.44	0.00	0.0000	0.0%	1.0000
2B1	2B1_Ammonia_Production	N_2O	0.31	0.30	0.0000	0.0%	1.0000

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Trend Assessment with Uncertainty	% Contribution to Trend Uncertainty	Cumulative Total
1B1	1B1_Fugitive_Emissions_from_Solid_Fuels	N_2O	0.09	0.02	0.0000	0.0%	1.0000
1B1	1B1_Solid Fuel Transformation	CH_4	0.07	0.02	0.0000	0.0%	1.0000
2E	2E_Electronics_Industry	NF_3	0.83	0.48	0.0000	0.0%	1.0000
2D	2D_Non-energy_Products_from_Fuels_and_Solvent_Use	CH_4	0.00	0.00	0.0000	0.0%	1.0000
2D	2D_Non-energy_Products_from_Fuels_and_Solvent_Use	N_2O	0.00	0.00	0.0000	0.0%	1.0000

A 1.5 KEY CATEGORY ANALYSIS (KCA) RANKING SYSTEM

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

The assessments used in this ranking exercise are only those *including* LULUCF, because if the additional *excluding* LULUCF assessments were also used, the LULUCF sectors would only be included in half of the assessments and would therefore give an unrepresentative weighting.

The results of this ranking are presented in **Table A 1.5.1.**

Table A 1.5.1 KCA Ranking

KCA rank	IPCC Code	IPCC Category	Greenhouse Gas
1	1A3b	Road transportation: liquid fuels	CO_2
2	1A1	Energy industries: solid fuels	CO_2
3	1A4	Other sectors: gaseous fuels	CO_2
4	5A	Solid waste disposal	CH_4
5	1A1	Energy industries: gaseous fuels	CO_2
6	1A1	Energy industries: liquid fuels	CO_2
7	1A2	Manufacturing industries and construction: gaseous fuels	CO_2

KCA rank	IPCC Code	IPCC Category	Greenhouse Gas
8	1A2	Manufacturing industries and construction: solid fuels	CO_2
9	3A1	Enteric fermentation from Cattle	CH_4
10	1A2	Manufacturing industries and construction: liquid fuels	CO_2
11	1A4	Other sectors: liquid fuels	CO_2
12	4B	Cropland	CO_2
13	3D	Agricultural soils	N_2O
14	1A4	Other sectors: solid fuels	CO_2
15	1B2	Oil and gas extraction	CH_4
16	4C	Grassland	CO_2
17	4E	Settlements	CO_2
18	4A	Forest land	CO_2
19	1B1	Coal mining and handling	CH_4
20	1A3d	Domestic Navigation: liquid fuels	CO_2
21	2F1	Refrigeration and air conditioning	HFCs, PFCs, SF_6 and NF_3
22	3A2	Enteric fermentation from Sheep	CH_4
23	3B1	Manure management from Cattle	CH_4
24	1B2	Oil and gas extraction	CO_2
25	1A5	Other: liquid fuels	CO_2
26	5D	Wastewater treatment and discharge	CH_4
27	2C1	Iron and steel production	CO_2
28	2B9	Fluorochemical production	HFCs, PFCs, SF_6 and NF_3
29	1A3c	Railways: liquid fuels	CO_2
30	2A1	Cement production	CO_2
31	4G	Harvested wood products	CO_2
32	3B1	Manure management from Cattle	N_2O
33	1A3a	Domestic aviation: liquid fuels	CO_2
34	2F4	Aerosols	HFCs, PFCs, SF_6 and NF_3
35	1A1	Energy industries: other fuels	CO_2
36	2B8	Petrochemical and carbon black production	CO_2
37	2B2	Nitric acid production	N_2O
38	2B3	Adipic acid production	N_2O
39	5B	Biological treatment of solid waste	CH_4

A 1.6 APPROACH USED TO IDENTIFY KP-LULUCF KEY CATEGORIES

From the 2010 NIR onwards, the NIR contains a list of the Key Categories for Land Use, Land-Use Change and Forestry Activities under the Kyoto Protocol. The description below explains the Key Category analysis for Article 3.3 activities and any elected activities under Article 3.4.

Five categories are considered to be key: Article 3.3 Afforestation and Reforestation (CO_2), Article 3.3 Deforestation (CO_2), Article 3.4 Forest Management (CO_2), Article 3.4 Cropland Management (CO_2) and Article 3.4 Grazing Land Management (CO_2). These have been assessed according to the 2006 IPCC good practice guidance for KP (Chapter 2, Section 2.3.6). The numbers have been compared with **Table A 1.4.2**. The key category analysis for the latest reported year based on level of emissions (including LULUCF) is given in section 11.6.1 of the main NIR.

A 1.7 USING THE UNCERTAINTY ANALYSIS TO PLAN IMPROVEMENTS IN THE PREPARATION OF THE INVENTORY

The key category analysis is used to prioritise and plan improvements. The approach the UK takes to achieve this is described in **Section 1.2.2.5**. **Table 1.7** to **Table 1.11** in **Chapter 1** show the key category summary tables.

A 1.8 TABLE NIR 3, AS CONTAINED IN THE ANNEX TO DECISION 6/CMP.3

Table A 1.7.1 below is Table NIR 3, containing a summary overview for Key Categories for Land Use, Land-Use Change and Forestry Activities under the Kyoto Protocol[3].

Table A 1.7.1 Table NIR 3. Summary overview for Key Categories for Land Use, Land-Use Change and Forestry Activities under the Kyoto Protocol

KEY CATEGORIES OF EMISSIONS AND REMOVALS	GAS	CRITERIA USED FOR KEY CATEGORY IDENTIFICATION			COMMENTS (3)
		Associated category in UNFCCC inventory (1) is key (indicate which category)	Category contribution is greater than the smallest category considered key in the UNFCCC inventory (1), (4) (including LULUCF)	Other (2)	
Specify key categories according to the national level of disaggregation used (1)					
Afforestation and Reforestation	CO_2	Land converted to forest land	No	Associated UNFCCC category (4A) is key	The associated UNFCCC inventory category is a key category for level.
Deforestation	CO_2	Land converted to cropland, Land converted to grassland, Land converted to settlements	Yes	Associated UNFCCC categories (4B2, 4C2 and 4E2) are key.	The associated UNFCCC inventory categories are key categories for level and trend.

[3] Table NIR 3 can be found in FCCC/KP/CMP/2007/9/Add.2.

KEY CATEGORIES OF EMISSIONS AND REMOVALS	GAS	CRITERIA USED FOR KEY CATEGORY IDENTIFICATION			COMMENTS (3)
		Associated category in UNFCCC inventory (1) is key (indicate which category)	Category contribution is greater than the smallest category considered key in the UNFCCC inventory (1), (4) (including LULUCF)	Other (2)	
Forest Management	CO_2	Forest land remaining forest land, Land converted to forest land	Yes	Associated UNFCCC category (4A) is key	The associated UNFCCC inventory category is a key category for level and the Forest Management category contribution is greater than the smallest UNFCCC key category.
Cropland Management	CO_2	Cropland remaining Cropland, Land converted to Cropland	Yes	Associated UNFCCC category (4B) is key.	The associated UNFCCC inventory category is a key category for level and trend and the Cropland Management category contribution is greater than the smallest UNFCCC key category.
Grazing Land Management	CO_2	Grassland remaining Grassland, Land converted to Grassland	Yes	Associated UNFCCC category (4C) is key.	The associated UNFCCC inventory category is a key category for level and trend and the Grazing Land Management category contribution is greater than the smallest UNFCCC key category.

(1) See section 5.4 of the IPCC good practice guidance for LULUCF

(2) This should include qualitative consideration as per Section 5.4.3 of the IPCC Good Practice Guidance for LULUCF or any other criteria

(3) Describe the criteria identifying the category as key

(4) If the emissions or removals of the category exceed the emissions of the smallest category identified as key in the UNFCCC inventory (including LULUCF), Parties should indicate YES. If not, Parties should indicate NO

ANNEX 2: Assessment of Uncertainty

Uncertainty estimates are calculated using two methods: Approach 1 (error propagation) and Approach 2 (Monte Carlo simulation). These are not to be confused with Approaches 1 and 2 for Key Category Analysis, of which Approach 2 KCA uses Approach 1 uncertainties to account for uncertainty in determining Key Categories.

The uncertainty assessment estimates uncertainties according to IPCC sector in addition to presenting estimates by direct greenhouse gas. Estimated uncertainty presented for the sector breakdown used in UK Official Statistics are not reported here, since the categories are not consistent with the requirements of the UK's commitments under the UNFCCC and Kyoto Protocol.

Uncertainty parameters for new sources and sources which have been significantly revised are reviewed each year, particularly for sources which have a significant impact on overall uncertainties.

The overall method used to estimate uncertainties is described below, and the work to improve the accuracy of the uncertainty analysis continues. The key category analysis used data from the uncertainty analysis, and the results of the key category analysis are given in **Annex 1**.

A 2.1 ESTIMATION OF UNCERTAINTIES USING AN ERROR PROPAGATION APPROACH (APPROACH 1)

The IPCC 2006 Guidelines defines error propagation and Monte Carlo modelling approaches to estimating uncertainties in national greenhouse gas inventories. The results of the error propagation approach are shown in **Table A 2.1.1**. The uncertainties used in the error propagation approach are not exactly the same as those used in the Monte Carlo Simulation since the error propagation source categorisation is less detailed and has a more simplistic approach to uncertainties. The approach 1 uncertainties assumes all parameters are normally distributed (which means it doesn't account for the skew, kurtosis or any other non-normal features of the expected distributions), and does not account for variations in uncertainty in the time series unlike the Monte Carlo approach which takes into account these factors. The parameters used for the Approach 1 uncertainties for both the base year and the most recent year are the values given for the most recent year in **Table A 2.3.1** to **Table A 2.3.4.**

A 2.1.1 Key Categories

Certain source categories are particularly significant in terms of their contribution to the overall uncertainty of the inventory. Key source categories in this respect are identified using Approach 1 uncertainties in the Approach 2 KCA. These have been identified so that the resources available for inventory preparation may be prioritised, and the best possible estimates prepared for the most significant source categories. We have used the method described in Section 4.3.2 of the 2006 IPCC Guidelines Volume 1 General Guidance and Reporting (Approach 2 to identify key categories).

The results of this key category analysis can be found in **Annex 1.**

A 2.1.2 Tables of uncertainty estimates from the error propagation approach

Table A 2.1.1 Summary of error propagation uncertainty estimates including LULUCF, base year to the latest reported year

IPCC Category	Gas	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty (%)	Contribution to variance by Category in 2016	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
1A (Stationary) Oil	CO_2	95,348.82	44,562.54	5.84%	2.53%	6.4%	0.0000	1.441%	5.560%	0.0365%	0.4592%	0.0021%
1A Coal	CO_2	243,845.45	43,827.78	1.35%	2.55%	2.9%	0.0000	12.403%	5.469%	0.3159%	0.1043%	0.0011%
1A Natural Gas	CO_2	106,944.95	162,504.72	1.03%	1.67%	2.0%	0.0000	12.406%	20.277%	0.2066%	0.2946%	0.0013%
1A Other (waste)	CO_2	229.09	4,018.69	1.17%	13.48%	13.5%	0.0000	0.485%	0.501%	0.0653%	0.0083%	0.0000%
1A3 Other diesel	CO_2	1,679.92	2,473.98	15.00%	2.00%	15.1%	0.0000	0.185%	0.309%	0.0037%	0.0655%	0.0000%
1A3a Aviation Fuel	CO_2	1,837.04	1,813.18	19.55%	3.23%	19.8%	0.0000	0.091%	0.226%	0.0029%	0.0626%	0.0000%
1A3b DERV	CO_2	33,005.80	76,795.02	1.00%	2.00%	2.2%	0.0000	7.155%	9.582%	0.1431%	0.1355%	0.0004%
1A3b Gasoline/ LPG	CO_2	75,562.72	36,568.31	0.99%	1.99%	2.2%	0.0000	0.986%	4.563%	0.0196%	0.0642%	0.0000%
1A3c Coal	CO_2	-	35.72	20.00%	6.00%	20.9%	0.0000	0.004%	0.004%	0.0003%	0.0013%	0.0000%
1A3d Marine fuel	CO_2	7,611.13	5,424.06	17.87%	1.79%	18.0%	0.0000	0.118%	0.677%	0.0021%	0.1711%	0.0003%
1A4 Peat	CO_2	488.50	6.34	30.00%	10.00%	31.6%	0.0000	0.035%	0.001%	0.0035%	0.0003%	0.0000%
1A4 Petroleum Coke	CO_2	81.64	278.57	20.00%	15.00%	25.0%	0.0000	0.029%	0.035%	0.0043%	0.0098%	0.0000%
1B1 Solid Fuel Transformation	CO_2	1,698.56	348.63	5.56%	4.81%	7.4%	0.0000	0.081%	0.044%	0.0039%	0.0034%	0.0000%
1B2 Oil & Natural Gas	CO_2	5,777.92	4,115.18	4.35%	5.23%	6.8%	0.0000	0.089%	0.513%	0.0047%	0.0316%	0.0000%
2A1 Cement Production	CO_2	7,295.26	4,553.32	1.00%	3.00%	3.2%	0.0000	0.032%	0.568%	0.0010%	0.0080%	0.0000%

IPCC Category	Gas	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty (%)	Contribution to variance by Category in 2016	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
2A2 Lime Production	CO_2	1,462.05	1,021.20	0.00%	5.00%	5.0%	0.0000	0.020%	0.127%	0.0010%	0.0000%	0.0000%
2A3 Glass production	CO_2	405.54	360.75	0.00%	5.00%	5.0%	0.0000	0.015%	0.045%	0.0008%	0.0000%	0.0000%
2A4 Other process uses of carbonates	CO_2	640.93	391.24	2.00%	3.00%	3.6%	0.0000	0.002%	0.049%	0.0001%	0.0014%	0.0000%
2B Chemical industries	CO_2	6,767.84	4,522.54	18.33%	3.11%	18.6%	0.0000	0.067%	0.564%	0.0021%	0.1463%	0.0002%
2C Metal Industries	CO_2	7,400.69	2,481.47	1.17%	4.85%	5.0%	0.0000	0.234%	0.310%	0.0113%	0.0051%	0.0000%
2D Non Energy Products from Fuels and Solvent Use	CO_2	553.12	352.37	38.72%	38.58%	54.7%	0.0000	0.003%	0.044%	0.0013%	0.0241%	0.0000%
3G Liming	CO_2	1,015.18	928.72	0.00%	20.90%	20.9%	0.0000	0.041%	0.116%	0.0086%	0.0000%	0.0000%
3H Urea application to agriculture	CO_2	327.53	365.57	0.00%	50.00%	50.0%	0.0000	0.022%	0.046%	0.0108%	0.0000%	0.0000%
4A Forest Land	CO_2	-17,445.77	-24,050.29	1.00%	35.00%	35.0%	0.0003	1.720%	3.001%	0.6020%	0.0424%	0.0036%
4B Cropland	CO_2	15,033.60	11,504.76	1.00%	45.00%	45.0%	0.0001	0.331%	1.436%	0.1491%	0.0203%	0.0002%
4C Grassland	CO_2	-7,756.55	-9,371.91	1.00%	50.00%	50.0%	0.0001	0.600%	1.169%	0.2999%	0.0165%	0.0009%
4D Wetland	CO_2	486.95	319.71	1.00%	100.00%	100.0%	0.0000	0.004%	0.040%	0.0041%	0.0006%	0.0000%
4E Settlements	CO_2	6,901.20	6,422.08	1.00%	50.00%	50.0%	0.0000	0.294%	0.801%	0.1472%	0.0113%	0.0002%
4F Other Land	CO_2	-	-	0.00%	0.00%	0.0%	-	0.000%	0.000%	0.0000%	0.0000%	0.0000%
4G Other Activities	CO_2	-1,614.71	-844.44	1.00%	45.00%	45.0%	0.0000	0.013%	0.105%	0.0060%	0.0015%	0.0000%
5C Waste Incineration	CO_2	1,363.29	283.37	7.21%	21.99%	23.1%	0.0000	0.065%	0.035%	0.0142%	0.0036%	0.0000%

IPCC Category	Gas	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty (%)	Contribution to variance by Category in 2016	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
1A1 & 1A2 & 1A4 & 1A5 Other Combustion	CH_4	1,911.40	1,430.30	0.72%	36.24%	36.2%	0.0000	0.038%	0.178%	0.0138%	0.0018%	0.0000%
1A3 Other diesel	CH_4	2.75	2.33	15.00%	130.00%	130.9%	0.0000	0.000%	0.000%	0.0001%	0.0001%	0.0000%
1A3a Aviation Fuel	CH_4	4.13	1.31	14.23%	55.84%	57.6%	0.0000	0.000%	0.000%	0.0001%	0.0000%	0.0000%
1A3b DERV	CH_4	88.75	11.31	1.00%	130.00%	130.0%	0.0000	0.005%	0.001%	0.0066%	0.0000%	0.0000%
1A3b Gasoline/ LPG	CH_4	1,157.96	90.12	1.00%	74.92%	74.9%	0.0000	0.074%	0.011%	0.0553%	0.0002%	0.0000%
1A3c Coal	CH_4	-	0.94	20.00%	110.00%	111.8%	0.0000	0.000%	0.000%	0.0001%	0.0000%	0.0000%
1A3d Marine fuel	CH_4	3.66	6.04	19.17%	124.63%	126.1%	0.0000	0.000%	0.001%	0.0006%	0.0002%	0.0000%
1B1 Coal Mining	CH_4	21,826.78	506.55	2.00%	20.00%	20.1%	0.0000	1.539%	0.063%	0.3079%	0.0018%	0.0009%
1B1 Solid Fuel Transformation	CH_4	0.07	0.02	1.00%	50.00%	50.0%	0.0000	0.000%	0.000%	0.0000%	0.0000%	0.0000%
1B2 Natural Gas Transmission	CH_4	10,168.33	3,782.53	3.00%	20.00%	20.2%	0.0000	0.275%	0.472%	0.0550%	0.0200%	0.0000%
1B2 Offshore Oil& Gas	CH_4	2,176.71	1,080.81	4.54%	18.15%	18.7%	0.0000	0.025%	0.135%	0.0045%	0.0087%	0.0000%
2A Minerals industry	CH_4	31.11	5.99	0.00%	100.00%	100.0%	0.0000	0.002%	0.001%	0.0015%	0.0000%	0.0000%
2B Chemical Industry	CH_4	213.73	73.02	0.00%	20.00%	20.0%	0.0000	0.007%	0.009%	0.0013%	0.0000%	0.0000%
2C Iron & Steel Production	CH_4	36.89	10.69	1.92%	47.92%	48.0%	0.0000	0.001%	0.001%	0.0007%	0.0000%	0.0000%
2D Non-energy Products from Fuels and Solvent Use	CH_4	-	-	0.00%	0.00%	0.0%	-	0.000%	0.000%	0.0000%	0.0000%	0.0000%

IPCC Category	Gas	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty (%)	Contribution to variance by Category in 2016	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
3A Enteric Fermentation	CH_4	26,252.83	22,129.07	13.73%	0.00%	13.7%	0.0000	0.833%	2.761%	0.0000%	0.5363%	0.0029%
3B Manure Management	CH_4	4,880.44	4,336.19	4.82%	0.00%	4.8%	0.0000	0.183%	0.541%	0.0000%	0.0369%	0.0000%
3F Field Burning	CH_4	186.57	-	25.61%	0.00%	25.6%	-	0.014%	0.000%	0.0000%	0.0000%	0.0000%
4A Forest Land	CH_4	2.92	0.40	1.00%	55.00%	55.0%	0.0000	0.000%	0.000%	0.0001%	0.0000%	0.0000%
4B Cropland	CH_4	0.09	0.05	1.00%	55.00%	55.0%	0.0000	0.000%	0.000%	0.0000%	0.0000%	0.0000%
4C Grassland	CH_4	10.00	23.63	1.00%	55.00%	55.0%	0.0000	0.002%	0.003%	0.0012%	0.0000%	0.0000%
4E Settlements	CH_4	3.05	10.66	1.00%	55.00%	55.0%	0.0000	0.001%	0.001%	0.0006%	0.0000%	0.0000%
5A Solid Waste Disposal	CH_4	60,432.98	14,016.99	15.00%	46.00%	48.4%	0.0002	2.688%	1.749%	1.2363%	0.3710%	0.0167%
5B Biological treatment of solid waste	CH_4	5.48	1,070.53	30.00%	99.50%	103.9%	0.0000	0.133%	0.134%	0.1325%	0.0567%	0.0002%
5C Waste Incineration	CH_4	137.63	9.89	5.00%	50.00%	50.2%	0.0000	0.009%	0.001%	0.0044%	0.0001%	0.0000%
5D Wastewater Handling	CH_4	4,219.05	3,421.01	10.00%	25.00%	26.9%	0.0000	0.117%	0.427%	0.0292%	0.0604%	0.0000%
1A1 & 1A2 & 1A4 & 1A5 Other Combustion	N_2O	3,415.05	2,294.55	0.58%	57.45%	57.5%	0.0000	0.035%	0.286%	0.0204%	0.0023%	0.0000%
1A3 Other diesel	N_2O	41.61	82.22	15.00%	130.00%	130.9%	0.0000	0.007%	0.010%	0.0094%	0.0022%	0.0000%
1A3a Aviation Fuel	N_2O	17.39	17.16	19.55%	107.53%	109.3%	0.0000	0.001%	0.002%	0.0009%	0.0006%	0.0000%
1A3b DERV	N_2O	322.92	967.70	1.00%	130.00%	130.0%	0.0000	0.097%	0.121%	0.1261%	0.0017%	0.0002%

IPCC Category	Gas	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty (%)	Contribution to variance by Category in 2016	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
1A3b Gasoline/ LPG	N_2O	989.41	104.77	0.99%	74.50%	74.5%	0.0000	0.060%	0.013%	0.0444%	0.0002%	0.0000%
1A3c Coal	N_2O	-	0.09	20.00%	110.00%	111.8%	0.0000	0.000%	0.000%	0.0000%	0.0000%	0.0000%
1A3d Marine fuel	N_2O	103.71	68.57	17.64%	114.63%	116.0%	0.0000	0.001%	0.009%	0.0011%	0.0021%	0.0000%
1B1 Fugitive Emissions from Solid Fuels	N_2O	0.09	0.02	1.00%	118.00%	118.0%	0.0000	0.000%	0.000%	0.0000%	0.0000%	0.0000%
1B2 Oil & Natural Gas	N_2O	40.75	36.06	4.75%	104.56%	104.7%	0.0000	0.002%	0.004%	0.0016%	0.0003%	0.0000%
2B1 Ammonia Production	N_2O	0.31	0.30	2.00%	50.00%	50.0%	0.0000	0.000%	0.000%	0.0000%	0.0000%	0.0000%
2B2 Nitric Acid Production	N_2O	3,860.26	24.73	10.00%	100.00%	100.5%	0.0000	0.280%	0.003%	0.2804%	0.0004%	0.0008%
2B3 Adipic Acid Production	N_2O	19,934.61	-	2.00%	100.00%	100.0%	-	1.464%	0.000%	1.4637%	0.0000%	0.0214%
2B8 Petrochemical and Carbon Black Production	N_2O	2.10	1.48	10.00%	100.00%	100.5%	0.0000	0.000%	0.000%	0.0000%	0.0000%	0.0000%
2C Iron & Steel	N_2O	17.74	6.36	1.00%	118.00%	118.0%	0.0000	0.001%	0.001%	0.0006%	0.0000%	0.0000%
2D Non-energy Products from Fuels and Solvent Use	N_2O	-	-	0.00%	0.00%	0.0%	-	0.000%	0.000%	0.0000%	0.0000%	0.0000%
2G Other Product Manufacture and Use	N_2O	593.57	827.46	100.00%	100.00%	141.4%	0.0000	0.060%	0.103%	0.0597%	0.1460%	0.0002%

IPCC Category	Gas	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty (%)	Contribution to variance by Category in 2016	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
3B Manure Management	N_2O	3,518.14	2,895.67	0.00%	68.07%	68.1%	0.0000	0.103%	0.361%	0.0701%	0.0000%	0.0000%
3D Agricultural Soils	N_2O	13,762.28	11,349.08	0.00%	53.28%	53.3%	0.0002	0.405%	1.416%	0.2159%	0.0000%	0.0005%
3F Field Burning	N_2O	57.66	-	25.63%	0.00%	25.6%	-	0.004%	0.000%	0.0000%	0.0000%	0.0000%
4 Indirect LULUCF Emissions	N_2O	401.41	248.33	1.00%	165.00%	165.0%	0.0000	0.002%	0.031%	0.0025%	0.0004%	0.0000%
4A Forest land	N_2O	230.75	152.39	1.00%	100.00%	100.0%	0.0000	0.002%	0.019%	0.0021%	0.0003%	0.0000%
4B Cropland	N_2O	1,019.85	476.64	1.00%	35.00%	35.0%	0.0000	0.015%	0.059%	0.0054%	0.0008%	0.0000%
4C Grassland	N_2O	10.36	37.62	1.00%	105.00%	105.0%	0.0000	0.004%	0.005%	0.0041%	0.0001%	0.0000%
4D Grassland	N_2O	4.13	0.30	1.00%	100.00%	100.0%	0.0000	0.000%	0.000%	0.0003%	0.0000%	0.0000%
4E Settlements	N_2O	584.71	526.89	1.00%	15.00%	15.0%	0.0000	0.023%	0.066%	0.0034%	0.0009%	0.0000%
5B Biological treatment of solid waste	N_2O	3.92	657.72	30.00%	90.00%	94.9%	0.0000	0.082%	0.082%	0.0736%	0.0348%	0.0001%
5C Waste Incineration	N_2O	47.47	41.33	7.00%	230.00%	230.1%	0.0000	0.002%	0.005%	0.0038%	0.0005%	0.0000%
5D Wastewater Handling	N_2O	783.59	719.86	10.00%	248.00%	248.2%	0.0000	0.032%	0.090%	0.0800%	0.0127%	0.0001%
2C Metal Industries	SF_6	387.17	75.31	5.00%	5.00%	7.1%	0.0000	0.019%	0.009%	0.0010%	0.0007%	0.0000%
2G Other Product Manufacture and Use	SF_6	877.33	431.72	0.00%	6.03%	6.0%	0.0000	0.011%	0.054%	0.0006%	0.0000%	0.0000%
2B Chemical industry	HFCs	17,680.04	7.51	0.00%	10.00%	10.0%	0.0000	1.297%	0.001%	0.1297%	0.0000%	0.0002%

IPCC Category	Gas	Base year emissions (Gg CO_2e)	2016 emissions (Gg CO_2e)	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty (%)	Contribution to variance by Category in 2016	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
2C Metal Industries	HFCs	-	2.20	5.00%	10.00%	11.2%	0.0000	0.000%	0.000%	0.0000%	0.0000%	0.0000%
2E Electronics Industry	HFCs	8.73	19.25	0.00%	47.15%	47.1%	0.0000	0.002%	0.002%	0.0008%	0.0000%	0.0000%
2F Product Uses as Substitutes for ODS	HFCs	1,407.19	15,264.79	8.29%	8.36%	11.8%	0.0000	1.801%	1.905%	0.1505%	0.2234%	0.0007%
2E Electronics Industry	NF_3	0.83	0.48	0.00%	47.15%	47.1%	0.0000	0.000%	0.000%	0.0000%	0.0000%	0.0000%
2B Chemical industry	PFCs	113.90	171.18	0.00%	10.00%	10.0%	0.0000	0.013%	0.021%	0.0013%	0.0000%	0.0000%
2C Metal Industries	PFCs	333.43	14.27	0.00%	20.00%	20.0%	0.0000	0.023%	0.002%	0.0045%	0.0000%	0.0000%
2F Product Uses as Substitutes for ODS	PFCs	0.44	-	0.00%	25.00%	25.0%	-	0.000%	0.000%	0.0000%	0.0000%	0.0000%
2G Other Product Manufacture and Use	PFCs	149.16	168.48	0.00%	47.15%	47.1%	0.0000	0.010%	0.021%	0.0047%	0.0000%	0.0000%

Percentage uncertainty in total inventory:	**3.5%**

Trend uncertainty	**2.4%**

A 2.2 ESTIMATION OF UNCERTAINTY BY SIMULATION (APPROACH 2)

A 2.2.1 Overview of the Method

Quantitative estimates of the uncertainties in the emissions were calculated using a Monte Carlo simulation. This corresponds to the IPCC Approach 2 method, discussed in the 2006 Guidelines (IPCC, 2006). The background to the implementation of the Monte Carlo simulation is described in detail by Eggleston *et al* (1998), with the estimates reported here revised to reflect changes in the latest inventory and improvements made in the model. This section gives a brief summary of the methodology, assumptions and results of the simulation.

The computational procedure is detailed below.

- A probability distribution function (PDF) was allocated to each unique emission factor and piece of activity data. The PDFs were mostly normal or log-normal, with more specific distributions given to a handful of sources. The parameters of the PDFs were set by analysing the available data on emission factors and activity data, and by expert judgement;
- A calculation was set up to estimate the total emissions of each gas for the years 1990 and the latest reported year;
- Using the software tool @RISK™, each PDF was sampled at least 20,000 times, such that the emission calculations performed produced a converged output distribution;
- The distribution of errors in the parameter values was calculated from the difference between 2.5 and 97.5 percentile values in the distribution, as a percentage of the distribution mean; and,
- The uncertainty in the trend between 1990 and the latest reported year, according to gas, was also estimated. This is expressed as the 95% confidence interval for the percentage reduction in emissions between the latest year and 1990.

A 2.2.2 Methodological details of the Monte Carlo model

A 2.2.2.1 Uncertainty Distributions

A 2.2.2.1.1 Distributions

Nearly all of the distributions of emissions from sources in the inventory are modelled used normal or log normal distributions, with more specific distributions given to a handful of sources. The specific distributions include log-logistic, Pearson and Gamma distributions. The primary use of custom distributions is for agriculture; these are fitted distributions that reflect the results of an agriculture-specific Monte Carlo analysis done by Rothamsted Research which accounts for the various factors that influence the modelled agriculture emissions.

Emissions from landfill have been modelled using a custom distribution. Aitchson *et al*. (cited in Eggelston *et al*., 1998) estimated the uncertainty for landfill emissions using Monte Carlo analysis and found it to be skewed. The distribution histogram was used to generate an empirical distribution of emissions. We examined the distribution and fitted a log normal distribution to Aitchison’s data. The emissions are scaled according to the mean estimate of landfill emissions for each year.

There a couple of other specific distributions for F-gases and waste water which reflect specific distributions we expect for those sources.

A 2.2.2.2 Correlations

The Monte Carlo model contains a number of correlations. If A and B are correlated, then if emissions are under or overestimated from A it would be expected to be over or underestimated by a similar amount from B.

The type and implementation of the correlations has been examined as part of a review (Abbott *et al.*, 2007). The sensitivity analysis that we have completed on the Monte Carlo model suggest that the uncertainties are not sensitive to the correlations between emission factors for fuel used, and for LULUCF sources.

A 2.2.2.2.1 Across years

In running this simulation, it was necessary to make assumptions about the degree of correlation between sources in 1990 and the latest reported year. If source emission factors are correlated this will have the effect of reducing the trend uncertainty, but will not affect uncertainties on emission totals in 1990 or the latest inventory year. The trend estimated by the Monte Carlo model is particularly sensitive to N_2O emissions from agricultural soils.

A 2.2.2.2.2 Between Sources in the same year

In many cases the same factors, or factors derived on the same basis are used for multiple sources. In these cases, we'd say that the emission factors are correlated. For example, the coal emissions factors for N_2O used for cement industry use may be the same as coal use in other industrial combustion due to lack of a more specific factor, in this case we may say the two factors are correlated. Omitting these correlations leads to an underestimate of emissions in any given year.

A 2.2.2.3 Simulation Method

Following recommendations in the 2006 IPCC Guidelines, the model uses a true Monte Carlo sampling method.

A 2.2.3 Quality Control Checks on the Monte Carlo Model Output

A number of quality control checks are completed as part of the uncertainty analysis.

a) *Checks against totals of the national emissions*

To ensure the emissions in the Monte Carlo model closely agree with the reported totals in the NIR, the emissions in the model were checked against the national totals both before and after the simulation was run. The central estimates from the model are expected to be similar to the reported emissions totals, but are not expected to match exactly.

b) *Inter-comparison between the output of the error propagation and Monte Carlo models*

A formal check to compare the output of the error propagation and Monte Carlo model is completed. The results of this comparison are discussed in **Section A 2.6.**

c) *Calculation of uncertainty on the total*

The uncertainty on the 1990 and the most recent year emissions was calculated using two different methods;

i) Using $\frac{1.96 s.d}{\mu}$

ii) Using $\frac{(97.5 percentile - 2.5 percentile)}{2 \times \mu}$

The first method uses the standard deviation calculated by @RISK and the mean to give an percentage uncertainty, while the second method uses the 95% confidence interval given by the percentiles quoted. When a distribution is completely normally distributed, the two methods should give the same results. However, when a distribution is skewed the two methods diverge, since the variance is dominated by outliers which aren't necessarily accounted for in the 95% confidence interval. The overall uncertainty quoted in **Table A 2.4.1** is calculated using the second method so that uncertainties in sectors that show a skewed distribution (such as agricultural soils and N_2O) are better represented.

Calculating the uncertainty using both of these methods allows us to check that the Monte Carlo analysis is behaving in the way we would expect, and that convergence of the distributions is being achieved. Comparing the results using both calculations showed that the uncertainties were almost the same for gases where the distributions used were predominantly normal, but higher for N_2O and the GWP weighted total, as expected.

A 2.3 UNCERTAINTY PARAMETERS

The following sections present the uncertainties in emissions, and the trend in emissions according to gas.

A 2.3.1 Uncertainty Parameters used

Table A 2.3.1 to **Table A 2.3.4** summarise the uncertainty parameters used for both Approach 1 and 2 uncertainties. For all of these tables the following apply:

- Uncertainties expressed as 0.5*R/E where R is the difference between 2.5 and 97.5 percentiles and E is the mean;
- Where custom distributions are used for the Approach 2 uncertainties the parameters are not used directly, but the below parameters should still be a reasonable indicator of the uncertainty in the distribution used for Approach 2;
- (r) means revised in comparison to previous NIR; and
- (a) means uncertainty for emission factors and activity cannot be separated, so one uncertainty that represents both is displayed.

Table A 2.3.1 Uncertainties in the activity data and emission factors for fuels used in the carbon dioxide (CO_2) inventory

Category	Fuel	1990		2016	
		Activity uncertainty (%)	Emission factor uncertainty (%)	Activity uncertainty (%)	Emission factor uncertainty (%)
1A1	Blast Furnace Gas	1.50%	10.00%	1.00%	10.00%
1A1	Coke Oven Coke	1.00%	10.00%	1.00%	10.00%
1A1	Coke Oven Gas	1.50%	10.00%	1.00%	10.00%
1A1	Colliery Methane	5.00%	5.00%	5.00%	5.00%
1A1	Gas/Diesel Oil	1.80%	2.10%	1.75%	2.10%
1A1	Liquefied Petroleum Gas	25.70%	2.10%	2.50%	2.10%
1A1	Motor Gasoline	2.50%	2.10%	2.50%	2.10%
1A1	Municipal Solid Waste	1.00%	15.00%	1.00%	15.00%
1A1	Naphtha	50.00%	5.00%	50.00%	5.00%
1A1	Natural Gas	2.80%	2.00%	1.00%	2.00%
1A1	Orimulsion	5.00%	5.00%	5.00%	5.00%
1A1	Other Bituminous Coal	2.00%	2.00%	2.00%	2.00%
1A1	Other Kerosene	1.25%	5.00%	1.25%	5.00%
1A1	Other Oil: Other	11.90%	5.00%	10.00%	5.00%
1A1	Petroleum Coke	7.80%	10.00%	5.00%	10.00%
1A1	Refinery Gas	50.00%	20.00%	25.00%	15.00%
1A1	Residual Fuel Oil	5.50%	2.55%	1.25%	2.55%
1A1	Scrap Tyres	15.00%	10.00%	15.00%	10.00%
1A2	Blast Furnace Gas	1.50%	10.00%	1.00%	10.00%
1A2	Coke Oven Coke	3.00%	10.00%	1.00%	10.00%
1A2	Coke Oven Gas	3.00%	10.00%	1.00%	10.00%
1A2	Colliery Methane	5.00%	5.00%	5.00%	5.00%
1A2	Gas/Diesel Oil	20.00%	2.00%	20.00%	2.00%
1A2	Liquefied Petroleum Gas	25.70%	2.10%	2.50%	2.10%
1A2	Motor Gasoline	20.00%	2.10%	20.00%	2.10%
1A2	Municipal Solid Waste	5.00%	15.00%	5.00%	15.00%
1A2	Natural Gas	2.80%	3.00%	1.00%	3.00%
1A2	non-fuel combustion	50.00%	100.00%	50.00%	100.00%
1A2	Other Bituminous Coal	5.00%	10.00%	5.00%	10.00%
1A2	Other Kerosene	6.00%	2.00%	6.00%	2.00%
1A2	Other Oil: Other	5.00%	50.00%	5.00%	3.00%
1A2	Patent Fuel	10.00%	3.00%	10.00%	3.00%
1A2	Petroleum Coke	25.00%	15.00%	20.00%	15.00%
1A2	Refinery Gas	50.00%	15.00%	50.00%	15.00%
1A2	Residual Fuel Oil	5.50%	2.10%	1.50%	2.10%

Category	Fuel	1990		2016	
		Activity uncertainty (%)	Emission factor uncertainty (%)	Activity uncertainty (%)	Emission factor uncertainty (%)
1A2	Scrap Tyres	15.00%	10.00%	15.00%	10.00%
1A3	Aviation Gasoline	20.00%	3.30%	20.00%	3.30%
1A3	Jet Gasoline	20.00%	3.30%	20.00%	3.30%
1A3	Other Bituminous Coal	20.00%	6.00%	20.00%	6.00%
1A3	Other Gas/Diesel Oil	15.00%	2.00%	15.00%	2.00%
1A3b	Gas/Diesel Oil	1.80%	2.00%	1.00%	2.00%
1A3b	Liquefied Petroleum Gas	5.00%	2.00%	5.00%	2.00%
1A3b	Motor Gasoline	1.00%	2.00%	1.00%	2.00%
1A3d	Gas/Diesel Oil	23.00% (r)	2.00%	23.00% (r)	1.00% (r)
1A3d	Residual Fuel Oil	23.00% (r)	3.50% (r)	23.00% (r)	3.50% (r)
1A4	Anthracite	1.50%	6.00%	1.00%	6.00%
1A4	Coke Oven Coke	3.00%	10.00%	1.00%	10.00%
1A4	Gas Works Gas	5.00%	5.00%	5.00%	5.00%
1A4	Gas/Diesel Oil	30.00%	2.00%	30.00%	2.00%
1A4	Liquefied Petroleum Gas	25.70%	2.10%	2.50%	2.10%
1A4	Motor Gasoline	50.00%	2.00%	50.00%	2.00%
1A4	Natural Gas	2.80%	3.00%	2.00%	3.00%
1A4	Other Bituminous Coal	3.00%	10.00%	3.00%	10.00%
1A4	Other Kerosene	3.00%	2.00%	3.00%	2.00%
1A4	Patent Fuel	3.30%	3.00%	2.00%	3.00%
1A4	Peat	30.00%	10.00%	30.00%	10.00%
1A4	Petroleum Coke	20.00%	15.00%	20.00%	15.00%
1A4	Residual Fuel Oil	15.00% (r)	2.10%	15.00% (r)	2.10%
1A5	Gas/Diesel Oil	6.25%	2.05%	6.25%	1.00% (r)
1A5	Jet Gasoline	10.00%	3.00%	10.00%	3.00%
1B1	Coke Oven Gas	1.50%	10.00%	1.00%	10.00%
1B1	petroleum coke	20.00%	10.00%	20.00%	10.00%
1B1	Other Bituminous Coal	1.50%	6.00%	1.50%	6.00%
1B2a	non-fuel combustion	5.00%	6.00%	5.00%	6.00%
1B2b	non-fuel combustion	3.00	6.00%	3.00	6.00%
1B2c	non-fuel combustion	5.00%	6.00%	5.00%	6.00%
2A1	non-fuel combustion	1.00%	3.00%	1.00%	3.00%
2A2	non-fuel combustion	10.00%	5.00%	(a)	5.00%
2A3	non-fuel combustion	(a)	5.00%	(a)	5.00%
2A4	non-fuel combustion	2.00%	3.00%	2.00%	3.00%
2B	Coke	1.00%	20.00%	1.00%	10.00%
2B	coke oven coke	(a)	20.00%	(a)	20.00%

Category	Fuel	1990		2016	
		Activity uncertainty (%)	Emission factor uncertainty (%)	Activity uncertainty (%)	Emission factor uncertainty (%)
2B	Natural Gas	2.80%	1.25%	1.75%	1.25%
2B	non-fuel combustion	2.00%	5.00%	2.00%	5.00%
2B	OPG	(a)	5.00%	(a)	5.00%
2B	petroleum coke	1.00%	10.00%	1.00%	10.00%
2B	refinery gas	30.00%	5.00%	30.00%	5.00%
2C	Blast Furnace Gas	2.00%	10.00%	2.00%	10.00%
2C	Coke	2.00%	10.00%	2.00%	10.00%
2C	coke oven coke	2.00%	5.00%	2.00%	5.00%
2C	non-fuel combustion	2.00%	10.00%	2.00%	10.00%
2C	Petroleum Coke	10.00%	7.50%	10.00%	7.50%
2D	Lubricants	50.00%	50.00%	50.00%	50.00%
2D	non-fuel combustion	25.00%	2.00%	25.00%	2.00%
2D	Petroleum Coke	20.00%	30.00%	20.00%	30.00%
2D	Petroleum Waxes	10.00%	50.00%	10.00%	50.00%
3G	non-fuel combustion	(a)	20.90%	(a)	20.90%
3H	non-fuel combustion	(a)	50.00%	(a)	50.00%
4A	non-fuel combustion	1.00%	40.00%	1.00%	35.00% (r)
4B	non-fuel combustion	1.00%	45.00%	1.00%	45.00%
4C	non-fuel combustion	1.00%	50.00%	1.00%	50.00%
4D	non-fuel combustion	1.00%	100.00% (r)	1.00%	100.00% (r)
4G	non-fuel combustion	1.00%	45.00%	1.00%	45.00%
5C	Chemical waste	10.00%	30.00%	10.00%	30.00%
5C	Clinical waste	5.00%	20.00%	5.00%	20.00%
5C	Municipal Solid Waste	1.00%	15.00%	1.00%	15.00%
5C	non-fuel combustion	300.00%	40.00%	300.00%	40.00%

Table A 2.3.2 Estimated uncertainties in the activity data and emission factors used in the methane (CH_4) inventory

Category	Fuel	1990		2016	
		Activity uncertainty (%)	Emission factor uncertainty (%)	Activity uncertainty (%)	Emission factor uncertainty (%)
1A1	All fuels	1.50%	50.00%	1.00%	50.00%
1A2	All fuels	1.50%	50.00%	1.00%	50.00%
1A3	Aviation Gasoline	20.00%	78.50%	20.00%	78.50%
1A3	Jet Gasoline	20.00%	78.50%	20.00%	78.50%
1A3	Other Bituminous Coal	20.00%	110.00%	20.00%	110.00%

Category	Fuel	1990		2016	
		Activity uncertainty (%)	Emission factor uncertainty (%)	Activity uncertainty (%)	Emission factor uncertainty (%)
1A3	Other Gas/Diesel Oil	15.00%	130.00%	15.00%	130.00%
1A3b	Gas/Diesel Oil	1.80%	130.00%	1.00%	130.00%
1A3b	Liquefied Petroleum Gas	5.00%	130.00%	5.00%	130.00%
1A3b	Motor Gasoline	1.00%	75.00%	1.00%	75.00%
1A3d	Gas/Diesel Oil	23.00% (r)	130.00%	23.00% (r)	50.00% (r)
1A3d	Residual Fuel Oil	23.00% (r)	130.00%	23.00% (r)	50.00% (r)
1A4	All fuels	1.50%	50.00%	1.00%	50.00%
1A5	All fuels	7.07%	65.55%	7.07%	65.55%
1B1	Coke Oven Gas	1.50%	50.00%	1.00%	50.00%
1B1	non-fuel combustion	2.00%	20.00%	2.00%	20.00%
1B1	Wood	(a)	50.00%	(a)	50.00%
1B2a	non-fuel combustion	5.00%	20.00%	5.00%	20.00%
1B2b	non-fuel combustion	3.00%	20.00%	3.00%	20.00%
1B2c	non-fuel combustion	5.00%	20.00%	5.00%	20.00%
2A4	All fuels	(a)	100.00%	(a)	100.00%
2B	All fuels	(a)	20.00%	(a)	20.00%
2C	Blast Furnace Gas	2.00%	50.00%	2.00%	50.00%
2C	coke oven coke	2.00%	50.00%	2.00%	50.00%
2C	non-fuel combustion	1.00%	50.00%	1.00%	50.00%
2D	All fuels	50.00%	50.00%	50.00%	50.00%
3A	non-fuel combustion	(a)	13.73%	(a)	13.73%
3B	non-fuel combustion	(a)	4.82%	(a)	4.82%
3F	non-fuel combustion	(a)	25.61%	(a)	25.61%
4A	non-fuel combustion	1.00%	55.00%	1.00%	55.00%
4B	non-fuel combustion	1.00%	55.00%	1.00%	55.00%
4C	non-fuel combustion	1.00%	55.00%	1.00%	55.00%
4E	non-fuel combustion	1.00%	55.00%	1.00%	55.00%
5A	non-fuel combustion	15.00%	46.00%	15.00%	46.00%
5B	All fuels	30.00%	99.50%	30.00%	99.50%
5C	Municipal Solid Waste	1.00%	75.00%	1.00%	75.00%
5C	non-fuel combustion	5.00%	50.00%	5.00%	50.00%
5D	non-fuel combustion	10.00%	25.00%	10.00%	25.00%

Table A 2.3.3 Estimated uncertainties in the activity data and emission factors used in the nitrous oxide (N_2O) inventory

Category	Fuel	1990		2016	
		Activity uncertainty (%)	Emission factor uncertainty (%)	Activity uncertainty (%)	Emission factor uncertainty (%)
1A1	All fuels	1.50%	100.00%	1.00%	100.00%
1A2	All fuels	1.50%	100.00%	1.00%	100.00%
1A3	Aviation Gasoline	20.00%	110.00%	20.00%	110.00%
1A3	Jet Gasoline	20.00%	110.00%	20.00%	110.00%
1A3	Other Bituminous Coal	20.00%	110.00%	20.00%	110.00%
1A3	Other Gas/Diesel Oil	15.00%	130.00%	15.00%	130.00%
1A3b	Gas/Diesel Oil	1.80%	130.00%	1.00%	130.00%
1A3b	Liquefied Petroleum Gas	5.00%	130.00%	5.00%	130.00%
1A3b	Motor Gasoline	1.00%	75.00%	1.00%	75.00%
1A3d	Gas/Diesel Oil	23.00% (r)	130.00%	23.00% (r)	90.00% (r)
1A3d	Residual Fuel Oil	23.00% (r)	130.00%	23.00% (r)	90.00% (r)
1A4	All fuels	1.50%	100.00%	1.00%	100.00%
1A5	All fuels	7.07%	85.15%	7.07%	85.15%
1B1	All fuels	1.50%	118.00%	1.00%	118.00%
1B2a	All fuels	5.00%	110.00%	5.00%	110.00%
1B2b	All fuels	5.00%	110.00%	5.00%	110.00%
1B2c	All fuels	5.00%	110.00%	5.00%	110.00%
2B1	All fuels	2.00%	50.00%	2.00%	50.00%
2B2	All fuels	10.00%	100.00%	10.00%	100.00%
2B3	All fuels	2.00%	100.00%	2.00%	100.00%
2B8	All fuels	10.00%	100.00%	10.00%	100.00%
2C	All fuels	1.50%	118.00%	1.00%	118.00%
2D	All fuels	50.00%	100.00%	50.00%	100.00%
2G	All fuels	100.00%	100.00%	100.00%	100.00%
3B	All fuels	(a)	68.07%	(a)	68.07%
3D	All fuels	(a)	53.28%	(a)	53.28%
3F	All fuels	(a)	25.63%	(a)	25.63%
4	non-fuel combustion	1.00%	165.00% (r)	1.00%	165.00% (r)
4A	non-fuel combustion	1.00%	105.00%	1.00%	100.00% (r)
4B	non-fuel combustion	1.00%	35.00%	1.00%	35.00%
4C	non-fuel combustion	1.00%	125.00%	1.00%	105.00% (r)
4D	non-fuel combustion	1.00%	100.00%	1.00%	100.00%
4E	non-fuel combustion	1.00%	15.00%	1.00%	15.00%
5B	All fuels	30.00%	90.00%	30.00%	90.00%

Category	Fuel	1990		2016	
		Activity uncertainty (%)	Emission factor uncertainty (%)	Activity uncertainty (%)	Emission factor uncertainty (%)
5C	All fuels	7.00%	230.00%	7.00%	230.00%
5D	All fuels	10.00%	248.00%	10.00%	248.00%

Table A 2.3.4 Estimated uncertainties in the activity data and emission factors used in the F-gas inventory

Gas	Category	1990		2016	
		Activity uncertainty (%)	Emission factor uncertainty (%)	Activity uncertainty (%)	Emission factor uncertainty (%)
SF_6	2C4	5.00%	5.00%	5.00%	5.00%
SF_6	2G1	(a)	5.00%	(a)	5.00%
SF_6	2G2a	(a)	17.50%	(a)	17.50%
SF_6	2G2b	(a)	40.00%	(a)	40.00%
SF_6	2G2e	(a)	47.15%	(a)	47.15%
HFCs	2B9	(a)	10.00%	(a)	10.00%
HFCs	2C4	5.00%	10.00%	5.00%	10.00%
HFCs	2E1	(a)	47.15%	(a)	47.15%
HFCs	2F1	10.00%	10.00%	10.00%	10.00%
HFCs	2F2	(a)	15.00%	(a)	15.00%
HFCs	2F3	(a)	25.00%	(a)	25.00%
HFCs	2F4a	5.00%	10.00%	5.00%	10.00%
HFCs	2F4b	(a)	10.00%	(a)	10.00%
HFCs	2F5	(a)	25.50%	(a)	25.50%
HFCs	2F6	(a)	20.00%	(a)	20.00%
NF_3	2E1	(a)	47.15%	(a)	47.15%
PFCs	2B9	(a)	10.00%	(a)	10.00%
PFCs	2C3	(a)	20.00%	(a)	20.00%
PFCs	2F1	10.00%	10.00%	10.00%	10.00%
PFCs	2F3	(a)	25.00%	(a)	25.00%
PFCs	2G2e	(a)	47.15%	(a)	47.15%

A 2.3.2 General Considerations

The uncertainty parameters presented in **Section 0** are based primarily on expert judgment, but where applicable will account for:

- The uncertainty range presented for data (for example the confidence interval in the 2006 IPCC guidelines for default factors)

- Monte Carlo Analysis of some of the more sophisticated models, most notably for agriculture, LULUCF and F-gases

In some cases, the individual uncertainties for the activity data and the emission factor are difficult to separate, but the uncertainty on the total emission can more easily be estimated. In these cases, the uncertainties are listed in the column marked “uncertainty in emission”.

The analysis of the uncertainties in the nitrous oxide emissions is particularly difficult because emissions sources are diverse, and few data are available to form an assessment of the uncertainties in each source. Emission factor data for the combustion sources are scarce and for some fuels are not available. The uncertainty assumed for agricultural soils (IPCC category 3D) uses a custom distribution. These parameterised functions have been defined and provided by Rothamsted Research as the best possible fit to the expected distribution of uncertainties in 1990 and the most recent year’s emissions, and are normalised in the Approach 2 methodology such that the resultant mean is consistent with the current inventory emissions in 1990 and the most recent year.

Many of uncertainties in the emissions of HFCs, PFCs, NF_3 and SF_6 (collectively known as F-gases) are based on the recent study to update emissions and projections of F-gases (ICF, 2014). Some sources have been updated since then and the uncertainties for those sources have been revisited accordingly.

We assume that all F-gas emissions are independent between years as the technologies, gases (which have a very wide range of GWPs) used and regulations have changed drastically between the base year and the most recent year. Many HFCs in particular were not in use until the early 90s.

A 2.3.3 Uncertainty in the Trend

The uncertainty in the trend between 1990 and the most recent year is given in **Section 0**. In running this simulation, it was necessary to make assumptions about the degree of correlation between sources and between 1990 and the most recent year. The assumptions were as follows:

- Activity data are uncorrelated;
- Emission factors of some similar fuels are correlated;
- Land Use Change and forestry emissions are correlated (e.g. 1990 4A CO_2 with 4A CO_2 for the most recent year);
- Offshore emissions are not correlated since they are based on separate studies using emission factors appropriate for the time;
- Emission factors covered by the Carbon Factors Review (Baggott et al, 2004) are not correlated; and
- Process emissions from blast furnaces, coke ovens and ammonia plants are not correlated.
- Landfill emissions were partly correlated across years in the simulation. It is likely that the emission factors used in the model will be correlated, and also the historical estimates of waste arisings will be correlated since they are estimated by extrapolation from the year of the study. However, the reduction in emissions is due to flaring and utilisation systems installed since 1990 and this is unlikely to be correlated. As a simple estimate it was assumed that the degree of correlation should reflect the reduction in emissions since 1990;
- Emissions from agricultural soils and manure management are correlated in the base and inventory year;

- The emission factor used for sewage treatment was assumed to be correlated between years, though the protein consumption data used as activity data were assumed not to be correlated between years;
- Nitric acid production emission factors were assumed not to be correlated, since the mix of operating plants is very different in the most recent year compared with 1990 – only two of the original eight units are still operating in the latest inventory year, all of which now have differing levels of abatement fitted.

A 2.4 UNCERTAINTIES IN GWP WEIGHTED EMISSIONS

A 2.4.1 Uncertainty in the emissions

The uncertainty in the combined GWP weighted emission is given in **Table A 2.4.1**, along with uncertainties for each of the seven categorised GHGs. This is calculated as half of the 95% confidence range, i.e. the limits between which there is a 95% probability that the actual value of emissions falls. Note that the uncertainty in the GWP is not accounted for.

A 2.4.2 Uncertainty in the Trend

The uncertainty estimates for all gases are summarised in **Table A 2.4.1** under ‘Range of likely % change’. This indicates the range between which there is a 95% probability that the actual trend in inventory emissions falls. Note that the uncertainty in the GWP is not accounted for.

Table A 2.4.1 Summary of Monte Carlo Uncertainty Estimates

IPCC Source Category	Gas	1990 Emissions	2016 Emissions	95% confidence interval for 1990 emissions		Uncertainty in 1990 emissions as % of emissions in category	95% confidence interval for 2016 emissions		Uncertainty in 2016 emissions as % of emissions in category	% change in emissions between 1990 and 2016	95% confidence interval for the% change in emissions between 1990 and 2016	
				2.5 percentile	97.5 percentile		2.5 percentile	97.5 percentile			2.5 percentile	97.5 percentile
		Gg CO_2e	Gg CO_2e	Gg CO_2e	Gg CO_2e	%	Gg CO_2e	Gg CO_2e	%	%	%	%
TOTAL	CO_2 (net)	596,955	381,977	582,528	611,425	2.4%	369,706	394,203	3.2%	-36%	-38%	-34%
	CH_4	133,716	52,047	106,911	171,122	24.0%	44,585	61,573	16.3%	-61%	-70%	-50%
	N_2O	49,698	21,533	37,506	68,240	30.9%	17,361	28,789	26.5%	-56%	-70%	-38%
	HFC	14,406	15,297	12,240	16,577	15.1%	13,894	16,724	9.3%	7%	-10%	28%
	PFC	1,651	354	1,571	1,732	4.9%	279	441	22.9%	-79%	-83%	-73%
	SF_6	1,279	507	1,149	1,413	10.3%	445	569	12.2%	-60%	-66%	-54%
	NF_3	0.4	0.5	0.2	0.6	44.9%	0.3	0.7	46.7%	23%	-41%	132%
	All	797,706	471,714	763,172	840,557	4.9%	456,176	488,488	3.4%	-41%	-44%	-38%

Uncertainty calculated as 0.5*R/E where R is the difference between 2.5 and 97.5 percentiles and E is the mean calculated in the simulation.
Emissions of CO_2 are net emissions (i.e. sum of emissions and removals).
Emissions in this table are taken from the Monte Carlo model output. The central estimates, according to gas, for 1990 and the latest inventory year are very similar but not identical to the emission estimates in the inventory. The Executive Summary of this NIR and the accompanying CRF tables present the agreed national GHG emissions and removals reported to the UNFCCC.

A 2.5 SECTORAL UNCERTAINTIES

A 2.5.1 Overview of the Method

Sectoral uncertainties were calculated from the same base data used for the “by gas” analysis. The emissions and uncertainties per sector are presented in **Table A 2.5.1**. The estimates are presented in IPCC categories, which is consistent with the reporting format used within this submission to the UNFCCC, but we recommend that these estimates should only be considered as indicative.

Table A 2.5.1 Sectoral Uncertainty Estimates

IPCC Source Category	1990 Emissions	2016 Emissions	95% confidence interval for 2016 emissions		Uncertainty in 2016 emissions as % of emissions in category	% change in emissions between 1990 and 2016	95% confidence interval for the% change in emissions between 1990 and 2016	
			2.5 percentile	97.5 percentile			2.5 percentile	97.5 percentile
1A1a	205,331	83,215	81,491	84,941	2.1%	-59%	-61%	-58%
1A1b	17,851	13,615	11,675	15,734	14.9%	-24%	-42%	3%
1A1c	14,188	14,828	14,431	15,297	2.9%	5%	-1%	11%
1A2a	21,552	10,030	9,171	10,900	8.6%	-53%	-59%	-48%
1A2b	4,357	511	482	540	5.6%	-88%	-90%	-86%
1A2c	12,118	5,008	4,737	5,280	5.4%	-59%	-62%	-55%
1A2d	4,616	2,133	2,012	2,256	5.7%	-54%	-59%	-48%
1A2e	7,616	4,297	4,073	4,517	5.2%	-44%	-48%	-39%
1A2f	7,149	2,644	2,337	2,968	11.9%	-63%	-71%	-52%
1A2g	39,527	27,359	25,904	28,841	5.4%	-31%	-37%	-24%
1A3a	1,858	1,832	1,479	2,187	19.3%	-1%	-25%	30%
1A3b	111,135	114,531	112,549	116,549	1.7%	3%	0%	6%
1A3c	1,472	2,018	1,660	2,382	17.9%	37%	7%	76%
1A3d	7,716	5,499	4,368	6,607	20.4%	-29%	-46%	-8%
1A3e	253	579	471	700	19.8%	129%	73%	200%
1A4a	25,641	19,906	19,269	20,558	3.2%	-22%	-27%	-17%
1A4b	80,374	68,475	65,755	71,232	4.0%	-15%	-19%	-10%
1A4c	6,608	5,316	3,718	6,945	30.3%	-20%	-51%	42%
1A5b	5,354	1,564	1,444	1,685	7.7%	-71%	-74%	-67%
1B1	23,531	855	761	949	11.0%	-96%	-97%	-95%
1B2	18,172	9,001	5,981	12,083	33.9%	-50%	-66%	-34%
2A1	7,296	4,554	4,414	4,697	3.1%	-38%	-38%	-37%
2A2	1,463	1,021	970	1,073	5.0%	-30%	-37%	-23%
2A3	406	361	342	379	5.1%	-11%	-12%	-10%
2A4	672	397	383	412	3.8%	-41%	-44%	-37%
2B1	1,895	1,443	1,412	1,474	2.2%	-24%	-27%	-21%

IPCC Source Category	1990 Emissions	2016 Emissions	95% confidence interval for 2016 emissions		Uncertainty in 2016 emissions as % of emissions in category	% change in emissions between 1990 and 2016	95% confidence interval for the% change in emissions between 1990 and 2016	
			2.5 percentile	97.5 percentile			2.5 percentile	97.5 percentile
2B2	3,861	25	11	47	71.8%	-99%	-100%	-98%
2B3	19,886	-	-	-	n/a	-100%	-100%	-100%
2B6	105	169	152	186	10.0%	62%	31%	106%
2B7	232	144	135	152	5.6%	-38%	-44%	-31%
2B8	4,564	2,781	1,938	3,628	30.4%	-39%	-60%	-12%
2B9	14,420	179	161	196	9.6%	-99%	-99%	-99%
2B10	186	63	48	77	23.0%	-66%	-76%	-53%
2C	9,397	2,591	2,467	2,713	4.8%	-72%	-74%	-71%
2D	554	353	190	597	57.7%	-36%	-72%	54%
2E	5	20	12	30	45.7%	316%	119%	696%
2F	-	15,268	13,863	16,695	9.3%	n/a	n/a	n/a
2G	1,564	1,428	754	2,624	65.5%	-9%	-58%	96%
3A	26,248	22,143	19,863	24,692	10.9%	-16%	-28%	-1%
3B	8,395	7,225	6,107	9,020	20.2%	-14%	-30%	6%
3D	13,757	11,352	8,206	17,767	42.1%	-17%	-42%	23%
3F	244	-	-	-	n/a	-100%	-100%	-100%
3G	1,015	927	735	1,121	20.8%	-9%	-32%	24%
3H	327	366	239	536	40.7%	12%	-37%	97%
4	402	248	82	582	100.7%	-38%	-84%	141%
4A	-17,219	-23,905	-32,458	-15,486	35.5%	39%	30%	48%
4B	16,066	11,990	6,747	17,159	43.4%	-25%	-37%	-15%
4C	-7,737	-9,311	-13,908	-4,717	49.4%	20%	11%	30%
4D	492	321	152	600	69.9%	-35%	-65%	-17%
4E	7,476	6,946	4,698	9,906	37.5%	-7%	-20%	-1%
4F	-	-	-	-	n/a	n/a	n/a	n/a
4G	-1,620	-847	-1,226	-468	44.8%	-48%	-69%	-26%
5A	60,384	14,036	8,012	22,807	52.7%	-77%	-88%	-56%
5B	9	1,734	1,048	2,746	49.0%	18251%	8166%	43552%

IPCC Source Category	1990 Emissions	2016 Emissions	95% confidence interval for 2016 emissions		Uncertainty in 2016 emissions as % of emissions in category	% change in emissions between 1990 and 2016	95% confidence interval for the% change in emissions between 1990 and 2016	
			2.5 percentile	97.5 percentile			2.5 percentile	97.5 percentile
5C	1,549	334	130	778	97.0%	-78%	-94%	-30%
5D	4,994	4,143	2,824	7,031	50.8%	-17%	-42%	16%
Total	**797,707**	**471,715**	**456,177**	**488,489**	**3.4%**	**-41%**	**-44%**	**-38%**

Note: Emissions in this table are taken from the Monte Carlo model output. The central estimates, according to gas, for 1990 and the latest inventory year are very similar but not identical to the emission estimates in the inventory. The Executive Summary of this NIR and the accompanying CRF tables present the agreed national GHG emissions and removals reported to the UNFCCC.

A 2.6 COMPARISON OF UNCERTAINTIES FROM THE ERROR PROPAGATION AND MONTE CARLO ANALYSES

Comparing the results of the error propagation approach, and the Monte Carlo estimation of uncertainty by simulation, is a useful quality control check on the behaviour of the Monte Carlo model.

The reason that the error propagation approach is used as a reference is because the approach to the error propagation approach has been defined and checked by the IPCC, and is clearly set out in the IPCC 2000 Good Practice Guidance and the 2006 Guidelines. The UK has implemented the IPCC error propagation approach as set out in this guidance. The implementation of an uncertainty estimation by simulation cannot be prescriptive, and will depend on how the country constructs its model, and the correlations included within that model. Therefore, there is a greater likelihood of errors being introduced in the model used to estimate uncertainty by Monte Carlo simulation.

If all the distributions in the Monte Carlo model were normal, and the assumed correlations were identical, the estimated errors on the trend from the Monte Carlo model should approach those estimated by the error propagation approach if enough iterations are done. The error propagation approach assumes 100% correlation between EFs in the base and inventory year, and no correlation between sources, however in reality the nature and degree of correlation varies by source, and many distributions are not normal but heavily skewed, particularly those with very high uncertainty. These differences interact in various ways, but would be expected broadly to result in higher trend uncertainty, and lower uncertainty on the most recent year's total in the Monte Carlo uncertainty estimates compared to the error propagation approach. This can be seen in **Table A 2.6.1** which shows differences in the trend uncertainty between the error propagation and Monte Carlo approaches. These differences mostly arise from the fact that the error propagation approach only uses normal distributions, cannot account for different uncertainty parameters between the 1990 and the latest inventory year, cannot account for correlations between sources, and automatically assumes a correlation between the emission factor uncertainty in 1990 and the most recent year.

The central estimates of emissions generated by the Monte Carlo model in 1990, and those in the latest inventory year, are very close. We would not expect the central estimates from the two methods to be identical, but with a very large number of iterations we would expect the difference to tend to zero. It should be noted that the Approach 1 uncertainties base year is 1990 for N_2O, CH_4 and CO_2, but is 1995 for the F-gases; this differs from the Approach 2 uncertainties which uses 1990 emission for all gases for the starting year.

Table A 2.6.1 Comparison of the central estimates and trends in emissions from the error propagation (Approach 1) and Monte Carlo (Approach 2) uncertainty analyses

Method of uncertainty estimation	Central estimate ($Gg\ CO_2$ equivalent) [b]		Uncertainty on trend, 95% CI (1990 / base year to 2016)[a]
	Base year	2016	
Error propagation	801,423	471,726	2.4%
Monte Carlo	801,325	471,714	2.9%

Notes:

CI Confidence Interval

[a] Calculated as half the difference between 2.5 and 97.5 percentiles , assuming a normal distribution is equal to ±1.96 standard deviations on the central estimate.

[b] Net emissions, including emissions and removals from LULUCF

ANNEX 3: Other Detailed Methodological Descriptions for Individual Source or Sink Categories, Including for KP-LULUCF Activities.

This Annex contains background information about methods used to estimate emissions in the UK GHG inventory. This information has not been incorporated in the main body of the report because of the level of detail, and because the methods used to estimate emissions cut across sectors.

This Annex provides background information on the fuels used in the UK GHG inventory, mapping between IPCC and NAEI source categories and detailed description of methods used to estimate GHG emissions, and emission factors used in those methods.

A 3.1 ENERGY

Methods for calculating emissions within the energy sector are detailed in the method statements set out in **Chapter 3**. This Annex details the emission factors used and their source, and elaborates on references commonly used within the Energy sector. The national energy balance (and how it is used) is described in **Annex 4.**

A 3.1.1 Emission factors

Emission factors used for the 2018 submission for sectors 1A and 1B can be found in the accompanying excel file: 'Energy_background_data_uk_2018.xlsx'. This can be found as one of the additional documents in on http://naei.defra.gov.uk/reports/reports?report_id=929. Note that there can be a delay between the NIR being published on the NAEI website after official submission.

A 3.1.2 Commonly used references

This section describes data sources that are used across multiple emission sources within the energy sector, and how they are used.

A 3.1.2.1 Baggott et al., 2004 – Carbon factors review

A review of the carbon factors used in the UK GHG inventory was carried out in 2004. The report detailing this study is available from:

http://naei.beis.gov.uk/reports/reports?report_id=417

This aimed to validate existing emission factors and seek new data for country specific emission factors for the UK. At the time of publication this reference provided new emission factors for:

- coal from power stations;
- fuels used in the cement industry;
- a number of petroleum based fuels;
- natural gas; and

- coke oven and blast furnace gas.

Since then following updates are made to the following emission factors based on new information:

1. Coal emission factors are adjusted based on the annual variations in the GCV of the fuels using methods developed as part of the 2004 analysis (Baggott et al., 2004).

   $EF_y = EF_{ref} / GCV_{ref} * GCV_y$

   Where

   EF_y is the emission factor (EF) in year y

   EF_{ref} is the EF in the reference year (the year for which data are available)

   GCV_{ref} is the GCV in the reference year

   GCV_y is the GCV in year y

2. Since the advent of EU ETS in 2005, a number of sources of emissions from coal which had previously been reliant on Baggott et al., 2004 have now been replaced with data from the ETS, where the data set was considered suitable (high proportion of source included, and high proportion of T3 plant specific data). In addition, in 2014 the use of oxidation factors from this report was reviewed, and where suitable background evidence to support the factors used were not available, the IPCC default (of 1, IPCC 2006) has been used.
3. Emission factors for petroleum based fuels (where ETS data are not available) are still largely based on Baggott et al., 2004. These were reviewed in 2014 and compared with the defaults in the 2006 IPCC Guidelines and found to be largely within the range of the 2006 Guidelines. No new data for the UK has been identified and the emission factors from Baggott et al., 2004 are still considered to be relevant country specific emission factors.
4. During 2017-18, a review of the UK's shipping inventory was conducted (Scarborough et al., 2018). This identified new carbon emission factors for marine fuels, which replace the factors identified as part of Baggot et al., 2004.
5. Emission factors for natural gas are updated annually based on analyses from the gas network operators (Personal Communications from network operators, 2015).
6. Emission factors for coke oven gas and blast furnace gas are estimated based on a carbon balance approach (as described in Chapter 3, **MS 4**).
7. The Mineral Products Association provide data for fuels used in the cement industry annually on a confidential basis, and these are validated with EU ETS data (Personal Communication, MPA, 2017).

A new review of carbon emission factors was conducted during 2017, focusing on those factors retained from the 2004 review (Brown et al., 2017). This concluded that the factors that are currently in use are slightly more conservative than more recent values identified, and that there was no new robust evidence upon which we could justify changing the current factors. This report is available here: http://naei.beis.gov.uk/reports/reports?report_id=947

A 3.1.2.2 The Pollution Inventory and other regulators' inventories

The Pollution Inventory (PI) has, since 1998, provided emission data for the six Kyoto gases and other air pollutant for installations regulated by the Environment Agency (EA) in England and Natural Resources Wales (NRW) in Wales. This is part of the UK's process for managing regulated emissions from industry processes under the IPPC permitting system. The PI does contain earlier data of carbon dioxide emissions at some sites reported from 1994 onwards. The Scottish Pollutant Release Inventory (SPRI) covers processes regulated by the Scottish Environment Protection Agency (SEPA), and contains data from 2002 and 2004 onwards. The Northern Ireland Pollution Inventory (NIPI) covers processes regulated by the Northern Ireland Environment Agency and includes data for 1999 onwards.

These data are subject to some very significant limitations:

- Emissions of each pollutant are reported for each permitted installation as a whole, so emissions data for carbon dioxide, for example, can cover emissions from fuel use as well as from an industrial process. No information is given on what the source of emissions is, so a judgement has to be made about the scope of reporting;
- Permitting arrangements have changed over time, so the reporting of data is not on a consistent basis across the time-series. In general, the tendency has been to reduce the number of permits, so that whereas in the early 1990s there might have been separate permits at an industrial installation covering the boiler plant and the chemical processes, from the late 1990s onwards the tendency would be to issue a single permit to cover both. Therefore, the problems with the scope of emissions data mentioned in the first bullet point are most severe for the second half of the GHGI time series; and,
- Since 1998, process operators need only report emissions of each pollutant if those emissions exceed a reporting threshold. For example, where emissions from an installation are less than 10,000 tonnes of CO_2, or 10 tonnes of methane, the operator does not need to report any emissions data for that substance in that year. Reporting thresholds are irrelevant for many of the sectors of interest to this study, since emissions would be many times higher than the thresholds, but the reporting thresholds do mean that it is necessary to consider whether the data available in the PI (and in the SPRI & NIPI for later years) will be complete.

Despite these limitations, these data are still a useful source of information for the UK GHG inventory. A considerable amount of effort is put into manually interpreting the individual returns and allocating these to appropriate categories for use in the inventory estimates by the Inventory Agency.

A 3.1.2.3 The Environmental and Emissions Monitoring System (EEMS) Reporting System

Emissions from upstream oil and gas production facilities, including onshore terminals, are estimated based on operator reporting via EEMS, regulated by the BEIS Offshore Inspectorate and developed in conjunction with the trade association Oil & Gas UK (formerly the UK Offshore Operators' Association, UKOOA). The EEMS data provides a detailed inventory of point source emissions estimates, based on operator returns for the years 1995-2016. However, the EEMS data for 1995 to 1997 are not complete, frequently exhibiting duplicate entries with identical submissions by operators across years. Since the 1995 – 1997 data are not considered reliable, the EEMS dataset is only used directly to inform national inventory estimates from 1998 onwards for the following sources:

- gas flaring;
- own gas combustion;
- well testing; and
- oil loading (onshore and offshore).

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

These EEMS-derived activity data enable greater analysis of the oil & gas emissions and related emission factors at the installation level, providing a high degree of data transparency and improving the level of detail for performing quality checks by source, by site, by year. For those sources, this has led to an improvement in data transparency and easier query of Implied Emission Factor trends. However, the EEMS activity data are only available back to 1998, and hence the activity data back to 1990 are extrapolated using the oil and gas production time-series that were collected at that time for the purposes of energy data reporting.

A 3.1.2.4 Fynes & Sage (1994)

Fynes and Sage is a country-specific reference from the mid-1990s and it includes analysis of solid fuels typically used in the UK economy in that period, deriving mass-based emission factors that are used within the UK GHGI. In the 1990s, coal used in the UK economy was predominantly mined in the UK, whereas over the time series of the inventory there has been a decline in the share of coal from UK sources and an increase in coal imports from around the world.

For recent years, for the more significant emission sources, e.g. energy industries and manufacturing industries, the inventory agency uses EFs that are derived from EU ETS data, but for smaller emission sources in the UK that still use solid fuels (such as residential, collieries) the Fynes and Sage data are retained, as there are no EU ETS data for fuels used in these sectors. There is some uncertainty regarding how representative the EFs from Fynes and Sage may be for these smaller combustion sources, but we note that the use of coal-fired technology in sectors such as collieries and residential is predominantly in the UK coal production areas, where local supplies are still available.

A 3.1.3 Feedstocks and Non-Energy Use (NEU) of fuels

The estimation methods are described within individual sections of the NIR, but are summarised here. The general approach adopted in the UK GHG inventory is to assume that emissions from all non-energy uses of fuels are zero (i.e. the carbon is assumed to be sequestered in products such as plastics and other chemicals), except for cases where emission sources can be identified and emission estimates included in the inventory. There is one exception to this, for petroleum coke where we have no information on any non-emissive uses at all, and so we adopt the conservative approach of assuming that all petroleum coke use is emissive.

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

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

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

Table A 3.1.1 Summary of Emission Sources for UK Fuels Allocated as Non Energy Use in UK Energy Statistics

Fuel	IPCC	Source Category
Liquid Fossil		
Naphtha, Liquid Petroleum Gases (LPG), Refinery Fuel Gas (RFG) / Other Petroleum Gases (OPG), gas oil and Ethane	1A1a	Scrap tyre combustion in power stations (1994 to 2000 only). Fossil carbon in MSW combustion in energy from waste plant. *Emissions of carbon from chemical feedstock via combustion of products such as synthetic rubbers and plastics.*
	1A1b	Other petroleum gas use in refineries (2004, 2006 to 2011, 2013 to 2016 only). *Re-allocated from non-energy use as EU ETS and trade association data indicates that DUKES data on OPG combustion are an under-report.*
	1A2f	Waste solvents, waste-derived fuels containing fossil carbon, in cement kilns. Scrap tyres and waste plastics etc. combusted in cement kilns.
	1A2g	Industrial combustion of waste solvents. *Emissions of carbon from chemical feedstock via combustion of products such as synthetic rubbers and solvents.*
	2B8	Energy recovery from process gases in the chemical industry. *Large quantities of naphtha, butane, propane, ethane, and other petroleum gases are listed in DUKES as used for non-energy applications and these fuels are known to be used extensively as chemical feedstocks. However, EU ETS and operator data indicate that process off-gases, derived from the chemical feedstocks, are a major fuel for ethylene production processes and other petrochemical sites. Emissions of carbon are reported in 2B8.*
	5C	Fossil carbon in chemical waste incineration. Fossil carbon in MSW incineration. Fossil carbon in clinical waste incineration. *Emissions of carbon from chemical feedstock via combustion of products such as synthetic rubbers and plastics.*
Lubricants	1A1a	Waste oil combustion in power stations.
	1A2f	Waste oil combustion in cement kilns.
	1A2g	Waste oil combustion in unclassified industry (including road-stone coating plant)
	1A3biv	Lubricant combustion in moped engines
	2D1	Lubricant combustion in aircraft, industrial, road vehicle (except moped), marine shipping and agricultural engines.
	5C	Incineration of waste oil.
Bitumen	n/a	*No known UK applications that lead to GHG emissions.*

Fuel	IPCC	Source Category
Petroleum coke	1A2f 1A2g 1A4b 2A4 2B6 2C1 2C3 2D4	Based on reported energy use data by specific industries within datasets such as EU ETS and also from direct dialogue with industry representatives, the Inventory Agency re-allocates a small proportion of the reported "NEU" allocation from DUKES, and reports emissions within the UK GHG inventory. This re-allocation generates emissions for the mineral processing sector (1A2f) and other industry (1A2g) and for petcoke use in the domestic sector (1A4b). There are also non-combustion, emissive uses of petcoke in the UK through the use of petcoke-derived anodes in the metal processing industries. Emissions from these uses of petcoke are reported in 2C1 (electrode use in electric arc furnaces) and 2C3 (anode use in aluminium manufacture). Petroleum coke is also used in the minerals (2A4) and chemicals industries (2B6) leading to further emissions. The remaining consumption of petroleum coke is also assumed to be emissive, with emissions reported under 2D4. *Note that DUKES already includes allocations of petcoke use as a fuel in combustion in power stations (1A1a) and refineries (1A1b), which are included in the UK GHG inventory.*
Other Oil	2D2	Carbon released from use of petroleum waxes. Uses of petroleum waxes includes candles, with carbon emitted during use.
Solid Fossil		
Coking coal (coal oils and tars)	n/a	*Unknown quantities of coal tar pitch are used in the manufacture of anodes for industrial processes. In the UK inventory the emissions from the use of these anodes are allocated only against petroleum coke (also used in anode production). This is a small mis-allocation of emissions between the two fuels since the carbon emitted is likely to arise from both petroleum coke and the coal tar pitch, but it is due to lack of detailed data, and does not affect the accuracy of UK inventory emissions.*
Gaseous Fossil		
Natural Gas	2B1 2B8	Ammonia and methanol production leading to direct release of CO_2 from natural gas used to provide the energy for steam reforming and from natural gas feedstock to the reformer. Carbon originating in the natural gas feedstock which is converted into methanol is assumed stored, however.

A 3.1.3.1 Naphtha, Ethane, Gas Oil, Refinery/Other Fuel Gas (RFG/OPG) Propane and Butane (LPG)

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

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

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

The majority of emissions are from installations manufacturing ethylene, but a number of other chemical sites report additional emissions in the EU ETS that can be attributed to the combustion of process off-gases and residues derived from the chemical feedstock. As a result, the UK inventory emissions in 2B8 now include estimates of emissions from use of process off-gases and residues at 5 ethylene manufacturing installations and 16 other chemical manufacturing installations in the UK (some of these 16 may be using process off-gases from neighbouring ethylene plant). The derivation of a time series of emission estimates from these sources is based as far as possible on reported data by plant operators within trading scheme data and other regulatory reporting mechanisms. For the early part of the time series, data on changes in plant capacity over time is used to derive the best estimates of activity and emissions by extrapolation back from later emission estimates, whilst for later years the completeness and transparency of operator reporting is greater. Therefore, whilst the uncertainty for the emission estimates in the early part of the time series is significantly greater than for those in recent years, the Inventory Agency has made best use of the available data to derive the time series estimates of emissions from "NEU" activity. Consultation with a sector trade association has also confirmed that there are no other sector estimates of this activity, or of production data across the time series, that could be used to further improve the time series (Personal communication: Chemical Industries Association, 2014).

Other emissions included within the UK GHG inventory include emissions from the destruction of chemical products, e.g. when wastes are incinerated or used as fuels. Although emissions from incineration and combustion of wastes are estimated, we cannot relate the carbon in these wastes back to individual feedstock, so it is not possible to generate reliable UK estimates of the proportion of carbon that is ultimately emitted from each individual fuel. Incineration of wastes derived from chemical feedstocks will be reported in 1A1a (in the case of plastics etc. in municipal waste incinerated with energy recovery) and in 6C (in the case of chemical, clinical and municipal wastes incinerated without energy recovery. Waste-derived fuels, including waste solvents, waste plastics and scrap tyres are used as fuels in cement kilns and other industrial plants, and emissions reported in 1A2. Tyres contain a mixture of natural and synthetic rubbers, and so where waste tyres are used as a fuel, the emission estimates take into account that only some of the carbon emitted is derived from fossil fuels.

Some butane is used as a propellant in aerosols and is emitted as VOC. The UK inventory contains estimates of these VOC emissions, combined with emissions of solvents used in aerosols.

We assume that all gas oil used for non-energy purposes is used a feedstock material, and consultation with DECC (now BEIS) energy statisticians supports this (Personal communication: Will Spry, DECC Energy Statistics team, 2014). A possible alternative use would be in explosives, but consultation with the Health and Safety Executive, who regulate the UK explosives industry, has confirmed that no UK installations manufacture explosives using gas oil or fuel oil as a feedstock (HSE, 2013).

A 3.1.3.2 Lubricants

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

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

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

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

The emission trends from power station use of waste lubricants reflect the fact that the Waste Incineration Directive (WID) had a profound impact on the market for waste oil, used as a fuel. It is assumed that no waste oil was burnt in power stations for the years 2006-2008, on the basis that the classification of waste oil as a fuel would have led to users being subject to the requirements of WID. In 2009 a Quality Protocol[4] was introduced that allowed compliant fuel produced from waste oils to be burned as non-waste and this has encouraged a resumption in the consumption of waste oil-derived fuels from 2009 onwards.

Carbon dioxide emission estimates for the oxidation of lubricants within vehicle engines and machinery, and the use of waste oils for energy are all based on a single carbon emission factor derived from analysis of the elemental composition of a series of UK-sourced samples of waste oil (Passant, 2004). The UK inventory adopts the IPCC Tier 1 methodology for lubricant use i.e. assuming that 20% of all lubricants are oxidized during use. This assumption is used for the various sub-categories of lubricant use (including road, rail, marine, off-road and air transport) given in DUKES.

A 3.1.3.3 Bitumen

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

A 3.1.3.4 Coal Oils and Tars

Coal-tars and benzole are by-products of coke ovens. Consultation with the operators of coal ovens (Tata, 2013) and also the UK company that refines and processes coal tars and benzole

[4] http://webarchive.nationalarchives.gov.uk/20140328084622/http://www.environment-agency.gov.uk/business/topics/waste/116133.aspx

(Koppers UK, 2013) has confirmed that all of these materials are collected, refined and processed into a range of products that are not used as fuels. The carbon within coal tars and oils are entirely used within chemical processes. In some cases, the carbon is processed into anodes used in the ferrous and non-ferrous metals industries and then used (in the UK and overseas) within emissive applications. The UK inventory already includes estimates of emissions from UK consumption of carbon anodes within these industries, using methods based on UK metal production statistics.

Based on the evidence from process operators, the Inventory Agency allocates all of the reported coal tars and oils to Non Energy Use, i.e. assuming that all carbon is stored and there are no GHG emissions from this source-activity. The Digest of UK Energy Statistics (BEIS, 2016) also report the use of tars and benzole entirely to Non Energy Use.

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

A 3.1.3.5 Natural Gas

Natural gas is used as a chemical feedstock for the manufacture of ammonia and formerly for methanol as well, though production of the latter ceased in 2001. Emissions occur directly as a result of a) combustion of gas used to power the steam reforming process that is required for manufacture of both ammonia and methanol; b) oxidation of gas in the steam reforming, producing CO_2 which in the case of ammonia production is not needed and is instead emitted. The emissions are reported under 2B1 for ammonia and 2B8 for methanol.

Most of the emissions from feedstock use of natural gas in ammonia production are at source, i.e. waste gases containing carbon are emitted directly from the ammonia plant. Up until 2001, some was exported to a neighbouring methanol plant and here converted into methanol, and this CO_2 is treated as stored. Further CO_2 is captured and sold for use elsewhere, for example, in carbonated drinks and this CO_2 is assumed all to be emitted in the UK.

A 3.1.3.6 Other Oil (industrial spirit, white spirit, petroleum wax, miscellaneous products)

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

The only emissions from this group of petroleum feedstock that are included in the UK GHG inventory are the releases of carbon from petroleum waxes which are reported under 2D2. These are accounted for in the UK inventory under the fuel category “Other Oils” in CRF Table 1Ad.

A 3.1.3.7 Petroleum Coke

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

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

- 1A1a: Power station use of petroleum coke, primarily within blends with coal at a small number of UK facilities;
- 1A1b: Refinery emissions from regeneration of catalysts;
- 1A2f: Cement industry use of petroleum coke as a fuel;
- 1A2g: Other industry use of petroleum coke as a fuel;
- 1A4b: Petroleum coke use within domestic fuels;
- 2A4: Use in brick manufacture (reported combined with other emissions e.g. from use of carbonate minerals in brickmaking;
- 2B6: Use in chemicals manufacturing;
- 2C1: Carbon emissions from electrodes used in electric arc furnaces and ladle arc furnaces and petroleum coke added to furnaces as a carbon source;
- 2C3: Carbon emissions from anode use in primary aluminium production; and
- 2D4: Petroleum coke used for non-energy applications not included elsewhere.

The UK energy balance tables in DUKES contain data on the energy use in power stations (1A1a) and refineries (1A1b), although the former are only available for 2007 onwards, and both sets of data do not always agree with the available activity data from EU ETS. The remaining energy uses in industrial combustion (1A2f, 1A2g) and the domestic sector (1A4b) are not included in DUKES. The UK Inventory Agency therefore makes independent estimates of the consumption of petroleum coke in all of these sectors.

Petroleum coke is burnt in **cement kilns** (1A2f) and in a handful of **power stations** (1A1a). A few other **large industrial sites** (1A2g) have also used the fuel. Good estimates of the consumption of petroleum coke by these large sites are available from the operators themselves, from trade associations and from EU ETS data (from 2005 onwards).

Fuel grade petroleum coke is also used as a **domestic fuel** (both smokeless and non-smokeless types, reported in 1A4b). The Inventory Agency uses data supplied by the UK fuel supply industry to estimate petroleum coke consumption for domestic fuels over the period 1990 to 2016; these estimates are broadly consistent with fuel use data published in earlier editions of DUKES for a few years in the late 1990s.

Carbon deposits build up with time on catalysts used in **refinery** processes such as catalytic cracking. These deposits need to be burnt off to regenerate the surface area of the catalyst and ensure continued effectiveness of the catalyst; emissions from this process are reported within EU ETS since 2005, with the time series estimates provided by the trade association (UKPIA, 2017) and the catalyst regeneration is treated in the inventory as use of a fuel (since heat from the process is used) and are reported under 1A1b.

Estimates of carbon released from electrodes and anodes during **metal processes** are estimated based on operator data and reported in 2C1 and 2C3. Petroleum coke content of these electrodes and anodes is estimated based on operator data and literature sources such as Best available techniques REFerence documents (BREF notes). EU ETS data also show that some petroleum coke is added to electric arc furnaces as a carbon source, and the emissions from this use are also reported in 2C1. EU ETS data are also used for emission estimates for brickmaking, which include a component from petroleum coke. Finally, petroleum coke is used in the manufacture of titanium dioxide, with emission estimates generated from EU ETS and other operator data.

Based on data from DUKES we believe that there is some additional non-energy use of petroleum coke for most years; we assigned this residue to 2D4 and assume that it is all eventually emitted. The total fuel assigned to sector 2 is what we report as 'excluded carbon' in the CRF, table 1A(d). The consumption estimates for industrial users of petcoke as a fuel or in industrial processes are associated with low uncertainty as they are primarily based on operator reported data within the EU ETS or other regulatory reporting mechanisms. Whilst it is conceivable that other sectors may also use petroleum coke as a fuel, there is no evidence from resources such as EU ETS and Climate Change Agreement reporting that this is the case in the UK. The remaining petroleum coke consumption given in DUKES is therefore assumed to be used in various unidentified non-energy uses, all of which are assumed to be emissive. The estimates of petroleum coke used to generate fuels for the domestic sector are associated with higher uncertainty as they are based on periodic consultation with fuel suppliers to that market, and expert judgement of stakeholders.

As well as the total UK supply figure from UK energy statistics, DUKES has data on UK production, imports and exports of petroleum coke, which together provide more information on the nature of the UK consumption of petroleum coke. These data cover three distinct types of petroleum coke – catalyst coke, produced and consumed at refineries only (so no import/export or supply of fuel to other UK sectors), and then two products made in a refinery process known as coking: fuel grade (green) coke and anode-grade coke, with the former being used as a fuel, and the latter being a calcined[5] version of the former, used in various non-energy processes. Consultation with the DECC energy statistics team and the only UK refinery with a coking process (DECC, 2013) has confirmed that the UK produces only anode-grade coke, and exports will also be anode-grade coke, whilst imports will be fuel grade coke for use as a cost-effective fuel source or raw material for production processes under NEU.

Carbon factors for petroleum coke use are derived from industry-specific data (including EU ETS fuel analysis) in the case of cement kilns (MPA, 2016), power stations and other industrial sites (EA, 2017; SEPA, 2017). The petroleum coke factor for refinery consumption is based on trade association analysis conducted as part of the 2004 Carbon Factors Review (UKPIA, 2004) while the factor for domestic consumption is based on compositional analysis of samples of petroleum coke sold as domestic fuels (Loader et al, 2008).

These factors do show quite a large variation from sector to sector: this is probably primarily a reflection of the different requirements of fuels for different sectors (higher quality, higher carbon for some, less so for others). The highest carbon factor is for 'petroleum coke' burnt in sector 1A1b, but this fuel is actually of a different nature from the fuel burnt as petroleum coke in sectors 1A1a, 1A2f and 1A4b. In the case of 1A1b, the fuel is a build-up of carbon on catalysts used in various refinery process units, while in the other three cases, the petroleum coke is a solid by-product of a totally different refinery process (coking) which has different characteristics.

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

The analysis within the UK energy statistics or GHG inventory compilation system cannot accurately account for the variable (over time) import-export balance of carbon-containing

[5] Caclined petroleum coke is a processed petroleum coke that has a very high carbon content; the resulting fuel is somewhat similar to coke oven coke

materials in the UK economy. For example, where the Inventory Agency accounts for the carbon emissions from scrap tyres burned in cement kilns, power stations, incinerators and so on within the inventory estimates or from the incineration of plastics or synthetic fibres, there is no way of tracing the quantity that is derived from imported tyres/plastics/fibres.

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

A 3.1.4 Aviation (MS 7)

Table A 3.1.2 CAA aircraft types assigned to EMEP-EEA Emissions Inventory Guidebook aircraft types

EMEP/EEA Aircraft Type	CAA Aircraft Types
Airbus A300 – B4	AIRBUS A300 (ALL FREIGHTER); AIRBUS A300-600; AIRBUS A300-600F (ALL FREIGHTER); AIRBUS A300B1/B2; AIRBUS A300B4-100/200; AIRBUS A300F4
Airbus A310	AIRBUS A310; AIRBUS A310-202; AIRBUS A310-300
Airbus A318	AIRBUS A318
Airbus A319	AIRBUS A319; AIRBUS A319 CJ (EXEC); BOMBARDIER CSERIES CS100
Airbus A320	AIRBUS A320-100/200
Airbus A321	AIRBUS A321
Airbus A330-200	AIRBUS A330-200
Airbus A330-300	AIRBUS A330-300
Airbus A340-200/300	AIRBUS A340-200; AIRBUS A340-300; AIRBUS A350-900
Airbus A340-500	AIRBUS A340-500
Airbus A340-600	AIRBUS A340-600
Airbus A380-800	AIRBUS A380-800
Antonov 26	ANTONOV AN-24; ANTONOV AN26B/32; DOUGLAS DC4 SKYMASTER; NAMC YS11; VICKERS VISCOUNT 700
ATR 42 - 320	ATR42-300; BRISTOL 170 FREIGHTER; CONVAIR 240/340/440; GULF AMERICAN GULFSTREAM I; ILYUSHIN IL12/IL14
ATR 42 - 45	ATR42-500
ATR 72 - 200	ATR72; ATR72 200/500; ATR72 200/500/600; HANDLEY PAGE HERALD 200; HANDLEY PAGE HERALD 700; NORD 2501 NORTALAS
Avro RJ85	AVROLINER RJ100/115; AVROLINER RJ70; AVROLINER RJ85/QT
BAe 1-11	AEROSPATIALE CARAVELLE 10B/10R; AEROSPATIALE CARAVELLE 12; AEROSPATIALE CARAVELLE 6/6R; BAE(BAC)111-200; BAE(BAC)111-300/400/475; BAE(BAC)111-500; GA GULFSTREAM 3; GULF AMERICAN GULFSTREAM II; TUPOLEV TU124

EMEP/EEA Aircraft Type	CAA Aircraft Types
Bae Jetstream 31	BAE JETSTREAM 31/32
Bae Jetstream 41	BAE JETSTREAM 41
BAe146 -100/200/300	BAE 146-100; BAE 146-200/QT; BAE 146-300
Beech 1900C airline	AEROSPATIALE (NORD)262; BEECHCRAFT 1900C/D AIRLINER; BEECHCRAFT STARSHIP MODEL 2000; DOUGLAS DC3 C47 DAKOTA
Beech Super King Air 200B	BEECHCRAFT 200 SUPERKING AIR; BEECHCRAFT B200 SUPERKING AIR; PIAGGIO P.180 AVANTI
Beech Super King Air 350	BEECHCRAFT 300 / 350 SUPER KING AIR; PIPER PA42 CHEYENNE III/IV
Boeing 727-100	BOEING 727-100/100C
Boeing 727-200	BOEING 727-200/200 ADVANCED; TUPOLEV TU154A/B; TUPOLEV TU154M
Boeing 737 100	ANTONOV 148/158; ANTONOV AN72; ANTONOV AN72 / 74; BOEING 737-100; CONVAIR 880; GULF AMERICAN GULFSTREAM 500-550; GULF AMERICAN GULFSTREAM IV; TUPOLEV TU134
Boeing 737-200	BOEING 737-200; DASSAULT-BREGUET MERCURE; GULFSTREAM G650
Boeing 737-300	BOEING 737-300
Boeing 737-400	BOEING 737-400
Boeing 737-500	BOEING 737-500
Boeing 737-600	BOEING 737-600
Boeing 737-700	BOEING 737-700; BOEING BBJ
Boeing 737-800	BOEING 737-800; BOEING 737-900; BOEING 737-900 ER
Boeing 747-100/300/800	BAC/AEROSPATIALE CONCORDE; BOEING 747-100/100F; BOEING 747-300(STRETCH UP DK); BOEING 747-300M (COMBI); BOEING 747-8 (FREIGHTER); BOEING 747-8 (I); BOEING 747SP
Boeing 747-200	ANTONOV AN-124; ANTONOV AN-225 MRIYA; BOEING 747-200B; BOEING 747-200B (COMBI); BOEING 747-200C/200F
Boeing 747-400	BOEING 747-400; BOEING 747-400F; BOEING 747-400M (COMBI)
Boeing 757-200	BOEING 757-200
Boeing 757-300	BOEING 757-300
Boeing 767 200	BOEING 767-200; BOEING 767-200ER
Boeing 767 300 ER	BOEING 767-300; BOEING 767-300ER/F; BOEING 767-400ER; BOEING 787-800 DREAMLINER; BOEING 787-900 DREAMLINER
Boeing 777-200 ER	BOEING 777-200; BOEING 777-200ER
Boeing 777-200 LRF	BOEING 777 FREIGHTER; BOEING 777 FREIGHTER SERIES; BOEING 777-200LR
Boeing 777-300	BOEING 777-300
Boeing 777-300 ER	BOEING 777-300ER
Canadair Regional Jet CRJ-200	BOMBARDIER CHALLENGER 850; BOMBARDIER REGIONAL JET 100/200; DASSAULT FALCON 7X

EMEP/EEA Aircraft Type	CAA Aircraft Types
Canadair Regional Jet CRJ-900	BOMBARDIER GLOBAL 5000; BOMBARDIER GLOBAL EXPRESS; BOMBARDIER GLOBAL EXPRESS (BD700 EXEC); BOMBARDIER REGIONAL CRJ 1000/1000 ER; BOMBARDIER REGIONAL JET CRJ900; BOMBARDIER REGIONAL JET CRJ900 ER; BOMBARDIER REGIONAL JET CRJ900 ER/LR; BOMBARDIER REGIONAL JET RJ700; BOMBARDIER REGIONAL JET RJ700ER
Cessna 208 Caravan	Other small piston aircraft
Cessna Citation II	Other small jets
Dash 8 A	BOMBARDIER DASH 8 Q100/200; DE HAVILLAND DASH 8-100
Dash 8 C	DE HAVILLAND DASH 8-300/Q300
Dash 8 D	ARMSTRONG WHITWORTH ARGOSY; BOMBARDIER DASH 8 Q400; DE HAVILLAND DASH 8 Q400
Dornier 328-110	DE HAVILLAND DHC-7 DASH-7; DORNIER 328
Embraer 110P2A Bandeirante	Other small turboprops
Embraer EMB120 Brasillia	EMBRAER EMB120 BRASILIA
Embraer ERJ145	BOMBARDIER CHALLENGER 300; BOMBARDIER CHALLENGER 300/350; EMBRAER LEGACY 600 (BJ135); EMBRAER LEGACY 600/650 (BJ135); EMBRAER RJ135; EMBRAER RJ145; LOCKHEED JETSTAR II
Embraer ERJ170-ERJ175	EMB ERJ170 (170-100); EMB ERJ175 (170-200); EMBRAER ERJ 170; EMBRAER ERJ170; EMBRAER ERJ175
Embraer ERJ190	CANADAIR CL-600-604 CHALLENGER; EMBRAER 195; EMBRAER ERJ190; EMBRAER ERJ195
Falcon 2000	BAE125-1000; CESSNA 680 CITATION SOVEREIGN; CESSNA 750 CITATION X; DASSAULT BREGUET FALCON 50; DASSAULT MYSTERE-FALCON 2000; DASSAULT MYSTERE-FALCON 900; DASSAULT MYSTERE-FALCON 900EX; DORNIER 328 JET; EMBRAER LEGACY 500 (EMB-550); GULFSTREAM G200 (IAI GALAXY); HAWKER 4000; LEARJET 60; RAYTHEON HAWKER HORIZON; YAKOVLEV YAK-40
Fokker F100	FOKKER 100; FOKKER 70
Fokker F27	BAE (HS) 748; FAIRCHILD HILLER FH 227B; FOKKER F27 100-400/600; FOKKER F27-500
Fokker F28	FOKKER F28-1000; FOKKER F28-2000; FOKKER F28-3000; FOKKER F28-4000/6000
Fokker F50	BAE ATP; FOKKER 50
Let L-410 Turbolet	LET 410; MITSUBISHI MU2; SHORTS SC7 SKYLINER; SHORTS SC7 SKYVAN
Lockheed C-130H Hercules	AEROSPACELINES B377SUPER GUPPY; ANTONOV AN-12; CANADAIR CL-44; ILYUSHIN IL18; LOCKHEED L100 HERCULES; LOCKHEED L188 ELECTRA; SHORTS BELFAST; V953C MERCHANTMAN
McDonnell Douglas DC-10	LOCKHEED L1011-1/100 TRISTAR; LOCKHEED L1011-200 TRISTAR; LOCKHEED L1011-500 TRISTAR; MCDONNELL-DOUGLAS DC10-10; MCDONNELL-DOUGLAS DC10-30; MCDONNELL-DOUGLAS DC10-40
McDonnell Douglas DC8-50	BOEING 707 ALL SERIES; BOEING 707-120/121B; BOEING 720B; MCDONNELL-DOUGLAS DC8-10/50; MCDONNELL-DOUGLAS DC8F 54/55

EMEP/EEA Aircraft Type	CAA Aircraft Types
McDonnell Douglas DC8-60/70	ILYUSHIN IL62; MCDONNELL-DOUGLAS DC861/3 71/3; MCDONNELL-DOUGLAS DC8-62/72; MCDONNELL-DOUGLAS DC8-71/73
McDonnell Douglas DC-9-10	MCDONNELL-DOUGLAS DC9-10/15
McDonnell Douglas DC-9-20/30/40/50	McDONNELL-DOUGLAS DC9-20; MCDONNELL-DOUGLAS DC9-30; MCDONNELL-DOUGLAS DC9-40; MCDONNELL-DOUGLAS DC9-50
McDonnell Douglas MD-11	MCDONNELL-DOUGLAS MD11
McDonnell Douglas MD-82/87/88	BOEING 717-200; MCDONNELL-DOUGLAS MD80-MD83; MCDONNELL-DOUGLAS MD87; MCDONNELL-DOUGLAS MD88; SUKHOI RRJ95
McDonnell Douglas MD-83	Mc DONNELL DOUGLAS MD90; TUPOLEV TU104; YAKOVLEV YAK-42
Saab 2000	CONVAIR 580/600/640; DOUGLAS DC6/6A/6B/6C; SAAB 2000; VICKERS VISCOUNT 800
Saab 340B	SAAB FAIRCHILD 340
Shorts 360-300	SHORTS 330; SHORTS 360
Swearingen Metro III	FAIRCHILD SA-227 METRO 23; FAIRCHILD SA-227 METRO III; SWEARINGEN MERLIN IIA/IIB/IIIB; SWEARINGEN MERLIN IVA; SWEARINGEN METRO II
Tupolev TU 204	ILYUSHIN 76 90VD (PERM); ILYUSHIN IL76; ILYUSHIN IL86; ILYUSHIN IL96-300; TUPOLEV TU204

A 3.1.5 Gas leakage

An overview of the time series of estimates of gas leakage at the point of use, together with overall gas use by economic sector and appliance type is presented in **Table A 3.1.3** below.

Table A 3.1.3 Activity data and methane leakage estimates for Gas leakage at Point of Use, including cooking appliances, gas fires and boilers

Source / Appliance type	Units	1990	1995	2000	2005	2010	2014	2015	2016
Annual Gas Use									
Domestic gas fires	ktoe	462	520	621	650	673	510	536	561
Domestic manual ignition hobs / cookers	ktoe	590	530	511	496	444	333	328	333
Domestic auto-ignition hobs / cookers	ktoe	211	190	183	177	159	119	118	119
Domestic auto-ignition space	ktoe	24572	26796	30491	31512	32223	23430	24606	25760

Source / Appliance type	Units	1990	1995	2000	2005	2010	2014	2015	2016
and water heating									
Service sector catering (ovens and hobs)	ktoe	596	762	772	774	705	603	570	590
Other service sector appliances (boilers)	ktoe	6646	8508	9818	9290	8643	7423	7993	8250
Domestic cooking and gas fires	$ktCH_4$	1.02	0.94	0.86	0.85	0.80	0.61	0.61	0.62
Domestic boilers and water heating	$ktCH_4$	0.76	0.83	0.94	0.98	1.00	0.73	0.76	0.80
Service sector (all sources)	$ktCH_4$	0.83	1.06	1.09	1.05	1.00	0.87	0.90	0.93
Total	**$ktCH_4$**	**2.61**	**2.83**	**2.90**	**2.88**	**2.80**	**2.20**	**2.27**	**2.36**

A 3.2 INDUSTRIAL PROCESSES (CRF SECTOR 2)

There is currently no additional information for this sector in this Annex.

A 3.3 AGRICULTURE (CRF SECTOR 3)

Note that the references for this section are included in Section 17.4.

A 3.3.1 Characterisation of the UK Agriculture Sector

Livestock numbers and crop areas for each year (Table A 3.3.1) are derived from the June Agricultural Survey data for each Devolved Administration (England, Wales, Scotland, Northern Ireland) at farm holding level (Dragosits et al., 2017). From 2006 onwards, cattle numbers for England, Scotland and Wales are obtained at holding level on a monthly basis from the Cattle Tracing Scheme database. Each holding is associated with a location (by 10 km grid square) and with a Robust Farm Type category (to associate with other activity data collated in the same way). Confidentiality of individual holdings is maintained and published data are non-disclosive.

Physical data used in the inventory model at a 10 km resolution comprise soil class (by RB209 category – derived by expert interpretation of the National Soils Map), long-term annual and monthly temperature and rainfall (UKCIP 1981-2010), soil alkalinity (calcareous or non-calcareous), location of cultivated organic soils (histosols, based on soil type and use; Anthony et al., 2016) and location of common land (relevant to the sheep sector).

Activity data, including livestock housing types, manure management practices, fertiliser application rates and timings, etc., are derived from regular and ad-hoc surveys, reports and expert judgement and are described in more detail where relevant to the individual sectors.

More detailed information on the structure and emission calculations for each sector can be found in the individual sector reports published as part of Defra project AC0114.

A 3.3.1.1 Dairy cattle

Dairy cattle are categorised according to four age categories (calves <1 year being kept as dairy replacements, dairy replacements >1 year but not in calf, in-calf dairy heifers, dairy cows after first calf) and to three production intensity categories associated with proxy bree types (large/high yield – proxy breed Holstein; medium/medium yield – proxy breed Ayrshire; small/low yield – proxy breed Guernsey). For data derived from the Cattle Tracing Scheme for England, Wales and Scotland, all cattle breeds are associated with a role (dairy or beef) and a production intensity and thereby mapped to one of the dairy categories described above. Distribution of the dairy herd among production categories for 1990 was based on a Milk Marketing Board publication (1992), Dairy Facts and Figures, giving a breakdown of the national herd for each Devolved Administration for 1988/89. For Northern Ireland, data on herd disaggregation by breed type were provided by Conor McCormack (DAERA) for 2010. Data for intervening years for each country were interpolated. NB: Emissions from dairy cows are reported under 3A1 and 3B1 as 'Dairy cattle', while emissions from calves, replacements and in-calf heifers are reported under 'Other cattle' together with all beef cattle.

A standard growth curve is defined for dairy cattle, based on that given by Coffey et al, (2006) is used to define live weights for each age category, with annual data for mature cow weight by proxy breed type being obtained from UK slaughter statistics as analysed by SRUC (Tracey Pritchard). Calf birth weight is related to mature cow weight (AFRC, 1993). Average age of conception for first calving is defined as 19, 20 and 18 months for large, medium and small breed proxies, respectively, giving respective age at first calving of 28, 29 and 27 months, for which relevant live weights can be derived. There is no evidence from industry data of any consistent trend over time in age of first calving. Milk yield associated with each production intensity breed proxy for each year were derived from publications by the Centre for Dairy Information, and were normalised to agree with published devolved Administration and UK level milk production statistics. A time series of milk yield by proxy breed type is presented in the UK IIR.

Dairy cattle are managed according to four regimes: year-round housing, winter housed and summer part-housed (overnight), winter housed and summer grazing, extended grazing. The proportion of the national herd associated with each management regime is based on a survey reported by March et al. (2014) and industry expert judgement on trends between 1990 (assuming no year-round housing) and that time. Dairy cattle diet and location for any given month of the year are associated with diet (by age category and production intensity). Cattle are assumed to be fed concentrates at an average level as reported annually in Nix Farm Management Pocket book and the remainder of the diet derived from forage (at grazing or fed as conserved silage). Characteristics of the diets and proportional allocation are given in detail by Misselbrook et al. (2018). Increased use of forage maize, with associated higher energy and lower crude protein content, is reflected in the time series.

A review of livestock housing and manure management practices conducted by Ken Smith (ADAS) as part of Defra project AC0114, updated with 2016 survey data on manure spreading practices from the British Survey of Fertiliser Practice 2016 (https://www.gov.uk/government/statistics/british-survey-of-fertiliser-practice-2016) was used as the basis of developing the time series 1990 to 2016 across all livestock types of livestock housing and manure management practices for each country (England, Wales, Scotland and Northern Ireland) from which a weighted average was derived for the UK. Broad management categories (managed as slurry, Farm Yard Manure or outdoor excreta) are given in **Table A 3.3.5**. More detailed practice-specific data are applied at a country scale for each livestock category for the livestock housing, manure storage and manure application phases of the manure management continuum. Estimates for these activity data across the time series are derived from a number of routine and ad-hoc surveys including the Defra Farm Practices Surveys (https://www.gov.uk/government/collections/farm-practices-survey) and published manure management surveys (Smith et al., 2000, 2001a, 2001b).

A 3.3.1.2 Beef cattle

Beef cattle are disaggregated into 15 age bands, four breed types (Continental, lowland native, upland and dairy) and six sub-categories by role (beef cows, beef heifers for breeding, breeding bulls, beef females for slaughter, steers for slaughter, cereal fed bulls for slaughter).

Cattle live weights were derived using a fitted growth curve model (Lopez et al., 2000), requiring mature live weight, calf live weight and two fitted parameters (based on industry and literature sources). Mature live weight data were obtained from the established time series of slaughter weights that are collected at national level (SRUC, Tracey Pritchard). These were supplemented with a large sample of data (SRUC, Tracey Pritchard) from which separate populations were derived of the breed types and age bands as used in the model. Calf birth weights were calculated based on cow live weight (AFRC, 1993). The fractions of cattle lactating and / or gestating were derived from industry performance data and an analysis of the CTS dataset, and were applied uniformly over the population throughout the year.

Farm practices survey data was used to quantify the housing systems and manure management regimes used. The housing management regimes were used to define cattle locations by month, i.e. grazing, in resting areas and in feeding yards. Diets were associated with cattle type, location (housing or grazing) and production system. Included are 11 diets for housed cattle, three types of grass and two diets for suckled calves at grazing, with mixed nutrition from milk and grass. Data for feeds used (by material) were derived from the Farm Business Survey (Parsons and Williams, 2015). Nutritional properties of diet components were based on the MAFF Feed Composition Tables (1992), with some input from Ewing (1998).

Housing and manure management practice data were derived from review and surveys as described above for dairy cattle.

A 3.3.1.3 Sheep

Sheep are categorised as ewes (> 1 year old), rams and lambs (< 1 year old) present. The ewe category includes replacement breeding sheep and cull ewes, as well as the ewes and ewe lambs that were successfully lambed in the survey year. The lamb category includes slaughtered lambs and those retained for breeding. The survey count of lambs is raised by between 1% (Scotland) and 5% (England) to account for the fraction of early spring lamb that are born, reared and marketed before the June Agricultural Survey takes place (Pollott, 2003, 2012; Wheeler et al., 2009).

Sheep numbers are also partitioned between hill, upland and lowland breed and management systems, based on holding location with respect to the Less Favoured Areas (LFA) and survey weights taken from Wheeler et al. (2009). For each system, the fraction of ewes first tupped as ewe lambs, and the fractions of lambs finished at grass, finished as stores, or used for breeding replacements, are taken from the December Agricultural Survey (Defra) and Wheeler et al. (2009). Each type of ewe and lamb has separate growth-curves, access to housing and handling yards, and different access to forage, concentrate and conserved feeds that determine its feed intake.

The annual average weight of ewes and slaughter weight of lambs are calculated separately for each country based on average carcase weights and a fixed killing-out percentage of 46 and 44% respectively, derived from national slaughter house statistics (Defra, DARD-NI, Welsh Government, Scottish Government, 1990 to 2016). The relative ewe weights for the hill, upland and lowland systems within each country are estimated based on an analysis of breed lists and expected mature weights, and are centred on the country average. Lambs finished at grass are slaughtered at between 133 and 172 days, and store lambs at between 276 and 331 days, varying with country and system (Wheeler et al., 2009). Lambs intended for breeding replacement, and all ewes and rams are present all year.

The pregnant ewe and ewe lamb is housed for 42 days prior to lambing. The fraction of ewes housed varies with system from 40 (hill) to 75% (lowland) (Roderick, 2001). All ewes occupy handling yards for an overall average of 5 days, for essential welfare tasks. Feed and manure management is assumed to be the same as during housing. Further detail of sheep diet is given by Anthony et al. (2018). All managed manure is assumed to be as farm yard manure and applied to grassland.

A 3.3.1.4 Pigs

Pigs are disaggregated into six sub-categories representing the breeding herd (sows and boars), replacements and finishing pigs. Finishing pigs are subdivided into three categories according to live weight (> 80 kg live weight, 20-80 kg liveweight, < 20 kg liveweight) to reflect differences in diet, N excretion and management practices.

Housing and manure management practice data were derived from review and surveys as described above for dairy cattle.

A 3.3.1.5 Poultry

Poultry are disaggregated into eight subcategories (laying hens, broilers, pullets, breeding flock, turkeys, ducks, geese, all other poultry) to reflect differences in live weight, feeding and management practices.

Housing and manure management practice data were derived from review and surveys as described above for dairy cattle.

A 3.3.1.6 Other livestock

Other livestock included in the UK emission inventory are goats, horses and deer. Horses comprise those kept on agricultural holdings (and counted in the June Agricultural Surveys), those kept as domestic pets and not included in the June Agricultural Survey, and those kept as professional racehorses. Numbers in these latter two categories are derived from periodic surveys by the British Equestrian Trade Association. Professional horses are assumed to be on a higher nutritional plane that other horses, and are therefore assumed to have a greater N excretion.

Goats are assumed to be housed for 8% of the year, deer and domestic horses (including those on agricultural holdings) for 25% of the year and professional horses for 50% of the year. All of these livestock categories are assumed to be associated with deep litter manure management systems, with all farm yard manure produced being applied to grassland.

A 3.3.1.7 Crops, grassland and fertiliser use

Crops are categorised according to 49 crop types, representing the major cereal crops and roles (e.g. winter and spring sown, milling and non-milling wheat, malting barley and non-malting barley), oilseed crops, vegetables, forage crops and fruit crops, enabling consistent aggregation and discrimination across the time series and association with different fertiliser and residue management practices (see Williams et al., 2018 for more details).

For England, Wales and Scotland, data for fertiliser N use on crops were derived from the British Survey of Fertiliser Practice. For 1990-2003 these data were only available via printed reports. From 2004 on, access was granted to the field level data for N applications. For Northern Ireland, data were provided by DAERA statistics (Paul Keatley, www.daera-ni.gov.uk/topics/statistics). From 2004, the British Survey of Fertiliser Practice data set was disaggregated by country and Robust Farm Type as far as possible. The same data were used to disaggregate N rate by month and the proportion of N by fertiliser type (Ammonium Nitrate, Ammonium Sulphate or Diammonium Sulphate, Calcium Ammonium Nitrate, Urea, Urea Ammonium Nitrate, Other N).

Activity data for the areas of crop residues that were harvested or burned came initially from MAFF surveys from 1990 to 1993 and then from the British Survey of Fertiliser Practice field level data from 2004 onwards for England, Wales and Scotland. Primary crop yields were taken from national statistics. A Harvest Index approach is taken to estimate residues for cereals and oilseed crops. The default method and parameter values gave over-estimates of residue biomass when compared with data found in the literature. The approach for other crops was not changed, but UK-specific data values for above- and below-ground biomass and N contents were obtained where possible. The derivation of UK specific parameter values is described in the report under project AC0114 (Williams and Goglio, 2017).

Improved grassland is categorised as temporary (sown within the last 5 years) and permanent. Rough grazing and common land are excluded from the estimation of emissions from fertiliser applications and residue returns for the grassland sector. Grassland area is associated with Robust Farm Type for association with data on management including fertiliser application rate. Model calculations of grass offtake and N leached are made for soil-climate zones that aggregate areas of the same soil type (the RB209 classification) and climate (annual rainfall and temperature) within each country. Individual 10 km grid cells are aggregated if they fall within the same 100 mm annual rainfall band, and 0.5^{o}C annual average temperature band.

The British Survey of Fertiliser Practice (1990 to 2016) and the Northern Ireland Fertiliser Sales (1990 to 2016) survey are used to calculate the proportion of N applied by fertiliser type. Note that the distribution of fertiliser type for Wales (1990 to 2003) was a weighted average of those for Scotland (80%) and England and Wales (20%), based on importance of grassland. The British Survey of Fertiliser Practice (1990 to 2016) is also used to calculate the monthly distribution of total N applied to grassland. The records are specific to grass in the period 2004 to 2016, and are for all crops and grass with an expert adjustment for the period 1990 to 2003. Survey values for Scotland are used for Northern Ireland.

Renewal rates of between 3.7 (Wales) and 14.7% (England) for temporary grass, and between 2.0 (England) and 4.0% (Scotland) for permanent grass are assumed, based on analyses of field records from the British Survey of Fertiliser Practice (2004 to 2016) that records current and preceding crop. The UPCYCLE model (Anthony, 2017) is used to predict yield (cut and grazed) in response to fertiliser rate, sward clover content, and local soil and climate factors. The country average offtake is in the range 4.8 to 8.4 t dm ha-1 and stubble is in the range 1.3 to 1.6 t dm ha-1 and the root is in the range 4.9 to 6.1 t dm ha-1. The nitrogen content of the offtake and residue varies with fertiliser level and livestock excreta returns. Predicted offtake, N content and root mass are consistent with United Kingdom measurements, especially the GM 20, 21, 23 and 24 Manuring Trials against which the UPCYCLE model was calibrated. The trials measured grass offtake for ryegrass and mixed ryegrass-white clover swards at 21 sites across the United Kingdom, receiving fertiliser in the range 0 to 750 kg N ha-1. The UPCYCLE model assumes that grazed grass is stocked in proportion to the dry matter production.

Table A 3.3.1 Livestock Population Data by Animal Type (‘000 animal places)

Livestock Category	1990	1995	2000	2005	2010	2015	2016
Total cattle	12,125	11,760	11,048	10,698	10,014	9,785	9,886
- dairy cows	2,848	2,603	2,336	2,003	1,839	1,906	1,910
- all other cattle	9,277	9,157	8,713	8,695	8,175	7,879	7.977
Sheep	45,380	44,174	43,117	36,138	31,727	34,034	34,663
Pigs	7,548	7,627	6,482	4,862	4,468	4,739	4,866
Total poultry (x 10^3)	138,381	142,267	169,773	173,909	163,842	167,579	172,607
- laying hens	33,624	31,837	28,687	29,544	28,751	28,311	29,184
- broilers	73,944	77,177	105,689	111,475	105,309	107,056	110,639
Total horses	570	684	1006	1036	1024	978	963
- horses kept on agricultural holdings	202	273	287	346	312	283	268
- professional horses	62	62	70	91	91	87	87
- domestic horses	305	348	649	599	621	608	608
Goat	98	75	74	95	93	101	102
Deer	47	37	36	33	31	31	31

A 3.3.2 Enteric Fermentation (3A)

Table A 3.3.2 Methane Emission Factors for Livestock Emissions for 2016

Animal type		Enteric methane kg CH_4/head/year	Methane from manures kg CH_4/head/year
Cattle	Dairy cows	120.80	36.51
	Dairy heifers	71.88	10.94
	Dairy replacements >1 year	62.16	9.52

Animal type		Enteric methane kg CH_4/head/year	Methane from manures kg CH_4/head/year
	Dairy calves <1 year	46.78	6.42
	Beef cows	76.71	10.91
	Beef females for slaughter	50.61	6.75
	Bulls for breeding	59.66	8.69
	Cereal fed bull	54.21	11.39
	Heifers for breeding	51.85	7.40
	Steers	51.20	6.72
Pigs		1.50	5.20
Sheep	Ewes	6.48	0.18
	Rams	6.99	0.19
	Lambs	2.72	0.07
Goats		5.0	0.31
Horses		18.0	1.56
Deer		20.0	0.22
Poultry	Laying hens	NA	0.028
	Growing pullets	NA	0.013
	Broilers	NA	0.013
	Turkeys	NA	0.091
	Breeding flock	NA	0.013
	Ducks	NA	0.289
	Geese	NA	0.289
	All other poultry	NA	0.013

A 3.3.3 Manure Management (3B)

A 3.3.3.1 Methane emissions from animal manures

The emission factors for methane from manure management were given in **Table A 3.3.3.**

Table A 3.3.3 Methane conversion factors for Manure Management Systems in the UK

Manure Handling System	Methane Conversion Factor %
Liquid[a]	17
Daily spread	0.1
Deep bedding/farm yard manure	17
Pasture range and paddock	1.0
Poultry manure	1.5

[a]No differentiation is made between crusted and non-crusted slurry storage

A 3.3.3.2 Nitrous Oxide emissions from Animal Waste Management Systems

Table A 3.3.4 Nitrogen Excretion Factors, kg N animal place^{-1} year^{-1} for livestock in the UK (1990-2016)

Livestock Category	1990	1995	2000	2005	2010	2015	2016
Dairy cows	86.6	88.2	94.5	102.2	105.5	109.6	107.6
Other cattle[a]	48.4	48.8	49.6	48.7	48.7	48.5	48.3
Sows	23.6	22.5	21.4	20.1	18.1	18.1	18.1
Gilts	15.5	15.5	15.5	15.5	15.5	15.5	15.5
Boars	28.8	27.4	26.1	24.5	21.8	21.8	21.8
Fatteners > 80 kg	20.2	19.3	18.4	17.2	15.4	15.4	15.4
Fatteners 20-80 kg	14.6	13.9	13.2	12.4	11.1	11.1	11.1
Weaners (<20 kg)	4.6	4.4	4.2	3.9	3.4	3.4	3.4
Ewes	6.7	6.8	6.8	6.8	6.8	7.0	6.8
Rams	9.1	9.1	9.1	8.9	8.9	9.0	8.9
Lambs	2.9	2.9	3.0	3.2	3.2	3.4	3.3
Goats	20.6	20.6	20.6	20.6	20.6	20.6	20.6
Horses							
– horses kept on agricultural holdings	50	50	50	50	50	50	50
– professional horses	129	129	129	129	129	129	129
– domestic horses	50	50	50	50	50	50	50
Deer	13.0	13.0	13.0	13.0	13.0	13.0	13.0
Laying hens	0.85	0.82	0.78	0.74	0.67	0.67	0.67

Livestock Category	1990	1995	2000	2005	2010	2015	2016
Broilers	0.64	0.59	0.55	0.49	0.40	0.40	0.40
Turkeys	1.50	1.59	1.68	1.76	1.82	1.82	1.82
Pullets	0.42	0.39	0.36	0.34	0.33	0.33	0.33
Breeding flock	1.16	1.13	1.10	1.07	1.02	1.02	1.02
Ducks	1.30	1.41	1.52	1.62	1.71	1.71	1.71
Geese	1.30	1.41	1.52	1.62	1.71	1.71	1.71
Other poultry	1.30	1.41	1.52	1.62	1.71	1.71	1.71

[a]Weighted average for all other cattle categories

Table A 3.3.5 Distribution of Animal Waste Management Systems (%) used for Different Animal types, 2016

Animal Type		Liquid System	Daily Spread	Solid storage/Deep litter/Poultry litter[b]	Pasture Range and Paddock	Incineration
Cattle	Dairy cows	61.0	8.2	9.3	21.5	N/A
	All other cattle	18.0	11.4	21.6	48.9	N/A
Pigs	All pigs	38.74	0.01	50.43	10.81	N/A
Sheep	Ewes	0.0	0.0	8.9	91.1	N/A
	Rams	0.0	0.0	0.0	100.0	N/A
	Lambs	0.0	0.0	0.6	99.4	N/A
Goats		0.0	0.0	8.2	91.8	N/A
Deer		0.0	0.0	24.9	75.1	N/A
Horses		0.0	0.0	30.0	70.0	N/A
Poultry	All poultry	0.0	35.1	43.4	2.9	18.6

Table A 3.3.6 Nitrous Oxide Emission Factors for Animal Waste Handling Systems

Emission source	EF (% of total N)	Uncertainty limits (95% CI)	Data source
Cattle housing			
Slurry – solid floor	0	N/A	IPCC 2006
Slurry – slatted floor	0.2	Factor of 2	IPCC 2006
FYM systems	2.0	Factor of 2	UK measurement (at storage)
Outdoor yards	0	N/A	IPCC 2006
Cattle manure storage			
Slurry – without crust	0	N/A	IPCC 2006
Slurry – with crust	0.5	Factor of 2	IPCC 2006
Weeping wall store	0.5	Factor of 2	IPCC 2006
FYM heap	0.0	N/A	Included in housing
Pig housing			
Slurry – slatted floor	0.2	Factor of 2	IPCC 2006
FYM systems	2.0	Factor of 2	UK measurement (at storage)
Pig manure storage			
Slurry (no crust)	0	N/A	IPCC 2006
FYM heap	0	N/A	Included in housing
Sheep housing (FYM)	2.0	Factor of 2	Based on cattle/pig
Sheep FYM storage	0	N/A	Included in housing
Layer housing	0.5	Factor of 2	UK measurement (at storage)
Layer manure storage	0	N/A	Included in housing
Broiler housing	0.5	Factor of 2	UK measurement (at storage)
Broiler litter storage	0	N/A	Included in housing
Duck housing	2.0	Factor of 2	Based on cattle/pig
Duck manure storage	0	N/A	Included in housing

A 3.3.4 Agricultural Soils (3D)

A 3.3.4.1 Inorganic Fertiliser

Table A 3.3.7 EF for direct N_2O emissions from managed soils in the UK inventory

Emission source	EF (% of total N)	Uncertainty	Data source
Urea fertiliser	Non-linear function of application rate (see Section 5.5.2.1)		Topp et al., 2016
Other mineral fertilisers	Non-linear function of application rate and annual rainfall (see Section 5.5.2.1)		Topp et al., 2016
Livestock slurry	0.7475	SE 0.17328	Topp et al., 2016
Livestock solid manure (FYM, poultry manure)	0.3635	SE 0.06622	Topp et al., 2016
Sewage sludge	1.0	0.3 – 3.0	IPCC 2006
Crop residues	1.0	0.3 – 3.0	IPCC 2006
N mineralisation	1.0	0.3 – 3.0	IPCC 2006
Histosols	8 kg N_2O-N/ha	0 - 24	IPCC 2006
Cattle urine	0.629	SE 0.0930	Topp et al., 2016
Cattle dung	0.193	SE 0.0212	Topp et al., 2016
Sheep, goat, horse and deer urine	0.629	SE 0.0930	Cattle value assumed
Sheep, goat, horse and deer dung	0.193	SE 0.0212	Cattle value assumed
Outdoor pig and poultry			IPCC 2006

Table A 3.3.8 Areas of UK Crops and quantities of fertiliser applied for 2016

Crop Type	Crop area, ha	Fertiliser, ktN	Crop Type	Crop area, ha	Fertiliser, ktN
Oats	2,257	0.2	Potatoes (maincrop)	114,064	16.1
Spring oats	66,091	6.1	Potatoes (seed or earlies)	24,438	3.5
Winter oats	72,549	9.3	Sugar beet	85,947	8.6
Spring barley	14,708	1.4	Maize	62,994	3.3
Spring barley (malting)	349,245	40.0	Grain maize	7,589	0.4
Spring barley (non-malting)	319,015	31.9	Forage maize	123,212	6.4
Winter barley	7,628	1.0	Rootcrops for stockfeed	44,666	5.0

Crop Type	Crop area, ha	Fertiliser, ktN	Crop Type	Crop area, ha	Fertiliser, ktN
Winter barley (malting)	88,788	11.4	Leafy forage crops	4,306	0.4
Winter barley (non-malting)	343,025	52.4	Other fodder crops	30,768	2.8
Wheat	8,616	1.4	Vegetables (not-differentiated)	1,679	0.2
Wheat (milling)	609,595	123.4	Vegetables (brassicas)	3,008	0.4
Wheat (non-milling)	1,202,934	220.1	Vegetables (legumes)	37,225	0.1
Minor cereals	45,298	3.4	Vegetables (other non-legumes)	72,009	8.5
Oilseed rape	5,632	1.0	Other horticultural crops	16,542	1.7
Spring oilseed rape	9,386	1.7	Soft Fruit	8,041	0.8
Winter oilseed rape	564,093	102.8	Top Fruit	25,296	2.6
Linseed	27,339	2.0	Miscanthus	7,057	0.8
Field beans (harvested dry)	176,332	0.6	Willow (short rotation coppice)	3,518	0.3
Field peas (harvested dry)	50,719	0.2	Other field crops	24,183	2.4
Field beans and peas combined not Vining peas	870	0.0	Wine grapes	1,793	0.2
Fruit (mixed top & soft fruit)	4	0.0			
Permanent grass	6,117,743	308.4	Temporary grass	1,143,508	107.5

Table A 3.3.9 Trends in area grown ('000 ha) and N fertiliser applied (kg/ha) for the major UK crops, 1990-2016

Year	Wheat		Spring barley		Winter barley		Main crop potatoes		Oilseed rape		Grass leys (<5yrs)		Permanent grassland	
	'000 ha	kg/ha N	'000 ha	kg/ha N	'000 ha	kg/ha N	'000 ha	kg/ha N	'000 ha	kg/ha N	'000 ha	kg/ha N	'000 ha	kg/ha N
1990	2014	183	635	90	882	140	148	184	390	225	1,606	166	5,316	108
1991	1980	187	552	89	841	140	148	185	440	221	1,603	168	5,334	107
1992	2067	185	515	89	784	141	151	175	421	196	1,579	157	5,287	94
1993	1759	185	518	91	650	136	143	189	377	179	1,567	146	5,278	100
1994	1811	186	481	94	628	143	138	191	404	179	1,456	170	5,375	110
1995	1859	193	504	97	689	144	144	176	354	187	1,407	170	5,375	108
1996	1977	185	518	93	749	140	149	171	356	190	1,396	166	5,347	104
1997	2036	192	518	94	839	143	133	166	445	199	1,394	147	5,290	103
1998	2045	182	484	91	769	135	131	186	507	192	1,302	156	5,365	99
1999	1847	185	631	99	548	142	148	153	495	196	1,226	180	5,449	102
2000	2086	188	539	106	589	146	138	157	395	189	1,226	142	5,363	90
2001	1635	185	783	109	462	144	137	153	446	196	1,205	130	5,584	84
2002	1996	189	555	110	546	150	129	152	436	194	1,243	135	5,519	77
2003	1836	197	621	107	455	148	118	149	549	194	1,200	128	5,683	75
2004	1990	190	587	101	420	144	121	164	498	171	1,246	117	5,620	71
2005	1870	188	553	98	384	140	113	164	588	186	1,193	111	5,711	66
2006	1836	181	494	100	388	134	117	142	568	178	1,137	106	5,967	60
2007	1830	183	515	97	383	134	112	136	674	179	1,176	98	5,965	56

Year	Wheat		Spring barley		Winter barley		Main crop potatoes		Oilseed rape		Grass leys (<5yrs)		Permanent grassland	
	'000 ha	kg/ha N	'000 ha	kg/ha N	'000 ha	kg/ha N	'000 ha	kg/ha N	'000 ha	kg/ha N	'000 ha	kg/ha N	'000 ha	kg/ha N
2008	2080	179	616	92	416	134	114	150	598	180	1,141	92	6,036	45
2009	1814	188	749	98	411	137	118	169	581	167	1,262	88	6,081	48
2010	1939	192	539	96	382	140	114	137	642	186	1,231	98	5,925	53
2011	1969	194	611	99	359	140	120	157	705	186	1,278	91	5,877	51
2012	1992	194	618	99	385	144	123	141	756	183	1,357	92	5,799	50
2013	1615	183	903	108	310	143	114	160	715	149	1,390	94	5,802	55
2014	1936	192	651	108	429	145	115	149	675	186	1,396	97	5,824	51
2015	1832	193	659	105	442	148	105	162	652	190	1,135	96	5,886	49
2016	1821	189	683	107	439	147	114	141	579	182	1,144	94	6,118	50

A 3.3.4.2 Crop Residues

Table A 3.3.10 Parameter values for crop residue management.

Crop	Crop Harvest Index[a]	Above Ground Residue Retained after harvest	IPPC Crop Yield To Above Ground Residue Slope[b]	IPPC Crop Yield To Above Ground Residue Intercept[b]	IPCC Above To Below Ground Residue ratio
Oats	0.46	0.5	NA	NA	0.25
Spring oats	0.46	0.5	NA	NA	0.25
Winter oats	0.46	0.5	NA	NA	0.25
Spring barley	0.52	0.5	NA	NA	0.22
Spring barley (malting)	0.52	0.5	NA	NA	0.22
Spring barley (non-malting)	0.52	0.5	NA	NA	0.22
Winter barley	0.52	0.5	NA	NA	0.22
Winter barley (malting)	0.52	0.5	NA	NA	0.22
Winter barley (non-malting)	0.52	0.5	NA	NA	0.22
Wheat	0.50	0.5	NA	NA	0.23
Wheat (milling)	0.50	0.5	NA	NA	0.23
Wheat (non-milling)	0.50	0.5	NA	NA	0.23
Minor cereals	0.49	0.5	NA	NA	0.23
Oilseed rape	0.30	1	NA	NA	0.35
Spring oilseed rape	0.30	1	NA	NA	0.35
Winter oilseed rape	0.30	1	NA	NA	0.35
Linseed and Flax	0.38	0.5	NA	NA	0.35
Linseed	0.38	1	NA	NA	0.35
Flax	0.38	0.2	NA	NA	0.35
Field beans (harvested dry)	NA	1	1.13	0.85	0.19
Field peas (harvested dry)	NA	1	1.13	0.85	0.19
Field beans and peas combined not Vining peas	NA	1	1.13	0.85	0.19
Potatoes	NA	1	0.10	1.06	0.20
Potatoes (maincrop)	NA	1	0.10	1.06	0.20
Potatoes (seed or earlies)	NA	1	0.10	1.06	0.20
Sugar beet	NA	1	1.07	1.54	0.20
Maize	NA	1	1.03	0.61	0.22
Grain maize	NA	1	1.03	0.61	0.22
Forage maize	NA	0.15	1.03	0.61	0.22
Rootcrops for stockfeed	NA	0.15	1.07	1.06	0.20
Leafy forage crops	NA	0.15	0.30	0.00	0.35
Other fodder crops	NA	0.1	NA	NA	0.35
Vegetables (not-differentiated)	NA	1	0.30	0.00	0.35
Vegetables (brassicas)	NA	1	0.30	0.00	0.35
Vegetables (legumes)	NA	1	0.30	0.00	0.35
Vegetables (other non-legumes)	NA	1	0.30	0.00	0.35
Other horticultural crops	NA	1	0.30	0.00	0.35

Crop	Crop Harvest Index[a]	Above Ground Residue Retained after harvest	IPPC Crop Yield To Above Ground Residue Slope[b]	IPPC Crop Yield To Above Ground Residue Intercept[b]	IPCC Above To Below Ground Residue ratio
Soft Fruit	NA	1	0.20	0.00	0.35
Top Fruit	NA	1	0.20	0.00	0.35
Miscanthus	NA	1	1.00	0.00	0.35
Willow (short rotation coppice)	NA	1	1.00	0.00	0.35
Other field crops	0.52	0.5	NA	NA	0.22
Wine grapes	NA	1	0.20	0.00	0.35
Fruit (mixed top & soft fruit)	NA	1	0.20	0.00	0.35
Field beans and peas combined	NA	1	1.13	0.00	0.19

[a]Where 'NA' appears in the Harvest Index column, it indicates that the IPPC 2006 method was used; [b]where 'NA' appears in the IPPC slope or intercept column, it means that the Harvest Index approach was used

Table A 3.3.11 N concentrations in above and below ground biomass

Crop	Below Ground N, kg N/[t DM]	Crop Residue Above Ground N, kg N/[t DM]
Oats	8.0	5.4
Spring oats	8.0	5.4
Winter oats	8.0	5.4
Spring barley	14.0	6.7
Spring barley (malting)	14.0	6.7
Spring barley (non-malting)	14.0	6.7
Winter barley	14.0	6.7
Winter barley (malting)	14.0	6.7
Winter barley (non-malting)	14.0	6.7
Wheat	9.0	6.2
Wheat (milling)	9.0	6.2
Wheat (non-milling)	9.0	6.2
Minor cereals	9.0	6.6
Oilseed rape	11.0	9.9
Spring oilseed rape	11.0	9.9
Winter oilseed rape	11.0	9.9
Linseed and Flax	11.0	9.9
Linseed	11.0	9.9
Flax	11.0	9.9
Field beans (harvested dry)	8.0	8.0
Field peas (harvested dry)	8.0	8.0
Field beans and peas combined not Vining peas	8.0	8.0
Potatoes	14.0	17.3
Potatoes (maincrop)	14.0	17.3
Potatoes (seed or earlies)	14.0	17.3
Sugar beet	14.0	24.6

Crop	Below Ground N, kg N/[t DM]	Crop Residue Above Ground N, kg N/[t DM]
Maize	7.0	6.0
Grain maize	7.0	6.0
Forage maize	7.0	6.0
Rootcrops for stockfeed	14.0	12.6
Leafy forage crops	12.0	26.3
Other fodder crops	14.0	6.7
Vegetables (not-differentiated)	12.0	26.1
Vegetables (brassicas)	12.0	38.4
Vegetables (legumes)	22.0	23.2
Vegetables (other non-legumes)	22.0	16.7
Other horticultural crops	22.0	26.1
Soft Fruit	11.0	17.7
Top Fruit	11.0	3.9
Miscanthus	11.0	0.3
Willow (short rotation coppice)	11.0	0.3
Other field crops	11.0	6.7
Wine grapes	11.0	3.3
Fruit (mixed top & soft fruit)	11.0	8.1
Field beans and peas combined	8.0	8.0

A 3.3.4.3 Mineralisation

Mineralised N is reported in **Table A 3.3.12**.

Table A 3.3.12 Mineralised N from soils

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
N in mineral soils that is mineralised as a result of historical land use change to Cropland (kt N/y)	39.34	44.12	52.04	72.85	86.44	86.82	87.18	87.53	87.88	88.21	88.54
N in mineral soils that is mineralised as a result of Cropland Management (kt N/y)	0.0002287	0.0002600	0.0002423	0.0002411	0.0002338	0.0002235	0.0002372	0.0002277	0.0002219	0.0002314	0.0002169
Direct N_2O emissions from mineralised N as a result of historical land use change to Cropland, kt N_2O/y	0.62	0.69	0.82	1.14	1.36	1.36	1.37	1.38	1.38	1.39	1.39
Direct N_2O emissions from mineralised N as a result of Cropland Management, kt N_2O/y	0.000004	0.000004	0.000004	0.000004	0.000004	0.000004	0.000004	0.000004	0.000003	0.000004	0.000003

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
Indirect N_2O emissions from mineralised N as a result of historical land use change to Cropland and Cropland management (kt N_2O/y)	0.14	0.16	0.18	0.26	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Total N_2O emissions from Mineralisation (kt N/y)	0.76	0.85	1.00	1.40	1.66	1.67	1.68	1.69	1.69	1.70	1.70

A 3.3.4.4 Histosols

The total area used to calculate emissions from histosols is 2857 km^2.

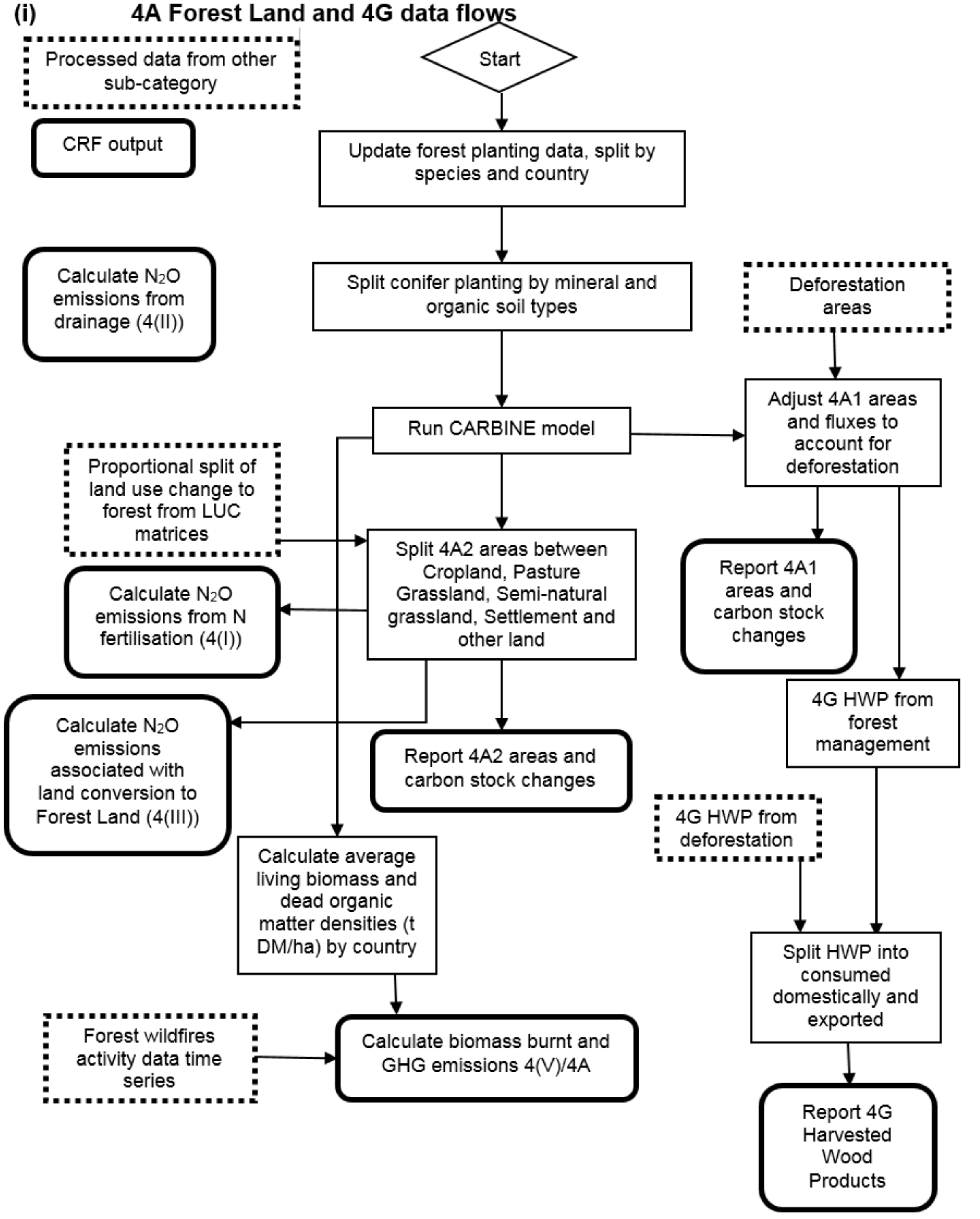
A 3.4 LAND USE, LAND USE CHANGE AND FORESTRY (CRF SECTOR 4)

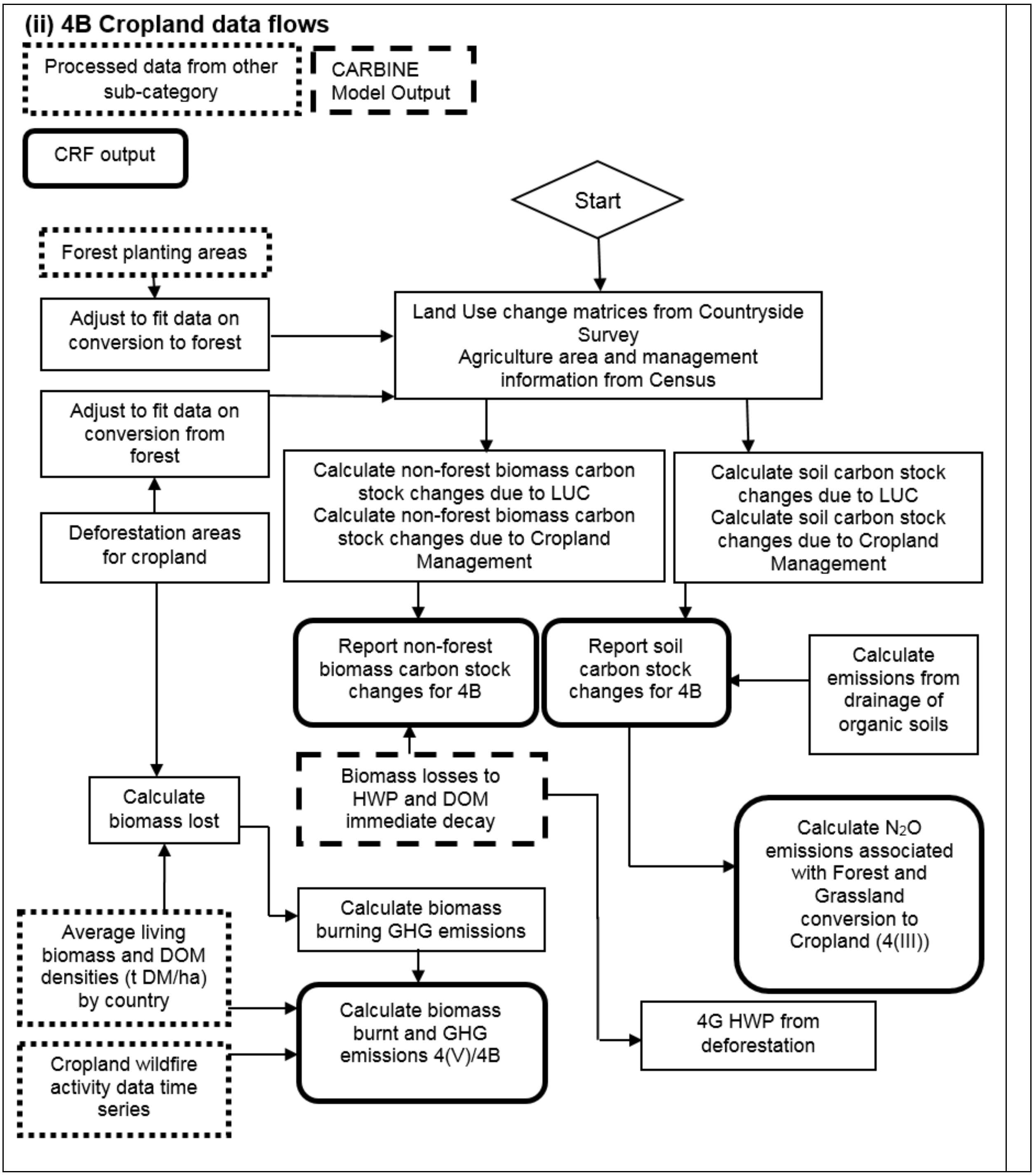
The following section describes in detail the methodology used in the LULUCF sector described in **Chapter 6**.

The flow chart (**Figure A 3.1**) shows the interrelationships between different data sources and the main calculation steps.

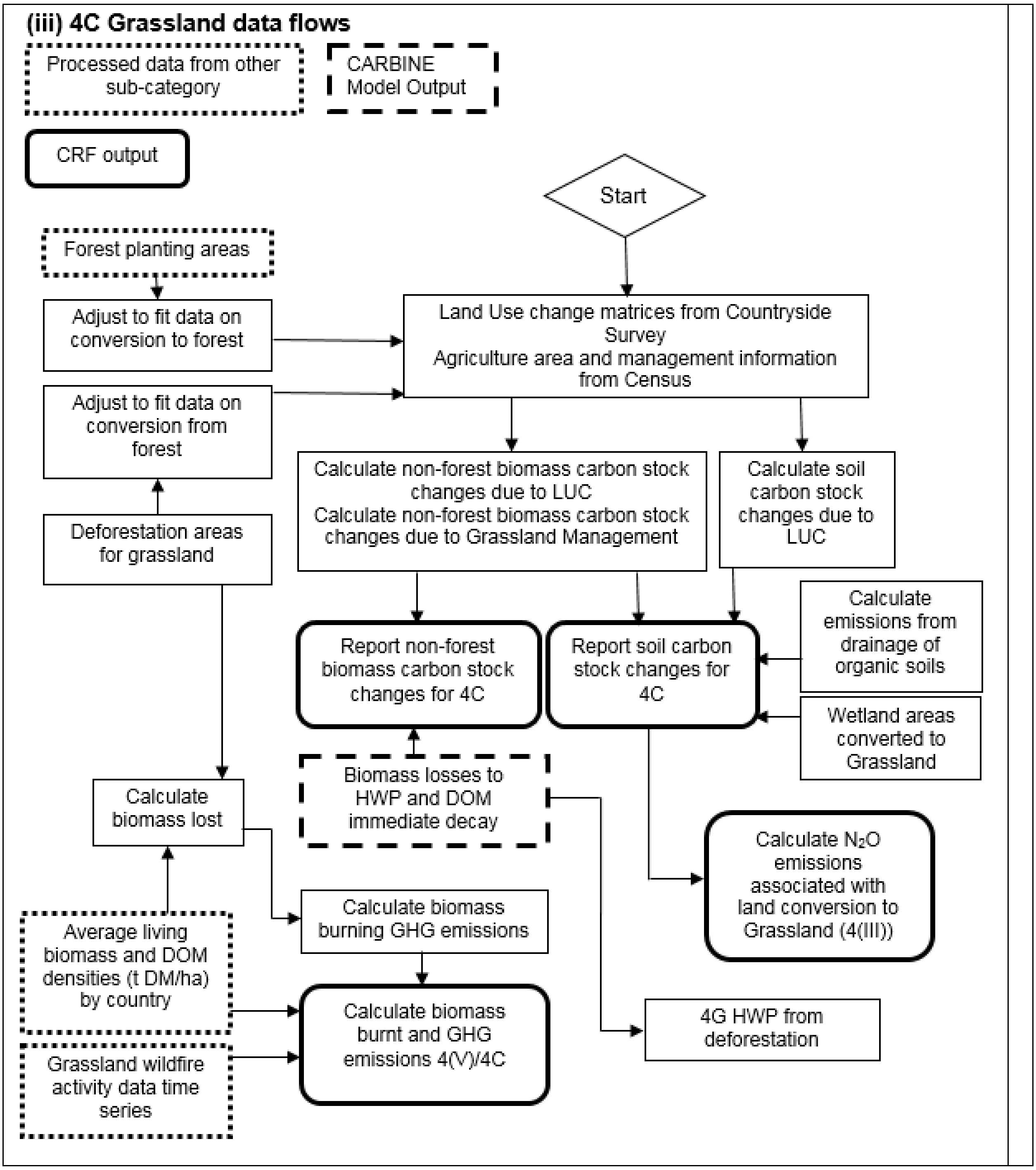
Figure A 3.1 Data flow diagrams for each land use sub-category, showing cross-linkages between sectors: (i) 4A and 4G, (ii) 4B, (iii) 4C, (iv) 4D, (v) 4E

(i) 4A Forest Land and 4G data flows

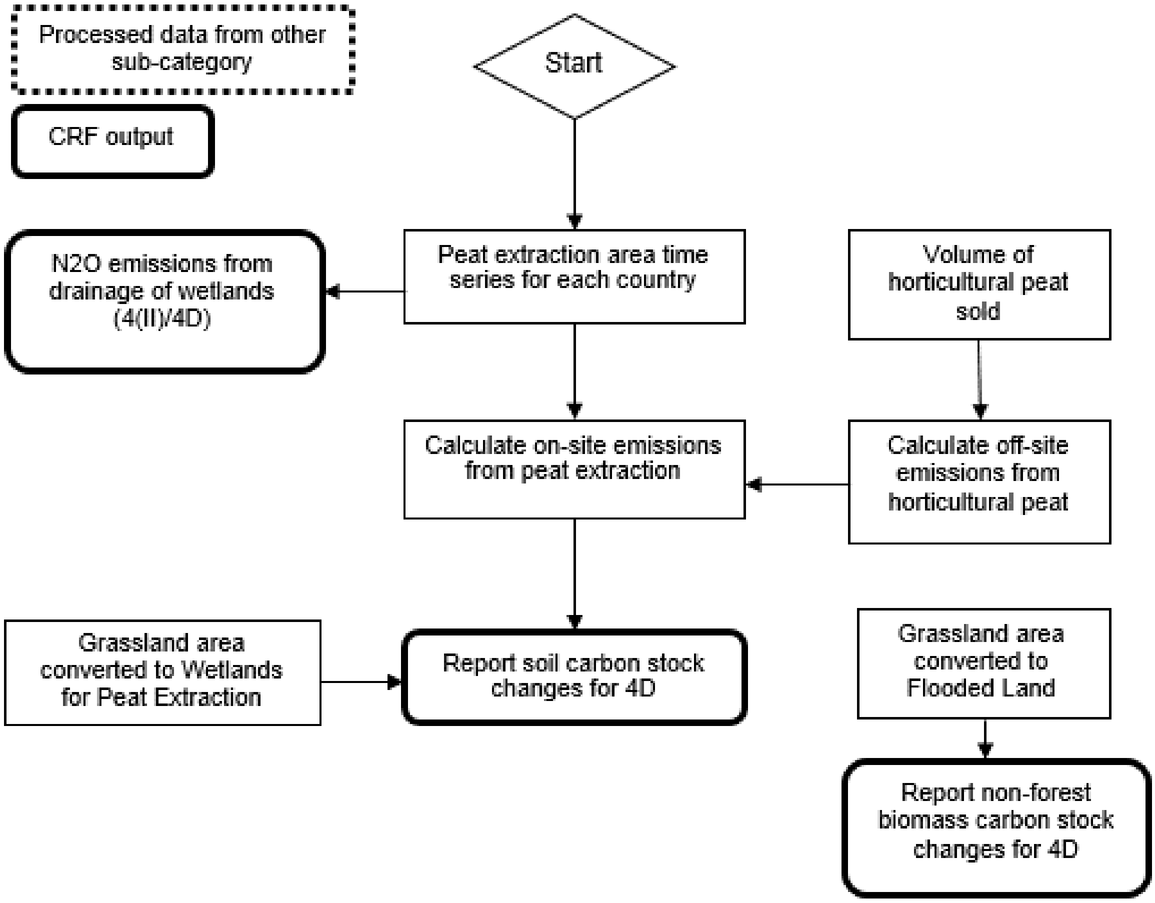




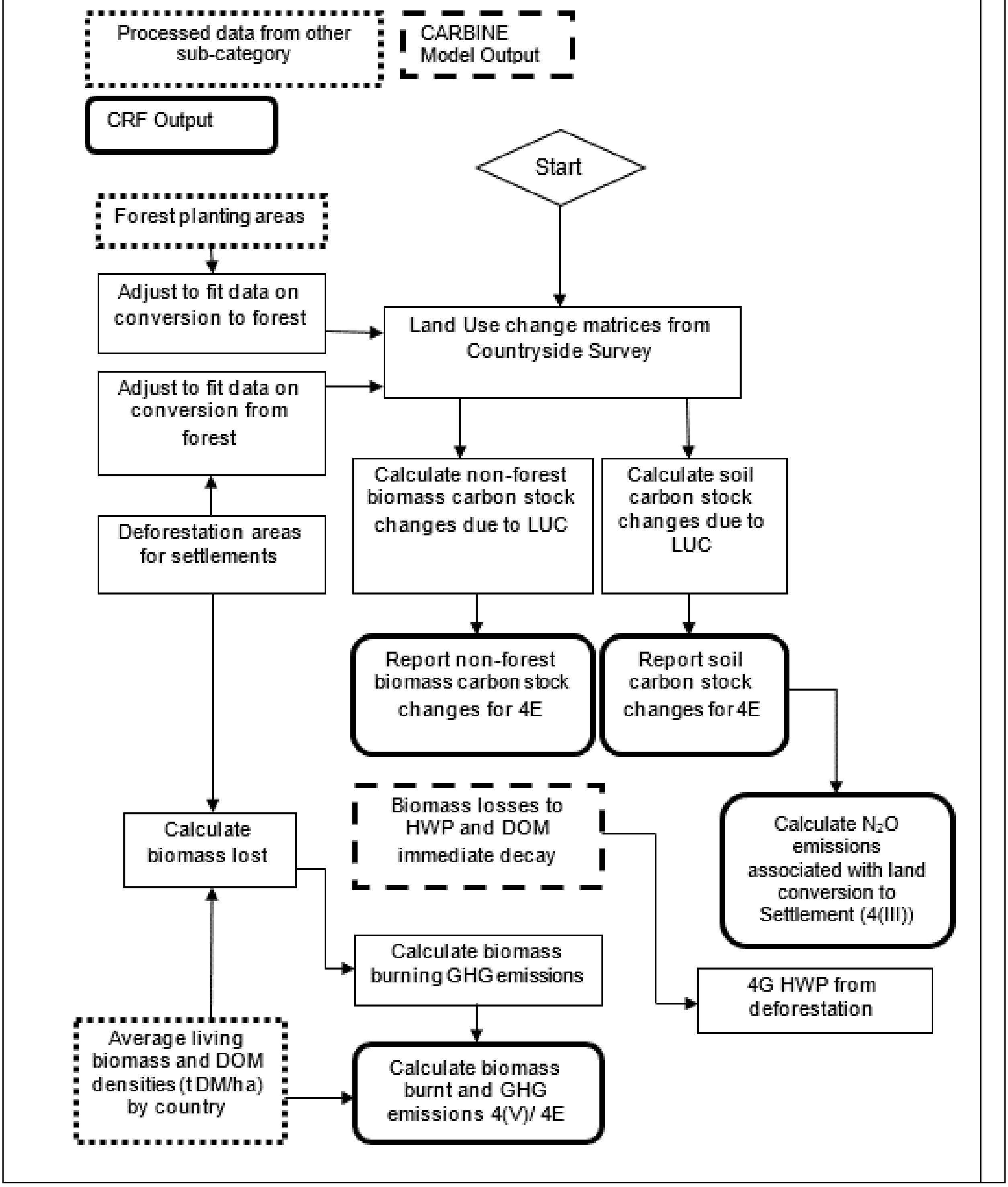
(ii) 4B Cropland data flows
Processed data from other sub-category
CARBINE Model Output
CRF output
Start
Forest planting areas
Adjust to fit data on conversion to forest
Land Use change matrices from Countryside Survey
Agriculture area and management information from Census
Adjust to fit data on conversion from forest
Calculate non-forest biomass carbon stock changes due to LUC
Calculate non-forest biomass carbon stock changes due to Cropland Management
Calculate soil carbon stock changes due to LUC
Calculate soil carbon stock changes due to Cropland Management
Deforestation areas for cropland
Report non-forest biomass carbon stock changes for 4B
Report soil carbon stock changes for 4B
Calculate emissions from drainage of organic soils
Biomass losses to HWP and DOM immediate decay
Calculate biomass lost
Calculate N2O emissions associated with Forest and Grassland conversion to Cropland (4(III))
Calculate biomass burning GHG emissions
Average living biomass and DOM densities (t DM/ha) by country
Calculate biomass burnt and GHG emissions 4(V)/4B
4G HWP from deforestation
Cropland wildfire activity data time series


(iii) 4C Grassland data flows
Processed data from other sub-category
CARBINE Model Output
CRF output
Start
Forest planting areas
Adjust to fit data on conversion to forest
Land Use change matrices from Countryside Survey
Agriculture area and management information from Census
Adjust to fit data on conversion from forest
Calculate non-forest biomass carbon stock changes due to LUC
Calculate non-forest biomass carbon stock changes due to Grassland Management
Calculate soil carbon stock changes due to LUC
Deforestation areas for grassland
Calculate emissions from drainage of organic soils
Report non-forest biomass carbon stock changes for 4C
Report soil carbon stock changes for 4C
Wetland areas converted to Grassland
Biomass losses to HWP and DOM immediate decay
Calculate biomass lost
Calculate N_2O emissions associated with land conversion to Grassland (4(III))
Calculate biomass burning GHG emissions
Average living biomass and DOM densities (t DM/ha) by country
Calculate biomass burnt and GHG emissions 4(V)/4C
4G HWP from deforestation
Grassland wildfire activity data time series

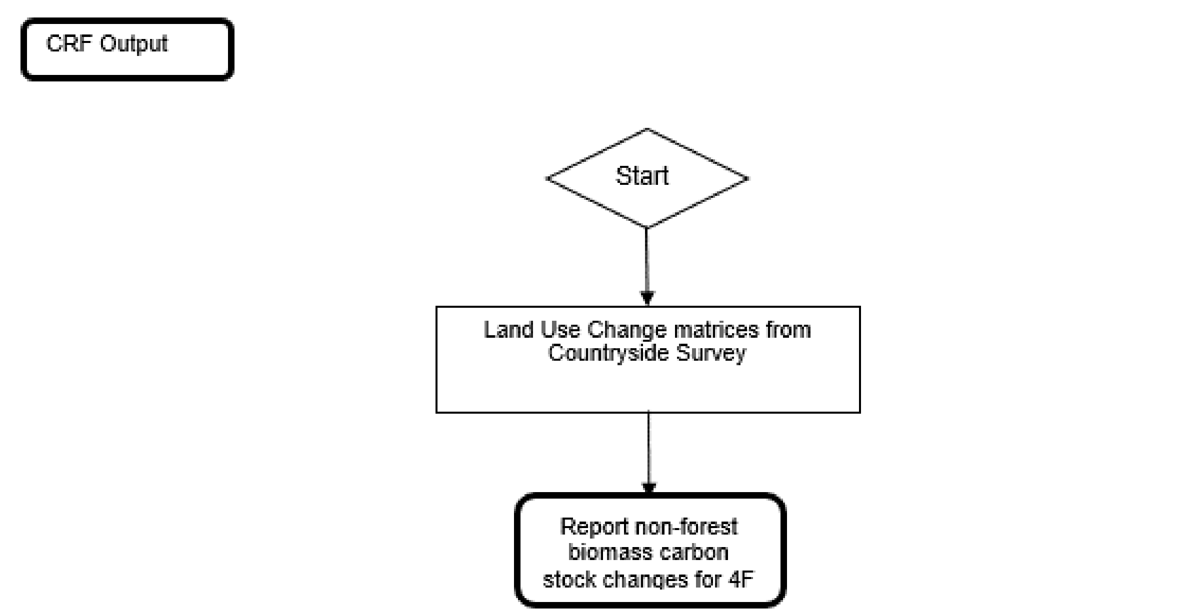
(iv) 4D Wetlands data flows



(v) 4E Settlements data flows



(vi) 4F Other Land data flows



A 3.4.1 Carbon stock changes due to afforestation and forest management (4A)

A 3.4.1.1 The Forest carbon accounting model CARBINE

Carbon uptake by the forests planted in the UK is calculated by a carbon accounting model, CARBINE, as gains and losses in pools of carbon in standing trees, litter and soil in conifer and broadleaf forests and in harvested wood products. Restocking is assumed in all forests. The method is Tier 3, as defined by IPCC (2006). Matthews *et al.* (2014) gives an overview of the CARBINE model and a comparison of its use in the 1990-2012 LULUCF inventory with the C-Flow model previously used model to forest carbon stock changes.

A key concept underlying the net exchanges of C between forests and the other C reservoirs is that it can be inferred from the changes in C stocks. So CARBINE simulates forest C stock changes represented by tree biomass growth, mortality and subsequent loss. The CARBINE model is primarily dedicated to reproducing the UK forest conditions. It is adapted to simulate relatively large number of important tree species, both native and introduced (maximum growth rate from 2 to >24 m^3 ha^{-1} yr^{-1}); and, in practice, is applicable to simulating carbon dynamics of forest species in many temperate, boreal and Mediterranean countries.

The essential information for the CARBINE driving module is supplied by the growth model M1 (Arcangeli and Matthews, unpublished model), which is based on the conventional UK forest yield tables (Matthews et al. (2016a, 2016b)). It is calibrated based on forest growth data from a network of permanent forest mensuration sample plots, and is designed to work with common forest mensuration parameters. The M1 model predicts the annual stem volume in a specified stand of trees, defined by three main factors: tree species, specific growth rate and management regime. The early stage stand growth is not explicitly represented in the M1 model. Trees that have diameter at breast height lower than 7cm, typically up to 20 years are assumed to have stem volume inferred from the interpolation of the growth curve between age 20 and 0, where stem volume is assumed to be zero at age zero. The M1 outputs are reported at a stand level, i.e. at 1 ha scale and include results for dominant height, numbers of trees, mean stem diameter and stem volume per hectare).

This does exclude certain mitigation measures, though it would be possible to model the effect of some of these factors (e.g. improved planting stock) by assuming a change in yield table to a higher growth rate. Carbon stock changes are inferred from differences in carbon stock estimates at different times. The model can represent all of the introduced and native plantation and naturally-occurring species relevant to the UK by mapping the tables for 19 different tree species for which there are yield tables (Norway spruce, Sitka spruce, Scots pine, Corsican pine, Lodgepole pine, European larch, Japanese larch, Douglas fir, Grand fir, Noble fir, Western red cedar, Western hemlock, Oak, Beech, Nothofagus, Poplar and a combined model table that covers Sycamore, Ash and Birch). All areas for a species are assumed to have been planted at the same spacing, with the selection of the spacing for each species based on historic Forestry Commission practice and the availability of yield tables

The model as used for this inventory consists of three sub-models or 'compartments' which estimate carbon stocks in the forest biomass, soil, and harvested wood products. The forest biomass carbon sub-model is further compartmentalised to represent fractions due to tree stems, branches, foliage, and roots.

Increases in stemwood volume were based on standard yield tables, with an extrapolation function applied for stemwood volumes prior to the first table age. The CARBINE model uses standard estimates for wood density wood carbon content to derive stem biomass from the stem volume predictions simulated by the M1 model (Lavers and Moore, 1983; Jenkins et al., 2011; Matthews, 1993). Wood and bark density along with the carbon content differences are not taken into account. The density of bark is lower than that of wood (Aaron, 1970), but the carbon content is usually higher (Matthews, 1993), hence it is assumed that the two effects cancel out. The volume, biomass and carbon in tree foliage, branches, and coarse and fine roots are derived from the results for the stem by applying expansion factors. Species-specific biomass expansion factors are applied for these calculations.

The biomass of a component of interest is calculated by multiplying stem biomass by a corresponding expansion factor. The UK species-specific crown and root biomass expansion factors were derived from the report of Jenkins *et al*., (2011) report. Branch biomass is calculated by subtracting foliage biomass from crown biomass. The coarse root biomass expansion factor includes an allowance for stump material. Robust information on foliage expansion factors relevant to UK conditions were not available, hence these were obtained from scientific literature. The ratio of foliage to stem changes over time, but approaches an asymptote (Matthews et al., 1991; Matthews and Duckworth, 2005). However, the asymptote in general is more suited to older, larger trees and as such is considered not to be representative of typical forests under regular management. It was decided to use a biomass expansion relationship for trees of approximately 20 cm diameter in order to better represent managed forests. It is likely that this will ultimately underestimate foliage biomass in smaller trees, and conversely over-estimate in older, larger trees. Finally, fine root biomass is calculated with a uniform expansion factor β_r=0.02 from a Liski et al., (2002) study. The expansion factors are not sensitive to stand age, management regime or growth rate. This approach was adopted for the simplicity and ease of implementation on the large scale simulations.

The mass of carbon in a forest was calculated from biomass by multiplying by the fraction of carbon in wood (0.5 assumed). As an example, the values used for these parameters for Sitka spruce (*P. Sitchensis*) are given in **Table A 3.4.1**. Sitka spruce is the most common species in UK forests (c. 30%); parameters for other tree species are given in Matthews *et al.* (2014).

Table A 3.4.1 Main parameters for forest carbon flow model used to estimate carbon uptake by planting of forests of Sitka spruce (*P. Sitchensis*), yield class 12.

Parameter	***Value***
Time of maximum mean annual increment (years)	60
Initial spacing (m)	2
First table age	20
Year of first thinning	25
Stemwood density (oven dried tonnes m^{-3})	0.33
Stemwood conversion loss	10%
% Branchwood left in forest	100%
% Branchwood harvested for fuel	0%
% fuel from bark	30%
% non-fuel products from bark	70%
% small roundwood (underbark) used as fuel	20%
% Pallets and fencing from small roundwood (under bark)	20%
% Paper from small roundwood (under bark)	35%
% Particleboard etc. from small roundwood (under bark)	25%
% Fuel from sawlogs (under bark)	30%
% Pallets and fencing from sawlogs (under bark)	0%
% Particleboard from sawlogs (under bark)	40%
% Structural timber from sawlogs (under bark)	30%
Root:Stem ratio	0.49
Crown:Stem ratio	0.32
Foliage:stem ratio	0.13
Fine root:stem ratio	0.02
Foliage turnover rate (annual)	0.2
Branchwood turnover rate (annual)	0.04
Coarse Root Turnover rate (annual)	0.02
Fine Root turnover rate (annual)	0.8
Underbark/overbark ratio at 15cm DBH (varies with DBH)	0.9
Ratio of thinned stem volume that is sawlog at 15cm DBH (varies with DBH)	0.05

CARBINE uses tree mortality and stand litter fall to represent dead biomass accumulation and transfer it to the soil carbon sub-model after partial degradation in a Fermented (F) pool. Contributions to deadwood (regarded as part of litter) due to tree mortality are predicted by the M1 model, generally resulting from competition between trees in dense stands. In addition, contributions to stand above-ground litter-fall are assumed to be made by dead foliage and branches, while contributions to below-ground litter come from dead coarse roots and fine roots. Litter and root mortality rates are expressed as a fixed proportion or percentage lost per annum, referred to as an Annual Turnover Rate (ATR), which is dependent on tree species. The information about the ATRs is limited due to required measurements of the amount of turnover and the amount of biomass entering the dead matter pool. Published studies, datasets and personal communications were referred to in determining the turnover rates. The biomass of a component of interest is calculated by multiplying stem biomass by a corresponding Annual Turnover Rate. Standing dead wood is regarded as distinct from other forms of dead wood, which effectively form part of the litter pool.

The other significant input of carbon to the dead wood and litter pool is due to harvesting operations (as part of either thinning or clearfelling). The carbon in roots of harvested trees is assumed to enter the litter pool. The harvesting of stem wood is assumed to involve a conversion loss equivalent to 10% of standing stem volume, which also enters the litter pool. It is difficult to make robust assumptions about the fate of branch wood and foliage at time of harvesting. In many situations, this material will be left on-site to deteriorate and decay. Sometimes it is possible that branch wood remaining after clearfelling may be deliberately burned. There has also been an increasing interest in active harvesting of branch wood (or at least some proportion of it) to supply biomass to the Energy sector. However, currently, such practice remains very limited. For this inventory the assumption has been made that no branch wood is harvested but is left to degrade and decay on site as part of the litter pool.

The branch ATR was fixed at 4% in accordance to Canadian forest carbon accounting model CBM-CFS (Kurz et al., 2009). Deciduous species foliage turnover is assumed to be 100% (Kurz et al., 2009; Ťupek et al., 2015). Conifer species foliage ATRs were obtained by referring to relevant scientific literature. If insufficient empirical literature and data was available the species were mapped to an allometrically similar species. Coarse root annual turnover was assumed to be 2% as in the CBM-CFS (Kurz et al., 2009; Kurz and Beukema, 1996; Li et al., 2003). Fine root ATRs were mapped from the available scientific literature and the UK specific datasets provided by Vanguelova (pers. com.). The UK ATRs for fine roots were derived from Kielder forest for Sitka spruce and Alice Holt forest for oak. Lastly, root exudate ATR was set to 160% of fine root dry biomass, the upper quartile of reported exudate mass from grassland was adopted (Jones et al., 2009), because of limited understanding about forest rhizodeposition. Aboveground shed litter, foliage and branches, are accumulated in a litter layer and after partial degradation passed to the Fermenting (F) layer. Residues that are left after thinning or felling can be set to enter a litter layer. If the crop is not a forest, it is assumed that the litter and F layers are zero. The litter layer decomposition is modelled using modified ForClim-D model version (Liski et al., 2002; Perruchoud et al., 1999). Below ground litter is not included in this simulation, while the annual transfer rates are applied to foliage (C_f) and branch (C_b) litter biomass. They are expressed as a proportion relocated annually.

Branch and foliage litter transfer are set according to the model proposed by Liski et al. (2002). The transferred biomass is pooled and degraded by a fixed constant of 0.5, which is the average of constants given in the Liski et al. (2002) study

The new CARBINE Soil Carbon Accounting model (CARBINE-SCA; **Figure A 3.2**), is based on a simplified version of the ECOSSE model (Smith *et al*., 2011), coupled with a litter decomposition model derived from the ForClim-D model (Perruchoud *et al*., 1999; Liski *et al*., 2002). Above-ground turnover of material such as foliage, branches and dead stemwood enters the litter pool, which is then broken down to F-material (Fermenting) as a function of temperature and rainfall, releasing CO_2. Within the soil, a number of layers exist, each with its own set of texture (Sand, Silt, Clay) characteristics. Carbon from decayed litter, dead roots, and root exudates enters each layer and is assigned to four active pools; resistant plant material (RPM), readily decomposable plant material (DPM), biological material (BIO) and humic material (HUM). A proportion of organic carbon is also assumed to be inert, and unavailable for further activity. The active pools undergo decomposition and transference, releasing CO_2. Decomposition (aerobic and anaerobic) within each pool and layer is influenced by response functions to water saturation in the soil, temperature, pH, and the presence (or not) of plant cover on the soil surface. The availability of water within each layer, and the level of saturation are largely defined from soil texture following Saxton and Rawls (2006) coupled with inputs from rainfall, (or drainage) and removal of water through evapotranspiration. In any soil layer, water above field capacity can drain to lower soil layers, complete with any dissolved organic carbon (DOC). The rates of potential decomposition of each carbon pool and the response functions follow ECOSSE (Smith et al., 2011).

New carbon input to the soil arises from four sources:

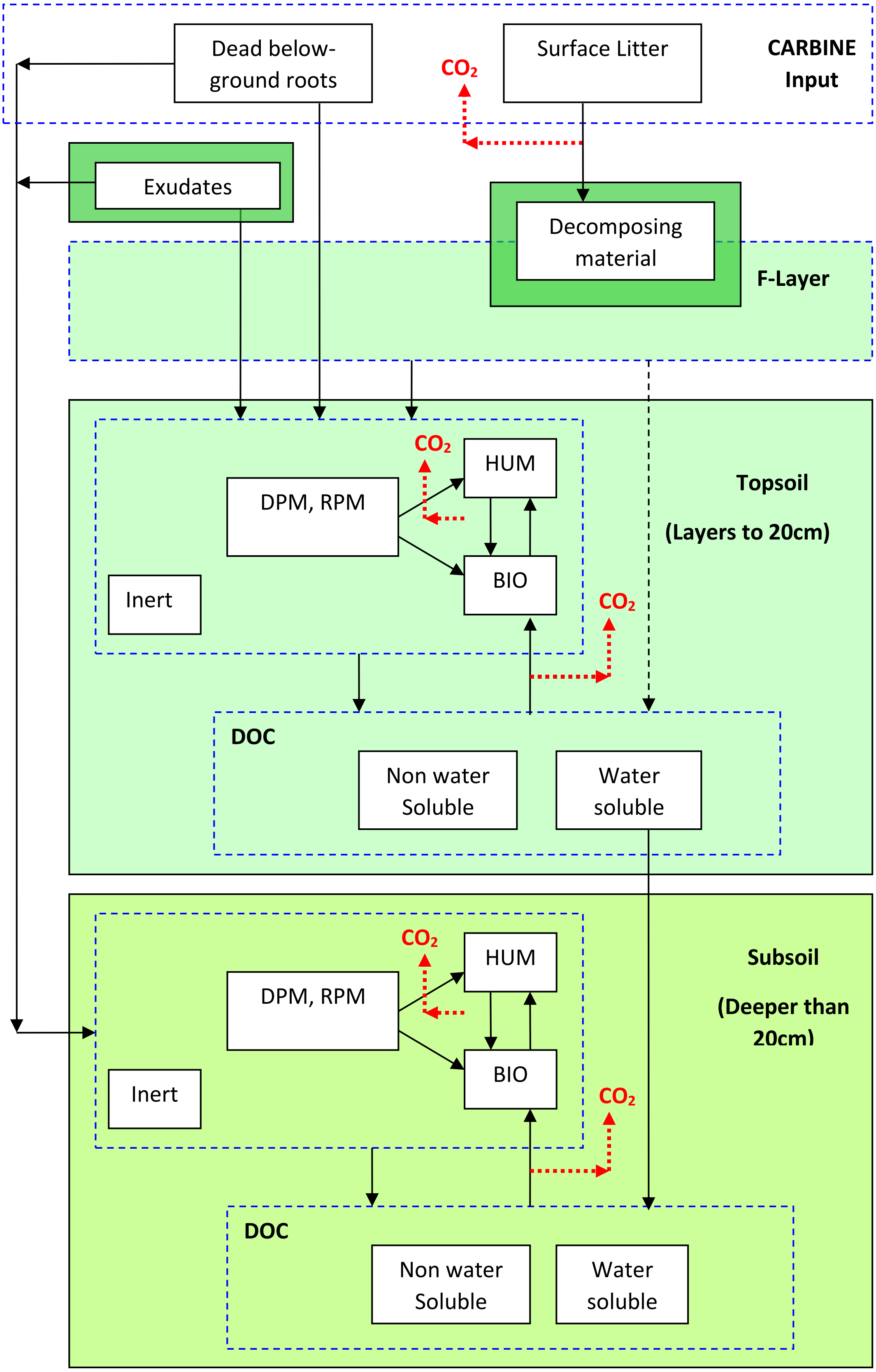
- Recently dead root material (according to a rooting profile depth),
- Transfer from the F-material arising from the decomposition of above-ground litter,
- Secretions and exudates from the roots,
- DOC; this carbon can become available to the biological pool and enter the ‘reactive material cycle’.

Turnover rates for mortality of tree components (roots, foliage etc.) are species dependent and obtained from scientific literature (see **Table A 3.4.1** for example). A full description of the model will be presented in a separate technical report.

An improved version of the soil sub-model has been implemented for the 1990-2016 inventory. This includes work on parametisation of litter input from ground flora and other non-forest vegetation, assuming a decrease in the contribution of non-tree litter from that assumed in Ecosse for pasture to zero contribution at canopy closure.

A more comprehensive description of the soil sub-model will be described in a technical report.

Figure A 3.2 The CARBINE-SCA model



The harvested wood products sub-model represents wood products as long-lived and short-lived sawn timber, particleboard, paper and fuel (see also **Section 6.8**). Carbon in harvested stemwood is allocated to these wood product categories using an assortment forecasting model that accounts for variation in product out-turn due to tree species and tree size class distribution at time of harvest (Rollinson and Gay, 1983). Wood products in primary use are assumed to decay over time with no account taken of carbon stocks in landfill or greenhouse gas emissions (due to wood products) from landfill (these are taken into account in the Waste sector).

A 3.4.1.2 Forest activity data: management

The forest data for the inventory have been estimated by using data from the Forestry Commission's planting statistics and the National Forest Inventory. Information from the Sub-compartment database (SCDB, the Forestry Commission database of information on the growth rate and management of the Forestry Commission (FC) and Natural Resources Wales (NRW) forest estate) was used to create a distribution of species and yield class (an indication of growth rate). For the non-FC/NRW forest estate information from the NFI survey of woodlands was analysed to estimate yield class and species by age class, and scaled to represent the whole private forest estate.

Management of forests is represented as one of four options: Clearfell with thinnings, clearfell without thinnings, managed but not clearfelled, and not used for timber production. For the clearfell forests restocking occurs after the rotation period. For non-clearfell productive woodlands it is assumed there is a 30 year overlap of restocking and non-restocked trees. It was assumed that the private sector distribution of managed forests would follow the same pattern as for the public forest estate. The area of land felled each year was estimated from the wood production statistics separately for both FC/NRW and private forests. The rotation periods for forests were estimated based on information on the intended management of the FC/NRW estate. This analysis gave a target rotation period for each modelled species and yield class. In order to match production, given the age class distribution of the forest, this rotation period was adjusted iteratively for the FC/NRW and private forests, separately, to match the timber production statistics. It was assumed that the forests would be felled evenly over a period +/-2 years from the target rotation period. A comprehensive description of this algorithm will be presented in a separate technical report.

A 3.4.1.3 Forestry activity data: historical and current afforestation rates

Irrespective of species assumptions, the variation in CO_2 removals from 1990 to the present is determined by the afforestation rate in earlier decades, the effect this has on the age structure in the present forest estate, and hence the average growth rate. Afforestation is assumed to occur on ground that has not been wooded for many decades, based on the assumption that if it had previously been woodland it would be in the restocking statistics rather than the new planting statistics as a result of the regulatory framework that applies to forestry in the UK.

A comparison of historical forest census data and the historical annual planting rates has been undertaken. Forest censuses were taken in 1924, 1947, 1965, 1980 and the late 1990s. The latest census (National Forest Inventory) has only just been completed. The comparison of data sources showed that discrepancies in annual planting rates and inferred planting/establishment date (from woodland age in the forest census) are due to restocking of older (pre-1920) woodland areas and variations in the harvesting rotations. However, there is also evidence of shortened conifer rotations in some decades and transfer of woodland between broadleaved categories (e.g. between coppice and high forest). It is difficult to incorporate non-standard management in older conifer forests and broadleaved forests into the Inventory because it is not known whether these forests are on their first rotation or subsequent rotations (which would affect carbon stock changes, particularly in soils). The area of afforestation in a given year is predicted based on applying the yearly distribution from the new planting and restocking statistics to the age class inventory. Age classes prior to the availability of new planting statistics are assigned evenly to individual years. For this inventory submission the assumption was made that we can estimate the area felled for recent years based on the timber production in the year of felling. It is assumed that woodland felled is immediately restocked. As we have an estimate of the area restocked for these years, the remainder of the area for each year was assumed to be restocking or natural regeneration. For years prior to the timber production statistics (i.e. prior to 1976), an estimated ratio between restocking and afforestation was used based on the earliest data. For restocked woodland the forest area was assumed to have been restocked twice and had been managed in the same fashion and on the same rotation.

The planting data used as input to the CARBINE model come from national planting statistics from 1921 to the present (provided by the Forestry Commission for England, Scotland and Wales and from 1900 to the present (provided by the Northern Ireland Forest Service). For England, Scotland and Wales estimates of area of woodland by species, yield class and broad age class came from analysis of the NFI (for private woodland) and the SCDB (for FC/NRW woodland).

The National Forest Inventory (NFI) provides woodland statistics for Great Britain, (England, Wales and Scotland), broken down by region or county. It comprises a digital woodland map based on comprehensive aerial photography and a field survey using 15,000 one-hectare sample squares. The digital map and field survey cover all woodland areas down to 0.5 hectares. An initial digital woodland map was published in spring 2011. The NFI woodland field survey provides direct assessments 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 including above and below ground biomass can be derived from these assessments using GB-specific conversion factors and allometric equations. A complete 5-year cycle of ground survey has now been completed. NFI data do not allow the carbon stocks of deadwood or litter to be estimated. The NFI has been supplemented by an assessment of the area of small woods (woodland between 0.1 ha and 0.5 ha) to align with the minimum woodland area for UNFCCC reporting as set out in CMP.7 (Forestry Commission, 2017). The analysis of small woods area included no characterisation of the resource. Since there is currently no information on the age-distribution of the area of small woods, it was assumed to have established evenly between 1900 and 1970.

The NFI uses a lower integral open space threshold of 0.5 ha (as opposed to 1 ha), which requires a downward adjustment to areas. However, the main differences in 2010 GB woodland cover between the NFI (2982 kha) and previous estimates (2757 kha, Forestry Statistics 2010) arise from identified errors in the previous woodland survey, particularly the under-estimate of woodland areas between 0.5 and 2 hectares. Estimates of woodland loss have been assessed, which affect the total estimated woodland area in the GHGI (but are not yet reflected in the national Forestry Statistics).

We assumed that the NFI survey gives a distribution of all the non FC/NRW forest area for a base year of 2011, and the SCDB gives a distribution of all the FC/NRW forest area for a base year of 2014. The main NFI survey includes areas of woodland >0.5 ha. An adjustment was made to the areas of woodland to account for woods between 0.1 ha and 0.5 ha. For England and Wales, the estimates are derived from a calibration of tree cover plotted in the National Tree Map (NTM) product across England and Wales[6], using a comparison of manual photographic interpretation with the NTM product within a sample of 1 km square tiles. For Scotland, the estimates are derived from a direct evaluation of polygons in the map constructed for the Native Woodlands of Scotland Survey (NWSS)[7], which mapped all woodland polygons in Scotland down to 0.1 hectares in size by photographic interpretation. The areas of small woods used in this inventory were based data published in 2017 by the Forestry Commission in the report “Tree cover outside woodland in Great Britain”[8].

An algorithm was used to obtain the area of woodland afforested each year by removing the area of felling from the age class distribution. The species were then allocated to this “residual distribution’ by starting in the base year and allocating the shortest rotations first. The planting years for all restocked woodland are assigned by the algorithm to give two rotations of the same length as the assigned rotation, and are thus notional. This approach was undertaken to spin up the model in terms of soil and litter. This algorithm will be described in detail in the same technical report as the description of allocation of the management of forests.

Conifer planting on organic soil is a subset of total conifer planting. All broadleaf planting is assumed to be on non-organic soil. As explained above, the planting rates given in **Table A 3.4.2** are derived from administrative records, information on forest age class distribution from NFI field assessments and interim assumptions about the age distribution of ‘small woods’. The planting rates given in **Table A 3.4.2** are therefore significantly different to those reported as official planting statistics supported by grant-aid. The afforestation rates for each planting type in the UK have been calculated from the data and are shown in **Table A 3.4.2.**

Table A 3.4.2 Afforestation rate of conifers and broadleaves in the United Kingdom since 1500 based on estimates of woodland area by age from the NFI and administrative records.

Period	Planting rate (kha annum^{-1})		
	Conifers on all soil types	Conifers on organic soil	Broadleaves
1501-1600	0.00	0.00	0.02
1601-1700	0.07	0.00	0.43
1701-1750	0.11	0.00	1.79
1751-1800	0.32	0.00	2.28
1801-1850	1.05	0.00	1.10
1851-1900	6.07	0.02	1.08
1901-1910	4.51	0.53	8.97
1911-1920	2.04	0.20	11.71
1921-1930	2.92	0.30	12.19
1931-1940	4.54	0.47	12.79
1941-1950	7.84	1.06	15.42

[6] http://www.bluesky-world.com/national-tree-map

[7] http://scotland.forestry.gov.uk/supporting/strategy-policy-guidance/native-woodland-survey-of-scotland-nwss

[8] https://www.forestry.gov.uk/fr/beeh-a2uegs#tree%20cover outside woodland

Period	Planting rate (kha annum^{-1})		
	Conifers on all soil types	Conifers on organic soil	Broadleaves
1951-1960	16.83	2.65	16.53
1961-1970	24.12	4.61	18.68
1971-1980	24.32	5.45	13.54
1981-1990	19.97	4.77	15.67
1991	12.00	2.93	11.95
1992	10.35	2.58	13.73
1993	8.09	2.04	16.91
1994	9.63	2.31	18.14
1995	8.62	2.07	15.61
1996	8.33	1.94	15.22
1997	7.77	1.73	15.00
1998	7.20	1.57	15.79
1999	7.03	1.49	16.77
2000	5.81	1.19	18.53
2001	8.21	1.57	14.16
2002	7.81	1.45	13.02
2003	7.28	1.32	12.42
2004	9.62	1.56	12.93
2005	8.16	1.27	11.47
2006	9.07	1.33	11.34
2007	8.29	1.18	9.18
2008	7.88	1.02	7.33
2009	7.45	0.89	7.24
2010	9.29	1.02	9.30
2011	12.35	1.23	12.70
2012	6.39	0.60	10.05
2013	6.38	0.60	10.97
2014	6.72	0.64	8.76
2015	2.17	0.23	4.73
2016	3.23	0.34	3.16

The proportion of forest planting on mineral and organic soils was re-assessed in 2012, as part of the work to estimate N_2O emissions due to drainage on forest soils (Yamulki et al. 2012).

A 3.4.1.4 Allocation of CARBINE outputs to UNFCCC inventory sub-categories

The CARBINE model output was post-processed using the IPCC default 20-year transition period for Land converted to Forest to move into the Forest remaining Forest category. The area within the Land converted to Forest Land sub-category is split between cropland, pasture grassland, semi-natural grassland, settlement and other areas. Pasture grassland and semi-natural grassland are then combined for Grassland reporting in the CRF. This split is based on the relative proportions of historical land use change from these categories to forest. The proportions for each country change over time because the 20-year transition period has a different start date for each reporting year.

The area and carbon stock changes in the Forest remaining Forest category are adjusted to take account of losses of forest converted to other land use categories (deforestation), as these losses, in their entirety, are not reflected in the statistics published by the Forestry Commission. Implied carbon stock changes per unit area are calculated using the unadjusted forest area and carbon stock changes. The forest area is then adjusted to reflect losses due to forest conversion and multiplied by the implied carbon stock change to obtain the adjusted carbon stock change.

The CARBINE model has not yet been implemented for forest in the Isle of Man and Guernsey (Crown Dependencies of the UK) and instead the C-Flow model is used as it was in previous submissions (UK Greenhouse Gas Inventory, 1990-2011, Annex 3.6).

A 3.4.1.5 Nitrogen fertilization of forest land

Nitrogen fertilization of forest land is assumed to occur only when absolutely necessary, i.e. new planting on ‘poor’ soils (mining spoil, impoverished brown field sites, or upland organic soils). In terms of the inventory, this means that N fertilisation is assumed for Settlement converted to Forest land and Grassland converted to Forest Land on organic soils. The areas of new planting with these conditions were taken from the same dataset used in the CARBINE model (see **Table A 3.4.2**) for 4.A.2. Land converted to Forest land.

Where fertilisation occurs, an application rate of 150 kg N ha^{-1} is assumed based on Forestry Commission fertilisation guidelines (Taylor 1991). The guidelines recommend applying fertiliser on a three-year cycle until canopy closure (at approximately 10 years), but this is thought to be rather high (Skiba 2007) and unlikely to occur in reality, so two applications are adopted as a compromise. These applications occur in year 1 and year 4 after planting. The N_2O emission factor for applied nitrogen fertiliser is the default value of 1% used in the IPCC 2006 Guidelines. Emissions of N_2O from N fertilisation of forests are estimated using a Tier 1 methodology and IPCC default emission factors. The emissions have fallen since 1990 due to reduced rates of new forest planting. A GWP of 298 for N_2O is used.

A 3.4.1.6 Emissions from drainage on forest soils

Work on developing this method was undertaken by Forest Research in 2012 (Yamulki *et al.* 2012), using new GIS data on forest planting in England, Wales and Scotland. Comparable data were not available for Northern Ireland. This method was described in the 1990-2012 National Inventory Report.

The calculations use the same data on forest planting on mineral and organic soils as are used by the CARBINE model for the calculation of carbon stock changes. It is assumed that only forests planted since 1920 have been drained. The areas of forest planted on mineral soil, nutrient-rich organic soil, nutrient-poor organic soils, nutrient-rich organo-mineral soils and nutrient-poor organo-mineral soils are estimated based on the proportion of forest cover on different soil types (Yamulki *et al*. 2012), adjusted by the amount of forest planted since 1920. The area of forest on mineral soil is adjusted further by splitting it between free-draining mineral soils and imperfectly draining (easily waterlogged) mineral soils, which require artificial drainage (based on the current guidance and policy for forest operations and management). The proportion of mineral soils requiring artificial drainage is: 34% in England, 24% in Scotland, 3% in Wales, 68% in Northern Ireland and 26% in the UK as a whole. We assumed all forest on organic and organo-mineral soils is cultivated prior to planting and therefore effectively drained.

N_2O emissions are estimated using the Tier 1 methodology and the IPCC default emission factors for drained mineral (0.06 kg N_2O-N ha^{-1} yr^{-1}), nutrient-rich organic (0.6 kg N_2O-N ha^{-1} yr^{-1}) and nutrient-poor organic soils(0.1 kg N_2O-N ha^{-1} yr^{-1}) (IPCC, 2006).

A 3.4.2 Land Use Change and Soils (4B, 4C, 4E)

Changes in soil carbon due to land use change are modelled with a dynamic model of carbon stock change which is driven by matrices of change calculated from land surveys.

A 3.4.2.1 Land Use Change Matrices

For Great Britain (England, Scotland and Wales), matrices from the Monitoring Landscape Change (MLC) data from 1947 & 1980 (MLC 1986) and the Countryside Surveys (CS) of 1984, 1990, 1998 (Haines-Young *et al*. 2000) and 2007 (Smart *et al*. 2009) are used.

In Northern Ireland, matrices were calculated from the Northern Ireland Countryside Surveys of 1990, 1998 (Cooper and McCann 2002) and 2007 (Cooper, McCann and Rogers 2009). The only data available for Northern Ireland pre-1990 are land use areas from The Agricultural Census and The Forest Service (Cruickshank and Tomlinson 2000). Matrices of land use change were estimated for 1970-79 and 1980-89 using area data. The relationship between the matrix of land use transitions and initial area from recent Countryside Surveys is assumed to be the same as the relationship between the matrix and area data for each of the earlier periods – 1970-79 and 1980-89. The matrices developed in this approach were used to extrapolate areas of land use transition back to 1950 to match the start year in the rest of the UK.

The AFOLU Guidance (IPCC 2006) recommends use of six types of land for descriptive purposes: Forest, Grassland, Cropland, Settlements, Wetlands and Other Land. Areas undergoing active commercial peat extraction and areas of inland water and flooded land are reported under Wetlands in the current inventory, and the remaining land in the UK has been placed into the five other types. The more detailed habitats for the two surveys in Great Britain were combined as shown in **Table A 3.4.3** for the Monitoring Landscape Change dataset and **Table A 3.4.4** for the Countryside Survey Broad Habitats (Jackson, 2000).

Table A 3.4.3 Grouping of MLC land cover types for soil carbon change modelling

CROPLAND	GRASSLAND	FORESTLAND	SETTLEMENTS (URBAN)	OTHER
Crops	Upland heath	Broadleaved wood	Built up	Bare rock
Market garden	Upland smooth grass	Conifer wood	Urban open	Sand/shingle
	Upland coarse grass	Mixed wood	Transport	Inland water
	Blanket bog	Orchards	Mineral workings	Coastal water
	Bracken		Derelict	
	Lowland rough grass			
	Lowland heather			
	Gorse			
	Neglected grassland			
	Marsh			
	Improved grassland			
	Rough pasture			
	Peat bog			
	Fresh Marsh			
	Salt Marsh			

Table A 3.4.4 Grouping of Countryside Survey Broad Habitat types (Jackson, 2000) for soil carbon change modelling

CROPLAND	GRASSLAND	FORESTLAND	SETTLEMENTS (URBAN)	OTHER
Arable and horticulture	Improved grassland	Broadleaved, mixed and yew woodland	Built up areas and gardens	Inland rock
	Neutral grassland	Coniferous woodland	Unsurveyed urban land	Supra littoral rock
	Calcareous grassland		Boundary and linear features	Littoral rock
	Acid grassland			Standing open water and canals
	Bracken			Rivers and streams
	Dwarf shrub heath			Sea
	Fen, marsh, swamp			
	Bogs			
	Montane			
	Supra littoral sediment			
	Littoral sediment			

The area data used between 1947 and the latest inventory year are shown in **Table A 3.4.5** and **Table A 3.4.6**.

The land use change data over the different periods were used to estimate annual changes by assuming that the rates of change were uniform across the period. The full set of annual land use change matrices 1990-latest inventory year are provided in Table 4.1 in the Common Reporting Format tables.

Table A 3.4.5 Sources of land use change data used to estimate changes in soil carbon in Great Britain for different periods.

Year or Period	Method	Change matrix data
1950-1979	Measured LUC matrix	MLC 1947->MLC1980
1980 - 1984	Interpolated	CS1984->CS1990
1984 - 1989	Measured LUC matrix	CS1984->CS1990
1990 - 1998	Measured LUC matrix	CS1990->CS1998
1999-2007	Measured LUC matrix	CS1998->CS2007
2008-latest year	*Extrapolated*	CS1998->CS2007

Table A 3.4.6 Sources of land use change data used to estimate changes in soil carbon in Northern Ireland for different periods.

Year or Period	Method	Change matrix data
1950 – 1969	Extrapolation and ratio method	NICS1990->NICS1998
1970 – 1989	Land use areas and ratio method	NICS1990->NICS1998

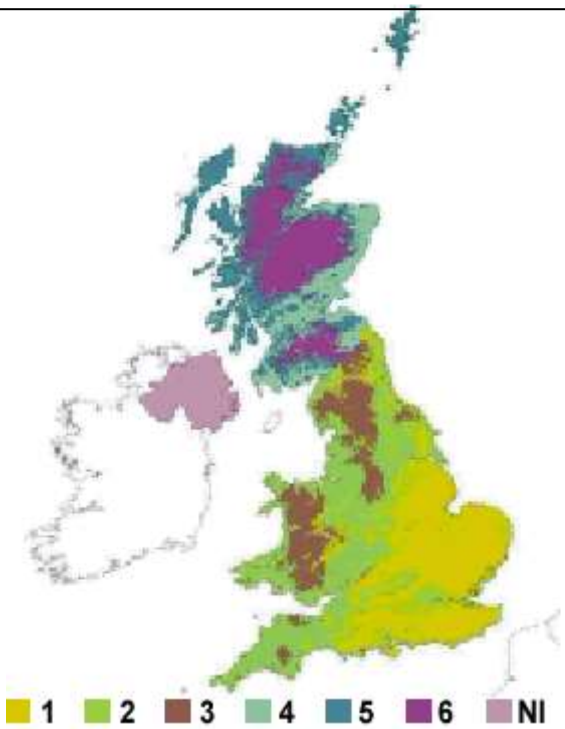
Year or Period	Method	Change matrix data
1990 – 1998	Measured LUC matrix	NICS1990->NICS1998
1999-2007	Measured LUC matrix	NICS1998->NICS2007
2008-latest year	*Extrapolated*	NICS1998->NICS2007

NICS = Northern Ireland Countryside Survey

The transitions between habitat types in the Countryside Surveys for the latest survey (2007) were calculated with Geographical Information System software (ArcGIS). 544 Countryside Survey squares of Great Britain were identified that coincided between the 1998 and 2007 surveys. Survey square locations are confidential. For each coincident square, the area that changed from one habitat type in 1998 to another in 2007 was calculated. There are 47 broad habitats described by the Countryside Survey. Individual surveyed squares contain a subset of these habitats and changes between habitats are called transitions. Each coincident survey square also has a 'land class' assigned to it that does not change between survey years. There are currently 45 land classes in the Land Classification of Great Britain. Land classes represent the stratification of environments across the UK. A simplified picture of the stratification is shown in **Figure A 3.3**. Northern Ireland is treated as a single uniform unit as its smaller area means that it does not display the climatic or elevation variations evident across the rest of the UK.

Transitions between broad habitats were grouped by land class. The ratio of the total area of each land class to the total area sampled within each land class is calculated so that the transitions can be up-scaled to the land class areas. Transitions can then be extracted at various scales i.e. UK or Devolved Authorities scale or 20 km by 20 km squares. These scales are required by the soil carbon and non-forest biomass models.

Figure A 3.3 **Stratification of environments across the UK with areas 1 to 6 based on the underlying Land Classification (45 classes).**



1. Easterly lowlands (England/ Wales)
2. Westerly lowlands (England/ Wales)
3. Uplands (England/ Wales)
4. Lowlands (Scotland)
5. Intermediate uplands and islands (Scotland)
6. True uplands (Scotland)
7. Northern Ireland

A 3.4.2.2 Soils modelling

A database of soil carbon density for the UK (Milne & Brown 1997, Cruickshank *et al*. 1998, Bradley *et al*. 2005) is used in conjunction with the land use change matrices. There are three soil surveys covering England and Wales, Scotland and Northern Ireland. The field data, soil classifications and laboratory methods for these surveys have been harmonized to reduce uncertainty in the final joint database. The depth of soil considered was also restricted to 1 m at maximum as part of this process. **Table A 3.4.7** shows total stock of soil carbon (1990) for different land types in the four devolved areas of the UK.

Table A 3.4.7 **Soil carbon stock (TgC = MtC) for depths to 1 m in different land types in the UK**

Region / **Type**	England	Scotland	Wales	N. Ireland	**UK**
Forestland	108	295	45	20	467
Grassland	995	2,349	283	242	3,870
Cropland	583	114	8	33	738

Region **Type**	England	Scotland	Wales	N. Ireland	**UK**
Settlements	54	10	3	1	69
Other	0	0	0	0	-
TOTAL	**1,740**	**2,768**	**340**	**296**	**5,144**

The dynamic model of carbon stock change requires the change in equilibrium carbon density from the initial to the final land use. The core equation describing changes in soil carbon with time for any land use transition is:

$$C_t = C_f - (C_f - C_0)e^{-kt}$$

where

C_t is carbon density at time t

C_0 is the assumed equilibrium carbon density initial land use

C_f is the assumed equilibrium carbon density after change to new land use

k is time constant of change

Differentiating this equation gives the flux f_t (emission or removal) per unit area:

$$f_t = k(C_f - C_o)e^{-kt}$$

This equation gives, for any inventory year, the land use change effects from any specific year in the past. If A_T is area in a particular land use transition in year T considered from 1950 onwards then total carbon lost or gained in an inventory year, e.g. 1990, is given by:

$$F_{1990} = \sum_{T=1950}^{t=1990} kA_T(C_f - C_o)(e^{-k(1990-T)})$$

This equation is used with k, A_T and (C_f-C_0) chosen by Monte Carlo methods within ranges set by prior knowledge, e.g. literature, soil carbon database, agricultural census, LUC matrices.

In the model, the change in equilibrium carbon density from the initial to the final land use is calculated. These are calculated for each land use category as averages for Scotland, England, Wales and Northern Ireland. These averages are weighted by the area of Land Use Change occurring in four broad soil groups (organic, organo-mineral, mineral, unclassified) in order to account for the actual carbon density where change has occurred. In the UK land use change other than afforestation generally is assumed not to occur on organic soils. Changes in soil carbon stock on afforested land are modelled using the CARBINE model rather than the exponential loss model described above. Other areas of land use change on organic soils are believed to be very small and are currently not separated out from change on mineral soils.

Hence mean soil carbon density change is calculated as:

$$\overline{C}_{ijc} = \frac{\sum_{s=1}^{6}(C_{sijc}L_{sijc})}{\sum_{s=1}^{6}L_{sijc}}$$

This is the weighted mean, for each country, of change in equilibrium soil carbon when land use changes, where:

i = initial land use (Forestland, Grassland, Cropland, Settlements)

j = new land use (Forestland, Grassland, Cropland, Settlements)

c = country (Scotland, England, N. Ireland & Wales)

s = soil group (organic, organo-mineral, mineral, unclassified)

C_{sijc} is change in equilibrium soil carbon for a specific land use transition

The land use data (1990 to 1998) is used in the weighting. The averages calculated are presented in **Table A 3.4.8-Table A 3.4.11**.

Table A 3.4.8 Weighted average change in equilibrium soil carbon density (t ha^{-1}) to 1 m deep for changes between different land types in England

From To	Forestland	Grassland	Cropland	Settlements
Forestland	0	25	32	83
Grassland	-21	0	23	79
Cropland	-31	-23	0	52
Settlements	-87	-76	-54	0

Table A 3.4.9 Weighted average change in equilibrium soil carbon density (t ha^{-1}) to 1 m deep for changes between different land types in Scotland

From To	Forestland	Grassland	Cropland	Settlements
Forestland	0	47	158	246
Grassland	-52	0	88	189
Cropland	-165	-90	0	96
Settlements	-253	-187	-67	0

Table A 3.4.10 Weighted average change in equilibrium soil carbon density (t ha^{-1}) to 1 m deep for changes between different land types in Wales

From To	Forestland	Grassland	Cropland	Settlements
Forestland	0	23	57	114
Grassland	-18	0	36	101
Cropland	-53	-38	0	48
Settlements	-110	-95	-73	0

Table A 3.4.11 Weighted average change in equilibrium soil carbon density (t ha^{-1}) to 1 m deep for changes between different land types in Northern Ireland

From To	Forestland	Grassland	Cropland	Settlements
Forestland	0	94	168	244
Grassland	-94	0	74	150
Cropland	-168	-74	0	76
Settlements	-244	-150	-76	0

The rate of loss or gain of carbon is dependent on the type of land use transition (**Table A 3.4.12**). For transitions where carbon is lost e.g. transition from Grassland to Cropland, a 'fast' rate is applied whilst a transition that gains carbon occurs much more slowly. A literature search for information on measured rates of changes of soil carbon due to land use was carried out and ranges of possible times for completion of different transitions were selected, in combination with modelling and expert judgement (Milne and Brown, 1999; Ashman, *et al,* 2000, Salway *et al*, 2001). These are shown in **Table A 3.4.13**.

Table A 3.4.12 Rates of change of soil carbon for land use change transitions

		Initial			
		Forestland	**Grassland**	**Cropland**	**Settlement**
Final	**Forestland**		*slow*	*slow*	*slow*
	Grassland	*fast*		*slow*	*slow*
	Cropland	*fast*	*fast*		*slow*
	Settlement	*fast*	*fast*	*fast*	

("Fast" & "Slow" refer to 99% of change occurring in times shown in **Table A 3.4.13**)

Table A 3.4.13 Range of times for soil carbon to reach 99% of a new value after a change in land use in England (E), Scotland (S) and Wales (W)

	Low (years)	High (years)
Carbon loss ("fast") E, S, W	50	150
Carbon gain ("slow") E, W	100	300
Carbon gain ("slow") S	300	750

Changes in soil carbon from equilibrium to equilibrium (C_f-C_0) were assumed to fall within ranges based on 2005 database values for each transition (Bradley *et al,* 2005) and the uncertainty indicated by this source (up to ± 11% of mean). The areas of land use change for each transition were assumed to fall in a range of uncertainty of ± 30% of the mean.

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 model of change was run 1000 times using parameters selected from within the ranges described above. The mean carbon flux for each region resulting from this imposed random variation is reported as the estimate for the Inventory. An adjustment was made to these calculations for each country to remove increases in soil carbon due to afforestation, as the CARBINE model provides a better estimate of these fluxes in the Land Converted to Forest Land category. Variations from year to year in the reported net emissions reflect the trend in land use change as described by the matrices of change.

Change in soil carbon stock due to cropland management activities

Change in soil carbon stocks due to cropland management activities is estimated using the methodology developed in Defra project SP1113 (Moxley *et al*, 2014a) which reviewed of UK relevant literature on the effects of cropland management practices on soil carbon stocks and attempted to model UK specific emission factors.

Increases in inputs of fertiliser, manure and crop residues were found to increase soil carbon stocks of tillage land, but changes in the tillage regime from conventional tillage to reduced or zero tillage were found to have no significant effect in a UK context.

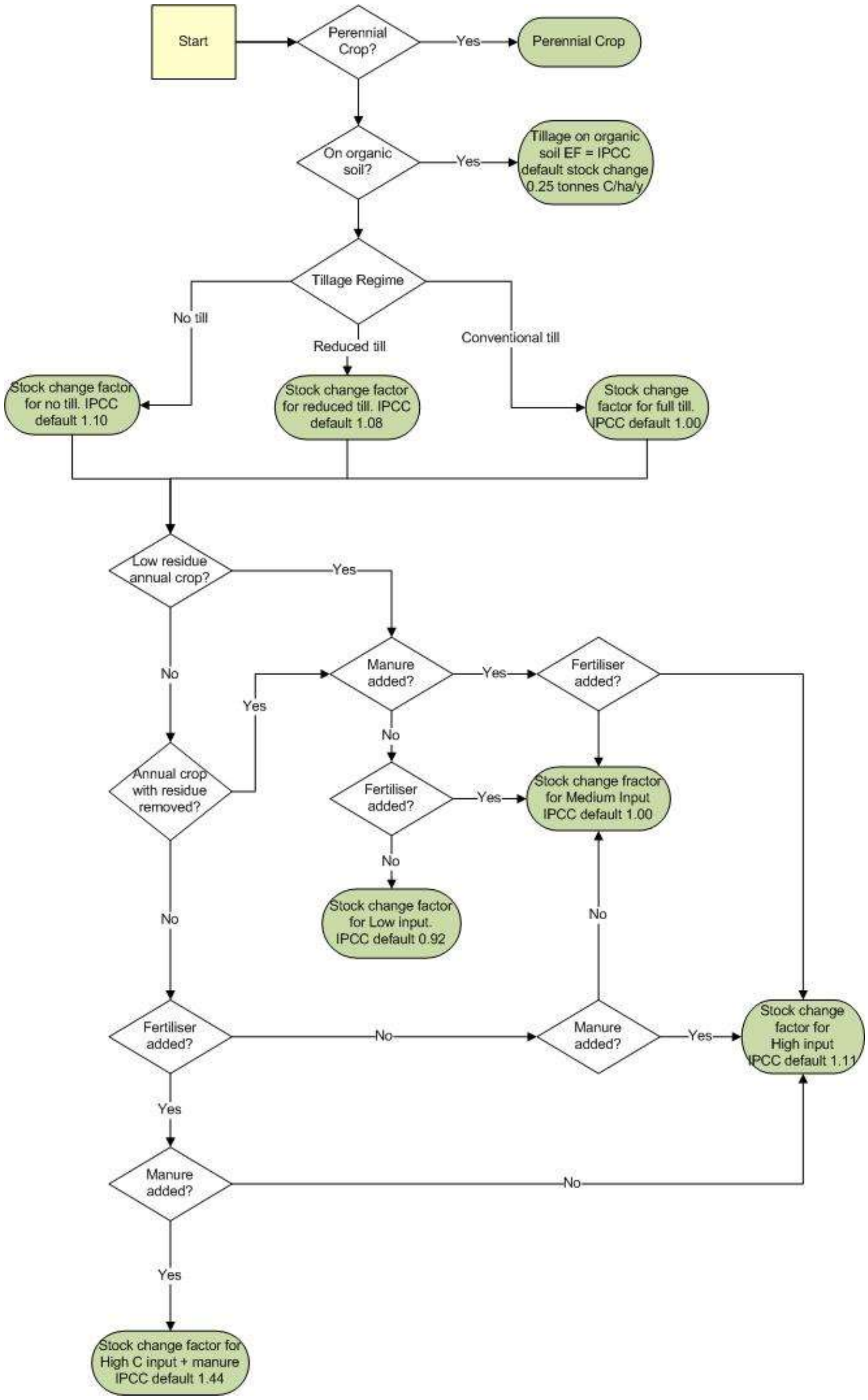
Using this methodology, tillage crops are divided into Medium and Low residue groups based on the data on total crop biomass. Where land receives inputs of fertiliser or manure the inputs moved up a class (e.g. cropland producing a Low residue crop which receives manure is considered to receive Medium inputs, while land producing a Medium residue crop which received manure inputs is considered to receive High inputs). If crop residues are removed from land the input level drops. A decision tree for assessing the effect of cropland management on soil carbon stocks is shown in **Figure A 3.4.**

For most cropland management activities there were insufficient UK field data to develop reliable Tier 2 stock change factors, and so Tier 1 factors have been used (for manure and residue inputs, and for differentiating perennial crops, annual crops and set-aside). However, for tillage reduction both a literature review and modelling work suggested that it did not have a significant effect on soil carbon stocks, and that the Tier 1 stock change factors over-estimated its effect under UK conditions. Therefore a stock change factor of 1 has been used for tillage reduction.

As changes in soil carbon stocks due to changes in cropland management are smaller than changes due to land use change the IPCC default transition time of 20 years is used.

Data on the areas under the main crop types is obtained from the annual June Agricultural Censuses carried out by each UK administration (Defra; Welsh Government; Scottish Government; DAERA). Data on the areas of cropland receiving inputs of manure, fertiliser and crop residues is obtained from the annual British Survey of Fertiliser Practice (Defra).

Figure A 3.4 Decision tree for assessing the effects of cropland management activities on soil carbon stocks.



Change in soil carbon stock due to grassland management activities

Defra project SP1113 attempted to develop a methodology to allow reporting of changes in soil carbon stocks resulting from grassland management activities. There are reasonable data on the effects of management practices such as liming, reseeding and drainage on improved grassland on mineral soils. However, there are few data on the effect of many management practices if applied to semi-natural grassland or those on organo-mineral or organic soils where there is a risk that more intensive management could increase carbon losses. As semi-natural grassland makes up a large proportion of grassland in the UK the lack of field data makes it impossible to reliably report changes in soil carbon stocks from grassland management activities. A research project commissioned by BEIS is currently underway to fill this knowledge gap; reporting on the effect of grassland management on soil carbon will be included in the inventory when new data from this project become available.

A 3.4.2.3 Future development

A new vector-based approach to tracking land use change (Levy et al. 2017) has been developed using data from the CORINE land cover map. The approach can be used to produce a set of 100 x 100 m resolution maps, where each 100 m square has an associated vector of land use over time. The maps can be aggregated into a set of distinct representative vectors with their corresponding areas. This has the potential to improve the modelling of change in soil carbon stocks resulting from land use change compared to the current statistically based land use change matrices.

The implementation of this approach has been delayed by the difficulties in obtaining and processing activity data in a timely manner for inventory production. As there will not be a repeat of the Countryside Survey (last undertaken in 2007), alternative data sources must be used, such as CEH land cover maps (1990,2000, 2007), the NFI map, annual agricultural survey data or the Integrated Administration and Control System (IACS) dataset (used to administer Common Agricultural Policy payments). These all have advantages and disadvantages in terms of their coverage, spatial and temporal resolution and/or processing requirements. BEIS are tendering a research contract to investigate the potential of Earth Observation sensor data at different resolutions to obtain suitable land use change data for use in the LULUCF sector inventory.

A BEIS-funded project developing an operational methodology for estimating the impact of grassland management activities on soil carbon, particularly on organo-mineral soils, is due to report in 2017.

A 3.4.3 Changes in stocks of carbon in non-forest biomass due to land use change (4B2, 4C2, 4E2)

Change in biomass carbon stock due to land use change.

Changes in stocks of carbon in biomass due to land use change are based on the same area matrices used for estimating changes in carbon stocks in soils (see previous section). The biomass carbon density for each land type other than Forest is assigned by expert judgement based on the work of Milne and Brown (1997) and these are shown in **Table A 3.4.14.** Five basic land uses were assigned initial biomass carbon densities, and then the relative occurrences of these land uses in the four countries of the UK were used to calculate mean densities for each of the IPCC types, Cropland, Grassland and Settlements.

Living biomass carbon stocks and Dead Organic Matter (DOM) stocks on Forest Land are modelled using CARBINE and used to calculate changes in carbon stocks due to conversions to and from Forest Land. When land is deforested to another land use, it is assumed that all living biomass and DOM is either converted to Harvested Wood Products or burnt on site in the year in which deforestation takes place. Under KP-LULUCF reporting all HWP from Article 3.3 Deforestation are assumed to be instantaneously oxidised. Increase in biomass carbon and DOM stocks on afforested land is modelled in CARBINE. Full details of CARBINE modelling of carbon stocks on Forest Land are given in **Annex A 3.4.1.1.**

The mean biomass carbon densities for each land type were further weighted by the relative proportions of change occurring between non-Forest land types (**Table A 3.4.15-Table A 3.4.18)** in the same way as the calculations for changes in soil carbon densities. Changes between these equilibrium biomass carbon densities were assumed to happen in a single year.

Table A 3.4.14 Equilibrium biomass carbon density (kg m^{-2}) for different land types

Density (kg m^{-2})	**Scotland**	**England**	**Wales**	**N. Ireland**
Arable	0.15	0.15	0.15	0.15
Gardens	0.35	0.35	0.35	0.35
Natural	0.20	0.20	0.20	0.20
Pasture	0.10	0.10	0.10	0.10
Urban	0	0	0	0
	Equilibrium biomass carbon density of IPPC types weighted by occurrence (kg m^{-2})			
Cropland	0.15	0.15	0.15	0.15
Grassland	0.18	0.12	0.13	0.12
Settlements	0.29	0.28	0.28	0.26

Biomass carbon stock for the IPCC land use categories were estimated using land cover data from the 2007 Land Cover Map (LCM) and the biomass carbon stocks for each LCM land cover type developed in Milne and Brown (1997). For Settlements LCM was used to assess the proportion of gardens, pasture-type grass (including sports pitches, golf courses and parks) and urban (built over) area within areas identified as Settlements.

Table A 3.4.15 Weighted average change in equilibrium biomass carbon density (kg m^2) for changes between different land types in England

From To	**Forestland**	**Grassland**	**Cropland**	**Settlements**
Forestland				
Grassland		0	0.08	-0.08
Cropland		-0.08	0	-0.13
Settlements		0.08	0.13	0

(Transitions to and from Forestland are considered elsewhere)

Table A 3.4.16 Weighted average change in equilibrium biomass carbon density (kg m^{-2}) for changes between different land types in Scotland.

From To	Forestland	Grassland	Cropland	Settlements
Forestland				
Grassland		0	0.02	-0.09
Cropland		-0.02	0	-0.14
Settlements		0.09	0.14	0

(Transitions to and from Forestland are considered elsewhere)

Table A 3.4.17 Weighted average change in equilibrium biomass carbon density (kg m^{-2}) for changes between different land types in Wales.

From To	Forestland	Grassland	Cropland	Settlements
Forestland				
Grassland		0	0.07	-0.08
Cropland		-0.07	0	-0.13
Settlements		0.08	0.13	0

(Transitions to and from Forestland are considered elsewhere)

Table A 3.4.18 Weighted average change in equilibrium biomass carbon density (kg m^{-2}) for changes between different land types in Northern Ireland.

From To	Forestland	Grassland	Cropland	Settlements
Forestland				
Grassland		0	0.08	-0.06
Cropland		-0.08	0	-0.11
Settlements		0.06	0.11	0

(Transitions to and from Forestland are considered elsewhere)

Change in biomass carbon stock due to change in Cropland and Grassland Management.

Change in Cropland biomass carbon stocks was assessed based on agricultural census data. Areas under different crop types were taken from annual agricultural census data and assigned on one of four categories: annual crops, orchard crops, shrubby perennial crops and set aside and fallow. Crop types reported in the agricultural census vary slightly for each administration. **Table A 3.4.19** shows how agricultural census crop types were grouped to assess biomass carbon stocks.

Table A 3.4.19 Aggregation of Agricultural Census crop types for estimating biomass carbon stock changes from Cropland Management

Devolved Administration	Annual Crops	Orchard Crops	Shrubby perennial crops	Set Aside and Fallow
England	Cereals, Other arable not stockfeed, Crops for stockfeeding, Vegetables for Human Consumption	Orchard Fruit	Soft fruit, Hardy nursery stock, bulbs and flowers, Area under glass or plastic covered structures.	Uncropped land
Scotland	Cereals, Oilseed rape, Peas for combining, Beans for combining, Linseed, Potatoes, Crops for stockfeeding, Vegetables for human consumption, Other crops	Orchard fruit	Soft fruit	Fallow , Set Aside
Wales	Cereals, Other arable not for stockfeeding, Crops for stockfeeding, Salad and vegetables grown in the open, Total hardy crops	Commercial orchards, Other orchards	Glasshouse	Bare fallow
Northern Ireland	Cereals, Other arable not for stockfeeding, Vegetables	Fruit	Ornamentals	Fallow and set aside

The areas under each aggregated crop type were multiplied by the biomass carbon stock of each crop type using the biomass carbon stock factors in **Table A 3.4.20.** These factors were generated from a literature review. (Moxley *et al.* 2014b).

Table A 3.4.20 Biomass stock factors for UK Cropland types

Crop Type	Total biomass Carbon Stock t C/ha	Uncertainty t C/ha (95% CI)	Root: Shoot ratio
Annual	5	1.2	Assume no Below Ground Biomass.
Orchards	10	6.75	0.24
Shrubby perennial crops	3.7	2.0	Assume no Below Ground Biomass.
Set Aside and Fallow	5	1	4.0

Biomass carbon stock change was assumed to occur in the year in which the change in crop type was reported. Cropland biomass stock changes resulting from land use change to or from Cropland were subtracted from the changes due to change in cropland management, as they are already accounted for under land use change.

Change in Grassland biomass carbon stocks was assessed based on Countryside Survey data. Grassland was separated into shrubby, non-shrubby and unvegetated Grassland based on Countryside Survey Broad Habitat types. **Table A 3.4.21** shows which Broad Habitats were allocated to which Grassland type.

Table A 3.4.21 Aggregation of Countryside Survey Broad Habitats for estimating biomass carbon stock changes from Grassland Management

Shrubby Grassland	Non-shrubby Grassland	Unvegetated Grassland
Dwarf Shrub Heath Bracken Montane	Improved Pasture Improved Pasture Neutral Grassland Calcerous Grassland Acid Grassland Bogs	Littoral sediment Supra littoral sediment

The areas under each aggregated Grassland type were multiplied by the biomass carbon stock of each crop types using the biomass carbon stock factors in **Table A 3.4.22.** These factors were generated from literature reviews (Moxley *et al.* 2014b). Only biomass carbon stock changes resulting from change between shrubby and non-shrubby Grassland were considered, as changes to and from unvegetated littoral and supra-littoral sediments were considered unlikely.

Table A 3.4.22 Biomass stock factors for UK Grassland types

Crop Type	Total biomass Carbon Stock t C/ha	Uncertainty t C/ha (95% CI)	Root: Shoot ratio
Non-shrubby Grassland	2.8	1.5	4.0
Shrubby Grassland.	10	3.6	0.53
Unvegetated Grassland	0	0	0
Managed hedge	34.86	68.75	0.3
Unmanaged hedge	175.3	476.6	0.3

Countryside Survey data are only collected on an approximately decadal bias. The annual stock change between survey years was estimated using linear interpolation. Biomass carbon stock change was assumed to occur in the year in which the change in Grassland type occurred. Grassland biomass stock changes resulting from land use change to or from Grassland were subtracted from the changes due to change in grassland management.

Change in Grassland biomass carbon stocks due to change in hedge length have been included in the estimate of change in Grassland biomass carbon stock for the first time using Countryside Survey data on hedge length and condition. Hedges were divided into managed hedges which are trimmed to prevent the growth of large trees and unmanaged hedges which do not received routine maintenance. Unmanaged hedges do not fall within the UK's definition of Forest, but which contain isolated trees and may also have some gaps in them. The biomass carbon stocks of managed and unmanaged hedges were estimated as the median of UK-relevant values in published literature, based on a literature review commissioned by BEIS (Moxley et al. 2014b) supplemented with more recent data. Full details of these values and data sources are included the Grassland Management Biomass calculation workbook.

A 3.4.3.1 Future development

A new vector based approach to tracking land use change using CORINE data has been developed, as described in **Section 6.4.8**. This has the potential to improve modelling of biomass carbon stock changes resulting from land use change. This approach could be combined with use of IACS data on agricultural land use making it possible to track change in Cropland use in a spatially explicit manner. However, the IACS data have some inconsistencies between administrations and over time, and these need to be resolved before these data could be used. In addition, a strategy needs to be developed to backfill the time series prior to the availability of IACS data.

A 3.4.4 Carbon stock changes and biomass burning emissions due to Deforestation (4B, 4C, 4E, 4G)

Deforestation is an activity that cuts across LULUCF categories, affecting net emissions and removals in all the land use categories except 4D Wetlands. The process of land use change affects carbon stock changes in biomass and soil, and the woody material left after felling either moves into the harvested wood products pool or is assumed to be burnt on-site, resulting in immediate biomass burning emissions.

Levy and Milne (2004) discuss methods for estimating deforestation since 1990 using a number of data sources. Their approach of combining Forestry Commission felling licence data for rural areas with Ordnance Survey data for non-rural areas has been expanded to include new sources of information and to improve coverage of all countries in the UK. Deforestation before 1990 (which contributes to soil carbon stock changes from historical land use change) is estimated from the land use change matrices described in **Section 0**.

A 3.4.4.1 Types of deforestation activity in the UK

In Great Britain, some activities that involve tree felling require permission from the Forestry Commission, in the form of a felling licence, or a felling application within the various forestry grant schemes. There is a presumption that the felled areas will be restocked, usually by replanting but sometimes by natural regeneration. However, some licences are granted without the requirement to restock – so-called unconditional felling licences. A felling licence is required unless special conditions are met[9].

Felling for urban development, with no requirement to restock, can be allowed under planning permission but only local planning authorities hold documentation for this. For years since 2006, remotely sensed data used in the NFI has included this changed, but prior to this, the need for collation of data from local authorities makes estimating the national total difficult. However, in England, the Ordnance Survey (the national mapping agency) makes an annual assessment of land use change from the data it collects for map updating and provides this assessment to the

[9] http://www.forestry.gov.uk/forestry/INFD-6DFKW6

Department of Communities and Local Government (DCLG)[10]. DCLG provides an extract of this dataset, listing annual land use change from Forest to developed land uses (1990-2008 in the latest submission). This dataset comes from a continuous rolling survey programme, both on the ground and from aerial photography. The changes reported each year may have actually occurred in any of the preceding 1-5 years. The survey frequency varies among areas, and can be up to 10 years for moorland/mountain areas. Consequently, for pre-2006 deforestation to Settlement a five-year moving average is applied to the data to smooth out the between-year variation appropriately, to give a suitable estimate with annual resolution.

The Countryside Survey land use change matrix (**Section 0**) gives estimates of forest conversion to other land use categories for all countries in the UK for 1990-1998 and 1999-2007. There are known issues with Countryside Survey over-estimating the extent of Forest conversion compared with the extent estimated by the Forestry Commission. Therefore, Forest Commission data is used for Forest areas and the areas of other land uses estimated by Countryside Survey are adjusted to account for this. This is due to differences in Forest definitions, amongst other causes.

A 3.4.4.2 Compilation of activity datasets

For 1990-1999 the deforestation activity dataset is compiled from the felling licence and DCLG datasets as far as possible, using Countryside Survey (CS) data to fill gaps in the time series, to estimate deforestation in Northern Ireland (for which no direct data are available) and to estimate the conversion to different land use categories. The DCLG data are used to estimate the area of Forest Land converted to Settlement (4.E.2.1). The unconditional felling licence data are used to estimate the area of Forest Land converted to Cropland (4.B.2.1) and of Forest Land converted to Grassland (4.C.2.1). Only England has any post-1990 forest to cropland conversion: the estimated areas in Scotland, Wales and Northern Ireland are so small that they are thought to be due to survey classification error rather than genuine land use change.

The CS data are used to estimate the relative split of Forest conversion between Grassland, Cropland and Settlements (**Table A 3.4.23**), using other known data (e.g. felling licences) to correct the CS areas where datasets overlap in time. **Table A 3.4.24** shows the Corrected Forest conversion rates. A correction ratio is used to adjust the estimated deforestation areas, as the Countryside Survey is known to over-estimate deforestation as described in the section above. There are no non-CS data for Northern Ireland so the correction ratios for England or Wales are used, depending on availability. The 1990-98 correction ratios are also applied to the pre-1990 CS land use change estimates.

The annual area of forest converted to other land uses is removed from the area of 4A1 Forest Land remaining Forest Land to maintain consistency in the land area matrix.

---

[10] http://www.communities.gov.uk/planningandbuilding/planningbuilding/planningstatistics/landusechange/

Table A 3.4.23 Countryside Survey data for Forest conversion

Countryside Survey land use change		Annual rate of change, kha/yr				Grassland/Cropland fractional split		
		England	Scotland	Wales	N Ireland	England	Scotland	Wales
1990-1998	Forest to Natural Grassland	5.600	4.418	1.099	0.171	0.61	0.86	0.72
	Forest to Pasture Grassland	3.081	0.608	0.418	0.086	0.33	0.14	0.28
	Forest to Cropland	0.545	0.097	0.019	0.008	0.06	0.00	0.00
	Forest to Settlements	1.242	0.293	0.132	0.072			
	Forest to Other Land	0.169	0.231	0.058	0.025			
1999-2007	Forest to Natural Grassland	2.656	10.327	0.120	0.209	0.86	0.98	0.42
	Forest to Pasture Grassland	0.277	0.186	0.162	0.102	0.09	0.02	0.58
	Forest to Cropland	0.141	0.006	0.001	0.001	0.05	0.00	0.00
	Forests to Settlements	0.617	0.098	0.095	0.142			
	Forest to Other Land	0.430	0.695	0.374	0.027			

Table A 3.4.24 Corrected Forest conversion rates

		Correction ratio			Estimated annual rate of change, kha/yr			
		England	Scotland	Wales	England	Scotland	Wales	N Ireland
1990-1998	Grassland & Cropland	2% [a]			0.159	0.088[c]	0.026 [c]	0.005 [c]
	Settlements & Other Land	28% [b]			0.390	0.145 [c]	0.052 [c]	0.027 [c]
1999-2007	Grassland & Cropland	20% [a]	2% [a]	15% [a]	0.602	0.262	0.041	0.045[d]
	Settlements & Other Land	28% [b]			0.296	0.224 [c]	0.133 [c]	0.048 [c]

[a] Unconditional felling licence data used for correction
[b] Land Use Change Statistics used for correction
[c] England correction ratio used
[d] Wales correction ratio used

For 2000 onward, the area and subsequent land-use of deforestation were estimated based on a combination of data sources:

- observations on forest loss by the National Forest Inventory (internal Forestry Commission analysis) by IPCC category. This inventory includes an analysis of deforestation from 2006 to the current inventory year based on a new analysis of woodland maps (Forestry Commission, 2016);
- unconditional felling licences granted (assumed all converted to Grassland);
- analysis of the FC Sub-Compartment Database for restoration of Forest land to open habitats (assumed all converted to Grassland); and

- conversion to non-forest on private sector forest covered by long-term forest plans rather than felling licences (internal Forestry Commission report, assumed all converted to Grassland).

The revision in deforestation was only done from 2000 onwards, partly because there were no suitable data on which to base adjustments for 1990-1999, but also because a number of policy developments came into play in 2000 or shortly beforehand, which affected deforestation to restore open habitats or develop wind-farms. These include the introduction of the UK's climate change policy (2000), and the diversification in relevant forest policies in England, Scotland and Wales following the devolution of forest policy to countries in the late 1990s (Matthews *et al.* 2014). The deforestation information used in this inventory is similar to the previous inventory, with some minor revisions based on further analysis of the data and inclusion of estimates for the latest inventory year.

Soil carbon stock changes associated with deforestation are estimated using the dynamic soil carbon model described in **Section 0**. When deforestation occurs it is assumed that 60% of the standing biomass is removed as timber products and the remainder is burnt. In the UNFCCC inventory, KP-LULUCF reporting of deforestation assumes instantaneous oxidation of HWP. Country-specific forest biomass densities for living and dead organic matter from CARBINE are used. These densities change over time in relation to the forest age and species structure. Biomass losses are reported in the relevant carbon stock change tables, assuming a carbon fraction of 0.5 on a dry weight basis. The carbon removed as timber is reported as Harvested Wood Products (HWP) in 4G, using CARBINE to model emission from HWP (described in **Section 6.8**).

Direct and indirect greenhouse gas emissions from associated biomass burning is estimated using the Tier 1 methodology described in the IPCC 2006 guidelines (IPCC 1997 a, b, c) and the emission ratios for CH_4, CO, N_2O and NO_x from Table 3A.1.15 in the IPCC 2003 GPG for LULUCF. Only immediate losses are considered because sites are normally completely cleared, leaving no debris to decay.

A 3.4.5 Biomass Burning – Forest and Non-Forest Wildfires (4A, 4B, 4C)

A 3.4.5.1 Activity dataset

Until 2010 only wildfires on Forest land were reported due to a lack of activity data for wildfires on other land use categories. Data on Forest wildfires prior to 2010 come from the Forestry Commission and the Forest Service of Northern Ireland.

In 2010 the Fire and Rescue Service (FRS) began recording wildfires in England, Scotland and Wales on a new Incidence and Reporting Systems (IRS) which includes wildfires on all land use categories. The IRS database contains 30 attributes for each fire to which a fire appliance was called, including date, spatial location, property type description (e.g. heathland and moorland, standing crop) and an estimate of the area burnt. This dataset is available from 1st April 2009. The original dataset had >126,000 fire records but 99% of these fires were less than 1 ha in size. The IRS database is manually completed by fire service personnel and its use requires some subjective judgement. This is likely to lead to non-systematic differences in the accuracy and precision of the data. The accuracy of the locations is variable, but an assessment of a number of the larger fires suggests that the land cover type attribute is reliable. The accuracy of the FRS burnt area estimates could not be validated using aerial photography as the available imagery was not recent enough, so Landsat images were used to validate the FRS data. However, it was still difficult to find cloud-free, pre- and post-fire images for fires in 2010. In addition Landsat has been affected by image 'striping' since 2003, which affects the quality of the images and causes some data loss. There are issues with re-ignited fires or additional fires in the same area being logged in the database as separate events. Overall, the uncertainty associated with this dataset is high but should be re-assessed once a longer time series is available.

To provide data on non-Forest wildfires prior to 2010, thermal anomaly data for 2010 from the NASA-operated MODerate Resolution Imaging Spectroradiometer (MODIS) were obtained from the Fire Information Resource Management System (FIRMS) and allocated to land uses using the proportions of fire on each land use type from the Fire and Rescue Service IRS data. The correlation between MODIS data and IRS data breaks down below 25 ha, so for consistency a 25 ha threshold was set for reporting wildfires logged on the IRS.

Thermal anomalies usually represent active fires, but may also detect industrial heat sources, although these are typically masked out by the thermal anomaly processing chain. The IRS dataset records 89 fires > 25ha occurring in 2010. The FIRMS dataset records 335 fire detections for the same period, however, the FIRMS detections may contain multiple detections for a single fire event and the FIRMS detections are for a single 1 km pixel, and do not have a straightforward conversion to burnt area. Searching the IRS and FIRMS data sets for temporally and spatially coincident events, using a 2 km buffer around the IRS data, suggests that 22 fires were recorded by both the IRS and FIRMS systems. There are wide discrepancies between the two datasets, reflecting their different natures. The IRS data set records fires where a fire service response was required, so does not record controlled burning, unless the fire gets out of control. The FIRMS dataset however, responds to anomalous heat signatures, so records controlled and uncontrolled fires. However, in the UK controlled burning, which is primarily carried out for heath management is only permitted between October and mid-April to reduce the risk of these burns running out of control (Natural England, 2014[11]; Scottish Government, 2011[12]). As the FIRMS thermal anomaly data is only collected between March and August it will not detect most fires from controlled burning. FIRMS is only able to detect fires under cloud-free or light cloud conditions and is also only able to detect fires alight at the time of the satellite overpass. The FIRMS data are more likely to detect larger fires than smaller ones, probably due to the stronger heat signature and the longer burn time that larger fires tend to exhibit.

The IRS and FIRMS thermal anomalies give a very different perspective on the extent, timing and duration of fire events in the UK. However, the datasets did show correlation (R^2= 70-81%) for fires larger than 25 ha, which enabled an empirical relationship to be derived to extend the burnt area record back to 2001. A burnt area threshold of 25 hectares was used to extract a subset of the IRS database: this captured 75% of the IRS wildfire-burnt area in England, 86% in Scotland and 64% in Wales.

As more IRS data become available confidence should increase in the relationship between fires detected by FIRMS and fires logged in the IRS. This may allow FIRMS data to be extrapolated to fires covering less than 25 ha the inventory in future. However to extend this to small fires there would need to be reasonable confidence that the ratio of large to small fires used was valid, and also some investigation of whether the distribution of small fires across land use classes was the same as that of larger fires.

---

[11] https://www.gov.uk/guidance/heather-and-grass-burning-apply-for-a-licence

[12] http://www.gov.scot/Resource/Doc/355582/0120117.pdf

It was assumed that all fires in the IRS database were wildfires: even if they started as controlled burning, because the need for a fire appliance call-out indicates that they are no longer under control. The IRS property type descriptions were assigned to LULUCF sub-categories (**Table A 3.4.25**). There is a very small area of wildfires that occur on Settlement types, and these are included in the Grassland category as the IRS land type classification suggests that they occur on grassy areas within Settlements and there is not a separate reporting field for wildfires in Settlements in the CRF.

Table A 3.4.25 IRS database property type descriptions by LULUCF sub-category

LULUCF sub-category	Forest	Cropland	Grassland	Settlement
IRS property type description	Woodland/forest - conifers/softwood	Straw/stubble burning	Heathland or moorland	Domestic garden (vegetation fire)
	Woodland/forest - broadleaf/hardwood	Stacked/baled crop	Grassland, pasture, grazing etc.	Park
		Nurseries, market garden	Scrub land	Roadside vegetation
		Standing crop	Tree scrub	Railway trackside vegetation
				Wasteland
				Canal/riverbank vegetation

A time series of wildfire-burnt areas for each non-forest land use type was constructed for 1990-2015 (**Figure A 3.8**). For non-forest wildfires for England, Scotland and Wales the IRS burnt areas were used for 2010 to the current inventory year and the burnt area estimated from thermal anomalies from 2000 to 2010. For 1990-2000 the average annual burnt area 2001-2011 was used.

In Northern Ireland, where no IRS data were available, it was assumed that the heathland and grassland burning rates were in the same proportions as the Scottish burning rates, using the area of heathland and grassland from the 2007 Northern Ireland Countryside Survey.

Estimates of the forest area burnt in wildfires 1990-2004 are published in different locations (FAO/ECE 2002; FAO 2005) but all originate from either the Forestry Commission (Great Britain) or the Forest Service (Northern Ireland). There is a gap in the time series 2005-2010 for Great Britain but areas of forest wildfires are reported annually for Northern Ireland. The gap was filled using the annual average areas burnt 1995-2005. These areas refer only to fire damage in state forests; no information is collected on fire damage in privately owned forests. The proportion of private-owned forest that was burnt each year was assumed to be the same as the percentage of the state forest that was burnt each year.

Figure A 3.7 Annual area of FIRMS thermal anomalies for GB for 2001 to the current inventory year (thermal anomalies were filtered to exclude those recorded over urban/industrial areas).

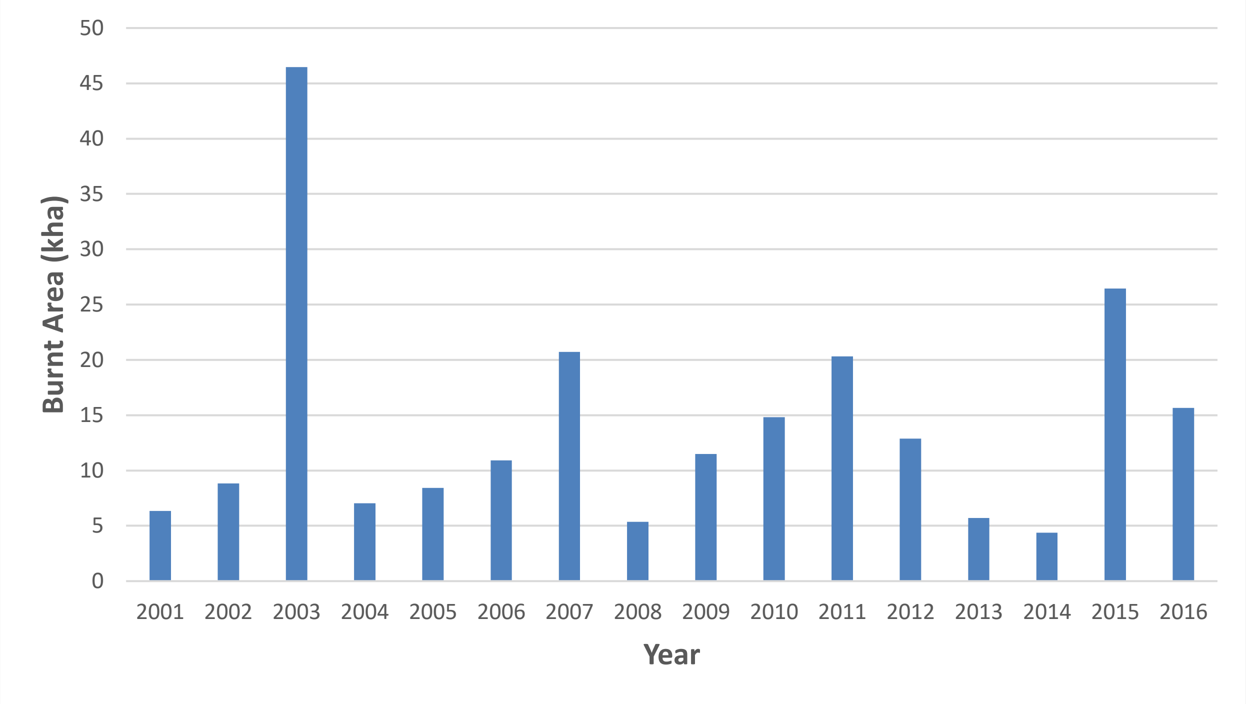
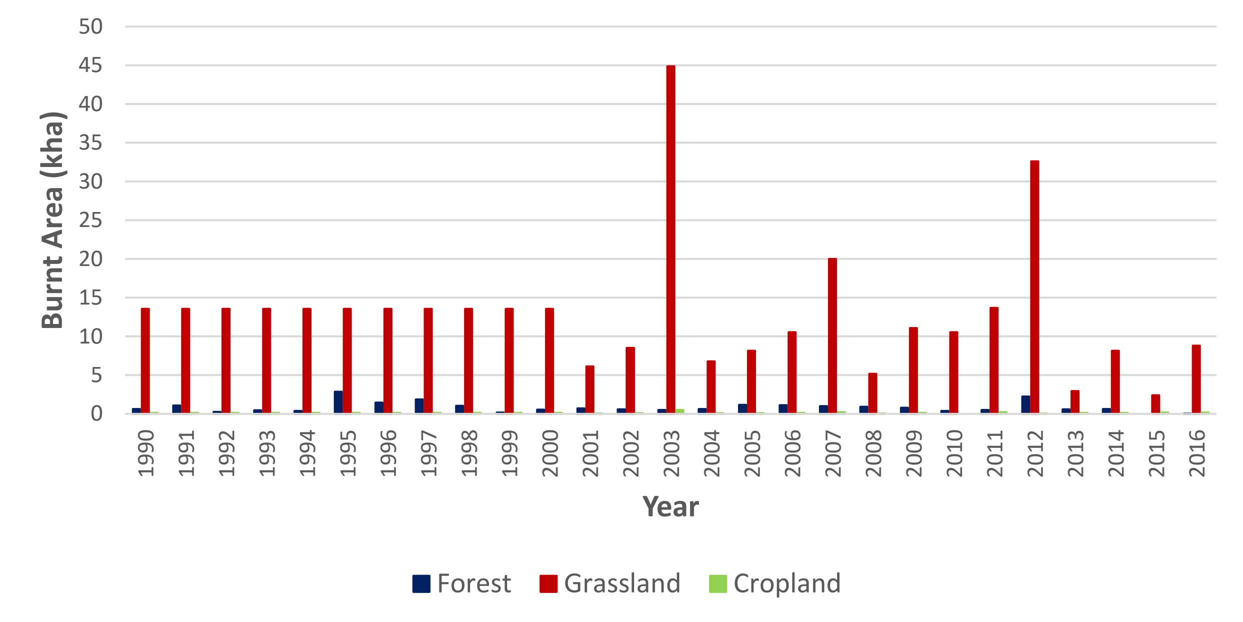


Figure A 3.7 shows the temporal pattern of FIRMS thermal anomalies, with peaks in hot dry years such as 2003. The FIRMS data used only includes thermal anomalies for March – August for each year, as these are the months where the IRS database recorded fires greater than 25 ha. Some FIRMS thermal anomalies were recorded outwith these months due to FIRMS detecting both controlled burns and some fires less than 25 ha in size which are not included in the IRS data.

Figure A 3.8 Time series of wildfire burnt areas in the UK 1990 to the current inventory year



A 3.4.5.2 Estimation of emissions

The IPCC Tier 1 method is used for estimating emissions of CO_2 and non-CO_2 gases from wildfires (IPCC 2006). The *Calluna* heath fuel biomass consumption factor and grassland emission factors are used for heathland and moorland fires, the agricultural residues EFs for cropland and the “savannah and grassland” EFs for other grassland and settlements.

Country-specific biomass and Dead Organic Matter densities from the CARBINE model are used for estimating fuel consumption in forest fires (as discussed in the deforestation methodology section) and the ‘extra tropical forest’ EFs in the 2006 Guidelines. In line with the default value in the 2006 AFOLU Guidance it is assumed that 45% of the biomass is consumed in a wildfire in an unfelled temperate forest.

Emissions from all wildfires are reported under the ‘Land remaining Land’ categories (i.e. 4A1, 4B1 and 4C1) and IE reporting under 4A2, 4B2 and 4C2.

A 3.4.6 Emissions from drainage (organic soils) (4B1, 4C1)

Some Wetlands in the UK were drained many years ago for agricultural purposes and continue to emit carbon from the soil. The inventory includes emissions from of areas of drained organic soils under Cropland and improved Grassland throughout the UK. The drained areas were generated from work on the UK Agricultural Greenhouse Gas Platform project (Defra project AC0114) (Anthony, ADAS pers. comm). A lack of data on drainage of semi-natural Grassland meant that the area of semi-natural Grassland on drained organic soils could not be estimated. These areas of drained organic soils have also been used for the Agricultural Sector, so there is consistency within the UK Greenhouse Gas Inventory. Work to implement the Wetlands Supplement (IPCC 2013a) guidance is developing a methodology to estimate the area of semi-natural Grassland on drained organic soils. Emissions have been estimated using Tier 1 emissions factors for drained organic soils under Cropland and Grassland taken from the AFOLU Guidelines (IPCC, 2006) applied to all depths of drained organic soil. Results from a BEIS-funded project to implement the Wetland Supplement guidance will allow more detailed estimates of emissions from drained organic soils to be developed in future inventories.

It is assumed that the area of drained organic soils has remained constant as no drainage or rewetting has occurred since 1990 as there have been no policy drivers to encourage drainage or rewetting of cropland or improved grassland. It is also assumed that land on organic soils has not been converted between land uses.

A 3.4.7 Emissions of N2O due to disturbance associated with land use conversion and land management changes (4(III))

Methodological coverage of this activity has expanded in the IPCC 2006 Guidelines, as previously only N_2O emissions due to soil disturbance associated with land use conversion to Cropland were included. All land use conversions or land management changes that result in a loss of soil carbon, leading to N mineralization and N_2O emissions are now reported. Direct emissions from soils, and indirect emissions from nitrogen leached from soil and subsequently oxidised are included in the inventory. The UK now includes emissions resulting from the land use conversions: 4A2 Land converted to Forest Land, 4B2 Forest to Cropland and Grassland to Cropland, 4C1 Grassland remaining Grassland, 4C2 Forest to Grassland, 4E1 Settlement remaining Settlement and 4E2 Land converted to Settlement. Emissions of N_2O from 4C1 and 4E1 arise from land use change over 20 years before the inventory reporting year where loss of soil organic matter is still ongoing. Emissions of N_2O from 4B1 Cropland remaining Cropland (resulting from land use change over 20 years before the inventory year) are calculated in the same way by the LULUCF inventory team but are included in the Agriculture sector (category 3D1).

The Tier 1 methodology described in the IPCC 2006 Guidelines is used. The activity data are the areas and soil carbon stock changes reported in the relevant categories in 4B, 4C and 4E. Some C:N ratios for UK soil/vegetation combinations are published in the Countryside Survey (with values of 11.7 to 13.4) but only for the top 15 cm of soil. However, the soil carbon stock changes reported in the inventory are from the top 1 m of soil, so these C:N ratios were not felt to be applicable. Therefore, the IPCC default C:N ratio of 15 is used for estimating mineralised N. The emission factor of 1% in the 2006 Guidelines was used to estimate N_2O emissions from mineralised N. Indirect N_2O emissions from mineralisation are also estimated from carbon stock change using Tier 1 methodology.

A 3.4.8 On-site and off-site emissions from peat extraction (4D)

On-site emissions of CO_2 and N_2O from peat extraction activities (for energy and horticultural use) and off-site emissions of CO_2 from the decomposition of horticultural peat are reported in category 4D.

A 3.4.8.1 Activity datasets

Available data sets on peat extraction vary between Northern Ireland and for Great Britain (England, Scotland and Wales). From 2002 onwards Google Earth imagery has been used to estimate the area of peat extraction and sites list in the Directory of Mines and Quarries. Until 2014, this inventory only covered Great Britain, but the 2014 Directory lists peat extraction sites in Northern Ireland for this first time. This has made it possible to use Google Earth to estimate the peat extraction site area in all UK administrations for the first time in the 1990-2014 inventory. Prior to the 2002 no Google Earth images are available, and peat extraction site areas have been estimated from other sources. **Table A 3.4.26** shows the sources of activity data used to estimate emissions from peat extraction.

Table A 3.4.26 Activity data for peat extraction sites in Northern Ireland

Data set	Information contained	Geographic extent	Time period	Publication frequency
Directory of Mines and Quarries (DMQ)	Location of active peat extraction sites	England, Scotland, Wales. The 2014 DMQ included sites in Northern Ireland for the first time	1984 - 2014	Approximately triennial
Google Earth	Land use images to estimate area of extraction sites identified from DMQ	UK	2002 - date	Variable
Cruickshank and Tomlinson (1997)	Area with planning consent for peat extraction Local authority planning consents for peat extraction sites	England, Scotland, Wales	1990/91	One off compilation of data
Tomlinson (2010)	Estimate of peat extraction area in Northern Ireland. Volume of peat extracted (sod cutting and vacuum harvesting)	Northern Ireland	1990 - 1991	One off compilation of data
Mineral Extraction in Great Britain (Annual Minerals Raised Inquiry)	Volume of peat extracted	England, Scotland, Wales	1947 - date	Annual
Cruickshank et al. 1995	Volume of peat extracted (hand cutting)	Northern Ireland	1990 - 1991	One off compilation of data

The area of peat extractions sites listed in the Directory of Mines and Quarries was assessed using Google Earth. Polygons were drawn around site boundaries and the area covered by the polygons was calculated in Google Earth. Change over time at individual sites was tracked to give an estimate of the extent of conversion to and from extraction sites. This method is repeated annually to incorporate changes in extraction site areas in new Google Earth images.

Any sites abandoned since 2002 where a change of land use cannot be identified are still judged to be producing on-site emissions, in line with good practice guidance. A time series was constructed using linear interpolation. The extraction area (active and abandoned where there has been no change in land use) declined between 1990 and 2015 by 40% in England, 43% on fuel peat sites in Scotland, 6% on horticultural peat sites in Scotland, 99% on fuel peat sites in Northern Ireland and 40 % on horticultural peat sites in Northern Ireland. This area was assumed to be converted to Grassland.

The 2014 Directory of Mines and Quarries lists two peat extraction sites in Wales, but the Mineral Extraction in Great Britain report for 2013 does not report any peat production in Wales, so it is assumed that the registered sites are currently inactive but have not been converted to another land use. In a few cases sites straddle to the Wales-England border and so sites may be registered in one administration but have part of the extraction area in the other. A small area of land conversion to Wetland (<0.14 kha) was recorded which was assumed to be all from Grassland.

Table A 3.4.27 Area of peat extraction sites in England, Scotland and Wales

Country	Area in 1991, ha	Area in 2002, ha	Area in 2005, ha	Area in 2010, ha	Area in 2015 ha
England	5864	4262	4724	3778	3602
Scotland	1734	1597	1706	1456	1431
Horticultural	1174	1298	1372	1122	1097
Fuel	560	299	334	334	334
Wales	258	258	258	258	258

Annual peat production in Great Britain is inferred from extractor sales by volume as published in the annual Mineral Extraction in Great Britain report, formerly known as the Minerals Raised Inquiry (ONS). This gives a breakdown for horticultural and other uses of peat, which are assumed to be fuel, for English regions and for Scotland. No peat extraction is reported in Wales. Annual production is highly variable because extraction methods depend on suitable summer weather for drying peat.

Table A 3.4.28 Annual peat production, m^3 for England and Scotland (from Annual Minerals Raised Inquiry/Mineral Extraction in Great Britain reports)

Year	England		Scotland	
	Horticultural	Fuel	Horticultural	Fuel
1990	1,116,940	2,727	293,170	93,163
1991	1,202,000	2,000	241,000	115,000
1992	1,079,000	4,000	332,000	91,000
1993	1,069,820	2,180	306,511	73,489
1994	1,375,000	1,000	498,000	108,000
1995	1,578,000	2,000	657,000	44,000
1996	1,313,000	2,000	517,000	53,000
1997	1,227,000	2,000	332,000	59,000
1998	936,000	0	107,000	32,000
1999	1,224,000	0	392,000	37,000
2000	1,258,000	1,000	336,000	31,000
2001	1,459,000	1,000	325,000	30,000
2002	856,000	1,000	107,000	10,000
2003	1,227,000	1,000	741,000	38,000
2004	902,000	1,000	338,000	21,000
2005	927,000	1,000	556,000	21,000
2006	856,000	1,000	712,000	24,000
2007	654,000	0	221,000	10,000
2008	455,000	41,000	243,000	21,000

Year	England		Scotland	
	Horticultural	Fuel	Horticultural	Fuel
2009	476,000	0	390,000	21,000
2010	456,000	1,000	527,000	21,000
2011	429,000	0	369,000	26,000
2012	422,000	0	126,000	20,000
2013	661,000	0	570,000	24,000
2014	294,000	0	469,000	32,000
2015*	563,000	0	417,772	22,528
2016*	563,000	0	417,772	22,528

* 2005 - 2014 average as no UK Minerals Yearbook is no longer produced, so need to gap fill.

A 3.4.8.2 Estimation of emissions

Default on-site emission factors for Tier 1 reporting (IPCC 2006) are used to estimate emissions. Peat extracted for horticultural use is inferred to be from oligotrophic (nutrient-poor) bogs. Peat for fuel is inferred to be from mineratrophic (nutrient-rich) fens or bogs. On-site emissions of CO_2 and N_2O from drainage are reported.

A value of 0.0641 tonnes C m^{-3} is used for Great Britain to estimate emissions from extracted horticultural peat volumes based on previous work (Thomson *et al*, 2011). This is slightly lower than the IPCC default emission factor of 0.07 tonnes C m^{-3} air-dry peat for nutrient-poor peats.

Tomlinson (2010) gives production estimates of horticultural peat production for Northern Ireland for 1990/91 and 2007/2008. These have been interpolated to produce a time series. The total emission from horticultural peat production is the sum of emissions from vacuum harvesting production, sod extraction production and mechanical extraction production.

Emissions from vacuum harvesting production =

area * annual depth of extraction * carbon fraction by volume

where

Annual depth of extraction by vacuum harvesting, m/ha = 0.1

Carbon fraction of air-dry peat by volume, tonnes C/m^3 air-dry peat = 0.0641

Emissions from sod extraction production =

area * sod extraction rate * % dry matter for sods * mean % C

where

Sod extraction rate, tonnes/ha/yr = 200

Sod extraction, mean % dry matter = 35%

Mean % carbon = 49%

Emissions from mechanical extraction production =

area * extraction rate * % dry matter for mechanical extraction * mean % C *where*

The mechanical extraction rate was estimated to be 206.45 tonnes/ha in 1990/91 and 243.06 tonnes/ha in 2007/08 (Tomlinson, 2010).

Mechanical extraction, mean % dry matter = 67%

Mean % carbon = 49%

A 3.4.9 Flooded Lands (4D)

Carbon stock changes on land converted to Flooded Land (reservoirs) are included in the inventory, based on the IPCC 2006 Guidance. Data on all reservoirs over 1 km^2 were compiled but only reservoirs established since 1990 were reported (areas of inland water under 1 km^2 are reported under 4F Other Land). Activity data were compiled for England and Wales from the Public Register of Large Raised Reservoirs provided by the Environment Agency, which listed location, surface area and year built. Activity data for Scotland were compiled from the SEPA Water Body Classification database (of water bodies > 0.5 km^2) and the associated Water Body data sheets. Additional information on the year of building was obtained from:

- the Gazetteer for Scotland http://www.scottish-places.info;
- hydro-electric power generators http://sse.com/whatwedo/ourprojectsandassets/ http://www.power-technology.com/projects/glendoehydropowerpla/; and
- local authorities http://www.argyll-bute.gov.uk.

It was established through discussion with local experts that no new large reservoirs had been built in Northern Ireland since the 1950s.

Only five large reservoirs have been established in the UK since 1990, three in England and one each in Scotland and Wales (another five in England are sacrificial floodplains and do not fit the criteria of permanent conversion to Flooded Land). These cover a total of 1.895 kha.

The location of each reservoir was examined using the www.magic.gov.uk geographic information portal. All reservoirs were in upland locations and were assumed to be Grassland prior to their conversion to Flooded Land. (Any forest removed as part of the land conversion will have been captured under the deforestation activity methodology). A Tier 1 methodology was followed, so carbon stock changes in living biomass stock in the year of flooding were estimated, but not carbon stock change in soils. A living biomass density of 2 t dry matter/ha was used to estimate carbon stock losses.

A 3.4.10 Harvested Wood Products (4G)

The activity data used for calculating this activity are the annual forest planting rates. CARBINE then applies a forest management regime as given in input to the model. For a given forest stand, carbon enters the HWP pool when thinning is undertaken and when harvesting takes place. Depending on the species, first thinning occurs approximately 20 years after planting.

At thinning and harvest, the CARBINE model allocates merchantable stem volume to various wood products, while the remainder is transferred to the harvesting residue pool. The ‘end-use’ wood products represented are:

- Long-lived sawn timber, e.g. timber used for construction;
- Short-lived sawn timber, e.g. timber used for fencing;

- Particleboard;
- Paper; and
- Fuel.

For reporting purposes the long-lived and short-lived sawn timber are reported together in the Sawnwood category.

During wood processing, conversion losses are assumed to be left as on-site harvest residue and decay within a year. The allocation of carbon to wood product categories is estimated by inputting the merchantable stem carbon (from the forest yield model) to a stand volume assortment forecasting model which estimates the volume allocated to sawn timber, roundwood and waste. This is implemented in CARBINE as a set of functions derived from the output of a more general and flexible assortment forecasting program known as ASORT (Rollinson and Gay, 1983). The proportions allocated to different product categories are based on proportions derived from FAO data[13] (prior to 1994) and forestry commission data[14] (after 1993) on production of semi-finished wood products. A carbon retention curve is used to estimate product decay and return of carbon to the atmosphere. Each wood product category has its own carbon retention curve using the default half-lives in the IPCC 2006 Guidelines (from the Durban KP decision, paragraph 29), taking into account the decay rate of wood products and the service life as influenced by socio-economic factors. The service lives are:sawn timber: 35 years; particleboard: 25 years; paper: 2 years; and fuel: instantaneous oxidation.

In implementing the 2006 IPCC guidelines for HWP the UK has elected to report using the production approach B2, which requires disaggregation of HWP into those produced and consumed domestically and those produced and exported. In the annual Forestry Statistics publication there is data on the apparent consumption of wood products in the UK. A consistent dataset is available at the product level (i.e. sawnwood, wood panels and paper & paperboard) for 2002 onwards. The ten year average of 2002-2011 was calculated for each product type and those values were used for the years 1990-2001. This dataset was used to assign the HWP output from the CARBINE model into either consumed domestically or exported.

A 3.4.11 Methods for the Overseas Territories (OTs) and Crown Dependencies (CDs)

The UK LULUCF inventory includes direct GHG emissions from UK Crown Dependencies (CDs) and Overseas Territories (OTs) which have joined, or are likely to join, the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol. Currently, these are: Guernsey, Jersey, the Isle of Man, the Falkland Islands, the Cayman Islands, Bermuda, and Gibraltar. It should be noted that Bermuda will not ratify the 2nd Commitment Period of the Kyoto Protocol and is therefore not included in the 'GBK' submission under the Kyoto Protocol.

A web search of statistical publications was undertaken for any updates in datasets in 2015. This work builds on an MSc project to calculate LULUCF net emissions/removals for the OTs and CDs undertaken during 2007 (Ruddock 2007).

[13] http://www.fao.org/faostat/en/#data/FO

[14] https://www.forestry.gov.uk/forestry/beeh-a9zjnu

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 (6 km^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 (**Table A 3.4.29**). 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 and Guernsey (using the C-Flow model, for information on C-Flow model please refer to 1990-2011 NIR). The assumptions and factors used for the estimation of emissions are given in **Table A 3.4.29** and **Table A 3.4.30**. The estimates have high uncertainty and may not capture all relevant activities, but given the size of the territories any missing sources are likely to be small.

Table A 3.4.29 Information sources for estimating LULUCF emissions from the Overseas Territories and Crown Dependencies

Territory	LULUCF category	Time period	Reference
Isle of Man	4A	1970-2011	Personal communication from Isle of Man Department of Agriculture, Fisheries and Forestry (Peter Williamson) FAO (2010) Global Forest Resources Assessment: Isle of Man
	4B, 4C	2002-2011	Isle of Man Agricultural and Horticultural Census: completed by all farmland occupiers on an annual basis Isle of Man Digest of Economic and Social Statistics
	4B, 4C	2012 - 2013	Isle of Man Digest of Economic and Social Statistics
	4B, 4C	2014	The Isle of Man in Numbers
	4E	1991-1994	Isle of Man Ecological Habitat Survey, Phase 1 Report (Sayle et al, 1995)
Guernsey	4A	1990-2010	FAO Global Forest Resources Assessment 2010: Guernsey
	4A, 4B, 4C, 4E	1998/9, 2005, 2010	Guernsey Habitat Survey Sustainable Guernsey 2005, 2009, Guernsey Facts and Figures 2011
Jersey	4A	1990-2010	FAO Global Forest Resources Assessment 2010: Jersey
	4B	1990 - 2014	Jersey Agricultural Statistics
	4A, 4B, 4C, 4E	2006, 2008, 2012, 2015	Jersey In Figures 2006/2008/2009/2010/2011/2012

Territory	LULUCF category	Time period	Reference
Falkland Islands	4A	1990-2011	Department of Mineral Resources, personal communication FAO Global Forest Resources Assessment 2010: Falkland Islands
	4B, 4C	1991-2013	Falkland Islands Agricultural Statistics
	4E	1990-2005	Falkland Islands Environment and Planning Department, personal communication
	4E	1986 – 2001 with projections 2006 - 2016	Stanley Town Plan, Environmental Planning Dept, Falkland Islands Government.

Table A 3.4.30 Assumptions used in applying the Tier 1 methodology to the Overseas Territories and Crown Dependencies

Land Use category	Sub-category	Isle of Man	Guernsey	Jersey	Falkland Islands
Forest land fluxes	Living biomass, DOM, Mineral soils, Organic soils	From C-Flow model	From C-Flow model	Assumed in equilibrium	No forest on Falklands
Crop remaining crop	Living biomass	N/A. Only for perennial crops	N/A. Only for perennial crops	N/A. Only for perennial crops	N/A. Only for perennial crops
	Dead organic matter	N/A	N/A	N/A	N/A
	Mineral soils	No change in SOC	No change in SOC	No change in SOC	N/A
	Organic soils	N/A	N/A	N/A	Default (-5 tC/ha)
Land converted to Crop	Living biomass	Use Wales values, grass to crop (-0.5 tC/ha)	Use England values, grass to crop (-0.5 tC/ha)	Use England values, grass to crop (-0.5 tC/ha)	Use Wales values, grass to crop (-0.5 tC/ha)
	Dead organic matter	N/A	N/A	N/A	N/A
	Mineral soils	Default . SOC = 95 tC/ha, assume conversion from natural grassland (-2.603 tC/ha)	Default . SOC = 95 tC/ha, assume conversion from natural grassland (-0.95 tC/ha)	Default . SOC = 95 tC/ha, assume conversion from natural grassland (-0.95 tC/ha)	N/A
	Organic soils	N/A	N/A	N/A	Default (-5 tC/ha)
	N_2O emissions	Default (0.002727 t N_2O/ha)	Default (0.000995 t N_2O/ha)	Default (0.000995 t N_2O/ha)	Default (0.012571 t N_2O/ha)

Land Use category	Sub-category	Isle of Man	Guernsey	Jersey	Falkland Islands
Grass remaining grass	Living biomass	N/A	N/A	N/A	N/A
	Dead organic matter	N/A	N/A	N/A	N/A
	Mineral soils	No change in SOC	No change in SOC	No change in SOC	N/A
	Organic soils	N/A	N/A	N/A	Assume no soil C stock change
Land converted to grass	Living biomass	Use Wales values, crop to pasture grass (-0.5 tC/ha)	Use England values, settlement to pasture grass (-1.8 tC/ha)	Use England values, crop to pasture grass (-0.5 tC/ha)	Use Wales values, crop to pasture grass (-0.5 tC/ha)
	Dead organic matter	N/A	N/A	N/A	N/A
	Mineral soils	Default . SOC = 95 tC/ha, assume conversion from cropland (2.603 tC/ha)	Default . SOC = 95 tC/ha, assume conversion from settlement, assume same soil C as for cropland (0.95 tC/ha)	Default . SOC = 95 tC/ha, assume conversion from cropland (0.95 tC/ha)	N/A
	Organic soils	N/A	N/A	N/A	Default (-0.25 tC/ha)
Settlements remaining Settlements	Living biomass, DOM, Mineral soils, Organic soils	N/A	N/A	N/A	N/A

Land Use category	Sub-category	Isle of Man	Guernsey	Jersey	Falkland Islands
Land converted to Settlements	Living biomass	Use Wales values, grass to settlement (-0.8 tC/ha)	Use England values, grass to settlement (-0.8 tC/ha)	Use England values, grass to settlement (-0.8 tC/ha)	Use Wales values, grass to settlement (-0.8 tC/ha)
	Dead organic matter	N/A	N/A	N/A	N/A
	Mineral soils	Default . SOC = 95 tC/ha, assume conversion from grassland and all soil C lost (-6.65 tC/ha)	Default . SOC = 95 tC/ha, assume 30% of land is paved over and the rest is turf grass (-1.14 tC/ha)	Default . SOC = 95 tC/ha, assume 30% of land is paved over and the rest is turf grass (-1.14 tC/ha)	N/A
	Organic soils	N/A	N/A	N/A	Default - assume cropland (-5 tC/ha)
	N_2O emissions	Default (0.002727 t N_2O/ha)	Default (0.00119 t N_2O/ha)	Default (0.00119 t N_2O/ha)	N/A
Other land remaining other land	Living biomass, DOM, Mineral soils, Organic soils	N/A	N/A	N/A	N/A
Land converted to other land	Living biomass	N/A	Assume loss of grassland to standing water or cliff (-2 t C/ha)	Assumed loss of grassland to standing water (-2 t C/ha)	N/A
	Dead organic matter	N/A	N/A	N/A	N/A
	Mineral soils	N/A	Assume no change in soil stocks	N/A	N/A
	Organic soils	N/A	N/A	N/A	N/A
	N_2O emissions	N/A	0	N/A	N/A
Harvested wood products		From C-Flow model	From C-Flow model	N/A	N/A

Table A 3.4.31 Tier 1 factors used for estimating LULUCF emissions from Overseas Territories and Crown Dependencies

	Factor	Isle of Man/ Guernsey/ Jersey	Falkland Islands
Biomass carbon densities, tC/ha	Cropland	1.5	1.5
	Grassland	2	2
	Pasture Grassland	1	1

	Factor	Isle of Man/ Guernsey/ Jersey	Falkland Islands
	Settlements	2.8	2.8
	Soil C density	95	87
	Grass F_{lu}	1	1
	Grass F_{mg}	1	1
	Grass F_i	1	1
	Crop F_{lu}	0.8	0.69
	Crop F_{mg}	1	1
	Crop F_i	1	0.92
	C/N ratio kg N_2O-N/kg N	15	15
	N_2O EF	0.01	0.01
	Cropland Organic soils EF, tC/ha/yr		-5
	Grassland Organic soils EF, tC/ha/yr		-0.25
	EF2 for temperate organic crop and grassland soils, kg N_2O-N/ha		8

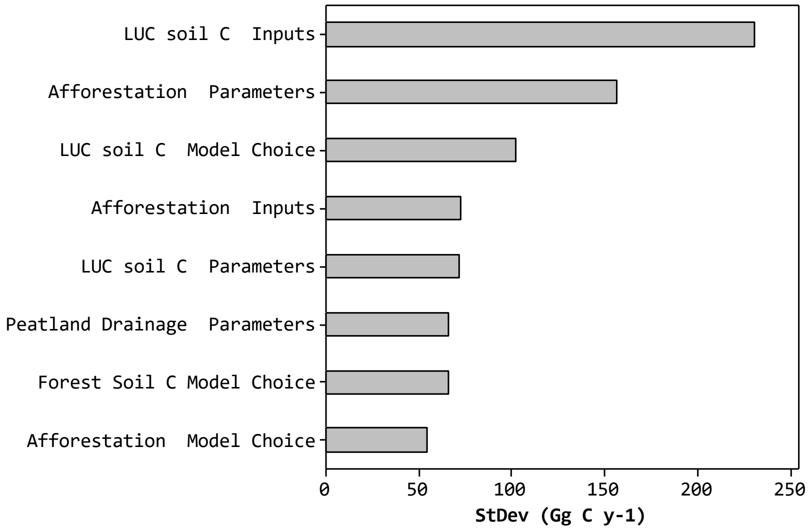
A 3.4.12 Uncertainty analysis of the LULUCF sector

The purpose of carrying out uncertainty analysis within the LULUCF inventory is to quantify where the largest sources of errors lie, and to identify areas to be targeted in future work so as to reduce the uncertainties. In the 1990-2010 inventory report a sensitivity analysis of the whole of the existing inventory methodology was undertaken, applying uncertainty quantification more widely and rigorously to all model parameters and empirical conversion factors, in order to quantify the impact of those uncertainties on the inventory. Although this analysis was carried out for the C-Flow model, which is no longer used, it is likely to be applicable to the CARBINE model as both are similar forest carbon accounting models, based on the same underlying yield tables and input data. A more rigorous uncertainty analysis of the CARBINE model will be performed in the future.

The results of the simulations, including both input and parameter uncertainty, are that the area undergoing land use change is the single biggest uncertainty in the inventory, followed by uncertainty in the forest model parameters and the choice of model for the change in soil carbon following land use change (**Figure A 3.5**). The next five terms are all of a similar magnitude. Full details of the methodology and results are in the 1990-2010 inventory report.

The uncertainty in the land use change areas is being addressed by the development of a new vector-based approach (see **Chapter 7, Section 1.1**), combining multiple sources of land use data.

Figure A 3.5 The largest uncertainties in the LULUCF inventory, in terms of standard deviation in the output distributions



Parameterisation of the forest model is the second largest source of uncertainty. This has been addressed with the move to CARBINE, as 19 tree species are now modelled instead of the two used in previous submissions. Results from the National Forest Inventory (NFI) and small woods dataset will also provide additional information on carbon stocks in trees (e.g. Forestry Commission 2015[15]). The choice of soil carbon model and its parameters are also important, because the time course of the flux following land use change may be quite different, depending on the equations used to represent this, and how carbon is distributed between fast- and slow-turnover pools. The choice of forest model is less important, largely because all the UK forest models are based on the same yield table data.

A 3.5 WASTE (CRF SECTOR 5)

A 3.5.1 Solid Waste Disposal on Land (5A)

A 3.5.1.1 Input data

Because waste sent to landfill is now evaluated using individual waste consignments by EWC code, there is no need to make assumptions regarding waste composition, other than for two waste categories. These EWC codes are 19.12.12 (residues from waste sorting) and 20.03.01 (mixed municipal waste). Wastes with these codes were allocated in accordance with the findings of a survey carried out on behalf of Defra (Resource Futures, 2012), as set out in **Table A 3.5.1**. Data on DOC, DOCf and material compositions are provided in **Table A 3.5.2**.

The model allocates waste to two types of landfill – old, closed sites which last received waste in 1979, and modern engineered landfills that came into operation from 1980. Only these latter sites

[15] This survey is preliminary and the carbon stocks have been estimated using the same relationships and calculation parameters that underlie CARBINE; they are therefore not an independent validation of the LULUCF estimates.

have gas management systems. The old closed sites have no gas control. The distribution of waste between these types of site is the same as used for compiling the previous NIR.

The quantities of waste sent to landfill are shown in **Table A 3.5.4**. The amounts of methane generated, recovered, used for power generation, flared, oxidised and emitted to the atmosphere from 1990 to 2016 are shown in **Table A 3.5.4**.

Table A 3.5.1 Composition of waste sorting residues and mixed municipal waste

Material	19.12.12 (residues from waste sorting)	20.03.01 (mixed municipal waste
Paper	10.3%	10.6%
Card	9.1%	7.7%
Plastic film	9.4%	8.4%
Dense plastics	13.2%	9.6%
Sanitary waste	1.3%	3.1%
Wood	10.0%	5.3%
Textiles and shoes	5.9%	5.6%
Glass	1.3%	3.0%
Food waste	8.2%	21.3%
Garden waste	1.8%	3.5%
Other organic	1.3%	2.1%
Metals	3.2%	3.7%
WEEE	1.4%	1.5%
Haz waste and batteries	1.1%	0.9%
Carpet, underlay & furniture	7.0%	5.0%
Other combustibles	2.7%	1.4%
Bricks, plaster and soil	7.9%	4.1%
Other non-combustible	1.7%	1.5%
Fines <10mm	3.3%	1.8%
Total	100%	100%

Table A 3.5.2 DOC, DOCf and composition of waste materials

Component	Lignin biodegradability DOCf	Non-lignin biodegradability DOCf	Moisture, %fresh matter	Lignin, % dm	Hemicellulose, %dm	Cellulose, %dm	Starch, %dm	Sugar, % dm	Fat, %dm	Proteins, %dm	Fibre, %dm	Readily soluble, %dm	Other (inert), % dm
Carbon contents (DOC)			**0%**	**65.1%**	**44.6%**	**40.0%**	**44.4%**	**42.1%**	**76.0%**	**40.0%**	**45.0%**	**45.0%**	**0.0%**
Waste composition on a dry matter basis (other than moisture)													
Municipal solid waste													
Paper	5%	65%	15%	15%	9%	61%							15.00%
Card	5%	65%	20%	15%	9%	61%							15.00%
Nappies	5%	65%	65%			47%							52.70%
Textiles and footwear	5%	65%	20%		15%	15%							69.68%
Miscellaneous combustible	5%	65%	20%		25%	25%							50.00%
Wood	5%	65%	17%	26%	12%	42%							21.00%
Food – corrected	15%	70%	70%	6%	4%	27%	13%	7%	14%	15%	14%	0%	0.00%
Garden	10%	65%	55%	20%	16%	20%			2%			26%	17.10%
Soil and other organic	5%	65%	30%		1%	1%							98.60%
Furniture	5%	65%	12%	1%	10%	11%	0%	0%	0%	0%	0%	0%	77.25%
Mattresses	5%	65%	20%		15%	15%							69.68%
Non-inert Fines		50%	40%		25%	25%							50.00%
Other (100% inert)													100.00%

Component	Lignin biodegradability DOCf	Non-lignin biodegradability DOCf	Moisture, %fresh matter	Lignin, % dm	Hemicellulose, %dm	Cellulose, %dm	Starch, %dm	Sugar, % dm	Fat, %dm	Proteins, %dm	Fibre, %dm	Readily soluble, %dm	Other (inert), % dm
Commercial & industrial waste													
Commercial	5%	65%	37%		8%	76%							16.00%
Paper and Card	5%	65%	15%	15%	9%	61%							15.00%
General industrial waste	5%	65%	37%		8%	76%							16.00%
Food and Abattoir	15%	70%	70%	5%	11%	11%	36%	7%	6%	18%			6.00%
Food effluent	15%	70%	65%		55%	7%							37.40%
Construction and demolition	5%	65%	30%		9%	9%							83.00%
Miscellaneous process waste	5%	65%	20%		10%	10%							80.00%
Other waste	5%	65%	20%		25%	25%							50.00%
Miscellaneous Combustible	5%	65%	20%		25%	25%							50.00%
Furniture	5%	65%	12%	1%	10%	11%	0%	0%	0%	0%			77.25%
Garden	10%	65%	55%	20%	16%	20%			2%			26%	17.10%
Sewage sludge	5%	65%	70%		14%	14%							72.00%
Textiles / Carpet and Underlay	5%	65%	20%	0%	15%	15%	0%	0%	0%	0%			69.68%
Wood	5%	65%	17%	26%	12%	42%							21.00%
Sanitary	5%	65%	65%	0%	0%	47%	0%	0%	0%	0%			52.70%
Other	5%	65%											100.00%

Table A 3.5.3 Amount of waste landfilled (1945 to 2016)

Year	England	Scotland	Wales	Northern Ireland	Total	Year	England	Scotland	Wales	Northern Ireland	Total
1945	70.9	9.0	4.6	2.3	86.9	**1981**	77.0	8.5	4.6	2.5	92.7
1946	71.2	9.0	4.6	2.4	87.2	**1982**	77.1	8.5	4.6	2.5	92.7
1947	71.5	9.0	4.6	2.4	87.4	**1983**	77.1	8.5	4.6	2.6	92.8
1948	71.7	9.0	4.6	2.4	87.7	**1984**	77.2	8.5	4.6	2.6	92.8
1949	72.3	9.0	4.6	2.4	88.4	**1985**	77.2	8.4	4.6	2.6	92.8
1950	72.9	9.1	4.6	2.4	89.1	**1986**	77.3	8.4	4.6	2.6	92.9
1951	73.6	9.1	4.6	2.5	89.8	**1987**	77.3	8.3	4.6	2.6	92.9
1952	74.2	9.1	4.7	2.5	90.5	**1988**	77.4	8.3	4.6	2.6	92.9
1953	74.2	9.1	4.7	2.5	90.4	**1989**	77.4	8.3	4.6	2.6	92.9
1954	74.2	9.0	4.6	2.4	90.3	**1990**	77.7	8.3	4.7	2.6	93.3
1955	74.2	9.0	4.6	2.4	90.3	**1991**	77.7	11.3	4.7	2.6	96.3
1956	75.7	9.1	4.7	2.5	92.0	**1992**	77.7	12.2	4.7	2.6	97.2
1957	77.2	9.2	4.8	2.5	93.7	**1993**	77.6	14.0	4.6	2.6	98.8
1958	78.6	9.3	4.8	2.6	95.4	**1994**	77.6	15.9	4.6	2.6	100.7
1959	80.1	9.5	4.9	2.6	97.1	**1995**	81.8	15.0	4.9	2.8	104.5
1960	81.5	9.6	5.0	2.6	98.8	**1996**	80.7	15.0	4.8	2.8	103.3
1961	81.1	9.7	4.9	2.7	98.4	**1997**	81.1	14.0	4.8	2.8	102.7
1962	80.9	9.6	4.9	2.7	98.0	**1998**	75.0	11.9	4.5	2.6	93.9
1963	84.5	10.0	5.1	2.8	102.4	**1999**	69.3	10.9	4.1	2.4	86.6
1964	84.6	9.9	5.1	2.8	102.4	**2000**	67.4	11.2	4.0	2.3	84.9
1965	85.7	10.0	5.1	2.8	103.6	**2001**	71.4	8.9	4.2	2.4	86.9
1966	85.3	9.9	5.1	2.8	103.2	**2002**	66.8	8.2	3.9	2.3	81.3
1967	85.0	9.8	5.1	2.8	102.7	**2003**	65.4	7.9	3.8	2.2	79.4
1968	84.8	9.7	5.1	2.8	102.4	**2004**	64.9	7.8	3.8	2.2	78.7
1969	84.0	9.6	5.0	2.8	101.4	**2005**	60.0	7.1	3.5	2.0	72.6
1970	83.8	9.5	5.0	2.8	101.0	**2006**	61.7	7.1	4.0	2.0	74.8
1971	82.8	9.3	4.9	2.7	99.8	**2007**	60.7	7.4	3.2	1.9	73.2
1972	81.8	9.2	4.8	2.7	98.5	**2008**	53.9	6.1	2.9	1.6	64.5
1973	81.3	9.1	4.8	2.7	97.9	**2009**	44.0	4.7	2.5	1.1	52.3

Year	England	Scotland	Wales	Northern Ireland	Total	Year	England	Scotland	Wales	Northern Ireland	Total
1974	79.9	9.0	4.8	2.6	96.3	**2010**	43.6	4.6	2.3	1.0	51.4
1975	80.1	9.0	4.8	2.6	96.5	**2011**	44.7	4.7	2.2	1.0	52.5
1976	78.8	8.8	4.7	2.6	94.9	**2012**	41.8	4.5	2.2	1.1	49.6
1977	78.4	8.8	4.7	2.6	94.5	**2013**	41.1	4.1	2.2	1.1	48.4
1978	78.8	8.8	4.7	2.6	95.0	**2014**	41.3	4.1	1.5	1.3	48.2
1979	78.7	8.8	4.7	2.6	94.7	**2015**	43.9	4.2	1.3	1.6	51.0
1980	78.6	8.7	4.7	2.6	94.6	**2016**	44.7	3.7	2.0	1.6	52.0

A 3.5.1.2 Methane emissions

The right-most column of **Table A 3.5.4** shows the current estimate of methane emitted from UK landfills, according to the approach outlined in **Chapter 7**, taking account of recovery and oxidation.

Table A 3.5.4 Amount of waste landfilled and methane generated, captured, utilised, flared, oxidised and emitted

Year	Waste Landfilled	Methane generated	Methane captured		Methane used for power generation		Methane flared		Residual methane oxidised		Methane emitted	
	Mt	Kt	kt	%	kt	%	kt	%	kt	%	kt	%
1990	93.25	2,709	33	1%	33	1%	0	0%	268	10%	2408	89%
1991	96.32	2,752	50	2%	50	2%	0	0%	270	10%	2432	88%
1992	97.18	2,797	90	3%	90	3%	0	0%	271	10%	2436	87%
1993	98.85	2,837	107	4%	107	4%	0	0%	273	10%	2457	87%
1994	100.75	2,878	124	4%	124	4%	0	0%	275	10%	2479	86%
1995	104.50	2,939	135	5%	135	5%	0	0%	280	10%	2524	86%
1996	103.26	2,983	170	6%	170	6%	0	0%	281	9%	2532	85%
1997	102.70	3,022	218	7%	218	7%	0	0%	280	9%	2524	84%
1998	93.85	3,038	278	9%	278	9%	0	0%	276	9%	2484	82%
1999	86.63	3,032	394	13%	394	13%	0	0%	264	9%	2374	78%

Year	Waste Landfilled	Methane generated	Methane captured		Methane used for power generation		Methane flared		Residual methane oxidised		Methane emitted	
	Mt	Kt	kt	%	kt	%	kt	%	kt	%	kt	%
2000	84.85	3,028	500	17%	500	17%	0	0%	253	8%	2275	75%
2001	86.92	3,040	566	19%	566	19%	0	0%	247	8%	2227	73%
2002	81.28	3,021	599	20%	598	20%	1	0%	242	8%	2180	72%
2003	79.38	2,981	723	24%	723	24%	0	0%	226	8%	2032	68%
2004	78.71	2,937	874	30%	874	30%	0	0%	206	7%	1857	63%
2005	72.59	2,870	926	32%	926	32%	0	0%	194	7%	1750	61%
2006	74.83	2,753	950	35%	944	34%	6	0%	180	7%	1622	59%
2007	73.21	2,645	989	37%	987	37%	2	0%	166	6%	1490	56%
2008	64.51	2,528	1073	42%	980	39%	93	4%	145	6%	1309	52%
2009	52.33	2,400	1115	46%	1015	42%	100	4%	128	5%	1156	48%
2010	51.38	2,278	1202	53%	1066	47%	136	6%	108	5%	969	43%
2011	52.54	2,159	1181	55%	1075	50%	106	5%	98	5%	880	41%
2012	49.55	2,041	1131	55%	1042	51%	90	4%	91	4%	818	40%
2013	48.43	1,929	1182	61%	1035	54%	147	8%	75	4%	672	35%
2014	48.15	1,820	1191	65%	1007	55%	184	10%	63	3%	566	31%
2015	50.98	1,716	1139	66%	974	57%	165	10%	58	3%	519	30%
2016	51.97	1,627	1012	62%	941	58%	71	4%	61	4%	553	34%

Notes

a. Methane generated is based on the MELMod model.
b. Methane captured is the sum of methane used for power generation and methane flared.
c. Methane used for power generation is calculated from official figures on landfill gas electricity generation (Digest of UK Energy Statistics (BEIS, 2016), in GWh/year, assuming a net calorific value for methane of 50 GJ/tonnes and a conversion efficiency between methane use and electricity export of 30% rising to 36%, which includes parasitic losses and on-site use of electricity, e.g. for gas blowers, leachate treatment and site offices.
d. Methane flared is calculated from site-specific data provided by the Environment Agency at regulated sites for 2009 to 2013, from SEPA for 2013, from a study carried out during 2014, and from site-specific data provided voluntarily by site operators.

e. Methane oxidised is based on the IPCC default oxidation factor of 10%, applied to methane remaining after subtraction of the amount captured.
f. Methane emitted = (methane generated – methane captured) x (1-oxidation factor).

A 3.5.1.3 Overseas Territories and Crown Dependencies

For the overseas territories and crown dependencies, the IPCC landfill model is used. Where available, country-specific waste generation and composition data have been applied and appropriate defaults chosen e.g. taking into account climatic variation. There are no landfill emissions for Gibraltar as waste is exported. **Table A 3.5.** below gives the parameters used.

Table A 3.5.5 Parameters used in landfill emission estimates for overseas territories and crown dependencies

Region	Methodology	Activity data	MCF	DOC
Guernsey	IPCC Landfill Model	2005 onwards: total MSW to landfill data and percentage that is plastics, other inert. Prior to 2005: flat-lined 2005 data	IPCC default values; waste management type is unmanaged, deep (results from expert consultation, 2014)	IPCC default values
Jersey	N/A, all MSW is incinerated for energy from waste	N/A	N/A	N/A
Gibraltar	N/A, all MSW used to be incinerated, now all waste is exported to be landfilled in Spain.	N/A	N/A	N/A
Isle of Man	IPCC Landfill Model	2004 onwards: all waste incinerated for energy from waste. Prior to 2004: population and IPCC default waste per capita for Western Europe	IPCC default values; waste management type is 50% unmanaged, deep and 50% managed, semi-aerobic (results from expert consultation, 2014)	IPCC default values
Bermuda	IPCC Landfill Model	Total MSW to landfill (Environmental Statistics Compendium)	IPCC default values; no information on management system so assume unmanaged deep	IPCC default values

Region	Methodology	Activity data	MCF	DOC
Cayman Islands	IPCC Landfill Model	2000 onwards: Total MSW to landfill (Department of Environmental Health). Prior to 2000: flat-lined 2000 data	IPCC default values; landfill sites are lined and managed to some degree, but with limited information, "Uncategorised" considered appropriate	IPCC default values
Falkland Islands	IPCC Landfill Model	1998: Halcrow Report. Other years: flat-lined after advice in personal communication from environmental officer	IPCC default values; waste management type is unmanaged, shallow (results from expert consultation, 2014)	IPCC default values

A 3.5.2 Biological Treatment of Solid Waste (5B)

Table A 3.5.6 Activity Data: Inputs in the composting process 1990-2016

Year	Composting (Non-household) (Mg)	Composting (Household) (Mg)	MBT - Composting (Mg)
1990	0	54,816	0
1991	19,283	54,816	0
1992	33,194	54,816	0
1993	48,000	54,816	0
1994	64,000	54,816	0
1995	140,000	54,816	0
1996	220,000	54,816	0
1997	315,000	54,816	0
1998	675,000	54,816	0
1999	833,044	54,816	0
2000	1,034,000	54,816	0
2001	1,663,852	54,816	0
2002	1,828,000	54,816	0
2003	1,953,000	54,816	53,618
2004	2,667,000	73,275	37,329
2005	3,424,000	91,733	85,360
2006	4,090,000	110,191	110,640
2007	4,459,000	128,650	542,678
2008	4,285,000	147,108	629,269
2009	5,265,711	165,567	438,011
2010	5,444,092	171,175	1,282,060
2011	6,053,273	176,783	1,520,184
2012	5,850,257	182,392	1,758,308
2013	5,867,640	188,000	1,987,913
2014	5,954,185	202,787	2,262,054
2015	6,010,218	212,067	2,536,195
2016	6,135,538	221,347	2,810,337

Table A 3.5.7 Activity Data: Inputs in the anaerobic digestion process 1990-2016

Year	Anaerobic digestion – non agricultural residue (Mg)	Anaerobic digestion - MBT (Mg)
1990	0	0
1991	1,678	0
1992	1,678	0
1993	1,678	0
1994	5,435	0
1995	5,435	0
1996	5,435	0
1997	6,061	0
1998	6,061	0
1999	6,061	0
2000	6,061	0
2001	6,061	0
2002	56,155	0
2003	56,155	17,873
2004	87,513	37,329
2005	191,153	21,340
2006	203,676	27,660
2007	223,714	40,847
2008	253,895	125,231
2009	386,642	209,616
2010	870,315	294,001
2011	1,341,943	378,385
2012	1,751,157	756,771
2013	2,582,580	743,155
2014	3,992,939	869,540
2015	5,250,437	995,925
2016	6,422,878	1,122,310

A 3.5.3 Waste Incineration (5C)

Table A 3.5.8 Activity Data: UK Waste Incineration 1990-2016

Year	Municipal Waste Incineration[a] (Mt)	Clinical Waste Incineration (Mt)	Chemical Waste Incineration (Mt)	Sewage Sludge Incineration (Mt)
1990	2.194	0.350	0.290	0.075
1991	2.172	0.350	0.290	0.069
1992	2.083	0.330	0.290	0.072
1993	1.841	0.310	0.290	0.084
1994	1.341	0.290	0.289	0.072
1995	1.223	0.270	0.289	0.082
1996	1.340	0.250	0.288	0.088
1997	-	0.230	0.287	0.081
1998	-	0.236	0.287	0.185
1999	-	0.242	0.286	0.189
2000	-	0.248	0.285	0.194
2001	-	0.254	0.285	0.198
2002	-	0.260	0.284	0.203
2003	-	0.221	0.257	0.207
2004	-	0.182	0.231	0.212
2005	-	0.143	0.204	0.216
2006	-	0.103	0.177	0.220
2007	-	0.110	0.168	0.215
2008	-	0.113	0.141	0.192
2009	-	0.120	0.129	0.199
2010	-	0.113	0.142	0.231
2011	-	0.106	0.141	0.224
2012	-	0.105	0.139	0.209
2013	-	0.100	0.159	0.204
2014	-	0.103	0.167	0.177
2015	-	0.095	0.163	0.170
2016	-	0.094	0.166	0.148

a Note that all MSW incinerators were either closed or converted to extract power by 1997. In the latter case they were then considered to be power generation and so emissions were reported in 1A1a.

Table A 3.5.9 Emissions Data: UK Waste Incineration 1990-2015

Year	Chemical Waste Incineration	Accidental Fires	MSW Incineration[a]	Clinical Waste Incineration	Sewage Sludge Incineration	Total
Carbon Dioxide (kt CO_2)						
1990	379.2	NE	670.8	308.0	NA	1,358.0
1995	377.5	NE	323.3	237.6	NA	938.4
2000	315.5	NE	NO	218.2	NA	533.8
2005	273.7	NE	NO	125.4	NA	399.1
2010	180.3	NE	NO	99.5	NA	279.7
2012	181.6	NE	NO	92.6	NA	274.2
2013	183.7	NE	NO	88.4	NA	272.1
2014	185.7	NE	NO	90.5	NA	276.2
2015	180.9	NE	NO	83.7	NA	264.7
2016	200.1	NE	NO	82.7	NA	282.8
Methane (kt CH_4)						
1990	NE	1.009	4.378	0.007	0.029	5.423
1995	NE	0.984	2.439	0.005	0.032	3.461
2000	NE	0.772	NO	0.005	0.076	0.852
2005	NE	0.704	NO	0.003	0.084	0.791
2010	NE	0.347	NO	0.002	0.090	0.439
2012	NE	0.331	NO	0.002	0.082	0.414
2013	NE	0.290	NO	0.002	0.080	0.372
2014	NE	0.277	NO	0.002	0.069	0.347
2015	NE	0.283	NO	0.002	0.066	0.351
2016	NE	0.287	NO	0.002	0.058	0.346

Year	Chemical Waste Incineration	Accidental Fires	MSW Incineration[a]	Clinical Waste Incineration	Sewage Sludge Incineration	Total
Nitrous oxide (kt N_2O)						
1990	0.029	NE	0.058	0.011	0.060	0.158
1995	0.029	NE	0.033	0.008	0.066	0.135
2000	0.029	NE	NO	0.007	0.155	0.191
2005	0.020	NE	NO	0.004	0.173	0.197
2010	0.014	NE	NO	0.003	0.185	0.202
2012	0.014	NE	NO	0.003	0.167	0.184
2013	0.016	NE	NO	0.003	0.163	0.182
2014	0.017	NE	NO	0.003	0.141	0.161
2015	0.016	NE	NO	0.003	0.136	0.155
2016	0.017	NE	NO	0.003	0.118	0.138

a Note that all MSW incinerators were either closed or converted to extract power by 1997. In the latter case they were then considered to be power generation and so emissions were reported in 1A1a.

A 3.5.4 Wastewater Handling (5D)

A 3.5.4.1 5D1 Domestic and Commercial Waste Water Handling and Sludge Disposal

Table A 3.5.10 UK Domestic and Commercial Waste Water Treatment (5D1) Activity Data

Treatment/disposal route		unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
Total Sludge		kt tds	1634	1657	1682	1768	1666	1635	1589	1598	1596	1597	1659
Population Equivalent		million	68.3	69.2	70.2	70.5	69.3	70.2	71.2	72.9	72.9	73.0	73.2
Additional Treatment	Digested	kt tds	402	434	469	818	840	794	722	694	710	657	673
	Advanced Digested	kt tds	100	107	115	329	374	363	379	295	406	454	556
	Composted	kt tds	7	8	8	15	25	31	41	48	27	7	18
Disposal route	Farmland	kt tds	508	547	590	1216	1282	1260	1270	1287	1332	1422	1434
	Landfill	kt tds	160	153	110	131	35	26	14	6	4	7	9
	Incineration	kt tds	68	80	211	252	238	248	237	252	232	161	198
	Sea	kt tds	782	721	611	-	-	-	-	-	-	-	-
	Composted	kt tds	2	2	2	13	23	30	42	53	28	7	18
	Land Reclamation	kt tds	31	30	30	96	44	41	10	-	-	-	-
	Other	kt tds	84	124	129	61	44	30	16	-	-	-	-

Where tds is total dissolvable solids; this is assumed to be comparable to Biochemical Oxygen Demand (BOD)

Table A 3.5.11 UK Domestic and Commercial Waste Water Treatment (5D1) Implied Emission Factors

Treatment/disposal route		unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
Mechanical treatment and storage[1]		kt/Mt tds	2.70	2.70	2.70	2.70	2.70	2.70	2.70	2.70	2.70	2.70	2.70
Additional Treatment	Digested[2]	kt/Mt tds	16.54	16.29	16.47	16.96	16.51	16.28	16.18	16.01	15.71	15.63	13.30
	Advanced Digested	kt/Mt tds	4.54	4.54	4.54	4.54	4.54	4.54	4.54	4.56	4.52	4.52	4.57
	Composted	kt/Mt tds	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Disposal route	Farmland[3]	kt/Mt tds	1.36	1.36	1.36	1.44	1.41	1.40	1.36	1.45	1.31	1.30	1.27
	Landfill	kt/Mt tds	15.09	15.09	15.09	15.09	15.09	15.09	15.09	15.09	15.09	15.09	15.09
	Incineration	kt/Mt tds	-	-	-	-	-	-	-	-	-	-	-
	Sea[4]	kt/Mt tds	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
	Composted	kt/Mt tds	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
	Land Reclamation[5]	kt/Mt tds	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.42	1.29	1.29	1.27
	Other[6]	kt/Mt tds	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.25	1.14	1.22	1.19
Total[7]		kt/Mt tds	29.83	28.55	31.00	13.70	13.67	13.19	12.65	12.04	12.14	11.68	10.93

1. All waste is mechanically treated and stored, so the emission factor is applied to total sludge.
2. Implied emission factor after methane capture.
3. Emission factor varies depending on how the waste is treated.
4. Not an IEF, this is the default IPCC factor for sea, river and lake discharge.
5. Land reclamation hasn't got associated reported emissions, so the factor is based on a weighted average of other waste to land (farmland, composting) IEFs.
6. Other hasn't got associated reported emissions, the factor is based on a weighted average of all other disposal IEFs.
7. For information, IEF when dividing total emissions by total activity.

Table A 3.5.12 UK Domestic and Commercial Waste Water Treatment (5D1) Emission Estimates (kt CH_4)

Treatment/disposal route		1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
Mechanical treatment and storage		4.41	4.47	4.54	4.77	4.50	4.42	4.29	4.31	4.31	4.31	4.48
Additional Treatment	Digested	6.65	7.07	7.72	13.88	13.87	12.92	11.68	11.11	11.15	10.27	8.95
	Advanced Digested	0.46	0.49	0.52	1.49	1.70	1.65	1.72	1.34	1.84	2.06	2.55
	Composted	0.07	0.08	0.08	0.15	0.25	0.31	0.41	0.48	0.27	0.07	0.18
Disposal route	Farmland	0.68	0.73	0.79	1.72	1.82	1.78	1.75	1.90	1.76	1.85	1.84
	Landfill	2.41	2.30	1.66	1.97	0.53	0.39	0.21	0.09	0.06	0.10	0.14
	Incineration	-	-	-	-	-	-	-	-	-	-	
	Sea	33.92	31.99	36.63	-	-	-	-	-	-	-	
	Composted	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.03	0.02	0.00	0.01
	Land Reclamation	0.04	0.04	0.04	0.13	0.06	0.06	0.01	-	-	-	
	Other	0.10	0.15	0.15	0.07	0.05	0.04	0.02	-	-	-	
Total		48.75	47.32	52.14	24.23	22.78	21.56	20.10	19.24	19.39	18.66	18.13

Table A 3.5.13 UK Private Waste Water Management System Emission Estimates Parameters (5D1)

Data	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
Estimated population connected to private waste water management systems	population (thousands)	1417.18	1440.63	1438.67	1465.29	1525.78	1537.59	1547.20	1562.08	1579.31	1584.43	1598.92

Data	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
BOD value applied	g/person/day	66.33	66.33	66.33	68.73	65.90	63.78	61.16	60.09	59.96	59.96	62.07

A 3.5.4.2 5D2 Industrial Waste Water Handling and Sludge Disposal

Table A 3.5.14 UK Industrial Waste Water Treatment Activity Data (5D2)

Sector	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016
Organic chemical production	Mt	1.617	1.617	1.751	1.752	1.487	1.554	1.558	1.541	1.584	1.676
Milk-processing	million PE	1.464	1.464	1.464	0.625	0.629	0.687	0.696	0.733	0.791	0.801
Manufacture of fruit and vegetable products	million PE	1.145	1.145	1.145	1.092	1.093	0.900	0.916	0.987	1.001	1.137
Potato-processing	million PE	0.302	0.302	0.302	0.288	0.288	0.237	0.242	0.260	0.264	0.300
Meat industry	million PE	0.623	0.623	0.623	0.618	0.648	0.638	0.652	0.634	0.696	0.723
Breweries	million PE	0.094	0.094	0.094	0.097	0.096	0.102	0.099	0.098	0.102	0.102
Production of alcohol and alcoholic beverages	million PE	1.931	1.931	1.931	1.991	1.963	2.093	2.039	2.005	2.089	2.087
Manufacture of animal feed from plant products	million PE	0.476	0.476	0.476	0.300	0.378	0.387	0.364	0.349	0.361	0.354
Manufacture of gelatine and of glue from hides, skin and bones	million PE	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
Malt-houses	million PE	0.207	0.207	0.207	0.213	0.210	0.224	0.218	0.215	0.224	0.223
Fish-processing industry	million PE	0.018	0.018	0.018	0.006	0.006	0.007	0.007	0.006	0.007	0.007
Total Food and Drink	million PE	6.273	6.273	6.273	5.244	5.324	5.289	5.246	5.300	5.548	5.747

Where PE is population equivalent

A 3.6 DATA FOR THE UK'S CROWN DEPENDENCIES AND OVERSEAS TERRITORIES

Table A 3.6.1 Isle of Man, Guernsey and Jersey – Emissions of Direct GHGs (Mt CO_2 equivalent)

Sector	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016
1. Energy	1.40	1.57	1.62	1.43	1.36	1.36	1.44	1.36	1.25	1.31
2. Industrial Processes and Product Use	0.0001	0.005	0.025	0.053	0.083	0.08	0.08	0.08	0.08	0.08
3. Agriculture	0.14	0.14	0.15	0.10	0.13	0.12	0.12	0.13	0.12	0.12
4. LULUCF	-0.03	-0.04	-0.04	-0.03	-0.02	-0.02	-0.02	-0.02	-0.01	-0.02
5. Waste	0.16	0.16	0.17	0.17	0.15	0.15	0.14	0.14	0.14	0.13
7. Other										
Total	1.68	1.84	1.93	1.72	1.71	1.69	1.77	1.68	1.58	1.64

Table A 3.6.2 Isle of Man, Guernsey and Jersey – Fuel use data

Fuel	Fuel Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016
Aviation spirit	Mt	0.008	0.009	0.012	0.013	0.007	0.006	0.006	0.006	0.004	0.003
Aviation turbine fuel	Mt	0.077	0.069	0.088	0.101	0.087	0.081	0.079	0.076	0.081	0.084
Burning oil	Mt	0.225	0.261	0.350	0.357	0.363	0.362	0.381	0.373	0.386	0.404
Coal	Mt	0.034	0.022	0.015	0.010	0.001	0.001	0.001	0.001	0.001	0.001
DERV	Mt	0.074	0.094	0.132	0.117	0.125	0.130	0.131	0.132	0.135	0.136
Fuel oil	Mt	0.469	0.580	0.438	0.078	0.089	0.203	0.222	0.158	0.060	0.078
Gas oil	Mt	0.164	0.174	0.162	0.181	0.119	0.103	0.095	0.087	0.085	0.085
LPG	Mth	11.696	13.491	46.367	25.032	22.431	18.844	19.094	17.414	16.902	16.160
MSW	Mt	0.121	0.169	0.216	0.391	0.359	0.340	0.321	0.309	0.296	0.293
Natural gas	Mth	-	-	-	106.062	126.499	83.717	114.360	124.051	113.072	127.442
Petrol	Mt	0.235	0.227	0.216	0.219	0.191	0.179	0.175	0.171	0.169	0.168
Urea consumption	Mt	-	-	-	-	0.001	0.002	0.002	0.002	0.002	0.002

Table A 3.6.3 Isle of Man, Guernsey and Jersey – Animal numbers

Livestock Category	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
Dairy	15,888	15,729	16,186	13,127	11,455	10,944	10,968	10,942	10,882	10,867	11,583
Non dairy	28,663	28,333	29,176	16,770	28,615	27,137	25,643	25,860	27,303	26,369	25,985
Sheep	151,764	160,228	176,259	87,537	138,251	134,963	134,701	134,501	134,310	133,666	126,201
Pigs	4,854	5,411	4,609	1,148	4,086	2,385	2,511	2,605	2,602	2,861	2,400
Poultry	84,048	46,481	46,448	58,160	54,400	52,152	57,193	57,924	58,850	62,916	62,742
Goats	333	347	376	141	288	302	364	416	477	539	349
Horses	2,785	2,785	2,785	2,822	3,236	3,203	3,233	3,265	3,163	2,891	3,262

Table A 3.6.4 Isle of Man, Guernsey and Jersey – Total emissions from Agricultural Soils (kg N_2O-N)

Territory	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
Isle of Man	39,508	40,171	43,747	27,134	37,952	35,997	34,791	34,908	36,109	35,426	35,641
Guernsey	5,714	5,760	5,279	4,752	4,625	4,622	4,643	4,699	4,757	4,694	4,694
Jersey	6,362	6,445	6,606	5,257	5,395	5,351	5,389	5,465	5,443	5,321	5,321

Table A 3.6.5 Cayman Islands, Falklands Islands, and Bermuda - Emissions of Direct GHGs (Mt CO_2 equivalent)

Sector	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
1. Energy	1.05	1.06	1.17	1.37	1.36	1.40	1.28	1.31	1.32	1.29	1.28
2. Industrial Processes and Product Use	0.0001	0.0025	0.0134	0.0292	0.0431	0.0372	0.0379	0.0382	0.0379	0.0372	0.0372
3. Agriculture	0.27	0.26	0.25	0.22	0.18	0.19	0.18	0.18	0.18	0.18	0.18
4. LULUCF	0.010	0.012	0.015	0.019	0.024	0.021	0.025	0.029	0.029	0.030	0.031
5. Waste	0.11	0.10	0.08	0.08	0.13	0.12	0.12	0.12	0.11	0.11	0.11
7. Other											
Total	1.45	1.44	1.53	1.72	1.73	1.77	1.65	1.67	1.68	1.65	1.63

Table A 3.6.6 Cayman Islands, Falklands Islands, and Bermuda – Fuel use data

Fuel	Fuel Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
Aviation spirit	Mt	3E-04	-	-	-	-	-	-	-	-	-	-
Aviation turbine fuel	Mt	0.081	0.037	0.041	0.056	0.070	0.055	0.051	0.050	0.050	0.05	0.05
Burning oil	Mt	0.004	0.005	0.006	0.008	0.007	0.007	0.007	0.007	0.008	0.01	0.01
Coal	Mt	-	-	-	-	-	-	-	-	-	-	-
DERV	Mt	0.147	0.127	0.103	0.232	0.096	0.130	0.085	0.086	0.086	0.09	0.09
Fuel oil	Mt	0.145	0.152	0.266	0.303	0.315	0.314	0.315	0.314	0.314	0.32	0.32
Gas oil	Mt	0.398	0.447	0.428	0.475	0.546	0.595	0.572	0.583	0.592	0.57	0.53
LPG	Mth	6.403	6.794	7.171	7.686	7.825	7.884	8.097	8.289	8.432	8.48	8.94
MSW	Mt	0.000	0.204	0.204	0.204	0.192	0.163	0	0	0	0	0.17
Natural gas	Mth	0.047	0.058	0.067	0.088	0.105	0.091	0.097	0.097	0.107	0.12	0.11
Petrol	Mt	0.189	0.192	0.214	0.170	0.196	0.174	0.135	0.147	0.147	0.14	0.16
Urea Consumption	Mt	-	-	-	-	6E-04	1E-03	1E-03	1E-03	1E-03	1E-03	1E-03
Lubricants	Mt	0.005	0.006	0.006	0.005	0.004	0.004	0.003	0.003	0.003	0.00	0.00
Petroleum waxes	Mt	2E-04	2E-04	2E-04	4E-04	2E-04	2E-04	2E-04	1E-04	2E-04	2E-04	2E-04

Table A 3.6.7 Cayman Islands, Falklands Islands, and Bermuda – Animal numbers

Livestock Category	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
Dairy Cattle	2,161	1,862	1,911	1,145	868	1,033	828	765	723	675	634
Non-dairy Cattle	5,256	4,861	5,077	7,845	6,360	6,244	5,994	5,795	5,609	4,748	4,503
Sheep	739,999	717,571	669,905	580,864	478,625	488,065	486,775	486,037	483,135	482,131	479,752
Goats	405	867	1,286	1,704	2,251	2,424	2,326	2,080	1,891	1,812	2,031
Horses	2,217	1,944	1,453	1,167	1,019	994	973	942	952	973	1,002
Swine	1,116	1,074	1,276	1,284	1,133	1,223	1,003	1,148	1,142	958	1,134
Poultry	15,319	14,664	20,890	27,164	32,293	35,754	36,832	33,699	24,884	36,405	32,984
Deer	0	0	0	0	184	184	243	243	243	243	243

Table A 3.6.8 Cayman Islands, Falklands Islands, and Bermuda – Total emissions from Agricultural Soils (kg N_2O-N)

Territory	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
Bermuda	2,366	2,355	2,378	2,359	2,371	2,372	2,373	2,374	2,375	2,375	2,375
Cayman Islands	2,732	2,944	3,336	3,730	3,916	4,033	3,834	3,842	3,459	3,575	3,485
Falkland Islands	363,352	350,805	328,288	288,471	237,339	239,030	239,821	241,051	239,038	235,218	234,431

Table A 3.6.9 Cayman Islands, Falklands Islands, and Bermuda - Amount of synthetic fertilizer applied

Country	kg N applied
Cayman Islands	21,960
Falkland Islands	0
Bermuda	1,480

Table A 3.6.10 Gibraltar – Emissions of Direct GHGs (Mt CO_2 equivalent)

Sector	1990	1995	2000	2005	2010	2013	2014	2015	2016
1. Energy	0.219	0.216	0.242	0.278	0.288	0.319	0.307	0.329	0.324
2. Industrial Processes and Other Product Use	0.000	0.001	0.003	0.006	0.010	0.011	0.011	0.012	0.012
3. Agriculture	-	-	-	-	-	-	-	-	-
4. LULUCF	-	-	-	-	-	-	-	-	-
5. Waste	0.007	0.007	0.008	0.001	0.003	0.002	0.002	0.002	0.002
6. Other	-	-	-	-	-	-	-	-	-
Total	0.227	0.224	0.252	0.285	0.301	0.331	0.320	0.343	0.337

Table A 3.6.11 Gibraltar – Fuel use data

Fuel	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016
Aviation turbine fuel	Mt	0.009	0.007	0.006	0.009	0.007	0.009	0.009	0.010	0.012
Charcoal	Mt	-	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DERV	Mt	0.002	0.002	0.003	0.008	0.008	0.006	0.008	0.010	0.010
Fuel oil	Mt	0.023	0.022	0.024	0.021	0.018	0.007	0.009	0.010	0.009
Gas oil	Mt	0.020	0.024	0.026	0.033	0.041	0.064	0.057	0.060	0.057
MSW	Mt	0.016	0.019	0.024	-	-	-	-	-	-
LPG	Mth	4.125	4.125	4.125	4.125	4.125	4.125	4.125	4.125	4.125
Petrol	Mt	0.007	0.006	0.008	0.008	0.007	0.005	0.005	0.004	0.004
Clinical waste	Mt	-	-	-	-	0.002	0.000	0.000	0.000	0.000
Petroleum Waxes	Mt	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

ANNEX 4: National Energy Balance for the Most Recent Inventory Year

A 4.1 UK ENERGY BALANCE

The UK energy balance is produced and published annually by the Department of Business, Energy & Industrial Strategy in the Digest of UK Energy Statistics – DUKES. This is available online from:

https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes

The aggregate energy balance for the latest year is presented below (Table 1.1 in DUKES). The following sections explain how the energy balance is used for the UK inventory for individual fuel types, and how the data are supplemented with other statistics that may lead to deviations from the DUKES statistics.

The UK energy statistics (detailed breakdown) are presented on a mass basis for liquid and solid fuels, and on a gross energy basis for gaseous fuels (including derived gases). The UK inventory is calculated using these data directly, and for the purposes of reporting in the CRF and NIR, activity data and emission factors are converted to energy units, on a net basis.

Table A 4.1.1 UK Energy Balance (thousand tonnes of oil equivalent, gross energy basis)

	Coal	Manufactured fuel*(1)*	Primary oils	Petroleum products	Natural gas*(2)*	Bioenergy & waste*(3)*	Primary electricity	Electricity	Heat sold	Total
Supply										
Production	2,633	-	51,952	-	39,789	10,774	19,987	-	-	125,135
Imports	5,747	890	53,380	38,254	45,979	3,743	-	1,694	-	149,687
Exports	-333	-16	-38,180	-26,663	-10,048	-338	-	-185	-	-75,763
Marine bunkers	-	-	-	-2,840	-	-	-	-	-	-2,840
Stock change*(4)*	+3,658	-89	-135	+77	+1,397	-	-	-	-	+4,907
Primary supply	**11,705**	**785**	**67,016**	**8,828**	**77,117**	**14,180**	**19,987**	**1,509**	**-**	**201,125**
Statistical difference*(5)*	-58	+1	-86	+32	+127	-	-	+17	-	+32
Primary demand	**11,763**	**784**	**67,102**	**8,796**	**76,990**	**14,180**	**19,987**	**1,492**	**-**	**201,093**
Transfers	-	+27	-1,640	+1,629	+135	-165	-4,573	+4,573	-	-14
Transformation	**-10,243**	**231**	**-65,462**	**64,560**	**-27,876**	**-8,964**	**-15,414**	**24,356**	**1,409**	**-37,404**
Electricity generation	-7,533	-540	-	-559	-25,630	-8,894	-15,414	24,356	-	-34,214
Major power producers	-7,521	-	-	-194	-23,350	-4,233	-15,414	21,778	-	-28,934
Autogenerators	-12	-540	-	-365	-2,280	-4,661	-	2,577	-	-5,280
Heat generation	-132	-51	-	-62	-2,246	-70	-	-	1,409	-1,152
Petroleum refineries	-	-	-65,931	65,776	-	-	-	-	-	-155
Coke manufacture	-1,384	1,303	-	-	-	-	-	-	-	-81
Blast furnaces	-1,037	-656	-	-	-	-	-	-	-	-1,692
Patent fuel manufacture	-157	175	-	-81	-	-	-	-	-	-64

	Coal	Manufactured fuel*(1)*	Primary oils	Petroleum products	Natural gas*(2)*	Bioenergy & waste*(3)*	Primary electricity	Electricity	Heat sold	Total
Other(7)	-	-	469	-515	-	-	-	-	-	-46
Energy industry use	**-**	**417**	**-**	**4,188**	**4,968**	**-**	**-**	**2,035**	**273**	**11,881**
Electricity generation	-	-	-	-	-	-	-	1,313	-	1,313
Oil and gas extraction	-	-	-	715	4,306	-	-	51	-	5,072
Petroleum refineries	-	-	-	3,473	93	-	-	379	273	4,218
Coal extraction	-	-	-	-	5	-	-	40	-	46
Coke manufacture	-	145	-	-	-	-	-	1	-	146
Blast furnaces	-	272	-	-	25	-	-	18	-	315
Patent fuel manufacture	-	-	-	-	-	-	-	-	-	-
Pumped storage	-	-	-	-	-	-	-	91	-	91
Other	-	-	-	-	539	-	-	142	-	680
Losses	**-**	**96**	**-**	**-**	**464**	**-**	**-**	**2,263**	**-**	**2,823**
Final consumption	**1,520**	**529**	**-**	**70,797**	**43,818**	**5,050**	**-**	**26,122**	**1,136**	**148,971**
Industry	**1,072**	**316**	**-**	**4,074**	**8,427**	**1,337**	**-**	**7,894**	**610**	**23,730**
Unclassified	-	-	-	3,114	1	134	-	-	-	3,249
Iron and steel	25	316	-	4	357	-	-	245	-	946
Non-ferrous metals	11	-	-	0	162	-	-	370	-	542
Mineral products	542	-	-	192	1,007	185	-	517	-	2,443
Chemicals	42	-	-	117	1,686	26	-	1,328	202	3,401
Mechanical engineering etc	8	-	-	-	523	2	-	536	-	1,068
Electrical engineering etc	3	-	-	1	293	-	-	502	-	799

	Coal	Manufactured fuel *(1)*	Primary oils	Petroleum products	Natural gas *(2)*	Bioenergy & waste *(3)*	Primary electricity	Electricity	Heat sold	Total
Vehicles	37	-	-	200	783	-	-	402	-	1,423
Food, beverages etc	31	-	-	140	1,704	37	-	923	0	2,835
Textiles, leather etc	48	-	-	44	356	-	-	227	-	675
Paper, printing etc	75	-	-	32	716	599	-	911	-	2,333
Other industries	247	-	-	37	562	355	-	1,818	408	3,426
Construction	4	-	-	193	278	-	-	115	-	590
Transport *(6)*	**11**	**-**	**-**	**54,345**	**-**	**1,010**	-	**401**	**-**	**55,767**
Air	-	-	-	12,635	-	-	-	-	-	12,635
Rail	11	-	-	627	-	-	-	390	-	1,028
Road	-	-	-	40,429	-	1,010	-	11	-	41,450
National navigation	-	-	-	654	-	-	-	-	-	654
Pipelines	-	-	-	-	-	-	-	-	-	-
Other	**437**	**168**	-	**4,559**	**34,952**	**2,704**	**-**	**17,826**	**526**	**61,170**
Domestic	414	168	-	2,525	26,773	2,079	-	9,284	52	41,295
Public administration	14	-	-	377	3,203	38	-	1,705	471	5,807
Commercial	4	-	-	872	3,995	299	-	6,457	3	11,629
Agriculture	-	-	-	488	81	288	-	380	-	1,237
Miscellaneous	5	-	-	297	900	-	-	-	-	1,201
Non energy use	-	**46**	-	**7,818**	**439**	-	-	-	-	**8,303**

(1) Includes all manufactured solid fuels, benzole, tars, coke oven gas and blast furnace gas.

(2) Includes colliery methane.

(3) Includes geothermal and solar heat.

	Coal	Manufactured fuel*(1)*	Primary oils	Petroleum products	Natural gas*(2)*	Bioenergy & waste*(3)*	Primary electricity	Electricity	Heat sold	Total

(4) Stock fall (+), stock rise (-).

(5) Primary supply minus primary demand.

(6) See paragraphs 5.42 regarding electricity use in transport and 6.66 regarding renewables use in transport.

(7) Back-flows from the petrochemical industry.

A 4.2 FUELS DATA

The fuels data are taken from DUKES - the Digest of UK Energy Statistics (BEIS, 2017), so the fuel definitions and the source categories used in the NAEI reflect those in DUKES.

IPCC Guidelines (IPCC, 2006) lists fuels that should be considered when reporting emissions. **Table A 4.2.1** lists the fuels that are used in the GHGI (based on DUKES) and indicates how they relate to the fuels listed in the IPCC Guidelines. In most cases the mapping is obvious but there are a few cases where some explanation is required.

Table A 4.2.1 Mapping of fuels used in IPCC and the NAEI

	IPCC	NAEI
Category	**Subcategory**	**Subcategory**
Liquid	Motor Gasoline	Petrol
	Aviation Gasoline	Aviation Spirit
	Jet Kerosene	Aviation Turbine Fuel[1] (ATF)
	Other Kerosene	Burning Oil
	Gas/Diesel Oil	Gas Oil/ DERV
	Residual Fuel Oil	Fuel Oil
	Orimulsion	Orimulsion
	Liquefied Petroleum Gases	Liquefied Petroleum Gas (LPG)
	Naphtha	Naphtha
	Petroleum Coke	Petroleum Coke
	Refinery Gas	Other Petroleum Gas (OPG)
	Other Oil: Other Petroleum Products	Refinery Miscellaneous
	Lubricants	Lubricants
Solid	Anthracite	Anthracite
	Coking Coal	Coal[2]
	Other Bituminous Coal	Coal
		Slurry[3]
	Coke Oven Coke	Coke
	Patent Fuel	Solid Smokeless Fuel (SSF)
	Coke Oven Gas	Coke Oven Gas
	Blast Furnace Gas	Blast Furnace Gas

	IPCC	NAEI
Category	**Subcategory**	**Subcategory**
Gas	Natural Gas	Natural Gas
		Sour Gas[4]
		Colliery Methane[5]
Other Fuels	Municipal Solid Waste	Municipal Solid Waste
	Industrial Waste: Scrap Tyres	Scrap Tyres
	Waste Oils	Waste Oil
Peat	Peat	Peat
Biomass	Wood/Wood Waste	Wood
	Other Primary Solid Biomass	Straw
		Poultry Litter, Meat & bone meal
	Landfill Gas	Landfill Gas
	Sludge Gas	Sewage Gas
	Charcoal	Charcoal
	Other liquid biofuels	Liquid Biofuels
	Other biogas	Biogas

1 Includes fuel that is correctly termed jet gasoline.
2 Used in coke ovens.
3 Coal-water slurry used in some power stations
4 Unrefined natural gas used on offshore platforms and some power stations
5 IPCC Guidelines (IPCC, 2006) specifies coal seam methane is included in Natural Gas.

A 4.2.1 Reallocations of energy data and differences from UK energy statistics

The main source of energy consumption data used in the UK inventory is the Digest of UK Energy Statistics (BEIS, 2017). This annual publication gives detailed sectoral energy consumption broken down by fuel type, and covering the entire time period covered by the inventory. In many cases, these data are used directly in the inventory without modification. However, there are instances where the activity data used in the inventory are not based directly on DUKES data, but where alternative data sources provide supplementary data to inform energy use and emission estimates. In general, the UK inventory totals by fuel are kept consistent with the DUKES national totals for each fuel. There are some exceptions where the UK total may be different to that presented in DUKES due to different scopes and reporting requirements.

The reasons for any deviations from use of DUKES data in the inventory are discussed within the source category methodological descriptions in Section 3 of the main report. The main reasons for reallocations or modifications are:

- To account for differences in geographical scope

- To make best use of EU ETS data (this data is only used indirectly in producing UK energy statistics)
- To utilise other operator reported data (e.g. direct to the Inventory Agency, or via the various regulator's inventories).
- When bottom-up models are available providing fuel consumption data on a more granular level and are considered to be a higher quality estimate by the Inventory Agency.

The fuel reconciliation tables (**Table A 4.2.2 – Table A 4.2.6**) show how the deviations are applied and how the energy data for the major fuels in the UK inventory are reconciled against the energy demand data from DUKES. The tables show:

1. where fuels are re-allocated between sectors, but the overall annual fuel consumption across all UK sectors is kept consistent with the data in DUKES, and
2. where deviations are made to DUKES figures for total UK consumption of a given fuel, and in which source categories these deviations are made.

The Inventory Agency presents data below for the fuel allocations for coal, natural gas, fuel oil, gas oil (including DERV) and petroleum gases (LPG, OPG) for the latest inventory year. Together these fuels constitute the majority of the UK inventory 1A sector emissions total.

Deviations to the energy balance are made in consultation with the authors of the energy statistics.

A 4.2.1.1 Coal

Total industrial coal use within the GHG inventory is consistent with the DUKES total and in the most part, coal use at the sectoral level is consistent with the DUKES data. However, there is an apparent step change in the amount of fuel allocated to other industries within DUKES between 1999 and 2000. In addition, between 1997 and 1999, the total coal use allocated to 1A2f is less than the independent estimates for cement and lime production used within the inventory. Cement and lime production would fall into the 1A2f category for IPCC reporting. Therefore, Inventory Agency estimates have been made to construct a consistent time series for coal use. **Table A 4.2.2** below compares inventory estimates with DUKES estimates for the latest inventory year.

Table A 4.2.2 Fuel reconciliation - coal use in the latest year (Mtonnes)

DUKES Category	DUKES	GHGI	Difference	GHGI category	CRF	Comment
Major power producers	**12.040**	**12.040**	**0.000**	Power stations	1A1a	
Blast furnaces	**1.364**	**1.364**	**0.000**	Blast furnaces	2C1	
Coal extraction	**0.000**	**0.000**	**0.000**	Collieries - combustion	1A1c	
		0.010		Autogenerators	1A2b	
		0.008		Autogeneration - exported to grid	1A2b	
Autogenerators	**0.019**		**0.000**			
Patent fuel manufacture etc.	**0.223**	**0.223**	**0.000**	Solid smokeless fuel production	1B1b	
Coke manufacture	1.821	1.747	0.074	Coke Production	1B1b	EU ETS
		0.035		Iron & steel - combustion plant	1A2a	
		0.035		Non-Ferrous Metal (combustion)	1A2b	
		0.088		Chemicals	1A2c	

DUKES Category	DUKES	GHGI	Difference	GHGI category	CRF	Comment
		0.137		Pulp, Paper and Print	1A2d	
		0.068		Food & drink, tobacco	1A2e	
		0.768		Other industrial combustion	1A2g	
		0.609		Cement production - combustion	1A2f	Operator data
		0.032		Lime production - non decarbonising	1A2f	EU ETS
Industry total	**1.697**	**1.771**	**-0.074**			
Rail	**0.015**	**0.015**	**0.000**	Rail	1A3c	
Domestic - anthracite	**0.188**	**0.188**	**0.000**	Domestic combustion - anthracite	1A4b	
		0.362		Domestic combustion - UK	1A4b	
		0.000		Domestic combustion - crown dependencies	1A4b	
Domestic - coal	**0.362**		**0.000**			
Agriculture	**0.000**	**0.000**	**0.000**	Agriculture - stationary combustion	1A4c	
Commercial	0.005					
Miscellaneous	0.007					
		0.012	**0.000**	Miscellaneous industrial/commercial combustion	1A4a	
Public administration	**0.150**	**0.150**	**0.000**	Public sector combustion	1A4a	
TOTAL	**17.889**	**17.889**	**0.000**			

Notes: Shaded rows indicate a comparison between fuel use between DUKES and GHGI.

A 4.2.1.2 Natural Gas

Data for natural gas use is largely taken directly from DUKES and the national total is consistent between the inventory and the energy statistics, other than a small additional use of natural gas at a number of (international) gas pipeline inter-connectors and also on the Isle of Man (IoM) which is added to the inventory, as natural gas use on IoM is not included in DUKES demand totals. Operator estimates for ammonia production (both fuel and feedstock), and ETS data for gas separation plant lead to minor reallocations of the DUKES data, these are summarised below in **Table A 4.2.3**. In addition, the NAEI model doesn't include any accounting for losses compared to DUKES tables.

Table A 4.2.3 Fuel reconciliation – natural gas use in the latest year (Mtherms)

DUKES Category	DUKES	GHGI	Difference	GHGI Category	CRF	Comment
Major power producers	**9266**	**9299**	**-33**	Power stations	1A1a	Difference is Isle of Man gas use not included in DUKES demand
Transformation - Heat generation	**0**		**0**			
		364		Autogenerators	1A2g	
		290		Autogeneration - exported to grid	1A2g	
		0		Railways - stationary combustion	1A4a	

DUKES Category	**DUKES**	**GHGI**	**Difference**	**GHGI Category**	**CRF**	**Comment**
Autogenerators	**890**	654	**236**			Offset against refineries
Coal extraction	**2**	**2**	**0**	Collieries - combustion	1A1c	
		1230		Upstream oil production - fuel combustion	1A1c	
		479		Upstream gas production - fuel combustion	1A1c	
Oil and gas extraction	**1709**	1709	**0**			
Petroleum refineries	**200**	**436**	**-236**	Refineries - combustion	1A1b	Offset against autogeneration
Blast furnaces	**10**	**10**	**0**	Blast furnaces	1A2a	
		237		Gas production	1A1c	EU ETS
		0		Nuclear fuel production	1A1c	
Other energy industries	**214**	**237**	**-23**			Difference reflects operator data for gas compressors on international pipelines
Non-Ferrous Metal	71	71		Non-Ferrous Metal (combustion)	1A2b	
Chemicals	872	872		Chemicals (combustion)	1A2c	
Pulp, Paper and Print	333	333		Pulp, Paper and Print (combustion)	1A2d	
Food & drink, tobacco	721	721		Food & drink, tobacco (combustion)	1A2e	
		107		Ammonia production - combustion	1A2c	Operator data
	1625	1391		Other industrial combustion	1A2g	
	0.3			Other industrial combustion (colliery methane)		
		47		Lime production - non decarbonising	1A2f	EU ETS
		3		Cement production - combustion	1A2f	Operator data
All industry except iron and steel	**3622**	3544	**78**			Offset against non-energy use
		161		Ammonia production - feedstock use of gas	2B2	Operator data
Non-energy use	174	91		Non-energy use (stored)		
	174	**252**	**-78**			Difference reflects operator data
Iron and steel	155	155		Iron and steel - combustion plant	1A2a	
Domestic	10625	10634	-9	Domestic combustion	1A4b	Difference is gas use in Isle of Man residential sector
Public administration	1416	1416		Public sector combustion	1A4a	
Commercial	1735					
Miscellaneous	357					
		2092		Miscellaneous industrial/commercial combustion	1A4a	
Commercial and miscellaneous	**2092**	**2092**	**0**			

DUKES Category	DUKES	GHGI	Difference	GHGI Category	CRF	Comment
Agriculture	**32**	**32**	**0**	Agriculture - stationary combustion	1A4c	
Autogenerators - colliery methane	15					
Coal extraction - colliery methane	0					
		15	**0**	Collieries - combustion (colliery methane)	1A1c	
	15	**15**	**0**			
Total	**32419**	**32484**	**65**			

Notes: Shaded rows indicate a comparison between fuel use between DUKES and GHGI.

1 Mtherm = 105.51 TJ

A 4.2.1.3 Fuel Oil

For shipping, a major research project has been completed and the results are incorporated into the inventory for the first time this submission, as discussed further in the main body of this report. The estimated total fuel oil consumption derived from this assumption is greater than as reported in DUKES and any deviations from the national navigation sector are considered additional and are not reconciled elsewhere in the inventory. Additional sectoral deviations are also made to account for known use of fuel oil in power stations, and the Crown Dependencies.

Table A 4.2.4 Fuel reconciliation – Fuel oils use in latest year (Mtonnes)

DUKES Category	DUKES	GHGI	Difference	GHGI Category	CRF	Comment
Major power producers	0.141					
		0.170		Power Stations - UK	1A1a	EU ETS data
		0.026		Power Stations - crown dependencies	1A1a	Local data sets
Autogenerators	0.020					
Industry	0.239					
		0.012		Iron and steel - combustion plant	1A2a	Reduced to offset increase in 1A1a
		0.000		Non-Ferrous Metal (combustion)	1A2b	
		0.025		Chemicals (combustion)	1A2c	
		0.001		Pulp, Paper and Print (combustion)	1A2d	
		0.074		Food & drink, tobacco (combustion)	1A2e	
		0.155		Other industrial combustion	1A2g	
		0.000		Cement production - combustion	1A2f	Operator data
Industry Total	**0.399**	**0.463**	**-0.064**			Offset against refineries
Petroleum refineries	0.232					
Oil and gas extraction	0.064					
	0.296	**0.232**	**0.064**	Refineries - combustion	1A1b	Offset against other industry
Agriculture	**0.017**	**0.017**	**0.000**	**Agriculture - stationary combustion**	**1A4c**	

DUKES Category	DUKES	GHGI	Difference	GHGI Category	CRF	Comment
Domestic	**0.000**	**0.000**	**0.000**	**Domestic combustion**	**1A4b**	
Commercial	0.060					
Miscellaneous	0.014					
		0.073		Miscellaneous combustion - UK	1A4a	
		0.000		Miscellaneous combustion - crown dependencies	1A4a	Local data sets
Commercial and Miscellaneous Total	**0.073**	**0.073**	**0.000**			
Public administration	**0.029**	**0.029**	**0.000**	**Public sector combustion**	**1A4a**	
National navigation	0.000	0.173		Shipping - coastal	1A3d	Bottom-up AIS approach estimates greater fuel oil and is considered additional to DUKES.
		0.010		Fishing vessels	1A4c	
		0.000		Shipping between UK and CDs	1A3d	
		0.008		Shipping between UK and Gibraltar	1A3d	
		0.000		Shipping between UK and Bermuda	1A3d	
		0.004		Shipping between UK and OTs (excl. Gib and Bermuda)	1A3d	
Marine bunkers	0.889	0.876		Shipping - international IPCC definition		
Shipping Total	**0.889**	**1.072**	**-0.182**			**Difference reflects the 2017 UK shipping study: Higher fuel use from bottom-up analysis than in DUKES.**
TOTAL	**1.704**	**1.886**	**-0.182**			

Notes: Shaded rows indicate a comparison between fuel use between DUKES and GHGI. Total includes marine bunkers.

A 4.2.1.4 Gas Oil

Gas oil is used in both off-road transport and machinery diesel engines, and as a fuel for stationary combustion. The varied use of this fuel and the complexity of the supply chain complicates the means of allocating consumption across the wide range of sectors that use the fuel in the inventory. DUKES provides a breakdown of gas oil consumption in different industry and other sectors, but the data resolution in DUKES does not distinguish between use of the fuel for stationary combustion and off-road machinery, a distinction which is necessary for the inventory.

The GHGI estimates consumption of gas oil and emissions for off-road machinery using a bottom-up method based on estimates of population and usage of different types of machinery. However, this has led to a situation where the total amount of gas oil consumption across sectors exceeds that which is available as given in DUKES. Therefore, consumption figures, mainly for stationary combustion in industry sectors, have had to be adjusted to obtain a total fuel balance.

The problem is extended when new sources of gas oil consumption are found. For example, the recent development of an inventory for the UK's inland waterways requires the allocation of gas oil to this sector (Walker et al, 2011). During the process of compiling the inland waterways inventory, it became clear that not all vessels with diesel engines use gas oil, but use road diesel and that this may also be the case for other off-road machinery sources, especially those that consume small amounts of fuel on an irregular basis, e.g. for private or recreational use rather than commercial use. There are also inconsistencies in terminology used to define types of fuel; it became apparent that the terms "gas oil", "red diesel" and "diesel" are used interchangeably by fuel suppliers and consumers and this confuses the situation when considering fuel allocations across different sectors.

In light of this, Task 5 of the 2011 UK GHG Inventory Improvement Programme aimed to address the allocation of gas oil and DERV in the GHGI (Murrells et al., 2011). The methodology outlined in Murrells et al. (2011) was used in the compilation of the 2011 inventory, and is summarised here. The same approach has been used in this inventory.

Several fuel suppliers and experts in the petroleum industry and at the Department for Transport were consulted to understand terminologies used, the physical differences between gas oil and DERV, and to gauge opinions on what determines where the fuels are mainly used where it is possible to use either gas oil or DERV. The study concluded that while the majority of agricultural and industrial machinery will be using low tax gas oil (red diesel), a small amount of DERV is likely to be used by private recreational boat users and by equipment with small engines used for private or small-scale commercial use on an irregular basis and the gas oil fuel supply infrastructure makes it more convenient to use DERV.

The study provided new estimates of the amount of DERV and petrol consumed by non-road transport sources with small internal combustion engines. This reduces the overestimation of gas oil consumption and relieves the pressure on how much gas oil consumption by other sources has to be adjusted to match the total amount available as given in DUKES.

The study also considered the allocation of gas oil given in DUKES to different industry and other sectors and how these can be mapped to inventory reporting categories. The detailed bottom-up method is used to estimate gas oil consumption by different off-road machinery and marine vessel types. Independent sources were used to estimate gas oil used by the rail sector while data provided by industrial sites reporting under emission trading schemes (EU ETS) were used to derive an allocation of gas oil consumption by stationary combustion sources in different industry, commercial and other sectors. Also, the UK energy statistics now include an allocation of gas oil for consumption by the oil and gas sector, but since only a partial time series was made available, the study included making estimates of gas oil for this category back to 1990.

A method of re-allocation was developed using an over-arching condition that the total sum of gas oil consumption across all sectors was consistent with the total consumption figures given in DUKES across all years. The method allowed the consumption estimates for industrial off-road machinery and stationary combustion by industry, commercial and public sector activities to vary in order to align the total consumption estimates with DUKES on the basis that the estimates for these sources are the most uncertain.

The introduction of the results of a major research project into the shipping sector, whereby Automatic Identification System (AIS) data was used to calculate shipping movements along the coast of the UK and the Crown Dependencies, however suggested that gas oil consumption reported by DUKES is an underestimate, as discussed further in the main body of the report. As a result, total gas oil use (not including DERV) deviates from DUKES as any further consumption in the national navigation sector are considered additional to DUKES and are not reconciled elsewhere in the inventory.

Table A 4.2.5 below summarised the DUKES and GHGI allocations for the latest inventory year.

Table A 4.2.5 Fuel reconciliation – Gas oil use in latest year (Mtonnes)

DUKES Category	DUKES	GHGI	Difference	GHGI Category	CRF	Comment
Petroleum refineries	**0.000**	**0.000**	**0.000**	Refineries - combustion	1A1b	
Major power producers	0.045					
		0.045		Power stations - UK	1A1a	EU ETS
		0.002		Power stations - crown dependencies	1A1a	Local data sets
Autogenerators	0.044					
		0.002		Iron and steel - combustion plant	1A2a	
		0.000		Non-Ferrous Metal	1A2b	
		0.003		Chemicals	1A2c	
		0.001		Pulp, Paper and Print	1A2d	
		0.001		Food & drink, tobacco	1A2e	
Industry	1.580					
		0.047		Other industrial combustion - UK	1A2g	
		0.000		Other industrial combustion - crown dependencies	1A2g	
		0.008		Cement production - combustion	1A2f	Operator data
		0.161		Aircraft - support vehicles	1A3e	IA estimates
		1.327		Industrial off-road mobile machinery	1A2g	IA estimates
Commercial	0.378					
Miscellaneous	0.261					
		0.031		Miscellaneous combustion - UK	1A4a	Reduced to offset higher consumption elsewhere
		0.007		Miscellaneous combustion - crown dependencies	1A4a	Reduced to offset higher consumption elsewhere
Public administration	0.303	0.020		Public sector combustion	1A4a	Reduced to offset higher consumption elsewhere
Agriculture	0.337					
		1.254		Agriculture - mobile machinery	1A4c	IA estimates
Rail	0.578					
		0.614		Railways	1A3c	IA estimates
	3.525	**3.525**	**0.000**			
		0.058		Upstream Gas Production - fuel combustion	1A1c	

DUKES Category	DUKES	GHGI	Difference	GHGI Category	CRF	Comment
		0.541		Upstream Oil Production - fuel combustion	1A1c	
Oil & gas extraction	0.599					
	0.599	**0.599**	**0.000**			
National navigation	0.602	1.233		Shipping - coastal	1A3d	Bottom-up AIS approach estimates greater gas oil and is considered additional to DUKES.
		0.164		Fishing vessels	1A4c	
		0.006		Shipping between UK and CDs	1A3d	
		0.137		Shipping - naval	1A5b	
		0.045		Motorboats / workboats	1A3d	
		0.002		Inland goods-carrying vessels	1A3d	
Marine bunkers	1.770	1.770		Shipping - international IPCC definition	0.000	
	2.373	**3.357**	**-0.985**			**Difference reflects the 2017 UK shipping study: higher fuel use from bottom-up analysis than in DUKES.**
		0.011		House and garden machinery - DERV	1A4b	IA estimates
		0.299		Industrial off-road mobile machinery - DERV	1A2g vii	IA estimates
		0.002		Sailing boats with auxiliary engines	1A3d	IA estimates
		0.107		Motorboats / workboats (e.g. canal boats, dredgers, service boats, tourist boats, river boats)	1A3d	IA estimates
		24.185		Road transport - UK	1A3b	Reduced to offset consumption from off-road and other sources
		0.045		Road transport - crown dependencies	1A3b	
Road	**24.648**	**24.648**	**0.000**			
		0.135		Domestic combustion - UK	1A4b	
		0.007		Domestic combustion - crown dependencies	1A4b	
Domestic	**0.141**	**0.142**	**0.000**			
TOTAL	**31.286**	**32.271**	**-0.985**			

Notes: Shaded rows indicate a comparison between fuel use between DUKES and GHGI. Total includes marine bunkers

A 4.2.1.5 Petroleum gases

For petroleum gases (LPG, OPG), the total fuel use in the inventory is greater than the national statistics in several years, to reflect information from other sources (such as EU ETS data) that indicate potential under-reports in the UK energy statistics. These modifications to the energy balance are set out in **Table A 4.2.6.** They mostly relate to refineries, use of feedstock as fuel in the petrochemicals sector, and fuel use for upstream oil and gas production.

Table A 4.2.6 Fuel reconciliation – Use of petroleum gases in the latest year (Mtherms)

DUKES Sector	DUKES	GHGI	Difference	GHGI sector	CRF	Comment
Petroleum refineries, other gases	903					
Autogenerators, other gases	117					
		1128		Refineries, OPG	1A1b	OPG total inferred from EU ETS dataset. This is slightly larger than the reported DUKES value
	1021	**1128**	**-107**			
Petroleum refineries, propane	**4**	**4**	**0**	Refineries, LPG	1A1b	
Iron & steel, propane	**0**	**0**	**0**	Iron & steel combustion, LPG	1A2a	
Industry, propane	144					
Industry, butane	36					
Agriculture, propane	42					
Agriculture, butane	0					
Commercial, propane	157					
Commercial, butane	1					
Public administration, propane	8					
		387		Industrial combustion, LPG - UK	1A2g	
		0		Industrial combustion, LPG - crown dependencies	1A2g	
	388	**387**	**1**			
Industry, other gases	**0**	**513**	**-513**	Chemicals, OPG	2B8g	Operator data (EU ETS) on use of process off-gases and residues
Road, propane	**33**	**33**	**0**	Road transport - all vehicles LPG use	1A3b	
Domestic, propane	100					
Domestic, butane	0					
		95		Domestic combustion, LPG - UK	1A4b	
		5		Domestic combustion, LPG - crown dependencies	1A4b	
	101	**100**	**1**			
(excluded from DUKES)		**114**	**-114**	Gas separation plant, OPG	1A1c	EEMS. Outside scope of DUKES

DUKES Sector	DUKES	GHGI	Difference	GHGI sector	CRF	Comment
(excluded from DUKES)		**6**	**-6**	Gas separation plant, LPG	1A1c	EEMS. Outside scope of DUKES
Total	**1548**	**2285**	**-738**			

Notes: Sequences of shaded rows indicate categories which are grouped for purposes of data reconciliation, and should be considered together.

1 Mtherm = 105.51 TJ

ANNEX 5: Additional Information to be Considered as Part of the Annual Inventory Submission and the Supplementary Information Required Under Article 7, paragraph 1, of the Kyoto Protocol Other Useful Reference Information.

A 5.1 ANNUAL INVENTORY SUBMISSION

No additional information.

A 5.2 SUPPLEMENTARY INFORMATION UNDER ARTICLE 7, PARAGRAPH 1

No additional information.

ANNEX 6: Verification

This Annex discusses the verification of the UK estimates of the Kyoto Gases.

A 6.1 MODELLING APPROACH USED FOR THE VERIFICATION OF THE UK GHGI

Verification of the UK GHGI is considered to be best practice by the UNFCCC as it allows for an independent assessment of the GHG emissions from the UK using a comprehensively different approach. Significant differences in the emissions estimated using the two methods are a means of identifying areas worthy of further investigation, for example as occurred with a re-assessment of the emissions of HFC-134a from mobile air conditioning.

In order to provide verification of the UK Greenhouse Gas Inventory (GHGI), BEIS (Department of Business, Energy, Innovation and Strategy) established and maintain a high-quality remote observation station at Mace Head (MHD) on the west coast of Ireland. The station reports high-frequency concentrations of the key greenhouse gases and is under the supervision of Prof. Simon O'Doherty of the University of Bristol (O'Doherty *et al.* 2004). BEIS extended the measurement programme in 2012 with three new tall tower stations across the UK (collectively called the UK DECC (Deriving Emissions linked to Climate Change) network): Tacolneston (TAC) near Norwich; Ridge Hill (RGL) near Hereford; and Tall Tower Angus (TTA) near Dundee, Scotland which relocated to Bilsdale (BSD) in North Yorkshire in Sept 2015. Methane (CH_4), carbon dioxide (CO_2), nitrous oxide (N_2O) and sulphur hexafluoride (SF_6) are measured across the UK DECC network, whereas the hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and nitrogen trifluoride (NF_3) are only measured at MHD and TAC.

The Met Office, under contract to BEIS, employs the Lagrangian dispersion model NAME (Numerical Atmospheric dispersion Modelling Environment) (Ryall *et al*. 1998, Jones *et al*. 2007) driven by three-dimensional modelled meteorology to interpret the observations. NAME determines the history of the air arriving at Mace Head at the time of each observation. By estimating the underlying *baseline* trends (Northern Hemisphere mid-latitude atmospheric concentrations where the short-term impact of regional pollution has been removed from the data) and by modelling where the air has passed over on route to the observation stations on a regional scale, estimates of UK emissions are made. A methodology called Inversion Technique for Emission Modelling (InTEM) has been developed that uses a minimisation technique, Non-Negative Least Squares (NNLS) (Lawson and Hanson, 1974) to determine the emission map that most accurately reproduces the observations (Manning *et al.* 2003, 2011 and Arnold *et al.* 2017).

In the work presented in this Chapter both the NAME *baseline* trends and the UK emission estimates are presented. InTEM estimates using only Mace Head (MHD) data are presented along with the estimates made using the full UK DECC network. In 2014 two additional tower sites, Heathfield (HFD) south of London and Bilsdale (BSD) in North Yorkshire, were established through the NERC GAUGE (Global And UK Greenhouse gas Emissions) programme and have been included in the emission estimates. HFD is now operated by NPL who have generously provided the observation data. For CH_4 only, a further dataset from the tall tower station at Cabauw in The Netherlands has been included courtesy of ECN, The Netherlands. When only MHD data are used a three-year inversion window is assumed (an inversion is performed for a three year period and then the period is incremented by one-month e.g. Mar 1989 – Feb 1992, Apr 1998 – Mar 1993 etc., from which a median for each year is estimated), however with the additional data from the other stations the inversion time window has been shortened to two years or smaller (6 months for CH_4, N_2O and SF_6) depending on data availability (similarly incremented by one month and the median emission calculated). The geographical spread of the UK DECC (and other stations) network allows the spatial distribution of the emissions across the UK to be better constrained within InTEM. The 'top-down' InTEM estimates of UK emissions are compared to the 'bottom-up' GHGI estimates.

A 6.2 METHANE

Figure A 6.1 Monthly Northern Hemisphere trend in methane estimated from Mace Head observations (blue line). Red line denotes the annual trend. Data under grey shading are not yet ratified.

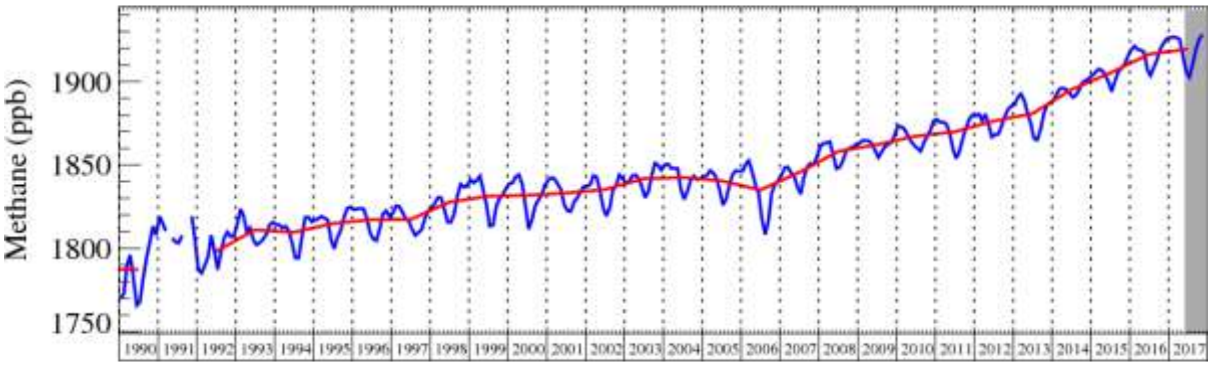


Figure A 6.2 Verification of the UK emission inventory estimates for methane in Gg yr^{-1} from 1990. GHGI estimates are shown in black. InTEM (MHD+CBW, 3-year) estimates are shown in brown (1σ uncertainty in yellow). InTEM (DECC, 6-mth) estimates are shown in red.

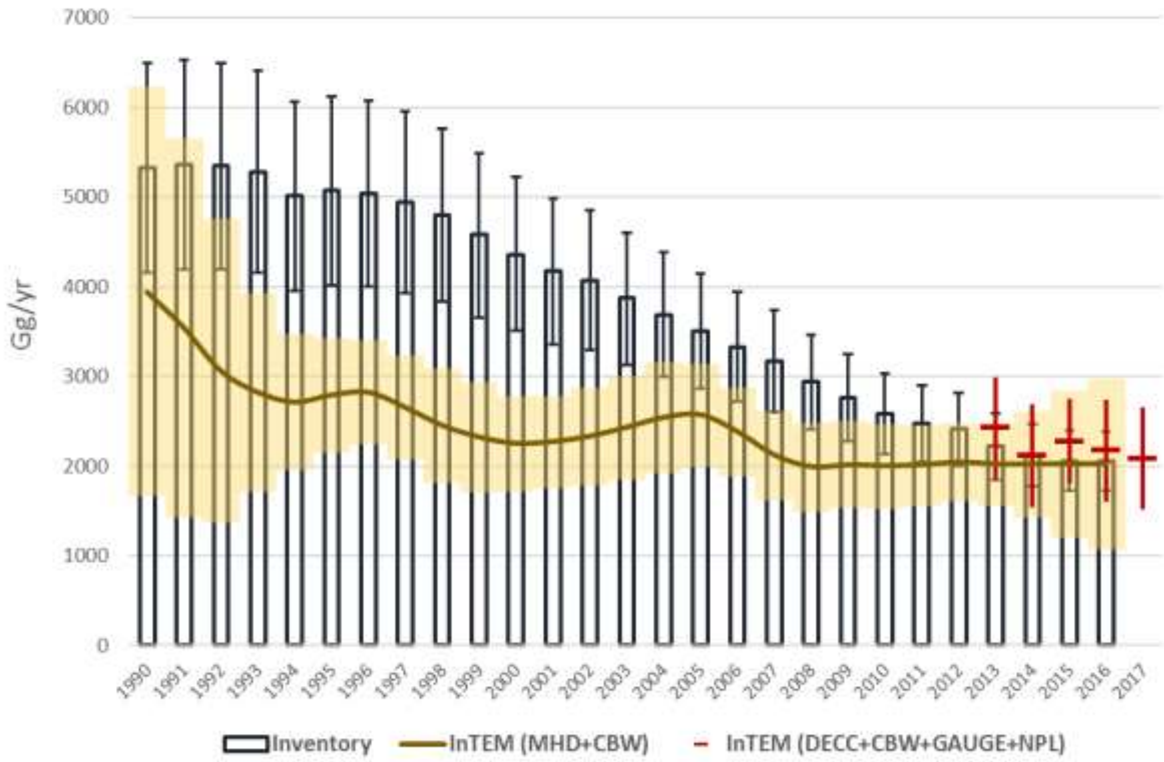


Figure A 6.1 shows the Northern Hemisphere baseline atmospheric concentration of methane from 1990 onwards. As with all of the baseline plots for the different gases, it shows how the overall atmospheric concentration of the gas in question is changing in the atmosphere as a result of global emissions and atmospheric loss processes. For CH_4, the underlying baseline trend is positive but there is strong year-to-year variability and a strong seasonal cycle. The growth rate over the last 10 years has been unusually and consistently positive (average +8 ppb/yr).

The emission estimates made for the UK using the InTEM methodology are compared to the GHGI emission estimates for the period 1990 onwards. It is interesting to note that although the UK methane emissions are estimated to have fallen over the last 26 years, the global atmospheric concentration of methane has increased, indicating that global emissions of methane are still outperforming the global natural removal of methane from the atmosphere.

Methane has a natural (biogenic) component and it is estimated that 22% of the annual global emission is released from wetlands (Nilsson *et al*. 2001). Usually natural emissions are strongly dependent on a range of meteorological factors such as temperature and also growth and decay cycles. Such non-uniform emissions will add to the uncertainties in the modelling, although in North West Europe the natural emissions are thought to be small compared to the anthropogenic emissions (<5%, Bergamaschi *et al* 2005). Due to the relatively strong local (within 20km) influence of biogenic emissions at some of the stations the influence of observations taken when local emissions are thought to be significant (low boundary layer heights and low wind speeds) has been reduced within InTEM by removing all observations taken during such meteorological conditions.

The GHGI trend is monotonically downwards whereas the InTEM estimates, after an initial fall, shows little change (Figure A 6.2). The InTEM estimates using all of the available observations (MHD+CBW+DECC+GAUGE) are consistent with the MHD+CBW estimates.

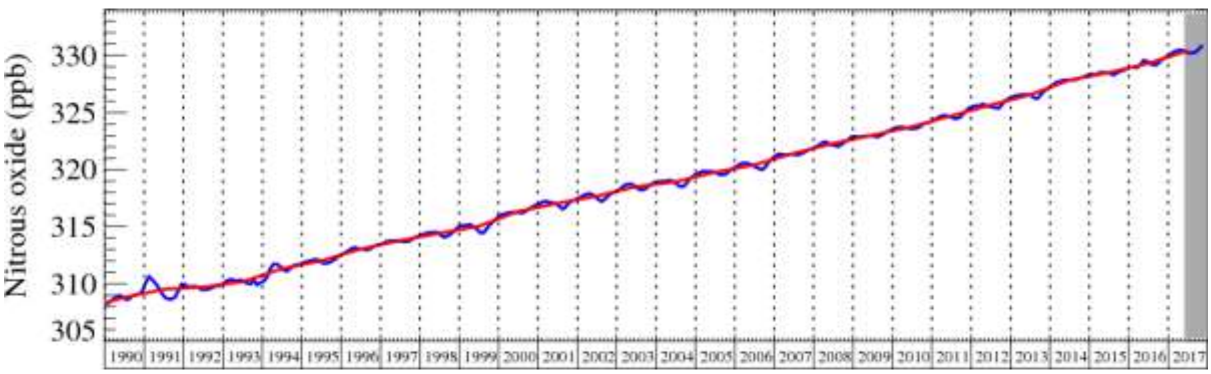
A 6.3 NITROUS OXIDE

Figure A 6.3 shows the Northern Hemisphere baseline atmospheric concentration of nitrous oxide (N_2O) from 1990 onwards. The baseline trend is monotonic and positive. In 2016, the baseline increased by 1.0 ppb.

The main activities in Europe resulting in the release of nitrous oxide are agricultural practices resulting in emissions from soils (~60%), chemical industry (~20%) and combustion (~15%) (UNFCCC 1998 figures). The amount emitted from soils has significant uncertainty and has a diurnal and seasonal release cycle. It is driven by the availability of nitrogen, temperature and the soil moisture content.

Figure A 6.4 shows the InTEM and GHGI emission estimates for nitrous oxide for the period 1990 onwards for the UK. The annual InTEM estimates are similar to the GHGI estimates, with both showing declining UK totals. The InTEM estimates are higher than the GHGI post 2000 although well within the 1σ uncertainty. The GHGI estimates show a sharp decline (40 Gg) between 1998 and 1999 in line with the introduction of clean technology at an adipic acid plant in Wilton, north east England. It is estimated to have cut its emissions of N_2O by 90%, from 46 thousand tonne yr^{-1} to around 6 thousand tonne yr^{-1}. The InTEM estimates show a more gradual decline over this period (expected due to the long 3-year inversion time periods) but the overall reduction is similar. The estimates using all available observations are very similar to the MHD-only estimates. Post-2012 the InTEM estimates are notably higher than the GHGI estimates. The improved network of observations from 2013 onwards allows a strong seasonal cycle in emissions to be highlighted, Figure A 6.5 There is a clear peak in UK emissions in spring-summer. This is aligned with the traditional fertiliser application period.

Figure A 6.3 Monthly Northern Hemisphere trend in nitrous oxide estimated from Mace Head observations (blue line). Red line denotes the annual trend. Data under grey shading are not yet ratified.



The nature of the nitrous oxide emissions challenges the InTEM assumption of uniformity of release both in time and space. Also the point of release to the atmosphere may not be coincident with the activity generating the nitrous oxide e.g. the nitrous oxide may be transported from its source, for example by rivers, prior to its release to the atmosphere.

Figure A 6.4 **Verification of the UK emission inventory estimates for nitrous oxide in Gg yr^{-1} from 1990. GHGI estimates are shown in black. InTEM (MHD-only, 3-year) estimates are shown in brown (1σ uncertainty in yellow). InTEM (DECC+GAUGE) estimates are shown in red.**

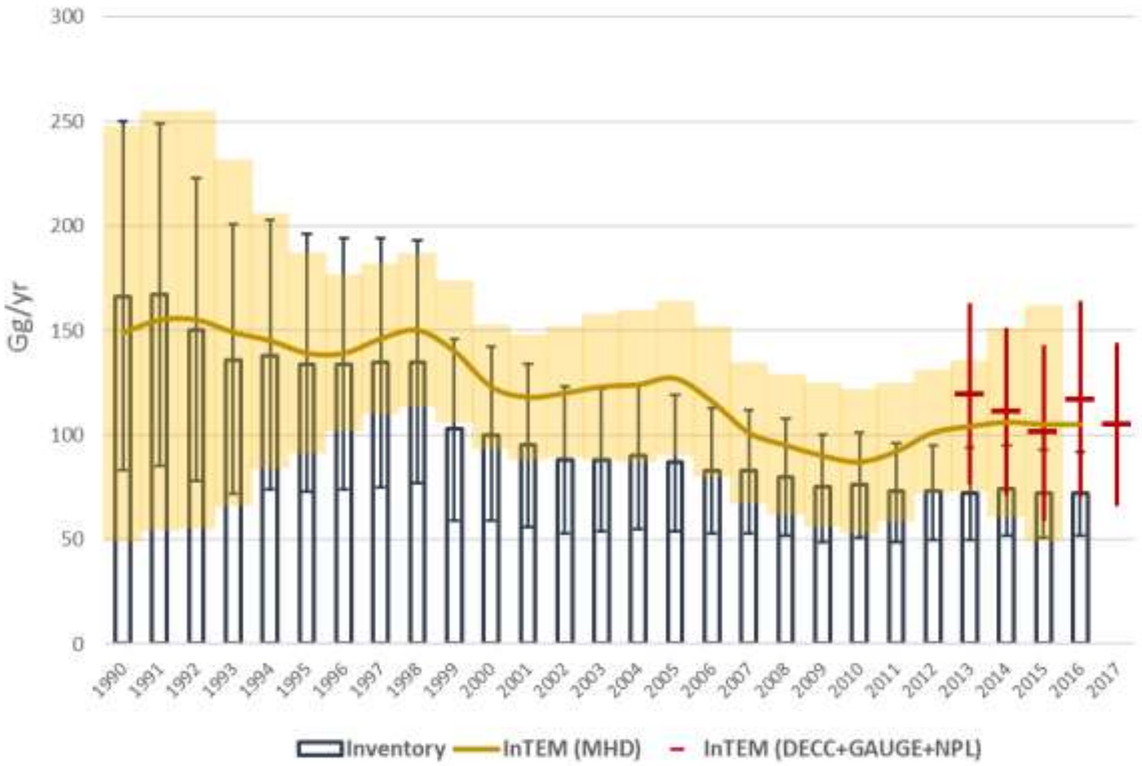
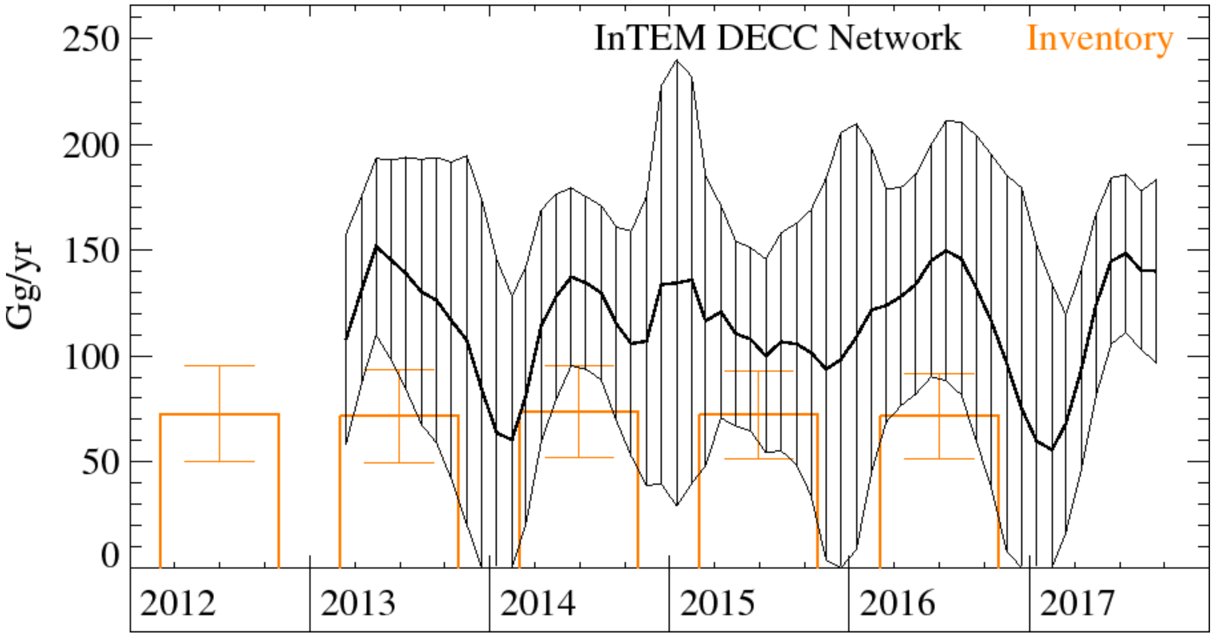


Figure A 6.5 Verification of the UK emission inventory estimates for nitrous oxide in Gg yr^{-1} from 2013. GHGI estimates are shown in orange. (DECC+GAUGE+NPL) estimates are shown in back (1σ uncertainty).



A 6.4 HYDROFLUOROCARBONS

A 6.4.1 HFC-134a

Figure A 6.6 Monthly Northern Hemisphere trend in HFC-134a estimated from Mace Head observations (blue line). Red line denotes the annual trend. Data under grey shading are not yet ratified.

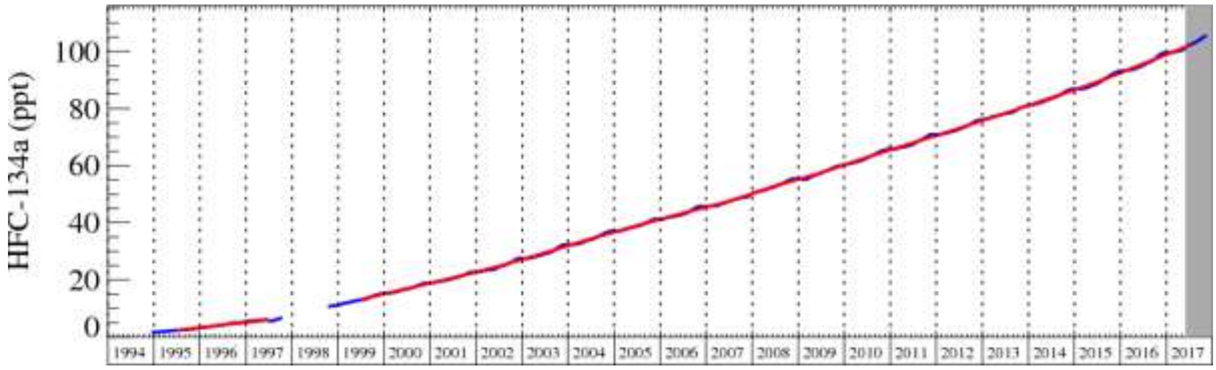


Figure A 6.6 shows the Northern Hemisphere baseline atmospheric concentration of HFC-134a from 1995 onwards. The baseline trend is monotonic and positive, in 2016 the baseline increased by 6.5 ppt.

Figure A 6.7 Verification of the UK emission inventory estimates for HFC-134a in Gg yr^{-1} from 1990. GHGI estimates are shown in black. InTEM (MHD-only, 3-year) estimates are shown in brown (1σ uncertainty in yellow). InTEM (DECC, 2-year) estimates are shown in red.

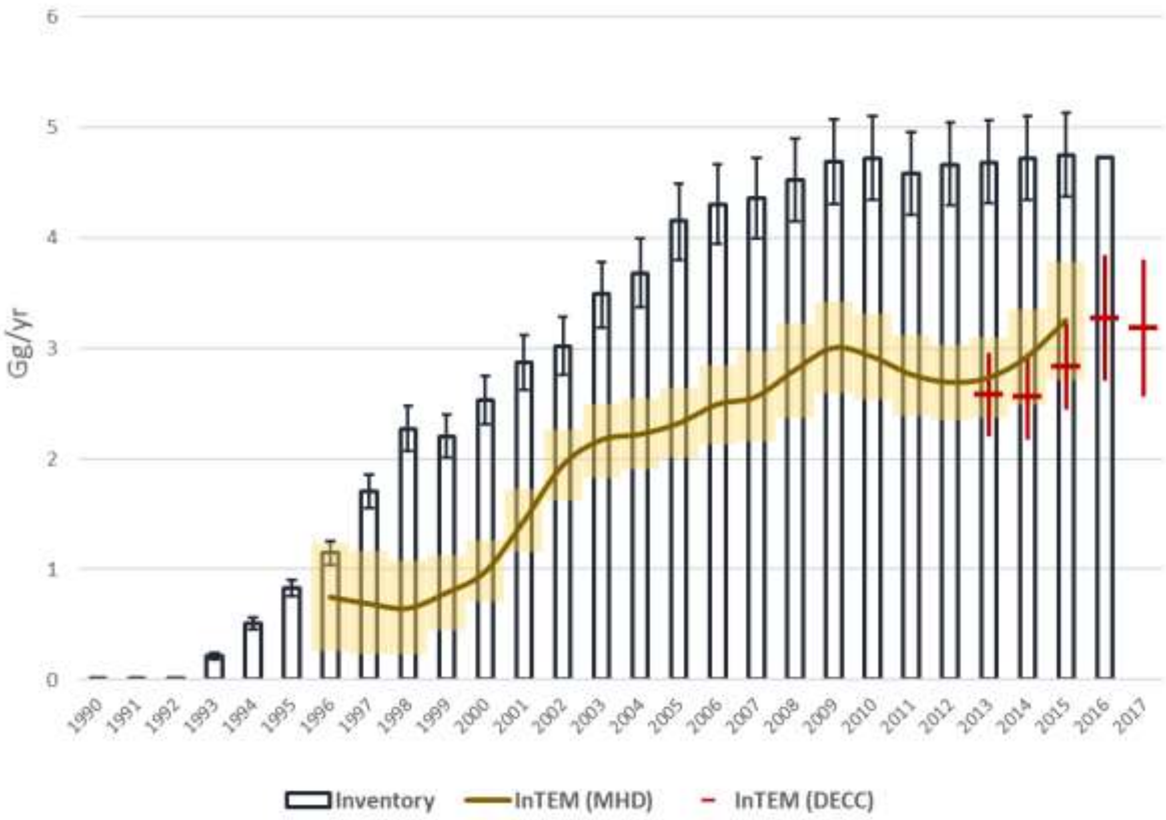


Figure A 6.7 shows the InTEM and GHGI emission estimates for the UK for HFC-134a for the period 1990 onwards. The GHGI shows a stronger increase in emission compared to the InTEM estimates. The InTEM estimates have risen at about 70% of the rate of the GHGI. Throughout the time series there is poor magnitude, but good trend, agreement between the GHGI and InTEM, with the InTEM estimates consistently about 70% of the GHGI estimates and well outside both uncertainty ranges. A similar result is obtained when the TAC observations are included (from 2013) within InTEM.

A 6.4.2 HFC-152a

Figure A 6.8 Monthly Northern Hemisphere trend in HFC-152a estimated from Mace Head observations (blue line). Red line denotes the annual trend. Data under grey shading are not yet ratified.

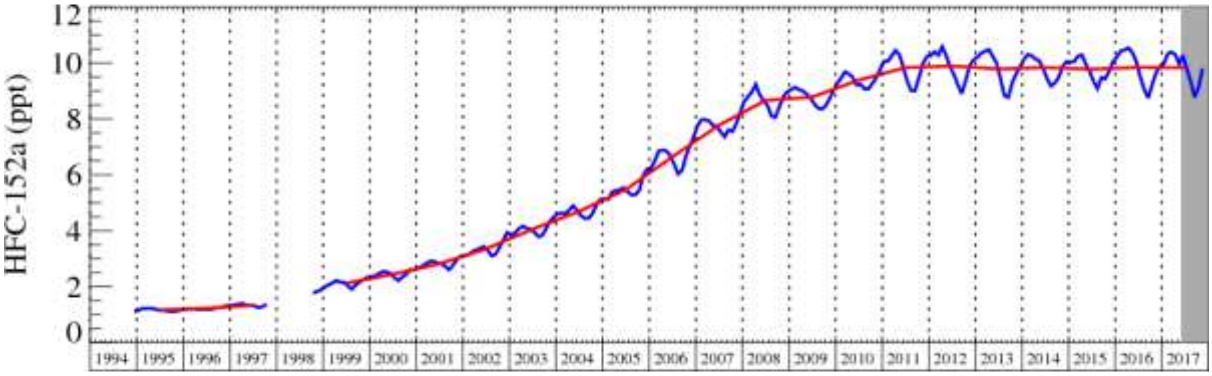


Figure A 6.8 shows the Northern Hemisphere baseline atmospheric concentration of HFC-152a from 1995 onwards. The baseline trend shows a strong rise from the mid-1990s until 2008, then a much reduced annual increase until 2012. From 2012 onwards a small decline is observed, a result seen globally (Simmonds et al, 2016).

Figure A 6.9 Verification of the UK emission inventory estimates for HFC-152a in Gg yr^{-1} from 1990. GHGI estimates are shown in black. InTEM (MHD-only, 3-year) estimates are shown in brown (1σ uncertainty in yellow blue). InTEM (DECC, 2-year) estimates are shown in red.

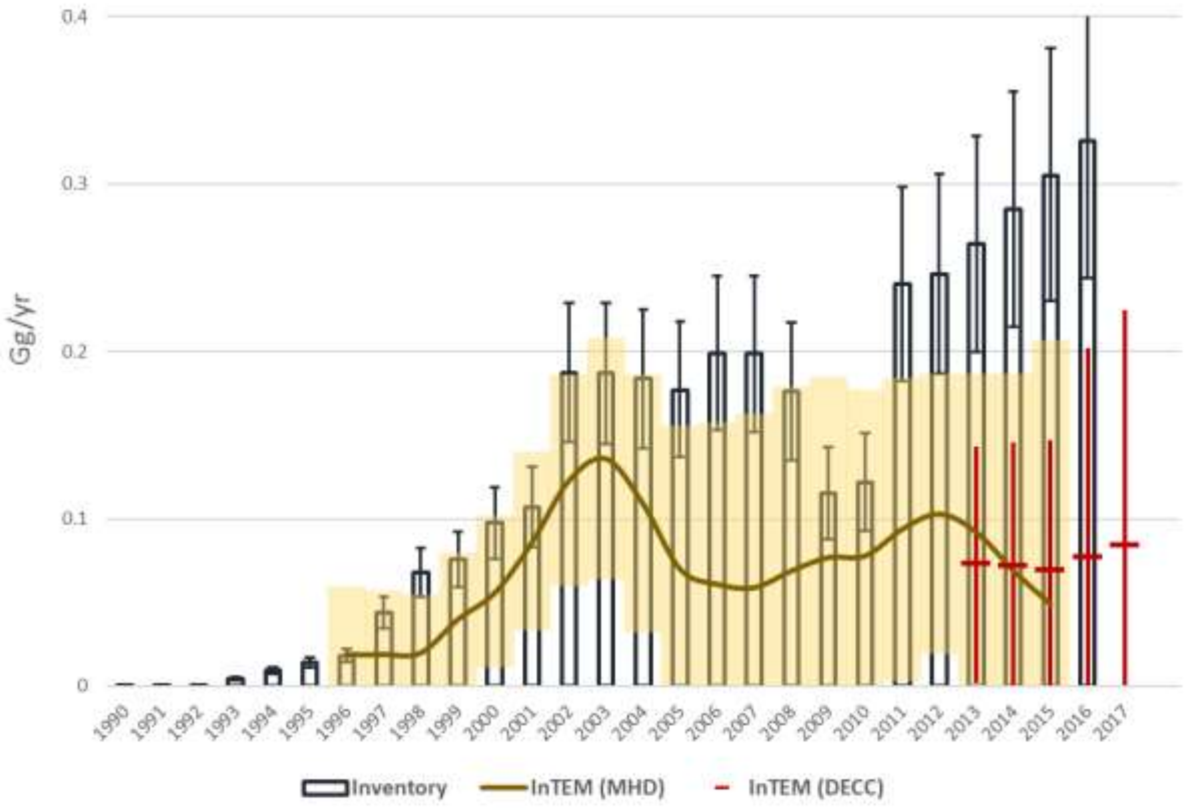


Figure A 6.9 shows the InTEM and the GHGI emission estimates for the UK for HFC-152a for the period 1990 onwards. Between 2005-2007 and from 2011 onwards the GHGI estimates are significantly larger than those estimated through the inversion modelling. The InTEM estimates are consistently on the lower side compared to the GHGI estimates with larger uncertainties. It is also interesting to note the trend from 2011 until 2016 where the UK GHGI is positive, conflicting with the flat/declining UK InTEM trend. The UK DECC network estimates are consistent with the MHD-only estimates.

A 6.4.3 HFC-125

Figure A 6.10 shows the Northern Hemisphere baseline atmospheric concentration of HFC-125 from 1998 onwards. The baseline trend is monotonic and exponentially increasing, in 2016 the baseline increased by 2.7 ppt.

Figure A 6.10 Monthly Northern Hemisphere trend in HFC-125 estimated from Mace Head observations (blue line). Red line denotes the annual trend. Data under grey shading are not yet ratified.

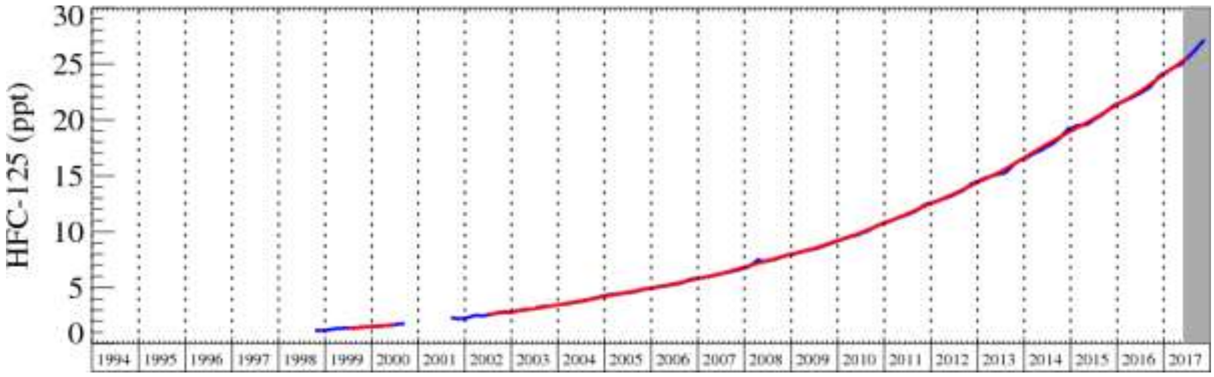
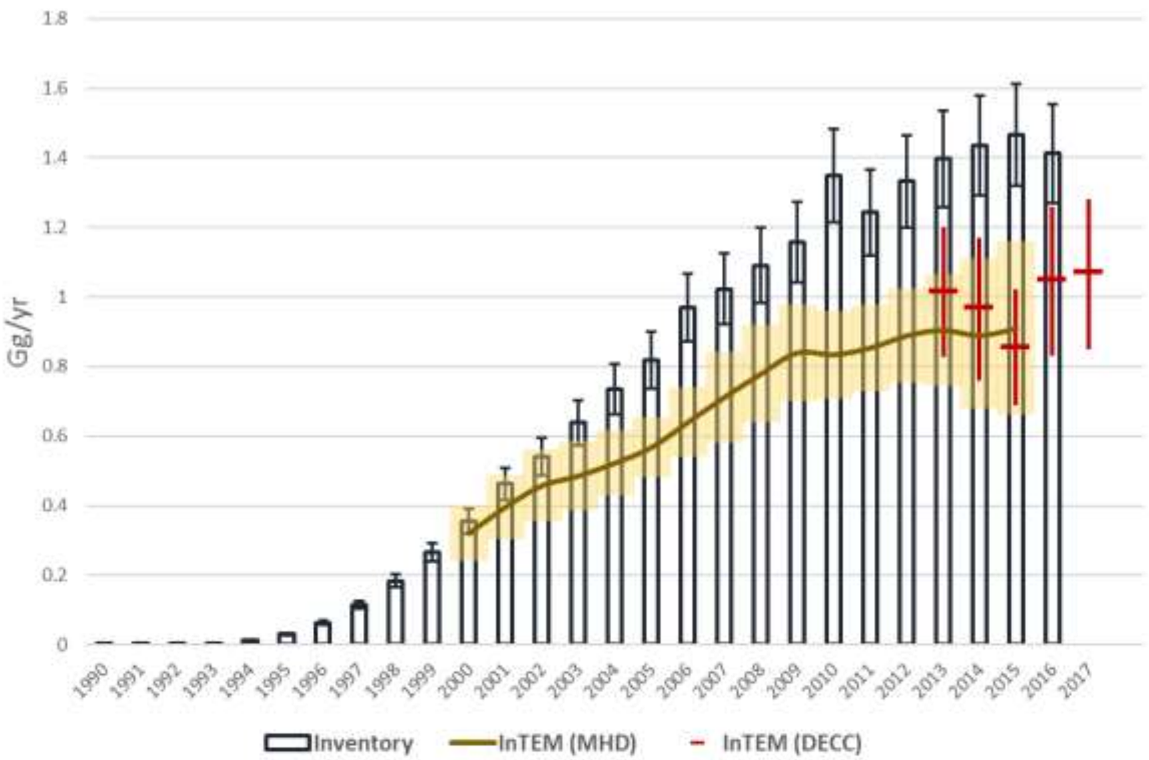


Figure A 6.11 Verification of the UK emission inventory estimates for HFC-125 in Gg yr^{-1} from 1990. GHGI estimates are shown in black. InTEM (MHD-only, 3-year) estimates are shown in brown (1σ uncertainty in yellow). InTEM (DECC, 2-year) estimates are shown in red.



InTEM emission estimates for the UK for HFC-125 for the period 1999 onwards are shown in Figure A 6.11. Both the InTEM and UK GHGI estimates suggest that the emissions of HFC-125 from the UK have increased significantly from the 1990s. The InTEM estimates are consistently lower than those from the GHGI (by ~30%) and the uncertainties do not overlap. The introduction of the TAC data shows consistency with the MHD-only estimates.

A 6.4.4 HFC-143a

Figure A 6.12 shows the Northern Hemisphere baseline atmospheric concentration of HFC-143a from 2004 onwards. The baseline trend is positive, in 2016 it increased by 1.7 ppt.

Figure A 6.12 Monthly Northern Hemisphere trend in HFC-143a estimated from Mace Head observations (blue line). Red line denotes the annual trend. Data under grey shading are not yet ratified.

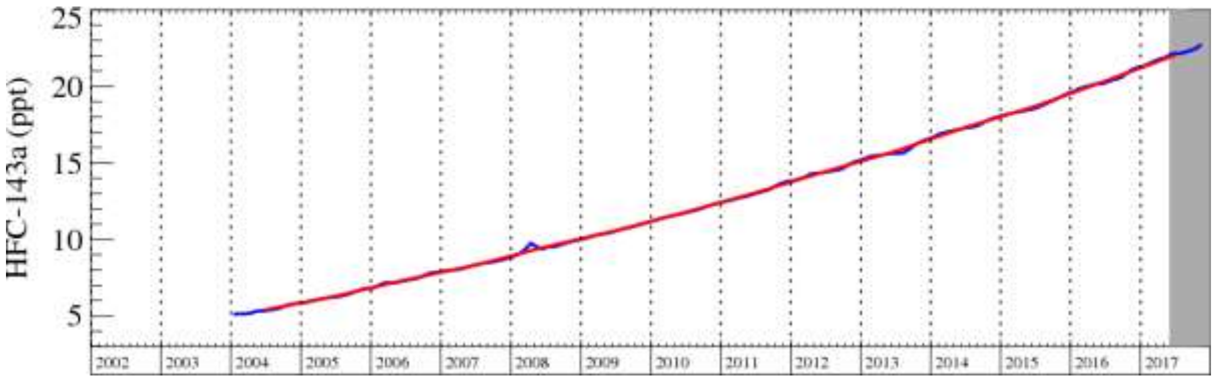
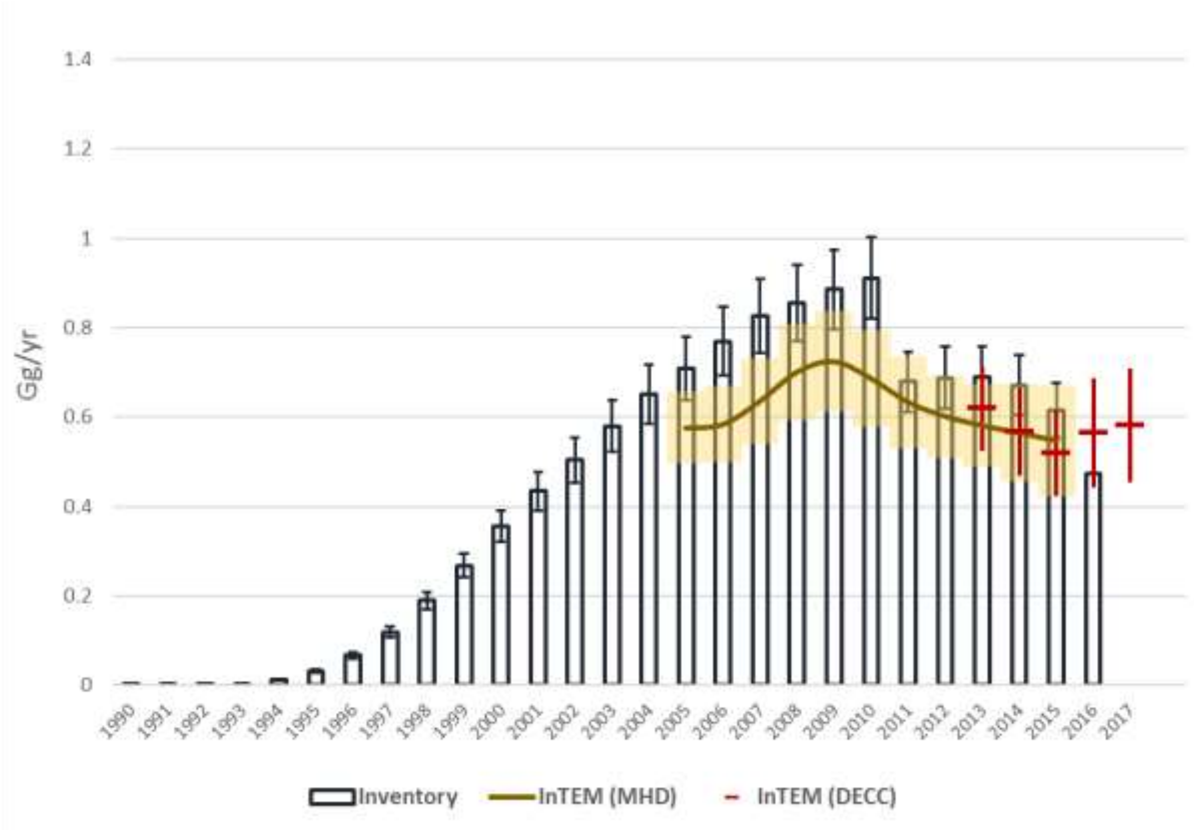


Figure A 6.13 Verification of the UK emission inventory estimates for HFC-143a in Gg yr^{-1} from 1990. GHGI estimates are shown in black. InTEM (MHD-only, 3-year) estimates are shown in brown (1σ uncertainty in yellow). InTEM (DECC, 2-year) estimates are shown in red.



InTEM emission estimates for the UK for HFC-143a for the period 2005 onwards are shown in Figure A 6.13 and are compared to the GHGI estimates. UK emissions, as estimated by the GHGI, have increased year on year from the early 1990s until 2010 when a sharp decline is estimated. The InTEM estimates show a slow rise during this period but are consistently lower than the GHGI estimates. From 2011 onwards the agreement is very good. The estimates with the DECC network (i.e. including TAC data) are consistent with those from MHD-only. There is another sharp decline in GHGI emissions in 2016, a change that is not estimated by InTEM.

A 6.4.5 HFC-23

Figure A 6.14 shows the Northern hemisphere baseline atmospheric concentration of HFC-23 from 2008 onwards. The baseline trend is monotonic and positive, in 2016 the baseline increased by 0.8 ppt.

InTEM emission estimates for the UK for HFC-23 from 2009 are higher than the low emissions estimated by the GHGI for this period. The introduction of the TAC emissions in 2013 re-enforces this finding, albeit the emissions are very small (Figure A 6.15).

Figure A 6.14 Monthly Northern Hemisphere trend in HFC-23 estimated from Mace Head observations (blue line). Red line denotes the annual trend. Data under grey shading are not yet ratified.

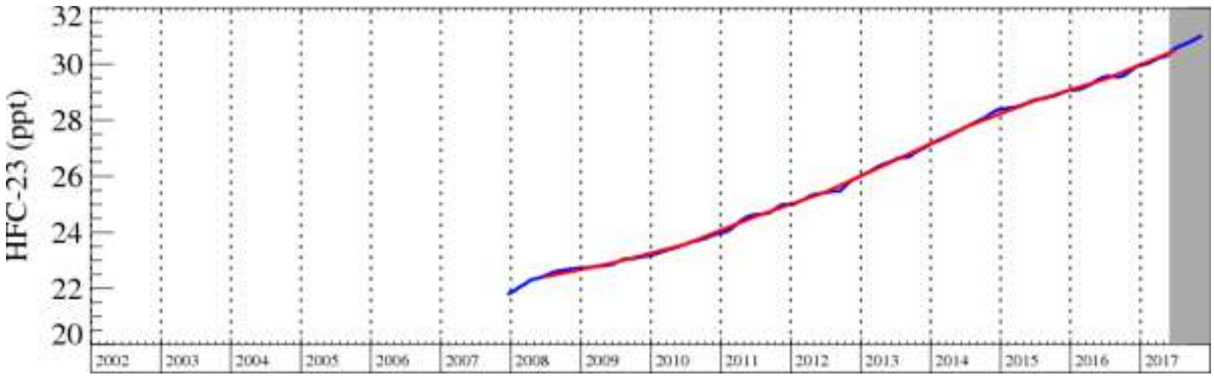
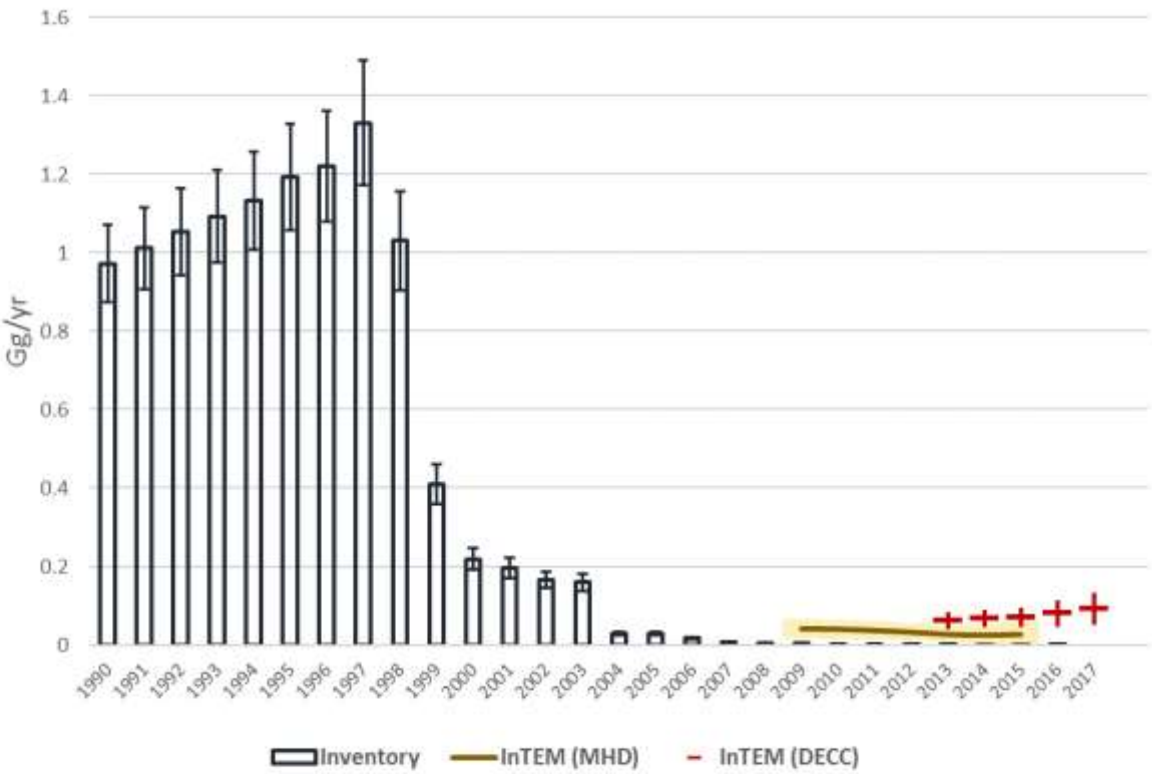


Figure A 6.15 Verification of the UK emission inventory estimates for HFC-23 in Gg yr^{-1} from 1990. GHGI estimates are shown in black. InTEM (MHD-only, 3-year) estimates are shown in brown (1σ uncertainty in yellow). InTEM (DECC, 2-year) estimates are shown in red.



A 6.4.6 HFC-32

Figure A 6.16 shows the Northern Hemisphere baseline atmospheric concentration of HFC-32 from 2004 onwards. The baseline trend is monotonic and positive, in 2016 the baseline increased by 2.5 ppt.

InTEM emission estimates for the UK for HFC-32 for 2004 onwards are shown in Figure A 6.17. The InTEM emission estimates are lower than the GHGI estimates. Both trends are positive but the rate of increase of the GHGI is larger than the InTEM estimates. By 2015 the GHGI estimated emissions are significantly (~70%) larger than those estimated by InTEM. The DECC network InTEM estimates show a slight decline and then rise but are broadly consistent with the MHD-only InTEM estimates.

Figure A 6.16 Monthly Northern Hemisphere trend in HFC-32 estimated from Mace Head observations (blue line). Red line denotes the annual trend. Data under grey shading are not yet ratified.

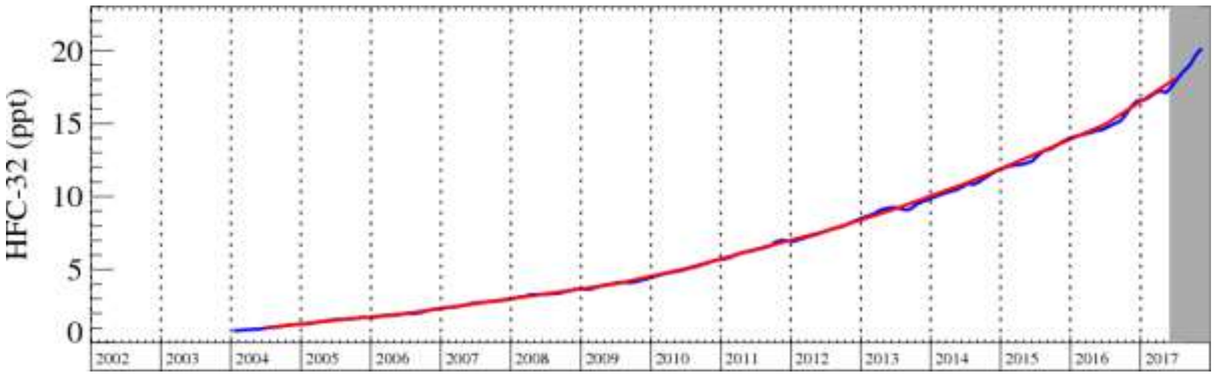
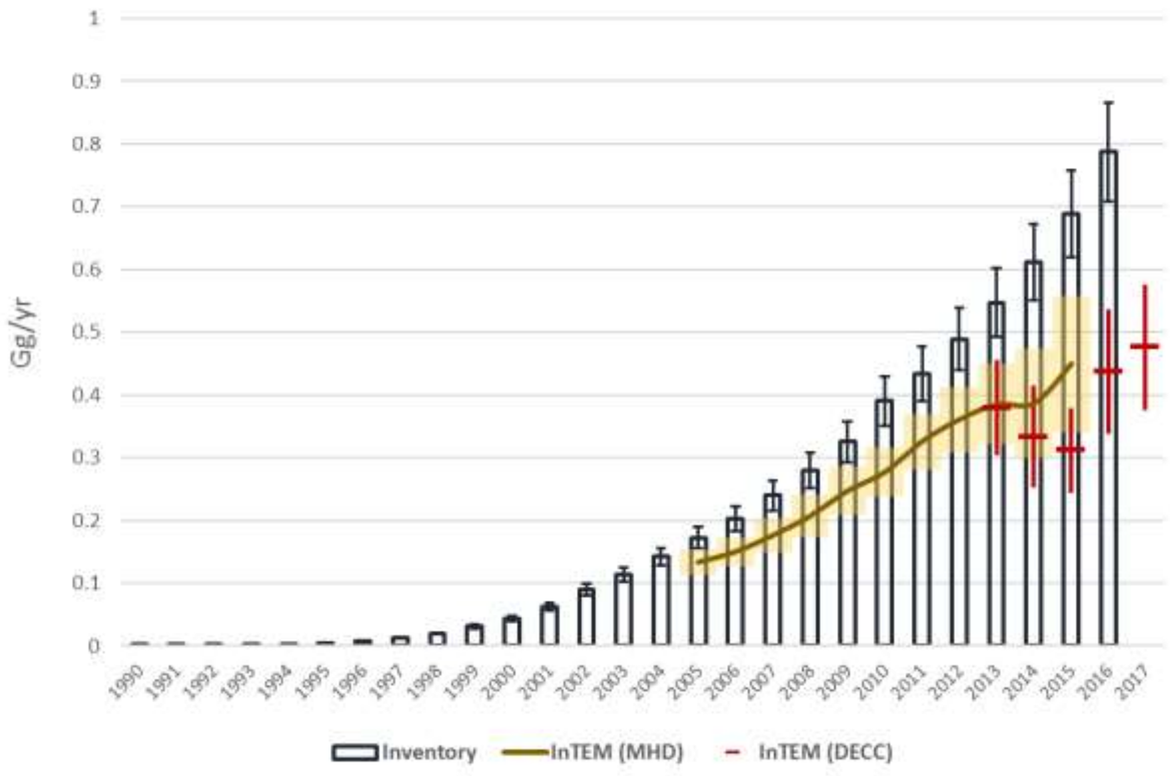


Figure A 6.17 Verification of the UK emission inventory estimates for HFC-32 in Gg yr^{-1} from 1990. GHGI estimates are shown in black. InTEM (MHD-only, 3-year) estimates are shown in brown (1σ uncertainty in yellow). InTEM (DECC, 2-year) estimates are shown in red.



A 6.4.7 HFC-43-10mee

Figure A 6.18 shows the Northern Hemisphere baseline atmospheric concentration of HFC-43-10mee from 2011 onwards. There is a slight positive trend in the baseline with a growth rate of ~0.01 ppt yr^{-1}. The UK emissions of this gas are small. The GHGI estimates are significantly higher (factor of 10) than those estimated by InTEM. The DECC network InTEM estimates are consistent with the MHD-only InTEM estimates.

Figure A 6.18 Monthly Northern Hemisphere trend in HFC-43-10mee estimated from Mace Head observations (blue line). Red line denotes the annual trend. Data under grey shading are not yet ratified.

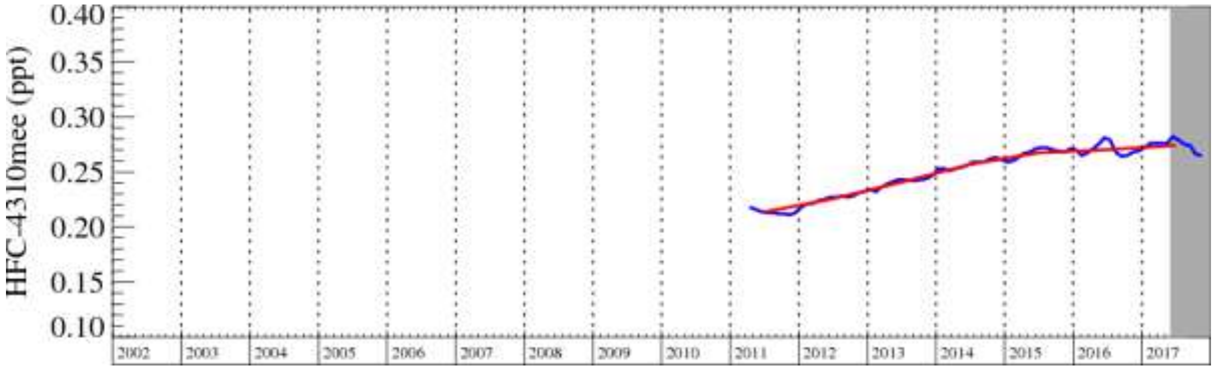
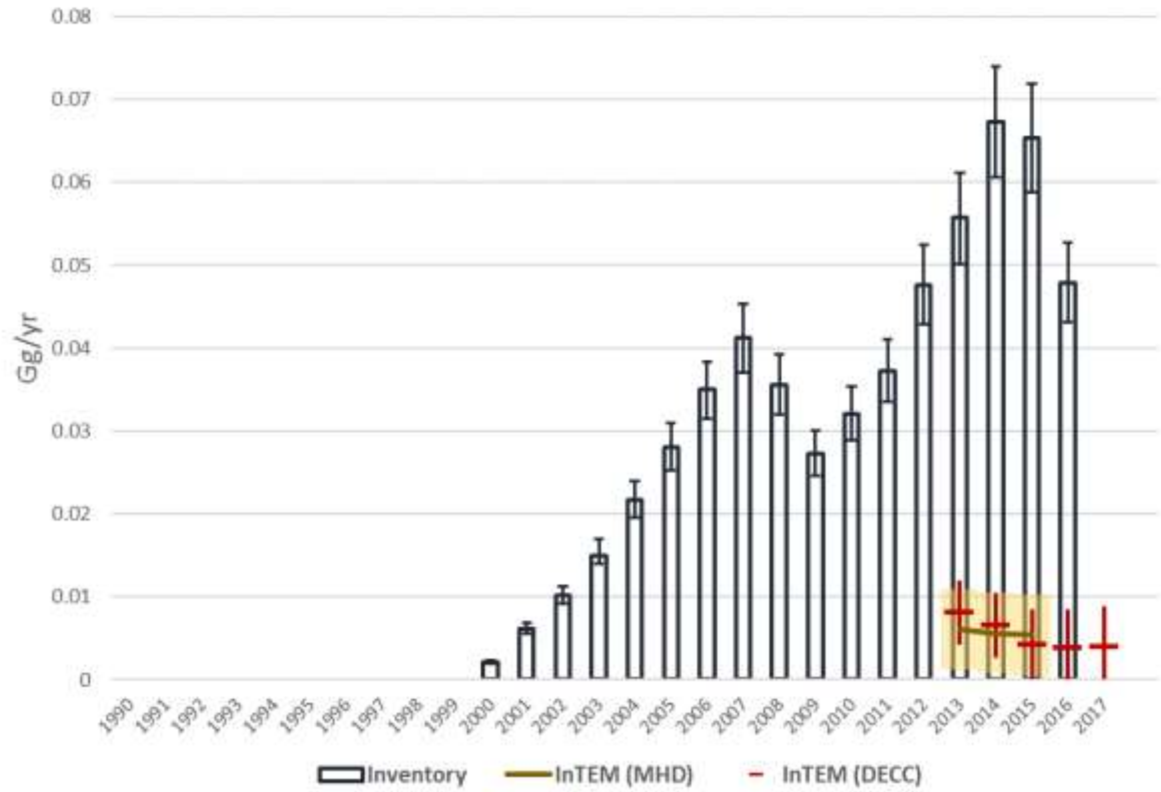


Figure A 6.19 Verification of the UK emission inventory estimates for HFC-43-10mee in Gg yr^{-1} from 1990. GHGI estimates are shown in black. InTEM (MHD-only, 3-year) estimates are shown in brown (1σ uncertainty in yellow). InTEM (DECC, 2-year) estimates are shown in red.



A 6.4.8 HFC-227ea

Figure A 6.20 shows the Northern Hemisphere baseline atmospheric concentration of HFC-227ea from 2007 onwards. There is a positive trend in the baseline; in 2016 it increased by 0.1 ppt. The GHGI estimates are significantly (~80%) higher than those obtained through inversion modelling. Both the GHGI and InTEM estimate increasing UK emissions.

Figure A 6.20 Monthly Northern Hemisphere trend in HFC-227ea estimated from Mace Head observations (blue line). Red line denotes the annual trend. Data under grey shading are not yet ratified.

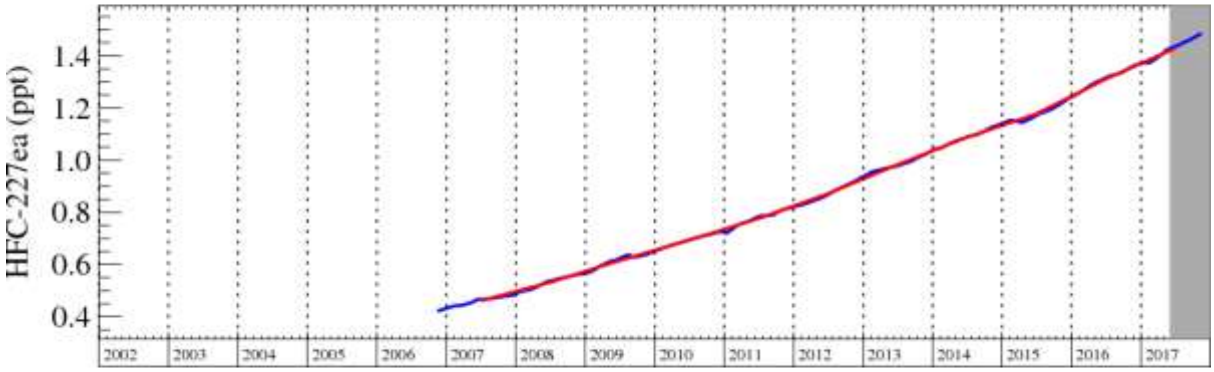
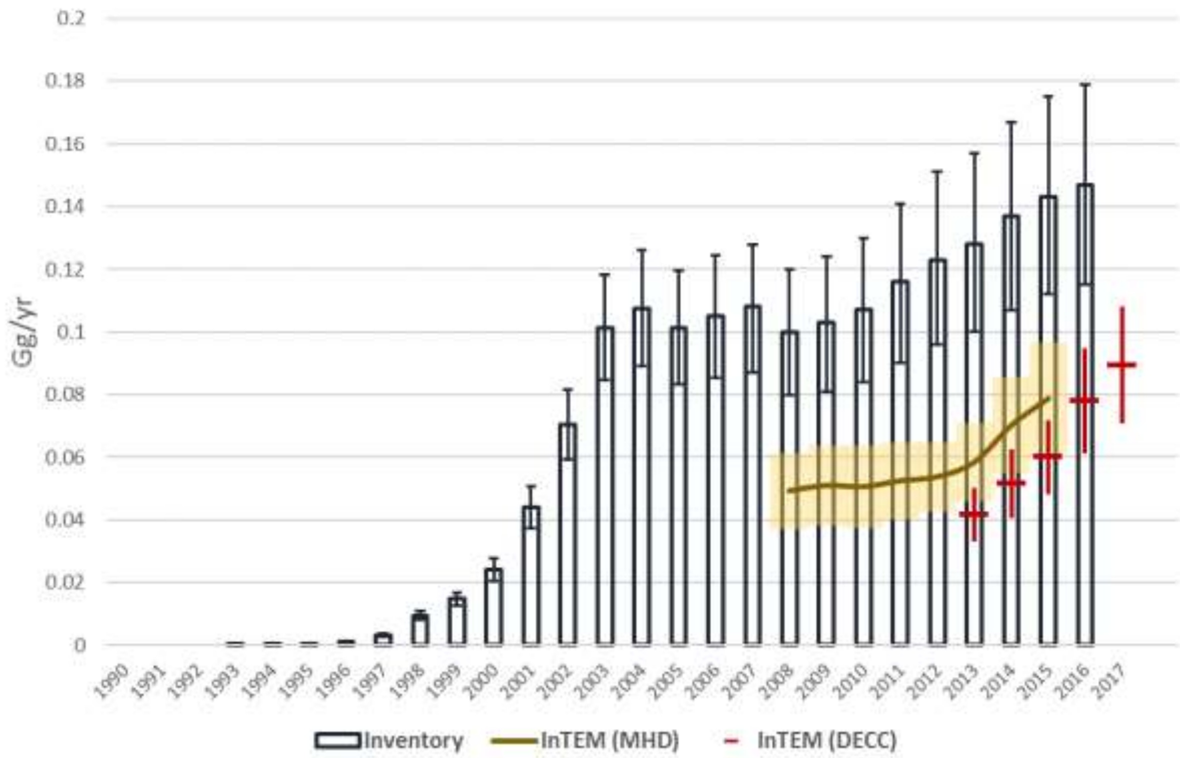


Figure A 6.21 Verification of the UK emission inventory estimates for HFC-227ea in Gg yr^{-1} from 1990. GHGI estimates are shown in black. InTEM (MHD-only, 3-year) estimates are shown in brown (1σ uncertainty in yellow). InTEM (DECC, 2-year) estimates are shown in red.



A 6.4.9 HFC-365mfc

Figure A 6.22 shows the Northern Hemisphere baseline atmospheric concentration of HFC-365mfc from 2005 onwards. There is positive trend in the baseline; in 2016 it increased by 0.06 ppt. The GHGI shows a sharp decline in emissions in 2008, the MHD-only InTEM estimates, with the 3-yr inversion time periods, shows the same but understandably slower response. The DECC network show a striking similarity to the GHGI estimates, both show rising UK emissions from 2013.

Figure A 6.22 Monthly Northern Hemisphere trend in HFC-365mfc estimated from Mace Head observations (blue line). Red line denotes the annual trend. Data under grey shading are not yet ratified.

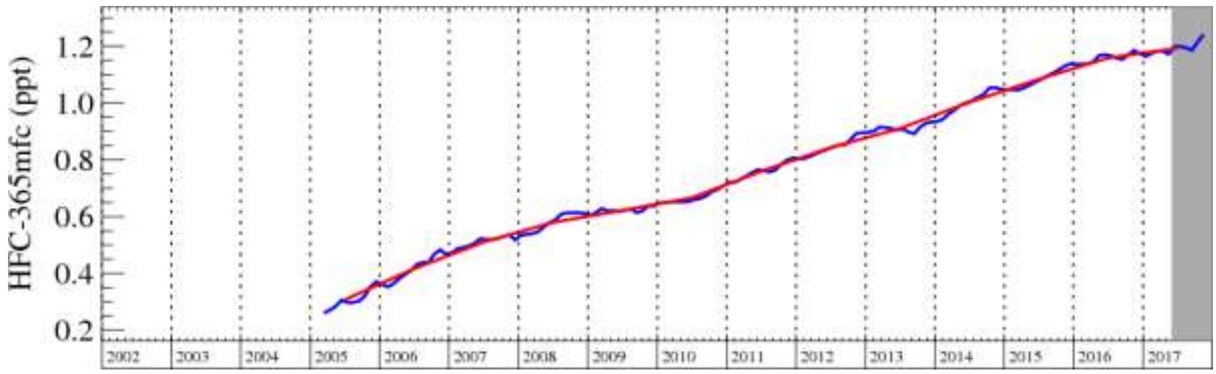
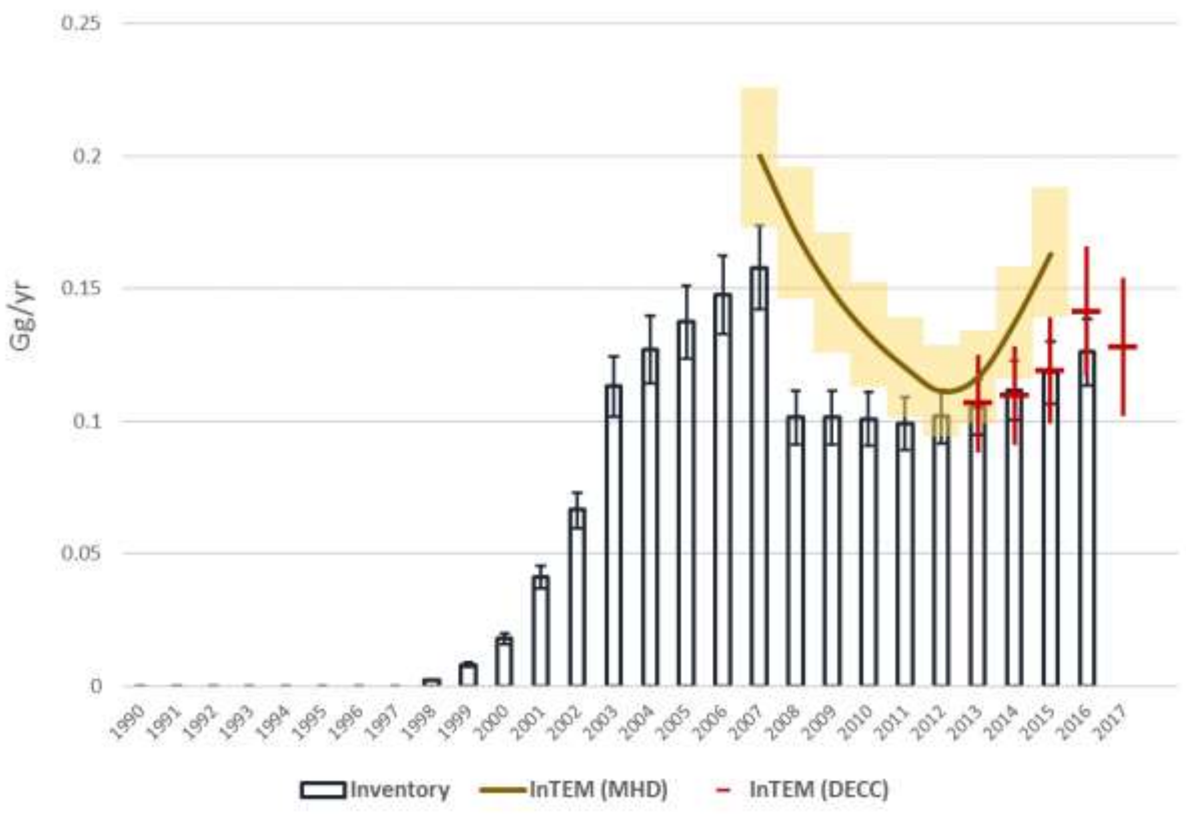


Figure A 6.23 Verification of the UK emission inventory estimates for HFC-365mfc in Gg yr^{-1} from 1990. GHGI estimates are shown in black. InTEM (MHD-only, 3-year) estimates are shown in brown (1σ uncertainty in yellow). InTEM (DECC, 2-year) estimates are shown in red.



A 6.4.10 HFC-245fa

Figure A 6.24 shows the Northern Hemisphere baseline atmospheric concentration of HFC-245fa from 2007 onwards. There is a positive trend in the baseline; in 2016 it increased by 0.2 ppt. The InTEM estimates have significant uncertainty compared to the GHGI estimates and the UK estimates are consistently lower. The GHGI estimates show a significant decline in 2008 and then a steady annual increase. The DECC network InTEM estimates show a strong rise in emissions from 2014 to 2017.

Figure A 6.24 Monthly Northern Hemisphere trend in HFC-245fa estimated from Mace Head observations (blue line). Red line denotes the annual trend. Data under grey shading are not yet ratified.

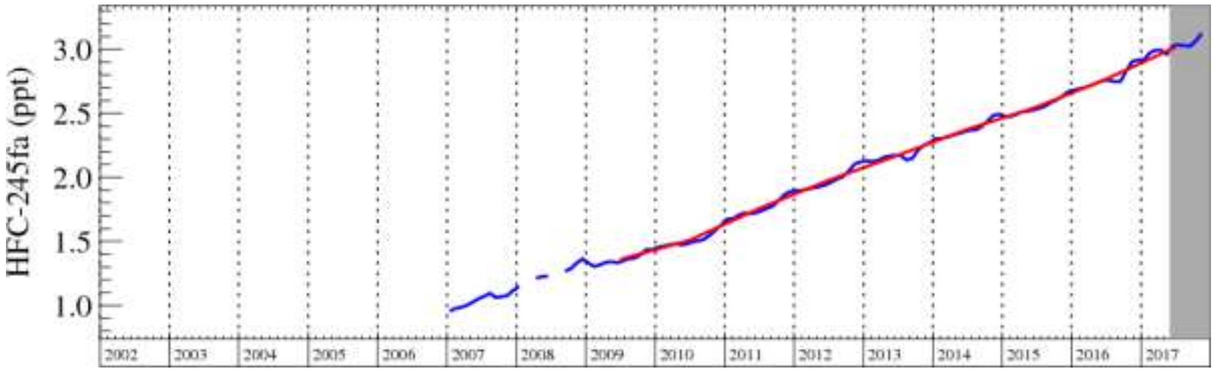
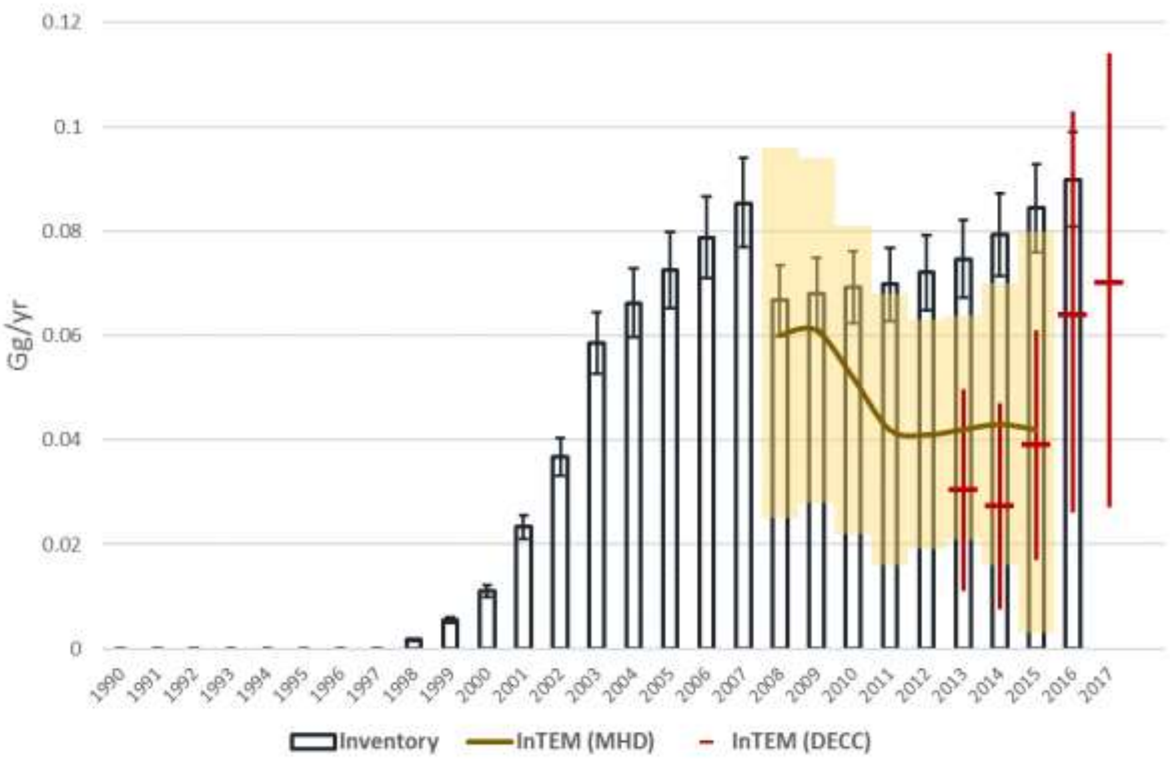


Figure A 6.25 Verification of the UK emission inventory estimates for HFC-245fa in Gg yr^{-1} from 1990. GHGI estimates are shown in black. InTEM (MHD-only, 3-year) estimates are shown in brown (1σ uncertainty in yellow). InTEM (DECC, 2-year) estimates are shown in red.



A 6.5 PERFLUOROCARBONS

A 6.5.1 PFC-14

Figure A 6.26 shows the Northern Hemisphere baseline atmospheric concentration of PFC-14 from 2004 onwards. The baseline trend is positive; in 2016 it increased by 0.8 ppt.

The sharp drop in emissions in 2012 in the GHGI reflects the closure of the last significant aluminium production plant in the UK. The InTEM uncertainty ranges for PFC-14 are large because the overwhelming majority of emissions come from a few point sources (smelters), which are not well captured in the large area averages within InTEM. If prior knowledge of the point sources is included within InTEM the uncertainty ranges are considerably reduced. Interestingly the InTEM estimates with the DECC network show a steady increase in emissions from 2015.

Figure A 6.26 Monthly Northern Hemisphere trend in PFC-14 estimated from Mace Head observations (blue line). Red line denotes the annual trend. Data under grey shading are not yet ratified.

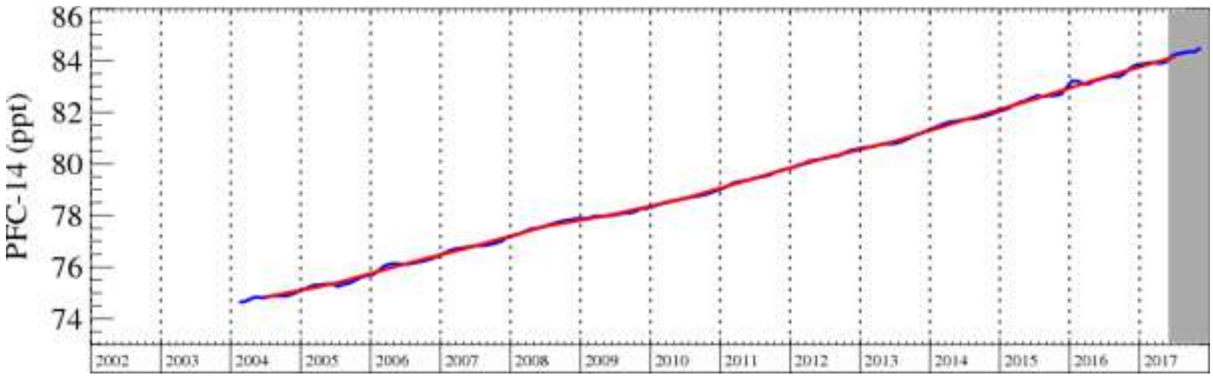
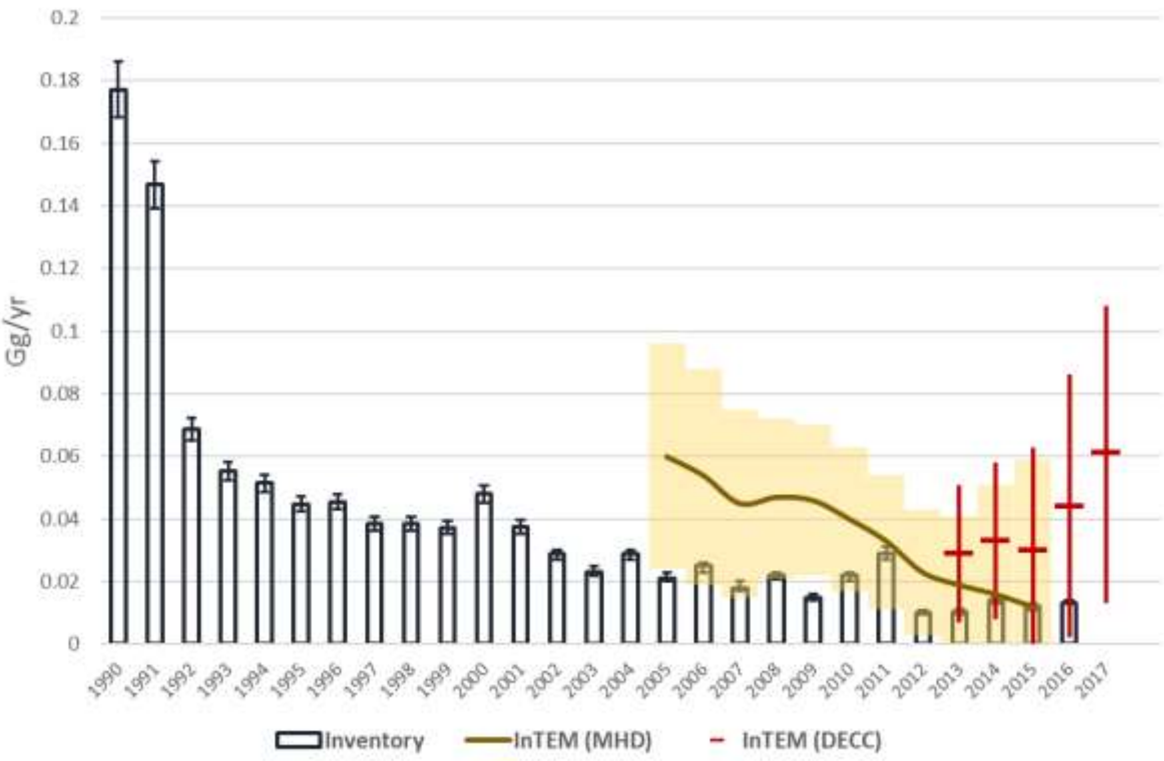


Figure A 6.27 Verification of the UK emission inventory estimates for PFC-14 in Gg yr^{-1} from 1990. GHGI estimates are shown in black. InTEM (MHD-only, 3-year) estimates are shown in brown (1σ uncertainty in yellow). InTEM (DECC, 2-year) estimates are shown in red.



A 6.5.2 PFC-116

Figure A 6.28 shows the Northern Hemisphere baseline atmospheric concentration of PFC-116 from 2004 onwards. The baseline trend is monotonic and positive; in 2016 the baseline increased by 0.07 ppt. The UK InTEM estimates are consistent with those reported in the GHGI (Figure A 6.) given the uncertainties in both estimates.

Figure A 6.28 Monthly Northern Hemisphere trend in PFC-116 estimated from Mace Head observations (blue line). Red line denotes the annual trend. Data under grey shading are not yet ratified.

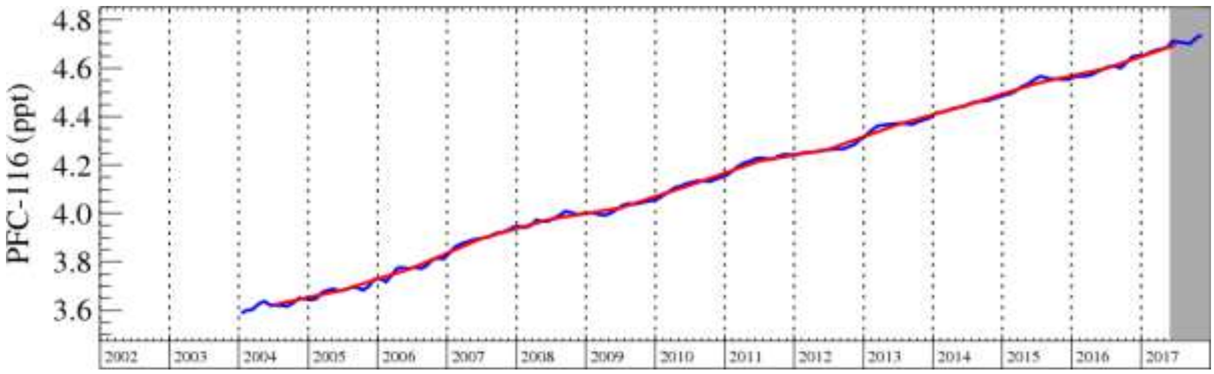
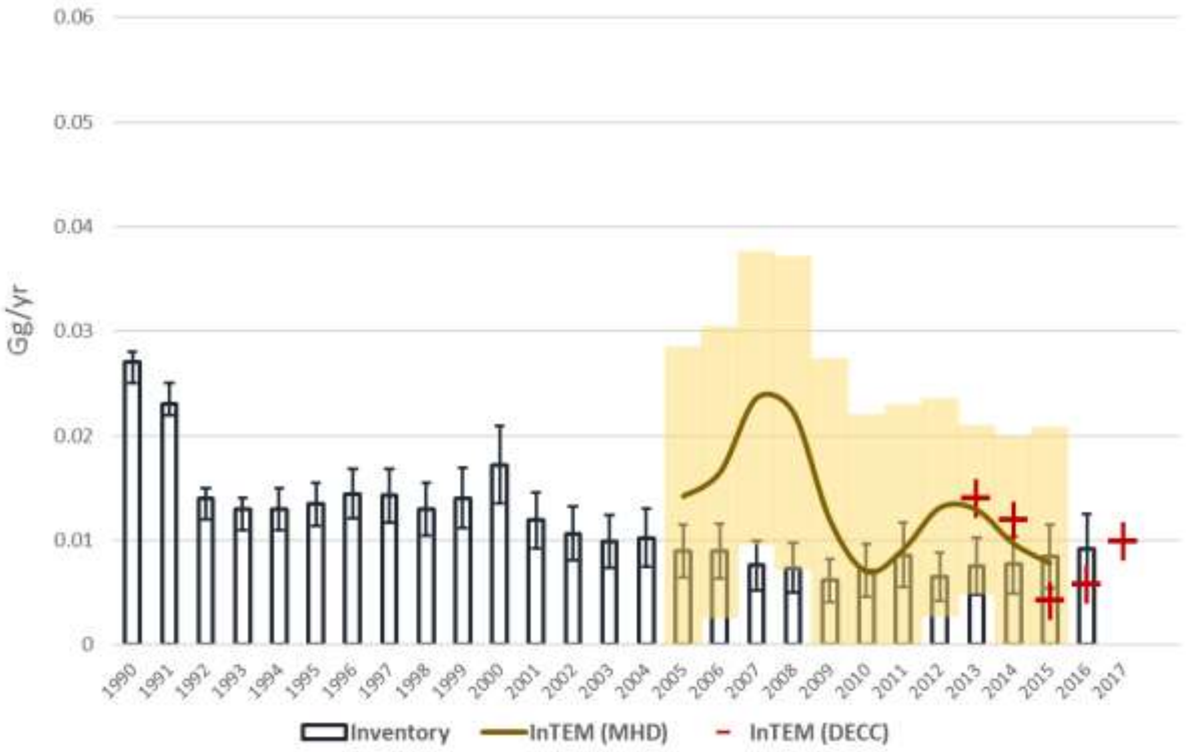


Figure A 6.29 Verification of the UK emission inventory estimates for PFC-116 in Gg yr^{-1} from 1990. GHGI estimates are shown in black. InTEM (MHD-only, 3-year) estimates are shown in brown (1σ uncertainty in yellow). InTEM (DECC, 2-year) estimates are shown in red.



A 6.5.3 PFC-218

Figure A 6.30 shows the Northern Hemisphere baseline atmospheric concentration of PFC-218 from 2004 onwards. The baseline trend is monotonic and positive; in 2016 the baseline increased by 0.02 ppt.

The MHD-only InTEM estimates are significantly higher than those reported in the GHGI (Figure A 6.31) until 2015. Interestingly the dip in UK GHGI estimates in 2008 and 2009 is matched by the InTEM estimates, albeit at a higher emission level. Between 2010 and 2013, InTEM shows a steady increase, similar to the GHGI. The DECC network InTEM estimates show a decline in emissions and are broadly consistent with the GHGI and the MHD-only estimates.

Figure A 6.30 Monthly Northern Hemisphere trend in PFC-218 estimated from Mace Head observations (blue line). Red line denotes the annual trend. Data under grey shading are not yet ratified.

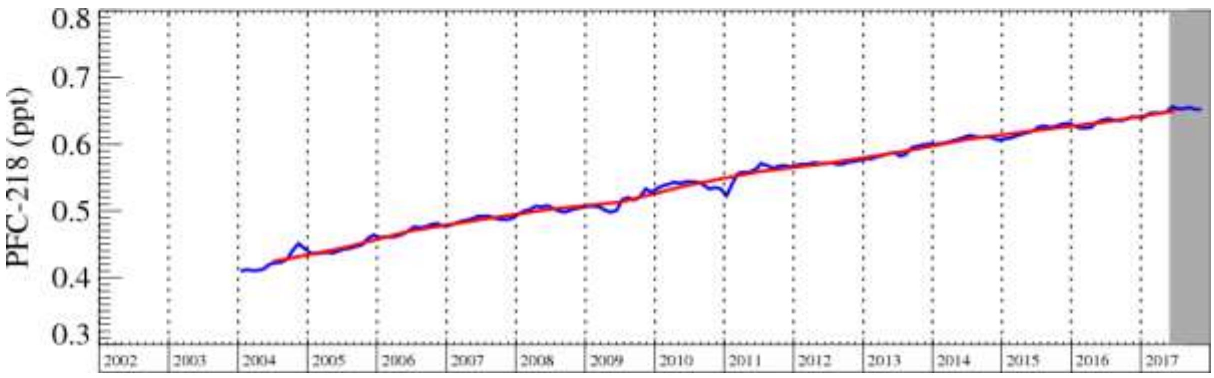
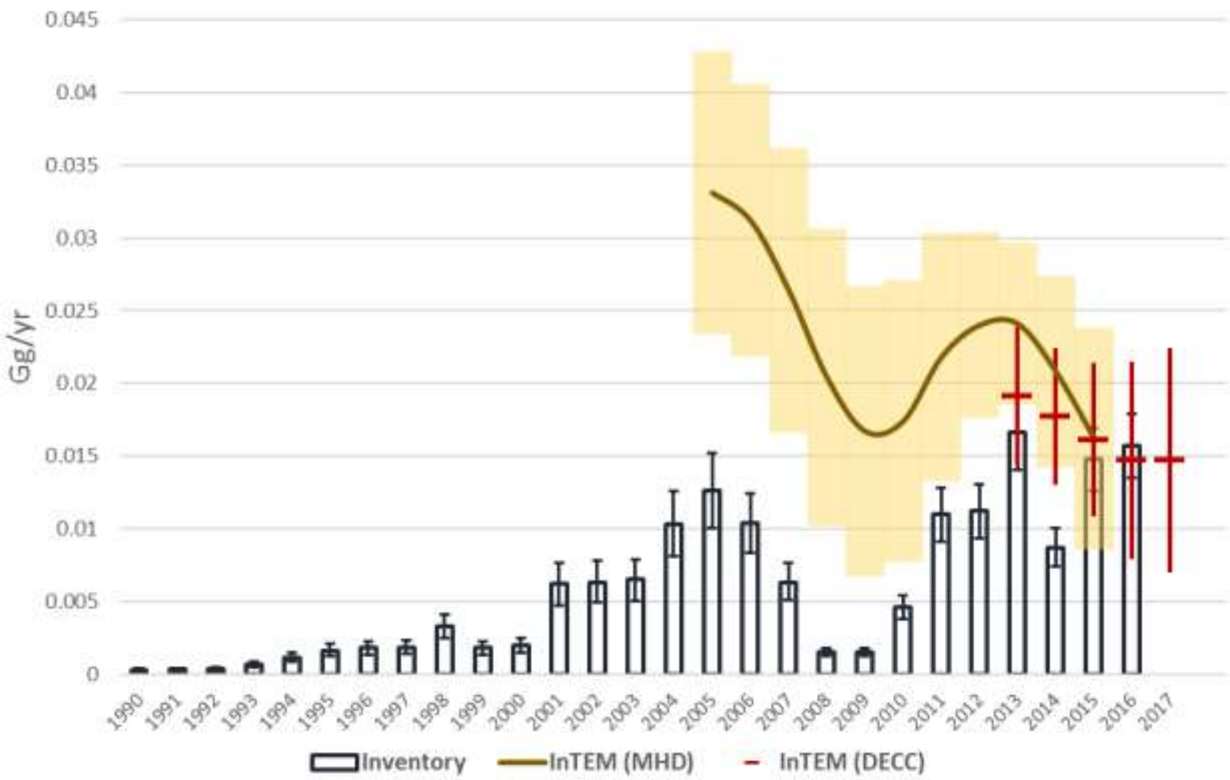


Figure A 6.31 **Verification of the UK emission inventory estimates for PFC-218 in Gg yr^{-1} from 1990. GHGI estimates are shown in black. InTEM (MHD-only, 3-year) estimates are shown in brown (1σ uncertainty in yellow). InTEM (DECC, 2-year) estimates are shown in red.**



A 6.5.4 PFC-318

Figure A 6.32 shows the Northern Hemisphere baseline atmospheric concentration of PFC-318 from 2010 onwards. The baseline trend is monotonic and positive; in 2016 the baseline increased by 0.06 ppt. The UK InTEM estimates are significantly higher than the very small emissions reported in the GHGI (Figure A 6.). However the estimated quantities are very small.

Figure A 6.32 Monthly Northern Hemisphere trend in PFC-318 estimated from Mace Head observations (blue line). Red line denotes the annual trend. Data under grey shading are not yet ratified.

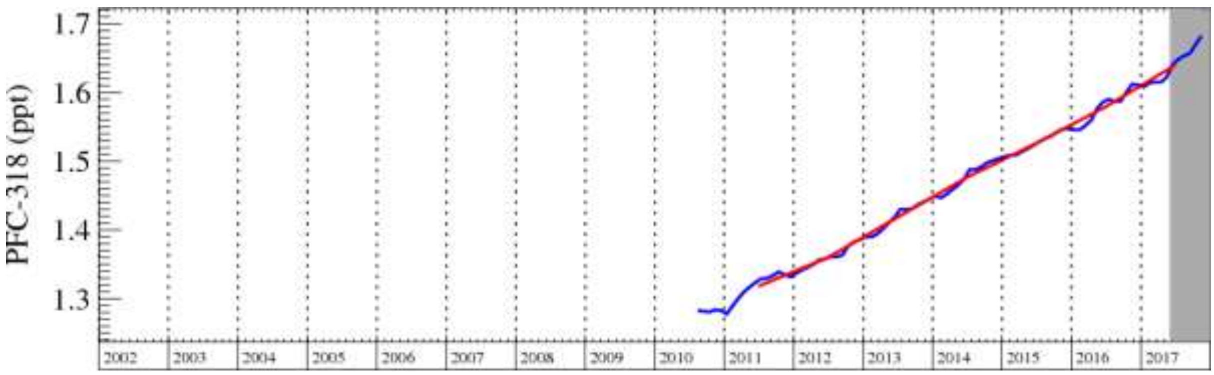
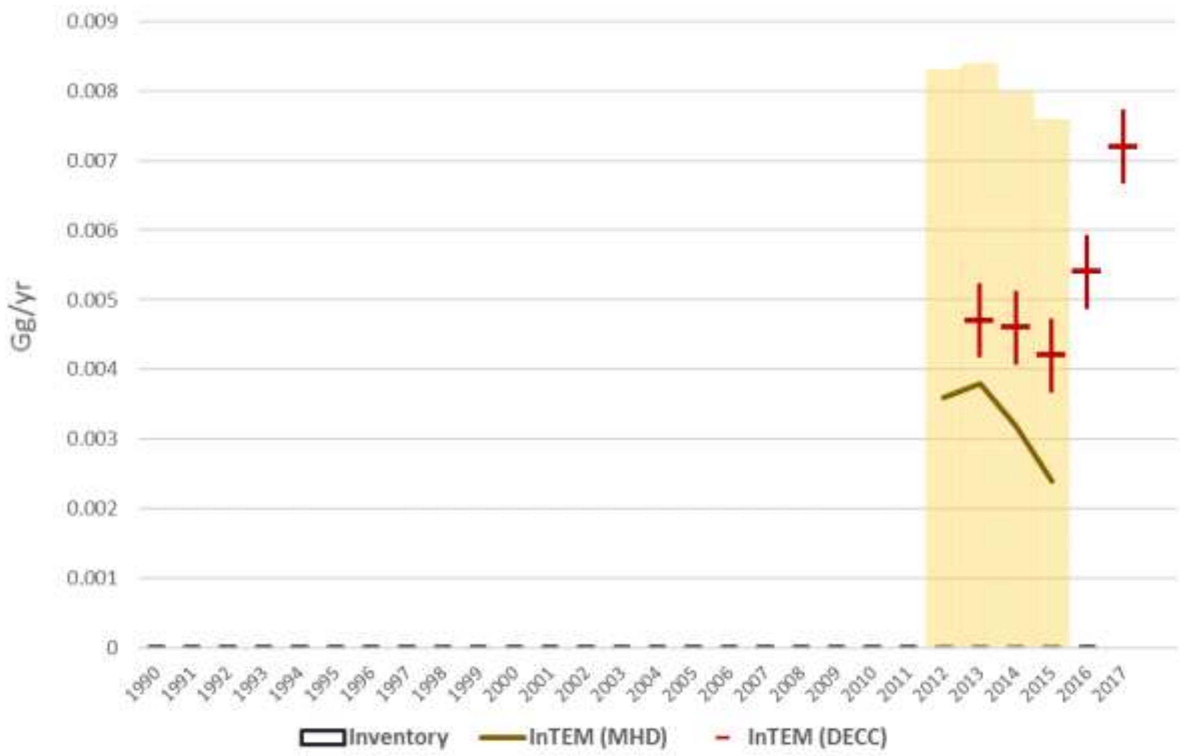


Figure A 6.33 Verification of the UK emission inventory estimates for PFC-318 in Gg yr^{-1} from 1990. GHGI estimates are shown in black. InTEM (MHD-only, 3-year) estimates are shown in brown (1σ uncertainty in yellow). InTEM (DECC, 2-year) estimates are shown in red.



A 6.6 SULPHUR HEXAFLUORIDE

Figure A 6.34 shows the Northern Hemisphere baseline atmospheric concentration of sulphur hexafluoride (SF_6) from 2004 onwards. The baseline trend is monotonic and positive; in 2016 the baseline increased by 0.33 ppt.

The UK MHD-only InTEM estimates show a rise from 2005 until 2009 and then a decline until 2015. From 2005 until 2009 the GHGI shows a steady decline from ~0.05 Gg yr^{-1} to ~0.02 Gg yr^{-1}, a small rise in 2010 and then a slow decline until 2015. There is a significant difference between the GHGI and InTEM estimates between 2008 and 2013. Between 2014 and 2016 the InTEM estimates with the DECC and GAUGE networks broadly agree with the MHD-only InTEM estimates and the GHGI.

Figure A 6.34 Monthly Northern Hemisphere trend in SF_6 estimated from Mace Head observations (blue line). Red line denotes the annual trend. Data under grey shading are not yet ratified.

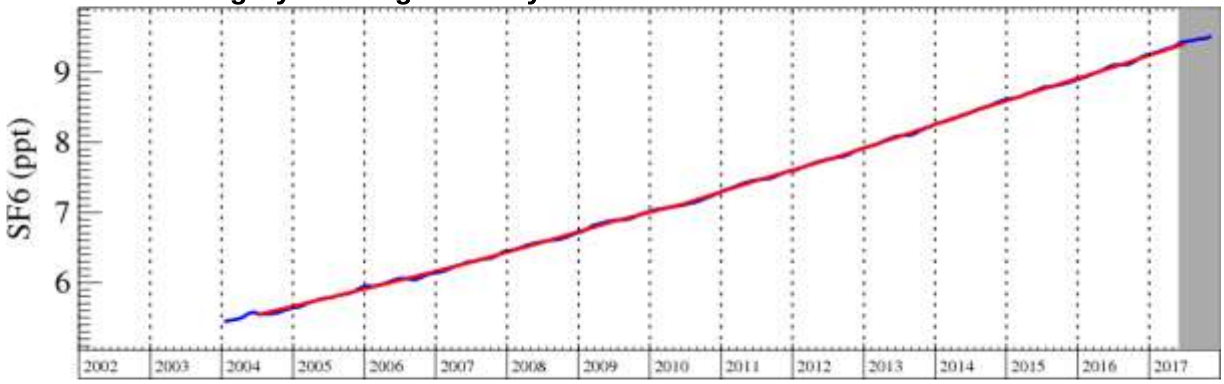
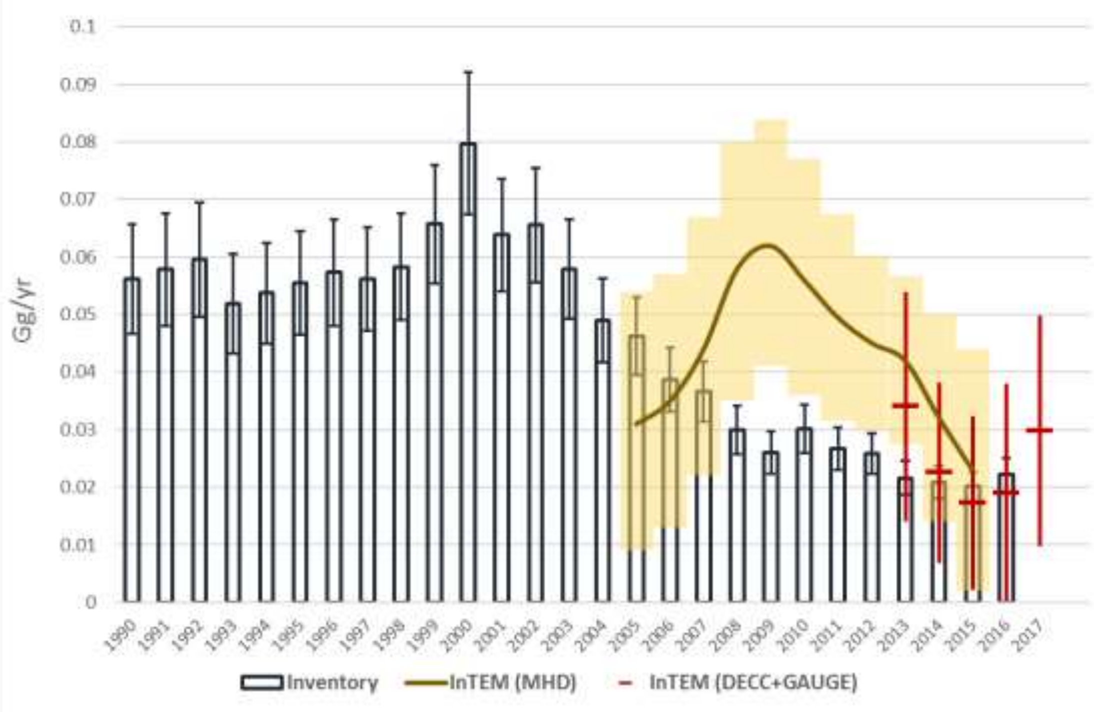


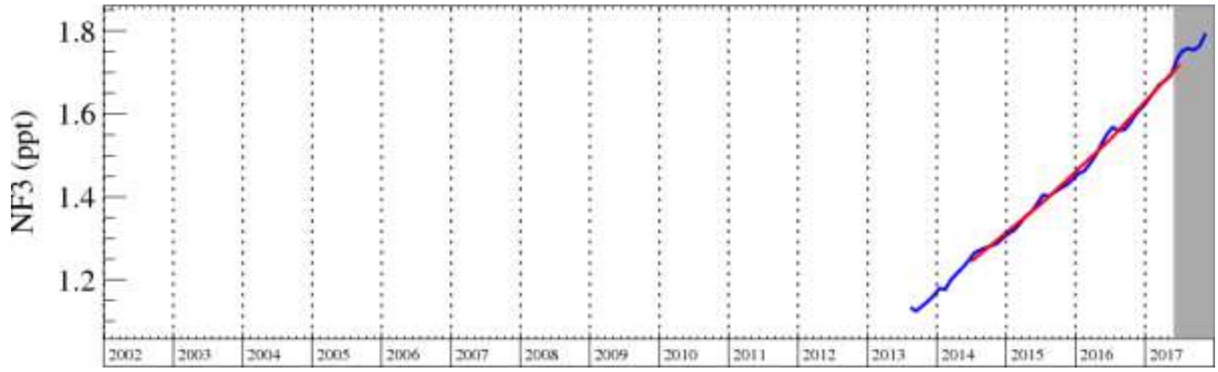
Figure A 6.35 Verification of the UK emission inventory estimates for SF_6 in Gg yr^{-1} from 1990. GHGI estimates are shown in black. InTEM (MHD-only, 3-year) estimates are shown in brown (1σ uncertainty in yellow). InTEM (DECC+GAUGE, 6-month) estimates are shown in red.



A 6.7 NITROGEN TRIFLUORIDE

Figure A 6.36 shows the Northern Hemisphere baseline atmospheric concentration of nitrogen trifluoride (NF_3) from 2013 onwards. The baseline trend is monotonic and positive; the growth rate in 2016 was estimated to be 0.17 ppt yr^{-1}. NF_3 is only measured at MHD, and measurements only started in May 2013. The InTEM emission estimates for the UK are insignificant. The GHGI estimate for 2016 is 28 kg.

Figure A 6.36 Monthly Northern Hemisphere trend in NF_3 estimated from Mace Head observations (blue line). Red line denotes the annual trend. Data under grey shading are not yet ratified.



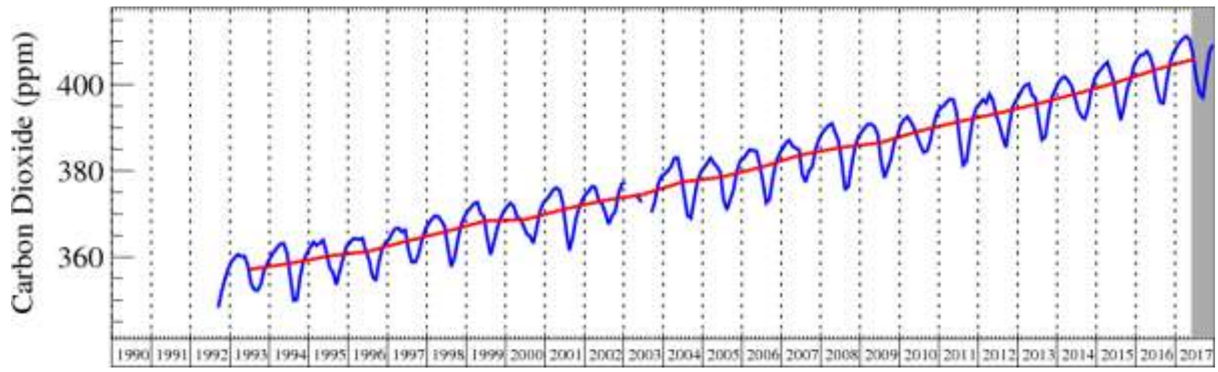
A 6.8 CARBON DIOXIDE

High precision, high frequency measurements of carbon dioxide (CO_2) are made across the UK DECC network. The Northern Hemisphere baseline trend is positive; in 2016 it increased by 2.9 ppm. It has a strong seasonal cycle due to the influence of the biosphere.

The CO_2 observed has three principle components:

1. Northern hemisphere baseline (Figure A 6.37).
2. Anthropogenic (man-made)
3. Non-anthropogenic (natural)

Figure A 6.37 Monthly Northern Hemisphere trend in CO_2 estimated from Mace Head observations (blue line). Red line denotes annual trend. Data under grey shading are not yet ratified.



Plants both respire CO_2 and absorb it through photosynthesis. Therefore the CO_2 flux from vegetation has a strong diurnal and seasonal cycle and switches from positive to negative on a daily basis. This unknown natural (biogenic) component of the observed CO_2 is significant when compared to the anthropogenic (man-made) component and cannot be assumed negligible (minimised during the winter months). From direct CO_2 observations it is not possible to distinguish between biogenic and anthropogenic CO_2. Therefore it is difficult to use the CO_2 observations directly in an inversion to estimate anthropogenic emissions. This is because the diurnally varying biogenic CO_2 flux is at odds with a key assumption of the inversion method, namely that emissions do not strongly vary in time over the inversion time-window (monthly). Methods are under development to attempt to over-come these challenges, such as: the use of isotopic observations; through ratios with respect to anthropogenic carbon monoxide (CO); and tracking at what time of day air passes over the ground and using biogenic process models. The uncertainties associated with each of these methods are predicted to be significant.

The estimated uncertainties in the CO_2 GHGI are very small compared to inversion results. Work is on-going to seek to improve our methods of verifying inventory CO_2 emission estimates.

ANNEX 7: Analysis of EU ETS Data

A 7.1 INTRODUCTION

This annex summarises the analysis of the 2016 European Union Emissions Trading System (EU ETS) energy and emissions data that is used within the compilation of the UK GHG inventory. The EU ETS data are used to inform activity data estimates for heavy industry sectors, carbon dioxide emission factors of UK fuels within those sectors, and for comparison of fuel allocations to specific economic sectors against data presented in the *Digest of UK Energy Statistics* (DUKES), published by the Department of Business, Energy and Industrial Strategy (BEIS).

The EU ETS data are used in the UK GHGI compilation as follows:

- EU ETS raw data on energy and emission estimates are processed and checked to enable integration of the activity data, implied emission factors and installation emission estimates as far as practicable within the UK GHG inventory compilation. Emission sources reported in EU ETS are allocated to inventory fuels and source codes, outliers are identified and clarifications of data inconsistencies are sought with the regulatory agencies;
- EU ETS activity data are closely compared against the UK national energy balance (DUKES) published by BEIS, and any inconsistencies are researched, seeking to resolve these through consultation with BEIS wherever possible;
- The verified EU ETS data provides up to date high quality fuel compositional analysis of UK fuels, and these data are used to improve inventory emission estimates across the highly energy intensive sources such as power stations, refineries, cement kilns, and oil and gas sources;
- The EU ETS dataset for offshore oil and gas installations are checked to assess data consistency in emissions reporting between the EU ETS and the (more comprehensive) EEMS dataset that is used within the UK GHGI compilation;
- Overall, the Inventory Agency approach seeks to minimise data discrepancies between EU ETS and the GHGI as far as practicable, in order that the derivation of traded and non-traded emission estimates from the UK GHGI are as accurate as possible. Close consistency between the EU ETS and GHGI is an important aspect of the development of a complete and consistent evidence base for policy development and tracking progress towards UK GHG reduction targets in the non-traded sector under the EU Effort Sharing Decision.

The scope of reporting under EU ETS increased from the 2013 dataset onwards. Phase II of the EU ETS ran from 2008-2012 inclusive. Phase III reporting began in 2013, with some new emission sources and new installations reporting for the first time on their GHG emissions; in particular, the definition of combustion has now been extended to cover installations such as furnaces, driers, and other plant where heat is used directly. A handful of industrial process sources of CO_2 are also included from 2013, such as soda ash production. In the UK, the changes in reporting in Phase III are most significant for the chemicals sector, where the scope of reporting is larger than previously and now encompasses both new industrial process emission sources, and additional energy use. There is also a notable shift towards estimation methods that are based on mass balance calculations (e.g. for chemical manufacturing) within the UK operator reporting to EU ETS. Other sectors with significant increases in reporting are food and drink manufacture, where installations such as driers, ovens etc. were included for the first time thus adding to the emissions from boilers and CHP plant that were reported in previous years, and roadstone coating, a sector which has not been present in the dataset before.

Analysis of the phase III data enabled the Inventory Agency to improve estimates of emissions from the combustion of waste residues and process off-gases within the chemical and petrochemical sectors (which are all reported under IPPU sector 2B10), as well as to generate improved estimates for the IPPU component of several specific manufacturing processes, such as for soda ash (2B7), and titanium dioxide (2B6). In addition, following a review of methodology for all IPPU sources, EU ETS data for phase II onwards has been used to improve emission estimates for glass production (2A3), brickmaking (2A4) and reductant use in electric arc furnaces (2C1).

The key findings from the analysis and use of the EU ETS data include:

- In the 2016 EU ETS dataset, a very high coverage of Tier 3 emissions data is evident for all fuel use in the power sector, and for solid, liquid and waste-derived fuels used in the cement and lime sectors. The proportion of Tier 3 data is somewhat lower for refinery fuel use, but still sufficiently high for the ETS to be considered the most reliable data available. All of the fuel quality data for these sources and fuels are therefore used within the UK GHGI, as the EU ETS fuel quality data is the most representative dataset available to inform UK carbon dioxide emission factors in the inventory;
- EU ETS emissions data from refineries are higher than estimates derived from DUKES activity data for all but two years within the time series, with a discrepancy evident in OPG emissions. Consultation with the industry trade association, UKPIA, and cross-checking with their data shows that the EU ETS data are felt to more accurately reflect estimates of CO_2, and therefore UK GHGI estimates are based on EU ETS data rather than refinery fuel use data reported in the UK energy balance;
- There are a range of other activity data discrepancies when compared to DUKES within the oil & gas, cement and lime, other industry and iron and steel sectors. Revisions to fuel allocations within the UK GHGI have been implemented for a number of sources, whilst further research is needed in some instances to clarify the issues where the reporting format of EU ETS does not map explicitly to energy balance and GHG inventory reporting requirements;
- EU ETS data for fuel use at chemical and petrochemical production facilities has helped to identify and quantify the combustion of process off-gases that are derived from Natural Gas Liquid (NGL) feedstock to petrochemical production processes, and from combustion of carbon-containing process residues. Analysis of “fuel gas” calorific values and carbon content informs the calculations to estimate emissions from NGL-derived gases and other residues.

The use of EU ETS data in the UK GHG inventory is summarised in **Table A 7.1.1**.

Table A 7.1.1 Summary of the use of EU ETS data in the UK inventory

Category	Sub-categories	EU ETS data used			Comments
		Factors	Activity	Emissions	
1A1a	Power stations - coal, fuel oil natural gas, sour gas	✓			
1A1a	Power stations – pet coke			✓	Some additional data is sourced from process operators.
1A1b	Refineries – pet coke & OPG			✓	EU ETS figures only used where higher than DUKES-based emissions.
1A1b	Refineries – natural gas	✓			
1A1c	Gas industry – natural gas		✓		
1A1c 1B1b 1A2a 2C1	Integrated steelworks	✓	✓		Use of various EU ETS data in complex carbon balance – factors for some fuels, activity data for others
1A1c	Collieries – Colliery methane	✓			
1A2b	Autogenerators - coal	✓			
1A2f	Lime - coal			✓	
1A2f	Lime – natural gas		✓		
1A2g	Industry - pet coke & waste solvents			✓	No alternative data available for this emission source.
1A2g	Industry – colliery methane	✓			
2A1	Cement			✓	Data used is actually from industry trade-association, but this is based on EU ETS returns
2A2	Lime			✓	
2A3	Glass			✓	
2A4	Bricks			✓	
2B7	Soda ash			✓	
2B8g	Ethylene & other petrochemicals			✓	

Category	Sub-categories	EU ETS data used			Comments
		Factors	Activity	Emissions	
2C1	Electric arc furnaces - reductants			✓	

A 7.2 BACKGROUND

A 7.2.1 EU ETS Data and GHG Inventories

The European Union Emissions Trading System (EU ETS) data provides annual estimates of fuel use and fuel quality data from the most energy intensive sites in the UK, and provides a source of data, or can be used to cross-check data held in the UK Greenhouse Gas Inventory (GHGI), and to inform the carbon contents of current UK fuels. The EU ETS has operated since 2005, and there are now 12 years' worth of data on fuel use and emissions across major UK industrial plant, for 2005-2016.

The data reported under the EU ETS includes quantities of fuels consumed (or other activity data for process sources of CO_2), carbon contents of fuels and other inputs, calorific values (fuels only) and emissions of carbon dioxide, all presented by installation and by emission source. Activity data are also given for many biofuels, although emissions of CO_2 from these fuels are not included in the emissions data. This is useful though, since PI/SPRI/WEI/NIPI emissions data for CO_2 often include biocarbon as well as fossil carbon, and the EU ETS data on biofuels helps to explain differences between CO_2 emissions reported in EU ETS and in those regulator inventories. EU ETS data for individual installations are treated as commercially confidential by the UK regulatory authorities and so only aggregated emissions data are reported in inventory outputs.

As part of the UK's annual reporting requirements to the MMR and UNFCCC, the UK must include a comparison of the EU ETS data against the national inventory dataset within the National Inventory Report. Furthermore, the analysis of the inventory against the EU ETS dataset is coming under increasing scrutiny due to the development of domestic GHG reduction targets that are based on non-traded[16] emissions data only, and the growing need to understand the UK non-traded sector emissions for future reporting under the Effort Sharing Decision.

The EU ETS dataset helps to improve the UK GHG inventory in a number of ways:

- Identifying new sources, therefore improving completeness;
- Helping assess true levels of uncertainty in fuel- and sector-specific data;
- Providing fuel quality data and oxidation factors for complex processes;
- Providing information on process-specific emissions that are not apparent from the national energy balances;
- Reducing uncertainty in the GHGI; and

[16] All GHG emissions that are regulated within the EU ETS are defined as "traded" emissions, whilst all other GHG emissions are defined as "non-traded". The EU Effort Sharing Decision will lead to the UK adopting a new target for GHG reductions by 2020 for all of the non-traded emissions (i.e. everything outside of EU ETS), and progress towards this target will be monitored through the UK GHG inventory.

- Acting as a source of quality assurance to inventory data.

In the 1990-2016 inventory cycle, the Inventory Agency has updated and extended the EU ETS analysis conducted for inventory compilation, using the 2016 EU ETS dataset, which is the fourth year of reporting under the Phase III EU ETS scope. This annex presents a comprehensive review of the twelve years' of EU ETS data, indicating where the data have already been used in the improvement of the GHGI, as well as highlighting outstanding issues which could be investigated further, with potential for further revision and improvement of the GHGI.

The Inventory Agency has also been provided with details of the 2011-2016 EU ETS data for all offshore oil and gas installations, which are regulated by the BEIS Offshore Inspectorate. Access to these detailed data has enabled a more thorough review of the fuel/gas quality and reported emissions from combustion and flaring sources at offshore installations, and has directly improved the completeness and accuracy of the sector estimates within the UK GHGI.

The analysis of the EU ETS data for use in the UK GHGI necessitates a detailed review of the available data, in order to ensure correct interpretation and application of the available data. The study team prioritises effort to the sources and sites that are the most significant in UK GHGI terms, and/or where data reporting discrepancies have been identified from previous work. For those sectors where EU ETS data are used in the GHGI, it is important to review emission factors from all major installations to ensure that any outliers are identified and checked prior to their inclusion in inventory calculations.

Wherever possible, consistent assumptions are made when interpreting data across all years of the EU ETS. For instance ensuring that each site is allocated to the same inventory sector in each year (unless there is reason to change it – some industrial combustion plants in recent years have been converted into power stations, and so these sites do need to be allocated to different sectors in different years), and that there is consistency in the way in which site-specific names for fuels are interpreted across the entire period. The information on the EU ETS method "Tier" used for each of the data dictates whether they are used in inventory compilation. The highest tier EU ETS data are assumed to be subject to the lowest level of uncertainty, and so only tier 3 and tier 4 emission factor data are used. Occasionally there are internal inconsistencies in the EU ETS data between the data on consumption of a given fuel and emissions from the use of that fuel. These need to be resolved before the data can be used in the UK GHGI. As emissions data are verified, we cross-check the detailed emissions data against the final verified emissions for each site. As a general rule it is found that the most appropriate solution to inconsistencies is to assume that the EU ETS emissions data are correct as EU ETS reporting requirements are well regulated, and that it is the activity data that need to be amended instead.

A 7.2.2 Scope of the UK EU ETS and Implications for the GHG Inventory

There are a number of limitations to the EU ETS data that affect the data usefulness in GHG inventory compilation, including:

- The EU ETS data are only available from 2005 onwards, whilst the UK GHG inventory reports emission trends back to 1990. The additional information that EU ETS provides (e.g. year-specific emission factors for many fuels in energy intensive sectors) helps to reduce the uncertainties in inventory emission estimates for the later years, but care is needed where revisions to the time series are made back to 2005. A consistent approach to inventory compilation across the time series is a key tenet of IPCC good practice guidance, and care is needed to ensure that the use of EU ETS data does not introduce a systematic reporting step-change in the UK GHGI;

- Further to this point, it is important to note that the scope of EU ETS reporting has evolved through the years, from Phase I (2005 to 2007) into Phase II (2008 to 2012 data) and now to Phase III (2013 onwards). The comparability of EU ETS data for many sectors is poor between these three phases. For example, many cement kilns did not report to EU ETS until Phase II: several sectors including cement were reporting under Climate Change Agreements and were opted-out of EU ETS during Phase I. Therefore in several sectors, more complete coverage of EU ETS reporting is evident in Phase II and data from 2008 onwards are therefore much more useful for UK GHGI reporting. The scope of coverage of chemical industry emissions has gone through two step changes – in 2008, and again in 2013, and some sectors (such as roadstone coating) only appear for the first time in the 2013 EU ETS data. Less significantly for the GHGI, many small installations, mostly in the public sector, were removed from EU ETS at the end of phase I. It is vital that the GHGI takes full account of such changes and that UK inventory data do not include trends that merely result from the increase (or decrease) in scope of EU ETS. The changes in EU ETS scope have made the data set increasingly useful, and there are now five years' worth of Phase II data and three years of data under Phase III, hence the EU ETS dataset is now an important source of information for the UK inventory;
- In the UK during EU ETS Phases I and II, the regulators adopted a "medium" definition of the term "combustion", and as a result there were many sectors where fuel use in specific types of combustion unit were not included in the EU ETS reporting scope until the start of Phase III (2013 onwards). Examples of this include flaring on chemical sites, and fuel use in heaters, dryers, fryers and stenters in industry sectors such as: chemicals, food and drink, textiles, paper and pulp. Hence the total fuel use and GHG emissions from these sectors have typically been under-reported within the EU ETS historically compared with the UK inventory, with many sites and sources excluded from the scope of EU ETS. However, the EU ETS data for these sectors is also incomplete both in phase II and phase III because small installations are not covered by EU ETS. Therefore, while the change in scope for combustion installations in phase III is a positive step, it has relatively little impact on the data used in GHGI compilation. Some phase III data has been used to improve the estimates of emissions from combustion of process wastes / off-gases in the chemical and petrochemical sector in the recent submissions.
- Phase III also brought an increased scope for industrial process sources of CO_2, and data appeared for the first time for soda ash production, and titanium dioxide manufacture.
- When using the EU ETS data, assumptions and interpretations are required to be made regarding the fuel types used by operators; assumptions are made on a case by case basis depending on knowledge of the site or industry and expert judgement. Operators are free to describe fuels as they wish in their returns, rather than choosing from a specific list of fuels, and so assumptions occasionally need to be made where the fuel type used is not clear from the operator's description. This issue was more significant in the earlier years of EU ETS reporting, with operators often using terms such as "Fuel 1". The assumption then made about fuel type was based both on the other data the operator provided on the fuel such as calorific value, but also by comparison with later data for the same site, since operators now tend to use more recognisable fuel names, and the use of wholly ambiguous terms is now very rare.

Note that:

- The direct use of EU ETS data (e.g. fuel use data by sector) to inform UK GHGI estimates is limited to where the EU ETS is known to cover close to 100% of sector installations. For example, the EU ETS is regarded as representative and 100% comprehensive in coverage of refineries, power stations (except in the case of some small power stations burning biomass, gas oil, or burning oil as the main fuel), integrated steelworks, cement and lime kilns, soda ash plant, titanium dioxide plant, petrochemical works and glassworks (container, flat, wool & continuous filament fibre only – small lead glass and frit producers are not included). Coverage is very close to 100% for brickworks and tilieries. For many other industrial sectors (such as chemicals, non-ferrous metals, food and drink, engineering) the EU ETS is not comprehensive and therefore the data are of more limited use, mainly providing a de-minimis fuel consumption figure for these sectors;
- EU ETS Implied Emissions Factors (IEFs) can be used within the UK GHGI, but only where the evidence indicates that EU ETS data are representative of the sector as whole and provides more comprehensive and accurate data than alternative sources. The key criteria to consider in the assessment of EU ETS IEF usefulness is the percentage of annual fuel use by sector where operator estimates use Tier 3 emission factors.
- Review of the EU ETS IEFs for different fuels across different sites provides a useful insight into the level of Tier 3 reporting within different sectors, the progression of higher-Tier reporting within EU ETS through the time series and the level of variability in fuel quality for the different major fuels in the UK. As a general rule, those energy-intensive sectors with near 100% coverage in EU ETS also report a very high proportion of emission factor data at Tier 3. Those sectors with incomplete coverage tend to report most emission factor data below Tier 3. As a result, in all cases where the level of sectoral coverage is high, the quality of reported data is also sufficiently high to be used with confidence in the UK inventory.

A 7.2.3 Limitations of EU ETS Data Integration with GHG Inventory: Autogeneration

Despite detailed research there remain some fundamental limitations in the use of EU ETS data within national inventories where the sector allocation of energy use and emissions cannot be resolved against the national energy statistics that underpin the GHG inventory compilation. One key example is that of the division between fuel use in autogeneration (or heat generation) and direct fuel use within a specific sector. For example, based on the data available from EU ETS, it is impossible to differentiate between gas use in autogeneration on a chemical installation, and gas used directly to heat chemical production processes. In this example, the allocation of EU ETS energy use and emissions between 1A2c (chemicals) and 1A2f (autogenerators) is uncertain, and therefore comparison of EU ETS and GHGI estimates is uncertain. The EU ETS data are not sufficiently detailed and transparent to enable accurate allocation, and so in all cases fuels and emissions are allocated to the industry sector, and not to autogeneration.

It is worth noting here that the UK energy statistics are also subject to some uncertainty, however small, and that there is likely to be more uncertainty in estimates at industrial sector-level, rather than at more aggregated levels. For example, while fuel producers and suppliers will be able to quantify total fuel demand with a high level of certainty, it would be far more difficult for them to estimate fuel use by specific industrial sectors. This will be reflected in the quality of UK energy statistics which are used to estimate emissions from 1A2c etc. We consider that a high proportion of fossil fuel use by the UK chemical industry will be included in the EU ETS, on the basis that most industrial chemical processes will require sufficiently large combustion installations to exceed the threshold for EU ETS. Therefore, we consider that it is reasonable to assume that EU ETS emissions for the chemical sector should cover most of the sector and therefore be similar in magnitude to those estimated from UK energy statistics and even, given the uncertainty in fuel allocation for autogeneration, to exceed them. For other sectors such as metals, paper, and food and drink, we would assume that the level of sectoral coverage by the EU ETS would be lower, so that emission estimates based on EU ETS would probably be lower than those based on energy statistics, even taking into account the uncertainty regarding autogeneration.

A 7.3 DATA PROCESSING

BEIS provided the detailed EU ETS regulator data from the Environment Agency, Natural Resources Wales, Scottish Environment Protection Agency and Northern Ireland Environment Agency during April & May 2017, and the Inventory Agency industrial emissions experts progressed the analysis, combining the datasets to generate a UK-wide EU ETS dataset. The work built on analysis conducted in previous years, as the EU ETS has been in place since 2005, but this latest analysis, while focussing on the 2016 submissions, did involve review of the data for earlier years, to ensure a consistent approach to the interpretation of energy and emissions data across the time series.

The initial step in the analysis is the allocation of all sites in the dataset to one of the economic sectors as reported within the DUKES Commodity Balance tables. Next, the reported fuels for every UK installation have to be allocated to one of the GHGI fuel names, which are also aligned with the fuel types reported within DUKES. This enables a direct comparison of EU ETS fuel totals against sector fuel allocations within DUKES and therefore used within the GHGI.

Most of the allocations have been made as part of previous years' work, and do not need to be revisited. However, several new installations included in the 2016 EU ETS data had to be allocated to DUKES' sectors, and all of the fuel data for 2016 also has had to be allocated to DUKES/GHGI fuel types. In a very small number of cases, we have revised data for earlier years, for example when it has become apparent that existing assumptions are likely to be incorrect. The allocation process does rely upon some expert judgement, with the Ricardo team using the reported EU ETS fuel names as well as the reported fuel quality data such as calorific values and carbon emission factors in order to make the fuel-type allocation for each entry in the EU ETS spreadsheet. The allocation is, occasionally, quite uncertain, particularly with the allocation of petroleum-based fuels such as the GHGI fuel categories LPG, OPG, gas oil and fuel oil, often because of the use of abbreviations or other slightly ambiguous names for fuels within the EU ETS reporting system. Cross-checking of data across the time series for each installation has been used to ensure as much consistency in fuel allocations as possible, although in some cases, operators of installations use different fuel terminology in different years, and the possibility of the use of different fuels in different years at a site cannot always be ruled out.

The quality checking and allocation process is very resource-intensive and essentially an open-ended task for such a large dataset, and hence the Inventory Agency focuses on the highest emitters and the known "problem" sites and fuel types. Where uncertainties arise in allocations, the most important allocation decisions are copied across to the BEIS DUKES team, for their information and input, as ultimately the EU ETS analysis by the Inventory Agency is taken into account to some degree within the compilation of DUKES for the following year.

As a data verification step, the installation emissions (broken down by fuel) from the EU ETS regulator spreadsheets are then compared against the total installation emissions for 2016 on the European Union Transaction Log (EUTL) which is a central website that holds the verified EU ETS emissions totals for all EU installations in the scheme. Each year we have noted that for some sites the regulator data does not match the EUTL dataset, and therefore some “residual” emissions allocations are generated, from the difference between EUTL and regulator information. In cases where these residual emissions are large, then these are fed back to the regulator contacts, for their consideration and to request any insights into the likely fuels that the residual emissions should be allocated against. Minor residual emissions are ignored for the purposes of the analysis reported here.

A final data set is then available for fuel combustion emission sources, which includes the following data fields:

- GHGI Source Category;
- GHGI Fuel Category;
- Fuel Consumed;
- Fuel Calorific Value;
- Fuel Carbon Emission Factor; and
- Related Emissions of CO_2

The Inventory Agency then combines the data by sector and/or fuel category to provide data for comparison against GHGI emissions data, and energy statistics published in DUKES. In this way, the analysis can:

- provide improved CO_2 emission factors for highly energy-intensive industrial sectors covered by the GHGI through the use of verified data;
- provide a comparison with UK energy statistics, allowing the identification of inconsistencies between EU ETS and DUKES;
- Identify any emission sources that are not contained in the GHGI.

The analysis of the EU ETS data for all onshore facilities was completed by May 2017 and provided to the BEIS team of energy statisticians, in time for them to consider the EU ETS dataset during compilation of the UK energy balance for 2016, as published within DUKES 2017 (which was published in July 2017).

The EU ETS data for offshore oil and gas installations was provided in May 2017 and were used directly in the compilation of emission estimates for the upstream oil and gas sector, after the UK energy balance had been compiled by BEIS. Access to these EU ETS data for offshore facilities provided more fuel-specific information (GCV, carbon content) to help improve completeness and accuracy of the upstream oil and gas estimates in the UK GHGI, augmenting the EEMS dataset which is a more comprehensive dataset (i.e. EEMS covers more emission sources than EU ETS) but does not provide the same level of fuel-specific data.

A 7.4 EU ETS DATA COVERAGE

The coverage of the EU ETS data has changed over the 12 years for which data are available. Major changes have been outlined in **Section A 7.1**, and these changes in scope have an impact on the usefulness of data for some sectors, with data generally being more complete for Phase II (2008-12) and Phase III (2013-15) of EU ETS. In addition, smaller combustion installations in the industrial, commercial and public sectors are outside the scope of EU ETS, and in fact coverage was decreased after 2007 due to the exemption of certain 'small emitters' from the UK EU ETS. For some source sectors in the GHGI, the EU ETS data therefore only includes a small proportion of the sector and the EU ETS data are not useful to directly inform the GHGI.

The following GHGI source sectors are well represented in the EU ETS data sets in the UK, with all UK installations included:

- Power stations burning coal, gas, and fuel oil as the principal fuel;
- Oil refineries;
- Coke ovens & Integrated steelworks;
- Cement kilns (from Phase II onwards); and
- Lime kilns (from Phase II onwards)
- Glassworks - container, flat, wool & continuous filament glass fibre subsectors only (from phase II onwards)
- Brickworks and other sites manufacturing heavy ceramic goods (from phase II onwards)
- Titanium dioxide and soda ash manufacture (from phase III onwards).

However, GHGI sectors such as industrial combustion, autogeneration, and public sector combustion are only partially represented in the EU ETS data. An indication of the actual level of coverage of the EU ETS data can be seen in . The number of sites in each sector which are included in the ETS dataset for 2005 and 2016 are given, together with the Inventory Agency's estimate of the total number of installations in that sector throughout the UK in those years.

Table A 7.4.1 Numbers of installations included in the EU ETS data

Sector	Number of installations			
	2005		2016	
	EU ETS	UK total	EU ETS	UK total
Power stations (fossil fuel, > 75MWe)	60	60	53	53
Power stations (fossil fuel, < 75MWe)	23	27	17	22
Power stations (nuclear)	12	12	8	8
Coke ovens	4	4	2	2
Sinter plant	3	3	2	2
Blast furnaces	3	3	2	2
Cement kilns	8	15	11	11
Lime kilns	4	15	11	11
Refineries	12	12	8	8
Combustion – iron & steel industry	11	200[a]	26	200[a]
Combustion – other industry	171	5000[a]	626	5000[a]
Combustion – commercial sector	28	1000[a]	95	1000[a]
Combustion – public sector	169	1000[a]	124	1000[a]

Sector	Number of installations			
	2005		2016	
	EU ETS	UK total	EU ETS	UK total
Glassworks (flat, special, container & fibre)	6	32	23	23
Brickworks	18	80[b]	48	48[b]
Soda ash & titanium dioxide	0	4	1	1

[a] These estimates are 'order of magnitude' figures, based on expert judgement of the inventory team, to show that the number of installations in the UK is likely to be considerably higher than the number of installations reporting in the EU ETS.

[b] Numbers of brickworks are not certain in 2005 but will have been significantly higher than in 2008 (when there were about 70) since many brickworks were closed or mothballed in the second half of 2007. All brickworks are believed to be covered by EU ETS in 2016.

Data are included in EU ETS for all coke ovens, refineries, sinter plant and blast furnaces. Power stations are divided into three categories in the table in order to show that, although a few stations are not included in the EU ETS data for 2016, these are all small (in most cases, very small diesel-fired plant supplying electricity to Scottish islands). In comparison, coverage is quite poor in 2005 for cement and lime kilns (due to CCA participants opting out during Phase I) and for combustion processes (due to CCA/UKETS opt-outs and the fact that numerous combustion plant are too small to be required to join the EU ETS). All cement kilns and all lime kilns are included in 2016. Coverage of glassworks and brickworks was very limited during phase I, but since 2008 has been very good: all large glassworks have been included since 2008, and all but one brickworks were included in phase II, with that remaining site being added for phase III. UK totals for brickworks are subject to some uncertainty however, and may be revised in future should more data be obtained. Both soda ash plant and both plants manufacturing titanium dioxide via the chloride process have only been included in EU ETS since the start of phase III.

For most emission sources the level of detail given in the EU ETS data matches well with the structures of the GHGI, allowing comparison of like with like. Only in the case of coke ovens and integrated steelworks is this not the case, since the EU ETS reporting format does not provide a breakdown of emissions for the sectors reported within the GHGI: i.e. estimates of emissions from coke ovens, blast furnaces and sinter plants are not provided explicitly. However, for these sectors, additional detailed analysis, including the collection of other industry data, has allowed for far greater use of EU ETS data for the inventory.

A 7.5 EU ETS DATA USE IN THE UK GHGI

The use of EU ETS data in the UK GHGI may conveniently be divided into two classes:

- Instances where activity data and, in most cases, emission totals as well are taken from EU ETS;
- Instances where emission factors only are taken from EU ETS and then used in the UK GHG Inventory with activity data from other sources such as DUKES.

A 7.5.1 Activity and Emissions Data

A 7.5.1.1 Crude Oil Refineries

The comparison of EU ETS emissions data against GHGI data based on DUKES fuel use allocations for petcoke, natural gas, fuel oil and OPG use is inconsistent to varying degrees in different years. Previous EU ETS analysis indicated that petcoke data in DUKES were too low; the BEIS energy statistics team have investigated this matter with the refinery operators and have revised data for a number of sites that had been misreporting through the DORS system used to compile DUKES. In recent years, therefore, the EU ETS and DUKES data are closely consistent for petcoke use by refineries.

Data inconsistencies between DUKES and EU ETS remain for other fuels, however. In some cases, this will be due to misallocation of fuel use data within the EU ETS analysis, where fuel names are unclear, e.g. “fuel gas” could be interpreted solely as refinery use of OPG or to also cover the use of natural gas as a back-up fuel within the refinery fuel gas system.

The fuel oil activity data in most years is around 10% higher in EU ETS than in DUKES. Natural gas is a relatively minor fuel in the sector; whilst the EU ETS allocations indicate an over-report in DUKES, there is considerable uncertainty over the allocations of gases in the EU ETS dataset, as noted above. However, DUKES data for natural gas used in autogeneration includes some fuel burnt at refineries, thus the difference between refinery fuel use as given in EU ETS, and that derived from DUKES data can be reduced by taking this into account. Consumption of naphtha reported in DUKES as “unclassified industry” is allocated to refineries as the only known consumers in the UK. However, in the case of OPG, there is typically an under-report in DUKES, although the data in DUKES is higher in two years. **Table A 7.5.1** below presents the emissions allocated to OPG for those years (2004 onwards except 2005, 2012) where UKPIA and EU ETS data indicates that DUKES data are too low. Note that the GHGI estimates also include the assumption that all of the OPG allocation to “autogenerators” within the DUKES commodity balance tables (in the column “Other gases”) is used within the refinery sector. Consultation with the BEIS DUKES team has indicated (Personal Communication, Evans, 2010) that the “Other gases” column in the Commodity Balance tables is the OPG on the refinery basis, with CHP plant on site allocated to the autogeneration line. We have therefore retained this assumption in the current analysis, including the autogenerator allocation of “other gases” within the refinery sector.

To resolve the refinery sector under-report, we have compared DUKES data against EU ETS data, and also considered the total carbon dioxide emissions for the refinery sector provided annually by UKPIA. At the installation level, the UKPIA and EU ETS data show very close consistency for recent years (typically within 1%). The close consistency of the EU ETS and UKPIA data further strengthens the case for using EU ETS data as the primary dataset to inform the UK GHG inventory, in preference to the DUKES energy statistics.

At the fuel-specific level, the greatest disparity is evident in the reporting of OPG use at refineries; the reporting disparity has therefore been resolved through a top-down emissions comparison between DUKES-derived data and the best available operator data from EU ETS (2005 onwards) and UKPIA (pre-2005), with the difference between the two then allocated to OPG use in the UK GHGI. UK inventory estimates of emissions for the sector are therefore aligned with EU ETS totals back to 2005, and with UKPIA data prior to 2005, unless the estimates derived from DUKES data are higher than those from UKPIA or EU ETS (i.e. in 2005 and 2012).

No deviations from UK energy statistics have been made prior to 2004, as the data from UKPIA and GHGI estimates based on DUKES are closely consistent with the DUKES-derived data being slightly higher; therefore a conservative approach is adopted, using DUKES-derived GHG estimates.

The time series of emissions data and the additional OPG and petroleum coke emissions data (where DUKES data are low) for the sector are shown below.

Table A 7.5.1 Refinery Emissions Data Comparison and Revision to OPG Activity

Year	Best Operator Data[1]	Refinery emissions total (if based on DUKES)	Additional emissions assumed from OPG	Additional emissions assumed from Pet Coke
	kt C	kt C	kt C	kt C
2000	4599	4712	0	0
2001	4535	4659	0	0
2002	4767	5238	0	0
2003	4772	5080	0	0
2004	4999	4921	79	0
2005	5007	5273	0	150
2006	4910	4676	158	76
2007	4857	4725	82	50
2008	4712	4349	238	121
2009	4492	3994	371	126
2010	4632	4339	216	76
2011	4738	4520	238	0
2012	4287	4531	0	0
2013	4002	3849	152	2
2014	3678	3559	122	0
2015	3682	3617	19	47
2016	3708	3463	155	90

[1] For 2005 onwards, the EU ETS data are verified by third parties and regarded as the best available sector estimates; prior to 2005 the best available operator emissions data are from the trade association, UKPIA.

[2] For 2005, DUKES activity data for petroleum coke are somewhat lower than the corresponding figure in the EU ETS, so even though CO_2 emission estimates based on DUKES figures for all fuels exceed the CO_2 figure given in the EU ETS, we use the higher (EU ETS) figure for petroleum coke, with the result that for 2005, the UK inventory figure for refinery CO_2 is higher (at 5426 kt C) higher than either the operator or DUKES based totals.

There is some level of uncertainty in the allocation of fuels in EU ETS to specific “DUKES” fuels, although the OPG use in refineries seems to be reported quite consistently as “Refinery Gas”, “Refinery Off-Gas”, or “OPG/RFG”. The BEIS DUKES team have reviewed the year to year consistency of OPG use in refineries through the DORS system.

A 7.5.1.2 Oil & Gas Terminal OPG and LPG Use

The allocation of fuel use reported within EU ETS to UK energy balance fuel nomenclature is uncertain in some cases. Analysis of the EU ETS fuel use data does indicate that there are small amounts of LPG and OPG being used in the upstream oil & gas sector that are not evident within DUKES.

The DUKES team have noted previously (Personal communication, DECC, 2010) that some LPG and OPG fuels are abstracted from upstream oil and gas exploration and production sources, rather than purchased from other sources, and that no data have been collected for this source since DUKES last published data, for the year 2002.

Therefore, the data from the EU ETS from oil and gas processing terminals on LPG and OPG combustion are used directly within the UK GHG inventory for the Phase II and Phase III years of 2008 to 2016, with estimates for 2003 to 2007 derived by interpolation between the EU ETS 2008 data and the DUKES 2002 data.

A 7.5.1.3 Natural Gas Use by Downstream Gas Supply Installations

The EU ETS data includes natural gas use by large gas compressor and storage sites that operate on the UK gas transmission and distribution network, as well as the three operational LNG terminals and a small number of other downstream gas industry sites.

The gas use reported in EU ETS for these sites throughout Phase II and III has been notably higher than the allocation of gas within DUKES Commodity Balance table 4.2 (Energy Industry Use, Other). This has been evident in the traded / non-traded analysis for the gas supply sector in the UK and DA GHGI.

As this gas use arises from the downstream network, the Inventory Agency and the BEIS DUKES team consider that the DUKES data indicate a small misallocation of gas use, rather than a gap in reported gas use. For 2005 to 2016, therefore, the EU ETS data for this source are used within the UK GHG inventory, and the overall gas use data are balanced by reducing the allocation of gas use to “other industrial combustion" (IPCC source 1A2g); the EU ETS data since 2005 shows good consistency with the data from DUKES for earlier years.

The increased gas use for this sector based on EU ETS data is expected to still be a small under-report for the sector as a whole, as the EU ETS scope only includes around 35 of the larger gas compressor, LNG terminals and storage sites on the UK network, and it is likely that additional gas use on smaller sites also occurs. However, the Inventory Agency has no data to inform such estimates.

A 7.5.1.4 Other Industry OPG use

There are a number of “other industry” sites where OPG use has been allocated by the Inventory Agency from EU ETS data, where the fuel is defined as either a specific gas (e.g. ethane, propane, butane) or more generic terms such as “OPG”, “High Pressure Refinery Gas”, “Low Pressure Refinery gas”, “fuel gas” or “RFG/OPG/ROG” within the EU ETS forms.

In refinery complexes, the use of RFG for autogeneration (for the refinery and/or for co-located plant) is reported within the energy balance (allocated to “OPG”). At a number of other UK installations, commodities that are used initially as feedstocks in chemical and petrochemical production (e.g. naphtha, ethane, LPG, gas oil) are allocated to “non-energy use” in the UK energy statistics; any subsequent use of process off-gases (derived from these NEU feedstocks) as a fuel is not reflected in DUKES. Therefore the inventory agency uses other data from industry, primarily from EUETS, to generate estimates of the use of such secondary fuels. For a small number of sites, consultation with the DUKES team, regulators and operators has clarified that the EU ETS energy and emissions data are the best available dataset for use in the UK GHGI.

In the 1990-2016 inventory cycle, EU ETS data for fuel use at petrochemical production facilities helped to identify and quantify the combustion of process off-gases that are derived from Natural Gas Liquid (NGL) feedstock to petrochemical production processes. Analysis of "fuel gas" calorific values and carbon content informs the calculations to estimate emissions from NGL-derived gasesand other residues.

A 7.5.1.5 Industrial Processes

The EU ETS dataset contains data on a number of industrial processes for which alternative data sources are either unavailable or of low quality. The EU ETS data therefore constitute the most reliable set of emissions data for these processes and are used in the UK inventory. In almost all cases, the EU ETS activity data are difficult to use directly, largely because different operators provide activity data and emission factors on a different basis (e.g. some may provide input material and emission factors on a consumption basis, others will provide production data and emission factors on a production basis). Therefore, for all of the industrial process sources, the EU ETS emissions data are adopted, and activity data are generally back-calculated from the emissions using a suitable IPCC emission factor. The industrial process sources where EU ETS data have been used to generate estimates of emissions included within the UK GHGI in this submission, include:

- Emissions from the manufacture of lime. UK activity data for limestone and dolomite consumption in lime production would yield much lower emission estimates than is suggested by EU ETS returns therefore, as a conservative approach, the EU ETS data are used instead. Activity data are back-calculated using the IPCC default factor for lime production. See **Section 4.3** for further details.
- Emissions from the use of carbonates in the manufacture of glass. As with lime production, the available data on consumption of limestone and dolomite for glass production are suspect, being very inconsistent across the time series, and so EU ETS data are used in the generation of the inventory time series, as detailed in **Section 4.4**.
- Emissions from the use of clays, carbonate minerals and other additives in the manufacture of bricks and roofing tiles, as detailed in **Section 4.5**. The EU ETS data are very detailed, with separate lines for different input materials such as different types of clay, carbonate minerals used in the bricks or in scrubbers used to abate fluoride emissions, and coke oven coke/petroleum coke used as an additive in certain bricks. UK brick production data are used as activity data.
- Estimates for emissions from the use of limestone in flue-gas desulphurisation (FGD) plant for the years 2005-2016 are taken from EU ETS data, because UK activity data (for gypsum produced from the FGD plant) are incomplete for those years. Activity data for 1990-2004 are available from non-EU ETS sources, and are back-calculated from the EU ETS CO_2 emissions for 2005 onwards assuming an emission factor of 253 kg CO_2 per tonne gypsum produced (which is based on an assumed 100% conversion of limestone and SO_2 into gypsum and CO_2).
- EU ETS Phase III saw the introduction of data for soda ash manufacturing sites and EU ETS data, and CO_2 emissions reported for earlier years in the PI, are used as the basis of UK inventory emissions data for that sector. See **Section 4.12** for more details.
- Titanium dioxide production was also included in phase III of the EU ETS, but full data for the UK plant are not included in the data set provided, and so emission estimates are generated using an alternative, more conservative method.

- Petroleum coke is added to some electric arc furnaces as a reductant, and emissions and activity data for the period 2005-2016 are taken from EU ETS data, with emissions in earlier years being extrapolated on the basis of plant production. See **Section 4.16** for further details.

A 7.5.2 Implied Emission Factors

A 7.5.2.1 Power Stations

Table A 7.5.2 summarises EU ETS data for fuels burnt by major power stations and coal burnt by autogenerators. The percentage of emissions based on Tier 3 emission factors is given (Tier 3 factors are based on fuel analysis, and are therefore more reliable than emission factors based on default values), as well as the average emission factor for EU ETS emissions based on Tier 3 factors.

Table A 7.5.2 EU ETS data for Fuels used at Power Stations and Autogenerators (Emission Factors in kt / Mt for Coal & Fuel Oil, kt / Mth for Gases)

Year	Fuel	% Tier 3	Average Carbon Emission Factor (Tier 3 only)
2005	Coal	99	615.3
2006		100	615
2007		100	614.7
2008		100	612.4
2009		100	607.2
2010		100	609.2
2011		100	609.2
2012		100	612
2013		100	612.7
2014		100	612.3
2015		100	608.6
2016		100	613.0
2005	Fuel oil / Waste oil[a]	59	860.3
2006		66	873
2007		68	871.1
2008		91	869.5
2009		94	872.7
2010		95	873.3
2011		94	873.9
2012		96	873.4
2013		93	871.3
2014		92	871.8
2015		89	872.8
2016		90.8	876.9

Year	Fuel	% Tier 3	Average Carbon Emission Factor (Tier 3 only)
2005	Natural gas	52	1.443
2006		76	1.465
2007		95	1.464
2008		97	1.467
2009		100	1.464
2010		99	1.46
2011		99	1.458
2012		100	1.461
2013		99	1.464
2014		100	1.461
2015		100	1.462
2016		99	1.462
2005	Coal - autogenerators	100	594.3
2006		100	596.3
2007		100	594.5
2008		100	581.3
2009		100	600.6
2010		100	599.9
2011		100	594.9
2012		100	598.3
2013-16		0[b]	N/A

[a] It is not possible to distinguish between fuel oil and waste oil in the EU ETS data, so all emissions have been reported under fuel oil.

[b] Plant operated as a power station after 2012 and included in the figures for power stations burning coal

The EU ETS data shown are regarded as good quality data, since a high proportion of emissions are based on Tier 3 emission factors (i.e. verified emissions based on fuel analysis to ISO17025). The factors are also very consistent across the time-series, which would be expected for this sector. As shown in Section 3, the EU ETS data for power stations also cover almost all UK installations in this sector, and certainly cover all of the installations which burn coal, fuel oil and natural gas.

A few power stations burn small quantities of petroleum coke as well as coal. One supplies data to ETS for coal/petroleum coke blends i.e. there are no separate emissions data or carbon factors for the coal and the petroleum coke at that site. We therefore back-calculate the coal IEF in those blends by using an assumed default for the petcoke carbon content and more detailed activity data on the constituents of the fuel blends, obtained directly from the operator.

The EU ETS based emission factors presented above for power stations are used directly as the emission factors in the GHGI, with the exception of the 2005 figure for gas, where Tier 3 factors were only used for about half of the sector's emissions reported in EU ETS. Small quantities of sour gas were burnt at one power station in 2005-2007 and 2009 and EU ETS Tier 3 emission factors are available and therefore used. [Due to the confidentiality of the data, the emission factors are not shown]. Prior to 2005, the emission factors for these sectors are based on the methodology established by Baggott *et al*, 2004, since it has been concluded that this represents the most reliable approach.

The EU ETS factors for coal-fired autogenerators are slightly different to the factors for the power stations in that, although the EU ETS data are exclusively Tier 3, they only represent about 80-90% of total fuel used by the sector.

A 7.5.2.2 Crude Oil Refineries

Table A 7.5.3 below summarises the EU ETS data for the major fuels burnt by refineries in the UK.

The main fuels in refineries are fuel oil and OPG and emissions also occur due to the burning off of 'petroleum coke' deposits on catalysts used in processes such as catalytic cracking. In the latter case, emissions in the EU ETS are not generally based on activity data and emission factors but are instead based on direct measurement of carbon emitted. This is due to the technical difficulty in measuring the quantity of petroleum coke burnt and the carbon content. Refineries also use natural gas, although it is a relatively small source of emissions compared to other fuels.

Table A 7.5.3 Refinery EU ETS Data for Fuel Oil, OPG and Natural Gas (Emission Factors in kt / Mt for Fuel Oil and kt / Mth for OPG and Natural Gas)

Year	Fuel	% Tier 3	Average Carbon Emission Factor (Tier 3 sites only)
2005	Fuel Oil	25	861
2006		65	873.9
2007		79	877.4
2008		91	871.6
2009		91	876.2
2010		97	878.2
2011		85	877.6
2012		80	887.6
2013		98	874.3
2014		100	875.8
2015		60	876.7
2016		66	876.1
2005	OPG	59	1.499
2006		57	1.475
2007		68	1.582
2008		80	1.483
2009		80	1.489
2010		80	1.501
2011		67	1.453
2012		64	1.47

Year	Fuel	% Tier 3	Average Carbon Emission Factor (Tier 3 sites only)
2013		78	1.489
2014		65	1.505
2015		63	1.489
2016		62	1.47
2005	Natural Gas	0	N/A
2006		43	1.46
2007		45	1.462
2008		98	1.475
2009		98	1.48
2010		97	1.465
2011		81	1.447
2012		63	1.442
2013		89	1.459
2014		87	1.459
2015		87	1.465
2016		81	1.456

There has been some variation in the proportion of Tier 3 reporting for all three fuels, which will adversely affect the quality of the emission factors, although coverage is still in excess of 50% for all fuels.

Emission factors for **fuel oil** generated from EU ETS data have been adopted in the GHGI, with the exception of data for 2005, where Tier 3 methods were used for only 25% of fuel.

Carbon factors can be derived for **OPG** based on moderate levels of Tier 3 reporting for 2005-2007 and 2011-2016 but 80% for 2008-2010, which gives us a high confidence in the representativeness of the carbon factors for 2008-10. There is some uncertainty regarding the allocation of EU ETS fuels to the OPG fuel category, and the derived emission factors do cover a wider spread of values than for many other fuels in EU ETS. However, this reflects the nature of this fuel, and the data for all years have been used in the inventory.

Carbon factors for natural gas are based on a low % of Tier 3 reporting until 2008; in 2008 to 2010 over 90% of gas use is reported at Tier 3 and over 80% in 2011 and 2013-2016. Within the UK GHGI, the EU ETS factors for 2008 to 2016 are used directly, whilst emission factors for earlier years are derived from gas network operator gas compositional analysis.

EU ETS emission data for **petroleum coke** are higher in 2005-2010, when compared against the estimates derived from DUKES activity data and the industry-recommended emission factor. This is especially noticeable for 2005, where the petroleum coke consumption given in DUKES would have to be more than 100% carbon in order to generate the carbon emissions given in the EU ETS. Consultation with BEIS energy statisticians has identified that the figures given in DUKES are subject to uncertainty and hence the EU ETS data are used directly within the UK GHGI for those years.

A 7.5.2.3 Integrated Steelworks & Coke Ovens

Table A 7.5.1 summarises EU ETS data for the major fuels burnt at integrated steelworks and coke ovens. The data exclude one independent coke oven which calculated emissions using a detailed mass balance approach which makes it more difficult to assess the data in the same way as the other installations. This site closed at the end of 2014.

Table A 7.5.1 EU ETS data for fuels used at integrated steelworks & coke ovens (Emission Factors in kt/Mt for solid & liquid fuels, kt/Mth for gases)

Year	Fuel	% Tier 3	Average Carbon Emission Factor (Tier 3 sites only)
2005	Blast furnace gas	0	N/A
2006		100	6.871
2007		99	6.911
2008		97	6.903
2009		97	6.996
2010		100	6.92
2011		94	6.974
2012		96	6.811
2013		98	6.766
2014		95	6.774
2015		100	7.652
2016		100	7.578
2005	Coke oven gas	0	N/A
2006		0	N/A
2007		0	N/A
2008		54	1.094
2009		100	1.195
2010		100	1.15
2011		100	1.086
2012		100	1.097
2013		100	1.093
2014		100	1.143
2015		100	1.216
2016		48	1.659
2005	Natural gas	0	N/A
2006		3	1.479
2007		2	1.478
2008		0	N/A
2009		58	1.425
2010		68	1.441
2011		64	1.441
2012		64	1.443

Year	Fuel	% Tier 3	Average Carbon Emission Factor (Tier 3 sites only)
2013		27	1.447
2014		23	1.445
2015-2016		0	N/A
2005	Fuel oil	0	N/A
2006		0	N/A
2007		0	N/A
2008		84	878.3
2009		89	884.7
2010		83	887.6
2011		87	888.7
2012		66	878.2
2013		0	N/A
2014		30	844.7
2015		32	845.1
2016		0	N/A

Most of the ETS data for coke ovens and steelworks are now used in the GHGI, although not the emission factors shown above. Instead, the Inventory Agency have used the EU ETS data and other detailed, site-specific and fuel-specific data, provided by the process operators to refine the carbon balance model used to generate emission estimates for the sector. Details of the revisions to the carbon balance model can be found in the research report from the 2013-2014 inventory improvement programme (Ricardo-AEA, 2014)

A 7.5.2.4 Cement Kilns

Table A 7.5.2 summarises EU ETS data for the major fuels burnt at cement kilns.

Table A 7.5.2 EU ETS data for Fuels used at Cement Kilns (kt / Mt)

Year	Fuel	% Tier 3	Average Carbon Emission Factor (Tier 3 sites only)
2005	Coal	8	671.1
2006		100	546.2
2007		100	664.3
2008		100	655.8
2009		100	658.3
2010		100	637.7
2011		100	645.8
2012		100	662.4
2013		100	694.2
2014		100	673.9

Year	Fuel	% Tier 3	Average Carbon Emission Factor (Tier 3 sites only)
2015		100	675.3
2016		98	682.1
2005	Petroleum coke	-	N/A
2006		100	820.8
2007		100	830.2
2008		100	819.1
2009		100	796.8
2010		100	750.8
2011		100	738.4
2012		100	770.2
2013		100	811.1
2014		100	793.4
2015		100	824.6
2016		100	822.2

The EU ETS dataset also provides a detailed breakdown of cement sector process emissions from the decarbonisation of raw materials during the clinker manufacturing process. These data are useful to compare against statistics provided by the Mineral Products Association (MPA) regarding clinker production and the non-combustion emissions associated with UK cement production. The MPA data on clinker production are commercially confidential.

The two data sets show significant differences for 2005-2007; however the EU ETS data cover only a fraction of the sector, so differences might be expected. From 2008 onwards, there is close agreement (average of 0.5% difference) between the two data sets. The coal IEF data across the time series are also fairly consistent, other than in 2006 where the ETS value is very much lower than in other years. Because of the good agreement in both activity data and emission factors for 2008 onwards, the industry-wide estimates provided by the MPA and used within the GHGI show very close comparison with the EU ETS estimates. The difference between the EU ETS and those reported to the GHGI are consistently less than 1%, as outlined below in **Table A 7.5.3**.

Table A 7.5.3 Comparison of Cement Sector Carbon Dioxide Emissions* within the UK GHGI and the EU ETS for 2008-2016

	2008	2009	2010	2011	2012	2013	2014	2015	2016
GHGI CO_2 emissions (kt)	8294	5687	5788	6130	5565	5967	6187	6615	6813
Sum of EU ETS CO_2 emissions (kt)	8259	5647	5754	6087	5556	5972	6205	6539	6794
EU ETS / GHGI	99.6%	99.3%	99.4%	99.3%	99.8%	100.1%	100.3%	98.9%	99.7%

*The data in this table include fuel combustion emissions (reported under IPCC 1A2f) and process emissions (reported under IPCC sector 2A1) from UK cement kilns.

A 7.5.2.5 Lime Kilns

Table A 7.5.4 summarises data given in the EU ETS datasets for the major fuels burnt at lime kilns. Unlike cement kilns, which often burn a variety of fuels, many lime kilns burn just a single fuel, often natural gas. The data below exclude coke oven coke used in lime kilns at soda ash plant since these kilns were not covered by EU ETS until phase III, and the small number of sites make the data confidential in any case.

Table A 7.5.4 EU ETS data for Fuels used at Lime Kilns (Emission Factors in kt / Mt for Solid Fuels and kt / Mth for Gases)

Year	Fuel	% Tier 3	Average Carbon Emission Factor (Tier 3 sites only)
2005	Coal*	-	N/A
2006		-	N/A
2007		34	846.9
2008		79	701.4
2009		100	698.9
2010		100	634.4
2011		100	703.9
2012		100	725.6
2013		100	689.1
2014		100	680.2
2015		100	693.1
2016		100	688.8

*Coal used in the lime industry in the UK includes a proportion of anthracitic coal, and hence some of these IEFs are notably higher than for coal used in other sectors of UK industry.

The EU ETS data for lime kilns vary across the time series, both in terms of the proportion of emissions based on Tier 3 factors, and in the emission factors themselves. EU ETS based factors are currently used for coal and petroleum coke from 2008 onwards, as the EU ETS data do include all lime kilns burning those fuels and almost all of those data are Tier 3 and hence are regarded as highly reliable.

EU ETS data for natural gas use in the lime industry does cover all installations burning this fuel, however the proportion of emissions based on Tier 3 factors is very low. Therefore the EU ETS emission factors are not used in the UK GHGI, and the emission factors for natural gas continue to be based on the methodology given in Baggott *et al,* 2004.

Table A 7.5.5 shows implied emission factors for process-related emissions from lime kilns that are used within the UK GHG inventory. The lime industry can be sub-divided into those installations where lime is the primary product, and carbon dioxide is an unwanted by-product; and those installations where both lime and carbon dioxide are utilised. The latter include kilns in the sugar industry (where carbon dioxide is used in the purification stages) and soda ash production (where carbon dioxide is combined with other chemicals to produce sodium carbonate), and in these kilns, the carbon dioxide from decarbonisation of the limestone or dolomite feedstock is assumed to be fully consumed in the process, rather than emitted to atmosphere. **Table A 7.5.5** therefore does not cover these installations. None of the emission factors in EU ETS are Tier 3, so the table shows the overall emission factors for all tiers of data.

Table A 7.5.5 EU ETS emission factor data for production of lime (kt / Mt lime produced)

Year	Activity	EU ETS
2005	Lime production	200.4
2006		201.2
2007		201.3
2008		195.6
2009		195.0
2010		194.0
2011		195.6
2012		195.7
2013		194.4
2014		194.6
2015		195.3
2016		196.9

These factors compare with a theoretical emission factor based on the stoichiometry of the lime manufacturing process of 214 kt / Mt lime, assuming use of pure limestone. We note that the EU ETS factors are all lower than the theoretical emission factor and this is despite some use of dolomitic limestone in the UK industry which would be expected to further increase the emission factor above the 214 kt/Mt lime factor. The EU ETS data are subject to third party verification, and therefore the emissions data are assumed to be accurate. It is assumed that the reason for this deviation from the theoretical emission factor is due to the production activity data being inflated by either the products containing some proportion of slaked lime (i.e. hydrated product and hence containing a lower proportion of carbon than pure lime) and/or other additives to the lime product which decrease the % carbon content of the lime product.

A 7.5.2.6 Other Industrial Combustion

Table A 7.5.6 summarises EU ETS data for coal, fuel oil and natural gas used by industrial combustion installations.

At first sight, the data for coal looks like it should be reliable enough to be used in the GHGI with 92% or more of emissions based on Tier 3 factors in each year. However, it must be recalled that numerous smaller industrial consumers will not be represented in EU ETS and that the EU ETS data are not fully representative of UK fuels as a whole – see **Section A 7.4** for details. This is also true for EU ETS data for fuel oil and natural gas but here, in addition, very little of the EU ETS data are based on Tier 3 factors. Therefore, none of these data have been used directly in the compilation of the GHGI estimates.

Table A 7.5.6 EU ETS data for Coal, Fuel Oil and Natural Gas used by Industrial Combustion Plant (Emission Factors in kt / Mt for Coal & Fuel Oil, kt / Mth for Natural Gas)

Year	Fuel	% Tier 3	Average Carbon Emission Factor (Tier 3 sites only)	GHGI Carbon Emission Factor
2005	Coal	98	607.1	647.8
2006		98	603	647.8
2007		99	615.7	662.4
2008		94	598.6	656.6
2009		92	595.4	668.5
2010		92	589	674.3
2011		96	596.5	653.4
2012		96	605.8	653.7
2013		97	628.2	653.3
2014		98	635	651.2
2015		99	645.8	652.1
2016		97	624.9	650.9
2005	Fuel oil	17	864.7	879
2006		27	865.3	879
2007		44	872.3	879
2008		24	871.4	879
2009		39	871.3	879
2010		40	873	879
2011		51	874.2	879
2012		48	875.1	879
2013		43	871.3	879
2014		47	875	879
2015		53	872.1	879
2016		60	876.2	879
2005	Natural gas	14	1.593	1.477
2006		31	1.47	1.476
2007		42	1.466	1.476
2008		29	1.496	1.475
2009		43	1.499	1.473
2010		43	1.502	1.472
2011		41	1.468	1.47
2012		42	1.471	1.47
2013		44	1.474	1.473

Year	Fuel	% Tier 3	Average Carbon Emission Factor (Tier 3 sites only)	GHGI Carbon Emission Factor
2014		43	1.473	1.472
2015		44	1.481	1.472
2016		43	1.475	1.471

Emission factors can also be derived from EU ETS where a high percentage of Tier 3 analysis is evident, for a number of other minor fuels. Due to the very low number of sites that report data for each fuel type, these EU ETS-derived emission factors are confidential and are not tabulated here. The source/activity combinations for which EU ETS emission factor data are used within the inventory are:

- Other industrial combustion / petroleum coke
- Other industrial combustion / waste solvents
- Other industrial combustion / colliery methane

The EU ETS-derived emission factors for colliery methane for each year (2005-2016) are also applied to all other sources using these fuels.

ANNEX 8: UK Domestic Emissions Reporting Requirements

In addition to the reporting requirements of the UNFCCC, Kyoto Protocol (KP) and EU MMR, UK Greenhouse Gas Inventory statistics are published annually in a Department for Business, Energy and Industrial Strategy National Statistics release[17]. The geographical coverage of these estimates differs from the UNFCCC, KP and EU MMR coverage, with the totals mainly covering emissions from the UK only (i.e. excluding overseas territories and crown dependencies), although progress towards the Kyoto Protocol is still reported.

As part of the Climate Change Act 2008, the UK committed to reducing greenhouse gas emissions by at least 80 percent by 2050 (relative to the base year[18]), with an interim target of reducing greenhouse gas emissions by at least 34 percent by 2020, also relative to the base year. These targets are accompanied by legally binding five-year carbon budgets, which set the trajectory to reaching the targets by placing a restriction on the total amount of greenhouse gases the UK can emit over the five-year period.

Summary tables of the National Statistics release data are presented below. The data are presented in the nine categories used for the UK's National Communications to the UNFCCC and in UK Official Statistics (NC Categories). Note that the scope of emissions used for calculating Carbon Budgets differs slightly from those presented here – for example Carbon Budgets currently exclude NF_3. The 2018 UK GHG emissions statistical release included an update of the UK's performance against the second carbon budget[19]. Note that performance against the first carbon budget was set in May 2014[20], updated inventories do not update the first carbon budget or our performance against it.

A 8.1 NATIONAL STATISTICS

Table A 8.1.1 Summary table of GHG emissions by NC Category, including net emissions/removals from LULUCF (Mt CO_2eq) – National Statistics coverage (UK only)

NC category	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
Energy supply	277.9	237.8	221.0	231.3	207.2	192.4	202.8	189.6	164.5	144.4	120.2

[17] https://www.gov.uk/government/collections/final-uk-greenhouse-gas-emissions-national-statistics

[18] Under the Kyoto Protocol, the UK uses 1990 as the base year for carbon dioxide, methane and nitrous oxide emissions, and 1995 as the base year for the fluorinated gases (or F-gases: hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride). To ensure consistency with our international obligations, the same base year for each greenhouse gas is used under the Climate Change Act.

[19] https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2016

[20] https://www.gov.uk/government/statistics/final-statement-for-the-first-carbon-budget-period

NC category	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
Business	114.7	112.5	116.2	109.7	94.7	86.4	88.5	89.1	87.1	86.2	81.5
Transport	128.1	129.7	133.3	136.0	124.4	122.3	121.3	119.9	121.2	123.4	125.8
Public	13.5	13.3	12.1	11.2	9.5	8.0	8.9	9.1	7.8	8.0	8.2
Residential	80.2	81.7	88.7	85.7	87.5	70.1	76.6	77.4	64.8	67.4	69.8
Agriculture	55.3	54.3	51.6	49.1	45.9	46.0	45.7	45.5	46.9	46.3	46.5
Industrial processes	59.9	50.8	27.1	20.6	12.7	11.3	10.7	12.9	13.0	12.7	10.5
LULUCF[21]	-2.1	-5.0	-7.9	-11.4	-14.4	-15.0	-12.6	-13.6	-14.4	-15.1	-14.6
Waste management	66.7	69.1	62.9	49.0	29.7	27.7	26.1	22.4	20.0	19.0	19.9
Total	794.2	744.3	705.0	681.3	597.1	549.1	568.0	552.4	510.8	492.4	467.9

Table A 8.1.2 Summary table of GHG emissions by Gas, including net emissions/removals from LULUCF (Mt CO_2eq) – National Statistics coverage (UK only)

Gas	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
CO_2	594.1	556.6	553.7	553.3	492.7	449.7	469.9	459.0	419.1	402.5	378.9
CH_4	133.2	126.7	109.1	87.6	64.5	61.8	60.1	55.5	53.1	51.6	51.6
N_2O	49.6	40.0	29.9	25.8	22.5	21.7	21.7	21.4	21.9	21.5	21.4
HFCs	14.4	19.1	9.8	13.1	16.4	14.9	15.4	15.7	16.0	15.9	15.2
PFCs	1.7	0.6	0.6	0.4	0.3	0.4	0.3	0.3	0.3	0.3	0.4
SF_6	1.3	1.3	1.8	1.1	0.7	0.6	0.6	0.5	0.5	0.5	0.5
NF_3	0.0004	0.0008	0.0017	0.0003	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004	0.0005
Total	794.2	744.3	705.0	681.3	597.1	549.1	568.0	552.4	510.8	492.4	467.9

[21] Land use, land use change and forestry

ANNEX 9: End User Emissions

A 9.1 INTRODUCTION

This Annex explains the concept of an end user emissions (sometimes also referred to a "final user emissions", summarises the end user calculation methodology with examples, and contains tables of greenhouse gas emissions according to the end user from 1990 to 2016.

The end user sectoral categories used are consistent with those used in the National Communications (NC) to the UNFCCC. The sectoral categories in the NC are derived from the UNFCCC reporting guidelines on national communications[22].

The purpose of the end user calculations is to allocate emissions from fuel and electricity producers to the energy users - this allows the emission estimates for a consumer of energy to include the emissions from the production of the fuel or electricity they use.

The UNFCCC does not require end user data to be included in the UK's National Inventory Report. These data have been included to provide BEIS with information for their policy support needs.

The tables in this Annex present summary data for UK greenhouse gas emissions for the years 1990-2016, inclusive. These data are updated annually to reflect revisions in the methods used to estimate emissions, and the availability of new information within the inventory. These recalculations are applied retrospectively to earlier years to ensure a consistent time series and this accounts for any differences in data published in previous reports.

Emissions presented in this chapter show emissions from the UK only, consistent with the BEIS UK statistical release.

A 9.2 DEFINITION OF END USERS

The end user[23] or calculations allocate emissions from fuel producers to fuel users. The end user calculation therefore allows estimates to be made of emissions for a consumer of fuel, which also include the emissions from producing the fuel the consumer has used.

The emissions included in the end user categories can be illustrated with an example of two end users - the residential sector and road transport:

- Emissions in the **residential** end user category include:
    1. All direct emissions from domestic premises, for example, from burning gas, coal or oil for space heating.

[22] See page 84 of UNFCCC Guidelines contained in FCCC/CP/1999/7 available at: http://unfccc.int/resource/docs/cop5/07.pdf

[23] A end user is a consumer of fuel for useful energy. A 'fuel producer' is someone who extracts, processes or converts fuels for the end use of end users. Clearly there can be some overlap of these categories but here the fuel uses categories of the UK BEIS publication DUKES are used, which enable a distinction to be made.

2. A portion of indirect emissions used by domestic consumers from: power stations generating electricity ; emissions from refineries including refining, storage, flaring and extraction; emissions from coal mines (including emissions due to fuel use in the mining industry itself and fugitive emissions of methane from the mines); and emissions from the extraction, storage and distribution of mains gas.

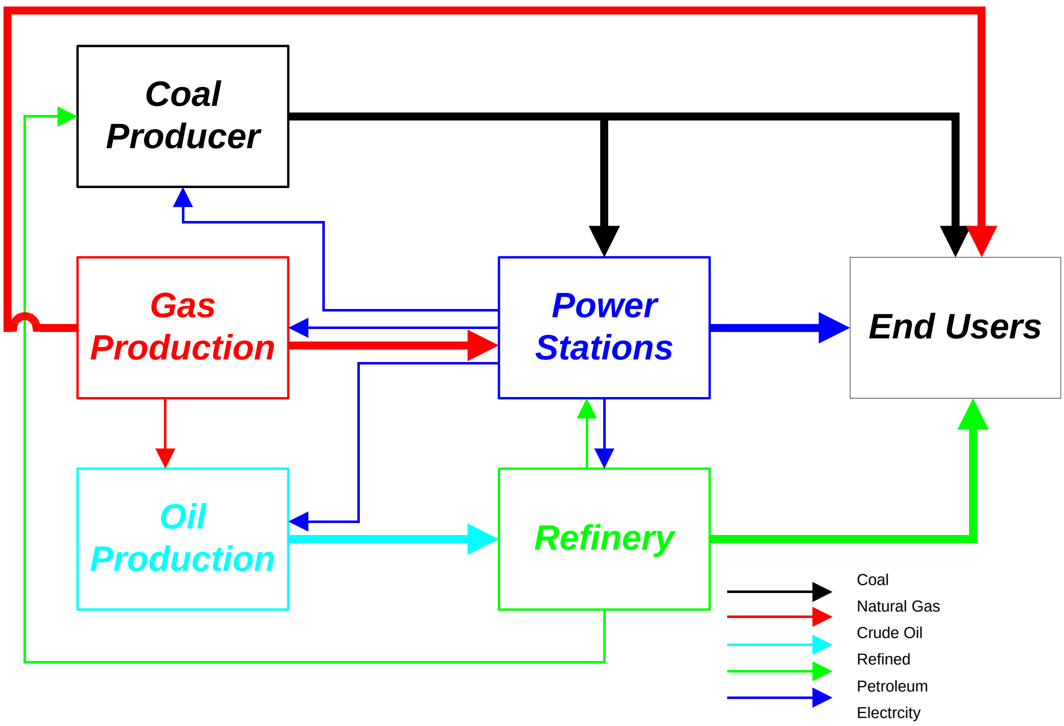
- Emissions in the **road transport** end user category include:
  1. Direct emissions from motor vehicle exhausts.
  2. A portion of indirect emissions from: refineries producing motor fuels, including refining, storage, flaring and extraction of oil; the distribution and supply of motor fuels; and power stations generating the electricity used by electric vehicles.

A 9.3 OVERVIEW OF THE END USER CALCULATIONS

Fuel and electricity producers also require the use of energy which comes from other producers. Thus in the process of reallocating emissions to the end user, emissions are allocated from one to the other and these have to then be reallocated to end users. This circularity results in an iterative approach being used to estimate emissions from categories of end users.

Figure A 9.1 shows a simplified view of the energy flows in the UK (the fuels used in the greenhouse gas inventory have hundreds of uses). This figure shows that while end users consuming electricity are responsible for a proportion of the emissions from power stations they are also responsible for emissions from collieries, and some of these emissions in turn come from electricity generated in power stations and from refineries.

Figure A 9.1 Simplified fuel flows for an end user calculation.



The approach for estimating end user emissions is summarised in the three steps below:

1. Emissions are calculated for each sector for each fuel.

2. Emissions from fuel and electricity producers are then distributed to those sectors that use the fuel according to the energy content[24] of the fuel they use (these sectors can include other fuel producers). This distribution is based on inventory fuel consumption data and DUKES electricity consumption data.
3. By this stage in the calculation, emissions from end users will have increased and those from fuel and electricity producers will have decreased. The sum of emissions from fuel producers and power stations in a particular year as a percentage of the total emissions is then calculated. If this percentage, for any year, exceeds a predetermined value (In the model used to determine emissions from end users, the value of this percentage can be adjusted. The tables presented later in this Appendix were calculated for a convergence at 0.0001%) the process continues at Step 2. If this percentage matches or is less than the predetermined value, the calculation is finished.

Convergence of this iterative approach is likely, as the fuel flows to the end users are much greater than fuel flows amongst the fuel producers.

While a direct solution could possibly be used it was decided to base the calculation on an iterative approach because:

- This can be implemented in the database structures already in existence for the UK greenhouse gas inventory;
- It can handle a wide range of flows and loops that occur without any of the limits that other approaches may incur; and
- The same code will cover all likely situations and will be driven by tabular data stored in the database.

A 9.4 EXAMPLE END USER CALCULATION

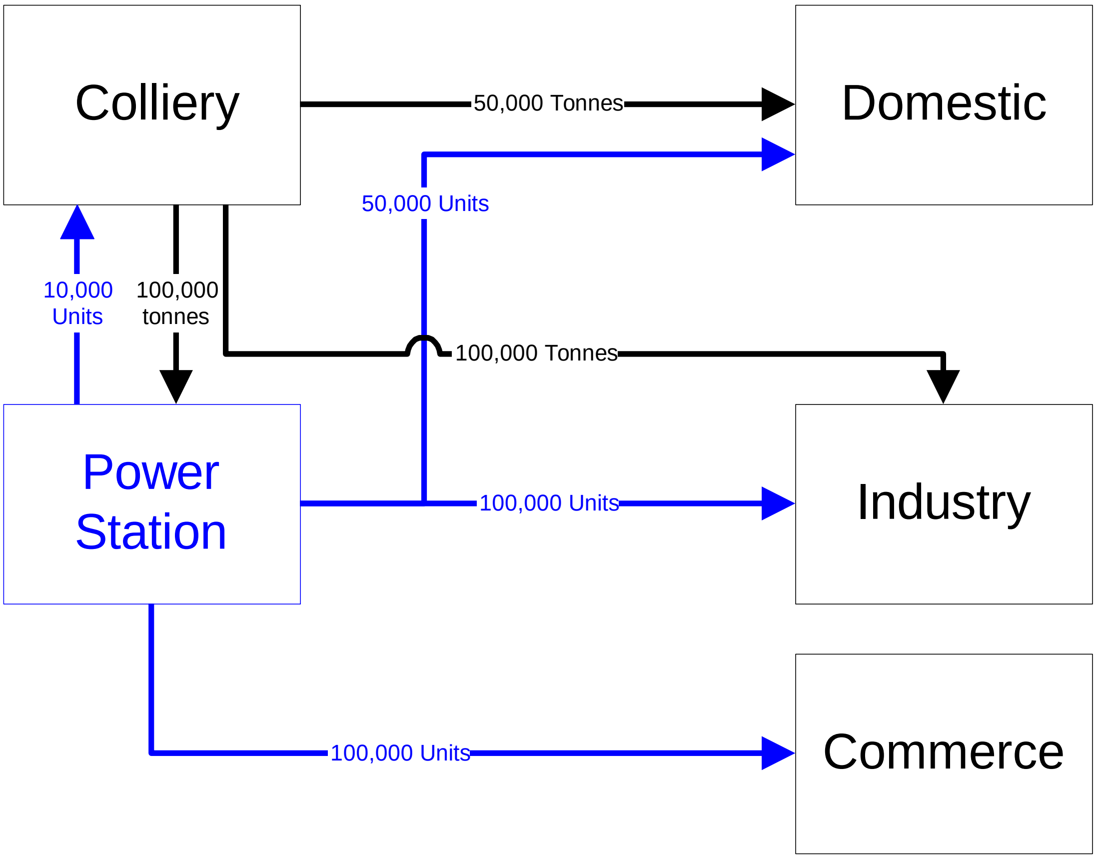
The following example illustrates the methodology used to calculate emissions according to end users. The units in this example are arbitrary.

The example in **Figure A 9.2** has two fuel producers, *power stations* and *collieries*, and three end users, *residential*, *industry* and *commercial*. The following assumptions have been made for simplicity:

- The only fuels used are coal and electricity;
- Coal is the only source of carbon emissions (released from burning coal in power stations to produce electricity and from burning coal in the home for space heating); and
- Commerce uses no coal and so has zero ‘direct’ emissions.

[24] If calorific data for the fuels is not available then the mass of fuel is used instead. This is the case for years prior to 1990.

Figure A 9.2 Fuel use in the example calculation



In **Figure A 9.2**, the tonnes refer to tonnes of coal burnt (black arrows), and the units refer to units of electricity consumed (blue arrows).

In this example the coal extracted by the colliery is burnt in the power station to produce electricity for the end users. Industrial and residential users also directly burn coal. Although the colliery uses electricity produced by the power station, it is not considered to be an end user. The colliery is a 'fuel producer' as it is part of the chain that extracts, processes and converts fuels for the end users.

Table A 9.4.1 summarises the outputs during this example end user calculation.

Table A 9.4.1 Example of the outputs during an end user calculation

			Sector						
			Colliery	Power Station	Residential	Industrial	Commercial	Unallocated emissions as percentage of total emission	Total emission of carbon (tonnes)
Coal use (tonnes)	Mass		100	100,000	50,000	100,000	0		
Coal use (tonnes)	Energy content		25,000	25,000,000	12,500,000	25,000,000	0		
Electricity use (arbitrary units)	Energy units		10,000		50,000	100,000	100,000		
Emissions of carbon (tonnes)	Initial		70	70,000	35,000	70,000	0	40.02	175,070
Emissions of carbon (tonnes)	Emissions after Iteration step	1	2,692	28	48,476	96,951	26,923	1.55	175,070
		2	1	1077	49,020	98,039	26,934	0.62	175,070
		3	41	1	49,227	98,454	27,348	0.02	175,070
		4	0	17	49,235	98,470	27,348	0.01	175,070
		5	1	0	49,238	98,477	27,355	0	175,070
		6	0	0	49,239	98,477	27,355	0	175,070

The initial carbon emissions are 70% of the mass of coal burnt. The emissions from the power stations are distributed to the other sectors by using the factor:

- (Electricity used by that sector)/(total electricity used minus own use by power stations);
- Similarly for the colliery emissions the following factor is used; and
- (Energy of coal used by that sector)/(total energy of coal consumed used minus own use by collieries).

At the end of iteration step one, the commerce sector has 26923 tonnes of carbon emissions allocated to it, mainly derived from power stations. Emissions allocated to the residential and industry sectors have also increased over their initial allocations. However collieries and power stations still have some emissions allocated to them (these come from each other) and so the reallocation process is repeated to reduce these allocations to zero – these two sectors are not end users. The total unallocated (in this example, equal to the total emissions from collieries and power stations) falls in each iteration until the emissions are consistently allocated across the sectors. In this example, six iterations are needed to achieve a consistent allocation across the sectors.

The sum of emissions allocated to the sectors (175,070 tonnes of carbon) remains unchanged from the initial allocation to the allocation in the sixth iteration. This check is an important quality control measure to ensure all emissions are accounted for during the end user calculations.

Figure A 9.3 Comparison of 'direct' and end user emissions of carbon according the sectors considered in the end user example

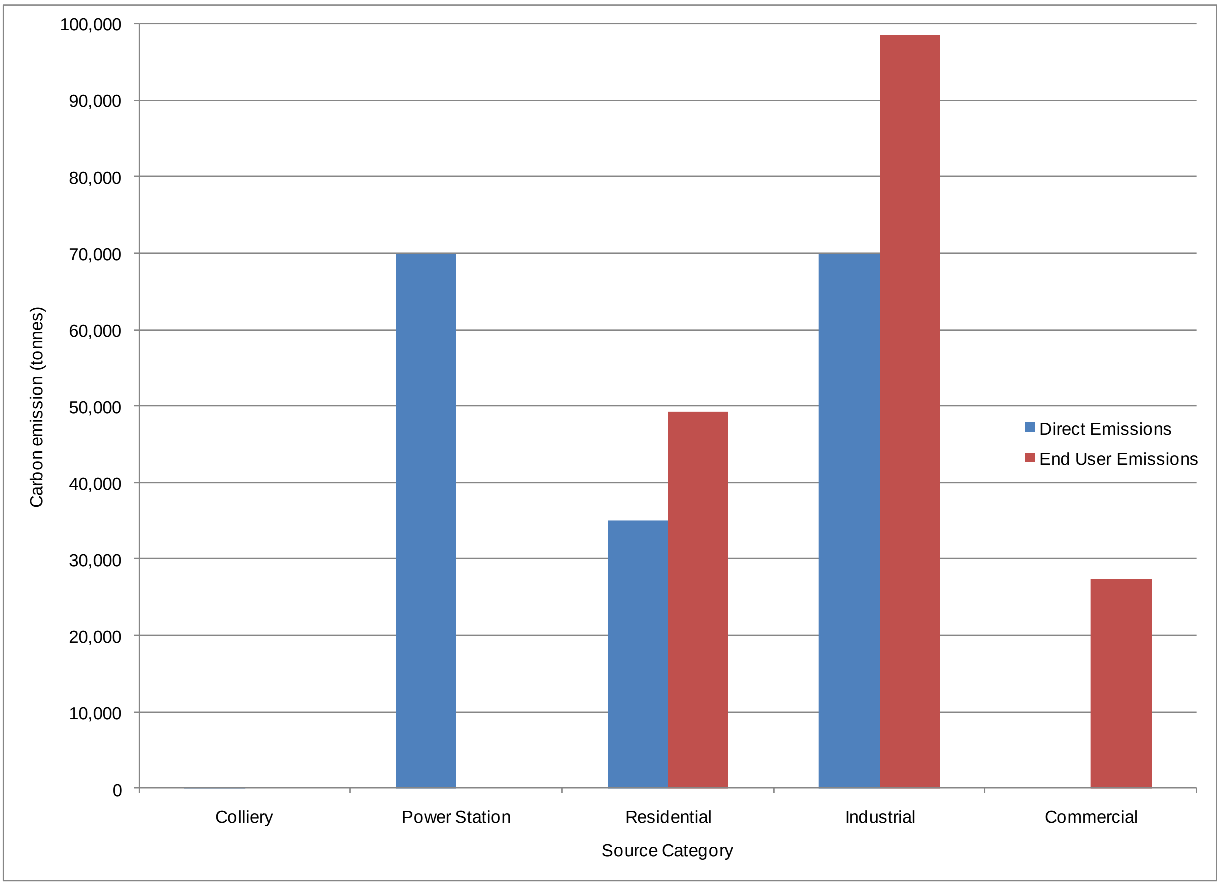


Figure A 9.3 compares the quantities of direct and end user carbon emitted from each sector at the end of the end user calculation. The direct emissions of carbon are from the combustion of coal in the sectors. The direct and end user emissions are from two distinct calculations and must be considered independently – in other words, the direct and end user emissions in each sector must not be summed. The sum of all the direct emissions and the sum of the end user emissions, are identical.

There are relatively large direct emissions of carbon from power stations, residential and industry sectors. The end user emissions from the power stations and the colliery are zero because these two sectors are not end users. The carbon emissions from these two sectors have been reallocated to the residential, industrial and commercial sectors. This reallocation means the end user emissions for the residential and industrial sectors are greater than their 'direct' emissions.

A 9.5 END USER CALCULATION METHODOLOGY FOR THE UK GREENHOUSE GAS INVENTORY

The approach divides fuel user emissions into 8 categories (see column 1 of **Table A 9.5.1**).For each of these groups, source categories are distributed by the total energy consumption of a group of fuels. For example, for the coal group, the emissions of four source categories are distributed to end users according to the energy use of anthracite and coal combined.

Table A 9.5.1 Sources reallocated to end users and the fuels used

End user group	Emission sources to be reallocated to end users	Fuels used for redistribution
1. Coke	Gasification processes	Coke
	Coke production	Blast furnace gas
	Iron and steel – flaring	
2. Coal	Closed Coal Mines	Coal
	Coal storage and transport	Anthracite
	Collieries – combustion	
	Deep-mined coal	
	Open-cast coal	
3. Natural gas	Gas leakage	Natural gas
	Gas production	
	Upstream Gas Production – flaring	
	Upstream Gas Production – fuel combustion	
	Upstream Gas Production – Gas terminal storage	
	Upstream Gas Production – Offshore Well Testing	
	Upstream Gas Production – process emissions	
	Upstream Gas Production – venting	
	Upstream Gas production – combustion at gas separation plant	
4. Electricity	Nuclear fuel production	Electricity
	Power stations	
	Autogeneration – exported to grid	
	Power stations – FGD	

End user group	Emission sources to be reallocated to end users	Fuels used for redistribution
5. Petroleum	Upstream Oil Production – fuel combustion	Aviation spirit
	Upstream Oil Production –flaring	Aviation turbine fuel
	Upstream Oil Production –venting	Biodiesel
	Upstream Oil Production – Offshore Oil Loading	Bioethanol
	Upstream Oil Production – Offshore Well Testing	Burning oil
	Upstream Oil Production – Oil terminal storage	Burning oil (premium)
	Upstream Oil Production – Onshore Oil Loading	DERV
	Upstream Oil Production – process emissions	Fuel oil
	Petrol stations – petrol delivery	Gas oil
	Petrol stations – vehicle refuelling	LPG
	Petrol terminals – storage	Naphtha
	Petrol terminals – tanker loading	OPG
	Petroleum processes	Petrol
	Refineries – combustion	Petroleum coke
	Refineries – drainage	Refinery miscellaneous
	Refineries – flares	Vaporising oil
	Refineries – general	
	Refineries – process	
	Refineries – road/rail loading	
	Refineries – tankage	
	Sea going vessel loading	
	Ship purging	
6. Solid Smokeless Fuels	Solid Smokeless fuel production	Solid Smokeless Fuels
8. Charcoal	Charcoal production	Charcoal

Comments on the calculation methodology used to allocate emissions according to the end users are listed below:

- Emissions are allocated to end users on the basis of the proportion of the total energy produced that is used by a given sector. This approach is followed to allow for sectors such as petroleum where different products are made in a refinery;
- Some emissions are allocated to an “exports” category. This is for emissions within the UK from producing fuels, (for example from a refinery or coal mine), which are subsequently exported or sent to bunkers for use outside the UK. Therefore these emissions are part of the UK inventory even if the use of the fuel produces emissions that cannot be included in the UK inventory because it takes place outside the UK;
- No allowance is made for the emission from the production of fuels or electricity outside the UK that are subsequently imported;
- Some of the output of a refinery is not used as a fuel but used as feedstock or lubricants. This is not currently treated separately and the emissions from their production (which are small) are allocated to users of petroleum fuels. This is partly due to lack of data in the database used to calculate the inventory, and partly due to the lack of a clear, transparent way of separating emissions from the production of fuels and from the production of non-fuel petroleum products; and
- End user emissions are estimated for aviation in four categories: domestic take-off and landing, international take-off and landing, domestic cruise and international cruise. This enables both IPCC and UNECE categories to be estimated from the same end user calculation.

Our exact mapping of end user emissions to IPCC categories is shown in **Table A 9.5.2.** The NAEI source sectors and activity names are also shown, as it is necessary to subdivide some IPCC categories. This classification has been used to generate the end user tables for the greenhouse gases given in this section. As this table is for end users, no fuel producers are included in the table.

Table A 9.5.2 End user category, IPCC sectors, and NAEI source names and activity names used in the emission calculation

NC Category	IPCC	SourceName	ActivityName
Agriculture	1A4ci_Agriculture/Forestry/Fishing:Stationary	Agriculture - stationary combustion	Burning oil
			Coal
			Fuel oil
			Natural gas
			Straw
	1A4cii_Agriculture/Forestry/Fishing:Off-road	Agriculture - mobile machinery	Gas oil
			Petrol
	2D1_Lubricant_Use	Agricultural engines	Lubricants
	3A1_Enteric_Fermentation_dairy_cattle	Agriculture livestock - dairy cattle enteric	Livestock
	3A1_Enteric_Fermentation_non-dairy_cattle	Agriculture livestock - other cattle enteric	Livestock
	3A2_Enteric_Fermentation_sheep	Agriculture livestock - sheep enteric	Non-fuel combustion
	3A3_Enteric_Fermentation_swine	Agriculture livestock - pigs enteric	Non-fuel combustion
	3A4_Enteric_Fermentation_other:deer	Agriculture livestock - deer enteric	Non-fuel combustion
	3A4_Enteric_Fermentation_other:goats	Agriculture livestock - goats enteric	Non-fuel combustion
	3A4_Enteric_Fermentation_other:horses	Agriculture livestock - horses enteric	Non-fuel combustion
	3B1_Manure_Management_dairy_cattle	Agriculture livestock - dairy cattle wastes	Non-fuel combustion
		Agriculture livestock - dairy cattle wastes -direct -	Non-fuel combustion
		Agriculture livestock - dairy cattle wastes -indirect volatilisation -	Non-fuel combustion
		Agriculture livestock - manure leaching (indirect); dairy cattle wastes	Non-fuel combustion
	3B1_Manure_Management_non-dairy_cattle	Agriculture livestock - other cattle wastes	Non-fuel combustion

NC Category	IPCC	SourceName	ActivityName
		Agriculture livestock - other cattle wastes - direct -	Non-fuel combustion
		Agriculture livestock - other cattle wastes - indirect volatilisation -	Non-fuel combustion
	3B1_Manure_Management_other_cattle	Agriculture livestock - manure leaching (indirect); other cattle wastes	Non-fuel combustion
	3B2_Manure_Management_sheep	Agriculture livestock - manure leaching (indirect); sheep wastes	Non-fuel combustion
		Agriculture livestock - sheep wastes	Livestock
			Non-fuel combustion
		Agriculture livestock - sheep wastes - indirect volatilisation -	Non-fuel combustion
	3B3_Manure_Management_swine	Agriculture livestock - manure leaching (indirect); pigs wastes	Non-fuel combustion
		Agriculture livestock - pigs wastes	Livestock
			Non-fuel combustion
		Agriculture livestock - pigs wastes - indirect volatilisation -	Non-fuel combustion
	3B4_Manure_Management_other:deer	Agriculture livestock - deer wastes	Livestock
			Non-fuel combustion
		Agriculture livestock - deer wastes - indirect volatilisation -	Non-fuel combustion
	3B4_Manure_Management_other:goats	Agriculture livestock - goats wastes	Livestock
			Non-fuel combustion
		Agriculture livestock - goats wastes -indirect volatilisation -	Non-fuel combustion
	3B4_Manure_Management_other:horses	Agriculture livestock - horses wastes	Non-fuel combustion
		Agriculture livestock - horses wastes - direct -	Non-fuel combustion
		Agriculture livestock - horses wastes - indirect volatilisation -	Non-fuel combustion

NC Category	IPCC	SourceName	ActivityName
	3B4_Manure_Management_other:poultry	Agriculture livestock - all poultry wastes	Non-fuel combustion
		Agriculture livestock - all poultry wastes - direct -	Non-fuel combustion
		Agriculture livestock - all poultry wastes - indirect volatilisation -	Non-fuel combustion
	3B4_Other	Agriculture livestock - manure leaching (indirect); all poultry wastes	Non-fuel combustion
		Agriculture livestock - manure leaching (indirect); deer wastes	Non-fuel combustion
		Agriculture livestock - manure leaching (indirect); goats wastes	Non-fuel combustion
		Agriculture livestock - manure leaching (indirect); horses wastes	Non-fuel combustion
	3D_Agricultural_Soils	Agricultural soils - fertiliser to grassland - direct -	Non-fuel combustion
		Agricultural soils - fertiliser to grassland - indirect leaching -	Non-fuel combustion
		Agricultural soils - fertiliser to grassland - indirect volatilisation -	Non-fuel combustion
		Agricultural soils - fertiliser to tillage - direct -	Non-fuel combustion
		Agricultural soils - fertiliser to tillage - indirect leaching -	Non-fuel combustion
		Agricultural soils - fertiliser to tillage - indirect volatilisation -	Non-fuel combustion
		Agriculture livestock - Animal manure applied to soils; Goats	Manure and excreta
		Agriculture livestock - Animal manure applied to soils; Other animals (deer)	Manure and excreta
		Agriculture soils - all poultry FAM - direct -	Non-fuel combustion
		Agriculture soils - all poultry FAM - indirect leaching -	Non-fuel combustion
		Agriculture soils - all poultry FAM - indirect volatilisation -	Non-fuel combustion

NC Category	IPCC	SourceName	ActivityName
		Agriculture soils - all poultry PRP - direct -	Non-fuel combustion
		Agriculture soils - all poultry PRP - indirect leaching -	Non-fuel combustion
		Agriculture soils - all poultry PRP - indirect volatilisation -	Non-fuel combustion
		Agriculture soils - crop residues cropland - direct -	Non-fuel combustion
		Agriculture soils - crop residues cropland - indirect leaching -	Non-fuel combustion
		Agriculture soils - crop residues grassland - direct -	Non-fuel combustion
		Agriculture soils - crop residues grassland - indirect leaching -	Non-fuel combustion
		Agriculture soils - dairy cattle FAM -direct -	Non-fuel combustion
		Agriculture soils - dairy cattle FAM -indirect leaching -	Non-fuel combustion
		Agriculture soils - dairy cattle FAM -indirect volatilisation -	Non-fuel combustion
		Agriculture soils - dairy cattle PRP -indirect leaching -	Non-fuel combustion
		Agriculture soils - dairy cattle PRP -indirect volatilisation -	Non-fuel combustion
		Agriculture soils - deer FAM - indirect leaching -	Non-fuel combustion
		Agriculture soils - deer FAM - indirect volatilisation -	Non-fuel combustion
		Agriculture soils - deer PRP - indirect leaching -	Non-fuel combustion
		Agriculture soils - deer PRP - indirect volatilisation -	Non-fuel combustion
		Agriculture soils - goats FAM - indirect leaching -	Non-fuel combustion
		Agriculture soils - goats FAM - indirect volatilisation -	Non-fuel combustion
		Agriculture soils - goats PRP - indirect leaching -	Non-fuel combustion

NC Category	IPCC	SourceName	ActivityName
		Agriculture soils - goats PRP - indirect volatilisation -	Non-fuel combustion
		Agriculture soils - horses FAM - direct -	Non-fuel combustion
		Agriculture soils - horses FAM - indirect leaching -	Non-fuel combustion
		Agriculture soils - horses FAM - indirect volatilisation -	Non-fuel combustion
		Agriculture soils - horses PRP - direct -	Non-fuel combustion
		Agriculture soils - horses PRP - indirect leaching -	Non-fuel combustion
		Agriculture soils - horses PRP - indirect volatilisation -	Non-fuel combustion
		Agriculture soils - other cattle FAM - direct -	Non-fuel combustion
		Agriculture soils - other cattle FAM - indirect leaching -	Non-fuel combustion
		Agriculture soils - other cattle FAM - indirect volatilisation -	Non-fuel combustion
		Agriculture soils - other cattle PRP - indirect leaching -	Non-fuel combustion
		Agriculture soils - other cattle PRP - indirect volatilisation -	Non-fuel combustion
		Agriculture soils - pigs FAM - indirect volatilisation -	Non-fuel combustion
		Agriculture soils - pigs FAM -direct -	Non-fuel combustion
		Agriculture soils - pigs FAM - indirect leaching -	Non-fuel combustion
		Agriculture soils - pigs PRP - indirect volatilisation -	Non-fuel combustion
		Agriculture soils - pigs PRP - indirect leaching -	Non-fuel combustion
		Agriculture soils - sewage sludge application - indirect leaching -	Non-fuel combustion
		Agriculture soils - sewage sludge application - indirect volatilisation -	Non-fuel combustion

NC Category	IPCC	SourceName	ActivityName
		Agriculture soils - sewage sludge application -direct -	Non-fuel combustion
		Agriculture soils - sheep FAM - indirect volatilisation -	Non-fuel combustion
		Agriculture soils - sheep FAM - direct -	Non-fuel combustion
		Agriculture soils - sheep FAM - indirect leaching -	Non-fuel combustion
		Agriculture soils - sheep PRP - indirect volatilisation -	Non-fuel combustion
		Agriculture soils - sheep PRP - indirect leaching -	Non-fuel combustion
		Managed Histosols	Non-fuel fertilizer
		Urine and dung deposited by grazing animals - Dairy cattle	Manure and excreta
		Urine and dung deposited by grazing animals - Goats	Manure and excreta
		Urine and dung deposited by grazing animals - Non-dairy cattle	Manure and excreta
		Urine and dung deposited by grazing animals - Other animals (Deer)	Manure and excreta
		Urine and dung deposited by grazing animals - Sheep	Manure and excreta
		Urine and dung deposited by grazing animals - Swine	Manure and excreta
	3D1_Agricultural_soils-Mineralization/Immobilization	Cropland management mineralisation	Non-fuel combustion
		Cropland management mineralisation - indirect leaching -	Non-fuel combustion
	3F_Field_burning	Field burning	Barley residue
			Linseed residue
			Oats residue
			Wheat residue
	3G1_Liming - limestone	Liming	Limestone

NC Category	IPCC	SourceName	ActivityName
	3G2_Liming - dolomite	Liming	Dolomite
	3H_Urea application	Agriculture - application of urea	Urea consumption
	non-IPCC	Agriculture - stationary combustion	Electricity
Business	1A1ai_Public_Electricity&Heat_Production	Autogenerators	Biogas
	1A2a_Iron_and_steel	Blast furnaces	Blast furnace gas
			Coke oven gas
			LPG
			Natural gas
		Iron and steel - combustion plant	Blast furnace gas
			Coal
			Coke
			Coke oven gas
			Fuel oil
			Gas oil
			LPG
			Natural gas
	1A2b_Non-Ferrous_Metals	Autogeneration - exported to grid	Coal
		Autogenerators	Coal
		Non-Ferrous Metal (combustion)	Coal
			Fuel oil
			Gas oil
			Natural gas
	1A2c_Chemicals	Chemicals (combustion)	Coal
			Fuel oil
			Gas oil
			Natural gas

NC Category	IPCC	SourceName	ActivityName
	1A2d_Pulp_Paper_Print	Pulp, Paper and Print (combustion)	Coal
			Fuel oil
			Gas oil
			Natural gas
	1A2e_food_processing_beverages_and_tobacco	Food & drink, tobacco (combustion)	Coal
			Fuel oil
			Gas oil
			Natural gas
	1A2f_Non-metallic_minerals	Cement production - combustion	Coal
			Fuel oil
			Gas oil
			Natural gas
			Petroleum coke
			Scrap tyres
			Waste
			Waste oils
			Waste solvent
		Lime production - non decarbonising	Coal
			Coke
			Natural gas
		Other industrial combustion	Scrap tyres
	1A2gvii_Off-road_vehicles_and_other_machinery	Industrial off-road mobile machinery	DERV
			Gas oil
			Petrol
	1A2gviii_Other_manufacturing_industries_and_construction	Autogeneration - exported to grid	Natural gas
		Autogenerators	Natural gas

NC Category	IPCC	SourceName	ActivityName
		Other industrial combustion	Biomass
			Burning oil
			Coal
			Coke
			Coke oven gas
			Colliery methane
			Fuel oil
			Gas oil
			LPG
			Lubricants
			Natural gas
			OPG
			Petroleum coke
			SSF
			Waste solvent
			Wood
	1A4ai_Commercial/Institutional	Miscellaneous industrial/commercial combustion	Coal
			Fuel oil
			Gas oil
			Landfill gas
			MSW
			Natural gas
	2B1_Chemical_Industry:Ammonia_production	Ammonia production - combustion	Natural gas
	2B8a_Methanol_production	Methanol production – combustion	Natural gas
	2B8g_Petrochemical_and_carbon_black_production:Other	Chemicals (combustion)	OPG
	2C1b_Pig_iron	Blast furnaces	Coal

NC Category	IPCC	SourceName	ActivityName
	2D1_Lubricant_Use	Industrial engines	Lubricants
	2D4_Other_NEU	Non Energy Use: petroleum coke	Petroleum coke
	2E1_Integrated_circuit_or_semiconductor	Electronics - HFC	Non-fuel combustion
		Electronics - NF_3	Non-fuel combustion
	2F1a_Commercial_refrigeration	Commercial Refrigeration	Refrigeration and Air Conditioning - Disposal
			Refrigeration and Air Conditioning - Lifetime
			Refrigeration and Air Conditioning - Manufacture
	2F1b_Domestic_refrigeration	Domestic Refrigeration	Refrigeration and Air Conditioning - Disposal
			Refrigeration and Air Conditioning - Lifetime
			Refrigeration and Air Conditioning - Manufacture
	2F1c_Industrial_refrigeration	Industrial Refrigeration	Refrigeration and Air Conditioning - Disposal
			Refrigeration and Air Conditioning - Lifetime
			Refrigeration and Air Conditioning - Manufacture
	2F1d_Transport_refrigeration	Refrigerated Transport	Refrigeration and Air Conditioning - Disposal
			Refrigeration and Air Conditioning - Lifetime
			Refrigeration and Air Conditioning - Manufacture
	2F1e_Mobile_air_conditioning	Mobile Air Conditioning	Refrigeration and Air Conditioning - Disposal
			Refrigeration and Air Conditioning - Lifetime
			Refrigeration and Air Conditioning - Manufacture
	2F1f_Stationary_air_conditioning	Stationary Air Conditioning	Refrigeration and Air Conditioning - Disposal

NC Category	IPCC	SourceName	ActivityName
			Refrigeration and Air Conditioning - Lifetime
			Refrigeration and Air Conditioning - Manufacture
	2F2a_Closed_foam_blowing_agents	Foams	Non-fuel combustion
		Foams HFCs for the 2006 GLs	Non-fuel combustion
	2F2b_Open_foam_blowing_agents	One Component Foams	Non-fuel combustion
	2F3_Fire_Protection	Firefighting	Non-fuel combustion
	2F5_Solvents	Precision cleaning - HFC	Non-fuel combustion
	2F6b_Other_Applications:Contained-Refrigerant_containers	Refrigerant containers	Non-fuel combustion
	2G1_Electrical_equipment	Electrical insulation	Non-fuel combustion
	2G2_Military_applications	AWACS	Non-fuel combustion
	2G2_Particle_accelerators	Particle accelerators	Non-fuel combustion
	2G2e_Electronics_and_shoes	Electronics - PFC	Non-fuel combustion
		Electronics - SF_6	Non-fuel combustion
		Sporting goods	Non-fuel combustion
	2G2e_Tracer_gas	SF_6 used as a tracer gas	Non-fuel combustion
	2G3a_Medical applications	N_2O use as an anaesthetic	Population
	5C2.2b_Non-biogenic:Other	Accidental fires - other buildings	Mass burnt
	non-IPCC	Chemicals (combustion)	Electricity
		Food & drink, tobacco (combustion)	Electricity
		Iron and steel - combustion plant	Electricity
		Miscellaneous industrial/commercial combustion	Electricity
		Non-Ferrous Metal (combustion)	Electricity
		Other industrial combustion	Electricity
		Pulp, Paper and Print (combustion)	Electricity

NC Category	IPCC	SourceName	ActivityName
Exports	Aviation_Bunkers	Aircraft - international cruise	Aviation spirit
			Aviation turbine fuel
		Aircraft - international take-off and landing	Aviation spirit
			Aviation turbine fuel
		Aircraft between UK and Bermuda - Cruise	Aviation turbine fuel
		Aircraft between UK and Bermuda - TOL	Aviation turbine fuel
		Aircraft between UK and CDs - Cruise	Aviation spirit
			Aviation turbine fuel
		Aircraft between UK and CDs - TOL	Aviation spirit
			Aviation turbine fuel
		Aircraft between UK and Gibraltar - Cruise	Aviation spirit
			Aviation turbine fuel
		Aircraft between UK and Gibraltar - TOL	Aviation spirit
			Aviation turbine fuel
		Aircraft between UK and other OTs (excl Gib. and Bermuda) - Cruise	Aviation turbine fuel
		Aircraft between UK and other OTs (excl Gib. and Bermuda) - TOL	Aviation turbine fuel
	Marine_Bunkers	Shipping - international IPCC definition	Fuel oil
			Gas oil
		Shipping between UK and Bermuda	Fuel oil
		Shipping between UK and CDs	Fuel oil
			Gas oil
		Shipping between UK and Gibraltar	Fuel oil
		Shipping between UK and OTs (excl. Gib and Bermuda)	Fuel oil
	non-IPCC	Exports	Aviation turbine fuel

NC Category	IPCC	SourceName	ActivityName
			Burning oil
			Coke
			DERV
			Electricity
			Fuel oil
			Petrol
			SSF
Industrial Process	2A1_Cement_Production	Cement - decarbonising	Clinker production
	2A2_Lime_Production	Lime production - decarbonising	Limestone
	2A3_Glass_production	Glass - general	Dolomite
			Limestone
			Soda ash
	2A4a_Other_process_uses_of_carbonates:ceramics	Brick manufacture - all types	Bricks
		Brick manufacture - Fletton	Fletton bricks
	2B1_Ammonia_Production	Ammonia production - feedstock use of gas	Natural gas
	2B10_Chemical_Industry:Other	Chemical industry - general	Process emission
	2B2_Nitric_Acid_Production	Nitric acid production	Acid production
	2B3_Adipic_Acid_Production	Adipic acid production	Adipic acid produced
	2B6_Titanium_dioxide_production	Chemical industry - titanium dioxide	Coke
			Petroleum coke
	2B7_Soda_Ash_Production	Chemical industry - soda ash	Soda ash produced
	2B8a_Methanol_production	Chemical industry - methanol	Methanol
			Natural gas
	2B8b_Ethylene_Production	Chemical industry - ethylene	Ethylene
	2B8c_Ethylene_Dichloride_and_Vinyl_Chloride_Monomer	Chemical Industry - ethylene dichloride	Ethylene dichloride

NC Category	IPCC	SourceName	ActivityName
	2B8d_Ethylene_Oxide	Chemical industry - ethylene oxide	Ethylene oxide
	2B8e_Acrylonitrile	Chemical industry - acrylonitrile	Acrylonitrile
	2B8f_Carbon_black_production	Chemical industry - carbon black	Carbon black capacity
	2B9a1_Fluorchemical_production:By-product_emissions	Halocarbons production - by-product	Non-fuel combustion
	2B9b3_Fluorchemical_production:Fugitive_emissions	Halocarbons production - fugitive	Non-fuel combustion
	2C1a_Steel	Basic oxygen furnaces	Dolomite
		Electric arc furnaces	Petroleum coke
			Steel production (electric arc)
		Ladle arc furnaces	Steel production (electric arc)
			Steel production (oxygen converters)
	2C1b_Pig_iron	Blast furnaces	Coke
			Fuel oil
	2C1d_Sinter	Sinter production	Coke
			Dolomite
			Limestone
	2C3_Aluminium_Production	Primary aluminium production - general	Primary aluminium production
		Primary aluminium production - PFC emissions	Primary aluminium production
	2C4_Magnesium_production	Magnesium cover gas	Non-fuel combustion
	2C6_Zinc_Production	Non-ferrous metal processes	Coke
	2G3b_N_2O_from_product_uses:_Other	Other food - cream consumption	Process emission
	2G4_Other_product_manufacture_and_use	Chemical Industry – other process sources	Process emission
	non-IPCC	Blast furnaces	Electricity
Land Use Change	4_Indirect_N_2O_Emissions	LULUCF Indirect N_2O - Atmospheric Deposition	Non-fuel combustion

NC Category	IPCC	SourceName	ActivityName
		LULUCF Indirect N_2O - Nitrogen Leaching and Run-off	Non-fuel combustion
	4A_Forest Land_Emissions_from_Drainage	Forest Land - Drainage and rewetting and other management of organic and mineral soils	Non-fuel combustion
	4A1_ Forest Land remaining Forest Land	Forest Land remaining Forest Land - Biomass Burning - Wildfires	Biomass
		Forest Land remaining Forest Land - Carbon stock change	Non-fuel combustion
	4A2_1_Cropland converted to Forest Land	Cropland converted to Forest Land - Carbon stock change	Non-fuel combustion
	4A2_2_Grassland converted to Forest Land	Grassland converted to Forest Land - Carbon stock change	Non-fuel combustion
	4A2_4_Settlements converted to Forest Land	Settlements converted to Forest Land - Carbon stock change	Non-fuel combustion
	4A2_Cropland converted to Forest Land	Cropland converted to Forest Land - Direct N_2O emissions from N Mineralization/Immobilization	Non-fuel combustion
	4A2_Grassland converted to Forest Land	Grassland converted to Forest Land - Direct N_2O emissions from N Mineralization/Immobilization	Non-fuel combustion
	4A2_Land converted to Forest Land_Emissions_from_Fertilisation	Direct N_2O emission from N fertilisation of forest land	Non-fuel combustion
	4A2_Settlements converted to Forest Land	Settlements converted to Forest Land - Direct N_2O emissions from N Mineralization/Immobilization	Non-fuel combustion
	4B1_Cropland Remaining Cropland	Cropland remaining Cropland - Biomass Burning - Wildfires	Biomass
		Cropland remaining Cropland - Carbon stock change	Non-fuel combustion
	4B1_Cropland_Remaining_Cropland	Carbon stock change	Non-fuel combustion
	4B2_1_Forest Land converted to Cropland	Forest Land converted to Cropland - Biomass Burning - Controlled Burning	Biomass
		Forest Land converted to Cropland - Carbon stock change	Non-fuel combustion

NC Category	IPCC	SourceName	ActivityName
		Forest Land converted to Cropland - Direct N_2O emissions from N Mineralization/Immobilization	Non-fuel combustion
	4B2_2_Grassland converted to Cropland	Grassland converted to Cropland - Carbon stock change	Non-fuel combustion
		Grassland converted to Cropland - Direct N_2O emissions from N Mineralization/Immobilization	Non-fuel combustion
	4B2_4_Settlements converted to Cropland	Settlements converted to Cropland - Carbon stock change	Non-fuel combustion
	4C_Grassland_Emissions_from_Drainage	Grassland - Drainage and rewetting and other management of organic and mineral soils	Non-fuel combustion
	4C1_Grassland Remaining Grassland	Grassland remaining Grassland - Biomass Burning - Wildfires	Biomass
		Grassland remaining Grassland - Carbon stock change	Non-fuel combustion
		Grassland remaining Grassland - Direct N_2O emissions from N Mineralization/Immobilization	Non-fuel combustion
	4C2_1_Forest Land converted to Grassland	Forest Land converted to Grassland - Biomass Burning - Controlled Burning	Biomass
		Forest Land converted to Grassland - Carbon stock change	Non-fuel combustion
		Forest Land converted to Grassland - Direct N_2O emissions from N Mineralization/Immobilization	Non-fuel combustion
	4C2_2_Cropland converted to Grassland	Cropland converted to Grassland - Carbon stock change	Non-fuel combustion
	4C2_3_Wetlands converted to Grassland	Wetlands converted to Grassland - Carbon stock change	Non-fuel combustion
	4C2_4_Settlements converted to Grassland	Settlements converted to Grassland - Carbon stock change	Non-fuel combustion
	4D_Wetlands_Emissions_from_Drainage	Wetlands - Drainage and rewetting and other management of organic and mineral soils	Non-fuel combustion

NC Category	IPCC	SourceName	ActivityName
	4D1_Wetlands remaining wetlands	Peat Extraction Remaining Peat Extraction - Carbon stock change	Non-fuel combustion
	4D2_Land converted to Wetlands	Grassland converted to flooded land - Carbon stock change	Non-fuel combustion
		Land converted for Peat Extraction - Carbon stock change	Non-fuel combustion
	4E1_Settlements remaining settlements	Settlements remaining Settlements - Carbon stock change	Non-fuel combustion
		Settlements remaining Settlements - Direct N_2O emissions from N Mineralization/Immobilization	Non-fuel combustion
	4E2_1_Forest Land converted to Settlements	Forest Land converted to Settlements - Biomass Burning - Controlled Burning	Biomass
		Forest Land converted to Settlements - Carbon stock change	Non-fuel combustion
		Forest Land converted to Settlements - Direct N_2O emissions from N Mineralization/Immobilization	Non-fuel combustion
	4E2_2_Cropland converted to Settlements	Cropland converted to Settlements - Carbon stock change	Non-fuel combustion
		Cropland converted to Settlements - Direct N_2O emissions from N Mineralization/Immobilization	Non-fuel combustion
	4E2_3_Grassland converted to Settlements	Grassland converted to Settlements - Carbon stock change	Non-fuel combustion
		Grassland converted to Settlements - Direct N_2O emissions from N Mineralization/Immobilization	Non-fuel combustion
	4G_Harvested Wood Products	HWP Produced and Consumed Domestically - Carbon stock change	Non-fuel combustion
		HWP Produced and Exported - Carbon stock change	Non-fuel combustion
Public	1A4ai_Commercial/Institutional	Public sector combustion	Burning oil

NC Category	IPCC	SourceName	ActivityName
			Coal
			Coke
			Fuel oil
			Gas oil
			Natural gas
			Sewage gas
	non-IPCC	Public sector combustion	Electricity
Residential	1A4bi_Residential_stationary	Domestic combustion	Anthracite
			Burning oil
			Charcoal
			Coal
			Coke
			Fuel oil
			Gas oil
			LPG
			Natural gas
			Peat
			Petroleum coke
			SSF
			Wood
	1A4bii_Residential:Off-road	House and garden machinery	DERV
			Petrol
	2D2 Non-energy_products_from_fuels_and_solvent_use:Paraffin_wax_use	Non-aerosol products - household products	Petroleum waxes
	2F4a_Metered_dose_inhalers	Metered dose inhalers	Non-fuel combustion
	2F4b_Aerosols:Other	Aerosols - halocarbons	Non-fuel combustion
	5B1a_composting_municipal_solid_waste	Composting (at household)	Biological waste

NC Category	IPCC	SourceName	ActivityName
	5C2.2b_Non-biogenic:Other	Accidental fires - dwellings	Mass burnt
	5C2.2b_Non-biogenic:Other_Accidental fires (vehicles)	Accidental fires - vehicles	Mass burnt
	non-IPCC	Domestic combustion	Electricity
Transport	1A3a_Domestic_aviation	Aircraft - domestic cruise	Aviation spirit
			Aviation turbine fuel
		Aircraft - domestic take-off and landing	Aviation spirit
			Aviation turbine fuel
	1A3bi_Cars	Road transport - cars - cold start	DERV
			Petrol
		Road transport - cars - motorway driving	DERV
			Petrol
		Road transport - cars - rural driving	DERV
			Petrol
		Road transport - cars - urban driving	DERV
			Petrol
	1A3bii_Light_duty_trucks	Road transport - LGVs - cold start	DERV
			Petrol
		Road transport - LGVs - motorway driving	DERV
			Petrol
		Road transport - LGVs - rural driving	DERV
			Petrol
		Road transport - LGVs - urban driving	DERV
			Petrol
	1A3biii_Heavy_duty_trucks_and_buses	Road transport - buses and coaches - motorway driving	DERV
		Road transport - buses and coaches - rural driving	DERV

NC Category	IPCC	SourceName	ActivityName
		Road transport - buses and coaches - urban driving	DERV
		Road transport - HGV articulated - motorway driving	DERV
		Road transport - HGV articulated - rural driving	DERV
		Road transport - HGV articulated - urban driving	DERV
		Road transport - HGV rigid - motorway driving	DERV
		Road transport - HGV rigid - rural driving	DERV
		Road transport - HGV rigid - urban driving	DERV
	1A3biv_Motorcycles	Road transport - mopeds (<50cc 2st) - urban driving	Lubricants
			Petrol
		Road transport - motorcycle (>50cc 2st) - urban driving	Petrol
		Road transport - motorcycle (>50cc 4st) - motorway driving	Petrol
		Road transport - motorcycle (>50cc 4st) - rural driving	Petrol
		Road transport - motorcycle (>50cc 4st) - urban driving	Petrol
	1A3bv_Other_road_transport	Road transport - all vehicles LPG use	LPG
	1A3c_Railways	Rail - coal	Coal
		Railways - freight	Gas oil
		Railways - intercity	Gas oil
		Railways - regional	Gas oil
	1A3d_Domestic_navigation	Inland goods-carrying vessels	Gas oil
			DERV
			Gas oil

NC Category	IPCC	SourceName	ActivityName
		Motorboats / workboats (e.g. canal boats, dredgers, service boats, tourist boats, river boats)	Petrol
		Personal watercraft e.g. jet ski	Petrol
		Sailing boats with auxiliary engines	DERV
		Shipping - coastal	Fuel oil
			Gas oil
	1A3eii_Other_Transportation	Aircraft - support vehicles	Gas oil
	1A4ai_Commercial/Institutional	Railways - stationary combustion	Burning oil
			Fuel oil
			Natural gas
	1A4ciii_Fishing	Fishing vessels	Fuel oil
			Gas oil
	1A5b_Other:Mobile	Aircraft - military	Aviation spirit
			Aviation turbine fuel
		Shipping - naval	Gas oil
	2D1_Lubricant_Use	Marine engines	Lubricants
		Road vehicle engines	Lubricants
	2D3_Non-energy_products_from_fuels_and_solvent_use:Other	Road transport - urea	Urea consumption
	non-IPCC	Railways - regional	Electricity
		Road vehicle engines	Electricity
Waste Management	5A1a_Managed_Waste_Disposal_sites_anaerobic	Landfill	Non-fuel combustion
	5B1a_composting_municipal_solid_waste	Mechanical Biological Treatment - Composting	Biological waste
		Total composting (non-household)	Biological waste
	5B2a_Anaerobic_digestion_municipal_solid_waste	Anaerobic Digestion (other)	Biological waste
		Mechanical Biological Treatment - Anaerobic Digestion	Biological waste

NC Category	IPCC	SourceName	ActivityName
	5C1.1b_Biogenic:Sewage_sludge	Incineration - sewage sludge	Sewage sludge combustion
	5C1.2a_Non-biogenic:municipal_solid_waste	Incineration	MSW
	5C1.2b_Non-biogenic:Clinical_waste	Incineration - clinical waste	Clinical waste
	5C1.2b_Non-biogenic:Other_Chemical_waste	Incineration - chemical waste	Chemical waste
	5D1_Domestic_wastewater_treatment	Sewage sludge decomposition	Non-fuel domestic
		Sewage sludge decomposition in private systems	Non-fuel domestic
	5D2_Industrial_wastewater_treatment	Industrial Waste Water Treatment	Non-fuel combustion

A 9.6 DETAILED EMISSIONS ACCORDING TO END USER CATEGORIES

The end user categories in the data tables in this summary are those used in National Communications. The end user reallocation includes emissions from the UK, this is the coverage used for the UK statistical release, where the end users data are presented in more detail.

The base year for hydrofluorocarbons, perfluorocarbons, nitrogen trifluoride, and sulphur hexafluoride is 1995. For carbon dioxide, methane and nitrous oxide, the base year is 1990.

Table A 9.6.1 End user emissions from all National Communication categories, $MtCO_2$ equivalent

End user category	Base Year	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016
Agriculture	59.2	59.2	57.5	54.3	51.9	48.4	48.3	47.9	49.0	48.3	48.2
Business	249.3	248.5	218.7	217.4	212.6	187.0	180.4	175.8	161.1	149.0	131.0
Energy Supply	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Exports	9.1	9.1	13.0	12.8	16.7	16.1	14.6	13.9	12.3	12.0	12.0
Industrial Process	65.5	63.3	53.6	29.2	21.4	13.6	11.5	13.6	13.7	13.3	11.0
Land Use Change	-2.1	-2.1	-5.0	-7.9	-11.4	-14.4	-12.6	-13.6	-14.4	-15.1	-14.6
Public	31.5	31.5	28.9	24.4	22.4	19.0	18.6	17.8	15.2	14.5	13.3
Residential	172.0	171.4	157.1	158.0	162.3	155.9	144.4	139.7	117.8	113.1	106.7
Transport	146.6	146.6	151.3	153.8	156.3	141.8	136.9	134.9	136.1	138.3	140.2
Waste Management	66.7	66.7	69.1	62.9	49.0	29.7	26.1	22.4	20.0	19.0	19.9
Total greenhouse gas emissions	**797.8**	**794.2**	**744.3**	**705.0**	**681.3**	**597.1**	**568.0**	**552.4**	**510.8**	**492.4**	**467.9**

Table A 9.6.2 End user CO_2 emissions from all National Communication categories, $MtCO_2$ equivalent

End user category	Base Year	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016
Agriculture	10.0	10.0	9.4	8.0	8.8	7.9	7.9	7.5	7.6	7.4	7.2
Business	229.8	229.8	203.1	202.3	194.6	166.6	160.9	156.7	141.7	129.7	113.0
Energy Supply	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Exports	8.4	8.4	12.1	12.1	16.1	15.4	13.9	13.3	11.7	11.4	11.5
Industrial Process	20.9	20.9	18.9	18.1	16.8	11.2	10.5	12.7	12.8	12.5	10.3
Land Use Change	-4.4	-4.4	-7.2	-10.0	-13.2	-16.1	-14.2	-15.1	-15.9	-16.6	-16.0
Public	29.2	29.2	27.1	23.3	21.7	18.5	18.0	17.3	14.8	14.1	13.0
Residential	156.4	156.4	145.2	148.9	154.5	149.0	137.6	133.3	112.0	107.3	101.4
Transport	142.4	142.4	147.0	150.4	153.7	139.9	135.0	133.0	134.1	136.4	138.2
Waste Management	1.4	1.4	0.9	0.5	0.4	0.3	0.3	0.3	0.3	0.3	0.3
Total greenhouse gas emissions	**594.1**	**594.1**	**556.6**	**553.7**	**553.3**	**492.7**	**469.9**	**459.0**	**419.1**	**402.5**	**378.9**

Table A 9.6.3 End user CH_4 emissions from all National Communication categories, $MtCO_2$ equivalent

End user category	Base Year	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016
Agriculture	31.4	31.4	30.6	29.5	27.6	26.0	25.8	25.8	26.3	26.3	26.3
Business	15.5	15.5	11.7	7.4	4.8	3.7	3.4	2.9	2.9	2.7	2.2
Energy Supply	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Exports	0.7	0.7	0.8	0.6	0.5	0.6	0.6	0.5	0.5	0.4	0.4
Industrial Process	2.2	2.2	1.7	1.1	0.5	0.4	0.3	0.3	0.3	0.2	0.2
Land Use Change	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Public	2.1	2.1	1.7	0.9	0.6	0.5	0.5	0.4	0.4	0.4	0.3
Residential	14.3	14.3	10.7	6.7	4.9	4.5	4.3	4.0	3.6	3.5	3.2
Transport	2.5	2.5	2.2	1.5	1.0	0.8	0.7	0.7	0.7	0.6	0.6
Waste Management	64.5	64.5	67.3	61.4	47.6	28.2	24.5	20.8	18.4	17.4	18.3
Total greenhouse gas emissions	**133.2**	**133.2**	**126.7**	**109.1**	**87.6**	**64.5**	**60.1**	**55.5**	**53.1**	**51.6**	**51.6**

Table A 9.6.4 End user N_2O emissions from all National Communication categories, $MtCO_2$ equivalent

End user category	Base Year	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016
Agriculture	17.8	17.8	17.4	16.8	15.5	14.6	14.6	14.6	15.1	14.6	14.7
Business	2.3	2.3	2.1	2.0	2.1	1.8	2.0	1.8	1.8	1.9	1.7
Energy Supply	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Exports	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Industrial Process	23.9	23.9	14.4	5.4	3.1	1.5	0.3	0.3	0.3	0.3	0.3
Land Use Change	2.2	2.2	2.2	2.1	1.8	1.6	1.5	1.5	1.5	1.4	1.4
Public	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.0
Residential	0.7	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4
Transport	1.7	1.7	2.2	1.9	1.5	1.2	1.2	1.2	1.3	1.3	1.4
Waste Management	0.8	0.8	0.8	0.9	1.0	1.2	1.3	1.3	1.3	1.3	1.4
Total greenhouse gas emissions	**49.6**	**49.6**	**40.0**	**29.9**	**25.8**	**22.5**	**21.7**	**21.4**	**21.9**	**21.5**	**21.4**