Annexes

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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 (KP). 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 1.8.1**.

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.

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 UK Inventory Agency considers that the level of aggregation used in the UK method for the KCA is sufficiently detailed to target inventory improvements 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.

An additional assessment has been undertaken for the inventory submitted under Kyoto Protocol geographical scope. For clarity, the outcomes of this analysis are not presented in this Annex: results are very similar to those from the submission under the Convention (UNFCCC scope), and any differences are documented in **Chapter 1.5** of the main document.

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 - CO_2" 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) – UNFCCC scope

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	185,488.39	185,488.39	0.2182	0.2182
1A3b	Road transportation: liquid fuels	CO_2	108,569.24	108,569.24	0.1277	0.3460
1A4	Other sectors: gaseous fuels	CO_2	70,371.86	70,371.86	0.0828	0.4288
5A	Solid waste disposal	CH_4	60,389.54	60,389.54	0.0710	0.4998
1A1	Energy industries: liquid fuels	CO_2	40,804.35	40,804.35	0.0480	0.5478
1A2	Manufacturing industries and construction: solid fuels	CO_2	38,053.67	38,053.67	0.0448	0.5926
1A2	Manufacturing industries and construction: liquid fuels	CO_2	29,829.47	29,829.47	0.0351	0.6277
1A2	Manufacturing industries and construction: gaseous fuels	CO_2	27,330.46	27,330.46	0.0322	0.6598
1B1	Coal mining and handling	CH_4	21,826.68	21,826.68	0.0257	0.6855
4B	Cropland	CO_2	20,309.04	20,309.04	0.0239	0.7094
2B3	Adipic acid production	N_2O	19,934.61	19,934.61	0.0235	0.7329
1A4	Other sectors: solid fuels	CO_2	19,824.90	19,824.90	0.0233	0.7562
1A4	Other sectors: liquid fuels	CO_2	19,560.85	19,560.85	0.0230	0.7792
3A1	Enteric fermentation from Cattle	CH_4	18,887.10	18,887.10	0.0222	0.8014
2B9	Fluorochemical production	HFCs, PFCs, SF_6 and NF_3	17,784.67	17,784.67	0.0209	0.8223
4A	Forest land	CO_2	-14,364.93	14,364.93	0.0169	0.8392
3D	Agricultural soils	N_2O	14,258.81	14,258.81	0.0168	0.8560
1B2	Oil and gas extraction	CH_4	12,392.35	12,392.35	0.0146	0.8706
1A1	Energy industries: gaseous fuels	CO_2	9,271.01	9,271.01	0.0109	0.8815
1A3d	Domestic Navigation: liquid fuels	CO_2	7,611.13	7,611.13	0.0090	0.8905
2A1	Cement production	CO_2	7,295.26	7,295.26	0.0086	0.8990
4E	Settlements	CO_2	6,426.69	6,426.69	0.0076	0.9066
1B2	Oil and gas extraction	CO_2	5,777.92	5,777.92	0.0068	0.9134
2C1	Iron and steel production	CO_2	5,569.58	5,569.58	0.0066	0.9200
1A5	Other: liquid fuels	CO_2	5,293.44	5,293.44	0.0062	0.9262

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
3A2	Enteric fermentation from Sheep	CH_4	5,074.12	5,074.12	0.0060	0.9322
2B8	Petrochemical and carbon black production	CO_2	4,751.56	4,751.56	0.0056	0.9377
3B1	Manure management from Cattle	CH_4	4,262.01	4,262.01	0.0050	0.9428
2B2	Nitric acid production	N_2O	3,860.26	3,860.26	0.0045	0.9473
3B2	Manure management from Sheep	N_2O	3,216.05	3,216.05	0.0038	0.9511
4C	Grassland	CH_4	2,386.69	2,386.69	0.0028	0.9539
5D	Wastewater treatment and discharge	CH_4	2,171.62	2,171.62	0.0026	0.9564
4G	Harvested wood products	CO_2	-2,095.04	2,095.04	0.0025	0.9589
4D	Wetlands	CH_4	1,960.85	1,960.85	0.0023	0.9612
2B1	Ammonia production	CO_2	1,895.00	1,895.00	0.0022	0.9634
1A3a	Domestic aviation: liquid fuels	CO_2	1,875.74	1,875.74	0.0022	0.9657
1B1	Coal mining and handling solid fuels	CO_2	1,698.56	1,698.56	0.0020	0.9677
1A3c	Railways: liquid fuels	CO_2	1,471.82	1,471.82	0.0017	0.9694
2C6	Zinc production	CO_2	1,350.65	1,350.65	0.0016	0.9710
2A2	Lime production	CO_2	1,328.60	1,328.60	0.0016	0.9725
1A3b	Road transportation: liquid fuels	N_2O	1,312.05	1,312.05	0.0015	0.9741
1A4	Other sectors: solid fuels	CH_4	1,286.45	1,286.45	0.0015	0.9756
5C	Incineration and open burning of waste	CO_2	1,284.85	1,284.85	0.0015	0.9771
1A3b	Road transportation: liquid fuels	CH_4	1,246.62	1,246.62	0.0015	0.9786
4B	Cropland	N_2O	1,102.86	1,102.86	0.0013	0.9799
1A1	Energy industries: solid fuels	N_2O	1,056.46	1,056.46	0.0012	0.9811
3G	Liming	CO_2	1,016.78	1,016.78	0.0012	0.9823
5D	Wastewater treatment and discharge	N_2O	943.47	943.47	0.0011	0.9834
2G1	Electrical equipment	HFCs, PFCs, SF_6 and NF_3	797.11	797.11	0.0009	0.9844
4A	Forest land	N_2O	747.95	747.95	0.0009	0.9852
2A4	Other process uses of carbonates	CO_2	743.19	743.19	0.0009	0.9861
4D	Wetlands	CO_2	571.96	571.96	0.0007	0.9868
2G3	N_2O from product uses	N_2O	554.91	554.91	0.0007	0.9874
2D	Non-energy products from fuels and solvent use	CO_2	552.81	552.81	0.0007	0.9881
4E	Settlements	N_2O	526.45	526.45	0.0006	0.9887
4C	Grassland	CO_2	-482.28	482.28	0.0006	0.9893

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
2C3	Aluminium production	CO_2	450.32	450.32	0.0005	0.9898
2F4	Aerosols	HFCs, PFCs, SF_6 and NF_3	449.39	449.39	0.0005	0.9903
2A3	Glass production	CO_2	411.31	411.31	0.0005	0.9908
4	Indirect N_2O emissions from LULUCF	N_2O	403.85	403.85	0.0005	0.9913
2C4	Magnesium production	HFCs, PFCs, SF_6 and NF_3	387.17	387.17	0.0005	0.9917
1A4	Other sectors: peat	CO_2	372.48	372.48	0.0004	0.9922
2C3	Aluminium production	HFCs, PFCs, SF_6 and NF_3	333.43	333.43	0.0004	0.9926
3H	Urea application to land	CO_2	327.65	327.65	0.0004	0.9930
3A4	Enteric fermentation from Other livestock	CH_4	292.27	292.27	0.0003	0.9933
4B	Cropland	CH_4	291.97	291.97	0.0003	0.9937
3A3	Enteric fermentation from Swine	CH_4	283.06	283.06	0.0003	0.9940
2G2	SF_6 and PFCs from other product use	HFCs, PFCs, SF_6 and NF_3	278.49	278.49	0.0003	0.9943
3J	Agriculture activities in OTs and CDs	CH_4	270.85	270.85	0.0003	0.9946
1A4	Other sectors: solid fuels	N_2O	245.31	245.31	0.0003	0.9949
1A1	Energy industries: other fuels	CO_2	244.26	244.26	0.0003	0.9952
1A3e	Other transportation: liquid fuels	CO_2	224.74	224.74	0.0003	0.9955
2B7	Soda ash production	CO_2	224.40	224.40	0.0003	0.9957
2F1	Refrigeration and air conditioning	HFCs, PFCs, SF_6 and NF_3	216.96	216.96	0.0003	0.9960
1A1	Energy industries: gaseous fuels	N_2O	198.46	198.46	0.0002	0.9962
2B10	Other Chemical Industry	CH_4	191.21	191.21	0.0002	0.9964
4C	Grassland	N_2O	188.68	188.68	0.0002	0.9967
3F	Field burning of agricultural residues	CH_4	187.03	187.03	0.0002	0.9969
2F2	Foam blowing agents	HFCs, PFCs, SF_6 and NF_3	184.66	184.66	0.0002	0.9971
3J	Agriculture activities in OTs and CDs	N_2O	177.90	177.90	0.0002	0.9973
1A4	Other sectors: gaseous fuels	CH_4	157.65	157.65	0.0002	0.9975
1A2	Manufacturing industries and construction: solid fuels	N_2O	144.12	144.12	0.0002	0.9977

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: liquid fuels	N_2O	140.12	140.12	0.0002	0.9978
1A2	Manufacturing industries and construction: liquid fuels	N_2O	138.07	138.07	0.0002	0.9980
5C	Incineration and open burning of waste	CH_4	135.58	135.58	0.0002	0.9982
1A3d	Domestic Navigation: liquid fuels	N_2O	105.00	105.00	0.0001	0.9983
2B6	Titanium dioxide production	CO_2	104.63	104.63	0.0001	0.9984
1A4	Other sectors: liquid fuels	N_2O	102.28	102.28	0.0001	0.9985
1A1	Energy industries: gaseous fuels	CH_4	92.12	92.12	0.0001	0.9986
4A	Forest land	CH_4	88.16	88.16	0.0001	0.9987
1A2	Manufacturing industries and construction: other fuels	CO_2	70.70	70.70	0.0001	0.9988
1A4	Other sectors: biomass	CH_4	63.70	63.70	0.0001	0.9989
3F	Field burning of agricultural residues	N_2O	57.80	57.80	0.0001	0.9990
1A4	Other sectors: liquid fuels	CH_4	57.66	57.66	0.0001	0.9990
1A5	Other: liquid fuels	N_2O	56.12	56.12	0.0001	0.9991
5C	Incineration and open burning of waste	N_2O	50.93	50.93	0.0001	0.9992
1A1	Energy industries: solid fuels	CH_4	50.88	50.88	0.0001	0.9992
1A2	Manufacturing industries and construction: solid fuels	CH_4	47.01	47.01	0.0001	0.9993
1A2	Manufacturing industries and construction: liquid fuels	CH_4	44.24	44.24	0.0001	0.9993
1A1	Energy industries: liquid fuels	CH_4	43.27	43.27	0.0001	0.9994
2G4	Other product manufacture and use	N_2O	41.00	41.00	0.0000	0.9994
1B2	Oil and gas extraction	N_2O	40.75	40.75	0.0000	0.9995
1A4	Other sectors: gaseous fuels	N_2O	37.58	37.58	0.0000	0.9995
2F6	Other product uses as substitutes for ODS	HFCs, PFCs, SF_6 and NF_3	37.01	37.01	0.0000	0.9996
2C1	Iron and steel production	CH_4	36.94	36.94	0.0000	0.9996
2A4	Other process uses of carbonates	CH_4	31.11	31.11	0.0000	0.9996
2B8	Petrochemical and carbon black production	CH_4	30.17	30.17	0.0000	0.9997
1A4	Other sectors: peat	CH_4	26.35	26.35	0.0000	0.9997
4D	Wetlands	N_2O	21.29	21.29	0.0000	0.9997
1A2	Manufacturing industries and construction: biomass	N_2O	19.31	19.31	0.0000	0.9998
1A1	Energy industries: other fuels	CH_4	18.54	18.54	0.0000	0.9998

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
5B	Biological treatment of solid waste	CH_4	18.13	18.13	0.0000	0.9998
2C1	Iron and steel production	N_2O	18.02	18.02	0.0000	0.9998
1A3a	Domestic aviation: liquid fuels	N_2O	17.75	17.75	0.0000	0.9998
1A3c	Railways: liquid fuels	N_2O	16.63	16.63	0.0000	0.9999
4E	Settlements	CH_4	16.42	16.42	0.0000	0.9999
1A2	Manufacturing industries and construction: gaseous fuels	N_2O	14.59	14.59	0.0000	0.9999
5B	Biological treatment of solid waste	N_2O	12.97	12.97	0.0000	0.9999
1A2	Manufacturing industries and construction: gaseous fuels	CH_4	12.24	12.24	0.0000	0.9999
1A2	Manufacturing industries and construction: biomass	CH_4	12.15	12.15	0.0000	0.9999
2E1	Integrated circuit or semiconductor	HFCs, PFCs, SF_6 and NF_3	9.56	9.56	0.0000	0.9999
1A4	Other sectors: biomass	N_2O	9.35	9.35	0.0000	1.0000
1A1	Energy industries: other fuels	N_2O	6.70	6.70	0.0000	1.0000
1A3a	Domestic aviation: liquid fuels	CH_4	6.66	6.66	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
1A3e	Other transportation: liquid fuels	N_2O	2.79	2.79	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	2.21	2.21	0.0000	1.0000
1A4	Other sectors: peat	N_2O	1.47	1.47	0.0000	1.0000
2F3	Fire protection	HFCs, PFCs, SF_6 and NF_3	1.42	1.42	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	0.35	0.35	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	0.15	0.15	0.0000	1.0000
1B1	Coal mining and handling biomass	CH_4	0.10	0.10	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	N_2O	0.09	0.09	0.0000	1.0000
Total			**816,083.21**	**849,967.71**	**1.0000**	

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

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	185,488.39	185,488.39	0.2324	0.3685
1A3b	Road transportation: liquid fuels	CO_2	108,569.24	108,569.24	0.1361	0.3685
1A4	Other sectors: gaseous fuels	CO_2	70,371.86	70,371.86	0.0882	0.4567
5A	Solid waste disposal	CH_4	60,389.54	60,389.54	0.0757	0.5324
1A1	Energy industries: liquid fuels	CO_2	40,804.35	40,804.35	0.0511	0.5835
1A2	Manufacturing industries and construction: solid fuels	CO_2	38,053.67	38,053.67	0.0477	0.6312
1A2	Manufacturing industries and construction: liquid fuels	CO_2	29,829.47	29,829.47	0.0374	0.6686
1A2	Manufacturing industries and construction: gaseous fuels	CO_2	27,330.46	27,330.46	0.0342	0.7028
1B1	Coal mining and handling	CH_4	21,826.68	21,826.68	0.0274	0.7302
2B3	Adipic acid production	N_2O	19,934.61	19,934.61	0.0250	0.7552
1A4	Other sectors: solid fuels	CO_2	19,824.90	19,824.90	0.0248	0.7800
1A4	Other sectors: liquid fuels	CO_2	19,560.85	19,560.85	0.0245	0.8045
3A1	Enteric fermentation from Cattle	CH_4	18,887.10	18,887.10	0.0237	0.8282
2B9	Fluorochemical production	HFCs, PFCs, SF_6 and NF_3	17,784.67	17,784.67	0.0223	0.8505
3D	Agricultural soils	N_2O	14,258.81	14,258.81	0.0179	0.8683
1B2	Oil and gas extraction	CH_4	12,392.35	12,392.35	0.0155	0.8839
1A1	Energy industries: gaseous fuels	CO_2	9,271.01	9,271.01	0.0116	0.8955
1A3d	Domestic Navigation: liquid fuels	CO_2	7,611.13	7,611.13	0.0095	0.9050
2A1	Cement production	CO_2	7,295.26	7,295.26	0.0091	0.9142
1B2	Oil and gas extraction	CO_2	5,777.92	5,777.92	0.0072	0.9214
2C1	Iron and steel production	CO_2	5,569.58	5,569.58	0.0070	0.9284
1A5	Other: liquid fuels	CO_2	5,293.44	5,293.44	0.0066	0.9350
3A2	Enteric fermentation from Sheep	CH_4	5,074.12	5,074.12	0.0064	0.9414
2B8	Petrochemical and carbon black production	CO_2	4,751.56	4,751.56	0.0060	0.9473

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
3B1	Manure management from Cattle	CH_4	4,262.01	4,262.01	0.0053	0.9527
2B2	Nitric acid production	N_2O	3,860.26	3,860.26	0.0048	0.9575
3B2	Manure management from Sheep	N_2O	3,216.05	3,216.05	0.0040	0.9615
5D	Wastewater treatment and discharge	CH_4	2,171.62	2,171.62	0.0027	0.9643
2B1	Ammonia production	CO_2	1,895.00	1,895.00	0.0024	0.9666
1A3a	Domestic aviation: liquid fuels	CO_2	1,875.74	1,875.74	0.0024	0.9690
1B1	Coal mining and handling solid fuels	CO_2	1,698.56	1,698.56	0.0021	0.9711
1A3c	Railways: liquid fuels	CO_2	1,471.82	1,471.82	0.0018	0.9730
2C6	Zinc production	CO_2	1,350.65	1,350.65	0.0017	0.9746
2A2	Lime production	CO_2	1,328.60	1,328.60	0.0017	0.9763
1A3b	Road transportation: liquid fuels	N_2O	1,312.05	1,312.05	0.0016	0.9780
1A4	Other sectors: solid fuels	CH_4	1,286.45	1,286.45	0.0016	0.9796
5C	Incineration and open burning of waste	CO_2	1,284.85	1,284.85	0.0016	0.9812
1A3b	Road transportation: liquid fuels	CH_4	1,246.62	1,246.62	0.0016	0.9827
1A1	Energy industries: solid fuels	N_2O	1,056.46	1,056.46	0.0013	0.9841
3G	Liming	CO_2	1,016.78	1,016.78	0.0013	0.9853
5D	Wastewater treatment and discharge	N_2O	943.47	943.47	0.0012	0.9865
2G1	Electrical equipment	HFCs, PFCs, SF_6 and NF_3	797.11	797.11	0.0010	0.9875
2A4	Other process uses of carbonates	CO_2	743.19	743.19	0.0009	0.9885
2G3	N_2O from product uses	N_2O	554.91	554.91	0.0007	0.9891
2D	Non-energy products from fuels and solvent use	CO_2	552.81	552.81	0.0007	0.9898
2C3	Aluminium production	CO_2	450.32	450.32	0.0006	0.9904
2F4	Aerosols	HFCs, PFCs, SF_6 and NF_3	449.39	449.39	0.0006	0.9910
2A3	Glass production	CO_2	411.31	411.31	0.0005	0.9915
2C4	Magnesium production	HFCs, PFCs, SF_6 and NF_3	387.17	387.17	0.0005	0.9920
1A4	Other sectors: peat	CO_2	372.48	372.48	0.0005	0.9924
2C3	Aluminium production	HFCs, PFCs, SF_6 and NF_3	333.43	333.43	0.0004	0.9929
3H	Urea application to land	CO_2	327.65	327.65	0.0004	0.9933
3A4	Enteric fermentation from Other livestock	CH_4	292.27	292.27	0.0004	0.9936
3A3	Enteric fermentation from Swine	CH_4	283.06	283.06	0.0004	0.9940

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
2G2	SF_6 and PFCs from other product use	HFCs, PFCs, SF_6 and NF_3	278.49	278.49	0.0003	0.9943
3J	Agriculture activities in OTs and CDs	CH_4	270.85	270.85	0.0003	0.9947
1A4	Other sectors: solid fuels	N_2O	245.31	245.31	0.0003	0.9950
1A1	Energy industries: other fuels	CO_2	244.26	244.26	0.0003	0.9953
1A3e	Other transportation: liquid fuels	CO_2	224.74	224.74	0.0003	0.9956
2B7	Soda ash production	CO_2	224.40	224.40	0.0003	0.9959
2F1	Refrigeration and air conditioning	HFCs, PFCs, SF_6 and NF_3	216.96	216.96	0.0003	0.9961
1A1	Energy industries: gaseous fuels	N_2O	198.46	198.46	0.0002	0.9964
2B10	Other Chemical Industry	CH_4	191.21	191.21	0.0002	0.9966
3F	Field burning of agricultural residues	CH_4	187.03	187.03	0.0002	0.9968
2F2	Foam blowing agents	HFCs, PFCs, SF_6 and NF_3	184.66	184.66	0.0002	0.9971
3J	Agriculture activities in OTs and CDs	N_2O	177.90	177.90	0.0002	0.9973
1A4	Other sectors: gaseous fuels	CH_4	157.65	157.65	0.0002	0.9975
1A2	Manufacturing industries and construction: solid fuels	N_2O	144.12	144.12	0.0002	0.9977
1A1	Energy industries: liquid fuels	N_2O	140.12	140.12	0.0002	0.9979
1A2	Manufacturing industries and construction: liquid fuels	N_2O	138.07	138.07	0.0002	0.9980
5C	Incineration and open burning of waste	CH_4	135.58	135.58	0.0002	0.9982
1A3d	Domestic Navigation: liquid fuels	N_2O	105.00	105.00	0.0001	0.9983
2B6	Titanium dioxide production	CO_2	104.63	104.63	0.0001	0.9985
1A4	Other sectors: liquid fuels	N_2O	102.28	102.28	0.0001	0.9986
1A1	Energy industries: gaseous fuels	CH_4	92.12	92.12	0.0001	0.9987
1A2	Manufacturing industries and construction: other fuels	CO_2	70.70	70.70	0.0001	0.9988
1A4	Other sectors: biomass	CH_4	63.70	63.70	0.0001	0.9989
3F	Field burning of agricultural residues	N_2O	57.80	57.80	0.0001	0.9989
1A4	Other sectors: liquid fuels	CH_4	57.66	57.66	0.0001	0.9990
1A5	Other: liquid fuels	N_2O	56.12	56.12	0.0001	0.9991
5C	Incineration and open burning of waste	N_2O	50.93	50.93	0.0001	0.9991
1A1	Energy industries: solid fuels	CH_4	50.88	50.88	0.0001	0.9992
1A2	Manufacturing industries and construction: solid fuels	CH_4	47.01	47.01	0.0001	0.9993

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: liquid fuels	CH_4	44.24	44.24	0.0001	0.9993
1A1	Energy industries: liquid fuels	CH_4	43.27	43.27	0.0001	0.9994
2G4	Other product manufacture and use	N_2O	41.00	41.00	0.0001	0.9994
1B2	Oil and gas extraction	N_2O	40.75	40.75	0.0001	0.9995
1A4	Other sectors: gaseous fuels	N_2O	37.58	37.58	0.0000	0.9995
2F6	Other product uses as substitutes for ODS	HFCs, PFCs, SF_6 and NF_3	37.01	37.01	0.0000	0.9996
2C1	Iron and steel production	CH_4	36.94	36.94	0.0000	0.9996
2A4	Other process uses of carbonates	CH_4	31.11	31.11	0.0000	0.9997
2B8	Petrochemical and carbon black production	CH_4	30.17	30.17	0.0000	0.9997
1A4	Other sectors: peat	CH_4	26.35	26.35	0.0000	0.9997
1A2	Manufacturing industries and construction: biomass	N_2O	19.31	19.31	0.0000	0.9998
1A1	Energy industries: other fuels	CH_4	18.54	18.54	0.0000	0.9998
5B	Biological treatment of solid waste	CH_4	18.13	18.13	0.0000	0.9998
2C1	Iron and steel production	N_2O	18.02	18.02	0.0000	0.9998
1A3a	Domestic aviation: liquid fuels	N_2O	17.75	17.75	0.0000	0.9998
1A3c	Railways: liquid fuels	N_2O	16.63	16.63	0.0000	0.9999
1A2	Manufacturing industries and construction: gaseous fuels	N_2O	14.59	14.59	0.0000	0.9999
5B	Biological treatment of solid waste	N_2O	12.97	12.97	0.0000	0.9999
1A2	Manufacturing industries and construction: gaseous fuels	CH_4	12.24	12.24	0.0000	0.9999
1A2	Manufacturing industries and construction: biomass	CH_4	12.15	12.15	0.0000	0.9999
2E1	Integrated circuit or semiconductor	HFCs, PFCs, SF_6 and NF_3	9.56	9.56	0.0000	0.9999
1A4	Other sectors: biomass	N_2O	9.35	9.35	0.0000	1.0000
1A1	Energy industries: other fuels	N_2O	6.70	6.70	0.0000	1.0000
1A3a	Domestic aviation: liquid fuels	CH_4	6.66	6.66	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
1A3e	Other transportation: liquid fuels	N_2O	2.79	2.79	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	2.21	2.21	0.0000	1.0000
1A4	Other sectors: peat	N_2O	1.47	1.47	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
2F3	Fire protection	HFCs, PFCs, SF_6 and NF_3	1.42	1.42	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	0.35	0.35	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	0.15	0.15	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
1B1	Coal mining and handling solid fuels	CH_4	0.08	0.08	0.0000	1.0000
Total			**797,982.60**	**797,982.60**	**1.0000**	

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

IPCC Code	IPCC Category	GHG	Latest reported year (LY) emissions (Gg CO_2e)	Absolute value of LY emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A3b	Road transportation: liquid fuels	CO_2	109,591.01	109,591.01	0.2169	0.2169
1A4	Other sectors: gaseous fuels	CO_2	75,975.83	75,975.83	0.1504	0.3673
1A1	Energy industries: gaseous fuels	CO_2	58,915.05	58,915.05	0.1166	0.4838
1A2	Manufacturing industries and construction: gaseous fuels	CO_2	23,282.98	23,282.98	0.0461	0.5299
4A	Forest land	CO_2	-17,173.23	17,173.23	0.0340	0.5639
3A1	Enteric fermentation from Cattle	CH_4	16,409.82	16,409.82	0.0325	0.5964
4B	Cropland	CO_2	15,175.26	15,175.26	0.0300	0.6264
1A1	Energy industries: liquid fuels	CO_2	14,617.15	14,617.15	0.0289	0.6554
5A	Solid waste disposal	CH_4	14,346.67	14,346.67	0.0284	0.6837
1A2	Manufacturing industries and construction: liquid fuels	CO_2	14,154.90	14,154.90	0.0280	0.7118
1A4	Other sectors: liquid fuels	CO_2	13,805.71	13,805.71	0.0273	0.7391
3D	Agricultural soils	N_2O	12,250.42	12,250.42	0.0242	0.7633
1A2	Manufacturing industries and construction: solid fuels	CO_2	11,985.16	11,985.16	0.0237	0.7870

IPCC Code	IPCC Category	GHG	Latest reported year (LY) emissions (Gg CO_2e)	Absolute value of LY emissions (Gg CO_2e)	Level Assessment	Cumulative Total
2F1	Refrigeration and air conditioning	HFCs, PFCs, SF_6 and NF_3	10,293.85	10,293.85	0.0204	0.8074
1A1	Energy industries: solid fuels	CO_2	7,224.32	7,224.32	0.0143	0.8217
1A1	Energy industries: other fuels	CO_2	6,050.29	6,050.29	0.0120	0.8337
1A3d	Domestic Navigation: liquid fuels	CO_2	5,579.13	5,579.13	0.0110	0.8447
4E	Settlements	CO_2	5,550.20	5,550.20	0.0110	0.8557
1B2	Oil and gas extraction	CH_4	4,571.75	4,571.75	0.0090	0.8648
2A1	Cement production	CO_2	4,448.50	4,448.50	0.0088	0.8736
1B2	Oil and gas extraction	CO_2	4,200.23	4,200.23	0.0083	0.8819
3A2	Enteric fermentation from Sheep	CH_4	4,154.50	4,154.50	0.0082	0.8901
3B1	Manure management from Cattle	CH_4	3,994.92	3,994.92	0.0079	0.8980
4C	Grassland	CO_2	-3,675.33	3,675.33	0.0073	0.9053
3B2	Manure management from Sheep	N_2O	2,727.68	2,727.68	0.0054	0.9107
2B8	Petrochemical and carbon black production	CO_2	2,665.45	2,665.45	0.0053	0.9160
4C	Grassland	CH_4	2,420.49	2,420.49	0.0048	0.9207
4G	Harvested wood products	CO_2	-2,222.56	2,222.56	0.0044	0.9251
2C1	Iron and steel production	CO_2	2,185.94	2,185.94	0.0043	0.9295
1A4	Other sectors: solid fuels	CO_2	2,066.99	2,066.99	0.0041	0.9336
4D	Wetlands	CH_4	2,052.65	2,052.65	0.0041	0.9376
1A3a	Domestic aviation: liquid fuels	CO_2	1,767.88	1,767.88	0.0035	0.9411
1A5	Other: liquid fuels	CO_2	1,715.59	1,715.59	0.0034	0.9445
5D	Wastewater treatment and discharge	CH_4	1,679.50	1,679.50	0.0033	0.9478
1A3c	Railways: liquid fuels	CO_2	1,637.89	1,637.89	0.0032	0.9511
2B1	Ammonia production	CO_2	1,548.40	1,548.40	0.0031	0.9541
2F4	Aerosols	HFCs, PFCs, SF_6 and NF_3	1,461.63	1,461.63	0.0029	0.9570
4D	Wetlands	CO_2	1,408.08	1,408.08	0.0028	0.9598
3G	Liming	CO_2	1,313.00	1,313.00	0.0026	0.9624
5B	Biological treatment of solid waste	CH_4	1,233.54	1,233.54	0.0024	0.9649
1A3b	Road transportation: liquid fuels	N_2O	1,131.24	1,131.24	0.0022	0.9671
2A2	Lime production	CO_2	1,053.43	1,053.43	0.0021	0.9692
5D	Wastewater treatment and discharge	N_2O	1,020.10	1,020.10	0.0020	0.9712
5B	Biological treatment of solid waste	N_2O	731.02	731.02	0.0014	0.9727
4A	Forest land	N_2O	725.21	725.21	0.0014	0.9741

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1A2	Manufacturing industries and construction: other fuels	CO_2	711.45	711.45	0.0014	0.9755
1A4	Other sectors: biomass	CH_4	693.59	693.59	0.0014	0.9769
2G3	N_2O from product uses	N_2O	658.28	658.28	0.0013	0.9782
1A3e	Other transportation: liquid fuels	CO_2	605.87	605.87	0.0012	0.9794
2D	Non-energy products from fuels and solvent use	CO_2	482.19	482.19	0.0010	0.9803
1B1	Coal mining and handling	CH_4	480.64	480.64	0.0010	0.9813
4B	Cropland	N_2O	480.38	480.38	0.0010	0.9822
3A4	Enteric fermentation from Other livestock	CH_4	458.77	458.77	0.0009	0.9831
2A4	Other process uses of carbonates	CO_2	448.94	448.94	0.0009	0.9840
2F2	Foam blowing agents	HFCs, PFCs, SF_6 and NF_3	441.61	441.61	0.0009	0.9849
4E	Settlements	N_2O	434.17	434.17	0.0009	0.9858
2A3	Glass production	CO_2	369.43	369.43	0.0007	0.9865
2G2	SF_6 and PFCs from other product use	HFCs, PFCs, SF_6 and NF_3	354.56	354.56	0.0007	0.9872
3H	Urea application to land	CO_2	318.54	318.54	0.0006	0.9878
2F3	Fire protection	HFCs, PFCs, SF_6 and NF_3	314.57	314.57	0.0006	0.9884
2G1	Electrical equipment	HFCs, PFCs, SF_6 and NF_3	310.67	310.67	0.0006	0.9891
1A1	Energy industries: gaseous fuels	N_2O	291.95	291.95	0.0006	0.9896
4B	Cropland	CH_4	280.84	280.84	0.0006	0.9902
5C	Incineration and open burning of waste	CO_2	245.54	245.54	0.0005	0.9907
4	Indirect N_2O emissions from LULUCF	N_2O	223.54	223.54	0.0004	0.9911
1A3b	Road transportation: biomass	CO_2	221.69	221.69	0.0004	0.9916
1A1	Energy industries: biomass	N_2O	213.94	213.94	0.0004	0.9920
3J	Agriculture activities in OTs and CDs	CH_4	200.03	200.03	0.0004	0.9924
2G4	Other product manufacture and use	N_2O	196.26	196.26	0.0004	0.9928
3A3	Enteric fermentation from Swine	CH_4	190.44	190.44	0.0004	0.9931
4C	Grassland	N_2O	182.25	182.25	0.0004	0.9935
1A4	Other sectors: gaseous fuels	CH_4	168.87	168.87	0.0003	0.9938
1A4	Other sectors: solid fuels	CH_4	157.74	157.74	0.0003	0.9942
2B6	Titanium dioxide production	CO_2	152.38	152.38	0.0003	0.9945

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2B7	Soda ash production	CO_2	145.22	145.22	0.0003	0.9947
2C4	Magnesium production	HFCs, PFCs, SF_6 and NF_3	144.16	144.16	0.0003	0.9950
1A1	Energy industries: biomass	CH_4	135.38	135.38	0.0003	0.9953
1A1	Energy industries: other fuels	CH_4	123.09	123.09	0.0002	0.9955
2B9	Fluorochemical production	HFCs, PFCs, SF_6 and NF_3	120.73	120.73	0.0002	0.9958
4A	Forest land	CH_4	120.61	120.61	0.0002	0.9960
1A1	Energy industries: other fuels	N_2O	115.69	115.69	0.0002	0.9962
3J	Agriculture activities in OTs and CDs	N_2O	115.65	115.65	0.0002	0.9965
1A1	Energy industries: gaseous fuels	CH_4	114.67	114.67	0.0002	0.9967
1A2	Manufacturing industries and construction: biomass	N_2O	111.23	111.23	0.0002	0.9969
1A4	Other sectors: biomass	N_2O	108.87	108.87	0.0002	0.9971
1B1	Coal mining and handling solid fuels	CO_2	106.03	106.03	0.0002	0.9973
1A3b	Road transportation: liquid fuels	CH_4	95.76	95.76	0.0002	0.9975
1A2	Manufacturing industries and construction: liquid fuels	N_2O	90.73	90.73	0.0002	0.9977
1A4	Other sectors: liquid fuels	N_2O	82.37	82.37	0.0002	0.9979
1A1	Energy industries: liquid fuels	N_2O	74.36	74.36	0.0001	0.9980
1A3d	Domestic Navigation: liquid fuels	N_2O	73.51	73.51	0.0001	0.9982
1A2	Manufacturing industries and construction: biomass	CH_4	70.23	70.23	0.0001	0.9983
2C3	Aluminium production	CO_2	60.66	60.66	0.0001	0.9984
2B10	Other Chemical Industry	CH_4	58.54	58.54	0.0001	0.9985
2F6	Other product uses as substitutes for ODS	HFCs, PFCs, SF_6 and NF_3	53.70	53.70	0.0001	0.9987
1A3c	Railways: solid fuels	CO_2	41.15	41.15	0.0001	0.9987
1A4	Other sectors: gaseous fuels	N_2O	40.26	40.26	0.0001	0.9988
2B2	Nitric acid production	N_2O	38.17	38.17	0.0001	0.9989
1B2	Oil and gas extraction	N_2O	37.55	37.55	0.0001	0.9990
1A1	Energy industries: solid fuels	N_2O	36.66	36.66	0.0001	0.9990
4D	Wetlands	N_2O	36.19	36.19	0.0001	0.9991
1A4	Other sectors: liquid fuels	CH_4	34.17	34.17	0.0001	0.9992
1A2	Manufacturing industries and construction: liquid fuels	CH_4	32.28	32.28	0.0001	0.9992

IPCC Code	IPCC Category	GHG	Latest reported year (LY) emissions (Gg CO_2e)	Absolute value of LY emissions (Gg CO_2e)	Level Assessment	Cumulative Total
5C	Incineration and open burning of waste	N_2O	31.21	31.21	0.0001	0.9993
1B1	Coal mining and handling liquid fuels	CO_2	31.20	31.20	0.0001	0.9994
1A2	Manufacturing industries and construction: solid fuels	N_2O	30.63	30.63	0.0001	0.9994
1A4	Other sectors: solid fuels	N_2O	27.60	27.60	0.0001	0.9995
2E1	Integrated circuit or semiconductor	HFCs, PFCs, SF_6 and NF_3	26.27	26.27	0.0001	0.9995
4E	Settlements	CH_4	23.62	23.62	0.0000	0.9996
1A3c	Railways: liquid fuels	N_2O	18.49	18.49	0.0000	0.9996
1A5	Other: liquid fuels	N_2O	18.40	18.40	0.0000	0.9996
1A3a	Domestic aviation: liquid fuels	N_2O	16.73	16.73	0.0000	0.9997
2F5	Solvents	HFCs, PFCs, SF_6 and NF_3	16.11	16.11	0.0000	0.9997
1A1	Energy industries: liquid fuels	CH_4	15.80	15.80	0.0000	0.9997
1A2	Manufacturing industries and construction: gaseous fuels	N_2O	12.34	12.34	0.0000	0.9998
1A2	Manufacturing industries and construction: other fuels	N_2O	11.06	11.06	0.0000	0.9998
1A2	Manufacturing industries and construction: solid fuels	CH_4	10.61	10.61	0.0000	0.9998
1A2	Manufacturing industries and construction: gaseous fuels	CH_4	10.35	10.35	0.0000	0.9998
2C1	Iron and steel production	CH_4	10.15	10.15	0.0000	0.9999
2B8	Petrochemical and carbon black production	CH_4	9.54	9.54	0.0000	0.9999
5C	Incineration and open burning of waste	CH_4	8.09	8.09	0.0000	0.9999
1A3e	Other transportation: liquid fuels	N_2O	7.50	7.50	0.0000	0.9999
1A3d	Domestic Navigation: liquid fuels	CH_4	7.22	7.22	0.0000	0.9999
1A2	Manufacturing industries and construction: other fuels	CH_4	6.72	6.72	0.0000	0.9999
2C3	Aluminium production	HFCs, PFCs, SF_6 and NF_3	6.25	6.25	0.0000	0.9999
2C1	Iron and steel production	N_2O	6.13	6.13	0.0000	1.0000
2A4	Other process uses of carbonates	CH_4	5.34	5.34	0.0000	1.0000
1A4	Other sectors: peat	CO_2	4.83	4.83	0.0000	1.0000
1B1	Coal mining and handling biomass	CH_4	3.78	3.78	0.0000	1.0000
1A1	Energy industries: solid fuels	CH_4	1.90	1.90	0.0000	1.0000
2B8	Petrochemical and carbon black production	N_2O	1.43	1.43	0.0000	1.0000

IPCC Code	IPCC Category	GHG	Latest reported year (LY) emissions (Gg CO_2e)	Absolute value of LY emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A3a	Domestic aviation: liquid fuels	CH_4	1.34	1.34	0.0000	1.0000
1A5	Other: liquid fuels	CH_4	1.10	1.10	0.0000	1.0000
1A3c	Railways: solid fuels	CH_4	0.94	0.94	0.0000	1.0000
1A3c	Railways: liquid fuels	CH_4	0.83	0.83	0.0000	1.0000
1A4	Other sectors: peat	CH_4	0.34	0.34	0.0000	1.0000
2B1	Ammonia production	N_2O	0.31	0.31	0.0000	1.0000
1A3e	Other transportation: liquid fuels	CH_4	0.27	0.27	0.0000	1.0000
2B1	Ammonia production	CH_4	0.26	0.26	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	0.01	0.01	0.0000	1.0000
Total			**459,143.82**	**505,286.06**	**1.0000**	

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

IPCC Code	IPCC Category	GHG	Latest reported year (LY) emissions (Gg CO_2e)	Absolute value of LY emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A3b	Road transportation: liquid fuels	CO_2	109,591.01	109,591.01	0.2419	0.2419
1A4	Other sectors: gaseous fuels	CO_2	75,975.83	75,975.83	0.1677	0.4095
1A1	Energy industries: gaseous fuels	CO_2	58,915.05	58,915.05	0.1300	0.5396
1A2	Manufacturing industries and construction: gaseous fuels	CO_2	23,282.98	23,282.98	0.0514	0.5910
3A1	Enteric fermentation from Cattle	CH_4	16,409.82	16,409.82	0.0362	0.6272
1A1	Energy industries: liquid fuels	CO_2	14,617.15	14,617.15	0.0323	0.6594
5A	Solid waste disposal	CH_4	14,346.67	14,346.67	0.0317	0.6911
1A2	Manufacturing industries and construction: liquid fuels	CO_2	14,154.90	14,154.90	0.0312	0.7223
1A4	Other sectors: liquid fuels	CO_2	13,805.71	13,805.71	0.0305	0.7528
3D	Agricultural soils	N_2O	12,250.42	12,250.42	0.0270	0.7798
1A2	Manufacturing industries and construction: solid fuels	CO_2	11,985.16	11,985.16	0.0265	0.8063
2F1	Refrigeration and air conditioning	HFCs, PFCs, SF_6 and NF_3	10,293.85	10,293.85	0.0227	0.8290
1A1	Energy industries: solid fuels	CO_2	7,224.32	7,224.32	0.0159	0.8450

IPCC Code	IPCC Category	GHG	Latest reported year (LY) emissions (Gg CO_2e)	Absolute value of LY emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A1	Energy industries: other fuels	CO_2	6,050.29	6,050.29	0.0134	0.8583
1A3d	Domestic Navigation: liquid fuels	CO_2	5,579.13	5,579.13	0.0123	0.8706
1B2	Oil and gas extraction	CH_4	4,571.75	4,571.75	0.0101	0.8807
2A1	Cement production	CO_2	4,448.50	4,448.50	0.0098	0.8905
1B2	Oil and gas extraction	CO_2	4,200.23	4,200.23	0.0093	0.8998
3A2	Enteric fermentation from Sheep	CH_4	4,154.50	4,154.50	0.0092	0.9090
3B1	Manure management from Cattle	CH_4	3,994.92	3,994.92	0.0088	0.9178
3B2	Manure management from Sheep	N_2O	2,727.68	2,727.68	0.0060	0.9238
2B8	Petrochemical and carbon black production	CO_2	2,665.45	2,665.45	0.0059	0.9297
2C1	Iron and steel production	CO_2	2,185.94	2,185.94	0.0048	0.9345
1A4	Other sectors: solid fuels	CO_2	2,066.99	2,066.99	0.0046	0.9391
1A3a	Domestic aviation: liquid fuels	CO_2	1,767.88	1,767.88	0.0039	0.9430
1A5	Other: liquid fuels	CO_2	1,715.59	1,715.59	0.0038	0.9468
5D	Wastewater treatment and discharge	CH_4	1,679.50	1,679.50	0.0037	0.9505
1A3c	Railways: liquid fuels	CO_2	1,637.89	1,637.89	0.0036	0.9541
2B1	Ammonia production	CO_2	1,548.40	1,548.40	0.0034	0.9575
2F4	Aerosols	HFCs, PFCs, SF_6 and NF_3	1,461.63	1,461.63	0.0032	0.9607
3G	Liming	CO_2	1,313.00	1,313.00	0.0029	0.9636
5B	Biological treatment of solid waste	CH_4	1,233.54	1,233.54	0.0027	0.9664
1A3b	Road transportation: liquid fuels	N_2O	1,131.24	1,131.24	0.0025	0.9688
2A2	Lime production	CO_2	1,053.43	1,053.43	0.0023	0.9712
5D	Wastewater treatment and discharge	N_2O	1,020.10	1,020.10	0.0023	0.9734
5B	Biological treatment of solid waste	N_2O	731.02	731.02	0.0016	0.9750
1A2	Manufacturing industries and construction: other fuels	CO_2	711.45	711.45	0.0016	0.9766
1A4	Other sectors: biomass	CH_4	693.59	693.59	0.0015	0.9781
2G3	N_2O from product uses	N_2O	658.28	658.28	0.0015	0.9796
1A3e	Other transportation: liquid fuels	CO_2	605.87	605.87	0.0013	0.9809
2D	Non-energy products from fuels and solvent use	CO_2	482.19	482.19	0.0011	0.9820
1B1	Coal mining and handling	CH_4	480.64	480.64	0.0011	0.9831
3A4	Enteric fermentation from Other livestock	CH_4	458.77	458.77	0.0010	0.9841
2A4	Other process uses of carbonates	CO_2	448.94	448.94	0.0010	0.9851

IPCC Code	IPCC Category	GHG	Latest reported year (LY) emissions (Gg CO_2e)	Absolute value of LY emissions (Gg CO_2e)	Level Assessment	Cumulative Total
2F2	Foam blowing agents	HFCs, PFCs, SF_6 and NF_3	441.61	441.61	0.0010	0.9860
2A3	Glass production	CO_2	369.43	369.43	0.0008	0.9868
2G2	SF_6 and PFCs from other product use	HFCs, PFCs, SF_6 and NF_3	354.56	354.56	0.0008	0.9876
3H	Urea application to land	CO_2	318.54	318.54	0.0007	0.9883
2F3	Fire protection	HFCs, PFCs, SF_6 and NF_3	314.57	314.57	0.0007	0.9890
2G1	Electrical equipment	HFCs, PFCs, SF_6 and NF_3	310.67	310.67	0.0007	0.9897
1A1	Energy industries: gaseous fuels	N_2O	291.95	291.95	0.0006	0.9904
5C	Incineration and open burning of waste	CO_2	245.54	245.54	0.0005	0.9909
1A3b	Road transportation: biomass	CO_2	221.69	221.69	0.0005	0.9914
1A1	Energy industries: biomass	N_2O	213.94	213.94	0.0005	0.9919
3J	Agriculture activities in OTs and CDs	CH_4	200.03	200.03	0.0004	0.9923
2G4	Other product manufacture and use	N_2O	196.26	196.26	0.0004	0.9927
3A3	Enteric fermentation from Swine	CH_4	190.44	190.44	0.0004	0.9932
1A4	Other sectors: gaseous fuels	CH_4	168.87	168.87	0.0004	0.9935
1A4	Other sectors: solid fuels	CH_4	157.74	157.74	0.0003	0.9939
2B6	Titanium dioxide production	CO_2	152.38	152.38	0.0003	0.9942
2B7	Soda ash production	CO_2	145.22	145.22	0.0003	0.9945
2C4	Magnesium production	HFCs, PFCs, SF_6 and NF_3	144.16	144.16	0.0003	0.9949
1A1	Energy industries: biomass	CH_4	135.38	135.38	0.0003	0.9952
1A1	Energy industries: other fuels	CH_4	123.09	123.09	0.0003	0.9954
2B9	Fluorochemical production	HFCs, PFCs, SF_6 and NF_3	120.73	120.73	0.0003	0.9957
1A1	Energy industries: other fuels	N_2O	115.69	115.69	0.0003	0.9959
3J	Agriculture activities in OTs and CDs	N_2O	115.65	115.65	0.0003	0.9962
1A1	Energy industries: gaseous fuels	CH_4	114.67	114.67	0.0003	0.9965
1A2	Manufacturing industries and construction: biomass	N_2O	111.23	111.23	0.0002	0.9967
1A4	Other sectors: biomass	N_2O	108.87	108.87	0.0002	0.9969
1B1	Coal mining and handling solid fuels	CO_2	106.03	106.03	0.0002	0.9972
1A3b	Road transportation: liquid fuels	CH_4	95.76	95.76	0.0002	0.9974

IPCC Code	IPCC Category	GHG	Latest reported year (LY) emissions (Gg CO_2e)	Absolute value of LY emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A2	Manufacturing industries and construction: liquid fuels	N_2O	90.73	90.73	0.0002	0.9976
1A4	Other sectors: liquid fuels	N_2O	82.37	82.37	0.0002	0.9978
1A1	Energy industries: liquid fuels	N_2O	74.36	74.36	0.0002	0.9979
1A3d	Domestic Navigation: liquid fuels	N_2O	73.51	73.51	0.0002	0.9981
1A2	Manufacturing industries and construction: biomass	CH_4	70.23	70.23	0.0002	0.9982
2C3	Aluminium production	CO_2	60.66	60.66	0.0001	0.9984
2B10	Other Chemical Industry	CH_4	58.54	58.54	0.0001	0.9985
2F6	Other product uses as substitutes for ODS	HFCs, PFCs, SF_6 and NF_3	53.70	53.70	0.0001	0.9986
1A3c	Railways: solid fuels	CO_2	41.15	41.15	0.0001	0.9987
1A4	Other sectors: gaseous fuels	N_2O	40.26	40.26	0.0001	0.9988
2B2	Nitric acid production	N_2O	38.17	38.17	0.0001	0.9989
1B2	Oil and gas extraction	N_2O	37.55	37.55	0.0001	0.9990
1A1	Energy industries: solid fuels	N_2O	36.66	36.66	0.0001	0.9991
1A4	Other sectors: liquid fuels	CH_4	34.17	34.17	0.0001	0.9991
1A2	Manufacturing industries and construction: liquid fuels	CH_4	32.28	32.28	0.0001	0.9992
5C	Incineration and open burning of waste	N_2O	31.21	31.21	0.0001	0.9993
1B1	Coal mining and handling liquid fuels	CO_2	31.20	31.20	0.0001	0.9993
1A2	Manufacturing industries and construction: solid fuels	N_2O	30.63	30.63	0.0001	0.9994
1A4	Other sectors: solid fuels	N_2O	27.60	27.60	0.0001	0.9995
2E1	Integrated circuit or semiconductor	HFCs, PFCs, SF_6 and NF_3	26.27	26.27	0.0001	0.9995
1A3c	Railways: liquid fuels	N_2O	18.49	18.49	0.0000	0.9996
1A5	Other: liquid fuels	N_2O	18.40	18.40	0.0000	0.9996
1A3a	Domestic aviation: liquid fuels	N_2O	16.73	16.73	0.0000	0.9996
2F5	Solvents	HFCs, PFCs, SF_6 and NF_3	16.11	16.11	0.0000	0.9997
1A1	Energy industries: liquid fuels	CH_4	15.80	15.80	0.0000	0.9997
1A2	Manufacturing industries and construction: gaseous fuels	N_2O	12.34	12.34	0.0000	0.9997
1A2	Manufacturing industries and construction: other fuels	N_2O	11.06	11.06	0.0000	0.9998
1A2	Manufacturing industries and construction: solid fuels	CH_4	10.61	10.61	0.0000	0.9998

IPCC Code	IPCC Category	GHG	Latest reported year (LY) emissions (Gg CO_2e)	Absolute value of LY emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A2	Manufacturing industries and construction: gaseous fuels	CH_4	10.35	10.35	0.0000	0.9998
2C1	Iron and steel production	CH_4	10.15	10.15	0.0000	0.9998
2B8	Petrochemical and carbon black production	CH_4	9.54	9.54	0.0000	0.9999
5C	Incineration and open burning of waste	CH_4	8.09	8.09	0.0000	0.9999
1A3e	Other transportation: liquid fuels	N_2O	7.50	7.50	0.0000	0.9999
1A3d	Domestic Navigation: liquid fuels	CH_4	7.22	7.22	0.0000	0.9999
1A2	Manufacturing industries and construction: other fuels	CH_4	6.72	6.72	0.0000	0.9999
2C3	Aluminium production	HFCs, PFCs, SF_6 and NF_3	6.25	6.25	0.0000	0.9999
2C1	Iron and steel production	N_2O	6.13	6.13	0.0000	0.9999
2A4	Other process uses of carbonates	CH_4	5.34	5.34	0.0000	1.0000
1A4	Other sectors: peat	CO_2	4.83	4.83	0.0000	1.0000
1B1	Coal mining and handling biomass	CH_4	3.78	3.78	0.0000	1.0000
1A1	Energy industries: solid fuels	CH_4	1.90	1.90	0.0000	1.0000
2B8	Petrochemical and carbon black production	N_2O	1.43	1.43	0.0000	1.0000
1A3a	Domestic aviation: liquid fuels	CH_4	1.34	1.34	0.0000	1.0000
1A5	Other: liquid fuels	CH_4	1.10	1.10	0.0000	1.0000
1A3c	Railways: solid fuels	CH_4	0.94	0.94	0.0000	1.0000
1A3c	Railways: liquid fuels	CH_4	0.83	0.83	0.0000	1.0000
1A4	Other sectors: peat	CH_4	0.34	0.34	0.0000	1.0000
2B1	Ammonia production	N_2O	0.31	0.31	0.0000	1.0000
1A3e	Other transportation: liquid fuels	CH_4	0.27	0.27	0.0000	1.0000
2B1	Ammonia production	CH_4	0.26	0.26	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	0.01	0.01	0.0000	1.0000
Total			**453,101.46**	**453,101.46**	**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) – UNFCCC scope

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Latest reported year (LY) emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
1A1	Energy industries: solid fuels	CO_2	185,488.39	7,224.32	0.1143	0.2409	0.2409
1A1	Energy industries: gaseous fuels	CO_2	9,271.01	58,915.05	0.0632	0.1332	0.3741
1A3b	Road transportation: liquid fuels	CO_2	108,569.24	109,591.01	0.0571	0.1203	0.4945
1A4	Other sectors: gaseous fuels	CO_2	70,371.86	75,975.83	0.0428	0.0902	0.5847
5A	Solid waste disposal	CH_4	60,389.54	14,346.67	0.0231	0.0487	0.6334
1B1	Coal mining and handling	CH_4	21,826.68	480.64	0.0139	0.0293	0.6627
2B3	Adipic acid production	N_2O	19,934.61	-	0.0132	0.0278	0.6905
2F1	Refrigeration and air conditioning	HFCs, PFCs, SF_6 and NF_3	216.96	10,293.85	0.0120	0.0252	0.7157
2B9	Fluorochemical production	HFCs, PFCs, SF_6 and NF_3	17,784.67	120.73	0.0116	0.0245	0.7402
1A2	Manufacturing industries and construction: solid fuels	CO_2	38,053.67	11,985.16	0.0111	0.0234	0.7636
1A4	Other sectors: solid fuels	CO_2	19,824.90	2,066.99	0.0107	0.0225	0.7861
1A1	Energy industries: liquid fuels	CO_2	40,804.35	14,617.15	0.0098	0.0207	0.8068
1A2	Manufacturing industries and construction: gaseous fuels	CO_2	27,330.46	23,282.98	0.0093	0.0196	0.8264
1A1	Energy industries: other fuels	CO_2	244.26	6,050.29	0.0070	0.0147	0.8411
3A1	Enteric fermentation from Cattle	CH_4	18,887.10	16,409.82	0.0068	0.0143	0.8555
3D	Agricultural soils	N_2O	14,258.81	12,250.42	0.0050	0.0105	0.8659
4B	Cropland	CO_2	20,309.04	15,175.26	0.0044	0.0093	0.8752
4A	Forest land	CO_2	-14,364.93	-17,173.23	0.0041	0.0086	0.8839
4C	Grassland	CO_2	-482.28	-3,675.33	0.0035	0.0074	0.8913
1A4	Other sectors: liquid fuels	CO_2	19,560.85	13,805.71	0.0033	0.0069	0.8982
1A2	Manufacturing industries and construction: liquid fuels	CO_2	29,829.47	14,154.90	0.0031	0.0065	0.9047
1B2	Oil and gas extraction	CH_4	12,392.35	4,571.75	0.0028	0.0060	0.9107
2B2	Nitric acid production	N_2O	3,860.26	38.17	0.0025	0.0053	0.9160
4E	Settlements	CO_2	6,426.69	5,550.20	0.0023	0.0048	0.9208

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Latest reported year (LY) emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
3B1	Manure management from Cattle	CH_4	4,262.01	3,994.92	0.0019	0.0040	0.9247
3A2	Enteric fermentation from Sheep	CH_4	5,074.12	4,154.50	0.0015	0.0032	0.9280
1A3d	Domestic Navigation: liquid fuels	CO_2	7,611.13	5,579.13	0.0015	0.0032	0.9312
1A5	Other: liquid fuels	CO_2	5,293.44	1,715.59	0.0015	0.0031	0.9343
5B	Biological treatment of solid waste	CH_4	18.13	1,233.54	0.0014	0.0030	0.9373
2F4	Aerosols	HFCs, PFCs, SF_6 and NF_3	449.39	1,461.63	0.0014	0.0030	0.9403
4D	Wetlands	CO_2	571.96	1,408.08	0.0013	0.0027	0.9430
4C	Grassland	CH_4	2,386.69	2,420.49	0.0013	0.0027	0.9457
1B2	Oil and gas extraction	CO_2	5,777.92	4,200.23	0.0011	0.0024	0.9481
4D	Wetlands	CH_4	1,960.85	2,052.65	0.0011	0.0024	0.9504
2C1	Iron and steel production	CO_2	5,569.58	2,185.94	0.0011	0.0024	0.9528
3B2	Manure management from Sheep	N_2O	3,216.05	2,727.68	0.0011	0.0023	0.9550
1B1	Coal mining and handling solid fuels	CO_2	1,698.56	106.03	0.0010	0.0021	0.9571
1A3c	Railways: liquid fuels	CO_2	1,471.82	1,637.89	0.0010	0.0020	0.9592
4G	Harvested wood products	CO_2	-2,095.04	-2,222.56	0.0009	0.0020	0.9611
2C6	Zinc production	CO_2	1,350.65	-	0.0009	0.0019	0.9630
3G	Liming	CO_2	1,016.78	1,313.00	0.0009	0.0018	0.9648
5B	Biological treatment of solid waste	N_2O	12.97	731.02	0.0009	0.0018	0.9666
1A3a	Domestic aviation: liquid fuels	CO_2	1,875.74	1,767.88	0.0008	0.0018	0.9684
1A2	Manufacturing industries and construction: other fuels	CO_2	70.70	711.45	0.0008	0.0017	0.9701
1A4	Other sectors: biomass	CH_4	63.70	693.59	0.0008	0.0016	0.9717
1A3b	Road transportation: liquid fuels	CH_4	1,246.62	95.76	0.0007	0.0015	0.9732
1A4	Other sectors: solid fuels	CH_4	1,286.45	157.74	0.0007	0.0014	0.9746
1A1	Energy industries: solid fuels	N_2O	1,056.46	36.66	0.0007	0.0014	0.9760
5D	Wastewater treatment and discharge	N_2O	943.47	1,020.10	0.0006	0.0012	0.9772
2B1	Ammonia production	CO_2	1,895.00	1,548.40	0.0006	0.0012	0.9784
1A3e	Other transportation: liquid fuels	CO_2	224.74	605.87	0.0006	0.0012	0.9796

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Latest reported year (LY) emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
5C	Incineration and open burning of waste	CO_2	1,284.85	245.54	0.0006	0.0012	0.9808
5D	Wastewater treatment and discharge	CH_4	2,171.62	1,679.50	0.0005	0.0011	0.9819
1A3b	Road transportation: liquid fuels	N_2O	1,312.05	1,131.24	0.0005	0.0010	0.9829
2G3	N_2O from product uses	N_2O	554.91	658.28	0.0004	0.0009	0.9837
2A1	Cement production	CO_2	7,295.26	4,448.50	0.0004	0.0009	0.9846
2F2	Foam blowing agents	HFCs, PFCs, SF_6 and NF_3	184.66	441.61	0.0004	0.0008	0.9854
2F3	Fire protection	HFCs, PFCs, SF_6 and NF_3	1.42	314.57	0.0004	0.0008	0.9862
2A2	Lime production	CO_2	1,328.60	1,053.43	0.0004	0.0008	0.9870
4A	Forest land	N_2O	747.95	725.21	0.0004	0.0008	0.9877
3A4	Enteric fermentation from Other livestock	CH_4	292.27	458.77	0.0003	0.0007	0.9885
1A3b	Road transportation: biomass	CO_2	-	221.69	0.0003	0.0005	0.9890
1A1	Energy industries: biomass	N_2O	0.25	213.94	0.0003	0.0005	0.9895
1A4	Other sectors: peat	CO_2	372.48	4.83	0.0002	0.0005	0.9900
2G2	SF_6 and PFCs from other product use	HFCs, PFCs, SF_6 and NF_3	278.49	354.56	0.0002	0.0005	0.9905
2C3	Aluminium production	CO_2	450.32	60.66	0.0002	0.0005	0.9910
2C3	Aluminium production	HFCs, PFCs, SF_6 and NF_3	333.43	6.25	0.0002	0.0004	0.9915
1A1	Energy industries: gaseous fuels	N_2O	198.46	291.95	0.0002	0.0004	0.9919
2G4	Other product manufacture and use	N_2O	41.00	196.26	0.0002	0.0004	0.9923
2D	Non-energy products from fuels and solvent use	CO_2	552.81	482.19	0.0002	0.0004	0.9928
4B	Cropland	N_2O	1,102.86	480.38	0.0002	0.0003	0.9931
2A3	Glass production	CO_2	411.31	369.43	0.0002	0.0003	0.9935
4E	Settlements	N_2O	526.45	434.17	0.0002	0.0003	0.9938
2G1	Electrical equipment	HFCs, PFCs, SF_6 and NF_3	797.11	310.67	0.0002	0.0003	0.9941
1A1	Energy industries: biomass	CH_4	0.47	135.38	0.0002	0.0003	0.9945
3H	Urea application to land	CO_2	327.65	318.54	0.0002	0.0003	0.9948

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Latest reported year (LY) emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
4B	Cropland	CH_4	291.97	280.84	0.0001	0.0003	0.9951
1A1	Energy industries: other fuels	CH_4	18.54	123.09	0.0001	0.0003	0.9954
1A1	Energy industries: other fuels	N_2O	6.70	115.69	0.0001	0.0003	0.9956
1A4	Other sectors: solid fuels	N_2O	245.31	27.60	0.0001	0.0003	0.9959
3F	Field burning of agricultural residues	CH_4	187.03	-	0.0001	0.0003	0.9962
1A4	Other sectors: biomass	N_2O	9.35	108.87	0.0001	0.0003	0.9964
1A2	Manufacturing industries and construction: biomass	N_2O	19.31	111.23	0.0001	0.0002	0.9967
2B6	Titanium dioxide production	CO_2	104.63	152.38	0.0001	0.0002	0.9969
1A4	Other sectors: gaseous fuels	CH_4	157.65	168.87	0.0001	0.0002	0.9971
4C	Grassland	N_2O	188.68	182.25	0.0001	0.0002	0.9973
2C4	Magnesium production	HFCs, PFCs, SF_6 and NF_3	387.17	144.16	0.0001	0.0002	0.9975
4A	Forest land	CH_4	88.16	120.61	0.0001	0.0002	0.9977
5C	Incineration and open burning of waste	CH_4	135.58	8.09	0.0001	0.0002	0.9978
1A2	Manufacturing industries and construction: biomass	CH_4	12.15	70.23	0.0001	0.0002	0.9980
1A1	Energy industries: gaseous fuels	CH_4	92.12	114.67	0.0001	0.0002	0.9981
1A2	Manufacturing industries and construction: solid fuels	N_2O	144.12	30.63	0.0001	0.0001	0.9983
2B10	Other Chemical Industry	CH_4	191.21	58.54	0.0001	0.0001	0.9984
3J	Agriculture activities in OTs and CDs	CH_4	270.85	200.03	0.0001	0.0001	0.9985
1A3c	Railways: solid fuels	CO_2	-	41.15	0.0000	0.0001	0.9986
2F6	Other product uses as substitutes for ODS	HFCs, PFCs, SF_6 and NF_3	37.01	53.70	0.0000	0.0001	0.9987
3F	Field burning of agricultural residues	N_2O	57.80	-	0.0000	0.0001	0.9988
1B1	Coal mining and handling liquid fuels	CO_2	-	31.20	0.0000	0.0001	0.9989
3A3	Enteric fermentation from Swine	CH_4	283.06	190.44	0.0000	0.0001	0.9989
2A4	Other process uses of carbonates	CO_2	743.19	448.94	0.0000	0.0001	0.9990
1A1	Energy industries: solid fuels	CH_4	50.88	1.90	0.0000	0.0001	0.9991

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Latest reported year (LY) emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
1A4	Other sectors: liquid fuels	N_2O	102.28	82.37	0.0000	0.0001	0.9991
4D	Wetlands	N_2O	21.29	36.19	0.0000	0.0001	0.9992
2E1	Integrated circuit or semiconductor	HFCs, PFCs, SF_6 and NF_3	9.56	26.27	0.0000	0.0001	0.9993
1A4	Other sectors: gaseous fuels	N_2O	37.58	40.26	0.0000	0.0000	0.9993
2B7	Soda ash production	CO_2	224.40	145.22	0.0000	0.0000	0.9993
2F5	Solvents	HFCs, PFCs, SF_6 and NF_3	-	16.11	0.0000	0.0000	0.9994
1A2	Manufacturing industries and construction: solid fuels	CH_4	47.01	10.61	0.0000	0.0000	0.9994
3J	Agriculture activities in OTs and CDs	N_2O	177.90	115.65	0.0000	0.0000	0.9995
1B2	Oil and gas extraction	N_2O	40.75	37.55	0.0000	0.0000	0.9995
1A4	Other sectors: peat	CH_4	26.35	0.34	0.0000	0.0000	0.9995
1A3d	Domestic Navigation: liquid fuels	N_2O	105.00	73.51	0.0000	0.0000	0.9996
4E	Settlements	CH_4	16.42	23.62	0.0000	0.0000	0.9996
1A5	Other: liquid fuels	N_2O	56.12	18.40	0.0000	0.0000	0.9996
1A2	Manufacturing industries and construction: liquid fuels	N_2O	138.07	90.73	0.0000	0.0000	0.9997
2A4	Other process uses of carbonates	CH_4	31.11	5.34	0.0000	0.0000	0.9997
1A2	Manufacturing industries and construction: other fuels	N_2O	0.35	11.06	0.0000	0.0000	0.9997
2C1	Iron and steel production	CH_4	36.94	10.15	0.0000	0.0000	0.9998
1A3c	Railways: liquid fuels	N_2O	16.63	18.49	0.0000	0.0000	0.9998
1A1	Energy industries: liquid fuels	CH_4	43.27	15.80	0.0000	0.0000	0.9998
2B8	Petrochemical and carbon black production	CO_2	4,751.56	2,665.45	0.0000	0.0000	0.9998
2B8	Petrochemical and carbon black production	CH_4	30.17	9.54	0.0000	0.0000	0.9998
1A2	Manufacturing industries and construction: liquid fuels	CH_4	44.24	32.28	0.0000	0.0000	0.9999
1A3a	Domestic aviation: liquid fuels	N_2O	17.75	16.73	0.0000	0.0000	0.9999
1A2	Manufacturing industries and construction: other fuels	CH_4	0.15	6.72	0.0000	0.0000	0.9999

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Latest reported year (LY) emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
1A3e	Other transportation: liquid fuels	N_2O	2.79	7.50	0.0000	0.0000	0.9999
1A3d	Domestic Navigation: liquid fuels	CH_4	3.66	7.22	0.0000	0.0000	0.9999
1A1	Energy industries: liquid fuels	N_2O	140.12	74.36	0.0000	0.0000	0.9999
1A2	Manufacturing industries and construction: gaseous fuels	N_2O	14.59	12.34	0.0000	0.0000	0.9999
2C1	Iron and steel production	N_2O	18.02	6.13	0.0000	0.0000	0.9999
1B1	Coal mining and handling biomass	CH_4	0.10	3.78	0.0000	0.0000	1.0000
4	Indirect N_2O emissions from LULUCF	N_2O	403.85	223.54	0.0000	0.0000	1.0000
1A2	Manufacturing industries and construction: gaseous fuels	CH_4	12.24	10.35	0.0000	0.0000	1.0000
5C	Incineration and open burning of waste	N_2O	50.93	31.21	0.0000	0.0000	1.0000
1A3a	Domestic aviation: liquid fuels	CH_4	6.66	1.34	0.0000	0.0000	1.0000
1A4	Other sectors: liquid fuels	CH_4	57.66	34.17	0.0000	0.0000	1.0000
1A3c	Railways: solid fuels	CH_4	-	0.94	0.0000	0.0000	1.0000
1A5	Other: liquid fuels	CH_4	3.56	1.10	0.0000	0.0000	1.0000
1A4	Other sectors: peat	N_2O	1.47	0.02	0.0000	0.0000	1.0000
1A3c	Railways: liquid fuels	CH_4	2.46	0.83	0.0000	0.0000	1.0000
2B8	Petrochemical and carbon black production	N_2O	2.21	1.43	0.0000	0.0000	1.0000
2B1	Ammonia production	N_2O	0.31	0.31	0.0000	0.0000	1.0000
2B1	Ammonia production	CH_4	0.26	0.26	0.0000	0.0000	1.0000
1A3e	Other transportation: liquid fuels	CH_4	0.29	0.27	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	0.08	0.01	0.0000	0.0000	1.0000
Total			**816,083.21**	**459,143.82**	**0.4743**	**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) – UNFCCC scope

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Latest reported year (LY) emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
1A1	Energy industries: solid fuels	CO_2	185,488.39	7,224.32	0.1143	0.2515	0.2515
1A1	Energy industries: gaseous fuels	CO_2	9,271.01	58,915.05	0.0632	0.1390	0.3905
1A3b	Road transportation: liquid fuels	CO_2	108,569.24	109,591.01	0.0571	0.1256	0.5161
1A4	Other sectors: gaseous fuels	CO_2	70,371.86	75,975.83	0.0428	0.0942	0.6103
5A	Solid waste disposal	CH_4	60,389.54	14,346.67	0.0231	0.0508	0.6612
1B1	Coal mining and handling	CH_4	21,826.68	480.64	0.0139	0.0306	0.6917
2B3	Adipic acid production	N_2O	19,934.61	-	0.0132	0.0290	0.7207
2F1	Refrigeration and air conditioning	HFCs, PFCs, SF_6 and NF_3	216.96	10,293.85	0.0120	0.0263	0.7471
2B9	Fluorochemical production	HFCs, PFCs, SF_6 and NF_3	17,784.67	120.73	0.0116	0.0256	0.7727
1A2	Manufacturing industries and construction: solid fuels	CO_2	38,053.67	11,985.16	0.0111	0.0244	0.7971
1A4	Other sectors: solid fuels	CO_2	19,824.90	2,066.99	0.0107	0.0235	0.8206
1A1	Energy industries: liquid fuels	CO_2	40,804.35	14,617.15	0.0098	0.0216	0.8422
1A2	Manufacturing industries and construction: gaseous fuels	CO_2	27,330.46	23,282.98	0.0093	0.0205	0.8627
1A1	Energy industries: other fuels	CO_2	244.26	6,050.29	0.0070	0.0153	0.8780
3A1	Enteric fermentation from Cattle	CH_4	18,887.10	16,409.82	0.0068	0.0150	0.8930
3D	Agricultural soils	N_2O	14,258.81	12,250.42	0.0050	0.0109	0.9039
1A4	Other sectors: liquid fuels	CO_2	19,560.85	13,805.71	0.0033	0.0073	0.9112
1A2	Manufacturing industries and construction: liquid fuels	CO_2	29,829.47	14,154.90	0.0031	0.0068	0.9180
1B2	Oil and gas extraction	CH_4	12,392.35	4,571.75	0.0028	0.0062	0.9242
2B2	Nitric acid production	N_2O	3,860.26	38.17	0.0025	0.0055	0.9297
3B1	Manure management from Cattle	CH_4	4,262.01	3,994.92	0.0019	0.0041	0.9338
3A2	Enteric fermentation from Sheep	CH_4	5,074.12	4,154.50	0.0015	0.0034	0.9372
1A3d	Domestic Navigation: liquid fuels	CO_2	7,611.13	5,579.13	0.0015	0.0034	0.9406
1A5	Other: liquid fuels	CO_2	5,293.44	1,715.59	0.0015	0.0033	0.9438

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5B	Biological treatment of solid waste	CH_4	18.13	1,233.54	0.0014	0.0032	0.9470
2F4	Aerosols	HFCs, PFCs, SF_6 and NF_3	449.39	1,461.63	0.0014	0.0031	0.9501
1B2	Oil and gas extraction	CO_2	5,777.92	4,200.23	0.0011	0.0025	0.9526
2C1	Iron and steel production	CO_2	5,569.58	2,185.94	0.0011	0.0025	0.9550
3B2	Manure management from Sheep	N_2O	3,216.05	2,727.68	0.0011	0.0024	0.9574
1B1	Coal mining and handling solid fuels	CO_2	1,698.56	106.03	0.0010	0.0022	0.9596
1A3c	Railways: liquid fuels	CO_2	1,471.82	1,637.89	0.0010	0.0021	0.9617
2C6	Zinc production	CO_2	1,350.65	-	0.0009	0.0020	0.9637
3G	Liming	CO_2	1,016.78	1,313.00	0.0009	0.0019	0.9656
5B	Biological treatment of solid waste	N_2O	12.97	731.02	0.0009	0.0019	0.9675
1A3a	Domestic aviation: liquid fuels	CO_2	1,875.74	1,767.88	0.0008	0.0018	0.9693
1A2	Manufacturing industries and construction: other fuels	CO_2	70.70	711.45	0.0008	0.0017	0.9711
1A4	Other sectors: biomass	CH_4	63.70	693.59	0.0008	0.0017	0.9728
1A3b	Road transportation: liquid fuels	CH_4	1,246.62	95.76	0.0007	0.0016	0.9743
1A4	Other sectors: solid fuels	CH_4	1,286.45	157.74	0.0007	0.0015	0.9758
1A1	Energy industries: solid fuels	N_2O	1,056.46	36.66	0.0007	0.0014	0.9772
5D	Wastewater treatment and discharge	N_2O	943.47	1,020.10	0.0006	0.0013	0.9785
2B1	Ammonia production	CO_2	1,895.00	1,548.40	0.0006	0.0012	0.9798
1A3e	Other transportation: liquid fuels	CO_2	224.74	605.87	0.0006	0.0012	0.9810
5C	Incineration and open burning of waste	CO_2	1,284.85	245.54	0.0006	0.0012	0.9822
5D	Wastewater treatment and discharge	CH_4	2,171.62	1,679.50	0.0005	0.0012	0.9834
1A3b	Road transportation: liquid fuels	N_2O	1,312.05	1,131.24	0.0005	0.0010	0.9844
2G3	N_2O from product uses	N_2O	554.91	658.28	0.0004	0.0009	0.9853
2A1	Cement production	CO_2	7,295.26	4,448.50	0.0004	0.0009	0.9862
2F2	Foam blowing agents	HFCs, PFCs, SF_6 and NF_3	184.66	441.61	0.0004	0.0009	0.9871

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Latest reported year (LY) emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
2F3	Fire protection	HFCs, PFCs, SF_6 and NF_3	1.42	314.57	0.0004	0.0008	0.9879
2A2	Lime production	CO_2	1,328.60	1,053.43	0.0004	0.0008	0.9887
3A4	Enteric fermentation from Other livestock	CH_4	292.27	458.77	0.0003	0.0008	0.9895
1A3b	Road transportation: biomass	CO_2	-	221.69	0.0003	0.0006	0.9900
1A1	Energy industries: biomass	N_2O	0.25	213.94	0.0003	0.0006	0.9906
1A4	Other sectors: peat	CO_2	372.48	4.83	0.0002	0.0005	0.9911
2G2	SF_6 and PFCs from other product use	HFCs, PFCs, SF_6 and NF_3	278.49	354.56	0.0002	0.0005	0.9916
2C3	Aluminium production	CO_2	450.32	60.66	0.0002	0.0005	0.9921
2C3	Aluminium production	HFCs, PFCs, SF_6 and NF_3	333.43	6.25	0.0002	0.0005	0.9926
1A1	Energy industries: gaseous fuels	N_2O	198.46	291.95	0.0002	0.0005	0.9931
2G4	Other product manufacture and use	N_2O	41.00	196.26	0.0002	0.0004	0.9935
2D	Non-energy products from fuels and solvent use	CO_2	552.81	482.19	0.0002	0.0004	0.9940
2A3	Glass production	CO_2	411.31	369.43	0.0002	0.0004	0.9943
2G1	Electrical equipment	HFCs, PFCs, SF_6 and NF_3	797.11	310.67	0.0002	0.0004	0.9947
1A1	Energy industries: biomass	CH_4	0.47	135.38	0.0002	0.0003	0.9950
3H	Urea application to land	CO_2	327.65	318.54	0.0002	0.0003	0.9954
1A1	Energy industries: other fuels	CH_4	18.54	123.09	0.0001	0.0003	0.9957
1A1	Energy industries: other fuels	N_2O	6.70	115.69	0.0001	0.0003	0.9959
1A4	Other sectors: solid fuels	N_2O	245.31	27.60	0.0001	0.0003	0.9962
3F	Field burning of agricultural residues	CH_4	187.03	-	0.0001	0.0003	0.9965
1A4	Other sectors: biomass	N_2O	9.35	108.87	0.0001	0.0003	0.9968
1A2	Manufacturing industries and construction: biomass	N_2O	19.31	111.23	0.0001	0.0003	0.9970
2B6	Titanium dioxide production	CO_2	104.63	152.38	0.0001	0.0002	0.9973
1A4	Other sectors: gaseous fuels	CH_4	157.65	168.87	0.0001	0.0002	0.9975

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Latest reported year (LY) emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
2C4	Magnesium production	HFCs, PFCs, SF_6 and NF_3	387.17	144.16	0.0001	0.0002	0.9977
5C	Incineration and open burning of waste	CH_4	135.58	8.09	0.0001	0.0002	0.9979
1A2	Manufacturing industries and construction: biomass	CH_4	12.15	70.23	0.0001	0.0002	0.9980
1A1	Energy industries: gaseous fuels	CH_4	92.12	114.67	0.0001	0.0002	0.9982
1A2	Manufacturing industries and construction: solid fuels	N_2O	144.12	30.63	0.0001	0.0001	0.9983
2B10	Other Chemical Industry	CH_4	191.21	58.54	0.0001	0.0001	0.9984
3J	Agriculture activities in OTs and CDs	CH_4	270.85	200.03	0.0001	0.0001	0.9986
1A3c	Railways: solid fuels	CO_2	-	41.15	0.0000	0.0001	0.9987
2F6	Other product uses as substitutes for ODS	HFCs, PFCs, SF_6 and NF_3	37.01	53.70	0.0000	0.0001	0.9988
3F	Field burning of agricultural residues	N_2O	57.80	-	0.0000	0.0001	0.9988
1B1	Coal mining and handling liquid fuels	CO_2	-	31.20	0.0000	0.0001	0.9989
3A3	Enteric fermentation from Swine	CH_4	283.06	190.44	0.0000	0.0001	0.9990
2A4	Other process uses of carbonates	CO_2	743.19	448.94	0.0000	0.0001	0.9991
1A1	Energy industries: solid fuels	CH_4	50.88	1.90	0.0000	0.0001	0.9991
1A4	Other sectors: liquid fuels	N_2O	102.28	82.37	0.0000	0.0001	0.9992
2E1	Integrated circuit or semiconductor	HFCs, PFCs, SF_6 and NF_3	9.56	26.27	0.0000	0.0001	0.9993
1A4	Other sectors: gaseous fuels	N_2O	37.58	40.26	0.0000	0.0000	0.9993
2B7	Soda ash production	CO_2	224.40	145.22	0.0000	0.0000	0.9994
2F5	Solvents	HFCs, PFCs, SF_6 and NF_3	-	16.11	0.0000	0.0000	0.9994
1A2	Manufacturing industries and construction: solid fuels	CH_4	47.01	10.61	0.0000	0.0000	0.9994
3J	Agriculture activities in OTs and CDs	N_2O	177.90	115.65	0.0000	0.0000	0.9995
1B2	Oil and gas extraction	N_2O	40.75	37.55	0.0000	0.0000	0.9995
1A4	Other sectors: peat	CH_4	26.35	0.34	0.0000	0.0000	0.9996
1A3d	Domestic Navigation: liquid fuels	N_2O	105.00	73.51	0.0000	0.0000	0.9996

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Latest reported year (LY) emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
1A5	Other: liquid fuels	N_2O	56.12	18.40	0.0000	0.0000	0.9996
1A2	Manufacturing industries and construction: liquid fuels	N_2O	138.07	90.73	0.0000	0.0000	0.9997
2A4	Other process uses of carbonates	CH_4	31.11	5.34	0.0000	0.0000	0.9997
1A2	Manufacturing industries and construction: other fuels	N_2O	0.35	11.06	0.0000	0.0000	0.9997
2C1	Iron and steel production	CH_4	36.94	10.15	0.0000	0.0000	0.9998
1A3c	Railways: liquid fuels	N_2O	16.63	18.49	0.0000	0.0000	0.9998
1A1	Energy industries: liquid fuels	CH_4	43.27	15.80	0.0000	0.0000	0.9998
2B8	Petrochemical and carbon black production	CO_2	4,751.56	2,665.45	0.0000	0.0000	0.9998
2B8	Petrochemical and carbon black production	CH_4	30.17	9.54	0.0000	0.0000	0.9998
1A2	Manufacturing industries and construction: liquid fuels	CH_4	44.24	32.28	0.0000	0.0000	0.9999
1A3a	Domestic aviation: liquid fuels	N_2O	17.75	16.73	0.0000	0.0000	0.9999
1A2	Manufacturing industries and construction: other fuels	CH_4	0.15	6.72	0.0000	0.0000	0.9999
1A3e	Other transportation: liquid fuels	N_2O	2.79	7.50	0.0000	0.0000	0.9999
1A3d	Domestic Navigation: liquid fuels	CH_4	3.66	7.22	0.0000	0.0000	0.9999
1A1	Energy industries: liquid fuels	N_2O	140.12	74.36	0.0000	0.0000	0.9999
1A2	Manufacturing industries and construction: gaseous fuels	N_2O	14.59	12.34	0.0000	0.0000	0.9999
2C1	Iron and steel production	N_2O	18.02	6.13	0.0000	0.0000	1.0000
1B1	Coal mining and handling biomass	CH_4	0.10	3.78	0.0000	0.0000	1.0000
1A2	Manufacturing industries and construction: gaseous fuels	CH_4	12.24	10.35	0.0000	0.0000	1.0000
5C	Incineration and open burning of waste	N_2O	50.93	31.21	0.0000	0.0000	1.0000
1A3a	Domestic aviation: liquid fuels	CH_4	6.66	1.34	0.0000	0.0000	1.0000
1A4	Other sectors: liquid fuels	CH_4	57.66	34.17	0.0000	0.0000	1.0000
1A3c	Railways: solid fuels	CH_4	-	0.94	0.0000	0.0000	1.0000
1A5	Other: liquid fuels	CH_4	3.56	1.10	0.0000	0.0000	1.0000

IPCC Code	IPCC Category	GHG	Base year emissions (Gg CO_2e)	Latest reported year (LY) emissions (Gg CO_2e)	Trend Assessment	Contribution to Trend	Cumulative Total
1A4	Other sectors: peat	N_2O	1.47	0.02	0.0000	0.0000	1.0000
1A3c	Railways: liquid fuels	CH_4	2.46	0.83	0.0000	0.0000	1.0000
2B8	Petrochemical and carbon black production	N_2O	2.21	1.43	0.0000	0.0000	1.0000
2B1	Ammonia production	N_2O	0.31	0.31	0.0000	0.0000	1.0000
2B1	Ammonia production	CH_4	0.26	0.26	0.0000	0.0000	1.0000
1A3e	Other transportation: liquid fuels	CH_4	0.29	0.27	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	0.08	0.01	0.0000	0.0000	1.0000
Total			**797,982.60**	**453,101.46**	**0.4544**	**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, 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 – UNFCCC scope

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	60389.54	60389.54	0.2916	0.2916
1A	1A Coal	CO_2	243366.96	243366.96	0.1058	0.3974
1A	1A (Stationary) Oil	CO_2	95445.13	95445.13	0.0617	0.4591
4B	4B Cropland	CO_2	20309.04	20309.04	0.0507	0.5098
1B1	1B1 Coal Mining	CH_4	21826.68	21826.68	0.0438	0.5536
5C	5C Waste Incineration	CO_2	1284.85	1284.85	0.0388	0.5924
3A	3A Enteric Fermentation	CH_4	24536.54	24536.54	0.0336	0.6260
4A	4A Forest Land	CO_2	-14364.93	14364.93	0.0296	0.6556
2B	2B Chemical industries	N_2O	23797.38	23797.38	0.0243	0.6799
1A	1A Natural Gas	CO_2	106973.32	106973.32	0.0211	0.7010
1B2	1B2 Natural Gas Transmission	CH_4	10168.33	10168.33	0.0205	0.7215
2B	2B Chemical industry	HFCs	17670.77	17670.77	0.0176	0.7392
5D	5D Wastewater Handling	N_2O	943.47	943.47	0.0174	0.7565
1A3b	1A3b Gasoline/ LPG	CO_2	75561.88	75561.88	0.0168	0.7733
4E	4E Settlements	CO_2	6426.69	6426.69	0.0160	0.7894
3D	3D Agricultural Soils	N_2O	14258.81	14258.81	0.0159	0.8052
1A1 & 1A2 & 1A4 & 1A5	1A1 & 1A2 & 1A4 & 1A5 Other Combustion	N_2O	2170.54	2170.54	0.0140	0.8192
1A3d	1A3d Marine fuel	CO_2	7611.13	7611.13	0.0137	0.8329
2B	2B Chemical industries	CO_2	6975.59	6975.59	0.0125	0.8454
5D	5D Wastewater Handling	CH_4	2171.62	2171.62	0.0107	0.8562
4C	4C Grassland	CH_4	2386.69	2386.69	0.0095	0.8657
1A3b	1A3b Gasoline/ LPG	CH_4	1157.88	1157.88	0.0087	0.8744
2G	2G Other Product Manufacture and Use	N_2O	595.91	595.91	0.0084	0.8828
1A3b	1A3b Gasoline/ LPG	N_2O	989.26	989.26	0.0074	0.8901
1A3b	1A3b DERV	CO_2	33005.73	33005.73	0.0074	0.8975
1A1 & 1A2 & 1A4 & 1A5	1A1 & 1A2 & 1A4 & 1A5 Other Combustion	CH_4	1916.44	1916.44	0.0069	0.9044
4D	4D Wetland	CH_4	1960.85	1960.85	0.0069	0.9112
4E	4E Settlements	N_2O	526.45	526.45	0.0068	0.9181
4	4 Indirect LULUCF Emissions	N_2O	403.85	403.85	0.0067	0.9247

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
4A	4A Forest land	N_2O	747.95	747.95	0.0060	0.9307
4B	4B Cropland	N_2O	1102.86	1102.86	0.0044	0.9351
1A3b	1A3b DERV	N_2O	322.80	322.80	0.0042	0.9393
1B2	1B2 Offshore Oil& Gas	CH_4	2224.01	2224.01	0.0041	0.9434
1B2	1B2 Oil & Natural Gas	CO_2	5777.92	5777.92	0.0039	0.9473
1A3a	1A3a Aviation Fuel	CO_2	1875.74	1875.74	0.0037	0.9510
2C	2C Metal Industries	CO_2	7370.55	7370.55	0.0036	0.9547
3B	3B Manure Management	CH_4	4262.01	4262.01	0.0036	0.9582
2D	2D Non Energy Products from Fuels and Solvent Use	CO_2	552.81	552.81	0.0032	0.9614
4G	4G Other Activities	CO_2	-2095.04	2095.04	0.0031	0.9646
3B	3B Manure Management	N_2O	3216.05	3216.05	0.0031	0.9676
4B	4B Cropland	CH_4	291.97	291.97	0.0026	0.9703
2A	2A Mineral Industries	CO_2	9778.37	9778.37	0.0024	0.9726
1A3	1A3 Other diesel	CO_2	1696.57	1696.57	0.0023	0.9749
3G	3G Liming	CO_2	1016.78	1016.78	0.0021	0.9771
3J	3J OT & CD Agriculture	CH_4	270.85	270.85	0.0019	0.9790
3H	3H Urea application to agriculture	CO_2	327.65	327.65	0.0016	0.9806
4C	4C Grassland	CO_2	-482.28	482.28	0.0014	0.9820
4D	4D Wetland	CO_2	571.96	571.96	0.0014	0.9835
3J	3J OT & CD Agriculture	N_2O	177.90	177.90	0.0013	0.9847
1A3d	1A3d Marine fuel	N_2O	105.00	105.00	0.0012	0.9860
1A4	1A4 Peat	CO_2	372.48	372.48	0.0012	0.9871
5C	5C Waste Incineration	N_2O	50.93	50.93	0.0012	0.9883
1A3b	1A3b DERV	CH_4	88.73	88.73	0.0012	0.9895
1B1	1B1 Solid Fuel Transformation	CO_2	1698.56	1698.56	0.0011	0.9906
2F	2F Product Uses as Substitutes for ODS	HFCs	888.99	888.99	0.0010	0.9916
4C	4C Grassland	N_2O	188.68	188.68	0.0008	0.9924
2G	2G Other Product Manufacture and Use	PFCs	148.99	148.99	0.0007	0.9931
5C	5C Waste Incineration	CH_4	135.58	135.58	0.0007	0.9938
2C	2C Metal Industries	PFCs	333.43	333.43	0.0007	0.9945
4A	4A Forest Land	CH_4	88.16	88.16	0.0006	0.9951
2G	2G Other Product Manufacture and Use	SF_6	926.62	926.62	0.0006	0.9957
3F	3F Field Burning	CH_4	187.03	187.03	0.0005	0.9961

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	CH_4	221.63	221.63	0.0004	0.9966
1B2	1B2 Oil & Natural Gas	N_2O	40.75	40.75	0.0004	0.9970
1A	1A Other (waste)	CO_2	245.26	245.26	0.0003	0.9973
2A	2A Mineral Industries	CH_4	31.11	31.11	0.0003	0.9977
1A4	1A4 Petroleum Coke	CO_2	114.30	114.30	0.0003	0.9979
2C	2C Metal Industries	SF_6	387.17	387.17	0.0003	0.9982
1A3	1A3 Other diesel	N_2O	19.42	19.42	0.0003	0.9985
2C	2C Iron & Steel	N_2O	18.02	18.02	0.0002	0.9987
1A3a	1A3a Aviation Fuel	N_2O	17.75	17.75	0.0002	0.9989
5B	5B Biological treatment of solid waste	CH_4	18.13	18.13	0.0002	0.9991
2C	2C Iron & Steel Production	CH_4	36.94	36.94	0.0002	0.9992
3F	3F Field Burning	N_2O	57.80	57.80	0.0001	0.9994
4D	4D Wetland	N_2O	21.29	21.29	0.0001	0.9995
5B	5B Biological treatment of solid waste	N_2O	12.97	12.97	0.0001	0.9997
2B	2B Chemical industry	PFCs	113.90	113.90	0.0001	0.9998
4E	4E Settlements	CH_4	16.42	16.42	0.0001	0.9998
1A3d	1A3d Marine fuel	CH_4	3.66	3.66	0.0000	0.9999
2E	2E Electronics Industry	HFCs	8.73	8.73	0.0000	0.9999
1A3a	1A3a Aviation Fuel	CH_4	6.66	6.66	0.0000	1.0000
1A3	1A3 Other diesel	CH_4	2.75	2.75	0.0000	1.0000
2E	2E Electronics Industry	NF_3	0.83	0.83	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	0.18	0.18	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
Total			**816,083.21**	**849,967.71**	**1**	

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

IPCC Code	IPCC Category	Gas	Latest reported year (LY) emissions (Gg CO_2e)	Absolute value of LY emissions (Gg CO_2e)	Level Assessment	Cumulative Total
5A	5A Solid Waste Disposal	CH_4	14346.67	14346.67	0.1308	0.1308
4B	4B Cropland	CO_2	15175.26	15175.26	0.0716	0.2024
4A	4A Forest Land	CO_2	-17173.23	17173.23	0.0667	0.2691
1A	1A Natural Gas	CO_2	158173.87	158173.87	0.0589	0.3280
3A	3A Enteric Fermentation	CH_4	21213.52	21213.52	0.0549	0.3829
1A	1A (Stationary) Oil	CO_2	43852.33	43852.33	0.0535	0.4365
5D	5D Wastewater Handling	N_2O	1020.10	1020.10	0.0355	0.4719
1A3b	1A3b DERV	CO_2	73923.29	73923.29	0.0312	0.5031
2F	2F Product Uses as Substitutes for ODS	HFCs	12581.47	12581.47	0.0276	0.5307
4E	4E Settlements	CO_2	5550.20	5550.20	0.0262	0.5569
3D	3D Agricultural Soils	N_2O	12250.42	12250.42	0.0258	0.5826
1A3b	1A3b DERV	N_2O	1031.76	1031.76	0.0253	0.6079
5B	5B Biological treatment of solid waste	CH_4	1233.54	1233.54	0.0242	0.6321
2G	2G Other Product Manufacture and Use	N_2O	854.54	854.54	0.0228	0.6548
4C	4C Grassland	CO_2	-3675.33	3675.33	0.0208	0.6756
1A3d	1A3d Marine fuel	CO_2	5579.13	5579.13	0.0190	0.6946
4C	4C Grassland	CH_4	2420.49	2420.49	0.0183	0.7128
1A	1A Coal	CO_2	21276.47	21276.47	0.0175	0.7303
1A	1A Other (waste)	CO_2	6529.98	6529.98	0.0172	0.7475
5D	5D Wastewater Handling	CH_4	1679.50	1679.50	0.0157	0.7632
1A1 & 1A2 & 1A4 & 1A5	1A1 & 1A2 & 1A4 & 1A5 Other Combustion	N_2O	1266.10	1266.10	0.0154	0.7786
2B	2B Chemical industries	CO_2	4511.46	4511.46	0.0153	0.7939
1A3b	1A3b Gasoline/ LPG	CO_2	35667.29	35667.29	0.0150	0.8088
5C	5C Waste Incineration	CO_2	245.54	245.54	0.0140	0.8228
4D	4D Wetland	CH_4	2052.65	2052.65	0.0135	0.8364
1B2	1B2 Natural Gas Transmission	CH_4	3456.67	3456.67	0.0132	0.8495
5B	5B Biological treatment of solid waste	N_2O	731.02	731.02	0.0131	0.8626
4A	4A Forest land	N_2O	725.21	725.21	0.0109	0.8735
1A1 & 1A2 & 1A4 & 1A5	1A1 & 1A2 & 1A4 & 1A5 Other Combustion	CH_4	1576.84	1576.84	0.0107	0.8842
4E	4E Settlements	N_2O	434.17	434.17	0.0106	0.8948

IPCC Code	IPCC Category	Gas	Latest reported year (LY) emissions (Gg CO_2e)	Absolute value of LY emissions (Gg CO_2e)	Level Assessment	Cumulative Total
4	4 Indirect LULUCF Emissions	N_2O	223.54	223.54	0.0070	0.9018
1A3a	1A3a Aviation Fuel	CO_2	1767.88	1767.88	0.0067	0.9085
4D	4D Wetland	CO_2	1408.08	1408.08	0.0066	0.9151
1A3	1A3 Other diesel	CO_2	2465.45	2465.45	0.0064	0.9215
3B	3B Manure Management	CH_4	3994.92	3994.92	0.0063	0.9278
4G	4G Other Activities	CO_2	-2222.56	2222.56	0.0063	0.9341
1B2	1B2 Oil & Natural Gas	CO_2	4200.23	4200.23	0.0053	0.9394
2D	2D Non Energy Products from Fuels and Solvent Use	CO_2	482.19	482.19	0.0053	0.9447
3G	3G Liming	CO_2	1313.00	1313.00	0.0052	0.9498
3B	3B Manure Management	N_2O	2727.68	2727.68	0.0049	0.9547
4B	4B Cropland	CH_4	280.84	280.84	0.0048	0.9595
1B2	1B2 Offshore Oil& Gas	CH_4	1115.08	1115.08	0.0039	0.9634
4B	4B Cropland	N_2O	480.38	480.38	0.0036	0.9671
1A4	1A4 Petroleum Coke	CO_2	673.20	673.20	0.0032	0.9702
3H	3H Urea application to agriculture	CO_2	318.54	318.54	0.0030	0.9732
2A	2A Mineral Industries	CO_2	6320.30	6320.30	0.0029	0.9761
3J	3J OT & CD Agriculture	CH_4	200.03	200.03	0.0027	0.9788
2C	2C Metal Industries	CO_2	2246.60	2246.60	0.0021	0.9809
2G	2G Other Product Manufacture and Use	PFCs	217.71	217.71	0.0019	0.9828
1B1	1B1 Coal Mining	CH_4	480.64	480.64	0.0018	0.9846
1A3d	1A3d Marine fuel	N_2O	73.51	73.51	0.0016	0.9862
4A	4A Forest Land	CH_4	120.61	120.61	0.0016	0.9878
4C	4C Grassland	N_2O	182.25	182.25	0.0015	0.9894
3J	3J OT & CD Agriculture	N_2O	115.65	115.65	0.0015	0.9909
1A3b	1A3b Gasoline/ LPG	N_2O	99.48	99.48	0.0014	0.9923
5C	5C Waste Incineration	N_2O	31.21	31.21	0.0014	0.9937
1A3b	1A3b Gasoline/ LPG	CH_4	89.51	89.51	0.0013	0.9949
1B2	1B2 Oil & Natural Gas	N_2O	37.55	37.55	0.0007	0.9957
1A3	1A3 Other diesel	N_2O	25.99	25.99	0.0006	0.9963
2G	2G Other Product Manufacture and Use	SF_6	447.52	447.52	0.0005	0.9968
4D	4D Wetland	N_2O	36.19	36.19	0.0004	0.9973
1A3a	1A3a Aviation Fuel	N_2O	16.73	16.73	0.0003	0.9976

IPCC Code	IPCC Category	Gas	Latest reported year (LY) emissions (Gg CO_2e)	Absolute value of LY emissions (Gg CO_2e)	Level Assessment	Cumulative Total
2B	2B Chemical Industry	CH_4	68.35	68.35	0.0003	0.9979
2E	2E Electronics Industry	HFCs	25.63	25.63	0.0002	0.9981
2B	2B Chemical industry	PFCs	120.73	120.73	0.0002	0.9983
2C	2C Metal Industries	SF_6	141.87	141.87	0.0002	0.9985
4E	4E Settlements	CH_4	23.62	23.62	0.0002	0.9987
1A3d	1A3d Marine fuel	CH_4	7.22	7.22	0.0002	0.9989
1B1	1B1 Solid Fuel Transformation	CO_2	137.23	137.23	0.0002	0.9990
1A3c	1A3c Coal	CO_2	41.15	41.15	0.0002	0.9992
1A3b	1A3b DERV	CH_4	6.25	6.25	0.0002	0.9994
2C	2C Iron & Steel	N_2O	6.13	6.13	0.0001	0.9995
2A	2A Mineral Industries	CH_4	5.34	5.34	0.0001	0.9996
2C	2C Iron & Steel Production	CH_4	10.15	10.15	0.0001	0.9997
2B	2B Chemical industries	N_2O	39.92	39.92	0.0001	0.9998
5C	5C Waste Incineration	CH_4	8.09	8.09	0.0001	0.9998
1B1	1B1 Solid Fuel Transformation	CH_4	3.79	3.79	0.0000	0.9999
1A4	1A4 Peat	CO_2	4.83	4.83	0.0000	0.9999
1A3	1A3 Other diesel	CH_4	1.10	1.10	0.0000	0.9999
2C	2C Metal Industries	PFCs	6.25	6.25	0.0000	1.0000
1A3c	1A3c Coal	CH_4	0.94	0.94	0.0000	1.0000
1A3a	1A3a Aviation Fuel	CH_4	1.34	1.34	0.0000	1.0000
2E	2E Electronics Industry	NF_3	0.64	0.64	0.0000	1.0000
2C	2C Metal Industries	HFCs	2.29	2.29	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
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
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
2B	2B Chemical industry	HFCs	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
Total			**459,143.82**	**505,286.06**	**1**	

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

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	60389.54	60389.54	0.3418	0.3418
1A	1A Coal	CO_2	243366.96	243366.96	0.1241	0.4658
1A	1A (Stationary) Oil	CO_2	95445.13	95445.13	0.0723	0.5381
1B1	1B1 Coal Mining	CH_4	21826.68	21826.68	0.0513	0.5895
5C	5C Waste Incineration	CO_2	1284.85	1284.85	0.0455	0.6350
3A	3A Enteric Fermentation	CH_4	24536.54	24536.54	0.0394	0.6744
2B	2B Chemical industries	N_2O	23797.38	23797.38	0.0285	0.7028
1A	1A Natural Gas	CO_2	106973.32	106973.32	0.0247	0.7276
1B2	1B2 Natural Gas Transmission	CH_4	10168.33	10168.33	0.0241	0.7516
2B	2B Chemical industry	HFCs	17670.77	17670.77	0.0207	0.7723
5D	5D Wastewater Handling	N_2O	943.47	943.47	0.0204	0.7927
1A3b	1A3b Gasoline/ LPG	CO_2	75561.88	75561.88	0.0197	0.8124
3D	3D Agricultural Soils	N_2O	14258.81	14258.81	0.0186	0.8310
1A1 & 1A2 & 1A4 & 1A5	1A1 & 1A2 & 1A4 & 1A5 Other Combustion	N_2O	2170.54	2170.54	0.0164	0.8474
1A3d	1A3d Marine fuel	CO_2	7611.13	7611.13	0.0161	0.8634
2B	2B Chemical industries	CO_2	6975.59	6975.59	0.0146	0.8781
5D	5D Wastewater Handling	CH_4	2171.62	2171.62	0.0126	0.8907
1A3b	1A3b Gasoline/ LPG	CH_4	1157.88	1157.88	0.0102	0.9008
2G	2G Other Product Manufacture and Use	N_2O	595.91	595.91	0.0099	0.9107
1A3b	1A3b Gasoline/ LPG	N_2O	989.26	989.26	0.0086	0.9193
1A3b	1A3b DERV	CO_2	33005.73	33005.73	0.0086	0.9279
1A1 & 1A2 & 1A4 & 1A5	1A1 & 1A2 & 1A4 & 1A5 Other Combustion	CH_4	1916.44	1916.44	0.0081	0.9360
1A3b	1A3b DERV	N_2O	322.80	322.80	0.0049	0.9409
1B2	1B2 Offshore Oil& Gas	CH_4	2224.01	2224.01	0.0049	0.9458
1B2	1B2 Oil & Natural Gas	CO_2	5777.92	5777.92	0.0045	0.9503
1A3a	1A3a Aviation Fuel	CO_2	1875.74	1875.74	0.0044	0.9547
2C	2C Metal Industries	CO_2	7370.55	7370.55	0.0043	0.9589
3B	3B Manure Management	CH_4	4262.01	4262.01	0.0042	0.9631
2D	2D Non Energy Products from Fuels and Solvent Use	CO_2	552.81	552.81	0.0037	0.9669
3B	3B Manure Management	N_2O	3216.05	3216.05	0.0036	0.9705

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
2A	2A Mineral Industries	CO_2	9778.37	9778.37	0.0028	0.9732
1A3	1A3 Other diesel	CO_2	1696.57	1696.57	0.0027	0.9759
3G	3G Liming	CO_2	1016.78	1016.78	0.0025	0.9784
3J	3J OT & CD Agriculture	CH_4	270.85	270.85	0.0022	0.9807
3H	3H Urea application to agriculture	CO_2	327.65	327.65	0.0019	0.9826
3J	3J OT & CD Agriculture	N_2O	177.90	177.90	0.0015	0.9841
1A3d	1A3d Marine fuel	N_2O	105.00	105.00	0.0014	0.9855
1A4	1A4 Peat	CO_2	372.48	372.48	0.0014	0.9869
5C	5C Waste Incineration	N_2O	50.93	50.93	0.0014	0.9882
1A3b	1A3b DERV	CH_4	88.73	88.73	0.0013	0.9896
1B1	1B1 Solid Fuel Transformation	CO_2	1698.56	1698.56	0.0013	0.9909
2F	2F Product Uses as Substitutes for ODS	HFCs	888.99	888.99	0.0012	0.9921
2G	2G Other Product Manufacture and Use	PFCs	148.99	148.99	0.0008	0.9929
5C	5C Waste Incineration	CH_4	135.58	135.58	0.0008	0.9937
2C	2C Metal Industries	PFCs	333.43	333.43	0.0008	0.9945
2G	2G Other Product Manufacture and Use	SF_6	926.62	926.62	0.0006	0.9951
3F	3F Field Burning	CH_4	187.03	187.03	0.0006	0.9957
2B	2B Chemical Industry	CH_4	221.63	221.63	0.0005	0.9962
1B2	1B2 Oil & Natural Gas	N_2O	40.75	40.75	0.0005	0.9967
1A	1A Other (waste)	CO_2	245.26	245.26	0.0004	0.9971
2A	2A Mineral Industries	CH_4	31.11	31.11	0.0004	0.9975
1A4	1A4 Petroleum Coke	CO_2	114.30	114.30	0.0003	0.9978
2C	2C Metal Industries	SF_6	387.17	387.17	0.0003	0.9981
1A3	1A3 Other diesel	N_2O	19.42	19.42	0.0003	0.9984
2C	2C Iron & Steel	N_2O	18.02	18.02	0.0002	0.9987
1A3a	1A3a Aviation Fuel	N_2O	17.75	17.75	0.0002	0.9989
5B	5B Biological treatment of solid waste	CH_4	18.13	18.13	0.0002	0.9991
2C	2C Iron & Steel Production	CH_4	36.94	36.94	0.0002	0.9994
3F	3F Field Burning	N_2O	57.80	57.80	0.0002	0.9995
5B	5B Biological treatment of solid waste	N_2O	12.97	12.97	0.0001	0.9997
2B	2B Chemical industry	PFCs	113.90	113.90	0.0001	0.9998
1A3d	1A3d Marine fuel	CH_4	3.66	3.66	0.0001	0.9999
2E	2E Electronics Industry	HFCs	8.73	8.73	0.0000	0.9999

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	Absolute value of Base year emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A3a	1A3a Aviation Fuel	CH_4	6.66	6.66	0.0000	0.9999
1A3	1A3 Other diesel	CH_4	2.75	2.75	0.0000	1.0000
2E	2E Electronics Industry	NF_3	0.83	0.83	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	0.18	0.18	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
Total			**797,982.60**	**797,982.60**	**1**	

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

IPCC Code	IPCC Category	Gas	Latest reported year (LY) emissions (Gg CO_2e)	Absolute value of LY emissions (Gg CO_2e)	Level Assessment	Cumulative Total
5A	5A Solid Waste Disposal	CH_4	14346.67	14346.67	0.1794	0.1794
1A	1A Natural Gas	CO_2	158173.87	158173.87	0.0808	0.2602
3A	3A Enteric Fermentation	CH_4	21213.52	21213.52	0.0753	0.3354
1A	1A (Stationary) Oil	CO_2	43852.33	43852.33	0.0734	0.4088
5D	5D Wastewater Handling	N_2O	1020.10	1020.10	0.0487	0.4575
1A3b	1A3b DERV	CO_2	73923.29	73923.29	0.0427	0.5002
2F	2F Product Uses as Substitutes for ODS	HFCs	12581.47	12581.47	0.0378	0.5380
3D	3D Agricultural Soils	N_2O	12250.42	12250.42	0.0353	0.5733
1A3b	1A3b DERV	N_2O	1031.76	1031.76	0.0347	0.6080
5B	5B Biological treatment of solid waste	CH_4	1233.54	1233.54	0.0331	0.6411
2G	2G Other Product Manufacture and Use	N_2O	854.54	854.54	0.0312	0.6724
1A3d	1A3d Marine fuel	CO_2	5579.13	5579.13	0.0260	0.6984
1A	1A Coal	CO_2	21276.47	21276.47	0.0240	0.7223

IPCC Code	IPCC Category	Gas	Latest reported year (LY) emissions (Gg CO_2e)	Absolute value of LY emissions (Gg CO_2e)	Level Assessment	Cumulative Total
1A	1A Other (waste)	CO_2	6529.98	6529.98	0.0235	0.7459
5D	5D Wastewater Handling	CH_4	1679.50	1679.50	0.0215	0.7674
1A1 & 1A2 & 1A4 & 1A5	1A1 & 1A2 & 1A4 & 1A5 Other Combustion	N_2O	1266.10	1266.10	0.0211	0.7885
2B	2B Chemical industries	CO_2	4511.46	4511.46	0.0209	0.8094
1A3b	1A3b Gasoline/ LPG	CO_2	35667.29	35667.29	0.0205	0.8299
5C	5C Waste Incineration	CO_2	245.54	245.54	0.0192	0.8491
1B2	1B2 Natural Gas Transmission	CH_4	3456.67	3456.67	0.0181	0.8672
5B	5B Biological treatment of solid waste	N_2O	731.02	731.02	0.0179	0.8851
1A1 & 1A2 & 1A4 & 1A5	1A1 & 1A2 & 1A4 & 1A5 Other Combustion	CH_4	1576.84	1576.84	0.0146	0.8998
1A3a	1A3a Aviation Fuel	CO_2	1767.88	1767.88	0.0091	0.9089
1A3	1A3 Other diesel	CO_2	2465.45	2465.45	0.0088	0.9177
3B	3B Manure Management	CH_4	3994.92	3994.92	0.0086	0.9263
1B2	1B2 Oil & Natural Gas	CO_2	4200.23	4200.23	0.0073	0.9336
2D	2D Non Energy Products from Fuels and Solvent Use	CO_2	482.19	482.19	0.0072	0.9408
3G	3G Liming	CO_2	1313.00	1313.00	0.0071	0.9479
3B	3B Manure Management	N_2O	2727.68	2727.68	0.0067	0.9546
1B2	1B2 Offshore Oil& Gas	CH_4	1115.08	1115.08	0.0054	0.9600
1A4	1A4 Petroleum Coke	CO_2	673.20	673.20	0.0043	0.9643
3H	3H Urea application to agriculture	CO_2	318.54	318.54	0.0041	0.9685
2A	2A Mineral Industries	CO_2	6320.30	6320.30	0.0039	0.9724
3J	3J OT & CD Agriculture	CH_4	200.03	200.03	0.0037	0.9760
2C	2C Metal Industries	CO_2	2246.60	2246.60	0.0029	0.9789
2G	2G Other Product Manufacture and Use	PFCs	217.71	217.71	0.0027	0.9816
1B1	1B1 Coal Mining	CH_4	480.64	480.64	0.0025	0.9841
1A3d	1A3d Marine fuel	N_2O	73.51	73.51	0.0022	0.9863
3J	3J OT & CD Agriculture	N_2O	115.65	115.65	0.0021	0.9884
1A3b	1A3b Gasoline/ LPG	N_2O	99.48	99.48	0.0019	0.9903
5C	5C Waste Incineration	N_2O	31.21	31.21	0.0019	0.9922
1A3b	1A3b Gasoline/ LPG	CH_4	89.51	89.51	0.0017	0.9939
1B2	1B2 Oil & Natural Gas	N_2O	37.55	37.55	0.0010	0.9949
1A3	1A3 Other diesel	N_2O	25.99	25.99	0.0009	0.9958

IPCC Code	IPCC Category	Gas	Latest reported year (LY) emissions (Gg CO_2e)	Absolute value of LY emissions (Gg CO_2e)	Level Assessment	Cumulative Total
2G	2G Other Product Manufacture and Use	SF_6	447.52	447.52	0.0007	0.9965
1A3a	1A3a Aviation Fuel	N_2O	16.73	16.73	0.0005	0.9970
2B	2B Chemical Industry	CH_4	68.35	68.35	0.0004	0.9973
2E	2E Electronics Industry	HFCs	25.63	25.63	0.0003	0.9976
2B	2B Chemical industry	PFCs	120.73	120.73	0.0003	0.9980
2C	2C Metal Industries	SF_6	141.87	141.87	0.0003	0.9982
1A3d	1A3d Marine fuel	CH_4	7.22	7.22	0.0002	0.9985
1B1	1B1 Solid Fuel Transformation	CO_2	137.23	137.23	0.0002	0.9987
1A3c	1A3c Coal	CO_2	41.15	41.15	0.0002	0.9989
1A3b	1A3b DERV	CH_4	6.25	6.25	0.0002	0.9991
2C	2C Iron & Steel	N_2O	6.13	6.13	0.0002	0.9993
2A	2A Mineral Industries	CH_4	5.34	5.34	0.0001	0.9994
2C	2C Iron & Steel Production	CH_4	10.15	10.15	0.0001	0.9996
2B	2B Chemical industries	N_2O	39.92	39.92	0.0001	0.9997
5C	5C Waste Incineration	CH_4	8.09	8.09	0.0001	0.9998
1B1	1B1 Solid Fuel Transformation	CH_4	3.79	3.79	0.0000	0.9998
1A4	1A4 Peat	CO_2	4.83	4.83	0.0000	0.9999
1A3	1A3 Other diesel	CH_4	1.10	1.10	0.0000	0.9999
2C	2C Metal Industries	PFCs	6.25	6.25	0.0000	0.9999
1A3c	1A3c Coal	CH_4	0.94	0.94	0.0000	1.0000
1A3a	1A3a Aviation Fuel	CH_4	1.34	1.34	0.0000	1.0000
2E	2E Electronics Industry	NF_3	0.64	0.64	0.0000	1.0000
2C	2C Metal Industries	HFCs	2.29	2.29	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
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
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
2B	2B Chemical industry	HFCs	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
Total			**453,101.46**	**453,101.46**	**1**	

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

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	LY emissions (Gg CO_2e)	Trend Assessment with Uncertainty	% Contribution to Trend Uncertainty	Cumulative Total
5A	5A Solid Waste Disposal	CH_4	60389.54	14346.67	0.0112	22.7%	0.2271
1A	1A Coal	CO_2	243366.96	21276.47	0.0059	12.0%	0.3476
1B1	1B1 Coal Mining	CH_4	21826.68	480.64	0.0028	5.7%	0.4043
1A	1A Natural Gas	CO_2	106973.32	158173.87	0.0023	4.6%	0.4506
5C	5C Waste Incineration	CO_2	1284.85	245.54	0.0017	3.5%	0.4851
2F	2F Product Uses as Substitutes for ODS	HFCs	888.99	12581.47	0.0017	3.4%	0.5188
2B	2B Chemical industries	N_2O	23797.38	39.92	0.0016	3.3%	0.5514
5B	5B Biological treatment of solid waste	CH_4	18.13	1233.54	0.0015	3.0%	0.5818
1A3b	1A3b DERV	CO_2	33005.73	73923.29	0.0015	3.0%	0.6114
1A3b	1A3b DERV	N_2O	322.80	1031.76	0.0013	2.6%	0.6378
3A	3A Enteric Fermentation	CH_4	24536.54	21213.52	0.0012	2.4%	0.6621
2B	2B Chemical industry	HFCs	17670.77	0.00	0.0012	2.4%	0.6859
4B	4B Cropland	CO_2	20309.04	15175.26	0.0011	2.2%	0.7083
5D	5D Wastewater Handling	N_2O	943.47	1020.10	0.0011	2.2%	0.7299
4C	4C Grassland	CO_2	-482.28	-3675.33	0.0011	2.1%	0.7513
1A	1A Other (waste)	CO_2	245.26	6529.98	0.0010	2.1%	0.7727
2G	2G Other Product Manufacture and Use	N_2O	595.91	854.54	0.0009	1.8%	0.7902
4A	4A Forest Land	CO_2	-14364.93	-17173.23	0.0008	1.7%	0.8074
5B	5B Biological treatment of solid waste	N_2O	12.97	731.02	0.0008	1.6%	0.8238
1A	1A (Stationary) Oil	CO_2	95445.13	43852.33	0.0008	1.5%	0.8390
4E	4E Settlements	CO_2	6426.69	5550.20	0.0006	1.2%	0.8506
3D	3D Agricultural Soils	N_2O	14258.81	12250.42	0.0006	1.1%	0.8619
1B2	1B2 Natural Gas Transmission	CH_4	10168.33	3456.67	0.0005	1.1%	0.8728
4C	4C Grassland	CH_4	2386.69	2420.49	0.0005	1.0%	0.8831
1A3b	1A3b Gasoline/ LPG	CH_4	1157.88	89.51	0.0005	1.0%	0.8932
1A3b	1A3b Gasoline/ LPG	N_2O	989.26	99.48	0.0004	0.8%	0.9014
4D	4D Wetland	CH_4	1960.85	2052.65	0.0004	0.8%	0.9093
4D	4D Wetland	CO_2	571.96	1408.08	0.0003	0.6%	0.9158
4A	4A Forest land	N_2O	747.95	725.21	0.0003	0.6%	0.9216

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	LY emissions (Gg CO_2e)	Trend Assessment with Uncertainty	% Contribution to Trend Uncertainty	Cumulative Total
1A3d	1A3d Marine fuel	CO_2	7611.13	5579.13	0.0003	0.6%	0.9272
5D	5D Wastewater Handling	CH_4	2171.62	1679.50	0.0003	0.5%	0.9326
1A3	1A3 Other diesel	CO_2	1696.57	2465.45	0.0002	0.5%	0.9376
4E	4E Settlements	N_2O	526.45	434.17	0.0002	0.4%	0.9419
1A1 & 1A2 & 1A4 & 1A5	1A1 & 1A2 & 1A4 & 1A5 Other Combustion	CH_4	1916.44	1576.84	0.0002	0.4%	0.9462
3G	3G Liming	CO_2	1016.78	1313.00	0.0002	0.4%	0.9499
1A3b	1A3b Gasoline/ LPG	CO_2	75561.88	35667.29	0.0002	0.4%	0.9535
1A4	1A4 Petroleum Coke	CO_2	114.30	673.20	0.0002	0.4%	0.9572
1A3a	1A3a Aviation Fuel	CO_2	1875.74	1767.88	0.0002	0.3%	0.9606
3B	3B Manure Management	CH_4	4262.01	3994.92	0.0002	0.3%	0.9638
4G	4G Other Activities	CO_2	-2095.04	-2222.56	0.0001	0.3%	0.9666
2B	2B Chemical industries	CO_2	6975.59	4511.46	0.0001	0.3%	0.9691
4B	4B Cropland	CH_4	291.97	280.84	0.0001	0.3%	0.9716
2D	2D Non Energy Products from Fuels and Solvent Use	CO_2	552.81	482.19	0.0001	0.2%	0.9740
2C	2C Metal Industries	CO_2	7370.55	2246.60	0.0001	0.2%	0.9763
3B	3B Manure Management	N_2O	3216.05	2727.68	0.0001	0.2%	0.9783
3H	3H Urea application to agriculture	CO_2	327.65	318.54	0.0001	0.2%	0.9800
1A4	1A4 Peat	CO_2	372.48	4.83	0.0001	0.2%	0.9815
1B2	1B2 Oil & Natural Gas	CO_2	5777.92	4200.23	0.0001	0.2%	0.9830
2G	2G Other Product Manufacture and Use	PFCs	148.99	217.71	0.0001	0.2%	0.9845
1A3b	1A3b DERV	CH_4	88.73	6.25	0.0001	0.1%	0.9859
4B	4B Cropland	N_2O	1102.86	480.38	0.0001	0.1%	0.9872
1B1	1B1 Solid Fuel Transformation	CO_2	1698.56	137.23	0.0001	0.1%	0.9885
4A	4A Forest Land	CH_4	88.16	120.61	0.0001	0.1%	0.9897
2C	2C Metal Industries	PFCs	333.43	6.25	0.0000	0.1%	0.9906
5C	5C Waste Incineration	CH_4	135.58	8.09	0.0000	0.1%	0.9914
4C	4C Grassland	N_2O	188.68	182.25	0.0000	0.1%	0.9922
3J	3J OT & CD Agriculture	CH_4	270.85	200.03	0.0000	0.1%	0.9930
1A1 & 1A2 & 1A4 & 1A5	1A1 & 1A2 & 1A4 & 1A5 Other Combustion	N_2O	2170.54	1266.10	0.0000	0.1%	0.9937

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	LY emissions (Gg CO_2e)	Trend Assessment with Uncertainty	% Contribution to Trend Uncertainty	Cumulative Total
3F	3F Field Burning	CH_4	187.03	0.00	0.0000	0.1%	0.9943
1B2	1B2 Offshore Oil& Gas	CH_4	2224.01	1115.08	0.0000	0.1%	0.9950
2A	2A Mineral Industries	CO_2	9778.37	6320.30	0.0000	0.0%	0.9954
1A3	1A3 Other diesel	N_2O	19.42	25.99	0.0000	0.0%	0.9959
1A3d	1A3d Marine fuel	N_2O	105.00	73.51	0.0000	0.0%	0.9963
4D	4D Wetland	N_2O	21.29	36.19	0.0000	0.0%	0.9967
1B2	1B2 Oil & Natural Gas	N_2O	40.75	37.55	0.0000	0.0%	0.9970
2A	2A Mineral Industries	CH_4	31.11	5.34	0.0000	0.0%	0.9973
2B	2B Chemical Industry	CH_4	221.63	68.35	0.0000	0.0%	0.9976
3J	3J OT & CD Agriculture	N_2O	177.90	115.65	0.0000	0.0%	0.9979
2E	2E Electronics Industry	HFCs	8.73	25.63	0.0000	0.0%	0.9981
1A3c	1A3c Coal	CO_2	0.00	41.15	0.0000	0.0%	0.9983
3F	3F Field Burning	N_2O	57.80	0.00	0.0000	0.0%	0.9985
1A3a	1A3a Aviation Fuel	N_2O	17.75	16.73	0.0000	0.0%	0.9987
1A3d	1A3d Marine fuel	CH_4	3.66	7.22	0.0000	0.0%	0.9988
4	4 Indirect LULUCF Emissions	N_2O	403.85	223.54	0.0000	0.0%	0.9990
5C	5C Waste Incineration	N_2O	50.93	31.21	0.0000	0.0%	0.9991
4E	4E Settlements	CH_4	16.42	23.62	0.0000	0.0%	0.9993
2B	2B Chemical industry	PFCs	113.90	120.73	0.0000	0.0%	0.9994
2C	2C Metal Industries	SF_6	387.17	141.87	0.0000	0.0%	0.9995
2C	2C Iron & Steel Production	CH_4	36.94	10.15	0.0000	0.0%	0.9997
2C	2C Iron & Steel	N_2O	18.02	6.13	0.0000	0.0%	0.9998
2G	2G Other Product Manufacture and Use	SF_6	926.62	447.52	0.0000	0.0%	0.9999
1B1	1B1 Solid Fuel Transformation	CH_4	0.18	3.79	0.0000	0.0%	0.9999
1A3a	1A3a Aviation Fuel	CH_4	6.66	1.34	0.0000	0.0%	0.9999
1A3c	1A3c Coal	CH_4	0.00	0.94	0.0000	0.0%	1.0000
1A3	1A3 Other diesel	CH_4	2.75	1.10	0.0000	0.0%	1.0000
2C	2C Metal Industries	HFCs	0.00	2.29	0.0000	0.0%	1.0000
1A3c	1A3c Coal	N_2O	0.00	0.09	0.0000	0.0%	1.0000
2E	2E Electronics Industry	NF_3	0.83	0.64	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
1B1	1B1 Fugitive Emissions from Solid Fuels	N_2O	0.09	0.02	0.0000	0.0%	1.0000

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	LY emissions (Gg CO_2e)	Trend Assessment with Uncertainty	% Contribution to Trend Uncertainty	Cumulative Total
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
Total			**816,083.21**	**459,143.82**		**1**	

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

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	LY emissions (Gg CO_2e)	Trend Assessment with Uncertainty	% Contribution to Trend Uncertainty	Cumulative Total
5A	5A Solid Waste Disposal	CH_4	60389.54	14346.67	0.0112	25.7%	0.2571
1A	1A Coal	CO_2	243366.96	21276.47	0.0059	13.6%	0.3935
1B1	1B1 Coal Mining	CH_4	21826.68	480.64	0.0028	6.4%	0.4577
1A	1A Natural Gas	CO_2	106973.32	158173.87	0.0023	5.2%	0.5102
5C	5C Waste Incineration	CO_2	1284.85	245.54	0.0017	3.9%	0.5493
2F	2F Product Uses as Substitutes for ODS	HFCs	888.99	12581.47	0.0017	3.8%	0.5873
2B	2B Chemical industries	N_2O	23797.38	39.92	0.0016	3.7%	0.6243
5B	5B Biological treatment of solid waste	CH_4	18.13	1233.54	0.0015	3.4%	0.6587
1A3b	1A3b DERV	CO_2	33005.73	73923.29	0.0015	3.4%	0.6922
1A3b	1A3b DERV	N_2O	322.80	1031.76	0.0013	3.0%	0.7221
3A	3A Enteric Fermentation	CH_4	24536.54	21213.52	0.0012	2.8%	0.7497
2B	2B Chemical industry	HFCs	17670.77	0.00	0.0012	2.7%	0.7766
5D	5D Wastewater Handling	N_2O	943.47	1020.10	0.0011	2.4%	0.8010
1A	1A Other (waste)	CO_2	245.26	6529.98	0.0010	2.4%	0.8252
2G	2G Other Product Manufacture and Use	N_2O	595.91	854.54	0.0009	2.0%	0.8451
5B	5B Biological treatment of solid waste	N_2O	12.97	731.02	0.0008	1.9%	0.8636
1A	1A (Stationary) Oil	CO_2	95445.13	43852.33	0.0008	1.7%	0.8809
3D	3D Agricultural Soils	N_2O	14258.81	12250.42	0.0006	1.3%	0.8937
1B2	1B2 Natural Gas Transmission	CH_4	10168.33	3456.67	0.0005	1.2%	0.9061
1A3b	1A3b Gasoline/ LPG	CH_4	1157.88	89.51	0.0005	1.1%	0.9175
1A3b	1A3b Gasoline/ LPG	N_2O	989.26	99.48	0.0004	0.9%	0.9267

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	LY emissions (Gg CO_2e)	Trend Assessment with Uncertainty	% Contribution to Trend Uncertainty	Cumulative Total
1A3d	1A3d Marine fuel	CO_2	7611.13	5579.13	0.0003	0.6%	0.9330
5D	5D Wastewater Handling	CH_4	2171.62	1679.50	0.0003	0.6%	0.9392
1A3	1A3 Other diesel	CO_2	1696.57	2465.45	0.0002	0.6%	0.9448
1A1 & 1A2 & 1A4 & 1A5	1A1 & 1A2 & 1A4 & 1A5 Other Combustion	CH_4	1916.44	1576.84	0.0002	0.5%	0.9497
3G	3G Liming	CO_2	1016.78	1313.00	0.0002	0.4%	0.9539
1A3b	1A3b Gasoline/ LPG	CO_2	75561.88	35667.29	0.0002	0.4%	0.9580
1A4	1A4 Petroleum Coke	CO_2	114.30	673.20	0.0002	0.4%	0.9621
1A3a	1A3a Aviation Fuel	CO_2	1875.74	1767.88	0.0002	0.4%	0.9660
3B	3B Manure Management	CH_4	4262.01	3994.92	0.0002	0.4%	0.9696
2B	2B Chemical industries	CO_2	6975.59	4511.46	0.0001	0.3%	0.9724
2D	2D Non Energy Products from Fuels and Solvent Use	CO_2	552.81	482.19	0.0001	0.3%	0.9751
2C	2C Metal Industries	CO_2	7370.55	2246.60	0.0001	0.3%	0.9777
3B	3B Manure Management	N_2O	3216.05	2727.68	0.0001	0.2%	0.9800
3H	3H Urea application to agriculture	CO_2	327.65	318.54	0.0001	0.2%	0.9818
1A4	1A4 Peat	CO_2	372.48	4.83	0.0001	0.2%	0.9836
1B2	1B2 Oil & Natural Gas	CO_2	5777.92	4200.23	0.0001	0.2%	0.9853
2G	2G Other Product Manufacture and Use	PFCs	148.99	217.71	0.0001	0.2%	0.9870
1A3b	1A3b DERV	CH_4	88.73	6.25	0.0001	0.2%	0.9886
1B1	1B1 Solid Fuel Transformation	CO_2	1698.56	137.23	0.0001	0.1%	0.9900
2C	2C Metal Industries	PFCs	333.43	6.25	0.0000	0.1%	0.9910
5C	5C Waste Incineration	CH_4	135.58	8.09	0.0000	0.1%	0.9919
3J	3J OT & CD Agriculture	CH_4	270.85	200.03	0.0000	0.1%	0.9928
1A1 & 1A2 & 1A4 & 1A5	1A1 & 1A2 & 1A4 & 1A5 Other Combustion	N_2O	2170.54	1266.10	0.0000	0.1%	0.9936
3F	3F Field Burning	CH_4	187.03	0.00	0.0000	0.1%	0.9943
1B2	1B2 Offshore Oil& Gas	CH_4	2224.01	1115.08	0.0000	0.1%	0.9950
2A	2A Mineral Industries	CO_2	9778.37	6320.30	0.0000	0.1%	0.9956
1A3	1A3 Other diesel	N_2O	19.42	25.99	0.0000	0.1%	0.9961
1A3d	1A3d Marine fuel	N_2O	105.00	73.51	0.0000	0.0%	0.9966
1B2	1B2 Oil & Natural Gas	N_2O	40.75	37.55	0.0000	0.0%	0.9970

IPCC Code	IPCC Category	Gas	Base year emissions (Gg CO_2e)	LY emissions (Gg CO_2e)	Trend Assessment with Uncertainty	% Contribution to Trend Uncertainty	Cumulative Total
2A	2A Mineral Industries	CH_4	31.11	5.34	0.0000	0.0%	0.9973
2B	2B Chemical Industry	CH_4	221.63	68.35	0.0000	0.0%	0.9976
3J	3J OT & CD Agriculture	N_2O	177.90	115.65	0.0000	0.0%	0.9979
2E	2E Electronics Industry	HFCs	8.73	25.63	0.0000	0.0%	0.9982
1A3c	1A3c Coal	CO_2	0.00	41.15	0.0000	0.0%	0.9984
3F	3F Field Burning	N_2O	57.80	0.00	0.0000	0.0%	0.9986
1A3a	1A3a Aviation Fuel	N_2O	17.75	16.73	0.0000	0.0%	0.9988
1A3d	1A3d Marine fuel	CH_4	3.66	7.22	0.0000	0.0%	0.9990
5C	5C Waste Incineration	N_2O	50.93	31.21	0.0000	0.0%	0.9992
2B	2B Chemical industry	PFCs	113.90	120.73	0.0000	0.0%	0.9993
2C	2C Metal Industries	SF_6	387.17	141.87	0.0000	0.0%	0.9995
2C	2C Iron & Steel Production	CH_4	36.94	10.15	0.0000	0.0%	0.9996
2C	2C Iron & Steel	N_2O	18.02	6.13	0.0000	0.0%	0.9997
2G	2G Other Product Manufacture and Use	SF_6	926.62	447.52	0.0000	0.0%	0.9999
1B1	1B1 Solid Fuel Transformation	CH_4	0.18	3.79	0.0000	0.0%	0.9999
1A3a	1A3a Aviation Fuel	CH_4	6.66	1.34	0.0000	0.0%	0.9999
1A3c	1A3c Coal	CH_4	0.00	0.94	0.0000	0.0%	1.0000
1A3	1A3 Other diesel	CH_4	2.75	1.10	0.0000	0.0%	1.0000
2C	2C Metal Industries	HFCs	0.00	2.29	0.0000	0.0%	1.0000
1A3c	1A3c Coal	N_2O	0.00	0.09	0.0000	0.0%	1.0000
2E	2E Electronics Industry	NF_3	0.83	0.64	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
1B1	1B1 Fugitive Emissions from Solid Fuels	N_2O	0.09	0.02	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
Total			**797,982.60**	**453,101.46**		**1**	

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 (KCs only) - UNFCCC	KCA rank (KCs only) – KP	IPCC Code	IPCC Category	Greenhouse Gas
1	1	1A3b	Road transportation: liquid fuels	CO_2
2	2	1A4	Other sectors: gaseous fuels	CO_2
3	4	1A1	Energy industries: solid fuels	CO_2
4	3	5A	Solid waste disposal	CH_4
5	5	1A1	Energy industries: gaseous fuels	CO_2
6	6	1A2	Manufacturing industries and construction: gaseous fuels	CO_2
7	7	1A1	Energy industries: liquid fuels	CO_2
8	8	1A2	Manufacturing industries and construction: solid fuels	CO_2
9	9	4B	Cropland	CO_2
10	10	3A1	Enteric fermentation from Cattle	CH_4
11	11	1A2	Manufacturing industries and construction: liquid fuels	CO_2
12	12	4A	Forest land	CO_2
13	13	1A4	Other sectors: liquid fuels	CO_2
14	14	3D	Agricultural soils	N_2O
15	15	1A4	Other sectors: solid fuels	CO_2
16	16	1B2	Oil and gas extraction	CH_4
17	17	1A3d	Domestic Navigation: liquid fuels	CO_2
18	18	4E	Settlements	CO_2
19	19	1B1	Coal mining and handling	CH_4
20	20	3A2	Enteric fermentation from Sheep	CH_4
21	21	3B1	Manure management from Cattle	CH_4
22	22	1B2	Oil and gas extraction	CO_2
23	23	1A5	Other: liquid fuels	CO_2
24	24	2C1	Iron and steel production	CO_2
25	25	4C	Grassland	CH_4

KCA rank (KCs only) - UNFCCC	KCA rank (KCs only) – KP	IPCC Code	IPCC Category	Greenhouse Gas
26	26	3B2	Manure management from Sheep	N_2O
27	27	2F1	Refrigeration and air conditioning	HFCs, PFCs, SF_6 and NF_3
28	28	2A1	Cement production	CO_2
29	29	4C	Grassland	CO_2
30	30	4D	Wetlands	CH_4
31	31	4G	Harvested wood products	CO_2
32	32	1A1	Energy industries: other fuels	CO_2
33	33	2B9	Fluorochemical production	HFCs, PFCs, SF_6 and NF_3
34	35	1A3a	Domestic aviation: liquid fuels	CO_2
35	34	1A3c	Railways: liquid fuels	CO_2
36	36	5D	Wastewater treatment and discharge	CH_4
37	37	4D	Wetlands	CO_2
38	38	2F4	Aerosols	HFCs, PFCs, SF_6 and NF_3
39	39	2B2	Nitric acid production	N_2O
40	40	2B3	Adipic acid production	N_2O
41	41	2B8	Petrochemical and carbon black production	CO_2
42	42	5B	Biological treatment of solid waste	CH_4

A 1.6 APPROACH USED TO IDENTIFY KP-LULUCF KEY CATEGORIES

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.

Seven 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), Article 3.4 Grazing Land Management (CO_2), Article 3.4 Grazing Land Management (CH_4) and Article 3.4 Wetland Drainage and Rewetting (CH_4). These have been assessed according to the IPCC 2013 Kyoto Protocol Supplement Section 2.3.6. The numbers have been compared with key category analysis Approach 1 for the latest reported year based on level of emissions (including LULUCF). 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 1.8.1 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 1.8.1 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	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 Key Category Identification(2)	COMMENTS (3)
Specify key categories according to the national level of disaggregation used (1)					
Afforestation and Reforestation	CO_2	Land converted to forest land	Yes	Associated UNFCCC category (4A) is key	The associated UNFCCC inventory category is a key category for level and trend. The AR component is larger than the smallest UNFCCC key category.
Deforestation	CO_2	Land converted to cropland, Land converted to grassland, Land converted to settlements	No	Associated UNFCCC categories (4B, 4C and 4E) are key.	The associated UNFCCC inventory categories are key categories for level and trend. The Deforestation category contribution is also key for the latest inventory year.
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 trend and the Forest Management category contribution is greater than the smallest UNFCCC key category.

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

KEY CATEGORIES OF EMISSIONS AND REMOVALS	GAS	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 Key Category Identification(2)	COMMENTS (3)
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	No	Associated UNFCCC category (4C) is key.	The associated UNFCCC inventory category is a key category for level and trend.
Grazing Land Management	CH_4	Grassland remaining Grassland, Land converted to Grassland	No	Associated UNFCCC category (4C) is key.	The associated UNFCCC inventory category is a key category for level and trend.
Wetland Drainage and Rewetting	CH_4	Wetland remaining Wetland	No	Associated UNFCCC category (4D) is key	The associated UNFCCC inventory category is a key category for level.

(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[4]

IPCC Category	Gas	Base year emissions (Gg CO_2e)	2019 emissions (Gg CO_2e)	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty (%)	Contribution to variance by Category in 2019	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	95,445.13	43,852.33	5.99%	2.47%	6.5%	0.0000	1.205%	5.374%	0.0298%	0.4549%	0.0021%
1A Coal	CO_2	243,366.96	21,276.47	1.13%	4.21%	4.4%	0.0000	14.129%	2.607%	0.5948%	0.0415%	0.0036%
1A Natural Gas	CO_2	106,973.32	158,173.87	1.04%	1.68%	2.0%	0.0000	11.991%	19.382%	0.2016%	0.2853%	0.0012%
1A Other (waste)	CO_2	245.26	6,529.98	1.04%	13.92%	14.0%	0.0000	0.783%	0.800%	0.1090%	0.0118%	0.0001%
1A3 Other diesel	CO_2	1,696.57	2,465.45	13.66%	1.87%	13.8%	0.0000	0.185%	0.302%	0.0035%	0.0584%	0.0000%
1A3a Aviation Fuel	CO_2	1,875.74	1,767.88	19.71%	3.25%	20.0%	0.0000	0.087%	0.217%	0.0028%	0.0604%	0.0000%
1A3b DERV	CO_2	33,005.73	73,923.29	1.00%	2.00%	2.2%	0.0000	6.780%	9.058%	0.1356%	0.1281%	0.0003%
1A3b Gasoline/ LPG	CO_2	75,561.88	35,667.29	1.00%	1.99%	2.2%	0.0000	0.838%	4.371%	0.0167%	0.0615%	0.0000%
1A3c Coal	CO_2	-	41.15	20.00%	6.00%	20.9%	0.0000	0.005%	0.005%	0.0003%	0.0014%	0.0000%
1A3d Marine fuel	CO_2	7,611.13	5,579.13	17.95%	1.80%	18.0%	0.0000	0.159%	0.684%	0.0029%	0.1736%	0.0003%

[4] Data by source presented are for UNFCCC geographical coverage unless stated otherwise. Values for EU and KP geographical coverages are similar

IPCC Category	Gas	Base year emissions (Gg CO_2e)	2019 emissions (Gg CO_2e)	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty (%)	Contribution to variance by Category in 2019	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
1A4 Peat	CO_2	372.48	4.83	30.00%	10.00%	31.6%	0.0000	0.025%	0.001%	0.0025%	0.0003%	0.0000%
1A4 Petroleum Coke	CO_2	114.30	673.20	20.00%	15.00%	25.0%	0.0000	0.075%	0.082%	0.0112%	0.0233%	0.0000%
1B1 Solid Fuel Transformation	CO_2	1,698.56	137.23	4.64%	4.60%	6.5%	0.0000	0.100%	0.017%	0.0046%	0.0011%	0.0000%
1B2 Oil & Natural Gas	CO_2	5,777.92	4,200.23	4.28%	5.15%	6.7%	0.0000	0.116%	0.515%	0.0060%	0.0312%	0.0000%
2A Mineral Industries	CO_2	9,778.37	6,320.30	0.72%	2.30%	2.4%	0.0000	0.100%	0.774%	0.0023%	0.0079%	0.0000%
2B Chemical industries	CO_2	6,975.59	4,511.46	17.70%	3.00%	18.0%	0.0000	0.072%	0.553%	0.0022%	0.1384%	0.0002%
2C Metal Industries	CO_2	7,370.55	2,246.60	1.17%	4.81%	4.9%	0.0000	0.233%	0.275%	0.0112%	0.0045%	0.0000%
2D Non Energy Products from Fuels and Solvent Use	CO_2	552.81	482.19	41.10%	40.85%	57.9%	0.0000	0.021%	0.059%	0.0086%	0.0343%	0.0000%
3G Liming	CO_2	1,016.78	1,313.00	0.00%	20.90%	20.9%	0.0000	0.091%	0.161%	0.0190%	0.0000%	0.0000%
3H Urea application to agriculture	CO_2	327.65	318.54	0.00%	50.00%	50.0%	0.0000	0.016%	0.039%	0.0082%	0.0000%	0.0000%

IPCC Category	Gas	Base year emissions (Gg CO_2e)	2019 emissions (Gg CO_2e)	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty (%)	Contribution to variance by Category in 2019	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
4A Forest Land	CO_2	-14,364.93346	-17,173.23	5.00%	20.00%	20.6%	0.0001	1.114%	2.104%	0.2228%	0.1488%	0.0007%
4B Cropland	CO_2	20,309.04	15,175.26	1.00%	25.00%	25.0%	0.0001	0.459%	1.860%	0.1148%	0.0263%	0.0001%
4C Grassland	CO_2	-482.28	-3,675.33	1.00%	30.00%	30.0%	0.0000	0.417%	0.450%	0.1251%	0.0064%	0.0002%
4D Wetland	CO_2	571.96	1,408.08	1.00%	25.00%	25.0%	0.0000	0.133%	0.173%	0.0333%	0.0024%	0.0000%
4E Settlements	CO_2	6,426.69	5,550.20	1.00%	25.00%	25.0%	0.0000	0.237%	0.680%	0.0593%	0.0096%	0.0000%
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	-2,095.04	-2,222.56	1.00%	15.00%	15.0%	0.0000	0.128%	0.272%	0.0192%	0.0039%	0.0000%
5C Waste Incineration	CO_2	1,284.85	245.54	300.00%	40.00%	302.7%	0.0000	0.058%	0.030%	0.0234%	0.1277%	0.0002%
1A1 & 1A2 & 1A4 & 1A5 Other Combustion	CH_4	1,916.44	1,576.84	0.72%	35.90%	35.9%	0.0000	0.061%	0.193%	0.0219%	0.0020%	0.0000%
1A3 Other diesel	CH_4	2.75	1.10	15.00%	130.00%	130.9%	0.0000	0.000%	0.000%	0.0001%	0.0000%	0.0000%
1A3a Aviation Fuel	CH_4	6.66	1.34	14.49%	56.85%	58.7%	0.0000	0.000%	0.000%	0.0002%	0.0000%	0.0000%
1A3b DERV	CH_4	88.73	6.25	1.00%	130.00%	130.0%	0.0000	0.005%	0.001%	0.0070%	0.0000%	0.0000%
1A3b Gasoline/ LPG	CH_4	1,157.88	89.51	1.00%	74.95%	75.0%	0.0000	0.069%	0.011%	0.0516%	0.0002%	0.0000%

IPCC Category	Gas	Base year emissions (Gg CO_2e)	2019 emissions (Gg CO_2e)	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty (%)	Contribution to variance by Category in 2019	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
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	7.22	19.32%	125.58%	127.1%	0.0000	0.001%	0.001%	0.0008%	0.0002%	0.0000%
1B1 Coal Mining	CH_4	21,826.68	480.64	2.00%	20.00%	20.1%	0.0000	1.445%	0.059%	0.2891%	0.0017%	0.0008%
1B1 Solid Fuel Transformation	CH_4	0.18	3.79	0.00%	49.83%	49.8%	0.0000	0.000%	0.000%	0.0002%	0.0000%	0.0000%
1B2 Natural Gas Transmission	CH_4	10,168.33	3,456.67	3.00%	20.00%	20.2%	0.0000	0.277%	0.424%	0.0555%	0.0180%	0.0000%
1B2 Offshore Oil& Gas	CH_4	2,224.01	1,115.08	4.53%	18.14%	18.7%	0.0000	0.017%	0.137%	0.0030%	0.0088%	0.0000%
2A Mineral Industries	CH_4	31.11	5.34	0.00%	100.00%	100.0%	0.0000	0.001%	0.001%	0.0015%	0.0000%	0.0000%
2B Chemical Industry	CH_4	221.63	68.35	0.00%	20.00%	20.0%	0.0000	0.007%	0.008%	0.0014%	0.0000%	0.0000%
2C Iron & Steel Production	CH_4	36.94	10.15	1.91%	47.72%	47.8%	0.0000	0.001%	0.001%	0.0006%	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)	2019 emissions (Gg CO_2e)	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty (%)	Contribution to variance by Category in 2019	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	24,536.54	21,213.52	13.73%	0.00%	13.7%	0.0000	0.908%	2.599%	0.0000%	0.5049%	0.0025%
3B Manure Management	CH_4	4,262.01	3,994.92	0.00%	8.37%	8.4%	0.0000	0.196%	0.490%	0.0164%	0.0000%	0.0000%
3F Field Burning	CH_4	187.03	-	25.61%	0.00%	25.6%	-	0.013%	0.000%	0.0000%	0.0000%	0.0000%
3J OT & CD Agriculture	CH_4	270.85	200.03	50.00%	50.00%	70.7%	0.0000	0.006%	0.025%	0.0029%	0.0173%	0.0000%
4A Forest Land	CH_4	88.16	120.61	5.00%	70.00%	70.2%	0.0000	0.009%	0.015%	0.0061%	0.0010%	0.0000%
4B Cropland	CH_4	291.97	280.84	1.00%	90.00%	90.0%	0.0000	0.014%	0.034%	0.0129%	0.0005%	0.0000%
4C Grassland	CH_4	2,386.69	2,420.49	1.00%	40.00%	40.0%	0.0000	0.132%	0.297%	0.0528%	0.0042%	0.0000%
4D Wetland	CH_4	1,960.85	2,052.65	1.00%	35.00%	35.0%	0.0000	0.116%	0.252%	0.0407%	0.0036%	0.0000%
4E Settlements	CH_4	16.42	23.62	1.00%	40.00%	40.0%	0.0000	0.002%	0.003%	0.0007%	0.0000%	0.0000%
5A Solid Waste Disposal	CH_4	60,389.54	14,346.67	15.00%	46.00%	48.4%	0.0002	2.404%	1.758%	1.1056%	0.3729%	0.0136%
5B Biological treatment of solid waste	CH_4	18.13	1,233.54	30.00%	99.50%	103.9%	0.0000	0.150%	0.151%	0.1492%	0.0641%	0.0003%
5C Waste Incineration	CH_4	135.58	8.09	5.00%	50.00%	50.2%	0.0000	0.008%	0.001%	0.0042%	0.0001%	0.0000%

IPCC Category	Gas	Base year emissions (Gg CO_2e)	2019 emissions (Gg CO_2e)	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty (%)	Contribution to variance by Category in 2019	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
5D Wastewater Handling	CH_4	2,171.62	1,679.50	14.62%	47.31%	49.5%	0.0000	0.056%	0.206%	0.0265%	0.0425%	0.0000%
1A1 & 1A2 & 1A4 & 1A5 Other Combustion	N_2O	2,170.54	1,266.10	0.65%	64.63%	64.6%	0.0000	0.006%	0.155%	0.0036%	0.0014%	0.0000%
1A3 Other diesel	N_2O	19.42	25.99	15.00%	130.00%	130.9%	0.0000	0.002%	0.003%	0.0024%	0.0007%	0.0000%
1A3a Aviation Fuel	N_2O	17.75	16.73	19.71%	108.42%	110.2%	0.0000	0.001%	0.002%	0.0009%	0.0006%	0.0000%
1A3b DERV	N_2O	322.80	1,031.76	1.00%	130.00%	130.0%	0.0000	0.104%	0.126%	0.1354%	0.0018%	0.0002%
1A3b Gasoline/ LPG	N_2O	989.26	99.48	1.00%	74.61%	74.6%	0.0000	0.056%	0.012%	0.0418%	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	105.00	73.51	17.81%	115.75%	117.1%	0.0000	0.002%	0.009%	0.0020%	0.0023%	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	37.55	4.78%	105.21%	105.3%	0.0000	0.002%	0.005%	0.0019%	0.0003%	0.0000%
2B Chemical industries	N_2O	23,797.38	39.92	0.36%	10.22%	10.2%	0.0000	1.635%	0.005%	0.1672%	0.0000%	0.0003%

IPCC Category	Gas	Base year emissions (Gg CO_2e)	2019 emissions (Gg CO_2e)	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty (%)	Contribution to variance by Category in 2019	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 Iron & Steel	N_2O	18.02	6.13	1.00%	118.00%	118.0%	0.0000	0.000%	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	595.91	854.54	100.00%	100.00%	141.4%	0.0000	0.064%	0.105%	0.0636%	0.1481%	0.0003%
3B Manure Management	N_2O	3,216.05	2,727.68	0.00%	9.53%	9.5%	0.0000	0.113%	0.334%	0.0107%	0.0000%	0.0000%
3D Agricultural Soils	N_2O	14,258.81	12,250.42	0.00%	11.16%	11.2%	0.0000	0.518%	1.501%	0.0578%	0.0000%	0.0000%
3F Field Burning	N_2O	57.80	-	25.62%	0.00%	25.6%	-	0.004%	0.000%	0.0000%	0.0000%	0.0000%
3J OT & CD Agriculture	N_2O	177.90	115.65	50.00%	50.00%	70.7%	0.0000	0.002%	0.014%	0.0010%	0.0100%	0.0000%
4 Indirect LULUCF Emissions	N_2O	403.85	223.54	1.00%	165.00%	165.0%	0.0000	0.000%	0.027%	0.0007%	0.0004%	0.0000%
4A Forest land	N_2O	747.95	725.21	1.00%	80.00%	80.0%	0.0000	0.037%	0.089%	0.0298%	0.0013%	0.0000%
4B Cropland	N_2O	1,102.86	480.38	1.00%	40.00%	40.0%	0.0000	0.017%	0.059%	0.0069%	0.0008%	0.0000%
4C Grassland	N_2O	188.68	182.25	1.00%	45.00%	45.0%	0.0000	0.009%	0.022%	0.0042%	0.0003%	0.0000%

IPCC Category	Gas	Base year emissions (Gg CO_2e)	2019 emissions (Gg CO_2e)	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty (%)	Contribution to variance by Category in 2019	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
4D Wetland	N_2O	21.29	36.19	1.00%	65.00%	65.0%	0.0000	0.003%	0.004%	0.0019%	0.0001%	0.0000%
4E Settlements	N_2O	526.45	434.17	1.00%	130.00%	130.0%	0.0000	0.017%	0.053%	0.0220%	0.0008%	0.0000%
5B Biological treatment of solid waste	N_2O	12.97	731.02	30.00%	90.00%	94.9%	0.0000	0.089%	0.090%	0.0798%	0.0380%	0.0001%
5C Waste Incineration	N_2O	50.93	31.21	7.00%	230.00%	230.1%	0.0000	0.000%	0.004%	0.0007%	0.0004%	0.0000%
5D Wastewater Handling	N_2O	943.47	1,020.10	9.95%	184.32%	184.6%	0.0000	0.060%	0.125%	0.1105%	0.0176%	0.0001%
2C Metal Industries	SF_6	387.17	141.87	5.00%	5.00%	7.1%	0.0000	0.009%	0.017%	0.0005%	0.0012%	0.0000%
2G Other Product Manufacture and Use	SF_6	926.62	447.52	0.00%	5.96%	6.0%	0.0000	0.009%	0.055%	0.0005%	0.0000%	0.0000%
2B Chemical industry	HFCs	17,670.77	-	0.00%	10.00%	10.0%	-	1.218%	0.000%	0.1218%	0.0000%	0.0001%
2C Metal Industries	HFCs	-	2.29	5.00%	10.00%	11.2%	0.0000	0.000%	0.000%	0.0000%	0.0000%	0.0000%
2E Electronics Industry	HFCs	8.73	25.63	0.00%	47.15%	47.1%	0.0000	0.003%	0.003%	0.0012%	0.0000%	0.0000%
2F Product Uses as Substitutes for ODS	HFCs	888.99	12,581.47	8.19%	8.27%	11.6%	0.0000	1.480%	1.542%	0.1224%	0.1786%	0.0005%

IPCC Category	Gas	Base year emissions (Gg CO_2e)	2019 emissions (Gg CO_2e)	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty (%)	Contribution to variance by Category in 2019	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
2E Electronics Industry	NF_3	0.83	0.64	0.00%	47.15%	47.1%	0.0000	0.000%	0.000%	0.0000%	0.0000%	0.0000%
2B Chemical industry	PFCs	113.90	120.73	0.00%	10.00%	10.0%	0.0000	0.007%	0.015%	0.0007%	0.0000%	0.0000%
2C Metal Industries	PFCs	333.43	6.25	0.00%	20.00%	20.0%	0.0000	0.022%	0.001%	0.0044%	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	148.99	217.71	0.00%	47.15%	47.1%	0.0000	0.016%	0.027%	0.0077%	0.0000%	0.0000%

Percentage uncertainty in UNFCCC inventory:	**2.5%**
Percentage uncertainty in KP inventory:	**2.5%**

UNFCCC trend uncertainty	**1.7%**
KP trend uncertainty	**1.7%**

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

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 are 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 uncertainty 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 2.2.3.1 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.

A 2.2.3.2 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.**

A 2.2.3.3 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 a 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.

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;
- (n) represents a new uncertainty parameter, either because sources are considered at a more granular level, or because a new source is included in the inventory; 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 Activity uncertainty (%)	1990 Emission factor uncertainty (%)	2019 Activity uncertainty (%)	2019 Emission factor uncertainty (%)	Justification for key sources
1A	Lubricants	50.00%	5.00%	50.00%	5.00%	It's challenging to determine the proportion of lubricant used as a fuel, hence a high activity uncertainty.
1A1	Blast Furnace Gas	1.50%	10.00%	1.00%	10.00%	Overall uncertainty for all coke & steelmaking emissions is quite low but allocation to individual sources is definitely higher - we've assumed 10%
1A1	Coke Oven Coke	1.00%	10.00%	1.00%	10.00%	Overall uncertainty for all coke & steelmaking emissions is quite low but allocation to individual sources is definitely higher - we've assumed 10%
1A1	Coke Oven Gas	1.50%	10.00%	1.00%	10.00%	Overall uncertainty for all coke & steelmaking emissions is quite low but allocation to individual sources is definitely higher - we've assumed 10%
1A1	Colliery Methane	5.00%	5.00%	5.00%	5.00%	(Minor fuel in sector context)
1A1	Gas/Diesel Oil	1.80%	2.10%	1.75%	2.10%	ETS-based data, so low uncertainty.
1A1	Liquefied Petroleum Gas	25.70%	2.10%	2.50%	2.10%	The DUKES data from 2009 onwards were revised considerably in the energy / NEU split for LPG, and we have created a new split for earlier years. Chosen 2.1% EF uncertainty to be consistent with gas oil - the makeup of LPG is well understood and documented
1A1	Motor Gasoline	2.50%	2.10%	2.50%	2.10%	Outside of 1A3, the motor gasoline allocations are probably much more uncertain as they are reliant on the off-road model etc., so chosen 2.5%.

Category	Fuel	1990 Activity uncertainty (%)	1990 Emission factor uncertainty (%)	2019 Activity uncertainty (%)	2019 Emission factor uncertainty (%)	Justification for key sources
1A1	Municipal Solid Waste	1.00%	15.00%	1.00%	15.00%	MSW quantity is known accurately. Uncertainty is in mass of fossil carbon per tonne of residual MSW. This is based on reasonable waste composition data from peer reviewed sources, adapted from landfill data.
1A1	Naphtha	50.00%	5.00%	50.00%	5.00%	DUKES are uncertain about where naphtha is used (or not), so a high activity uncertainty has been chosen. EF uncertainty chosen as 5%. The content of naphtha is quite variable - it contains a huge range of hydrocarbons from C5 up to C70+, so the exact carbon content is variable and there are about 5 different grades of naphtha according to UKPIA.
1A1	Natural Gas	2.80%	2.00%	1.00%	2.00%	ETS-based data, so low uncertainties.
1A1	Orimulsion	5.00%	5.00%	5.00%	5.00%	(Minor fuel in sector context)
1A1	Other Bituminous Coal	2.00%	2.00%	2.00%	2.00%	ETS-based data, so low uncertainties.
1A1	Other Kerosene	1.25%	5.00%	1.25%	5.00%	ETS-based data, so low uncertainties.
1A1	Other Oil: Other	11.90%	5.00%	10.00%	5.00%	(Minor fuel in sector context)
1A1	Petroleum Coke	7.80%	10.00%	5.00%	10.00%	ETS-based data, so low uncertainties. 10% chosen for EF uncertainty as there is only a small dataset for the quality of petcoke used in the sector and the CEF could be quite variable depending on the source of the pet coke.
1A1	Refinery Gas	50.00%	20.00%	25.00%	15.00%	Comparisons between EU ETS and DUKES are variable over time. Risk that in earlier years the “own use” may have been mis-reported to energy stats. High uncertainty on AD. Also a variable quality fuel, so the EF is also uncertain.
1A1	Residual Fuel Oil	5.50%	2.55%	1.25%	2.55%	ETS-based data, so low uncertainties.

Category	Fuel	1990 Activity uncertainty (%)	1990 Emission factor uncertainty (%)	2019 Activity uncertainty (%)	2019 Emission factor uncertainty (%)	Justification for key sources
1A1	Scrap Tyres	15.00%	10.00%	15.00%	10.00%	Limited reported use of this fuel; only a small amount of reporting (typically cement kilns) within EU ETS and a modest number of fuel quality analyses either through the BCA/MPA (trade body) or the EU ETS. Also some variability in the fossil C versus bio-C content of the tyres adds to EF uncertainty.
1A2	Blast Furnace Gas	1.50%	10.00%	1.00%	10.00%	Overall uncertainty for all coke & steelmaking emissions is quite low but allocation to individual sources is definitely higher - we've assumed 10%
1A2	Coke Oven Coke	3.00%	10.00%	1.00%	10.00%	Overall uncertainty for all coke & steelmaking emissions is quite low but allocation to individual sources is definitely higher - we've assumed 10%
1A2	Coke Oven Gas	3.00%	10.00%	1.00%	10.00%	Overall uncertainty for all coke & steelmaking emissions is quite low but allocation to individual sources is definitely higher - we've assumed 10%
1A2	Colliery Methane	5.00%	5.00%	5.00%	5.00%	(Minor fuel in sector context)
1A2	Gas/Diesel Oil	20.00%	2.00%	20.00%	2.00%	Low EF uncertainty as the composition of gas oil is well understood across the time series. The AD for stationary combustion in industrial sectors is quite uncertain, however. DUKES does not distinguish between mobile and stationary sources, and other AD data sources (e.g. EU ETS) have limited coverage of gas oil use across all of 1A2.
1A2	Liquefied Petroleum Gas	25.70%	2.10%	2.50%	2.10%	The DUKES data from 2009 onwards were revised considerably in the energy / NEU split for LPG, and we have created a new split for earlier years. Chosen 2.1% EF uncertainty to be consistent with gas oil - the makeup of LPG is well understood and documented

Category	Fuel	1990 Activity uncertainty (%)	1990 Emission factor uncertainty (%)	2019 Activity uncertainty (%)	2019 Emission factor uncertainty (%)	Justification for key sources
1A2	Motor Gasoline	20.00%	2.10%	20.00%	2.10%	Outside of 1A3, the motor gasoline allocations are probably much more uncertain. Chosen 2.1% EF uncertainty to be consistent with gas oil - the makeup of motor gasoline is well understood and documented
1A2	Municipal Solid Waste	5.00%	15.00%	5.00%	15.00%	MSW quantity is known accurately. Uncertainty is in mass of fossil carbon per tonne of residual MSW. This is based on reasonable waste composition data from peer reviewed sources, adapted from landfill data.
1A2	Natural Gas	2.80%	3.00%	1.00%	3.00%	Low EF uncertainty as gas composition is monitored and reported across much of the time series, and the fuel has narrow compositional range. AD are also well understood and low uncertainty. Gas supplier data to DUKES can be checked against periodic data matching (meter point data against industry sector information).
1A2	non-fuel combustion	50.00%	100.00%	50.00%	100.00%	(Minor emission source in sector context)
1A2	Other Bituminous Coal	5.00%	10.00%	5.00%	10.00%	Limited compositional data over time (e.g. EU ETS data for coal is incomplete), so EF uncertainty reflects the range of composition of coal types in 1A2. AD uncertainty is moderate for 1A2, reflecting energy supplier reporting to BEIS.
1A2	Other Kerosene	6.00%	2.00%	6.00%	2.00%	(Minor fuel in sector context)
1A2	Other Oil: Other	5.00%	50.00%	5.00%	3.00%	(Minor fuel in sector context)
1A2	Patent Fuel	10.00%	3.00%	10.00%	3.00%	(Minor fuel in sector context)

Category	Fuel	1990 Activity uncertainty (%)	1990 Emission factor uncertainty (%)	2019 Activity uncertainty (%)	2019 Emission factor uncertainty (%)	Justification for key sources
1A2	Petroleum Coke	25.00%	15.00%	20.00%	15.00%	EF uncertainty reflects range of petcoke composition that may be used for fuel in 1A2. AD uncertainty is quite high as we have limited data from DUKES and not much AD from EU ETS on petcoke use.
1A2	Refinery Gas	50.00%	15.00%	50.00%	15.00%	(Minor fuel in sector context)
1A2	Residual Fuel Oil	5.50%	2.10%	1.50%	2.10%	Low EF uncertainty as the composition of fuel oil is well understood across the time series. The AD uncertainty is low in recent years as the fuel is not widely used other than by larger operators that report under EU ETS. Moderate uncertainty in earlier years, when fewer routine annual AD sources.
1A2	Scrap Tyres	15.00%	10.00%	15.00%	10.00%	(See 1A1 comment – same applies here.)
1A3	Aviation Gasoline	20.00%	3.30%	20.00%	3.30%	Activity uncertainty is higher than many other similar fuels because of the uncertainty in the international-domestic split
1A3	Jet Gasoline	20.00%	3.30%	20.00%	3.30%	Activity uncertainty is higher than many other similar fuels because of the uncertainty in the international-domestic split
1A3	liquid biofuels	5.00%	5.00%	5.00%	5.00%	Activity data are not very uncertain, as it's taken from RTFO data. There is a total potential range of 10% variability in the fossil fuel carbon content of FAME (i.e. judging from the contents of the different fatty acid types used to synthesize the FAME, the highest content is around 44.8g/kg, whilst the lowest is 40.2g/kg). In reality, these are the extremes, so a lower overall uncertainty is expected. the other liquid biofuels are consumed in much smaller quantities than FAME.
1A3	Other Bituminous Coal	20.00%	6.00%	20.00%	6.00%	(Minor fuel in sector context)

Category	Fuel	1990 Activity uncertainty (%)	1990 Emission factor uncertainty (%)	2019 Activity uncertainty (%)	2019 Emission factor uncertainty (%)	Justification for key sources
1A3	Other Gas/Diesel Oil	15.00%	2.00%	15.00%	2.00%	(Minor fuel in sector context)
1A3b	Gas/Diesel Oil	1.80%	2.00%	1.00%	2.00%	Low EF uncertainty as the composition of gas oil is well understood across the time series. Low AD uncertainty as good corroboration between fuel sales data and estimates based on vehicle movement data.
1A3b	Liquefied Petroleum Gas	5.00%	2.00%	5.00%	2.00%	EF uncertainty is consistent with gas oil - the makeup of LPG is well understood and documented. Not a major fuel in the sector but AD are considered moderately uncertain.
1A3b	Motor Gasoline	1.00%	2.00%	1.00%	2.00%	Low EF uncertainty as the composition of petrol is well understood across the time series. Low AD uncertainty as good corroboration between fuel sales data and estimates based on vehicle movement data.
1A3d	Gas/Diesel Oil	20.00%	2.00%	20.00%	2.00%	Activity uncertainty is higher than many other similar fuels because of the uncertainty in the international-domestic split
1A3d	Residual Fuel Oil	20.00%	2.00%	20.00%	2.00%	Activity uncertainty is higher than many other similar fuels because of the uncertainty in the international-domestic split
1A4	Anthracite	1.50%	6.00%	1.00%	6.00%	Low AD uncertainty as tax data helps establish residential use. EF uncertainty reflects variability in anthracite composition.
1A4	Coke Oven Coke	3.00%	10.00%	1.00%	10.00%	(Minor fuel in sector context)
1A4	Gas/Diesel Oil	30.00%	2.00%	30.00%	2.00%	Low EF uncertainty as the composition of gas oil is well understood across the time series. High AD uncertainty as scarce data on use of this fuel, e.g. in mobile machinery, in 1A4.

Category	Fuel	1990 Activity uncertainty (%)	1990 Emission factor uncertainty (%)	2019 Activity uncertainty (%)	2019 Emission factor uncertainty (%)	Justification for key sources
1A4	Gas Works Gas	5.00%	5.00%	5.00%	5.00%	(Minor fuel in sector context)
1A4	Liquefied Petroleum Gas	25.70%	2.10%	2.50%	2.10%	The DUKES data from 2009 onwards were revised considerably in the energy / NEU split for LPG, and we have created a new split for earlier years. Chosen 2.1% EF uncertainty to be consistent with gas oil - the makeup of LPG is well understood and documented
1A4	Motor Gasoline	50.00%	2.00%	50.00%	2.00%	Low EF uncertainty as the composition of petrol is well understood across the time series. High AD uncertainty as scarce data on use of this fuel in mobile machinery in 1A4.
1A4	Natural Gas	2.80%	3.00%	2.00%	3.00%	(As for 1A2)
1A4	Other Bituminous Coal	3.00%	10.00%	3.00%	10.00%	Chosen 3% activity uncertainty as we know that there are some limitations on the coal allocation to small-scale users.
1A4	Other Kerosene	3.00%	2.00%	3.00%	2.00%	Low AD uncertainty as tax data helps establish residential use. EF uncertainty reflects narrow range of fuel composition.
1A4	Patent Fuel	3.30%	3.00%	2.00%	3.00%	(Minor fuel in sector context)
1A4	Peat	30.00%	10.00%	30.00%	10.00%	(Minor fuel in sector context)
1A4	Petroleum Coke	20.00%	15.00%	20.00%	15.00%	Limited information on the AD of use in domestic fuels which increases uncertainty. Moderate emission factor uncertainty as there is only a small dataset for the quality of petcoke used in the sector and the CEF could be quite variable depending on the source of the pet coke.
1A4	Residual Fuel Oil	5.50%	2.10%	3.00%	2.10%	(Minor fuel in sector context)

Category	Fuel	1990 Activity uncertainty (%)	1990 Emission factor uncertainty (%)	2019 Activity uncertainty (%)	2019 Emission factor uncertainty (%)	Justification for key sources
1A5	Gas/Diesel Oil	6.25%	2.05%	6.25%	2.05%	Moderate AD uncertainty as data from very few data suppliers. EF uncertainty reflects narrow range of fuel composition.
1A5	Jet Gasoline	10.00%	3.00%	10.00%	3.00%	Activity Data comes directly from fuel users so should have high confidence.
1B1	Coke Oven Gas	1.50%	10.00%	1.00%	10.00%	(Minor fuel in sector context)
1B1	Other Bituminous Coal	1.50%	6.00%	1.50%	6.00%	EF uncertainty reflects the range of composition of coal types in SSF manufacture. AD uncertainty is quite low, reflecting the small number of operators and high level of AD reporting.
1B1	petroleum coke	20.00%	10.00%	20.00%	10.00%	(Minor fuel in sector context)
1B2a	non-fuel combustion	5.00%	6.00%	5.00%	6.00%	(Minor source in UK context)
1B2b	non-fuel combustion	3.00%	6.00%	3.00%	6.00%	(Minor source in UK context)
1B2c	non-fuel combustion	5.00%	6.00%	5.00%	6.00%	(Minor source in UK context)
2A1	non-fuel combustion	1.00%	3.00%	1.00%	3.00%	EU ETS-type data collected from BCA for all sites so assume very good quality and complete.
2A2	non-fuel combustion	10.00%	5.00%	(a)	5.00%	High level of reporting in EU ETS for recent years and EF reflects small range of data for carbonates used in lime production. AD uncertainty higher in earlier years.
2A3	non-fuel combustion	(a)	5.00%	(a)	5.00%	Mostly based on ETS data. Very small sites outside EU ETS; it's not certain how well EU ETS factor will apply to these non-EU ETS sites.
2A4	non-fuel combustion	2.00%	3.00%	2.00%	3.00%	(Minor source in UK context)

Category	Fuel	1990 Activity uncertainty (%)	1990 Emission factor uncertainty (%)	2019 Activity uncertainty (%)	2019 Emission factor uncertainty (%)	Justification for key sources
2B	Coke	1.00%	20.00%	1.00%	10.00%	(Minor source in UK context)
2B	coke oven coke	(a)	20.00%	(a)	20.00%	(Minor source in UK context)
2B	Natural Gas	2.80%	1.25%	1.75%	1.25%	Covers both feedstock and fuel (i.e. total fuel used at the sites), so AD should be very good.
2B	non-fuel combustion	2.00%	5.00%	2.00%	5.00%	(Minor source in UK context)
2B	OPG	(a)	5.00%	(a)	5.00%	Moderate uncertainty in EF reflecting good level of reporting of fuel quality in EU ETS but range of variability of process off-gases that are generated and used in the chemical sector.
2B	petroleum coke	1.00%	10.00%	1.00%	10.00%	(Minor source in UK context)
2B	refinery gas	30.00%	5.00%	30.00%	5.00%	High uncertainty, as we deviate from DUKES. Low emission factor uncertainty, but not a well-characterised fuel.
2C	Blast Furnace Gas	2.00%	10.00%	2.00%	10.00%	Overall uncertainty in 2C is quite low and uncertainty is more about where the carbon input (from the coking coal) ends up being emitted, and less about the overall amount of carbon emitted.
2C	Coke	2.00%	10.00%	2.00%	10.00%	Good level of reporting from I&S operators across the time series.
2C	coke oven coke	2.00%	5.00%	2.00%	5.00%	Activity data has low uncertainty since it's based on ETS/ISSB/DUKES. Emissions are based on regulator data, so low uncertainty.

Category	Fuel	1990 Activity uncertainty (%)	1990 Emission factor uncertainty (%)	2019 Activity uncertainty (%)	2019 Emission factor uncertainty (%)	Justification for key sources
2C	non-fuel combustion	2.00%	10.00%	2.00%	10.00%	Overall uncertainty in 2C is quite low and uncertainty is more about where the carbon input (from the coking coal) ends up being emitted, and less about the overall amount of carbon emitted.
2C	Petroleum Coke	10.00%	7.50%	10.00%	7.50%	(Minor source in UK context)
2D	Lubricants	50.00%	50.00%	50.00%	50.00%	It's challenging to determine the size of the recovered lubricant market, as this is outside the scope of energy statistics, hence a high activity uncertainty. The fraction of lubricant incidentally oxidised is also highly uncertain, so should be reflected in a high EF uncertainty.
2D	non-fuel combustion	25.00%	2.00%	25.00%	2.00%	Some uncertainty as to the proportion of HDVs requiring urea and how much is needed per vehicle. Very low EF uncertainty because carbon content of urea solution known accurately.
2D	Petroleum Coke	20.00%	30.00%	20.00%	30.00%	(Minor source in UK context)
2D	Petroleum Waxes	10.00%	50.00%	10.00%	50.00%	(Minor source in UK context)
2G		25.00% (n)	2.00% (n)	25.00% (n)	2.00% (n)	High activity uncertainty due to it being unclear if bicarbonate of soda is used for emissive or non-emissive applications. Low uncertainty in emission factors as it's determined from stoichiometry.
3G	non-fuel combustion	(a)	20.90%	(a)	20.90%	Reflects overall uncertainty of AD and EF for carbonate application to soils.
3H	non-fuel combustion	(a)	50.00%	(a)	50.00%	(Minor source in UK context)

Category	Fuel	1990 Activity uncertainty (%)	1990 Emission factor uncertainty (%)	2019 Activity uncertainty (%)	2019 Emission factor uncertainty (%)	Justification for key sources
4A	non-fuel combustion	5.00% (r)	20.00%	5.00% (r)	20.00%	In order to assess the uncertainties for Forest Land a Monte Carlo analysis was performed using the CARBINE model. The probability density functions (PDFs) assigned to the various CARBINE input parameters were based on information from the literature and expert judgement. A selection of 100 sets of input parameters were generated using a latin hypercube, as this was considered to be the minimum number of model runs to get a reasonable estimate of the uncertainty.
4B	non-fuel combustion	1.00%	25.00% (r)	1.00%	25.00% (r)	High uncertainty reflects modelled assumptions and limited AD, and is focussed in the EF parameter.
4C	non-fuel combustion	1.00%	30.00% (r)	1.00%	30.00% (r)	High uncertainty reflects modelled assumptions and limited AD, and is focussed in the EF parameter.
4D	non-fuel combustion	1.00%	25.00% (r)	1.00%	25.00% (r)	High uncertainty reflects modelled assumptions and limited AD, and is focussed in the EF parameter.
4E	non-fuel combustion	1.00%	25.00% (r)	1.00%	25.00% (r)	High uncertainty reflects modelled assumptions and limited AD, and is focussed in the EF parameter.
4F	non-fuel combustion	(a)	50.00%	(a)	50.00%	High uncertainty reflects modelled assumptions and limited AD, and is focussed in the EF parameter.
4G	non-fuel combustion	1.00% (r)	20.00% (r)	1.00% (r)	15.00% (r)	In order to assess the uncertainties for Forest Land a Monte Carlo analysis was performed using the CARBINE model. The probability density functions (PDFs) assigned to the various CARBINE input parameters were based on information from the literature and expert judgement. A selection of 100 sets of input parameters were generated using a latin hypercube, as this was considered to be the minimum number of model runs to get a reasonable estimate of the uncertainty.

Category	Fuel	1990 Activity uncertainty (%)	1990 Emission factor uncertainty (%)	2019 Activity uncertainty (%)	2019 Emission factor uncertainty (%)	Justification for key sources
5C	Chemical waste	300.00%	40.00%	10.00%	30.00%	(Minor source in UK context)
5C	Clinical waste	300.00%	40.00%	5.00%	20.00%	(Minor source in UK context)
5C	Municipal Solid Waste	300.00%	40.00%	1.00%	15.00%	(Minor source in UK context)
5C	non-fuel combustion	300.00%	40.00%	300.00%	40.00%	Unauthorised and widely dispersed activity, estimated from indirect data sources so high uncertainty. Significant uncertainty in the composition of material burnt.

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

Category	Fuel	1990 Activity uncertainty (%)	1990 Emission factor uncertainty (%)	2019 Activity uncertainty (%)	2019 Emission factor uncertainty (%)	Justification for key sources
1A1		1.50%	50.00%	1.00%	50.00%	Minor source but uncertainty mainly reflects uncertainty in the EF from combustion of biomass.
1A2		1.50%	50.00%	1.00%	50.00%	As above.
1A3	Aviation Gasoline	20.00%	78.50%	20.00%	78.50%	(Minor source in UK context)
1A3	Jet Gasoline	20.00%	78.50%	20.00%	78.50%	(Minor source in UK context)
1A3	Other Bituminous Coal	20.00%	110.00%	20.00%	110.00%	(Minor source in UK context)
1A3	Other Gas/Diesel Oil	15.00%	130.00%	15.00%	130.00%	(Minor source in UK context)

Category	Fuel	1990 Activity uncertainty (%)	1990 Emission factor uncertainty (%)	2019 Activity uncertainty (%)	2019 Emission factor uncertainty (%)	Justification for key sources
1A3b	Gas/Diesel Oil	1.80%	130.00%	1.00%	130.00%	Road transport fuel sales well documented, so uncertainty in AD should be low. Uncertainty in EF reflects the variability in EFs for the range of vehicle (car, van, HGV) and road types.
1A3b	Liquefied Petroleum Gas	5.00%	130.00%	5.00%	130.00%	(Minor source in UK context)
1A3b	Motor Gasoline	1.00%	75.00%	1.00%	75.00%	Road transport dominates consumption of these fuels, so uncertainty in AD should be low. Uncertainty in EF reflects the variability in EFs for petrol cars and road types. Lower uncertainty than diesel vehicles because consumption dominated by only one vehicle type.
1A3d	Gas/Diesel Oil	20.00%	130.00%	20.00%	130.00%	Uncertainty in AD due to uncertainty in getting domestic/international split from bottom-up method. Uncertainty in EF should be consistent with other 1A3 gas oil
1A3d	Residual Fuel Oil	20.00%	130.00%	20.00%	130.00%	Uncertainty in AD due to uncertainty in getting domestic/international split from bottom-up method.
1A4		1.50%	50.00%	1.00%	50.00%	Minor source but uncertainty mainly reflects uncertainty in the EF from combustion of biomass.
1A5		7.07%	65.55%	7.07%	65.55%	(Minor source in UK context)
1B1	Coke Oven Gas	1.50%	50.00%	1.00%	50.00%	(Minor source in UK context)
1B1	non-fuel combustion	2.00%	20.00%	2.00%	20.00%	High EF uncertainty reflects the modelled estimates of emissions from coal mines.
1B1	wood	(a)	50.00%	(a)	50.00%	(Minor source in UK context)

Category	Fuel	1990 Activity uncertainty (%)	1990 Emission factor uncertainty (%)	2019 Activity uncertainty (%)	2019 Emission factor uncertainty (%)	Justification for key sources
1B2a	non-fuel combustion	5.00%	20.00%	5.00%	20.00%	Good level of operator reporting. EF uncertainty reflects limited scope for verifying the factors applied in deriving operator estimates from fugitives especially.
1B2b	non-fuel combustion	3.00%	20.00%	3.00%	20.00%	As above.
1B2c	non-fuel combustion	5.00%	20.00%	5.00%	20.00%	As above.
2A4		(a)	100.00%	(a)	100.00%	(Minor source in UK context)
2B		(a)	20.00%	(a)	20.00%	(Minor source in UK context)
2C	Blast Furnace Gas	2.00%	50.00%	2.00%	50.00%	(Minor source in UK context)
2C	coke oven coke	2.00%	50.00%	2.00%	50.00%	Activity data has low uncertainty since it's based on ETS/ISSB/DUKES. Emissions are based on literature factors, so a high EF uncertainty.
2C	non-fuel combustion	1.00%	50.00%	1.00%	50.00%	(Minor source in UK context)
2D		50.00%	50.00%	50.00%	50.00%	(Minor source in UK context)
3A	non-fuel combustion	13.73%	(a)	13.73%	(a)	Based on monte carlo analysis for the agriculture model
3B	non-fuel combustion	(a)	8.37%	(a)	8.37%	Based on monte carlo analysis for the agriculture model
3F	non-fuel combustion	25.61%	(a)	25.61%	(a)	Based on monte carlo analysis for the agriculture model
3J		50.00%	50.00%	50.00%	50.00%	
4A	non-fuel combustion	5.00% (r)	90.00% (r)	5.00% (r)	70.00% (r)	(Minor source in UK context)
4B	non-fuel combustion	1.00%	90.00% (r)	1.00%	90.00% (r)	(Minor source in UK context)
4C	non-fuel combustion	1.00%	40.00% (r)	1.00%	40.00% (r)	(Minor source in UK context)

Category	Fuel	1990 Activity uncertainty (%)	1990 Emission factor uncertainty (%)	2019 Activity uncertainty (%)	2019 Emission factor uncertainty (%)	Justification for key sources
4D	non-fuel combustion	1.00% (n)	40.00% (n)	1.00% (n)	35.00% (n)	(Minor source in UK context)
4E	non-fuel combustion	1.00%	50.00% (r)	1.00%	40.00% (r)	(Minor source in UK context)
5A	non-fuel combustion	15.00%	46.00%	15.00%	46.00%	Moderate/high uncertainty in historical waste data, rates of decomposition and generation of methane in the modelled approach. Some extrapolation of data needed for methane utilisation, hence high uncertainty overall, across AD and EF.
5B		30.00%	99.50%	30.00%	99.50%	Scarce data for UK biological treatments. High uncertainty.
5C	Municipal Solid Waste	5.00%	75.00%	1.00%	75.00%	(Minor source in UK context)
5C	non-fuel combustion	5.00%	50.00%	5.00%	50.00%	(Minor source in UK context)
5C	wood	50.00%	50.00%	50.00%	50.00%	(Minor source in UK context)
5D1 (r)	non-fuel combustion	10.00%	25.00%	10.00%	25.00%	UK industry research and model. Moderate-high uncertainty.
5D2		25.00% (n)	82.54% (n)	25.00% (n)	82.54% (n)	Calculated based on 2006 IPCC guidelines ranges for model parameters and weighted depending on their contribution to the final emissions estimate.

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 Activity uncertainty (%)	1990 Emission factor uncertainty (%)	2019 Activity uncertainty (%)	2019 Emission factor uncertainty (%)	Justification for key sources
1A1		1.50%	100.00%	1.00%	100.00%	
1A2		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%	Road transport dominates consumption of these fuels, so uncertainty in AD should be low. Uncertainty in EF reflects the variability in Efs for different diesel vehicle types and road types.
1A3b	Liquefied Petroleum Gas	5.00%	130.00%	5.00%	130.00%	
1A3b	Motor Gasoline	1.00%	75.00%	1.00%	75.00%	Road transport dominates consumption of these fuels, so uncertainty in AD should be low. Uncertainty in EF reflects the variability in Efs for petrol cars and road types. Lower uncertainty than diesel vehicles because consumption dominated by only one vehicle type.
1A3d	Gas/Diesel Oil	20.00%	130.00%	20.00%	130.00%	Uncertainty in AD due to uncertainty in getting domestic/international split from bottom-up method. Uncertainty in EF should be consistent with other 1A3 gas oil
1A3d	Residual Fuel Oil	20.00%	130.00%	20.00%	130.00%	Uncertainty in AD due to uncertainty in getting domestic/international split from bottom-up method.

Category	Fuel	1990 Activity uncertainty (%)	1990 Emission factor uncertainty (%)	2019 Activity uncertainty (%)	2019 Emission factor uncertainty (%)	Justification for key sources
1A4		1.50%	100.00%	1.00%	100.00%	
1A5		7.07%	85.15%	7.07%	85.15%	
1B1		1.50%	118.00%	1.00%	118.00%	
1B2a	non-fuel combustion	5.00%	110.00%	5.00%	110.00%	
1B2b	non-fuel combustion	5.00%	110.00%	5.00%	110.00%	
1B2c	non-fuel combustion	5.00%	110.00%	5.00%	110.00%	
2B1		2.00%	50.00%	2.00%	50.00%	Strong activity data, so low activity uncertainty. Assume a high uncertainty for the literature factor.
2B2		10.00%	100.00%	(a)	10.00%	Emission estimates for recent years have been based partially (1998-2008) or wholly (2009-2017) on continuous monitoring, and therefore will be subject to low uncertainty. The monitoring systems used at the 2 sites currently in operation are subject to an uncertainty of 5-10%. Uncertainty in earlier years is much higher due to more limited information
2B3		2.00%	100.00%	2.00%	100.00%	
2B8		10.00%	100.00%	10.00%	100.00%	
2C		1.50%	118.00%	1.00%	118.00%	
2D		50.00%	100.00%	50.00%	100.00%	
2G		100.00%	100.00%	100.00%	100.00%	

Category	Fuel	1990 Activity uncertainty (%)	1990 Emission factor uncertainty (%)	2019 Activity uncertainty (%)	2019 Emission factor uncertainty (%)	Justification for key sources
3B		(a)	68.07%	(a)	9.53%	Based on separate monte carlo analysis for the agriculture model
3D		(a)	53.28%	(a)	11.16%	Based on separate monte carlo analysis for the agriculture model
3F		25.63%	(a)	25.62%	(a)	
3J		50.00%	50.00%	50.00%	50.00%	
4A	non-fuel combustion	1.00%	80.00% (r)	1.00%	80.00% (r)	
4B	non-fuel combustion	1.00%	40.00% (r)	1.00%	40.00% (r)	
4C	non-fuel combustion	1.00%	50.00% (r)	1.00%	45.00% (r)	
4D	non-fuel combustion	1.00%	120.00% (r)	1.00%	65.00% (r)	
4E	non-fuel combustion	1.00%	135.00%	1.00%	130.00%% (r)	
4only	non-fuel combustion	1.00%	165.00%	1.00%	165.00%	
5B		30.00%	90.00%	30.00%	90.00%	
5C		7.00%	230.00%	7.00%	230.00%	
5D1 (r)		10.00%	248.00%	10.00%	248.00%	
5D2		25.00% (n)	129.37% (n)	25.00% (n)	129.37% (n)	Calculated based on 2006 IPCC guidelines ranges for model parameters and weighted depending on their contribution to the final emissions estimate.

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

Category	Fuel	1990 Activity uncertainty (%)	1990 Emission factor uncertainty (%)	2019 Activity uncertainty (%)	2019 Emission factor uncertainty (%)	Justification for key sources
HFCs	2B9	(a)	15.00%	(a)	10.00%	
HFCs	2C4	5.00%	16.25%	5.00%	10.00%	
HFCs	2E1	(a)	44. 50%	(a)	47.15%	
HFCs	2F1	10.00%	10.00%	10.00%	10.00%	Good UK data on refrigerant supply is used to tune the model of emissions for this sector, which means that there is a high confidence in the overall estimates of an activity for this sector. Good activity data helps mitigate the uncertainty in emissions, as leakage and disposal is directly linked to refrigerant demand.
HFCs	2F2	(a)	30.00%	(a)	15.00%	
HFCs	2F3	(a)	10.00%	(a)	25.00%	
HFCs	2F4a	38.73%	10.00%	5.00%	10.00%	
HFCs	2F4b	(a)	20.00%	(a)	10.00%	
HFCs	2F5	(a)	25.50%	(a)	25.50%	
HFCs	2F6	(a)	51.00%	(a)	42.00%	
NF_3	2E1	(a)	44.50%	(a)	47.15%	
PFCs	2B9	(a)	15.00%	(a)	10.00%	
PFCs	2C3	(a)	5.00%	(a)	20.00%	
PFCs	2F3	(a)	20.00%	(a)	25.00%	
PFCs	2G2e	(a)	44.50%	(a)	47.15%	

Category	Fuel	1990 Activity uncertainty (%)	1990 Emission factor uncertainty (%)	2019 Activity uncertainty (%)	2019 Emission factor uncertainty (%)	Justification for key sources
SF_6	2C4	5.00%	5.00%	5.00%	5.00%	
SF_6	2G1	(a)	20.00%	(a)	5.00%	
SF_6	2G2a	(a)	50.00%	(a)	50.00%	
SF_6	2G2b	(a)	17.50%	(a)	15.50%	
SF_6	2G2e	(a)	40.00%	(a)	10.00%	

A 2.3.2 General Considerations

The uncertainty parameters presented in above 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 the uncertainties in the emissions of HFCs, PFCs, NF_3 and SF_6 (collectively known as F-gases) are based on the study to update emissions and projections of F-gases (ICF, 2014) in line with the 2006 IPCC guidelines. 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

In simulating trend uncertainty, 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;
- 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; and,
- 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	2019 Emissions	95% confidence interval for 1990 emissions 2.5 percentile	95% confidence interval for 1990 emissions 97.5 percentile	Uncertainty in 1990 emissions as % of emissions in category	95% confidence interval for 2019 emissions 2.5 percentile	95% confidence interval for 2019 emissions 97.5 percentile	Uncertainty in 2019 emissions as % of emissions in category	% change in emissions between 1990 and 2019	95% confidence interval for the% change in emissions between 1990 and 2019 2.5 percentile	95% confidence interval for the% change in emissions between 1990 and 2019 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)	611,480	368,795	600,157	622,685	1.8%	361,358	376,216	2.0%	-40%	-41%	-38%
	CH_4	134,535	54,442	107,814	172,306	24.0%	46,939	64,550	16.2%	-59%	-69%	-48%
	N_2O	49,731	22,408	38,170	67,626	29.6%	19,345	26,081	15.0%	-54%	-68%	-39%
	HFC	14,409	12,612	12,264	16,563	14.9%	11,422	13,795	9.4%	-12%	-26%	6%
	PFC	1,651	345	1,571	1,733	4.9%	250	459	30.3%	-79%	-85%	-72%
	SF_6	1,315	590	1,176	1,456	10.7%	527	652	10.6%	-55%	-61%	-48%
	NF_3	0.4	0.6	0.2	0.6	44.7%	0.4	1.0	46.9%	68%	-20%	207%
	All	**813,121**	**459,192**	**780,656**	**855,502**	**4.6%**	**447,836**	**471,839**	**2.6%**	**-43%**	**-46%**	**-41%**

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	2019 Emissions	95% confidence interval for 2019 emissions 2.5 percentile	95% confidence interval for 2019 emissions 97.5 percentile	Uncertainty in 2019 emissions as % of emissions in category	% change in emissions between 1990 and 2019	95% confidence interval for the% change in emissions between 1990 and 2019 2.5 percentile	95% confidence interval for the% change in emissions between 1990 and 2019 97.5 percentile
1A1a	205,432	60,001	58,204	61,807	3.0%	-71%	-72%	-70%
1A1b	17,871	12,648	10,802	14,714	15.5%	-29%	-46%	-4%
1A1c	14,141	15,277	14,853	15,769	3.0%	8%	2%	14%
1A2a	21,489	9,402	8,601	10,208	8.5%	-56%	-61%	-51%
1A2b	4,338	695	659	731	5.2%	-84%	-87%	-80%
1A2c	12,099	4,957	4,697	5,221	5.3%	-59%	-63%	-55%
1A2d	4,641	1,397	1,316	1,479	5.8%	-70%	-73%	-66%
1A2e	7,650	4,161	3,935	4,385	5.4%	-46%	-50%	-41%
1A2f	6,682	2,615	2,325	2,920	11.4%	-61%	-69%	-49%
1A2g	38,799	27,300	25,849	28,736	5.3%	-30%	-36%	-23%
1A3a	1,899	1,784	1,430	2,139	19.9%	-6%	-29%	24%
1A3b	111,132	111,035	109,137	113,004	1.7%	0%	-3%	2%
1A3c	1,491	1,698	1,381	2,015	18.7%	14%	-12%	46%
1A3d	7,727	5,658	4,654	6,667	17.8%	-27%	-42%	-8%
1A3e	228	614	497	733	19.2%	169%	107%	248%

IPCC Source Category	1990 Emissions	2019 Emissions	95% confidence interval for 2019 emissions 2.5 percentile	95% confidence interval for 2019 emissions 97.5 percentile	Uncertainty in 2019 emissions as % of emissions in category	% change in emissions between 1990 and 2019	95% confidence interval for the% change in emissions between 1990 and 2019 2.5 percentile	95% confidence interval for the% change in emissions between 1990 and 2019 97.5 percentile
1A4a	25,587	19,771	19,124	20,423	3.3%	-23%	-28%	-17%
1A4b	80,299	68,114	65,402	70,876	4.0%	-15%	-20%	-10%
1A4c	6,263	5,279	3,663	6,861	30.3%	-16%	-48%	49%
1A5b	5,354	1,735	1,608	1,865	7.4%	-68%	-71%	-64%
1B1	23,549	622	536	706	13.7%	-97%	-98%	-97%
1B2	18,223	8,822	5,780	11,860	34.5%	-52%	-68%	-35%
2A1	7,296	4,449	4,309	4,591	3.2%	-39%	-40%	-38%
2A2	1,329	1,054	1,001	1,106	5.0%	-21%	-28%	-12%
2A3	411	369	351	388	5.1%	-10%	-11%	-10%
2A4	774	454	438	471	3.7%	-41%	-45%	-38%
2B1	1,896	1,549	1,516	1,583	2.2%	-18%	-22%	-15%
2B2	3,870	38	34	42	10.1%	-99%	-99%	-98%
2B3	19,873	-	-	-	n/a	-100%	-100%	-100%
2B6	105	152	137	168	10.2%	46%	18%	86%
2B7	224	145	137	153	5.6%	-35%	-41%	-28%
2B8	4,785	2,680	1,871	3,500	30.4%	-44%	-63%	-19%
2B9	14,414	121	109	133	9.9%	-99%	-99%	-99%

IPCC Source Category	1990 Emissions	2019 Emissions	95% confidence interval for 2019 emissions 2.5 percentile	95% confidence interval for 2019 emissions 97.5 percentile	Uncertainty in 2019 emissions as % of emissions in category	% change in emissions between 1990 and 2019	95% confidence interval for the% change in emissions between 1990 and 2019 2.5 percentile	95% confidence interval for the% change in emissions between 1990 and 2019 97.5 percentile
2B10	192	58	45	72	23.4%	-69%	-78%	-57%
2C	9,366	2,413	2,302	2,523	4.6%	-74%	-76%	-73%
2D	552	482	247	840	61.5%	-13%	-63%	114%
2E	5	26	15	40	46.2%	455%	192%	951%
2F	8	12,584	11,395	13,767	9.4%	149768%	135236%	164136%
2G	1,605	1,517	830	2,724	62.4%	-5%	-56%	98%
3A	24,529	21,211	18,993	23,648	11.0%	-14%	-26%	1%
3B	7,481	6,721	5,881	7,630	13.0%	-10%	-25%	8%
3D	14,253	12,255	9,733	15,359	23.0%	-14%	-36%	15%
3F	245	-	-	-	n/a	-100%	-100%	-100%
3G	1,017	1,311	1,036	1,585	20.9%	29%	-5%	74%
3H	328	319	208	469	40.9%	-3%	-45%	73%
4	403	222	74	522	101.0%	-45%	-86%	111%
4A	-13,531	-16,328	-19,773	-12,973	20.8%	21%	12%	30%
4B	21,722	15,949	12,106	19,736	23.9%	-27%	-33%	-21%
4C	2,098	-1,068	-2,523	372	135.6%	-151%	-195%	-107%
4D	2,552	3,495	2,650	4,325	24.0%	37%	-6%	80%

IPCC Source Category	1990 Emissions	2019 Emissions	95% confidence interval for 2019 emissions 2.5 percentile	95% confidence interval for 2019 emissions 97.5 percentile	Uncertainty in 2019 emissions as % of emissions in category	% change in emissions between 1990 and 2019	95% confidence interval for the% change in emissions between 1990 and 2019 2.5 percentile	95% confidence interval for the% change in emissions between 1990 and 2019 97.5 percentile
4E	6,972	6,010	4,563	7,498	24.4%	-14%	-17%	-11%
4F	-	-	-	-	n/a	n/a	n/a	n/a
4G	-2,093	-2,221	-2,558	-1,882	15.2%	6%	2%	10%
5A	60,484	14,376	8,250	23,554	53.2%	-76%	-87%	-55%
5B	31	1,963	1,228	3,067	46.9%	6234%	3074%	12770%
5C	1,468	285	111	654	95.2%	-81%	-94%	-39%
5D	3,116	2,699	1,797	4,213	44.7%	-13%	-51%	52%
Grand Total	**813,121**	**459,193**	**447,837**	**471,839**	**2.6%**	**-44%**	**-46%**	**-41%**

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] Base year	Central estimate (Gg CO_2 equivalent) [b] 2019	Uncertainty on trend, 95% CI (1990 / base year to 2019)[a]
Error propagation	816,083	459,144	1.7%
Monte Carlo	816,223	459,192	2.7%

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 2021 submission for sectors 1A and 1B can be found in the accompanying excel file: 'Energy_background_data_uk_2021.xlsx'. This can be found as one of the additional documents here: https://naei.beis.gov.uk/reports/reports?report_id=1015. 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.

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, 2019). As part of the systems improvements made to the inventory database in 2020 (moving from mass to energy units, and from gross to net), data from the gas operators has been further analysed and a revised gross to net conversion has been derived. This has been applied to the data from the early part of the time series, which came from Baggott et al., 2004.
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, 2020). For the 2020 submission, data received for the 2004 review was reconsidered for cement, and revised coal factors for the early part of the time series

(that were not received in time for inclusion in the final review report) have now been incorporated into the inventory.

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 3.1.2.1 The Pollution Inventory and other regulators' inventories

The Pollution Inventory (PI) has, since 1998, provided emission data for the six Kyoto gases (NF_3 is not included) 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 3.1.2.2 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 Offshore Petroleum Regulator for Environment and Decommissioning (OPRED) 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 1995-2019. 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 3.1.2.3 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
Light petroleum distillates and natural gas liquids[5]	1A1a	Scrap tyre combustion in power stations (1994 to 2000 only). Fossil carbon in MSW combustion in energy from waste plant.
	1A1b	Other petroleum gas use in refineries (2004, 2006 to 2011, 2013 to 2019 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 off-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 CO_2 are reported in 2B8.*
	5C	Fossil carbon in chemical waste incineration. Fossil carbon in MSW incineration. Fossil carbon in clinical waste incineration.
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 oxidation 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.*

[5] I.e. naphtha, Liquid Petroleum Gases (LPG), Refinery Fuel Gas (RFG) / Other Petroleum Gases (OPG), gas oil and Ethane. Including emissions of carbon from chemical feedstock via combustion of products such as synthetic rubbers and plastics.

Fuel	IPCC	Source Category
Petroleum coke	1A2f, 1A2g, 1A4b	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).
	2A4, 2B6, 2C1, 2C3, 2D4	There are 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.
Other Oil	2D2	Carbon released from use of petroleum waxes. Uses of petroleum waxes includes candles, with carbon emitted during use.
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.*
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 to be stored.

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 17 other chemical manufacturing installations in the UK. The derivation of a time series of emission estimates from these sources is based as far as possible on reported data by plant operators within trading scheme data and other regulatory reporting mechanisms. For the early part of the time series, data on changes in plant capacity over time is used to derive the best estimates of activity and emissions by extrapolation back from later emission estimates, whilst for later years the completeness and transparency of operator reporting is greater. Therefore, whilst the uncertainty for the emission estimates in the early part of the time series is significantly greater than for those in recent years, the Inventory Agency has made best use of the available data to derive the time series estimates of emissions from "NEU" activity. Consultation with a sector trade association has also confirmed that there are no other sector estimates of this activity, or of production data across the time series, that could be used to further improve the time series (Personal communication: Chemical Industries Association, 2014).

Other emissions included within the UK GHG inventory 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 5C (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 propane / butane mixtures are used as a propellant in aerosols and are emitted as VOC. The UK inventory contains estimates of these VOC emissions, combined with emissions of solvents used in aerosols.

It is assumed that all gas oil used for non-energy purposes is used as 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[6] 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 (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

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

http://webarchive.nationalarchives.gov.uk/20140328084622/

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, 2020) 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 natural 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 has been burnt in some years at 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 across the time series, from 1990 to the latest year; 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, 2020a) 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[7] version of the former, used in various non-energy processes. Consultation with the DECC (now BEIS) 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, 2020), power stations and other industrial sites (EA, 2020; SEPA, 2020). 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.

A 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 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

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

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; BOMBARDIER CSERIES CS300
Airbus A320	AIRBUS A320-100/200; AIRBUS A320-200N
Airbus A321	AIRBUS A321; AIRBUS A321-200N
Airbus A330-200	AIRBUS A330-200
Airbus A330-300	AIRBUS A330-300
Airbus A340-200/300	AIRBUS A340-200; AIRBUS A340-300
Airbus A340-500	AIRBUS A340-500
Airbus A340-600	AIRBUS A340-600
Airbus A350	AIRBUS A350-900; AIRBUS A350-1000
Airbus A380-800	AIRBUS A380-800
Antonov 26	ANTONOV AN-24; ANTONOV AN26B/32; CURTISS C-46 COMMANDO; 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-

EMEP/EEA Aircraft Type	CAA Aircraft Types
	300/400/475; BAE(BAC)111-500; GA GULFSTREAM 3; GULF AMERICAN GULFSTREAM II; TUPOLEV TU124
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 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

EMEP/EEA Aircraft Type	CAA Aircraft Types
Boeing 777-300 ER	BOEING 777-300ER
Boeing 787-800	BOEING 787-800 DREAMLINER
Boeing 787-900	BOEING 787-900 DREAMLINER; BOEING 787-1000 DREAMLINER
Canadair Regional Jet CRJ-200	BOMBARDIER CHALLENGER 850; BOMBARDIER REGIONAL JET 100/200; DASSAULT FALCON 7X
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; BOMBARDIER REGIONAL JET RJ705
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 EMB 120 Brasilia	EMBRAER EMB 120 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

EMEP/EEA Aircraft Type	CAA Aircraft Types
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
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	2015	2017	2018	2019
Annual Gas Use										
Domestic gas fires	ktoe (net)	417	470	561	587	608	429	433	456	452

Source / Appliance type	Units	1990	1995	2000	2005	2010	2015	2017	2018	2019
Domestic manual ignition hobs / cookers	ktoe (net)	532	479	462	448	401	414	391	426	422
Domestic auto-ignition hobs / cookers	ktoe (net)	191	171	165	160	144	148	140	152	151
Domestic auto-ignition space and water heating	ktoe (net)	22,182	24,190	27,525	28,447	29,089	22,104	21,934	23,236	23,024
Service sector catering (ovens and hobs)	ktoe (net)	538	688	697	699	636	515	516	539	535
Other service sector appliances (boilers)	ktoe (net)	5,999	7,680	8,863	8,386	7,802	7,316	7,334	7,628	7,572
Methane Leakage										
Domestic cooking and gas fires	$ktCH_4$	1.02	0.94	0.86	0.85	0.8	0.78	0.76	0.82	0.81
Domestic boilers and water heating	$ktCH_4$	0.76	0.83	0.94	0.98	1	0.76	0.75	0.8	0.79
Service sector (all sources)	$ktCH_4$	0.83	1.06	1.09	1.05	1	0.91	0.93	0.96	0.96
Total	**$ktCH_4$**	**2.61**	**2.83**	**2.9**	**2.88**	**2.8**	**2.46**	**2.44**	**2.58**	**2.56**

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.**

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

Livestock Category	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Total cattle	12,125	11,760	11,048	10,698	10,014	9,785	9,886	9,838	9,735	9,574
- dairy cows	2,848	2,603	2,336	2,003	1,839	1,906	1,910	1,901	1,888	1,875
- all other cattle	9,277	9,157	8,713	8,695	8,175	7,879	7,977	7,937	7,847	7,699
Sheep	45,475	44,233	43,154	36,140	31,724	34,032	34,649	35,557	34,490	34,289
Pigs	7,548	7,627	6,482	4,862	4,468	4,739	4,866	4,969	5,012	5,078
Total poultry	138,381	142,267	169,773	173,909	163,842	167,579	172,607	181,811	188,442	186,982
- laying hens	33,624	31,837	28,687	29,544	28,751	28,311	29,184	30,193	31,098	31,820
- broilers	73,944	77,177	105,689	111,475	105,309	107,056	110,639	117,612	123,946	121,500
Total horses	570	684	1,006	1,036	1,024	978	963	954	945	947
- horses kept on agricultural holdings	202	273	287	346	312	283	268	258	250	251
- professional horses	62	62	70	91	91	87	87	87	87	87
- domestic horses	305	348	649	599	621	608	608	608	608	608
Goat	98	75	74	95	93	101	104	105	108	111
Deer	47	37	36	33	31	31	31	31	34	38

A 3.3.1 Enteric Fermentation (3A)

Table A 3.3.2 Methane Emission Factors for Livestock Emissions for 2019

Animal group	Animal sub-group	Enteric methane kg CH_4/head/year	Methane from manures kg CH_4/head/year
Cattle	Dairy cows	125.44	41.12
	Dairy heifers	53.20	6.15
	Dairy replacements >1 year	50.24	6.19
	Dairy calves <1 year	43.50	4.21
	Beef cows	76.16	10.63
	Beef females for slaughter	49.12	5.92
	Bulls for breeding	58.18	8.13
	Cereal fed bull	49.82	9.20
	Heifers for breeding	48.77	6.38
	Steers	49.96	5.97
Pigs		1.50	4.07
Sheep	Ewes	6.88	0.19
	Rams	8.05	0.23
	Lambs	2.94	0.07
Other livestock	Goats	5.0	0.13
	Horses	18.0	1.56
	Deer	20.0	0.22
Poultry	Laying hens	NA	0.016
	Growing pullets	NA	0.007
	Broilers	NA	0.009
	Turkeys	NA	0.061
	Breeding flock	NA	0.007
	Ducks	NA	0.121
	Geese	NA	0.122
	All other poultry	NA	0.007

A 3.3.2 Manure Management (3B)

A 3.3.2.1 Methane emissions from animal manures

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 – cattle, pigs	17
Deep bedding/farm yard manure – sheep	2.0
Pasture range and paddock	1.0
Poultry manure	1.5

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

A 3.3.2.2 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 (1990-2019)

Livestock Category	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Dairy cows	86.6	88.2	94.5	104.0	106.1	109.8	106.9	109.8	110.3	112.9
Other cattle[a]	39.7	41.1	43.1	44.5	45.5	45.6	45.1	44.6	43.8	44.4
Sows	23.6	22.5	21.4	20.1	18.1	18.1	18.1	18.1	18.1	18.1
Gilts	15.5	15.5	15.5	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	21.8	21.8	21.8
Fatteners > 80 kg	20.2	19.3	18.4	17.2	15.4	15.4	15.4	15.4	15.4	15.4
Fatteners 20-80 kg	14.6	13.9	13.2	12.4	11.1	11.1	11.1	11.1	11.1	11.1
Weaners (<20 kg)	4.6	4.4	4.2	3.9	3.4	3.4	3.4	3.4	3.4	3.4
Ewes	8.3	8.5	8.6	8.6	8.3	8.6	8.3	8.5	8.3	8.7
Rams	11.3	11.4	11.4	11.3	11.1	11.2	11.1	11.2	11.2	11.4
Lambs	3.7	3.8	3.9	4.1	4.0	4.2	4.0	4.1	4.1	4.3
Goats	20.6	20.6	20.6	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	50	50	50
– professional horses	129	129	129	129	129	129	129	129	129	129
– domestic horses	50	50	50	50	50	50	50	50	50	50
Deer	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0

Livestock Category	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Laying hens	0.87	0.84	0.80	0.77	0.70	0.70	0.70	0.70	0.70	0.70
Broilers	0.64	0.59	0.55	0.49	0.40	0.40	0.40	0.40	0.40	0.40
Turkeys	1.50	1.59	1.68	1.76	1.82	1.82	1.82	1.82	1.82	1.82
Pullets	0.42	0.39	0.36	0.34	0.33	0.33	0.33	0.33	0.33	0.33
Breeding flock	1.16	1.13	1.10	1.07	1.02	1.02	1.02	1.02	1.02	1.02
Ducks	1.30	1.41	1.52	1.62	1.71	1.71	1.71	1.71	1.71	1.71
Geese	1.30	1.41	1.52	1.62	1.71	1.71	1.71	1.71	1.71	1.71
Other poultry	1.30	1.41	1.52	1.62	1.71	1.71	1.71	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, 2019

Animal Group	Animal Sub-Group	Liquid System	Daily Spread	Solid storage/Deep litter/Poultry litter[b]	Pasture Range and Paddock	Anaerobic digestion
Cattle	Dairy cows	60	8	9	22	2
	All other cattle	18	12	21	48	1
Pigs	All pigs	36	14	36	10	4
Sheep	Ewes	0	0	8	92	0
	Rams	0	0	1	99	0
	Lambs	0	0	1	99	0
Other livestock	Goats	0	0	8	92	0
	Deer	0	0	25	75	0

Animal Group	Animal Sub-Group	Liquid System	Daily Spread	Solid storage/Deep litter/Poultry litter[b]	Pasture Range and Paddock	Anaerobic digestion
	Horses	0	0	30	70	0
Poultry	All poultry	0	39	50	3	8

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 manure management			
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
Pig manure management			
Slurry – slatted floor	0.2	Factor of 2	IPCC 2006
FYM systems	2.0	Factor of 2	UK measurement (at storage)
Sheep manure management (FYM)	0.5	Factor of 2	IPCC 2006
Layer manure management	0.5	Factor of 2	UK measurement (at storage)
Broiler manure management	0.5	Factor of 2	UK measurement (at storage)
Ducks and geese manure management	2.0	Factor of 2	Based on cattle/pig
Turkeys manure management	0.5	Factor of 2	UK measurement (at storage)
Other poultry manure management	0.5	Factor of 2	UK measurement (at storage)
Goats, deer and horses manure management	2	Factor of 2	UK measurement (at storage)
Anaerobic digestion	0	N/A	IPCC 2006

A 3.3.3 Agricultural Soils (3D)

Table A 3.3.7 Other Organic N Fertilisers applied to soils – manure and non-manure based digestates

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
N input from manure based digestate applied to soils (kt N/y)	0	63,475	64,520	148,457	756,643	11,005,899	15,779,647	17,168,750	17,385,140	17,544,478
Direct N_2O emissions from manure based digestate applied to soils (kt N_2O/y)	0	0.00075	0.00076	0.00174	0.00889	0.12928	0.18535	0.20167	0.20421	0.20608
N input from crop based digestate applied to soils (kt/y)	0	1,112	1,112	1,707	838,782	12,493,523	16,693,671	18,506,294	18,611,062	18,611,038
Direct N_2O emissions from crop based digestate applied to soils (kt N_2O/y)	0	0.00002	0.00002	0.00003	0.01318	0.19633	0.26233	0.29081	0.29246	0.29246
N input from food based digestate applied to soils (kt/y)	0	0	0	894,125	3,690,375	16,380,615	20,965,615	23,479,365	23,854,365	24,479,330
Direct N_2O emissions from food based digestate applied to soils (kt N_2O/y)	0	0	0	0.01405	0.05799	0.25741	0.32946	0.36896	0.37485	0.38468
N input from other organic residue digestate applied to soils (kt N/y)	0	0	670	345,720	359,120	2,165,641	2,443,021	2,737,821	2,737,821	2,737,817
Direct N_2O emissions from other organic residue digestate applied to soils (kt N_2O/y)	0	0	0.00001	0.00543	0.00564	0.03403	0.03839	0.04302	0.04302	0.04302

A 3.3.3.1 Inorganic Fertiliser

Table A 3.3.8 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
Manure-based digestate	0.7475	SE 0.17328	Topp et al., 2016
Non-manure based digestate	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 - cropland	13 kg N_2O-N/ha	SE 2.5	2013 Supplement to IPCC 2006: Wetlands, Artz, R., 2019
Histosols – intensive grassland	5.69 kg N_2O-N/ha	SE 2.110	2013 Supplement to IPCC 2006: Wetlands, Artz, R., 2019
Cattle urine	0.629	SE 0.0930	Topp et al., 2016
Cattle dung	0.193	SE 0.0212	Topp et al., 2016
Sheep urine	0.315	SE 0.0658	Topp et al., 2016, IPCC 2019
Sheep dung	0.097	SE 0.0150	Topp et al., 2016, IPCC 2019
Goat, horse and deer urine	0.629	SE 0.0930	Topp et al., 2016

Emission source	EF (% of total N)	Uncertainty	Data source
Goat, horse and deer dung	0.193	SE 0.0212	Topp et al., 2016
Outdoor pig and poultry	2.0	0.7 – 6.0	IPCC 2006

Table A 3.3.9 Areas of UK Crops and quantities of fertiliser applied for 2019

Crop Type	Crop area, ha	Fertiliser, ktN	Crop Type	Crop area, ha	Fertiliser, ktN
Oats	149,598	15.7	Potatoes (maincrop)	119,755	15.8
Spring oats	21,905	1.7	Potatoes (seed or earlies)	24,310	3.1
Winter oats	10,014	0.8	Sugar beet	107,794	10.1
Spring barley	11,948	1.0	Maize	81,999	5.7
Spring barley (malting)	414,980	44.2	Grain maize	9,093	0.6
Spring barley (non-malting)	282,585	27.7	Forage maize	137,160	8.7
Winter barley	7,739	1.0	Rootcrops for stockfeed	40,432	3.1
Winter barley (malting)	78,857	10.6	Leafy forage crops	4,216	0.3
Winter barley (non-malting)	366,115	57.2	Other fodder crops	54,100	4.3
Wheat	8,104	1.2	Vegetables (not-differentiated)	1,480	0.1
Wheat (milling)	648,209	128.1	Vegetables (brassicas)	4,301	0.3
Wheat (non-milling)	1,159,454	201.4	Vegetables (legumes)	40,585	0.0
Minor cereals	51,351	5.5	Vegetables (other non-legumes)	70,857	5.6

Crop Type	Crop area, ha	Fertiliser, ktN	Crop Type	Crop area, ha	Fertiliser, ktN
Oilseed rape	5,765	1.0	Other horticultural crops	14,538	1.2
Spring oilseed rape	4,556	0.8	Soft Fruit	8,229	0.6
Winter oilseed rape	519,328	94.2	Top Fruit	23,809	1.7
Linseed	15,270	1.3	Miscanthus	8,171	0.0
Field beans (harvested dry)	136,493	0.1	Willow (short rotation coppice)	2,818	0.0
Field peas (harvested dry)	40,855	0.0	Other field crops	21,695	1.7
Fruit (mixed top & soft fruit)	11	0.0	Wine grapes	2,548	0.2
Permanent grass	6,206,957	310.2	Temporary grass	1,193,421	116.2

Table A 3.3.10 Trends in area grown (‘000 ha) and N fertiliser applied (kg/ha) for the major UK crops, 1990-2019

Year	Wheat ‘000 ha	Wheat kg/ha N	Spring barley ‘000 ha	Spring barley kg/ha N	Winter barley ‘000 ha	Winter barley kg/ha N	Main crop potatoes ‘000 ha	Main crop potatoes kg/ha N	Oilseed rape ‘000 ha	Oilseed rape kg/ha N	Grass leys (<5yrs) ‘000 ha	Grass leys (<5yrs) kg/ha N	Permanent grassland ‘000 ha	Permanent grassland kg/ha N
1990	2,014	183	635	90	882	140	148	184	390	225	1,606	166	5,316	108
1991	1,981	187	553	89	841	140	148	185	440	221	1,607	168	5,314	107
1992	2,067	185	515	89	784	141	151	175	421	196	1,582	157	5,266	95
1993	1,759	185	518	91	649	136	143	189	377	179	1,581	146	5,261	100
1994	1,811	186	481	94	627	143	138	191	404	179	1,455	170	5,375	110

Year	Wheat '000 ha	Wheat kg/ha N	Spring barley '000 ha	Spring barley kg/ha N	Winter barley '000 ha	Winter barley kg/ha N	Main crop potatoes '000 ha	Main crop potatoes kg/ha N	Oilseed rape '000 ha	Oilseed rape kg/ha N	Grass leys (<5yrs) '000 ha	Grass leys (<5yrs) kg/ha N	Permanent grassland '000 ha	Permanent grassland kg/ha N
1995	1,859	193	504	97	689	144	144	176	354	187	1,407	170	5,375	108
1996	1,977	185	519	93	749	140	149	171	356	190	1,393	166	5,338	105
1997	2,036	192	519	94	840	143	133	166	445	199	1,403	147	5,266	103
1998	2,045	182	484	91	769	135	131	186	506	192	1,302	156	5,365	99
1999	1,847	185	631	99	548	142	148	153	493	196	1,226	180	5,449	101
2000	2,086	188	539	106	589	146	138	157	393	189	1,226	142	5,363	90
2001	1,635	185	783	109	462	144	137	153	444	196	1,205	130	5,584	84
2002	1,996	189	555	110	546	150	129	152	436	194	1,243	135	5,519	77
2003	1,836	197	621	107	455	148	118	149	549	194	1,200	129	5,683	75
2004	1,990	190	587	101	420	144	121	164	498	171	1,246	117	5,620	71
2005	1,870	188	553	98	384	140	113	164	588	186	1,193	112	5,711	66
2006	1,836	181	494	100	388	134	117	142	568	178	1,137	106	5,967	60
2007	1,830	183	515	97	383	134	112	136	674	179	1,176	98	5,965	55
2008	2,080	179	616	92	416	134	114	150	598	180	1,141	91	6,036	44
2009	1,814	188	749	98	411	137	118	169	581	167	1,262	87	6,081	47
2010	1,939	192	539	96	382	140	114	137	642	186	1,231	100	5,925	53
2011	1,969	194	611	99	359	140	120	157	705	186	1,278	92	5,877	50

Year	Wheat '000 ha	Wheat kg/ha N	Spring barley '000 ha	Spring barley kg/ha N	Winter barley '000 ha	Winter barley kg/ha N	Main crop potatoes '000 ha	Main crop potatoes kg/ha N	Oilseed rape '000 ha	Oilseed rape kg/ha N	Grass leys (<5yrs) '000 ha	Grass leys (<5yrs) kg/ha N	Permanent grassland '000 ha	Permanent grassland kg/ha N
2012	1,992	194	618	99	385	144	123	141	756	183	1,357	92	5,799	50
2013	1,615	183	903	108	310	143	114	160	715	149	1,390	96	5,802	54
2014	1,936	192	651	108	429	145	115	149	675	186	1,396	101	5,824	51
2015	1,832	193	659	105	442	148	105	162	652	190	1,167	96	6,078	49
2016	1,823	189	683	107	439	147	114	141	579	182	1,144	92	6,118	49
2017	1,792	183	754	104	423	154	121	134	562	182	1,144	98	6,135	49
2018	1,748	186	751	106	387	158	117	137	583	187	1,152	94	6,178	51
2019	1,816	182	710	103	453	152	120	132	530	181	1,193	97	6,207	50

A 3.3.3.2 Crop Residues

Table A 3.3.11 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

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
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

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
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
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 3.3.12 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

Crop	Below Ground N, kg N/[t DM]	Crop Residue Above Ground N, kg N/[t DM]
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
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

Crop	Below Ground N, kg N/[t DM]	Crop Residue Above Ground N, kg N/[t DM]
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 3.3.3.3 Mineralisation

Table A 3.3.13 Mineralised N from soils

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
N in mineral soils that is mineralised as a result of historical land use change to Cropland (kt N/y)	42.27	45.98	52.97	72.35	83.29	79.97	79.41	78.89	78.40	77.94
N in mineral soils that is mineralised as a result of Cropland Management (kt N/y)	0.047	0.073	0.061	0.062	0.055	0.057	0.047	0.056	0.061	0.163
Direct N_2O emisions from mineralised N as a result of historical land use change to Cropland, kt N_2O/y	0.66	0.72	0.83	1.14	1.31	1.26	1.25	1.24	1.23	1.22
Direct N_2O emisions from mineralised N as a result of Cropland Management, kt N_2O/y	0.0007	0.0011	0.0010	0.0010	0.0009	0.0009	0.0007	0.0009	0.0010	0.0026
Indirect N_2O emisions from mineralised N as a result of historical land use change to Cropland and Cropland management (kt N_2O/y)	0.15	0.16	0.19	0.26	0.29	0.28	0.28	0.28	0.28	0.28
Total N_2O emissions from Mineralisation (kt N_2O/y)	0.81	0.89	1.02	1.39	1.60	1.54	1.53	1.52	1.51	1.50

A 3.3.3.4 Histosols

Table A 3.3.14 N_2O emissions from drained organic soils

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Area of histosols - Cropland (ha)	197,152	196,353	195,528	193,715	192,086	190,720	190,460	190,201	189,941	189,681
Area of histosols - Intensive grassland (ha)	184,576	182,045	179,930	176,851	174,533	173,154	172,919	172,684	172,449	172,180
Direct N_2O emisions from histosols - Cropland, kt N_2O/y	4.03	4.01	3.99	3.96	3.92	3.90	3.89	3.89	3.88	3.87
Direct N_2O emisions from histosols – Intensive grassland, kt N_2O/y	1.65	1.63	1.61	1.58	1.56	1.55	1.55	1.55	1.54	1.54
Total N_2O emissions from histosols (kt N/y)	5.68	5.64	5.60	5.54	5.49	5.45	5.44	5.43	5.42	5.42

A 3.3.3.5 Atmospheric deposition of NO_x and NH_3

Table A 3.3.15 Amount of N that is volatilized from agricultural inputs and associated N_2O emissions

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Amount of volatilized N, kg/yr	142,502,950	127,412,437	122,746,172	112,957,859	110,823,427	122,732,021	126,290,610	126,177,055	126,552,434	124,519,915
Total N_2O emissions from volatilized N (kt N_2O/y)	2.24	2.00	1.93	1.78	1.74	1.93	1.98	1.98	1.99	1.96

A 3.3.3.6 Leaching and runoff

Table A 3.3.16 Amount of N fertilizers and other agricultural inputs that is lost through leaching and run-off and associated N_2O emissions

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Amount of N lost through leaching and runoff, kg/yr	534,158,821	509,445,703	513,993,232	491,023,427	480,837,461	498,768,373	488,538,691	503,639,751	495,826,932	502,759,851
Total N_2O emissions from N lost through leaching and runoff (kt N_2O/y)	6.30	6.00	6.06	5.79	5.67	5.88	5.76	5.94	5.84	5.93

A 3.3.4 Liming

Table A 3.3.17 Amount of limestone and dolomite applied to soils and associated CO_2 emissions

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Amount of limestone applied to soils, t/yr	1,648,058	1,614,700	983,011	2,704,048	2,204,136	1,739,412	1,748,314	1,819,942	1,986,206	2,601,344
Amount of dolomite applied to soils, t/yr	606,060	760,435	417,588	450,782	438,307	342,579	330,597	285,101	381,789	348,154
Total CO_2 emissions from application of limestone (kt CO_2/y)	725	710	433	1190	970	765	769	801	874	1145
Total CO_2 emissions from application of dolomite (kt CO_2/y)	289	362	199	215	209	163	158	136	182	166

A 3.3.5 Urea application

Table A 3.3.18 Amount of urea applied to soils and associated CO_2 emissions

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Amount of urea applied to soils, t/yr	445,701	202,979	180,943	221,652	322,576	451,634	466,735	412,433	405,181	433,451
Total CO_2 emissions from application of urea (kt CO_2/y)	327	149	133	163	237	331	342	302	297	318

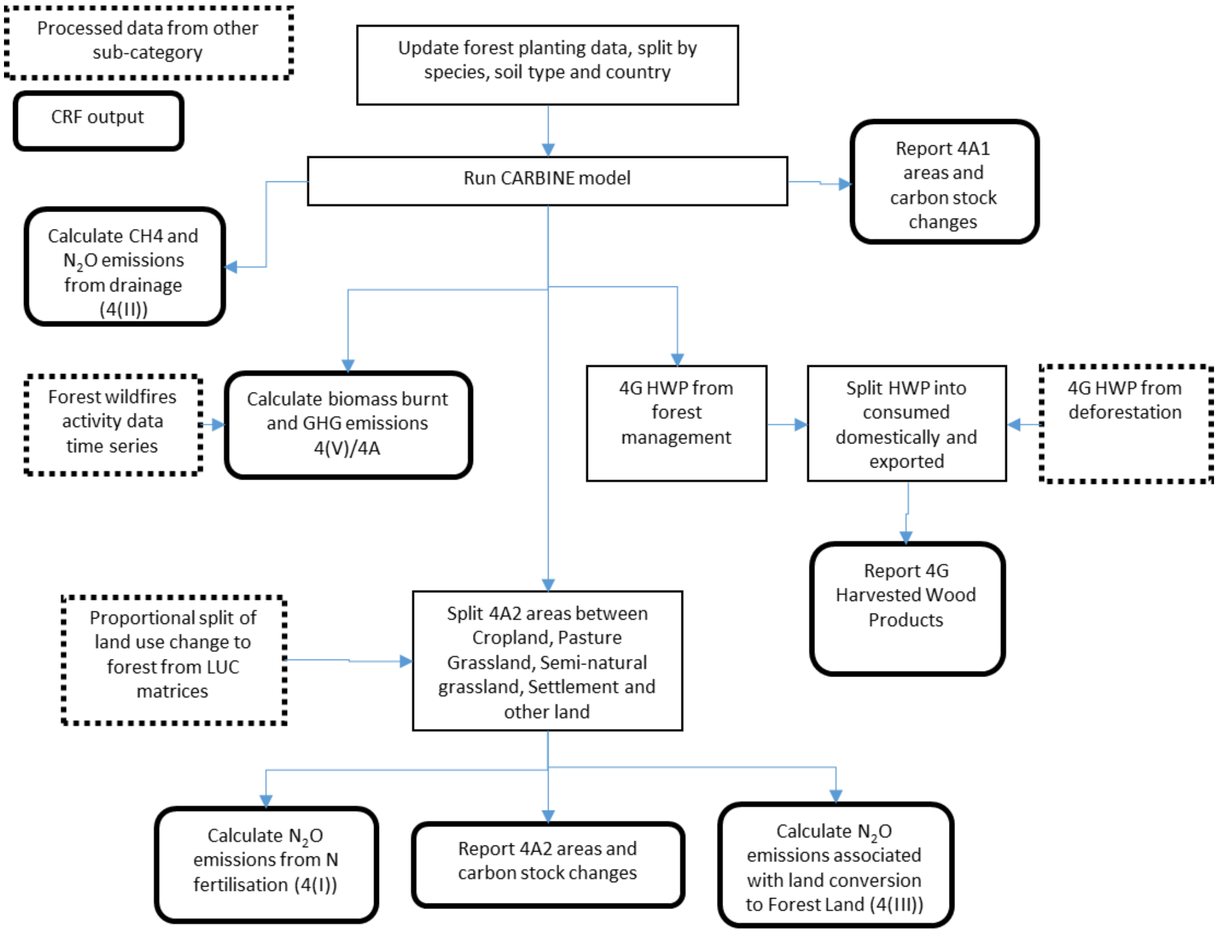
A 3.4 LAND USE, LAND USE CHANGE AND FORESTRY (CRF SECTOR 4)

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

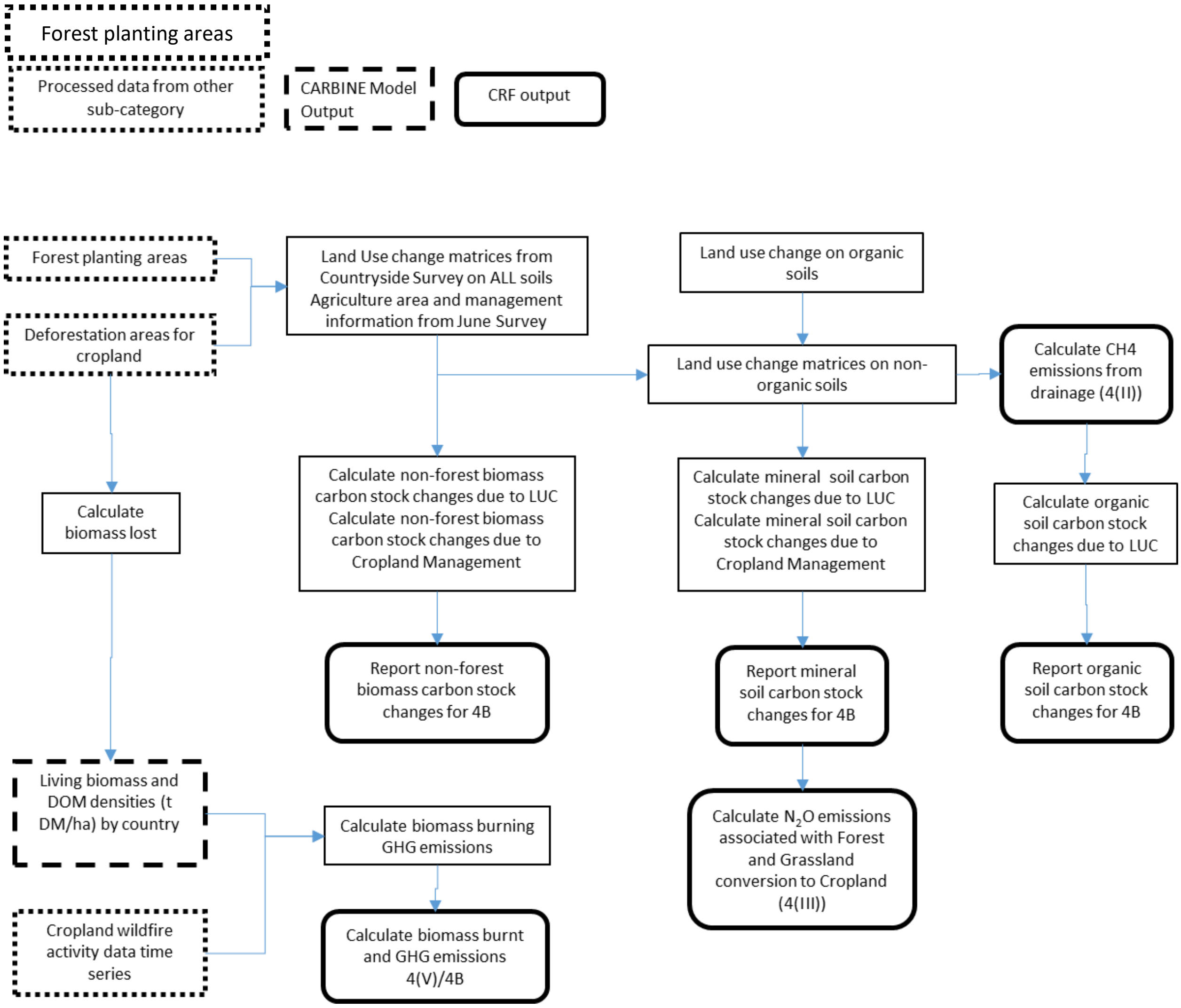
The flow chart below shows the interrelationships between different data sources and the main calculation steps.

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

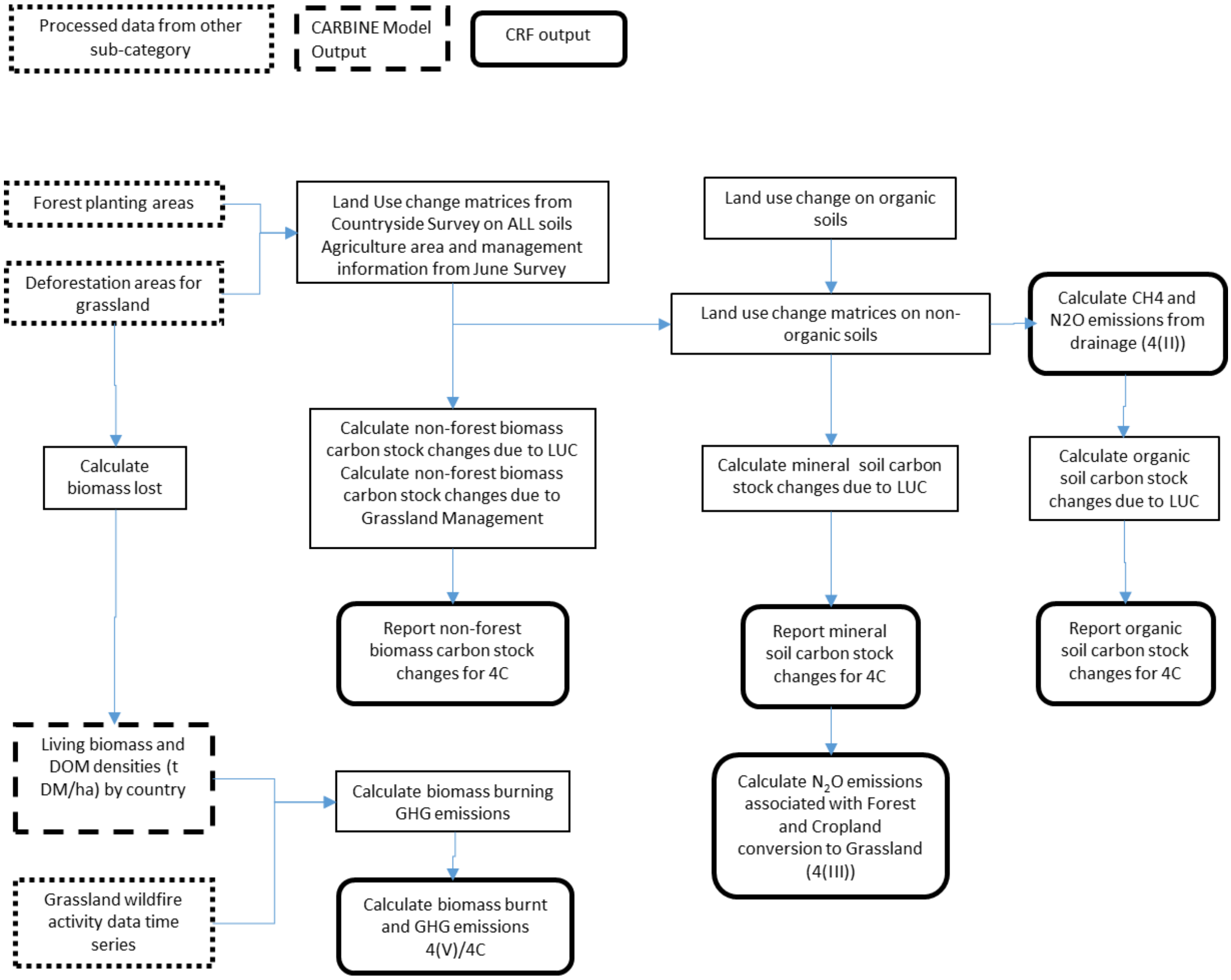
(i) 4A Forest Land and 4G Harvested Wood product data flows



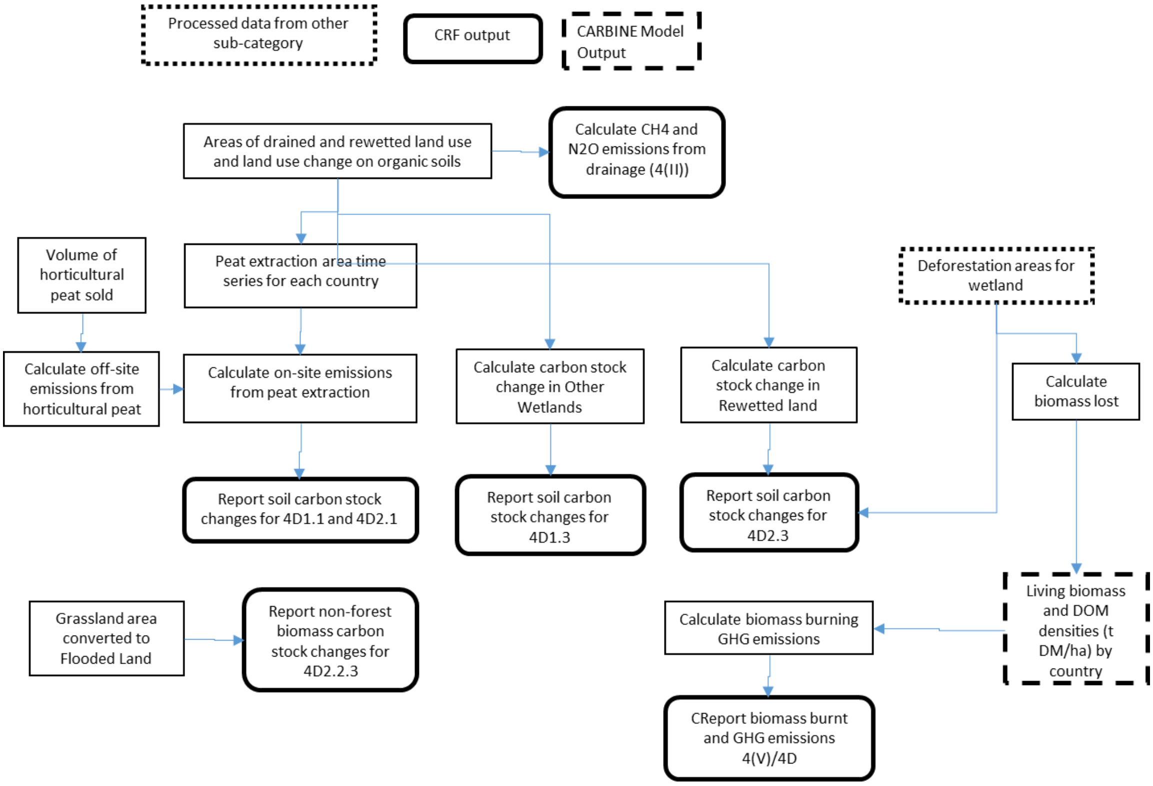
(ii) 4B Cropland data flows



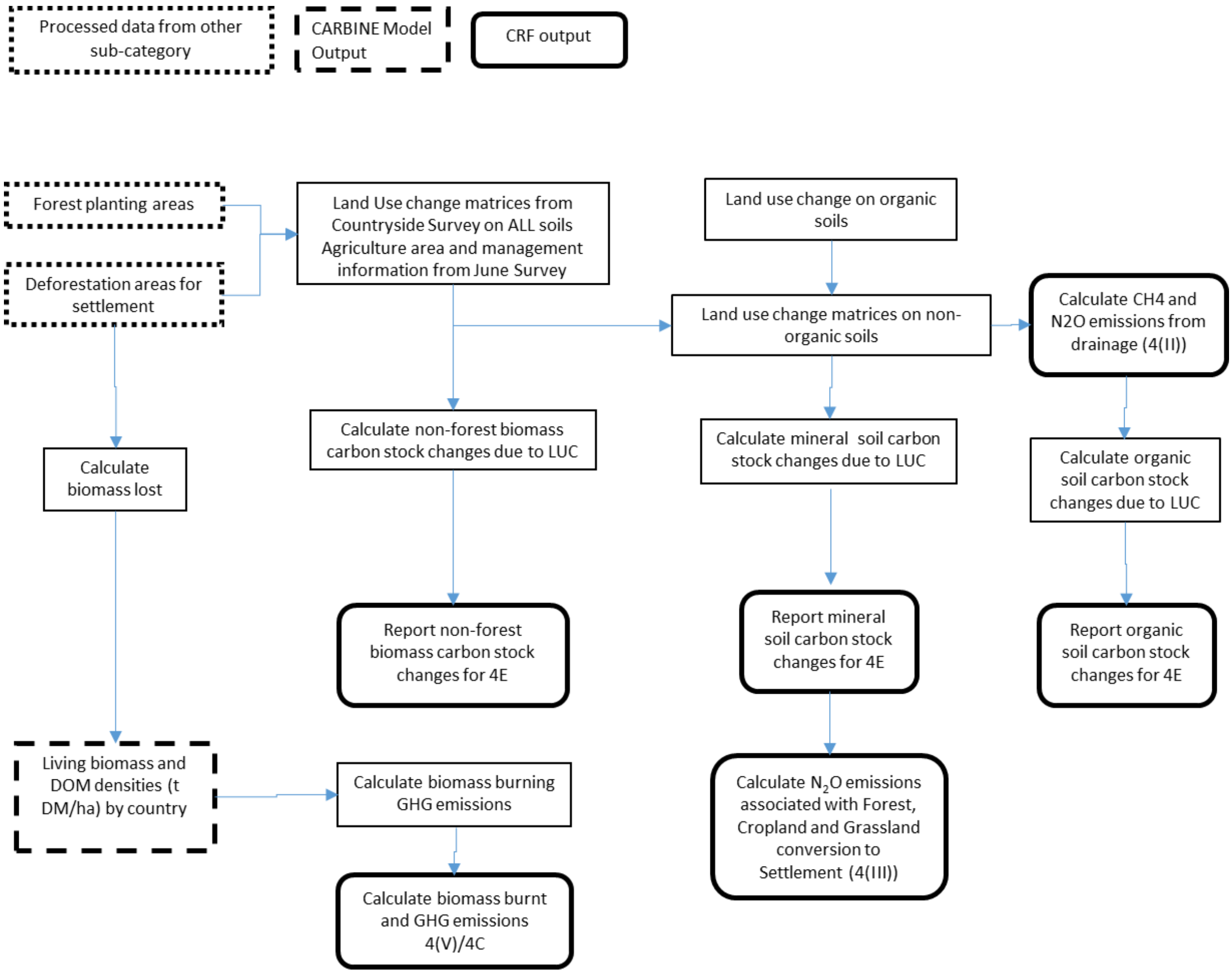
(iii) 4C Grassland data flows



(iv) 4D Wetlands data flows



(v) 4E Settlements 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). **Annex A 3.4.1.2** demonstrates how the use of this model complies with IPCC good practice criteria for the use tier 3 models.

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.

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.

A 3.4.1.1.1 Carbon in forest biomass

The main driving module of CARBINE consists of a set of computerised mathematical functions and algorithms describing the accumulation (and loss) of carbon in tree biomass of different forestry systems at the per-hectare scale. Different functions and algorithms are used to represent distinct forestry systems, defined in terms of:

- Tree species composition
- Tree growth rate (yield class)
- Management regime applied.

The tree species and growth rates represented are based on yield models originally produced by the British Forestry Commission (Matthews et al., 2016a, 2016b). The tree species covered include examples for coniferous species of spruces, pines, firs, larches, cedars, cypresses and all the major temperate and boreal broadleaf tree species. Growth rates in terms of mean annual increment (MAI) of stem volume can be represented in the range from 2 m^3 ha^{-1} yr^{-1} up to 30 m^3 ha^{-1} yr^{-1}.

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 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 (years)	20
Age at first thinning (years)	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

A 3.4.1.1.2 Dead wood and litter

CARBINE includes a sub-model for representing accumulation and loss of carbon in dead wood and litter. Inputs of litter are related to the standing biomass of trees and also to rates of tree mortality. Levels of tree mortality are represented implicitly in the standard Forestry Commission growth models, and explicit estimates are included in models for stands subject to no thinning, where mortality levels are high. Root and branch wood volume associated with dead trees is estimated in the same way as for living stemwood, by reference to allometric relationships. Deadwood and litter are assumed to decay according to a first order process, with rate constants that are normally set to be consistent with boreal and temperate conditions but can be adjusted for Mediterranean and tropical conditions. 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 accurate 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 Annual Turnover Rate (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.

A 3.4.1.1.3 Soil carbon

The new CARBINE Soil Carbon Accounting model (SCOTIA, formerly referred to as 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:

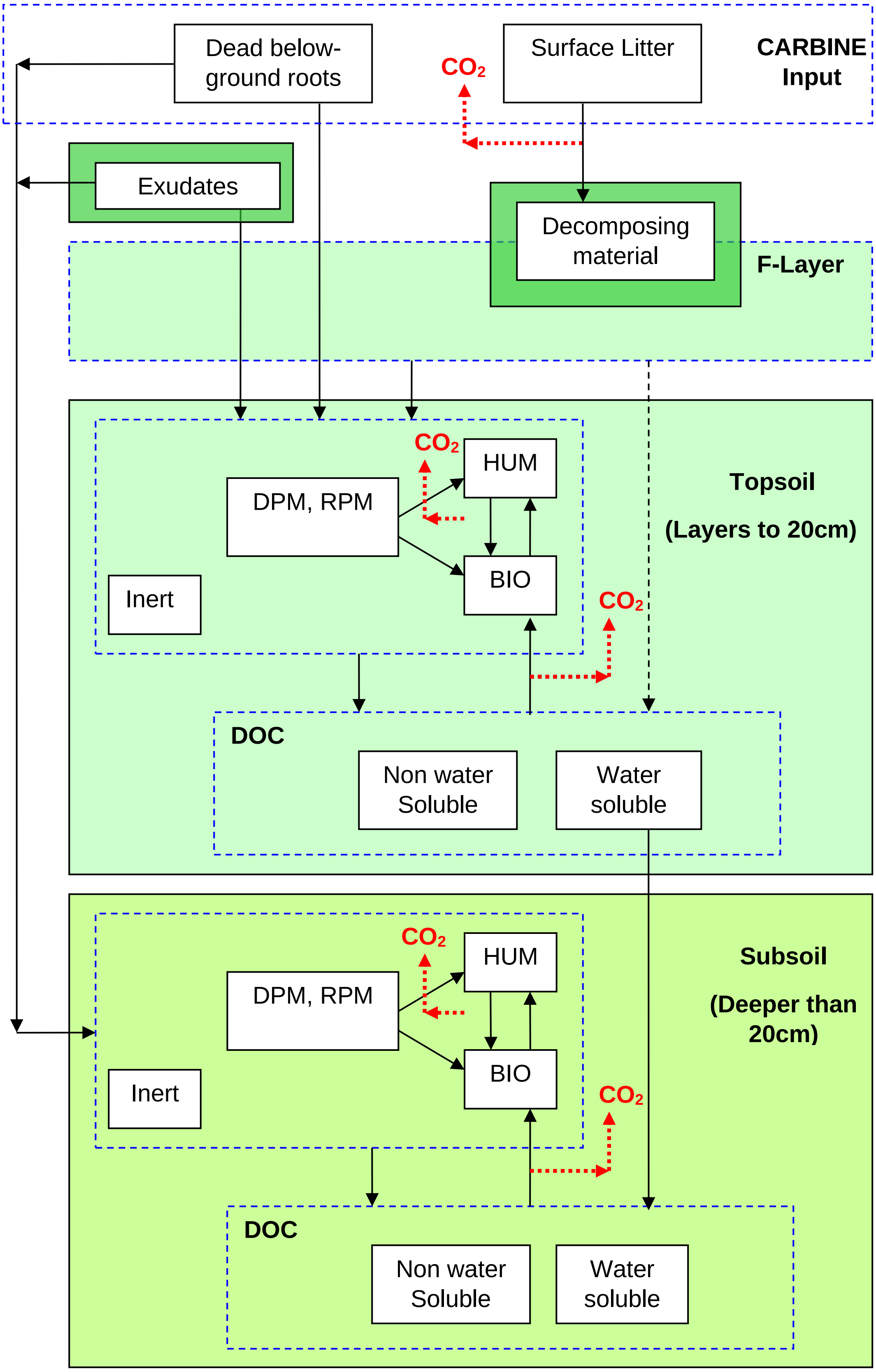
- Recently dead root material (according to a rooting profile depth),
- Transfer from the F-material arising from the decomposition of above-ground litter,
- Secretions and exudates from the roots,
- DOC; this carbon can become available to the biological pool and enter the ‘reactive material cycle’.

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).

An improved version of the soil sub-model was implemented for the 1990-2016 inventory. This included work on parameterisation 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. after an initial year of clearance of vegetation on planting.

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

Figure A 3.2 The CARBINE SCOTIA model



A 3.4.1.1.4 Harvested Wood Products

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 Alignment of CARBINE to the IPCC suggestions for "Use of Models in Good Practice National Greenhouse Gas Inventories"

The IPCC has published suggestions on the approach to implementing good practice in the use of models[8] in national GHG inventories. These suggestions are provided in "*Use of Models and Facility-Level Data in Greenhouse Gas Inventories. Report of the IPCC Expert Meeting on Use of Models and Measurements in GHG Inventories, 9-11 August 2010, Sydney, Australia*". Chapter 3 provides a bullet point list of the key elements of a model that can be used to guide the description provided by inventory compilers of the modelling approach they use. Providing this detail increases the transparency of the methodological description.

Table A 3.4.2 is based on this bullet point list, and summarises the methodological approaches used in CARBINE for each of the elements, or criteria, and provides references to where further information can be found.

Table A 3.4.2 Compliance of the CARBINE model with the IPCC criteria on the use of models

Criteria (or element)	Reference to documentation
Basis and type of model	**Summary** Carbon change in the forests of the UK (meeting the UK definition of forest for inventory purposes) is calculated by a carbon accounting model, CARBINE, as the sum of gains and losses in pools of carbon in vegetation, 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). **References** • UK NIR: Annex 3.4.1. Carbon stock changes due to afforestation and forest management (4A); Section 6.2. CATEGORY 4A – FOREST LAND; Section 6.8. CATEGORY 4G – HARVESTED WOOD PRODUCTS • Matthews et al. (in prep). The CARBINE model. A technical description Chapter 2. Modelling purpose and scope

[8] In the application of models in National Greenhouse Gas Inventories, critical issues are suitability, parameterization, calibration, evaluation, and uncertainty.

Criteria (or element)	Reference to documentation
Application and adaptation of model (*description of why and how the model was adapted for conditions outside the originally intended domain of application*)	**Summary** The CARBINE model was first developed by the then Research Division of the Forestry Commission in 1988 (Thompson and Matthews, 1989), now Forest Research. It is built around the stand level M1 growth and yield model which is based on yield tables published in the early 80s (see Arcangeli and Matthews). The general purpose of the CARBINE model is to address questions about the carbon and GHG balances of forestry systems, and to inform the development of forest policy and practice, particularly regarding the goal of climate change mitigation. It was adapted for use specifically with the UK GHG inventory and first used in the GHG inventory submitted in 2014. The UK replaced the C-FLOW model with CARBINE because CARBINE has several advantages which allows it to more accurately estimate GHG emissions and removals. CARBINE can model a more diverse range of species and forest management practices, and model complex changes or trends in forest management over time. It also addresses a key limitation of C-FLOW, which assumed that forests planted prior to 1921 were at carbon equilibrium. 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. The growth conditions of forests represented by CARBINE are principally of relevance to UK forest conditions. The CARBINE model is not operating outside its originally intended domain of application. **References** • UK NIR. Annex 3.4.1. Carbon stock changes due to afforestation and forest management (4A); Section 6.2. CATEGORY 4A – FOREST LAND; 6.8 CATEGORY 4G – HARVESTED WOOD PRODUCTS • Matthews et al. (in prep). The CARBINE model. A technical description. Chapter 2. Modelling purpose and scope • Thompson, D.A., Matthews, R.W., 1989. The storage of carbon in trees and timber. Forestry Commission Research Information Note 160. Forestry Commission: Edinburgh • Matthews, R., Malcolm, H., Buys, G., Henshall, P., Moxley, J., Morris, A. and Mackie, E. (2014) Changes to the representation of Forest Land and associated land-use changes in the 1990-2012 UK Greenhouse Gas Inventory. Forest Research and Centre for Ecology and Hydrology (DECC Contract GA0510, UKCEH Contract no. NEC0376)
Main equations / processes	**Summary** The CARBINE model is a complex model, with several sub models. These sub-models include: forest carbon sub-model, soil sub-model, SCOTIA, and wood products sub-model. The forest carbon and soil sub-models are used in the GHG inventory and the latest UK NIR provides a summary of CARBINE model. Forest Research are working on a report which documents the methods employed in the implementation of the CARBINE forest sector carbon accounting model. The report includes model equations, parameters, assumptions, verification and supporting scientific evidence, where available. Figure 2.2 in that report presents a schematic representation of the structure and components of CARBINE. **References** • Matthews et al. (in prep). The CARBINE model. A technical description. Chapter 3. Representation of forest stands; to; Chapter 4. Representation of harvested wood products; and; Annex 1. Detailed soil carbon model description • UK NIR: Annex 3.4.1. Carbon stock changes due to afforestation and forest management (4A)

Key assumptions (*important assumptions made in developing and applying the model*)	**Summary** The CARBINE model is a complex model, and only a summary of the key assumptions can be given here. A key concept of the methodology underlying the CARBINE model is that net exchanges of carbon between forest pools (trees, deadwood, litter and soil) and related pools (deforestation, HWP) can be inferred from the changes in the carbon stocks of these individual pools. The section numbers in the description below refer to the sections in Matthews et al. *The CARBINE model. A technical description*: **3.1. Stand volume growth.** The main assumption is that all types of forests and management in the UK can be represented by the FC yield models – including by assuming that species not covered by the UK yield tables can be mapped to a species for which a model is available. Immediate restocking is assumed in all forests. **3.2. Stand stem biomass and carbon.** The key assumption is that stem merchantable biomass can be calculated from stem volume from the yield tables using a species-specific stem density and a country-specific estimate of carbon content for all wood (50%) **3.3. Stand tree biomass and carbon.** The key assumption is that the stem biomass can be converted to whole tree biomass using biomass expansion factors for branches, leaves, coarse roots and fine roots. **3.4. Stand management.** Forest stand management is represented by four broad prescriptions: 1) No thinning and no felling (i.e. effectively no management for production); 2) Clear-felling on a specified rotation without thinning; 3) Thinning with clear-felling on a specified rotation; 4) 'Continuous cover' silviculture (i.e. woodland management with harvesting based on thinning only, that also aims to always maintain tree cover on the land). **3.5. Stand disturbance events.** The key assumption for the inventory is that there will be no mortality beyond the normal senescence of part of tree and within stand competition as predicted by the yield model as calibrated on the permanent sample plots. Supplementary calculations are carried out for the purposes of reporting relevant GHG emissions as part of GHG inventories for disturbances from fires on Forest Land. **3.6. Tree harvesting in stands.** The assumption is that the harvesting is as modelled in the yield tables and that only certain parts of the tree are removed – i.e. there is no whole-tree harvesting. **3.7. Losses of carbon from parts of living trees through senescence.** The key assumptions are that deadwood and litter inputs in the form of losses of branches and foliage from living trees can be modelled by annual turnover rates and that these losses will be replaced (i.e. that the relationships between the carbon in the different compartments implied by the biomass expansion factors still holds). **3.8. Stand deadwood and litter accumulation.** Carbon enters the deadwood and litter pools through several processes: • Losses of biomass from the senescence of parts of growing trees (Section 3.7) • Mortality of trees as a result of stand competition (Sections 3.2 and 3.3) • Mortality of trees as a result of stand natural disturbance (Section 3.5) • Tree biomass discarded in the forest during harvesting operations (Section 3.6). Carbon is lost from the deadwood and litter pools through decomposition. **3.10. Soil carbon (including fermenting material).** That the soil carbon and fermenting material can be represented using an "ECOSSE-style model". This model, called SCOTIA, was developed to allow full representation of UK specific conditions, including both mineral and organic soils.

Criteria (or element)	Reference to documentation
	4.1. Representation of Harvest Wood Products. While a more disaggregated description of HWP is available in CARBINE, for the purpose of the Convention and Kyoto Protocol reporting, wood products are grouped in a more limited set of semi-finished product categories consistent with the IPCC guidelines and modelled using first order decay functions and product half-lives specified as part of Tier 1 methods in the IPCC good practice guidance. The summary above of the key assumptions increases the transparency of the of the CARBINE model. **References** • Matthews et al. (in prep). The CARBINE model. A technical description. Chapter 3. Representation of forest stands; to; Chapter 4. Representation of harvested wood products • UK NIR: Annex 3.4.1. Carbon stock changes due to afforestation and forest management (4A)
Domain of application (*description of the range of conditions for which the model has been developed to apply*)	**Summary** A version of CARBINE has been specifically developed for the UK GHG inventory. In principle, the M1 forest growth model that underlies CARBINE permits a very wide range of possible stand management regimes to be represented. However, when modelling UK forests at national scale, forest stand management are represented by four broad prescriptions types and a range of rotation length (see Annex 3 of the National Forestry Accounting Plan). **References** • Matthews et al. (in prep). The CARBINE model. A technical description. Chapter 2. Modelling purpose and scope • UK National Forestry Accounting Plan, 2021 to 2025 (2019) Annex 3. https://www.gov.uk/government/publications/uk-national-forestry-accounting-plan-2021-to-2025
How the model parameters were estimated	Many of the parameters in CARBINE are based on literature reviews and the key parameters are described in the report describing CARBINE. **References** • Matthews et al. (in prep). The CARBINE model. A technical description. Chapter 2. Modelling purpose and scope. • Lavers, G.M. and Moore, G.L. (1983) The strength properties of timber. Building Research Establishment Report CI/SFB I(J3). Building Research Establishment, Garston • Levy, P.E., Hale, S.E. and Nicoll, B.C. (2004) Biomass expansion factors and root:shoot ratios for coniferous tree species in Great Britain. Forestry, 77, 421-430.

Criteria (or element)	Reference to documentation
Description of key inputs and outputs	**Summary** Inputs: CARBINE uses a wide range of input data – see above for a description of these. The main input data are, inter alia, 1) information on the growth of stem wood volume in different stands of trees from the M1 growth model; 2) standard estimates for wood density (see Table 3.2 in Matthews et al.) and wood carbon content (0.5 t C odt^{-1}); 3) management practices; 4) soil turnover rates; 5) decomposition rates of active soil pools to DOC, 6) occurrence of land use changes over time. Outputs: All the data necessary for the reporting of forest land inventory: gains and losses in pools of carbon in standing trees, litter and soil in conifer and broadleaf forests and in harvested wood products and forest. Gains and losses in forest soils are also estimated. References • Matthews et al. (in prep). The CARBINE model. A technical description. Chapter 3. Representation of forest stands; to; Chapter 4. Representation of harvested wood products; and; Annex 1. Detailed soil carbon model description
Details of calibration and model evaluation	**Summary** **CARBINE (excluding soil carbon):** In 2003, Robertson *et al*. undertook a study to evaluate the completeness and suitability of the C-FLOW and CARBINE models for estimating carbon stocks and potential stock changes in the forestry sector at the stand and national levels, and the reliability of underpinning data and parameter estimates used by C-FLOW and CARBINE. Based on the results considered, Robertson et al. concluded that, while there may be some issues to address with regard to some inaccuracies in predictions of tree carbon stocks made by both CARBINE and C-FLOW, such model predictions are reasonably accurate. Although the analysis of Robertson et al. can only be regarded as an initial investigation, the results indicated that the accuracy of predictions made by both models is well within short-term fluctuations observed for individual stands (±10%). A more recent verification of the growth model M1 underpinning CARBINE started in 2017 has also confirmed that the growth model displayed good to reasonable consistency with growth trend data collected in sample plots. For some tree species, evidence of deviations in growth trends at older stand ages. This included Sitka spruce, but beyond the ages of conventional forest rotations. A programme to refine existing growth models is in progress. Significant work already done (new growth curves calibrated). The aspiration is to integrate the new growth models into CARBINE once fully tested. This is discussed in the report describing CARBINE. **SCOTIA (soil sub-model in CARBINE):** The work done to confirm the suitability of the soil carbon sub-model, SCOTIA, for use in the UK GHG inventory is explained in detail in a report in preparation. The work presents the evidence that the estimates of soil carbon stocks and stock changes produced by the SCOTIA model are consistent with available field observations. **References** • Matthews et al. (in prep). The CARBINE model. A technical description. Section 8.2.5. Long-term trajectories • Matthews et al. (in prep). SCOTIA forest soil carbon model: Interim progress report on comparison of model estimates and measurements of soil carbon stocks and fluxes • Robertson *et al* . (2003). Evaluation of the C-FLOW and CARBINE carbon accounting models. Section 3 of UK Emissions by Sources and Removals by Sinks due to Land Use, Land Use Change and Forestry Activities (2003) (https://www.semanticscholar.org/paper/Comparison-of-the-CFLOW-and-CARBINE-carbon-models-Robertson-Ford-Robertson/22f909599387970eef6b61ff7057151f4b86d76e)

Criteria (or element)	Reference to documentation
QA/QC procedures adopted (including verification and model intercomparison)	**Summary** The QA/QC procedures used in the forest land inventory are summarised in this NIR: • Section 6.2.6. Category-Specific QA/QC and Verification (CATEGORY 4A – FOREST LAND) • Section 6.8.4. Category-Specific QA/QC and Verification (CATEGORY 4G – HARVESTED WOOD PRODUCTS) • Section 6.10. GENERAL COMMENTS ON QA/QC. There is a detailed QA/QC plan for the forest land inventory, which is described in Henshall (2018). Chapter 8 of the CARBINE description report presents some comparisons of parameters referred to in the CARBINE model with standard estimates for these parameters from scientific literature, where relevant, and with any published parameter estimates of particular relevance to UK conditions. The SCOTIA report provides a detailed comparison of the CARBINE SCOTIA soil carbon sub-model estimates and measurements of soil carbon stocks and fluxes. **References** • Matthews et al. (in prep). The CARBINE model. A technical description. Chapter 8. Comparisons with standard parameters and estimates • Matthews et al. (in prep). SCOTIA forest soil carbon model: Interim progress report on comparison of model estimates and measurements of soil carbon stocks and fluxes • Henshall (2018). UK Greenhouse Gas Inventory LULUCF Sector Forest Land QA Plan. Paul Henshall. Forest Research

Criteria (or element)	Reference to documentation
References to peer-reviewed literature	There are several papers describing the C-FLOW model which follows the same theory of combining the FC yield tables with biomass expansion factors and a soil and litter model. There are also non-journal publications that have been reviewed by peers. **Peer reviewed journal publications** • Cannell, M.G.R., Dewar, R.C. (1995). The carbon sink provided by plantation forests and their products in Britain. Forestry 68, 35–48. doi: https://doi.org/10.1093/forestry/68.1.35 • Dewar, R.C. (1990). A model of carbon storage in forests and forest products. Tree Physiol. 6, 417–28 • Dewar, R.C. (1991). Analytical model of carbon storage in the trees, soils, and wood products of managed forests. Tree Physiol. 8, 239–258 • Dewar, Roderick & Cannell, M. (1992). Carbon sequestration in the trees, products and soils of forest plantations: An analysis using UK examples. Tree physiology. 11. 49-71. 10.1093/treephys/11.1.49. **Non- journal publications** • Matthews, R.W. (1996). The influence of carbon budget methodology on assessments of the impacts of forest management on the carbon balance, in: Apps, M.J., Price, D.T. (Eds.), Forest Ecosystems, Forest Management and the Global Carbon Cycle. Springer-Verlag, Berlin, New York, pp. 233–243. • Matthews, R.W. (1994). Towards a methodology for the evaluation of the carbon budget of forests. In: Kanninen, M. (Ed.), Carbon Balance of the World’s Forested Ecosystems: Towards a Global Assessment. Proceedings of a Workshop Held by the Intergovernmental Panel on Climate Change AFOS, Joensuu, Finland, 11-15 May 1992. Painatuskeskus, Helsinki, pp. 105–114. • Matthews, R.W. (1992). Forests and arable energy crops in Britain: can they stop global warming? In: Richards, G.E. (Ed.), Wood: Fuel for Thought. Harwell, pp. 39-62. • Matthews, R.W. (1991). Biomass production and carbon storage by British forests. In: Aldhous, J.R. (Ed.), Wood for Energy?: The Implications for Harvesting, Utilisation and Marketing?: Proceedings - 1991 Discussion Meeting. Institute of Chartered Foresters, Edinburgh, pp. 162-177.

A 3.4.1.3 Forest activity data: management

The activity data for forests comes from different data sources for the public and private forest estates. The public forest estate is as defined in Forestry Statistics and covers the woodland that used to be managed by the Forestry Commission (FC) in Great Britain and that managed by the Northern Ireland Forest Service (NIFS). The public forest estate in Great Britain is now managed by separate organisations in England (Forestry England (FE)), Scotland (Forestry and Land Scotland (FLS)) and Wales (Natural Resources Wales (NRW)). The private forest estate covers all other woodland, including areas of forest managed by local authorities and other public bodies.

Each organisation maintains a Sub-Compartment DataBase (SCDB), containing information on location, size, species, growth rate and management of the forests. Information from the SCDB) was used to create a distribution of species and yield class (an indication of growth rate) for the public forest estate. For the private forest estate, information from the National Forest Inventory (NFI) survey of woodlands was analysed to estimate yield class and species by age class and scaled to represent the whole private forest estate. Data from the Forestry Commission’s new planting and wood production statistics were used to assign the areas in an age class to individual years, either as areas restocked or areas newly planted.

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. The area of land felled each year was estimated from the wood production statistics separately for both public and private forests. The rotation periods for forests were estimated based on information on the intended management of the public estate. This analysis gave a target rotation period for each modelled species and yield class.

The actual rotations historically applied to the forest estate are unknown and for the private forests the area of woodland used for timber production is also unknown. In order to match production, given the age class distribution of the forest, an algorithm was implemented to adjust the assumed rotations and the percentage of private sector woodland not used for timber production. This algorithm adjusts these assumptions in order to match the modelled wood production with the timber production statistics separately for the public and private forests. It was assumed that the forests would be felled evenly over a period +/-7 years from the target rotation period. A comprehensive description of this algorithm will be presented in a separate technical report.

Information on the management of privately owned forests that is used to inform the inventory estimates, as well as a description of how forest land AD (forest land remaining forest land; land converted to forest land) are derived, is included in the UK National Forest Accounting Plan, which can be found at:

https://www.gov.uk/government/publications/uk-national-forestry-accounting-plan-2021-to-2025

A 3.4.1.4 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 NFI provides woodland statistics for Great Britain, (England, Wales and Scotland), broken down by region. 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 private forest area for a base year of 2011, and the SCDB gives a distribution of all the public 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[9], 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)[10], which mapped all woodland polygons in Scotland down to 0.1 hectares in size

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

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

by photographic interpretation. The areas of small woods used in this inventory were based on data published in 2017 by the Forestry Commission in the report "Tree cover outside woodland in Great Britain"[11].

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 in order to reach a state consistent with land that has been forest for a long period. This algorithm will be described in detail in the same technical report as the description of allocation of the management of forests.

As part of implementation of wetland drainage and rewetting accounting, new maps of peat soils have been created for each of the DAs (see section A 3.4.6.1). These maps were combined with a forest map to give areas of conifer and broadleaf forests planted on organic soils for each DA. These total areas were assigned to individual afforestation years by adjusting the previously applied the distribution of organic soil areas and an analysis of recent grant-aided new planting on organic soils and implementation of policies against planting on organic soils in each of the DAs.

As explained above, the planting rates given in **Table A 3.4.3** 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 3.4.3** 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 3.4.3.**

Table A 3.4.3 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	Conifers on all soil types	Conifers on organic soil	Broadleaves on all soil types	Broadleaves on organic soils
1501-1600	0.00	0.00	0.33	0.00
1601-1700	0.06	0.00	0.63	0.00
1701-1750	0.13	0.00	1.52	0.00
1751-1800	0.44	0.00	1.30	0.00
1801-1850	1.34	0.00	0.75	0.00
1851-1900	4.64	0.54	0.94	0.02
1901-1910	4.45	0.78	9.17	0.19
1911-1920	3.07	0.51	11.14	0.25

[11] https://www.forestresearch.gov.uk/tools-and-resources/national-forest-inventory/what-our-woodlands-and-tree-cover-outside-woodlands-are-like-today-8211-nfi-inventory-reports-and-woodland-map-reports/

Period	Conifers on all soil types	Conifers on organic soil	Broadleaves on all soil types	Broadleaves on organic soils
1921-1930	3.43	0.60	13.02	0.35
1931-1940	4.61	0.81	13.80	0.49
1941-1950	7.84	1.94	16.75	0.78
1951-1960	17.24	4.83	17.94	1.03
1961-1970	21.03	6.77	19.49	1.21
1971-1980	28.24	10.43	13.25	0.91
1981-1990	20.73	7.35	15.70	0.94
1991	13.08	4.30	12.08	0.67
1992	1.43	3.66	13.86	0.78
1993	9.11	2.83	17.04	0.94
1994	9.85	3.16	18.11	1.02
1995	8.87	2.79	15.55	0.83
1996	8.57	2.60	15.13	0.80
1997	8.03	2.32	15.05	0.77
1998	7.44	2.05	15.71	0.77
1999	7.23	1.90	16.56	0.79
2000	5.87	1.47	18.46	0.90
2001	7.39	1.74	14.92	0.79
2002	6.99	1.57	14.18	0.67
2003	6.36	1.38	12.79	0.58
2004	8.91	1.63	12.86	0.49
2005	7.41	1.25	11.76	0.47
2006	8.25	1.31	12.06	0.48
2007	7.43	1.06	9.68	0.41
2008	7.03	0.90	7.53	0.28
2009	6.67	0.72	7.15	0.21
2010	8.32	0.81	9.19	0.24
2011	11.16	0.73	12.51	0.13
2012	6.05	0.18	10.35	0.06
2013	6.02	0.00	11.01	0.00

Period	Conifers on all soil types	Conifers on organic soil	Broadleaves on all soil types	Broadleaves on organic soils
2014	6.38	0.00	8.70	0.00
2015	2.17	0.00	4.72	0.00
2016	3.26	0.00	3.12	0.00
2017	4.88	0.00	3.66	0.00
2018	7.58	0.00	5.09	0.00
2019	7.71	0.00	5.78	0.00

A 3.4.1.5 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 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 CARBINE model outputs take account of forest area loss through conversion to other land uses (deforestation).

A 3.4.1.6 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 3.4.3**) 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 3.4.1.7 Emissions from drainage on forest soils

Emissions from forest on drained soils are calculated for mineral and organic soils separately using a Tier 1 methdology. Emissions of CH_4 and N_2O from organic soils are calculated using Tier 1 EFs (see Annex 3.4.6). Emissions of N_2O from mineral soils are calculated using Tier 1 EFs (IPCC 2006) and information on the distribution 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 by splitting it between organo-mineral soils, free-draining mineral soils and 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 organo-mineral soils is cultivated prior to planting and therefore effectively drained.

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

Changes in mineral 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

All land in the UK is assigned to one of the six AFOLU land categories, based on information from habitat surveys and administrative records.

For Great Britain (England, Scotland and Wales), matrices from the Monitoring Landscape Change (MLC) data from 1947 & 1980 (MLC 1986) (**Table A 3.4.4**) and the Countryside Surveys (CS) of 1984, 1990, 1998 (Haines-Young *et al*. 2000) and 2007 (Smart *et al*. 2009) (**Table A 3.4.5**) 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.

Table A 3.4.4 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			

CROPLAND	GRASSLAND	FORESTLAND	SETTLEMENTS (URBAN)	OTHER
	Rough pasture			
	Peat bog			
	Fresh Marsh			
	Salt Marsh			

Table A 3.4.5 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 3.4.6** and **Table A 3.4.7**.

Table A 3.4.6 Sources of land use change data 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

Year or Period	Method	Change matrix data
2008-latest year	*Extrapolated*	CS1998->CS2007

Table A 3.4.7 Sources of land use change data used 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
1990 – 1998	Measured LUC matrix	NICS1990->NICS1998
1999-2007	Measured LUC matrix	NICS1998->NICS2007
2008-latest year	*Extrapolated*	NICS1998->NICS2007

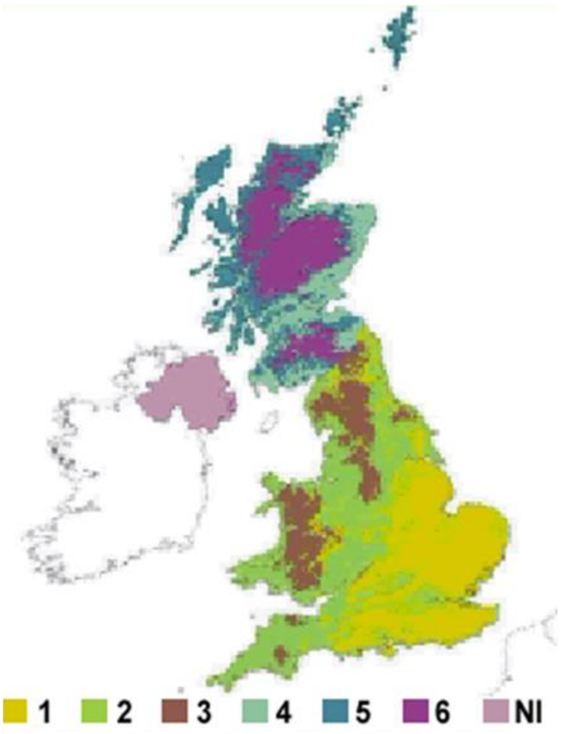
NICS = Northern Ireland Countryside Survey

The land use change data over the different periods (Box 3.4.1) 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 for the GBE, GBK and GBR submissions are provided in in Chapter 6 of the main NIR report, Section 6.1.1. The full set of annual matrices are used in the calculation of non-forest biomass carbon stock change. The full set is adjusted to take account of land use change on organic soils (see Annex 3.4.6) to produce a set of matrices for changes on non-organic soil only (which includes both mineral and organo-mineral soils).

Box 3.4.1: land use change up-scaling 1998-2007

- 544 Countryside Survey squares coincide in 1998 and 2007 surveys
- Each square is assigned a constant land class (45 stratified land classes in GB)*
- All habitat in a square is recorded
    - ➢ calculate habitat change in each square 1998-2007
    - ➢ changes between habitats are grouped by land class
    - ➢ Changes are upscaled to the land class based on the total: sampled area ratio
- Land use change can be extracted at national/regional scale.

* 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.



Simplified land class stratification

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 all soils in 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. 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 and *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.

The model calculates the change in equilibrium carbon density from the initial to the final land use for each land use category as averages for Scotland, England, Wales and Northern Ireland. These are weighted by the area of Land Use Change occurring in each soil group to account for the actual carbon density where change has occurred. In previous inventories four broad soil groups were used (organic, organo-mineral, mineral, unclassified). With the implementation for the first time of methodologies consistent with chapters 2 and 3 of the 2013 IPCC Wetlands supplement, we now have areas of land use change on organic soils and the emission factors for the associated carbon losses. This would lead to double-counting without the adjustment of the soil carbon model to exclude land use change on organic soils. The equilibrium soil carbon density and weighting is now based on the non-organic soil groups only.

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 (organo-mineral, mineral, unclassified) and 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 average change and range calculated are presented in **Table A 3.4.8** - **Table A 3.4.11.**

Table A 3.4.8 Weighted average change and range (%) in equilibrium non-organic 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	5 (44%)	30 (7%)	79 (4%)
Grassland	-5 (49%)	0	24 (0%)	75 (4%)
Cropland	-30 (7%)	-24 (2%)	0	49 (3%)
Settlements	-79 (4%)	-73 (3%)	-50 (2%)	0

Table A 3.4.9 Weighted average change and range (%) in equilibrium non-organic 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	56 (4%)	174 (2%)	235 (2%)
Grassland	-61 (4%)	0	101 (0%)	171(0%)
Cropland	-180 (1%)	-101 (0%)	0	62 (4%)
Settlements	-242 (0%)	-168 (1%)	-54 (14%)	0

Table A 3.4.10 Weighted average change and range (%) in equilibrium non-organic 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	14 (54%)	51 (13%)	105 (12%)
Grassland	-13 (65%)	0	38 (11%)	91 (10%)
Cropland	-48 (21%)	-39 (2%)	0	46 (10%
Settlements	-104 (12%)	-89 (6%)	-55 (6%)	0

Table A 3.4.11 Weighted average change and range (%) in equilibrium non-organic 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	39 (10%)	106 (10%)	192 (10%)
Grassland	-39 (10%)	0	68 (10%)	153 (10%)
Cropland	-106 (10%)	-68 (10%)	0	85 (10%)
Settlements	-192 (10%)	-153 (10%)	-85 (10%)	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

From / To	Forestland	Grassland	Cropland	Settlement
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), Wales (W) and Northern Ireland (NI)

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

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.

A 3.4.2.2.1 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 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. This activity is only relevant for non-organic soils in the UK.

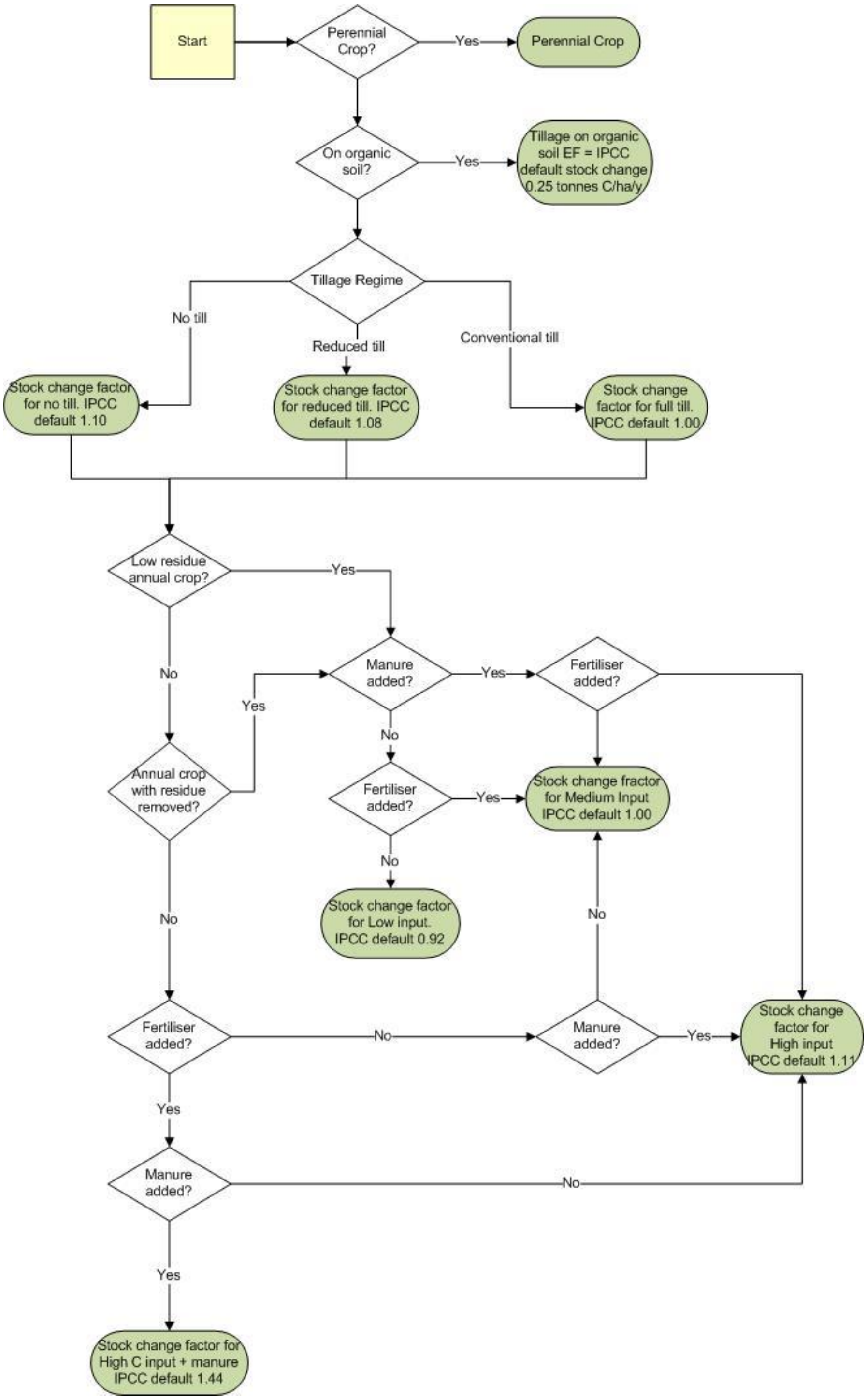
Using this methodology, tillage crops are divided into Medium and Low residue groups based on the data on total crop biomass. Where land receives inputs of fertiliser or manure the inputs moved up a class (e.g. cropland producing a Low residue crop which receives manure is considered to receive Medium 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 3.3.**

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). These Tier 1 factors have been derived for soil carbon reference stocks of 0-30 cm depth (as opposed to the 1 m depth used in the land use change calculations. The 0-30 cm reference stocks for cropland soils are 70 tC/ha for England and Wales, 100 tC/ha for Northern Ireland and 120 tC/ha for Scotland. These values come from the same database of soil carbon density used for the land use change modelling. 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 Surveys/Census 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 3.3 Decision tree for assessing the effects of cropland management activities on soil carbon stocks.



See Annex 3.4.6

A 3.4.2.2.2 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 BEIS-funded research project has been completed to improve understanding of the effect of grassland management practices on soil carbon stock changes. It is currently draft. An initial review of the research results suggests standard grassland management practices in the UK do not have a significant impact on soil carbon that can be separated from the soil carbon stock change associated with historic land use change.

A 3.4.2.3 Future development

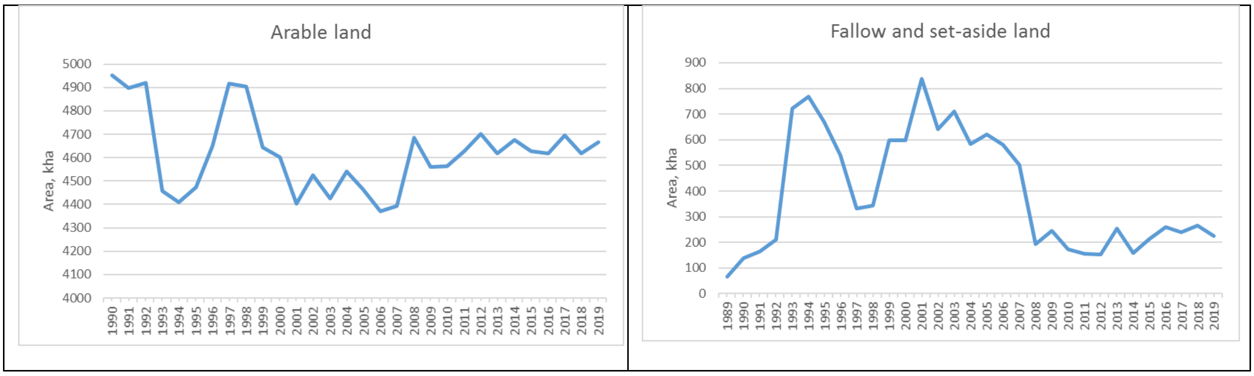
A BEIS-funded project to improve tracking of land use change is in progress (August 2020-September 2021). This will use Bayesian assimilation of multiple land use datasets (based on a pilot project described in Levy et al. 2018) to produce spatial and temporal vectors of land use change since 1990. The project will also assess the potential to include earth observation data in the assimilation and reduce the uncertainties of land use change dataset. 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. It is anticipated that the outputs from this project will be implemented in the next inventory submission.

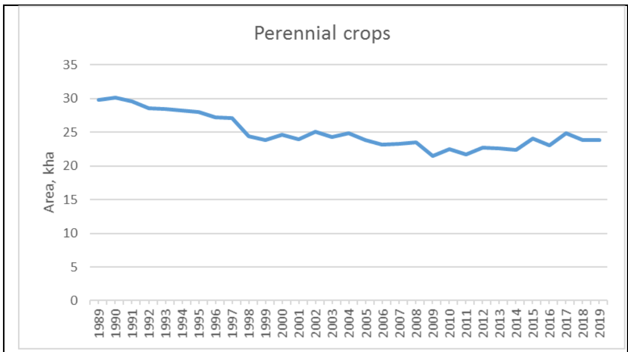
A 3.4.3 Changes in stocks of carbon in non-forest biomass due to management and land use change (4B2, 4C2, 4E2)

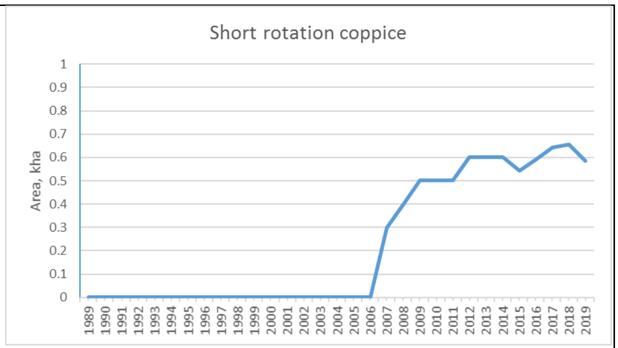
A 3.4.3.1 Change in biomass carbon stock due to change in Cropland and Grassland Management.

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 five categories: annual crops, orchard crops, shrubby perennial crops, short rotation coppice and set aside and fallow (**Figure A 3.4**). Crop types reported in the agricultural census vary slightly for each administration. **Table A 3.4.14** shows how agricultural census crop types were grouped to assess biomass carbon stocks.

Figure A 3.4 Crop type area in the UK 1990-2019







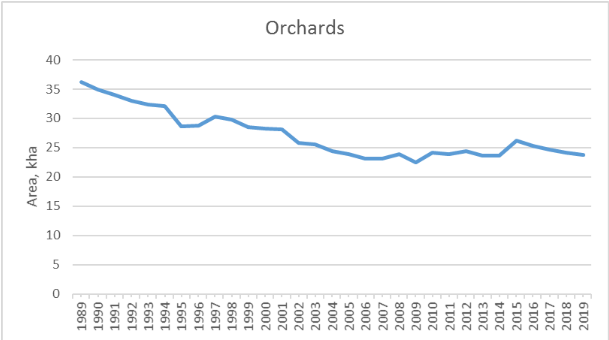


Table A 3.4.14 Aggregation of Agricultural Census crop types for estimating biomass carbon stock changes from Cropland Management

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 3.4.15.** These factors were generated from a literature review. (Moxley *et al.* 2014b).

Table A 3.4.15 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.
Short rotation coppice	4.36	2.9	0.46
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 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 3.4.16** shows which Broad Habitats were allocated to which Grassland type.

Table A 3.4.16 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 3.4.17**. 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 3.4.17 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 basis. 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 are included in the estimate of change in Grassland biomass carbon stock 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 may contain isolated trees and may also have some gaps in them. The biomass carbon stocks of managed and unmanaged hedges are 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 3.4.3.2 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 all-soils area matrices (see previous section). The average biomass carbon density for Cropland, Grassland and Settlement are shown in **Table A 3.4.18**: these were derived from the distribution and biomass densities of the different crop and grassland types in each country of the UK**.** For Settlements the biomass stocks from Milne and Brown (1997) and land cover data from the 2007 Land Cover Map 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.

The average change in biomass carbon density for each country is shown in **Table A 3.4.19** - **Table A 3.4.22**. Changes between these equilibrium biomass carbon densities were assumed to happen in a single year.

Table A 3.4.18 Mean biomass carbon stock densities, tC/ha

Mean C stock tC/ha	Cropland	Grassland	Settlement
England	5.02	3.37	2.77
Scotland	5.00	4.16	2.91
Wales	5.03	3.61	2.81
Northern Ireland	5.14	2.93	2.64

Table A 3.4.19 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	-1.66	0.60
Cropland		1.66	0	2.25
Settlements		-0.60	-2.25	0

(Transitions to and from Forestland are considered elsewhere)

Table A 3.4.20 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	-0.83	1.25
Cropland		0.83	0	2.08
Settlements		-1.25	-2.08	0

(Transitions to and from Forestland are considered elsewhere)

Table A 3.4.21 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	-1.42	0.80
Cropland		1.42	0	2.22
Settlements		-0.80	-2.22	0

(Transitions to and from Forestland are considered elsewhere)

Table A 3.4.22 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	-2.21	0.29
Cropland		2.21	0	2.49
Settlements		-0.29	-2.49	0

(Transitions to and from Forestland are considered elsewhere)

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.**

A 3.4.3.3 Future development

A new vector-based approach to tracking land use change is planned for implementation in the next nventory submission (**Section A 3.4.2.3)**.

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. 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 was 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 change from historical land use change) is estimated from the land use change matrices described in Section A 3.4.2.

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 with trees, 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[12].

Felling for urban development, with no requirement to restock, can be allowed under planning permission but only local planning authorities hold documentation for this. Since 2006, remotely sensed data used in the NFI has included this change, 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 Department of Communities and Local Government (DCLG)[13]. 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 A 3.4.2**) 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.

[12] https://www.gov.uk/guidance/tree-felling-licence-when-you-need-to-apply

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

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.

Table A 3.4.23 Countryside Survey data for Forest conversion

Years	Land change	England rate of change, kha/yr	Scotland rate of change, kha/yr	Wales rate of change, kha/yr	N Ireland rate of change, kha/yr	Grassland / Cropland split England	Grassland / Cropland split Scotland	Grassland / Cropland split 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

Years	Land type	England Correction ratio	Scotland Correction ratio	Wales Correction ratio	England rate of change, kha/yr	Scotland rate of change, kha/yr	Wales rate of change, kha/yr	N Ireland rate of change, kha/yr
1990-1998	Grassland & Cropland	2% [a]			0.159	0.088[c]	0.026 [c]	0.005 [c]

Years	Land type	England Correction ratio	Scotland Correction ratio	Wales Correction ratio	England rate of change, kha/yr	Scotland rate of change, kha/yr	Wales rate of change, kha/yr	N Ireland rate of change, kha/yr
	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 (conversion to Grassland or Wetland); 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 based on the assumptions used in the previous inventory, updated with the latest available information from the Forestry Commission on deforestation for recent years and to include estimates of areas deforested to allow rewetting to take place.

Soil carbon stock changes associated with deforestation are estimated using the dynamic soil carbon model described in **Section A 3.4.2**. 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 -(described in **Section 6.8**) or assumed to instantaneously oxidise for KP reporting.

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

Data on Forest wildfires prior to 2009 come from the Forestry Commission and the Forest Service of Northern Ireland.

In 2009 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 2009. 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 2009, thermal anomaly data 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 > 25 ha 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[14]; Scottish Government, 2011[15]). 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.

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

Forest	Cropland	Grassland	Settlement
Woodland/forest - conifers/softwood	Straw/stubble burning	Heathland or moorland	Domestic garden (vegetation fire)

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

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

Forest	Cropland	Grassland	Settlement
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-current inventory year (**Figure A 3.5**). For non-forest wildfires for England, Scotland and Wales the IRS burnt areas were used for 2009 to the current inventory year (previously this was from 2010 using fiscal years but for the 1990-2019 inventory the IRS data has been re-mapped to calendar years for consistency with other activity data) and the burnt area estimated from thermal anomalies from 2000 to 2008. 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 3.5 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).

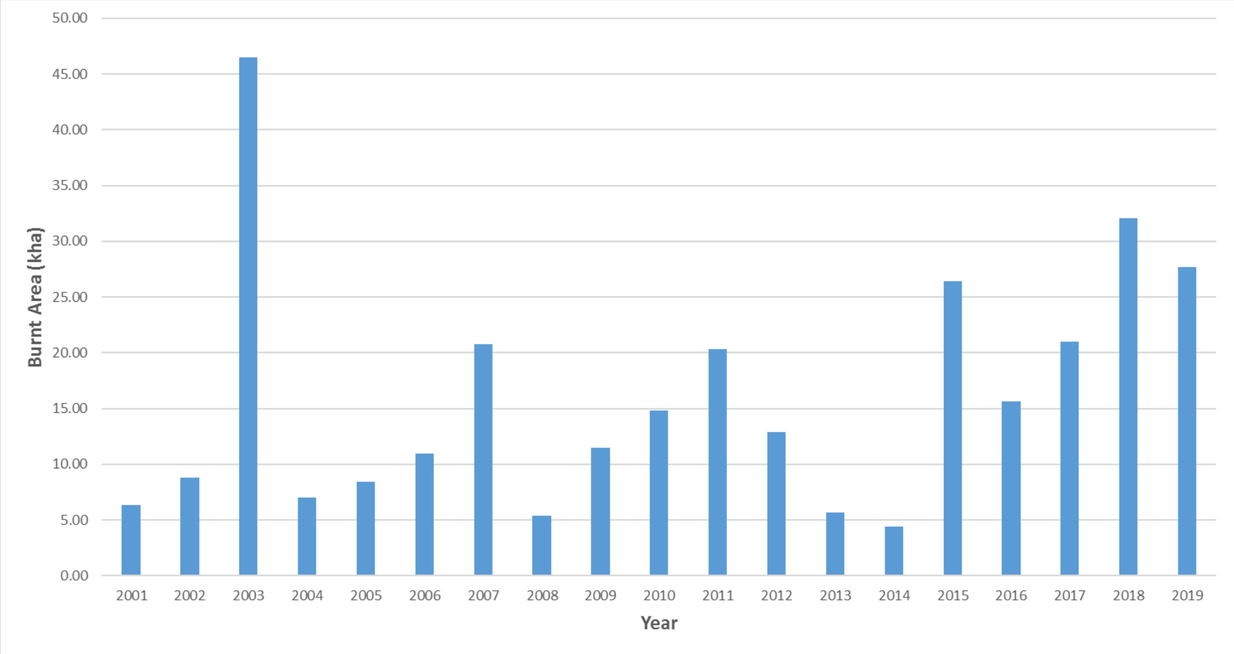
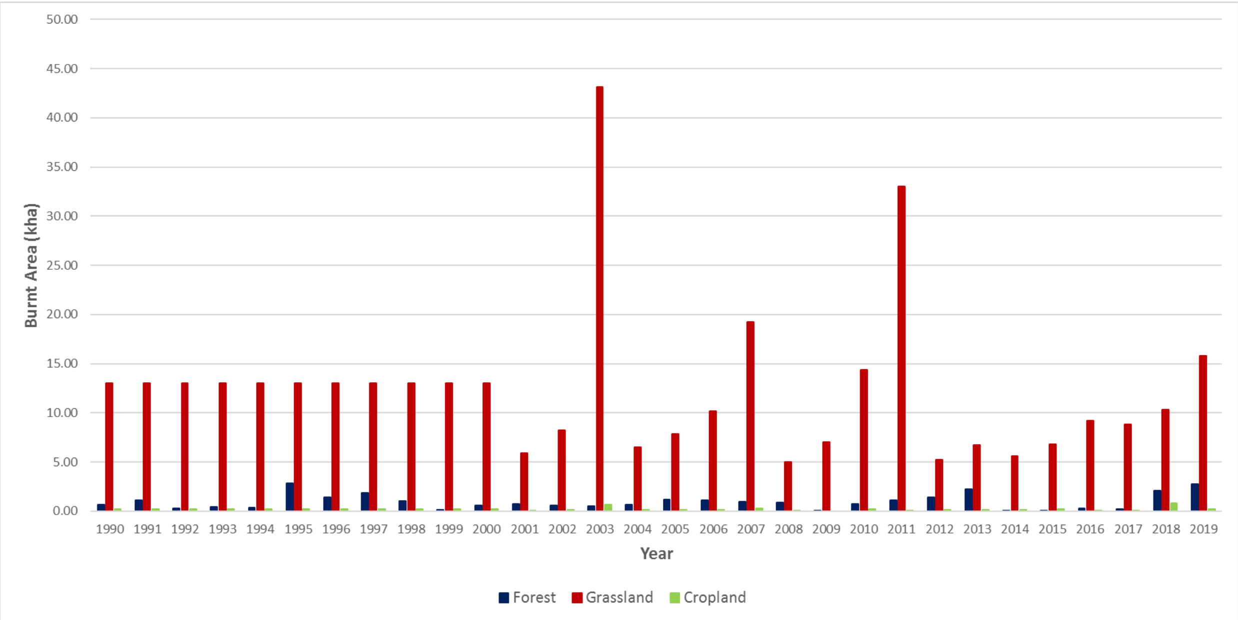


Figure A 3.6 shows the temporal pattern of FIRMS thermal anomalies, with peaks in hot dry years such as 2003. The FIRMS data used only includes thermal anomalies for March – August for each year, as these are the months where the IRS database recorded fires greater than 25 ha. Some FIRMS thermal anomalies were recorded outside 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 3.6 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 IPCC 2006 Guidelines for AFOLU 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 organic soils (4A, 4B, 4C, 4D, 4E, 4(II))

In a natural state, peatlands are important long-term sinks for carbon. However, drainage of peat can drastically alter the carbon balance in these systems, shifting them from a net sink to a net source of carbon. Peatlands comprise a high proportion of the total land area in the UK (~12%) . Of these peatlands, around 76% are in a modified state and no longer functioning as a carbon (C) sink. This ranges from relatively minor changes in vegetation composition and hydrology and GHG emissions, through to deep drainage and replacement of the wetland vegetation for agriculture, forestry, and peat extraction practices that result in large sources of anthropogenic GHG emissions. The remaining 24% of peatlands in the UK are classified as near-natural bog or fen with suitable conditions for C sequestration.

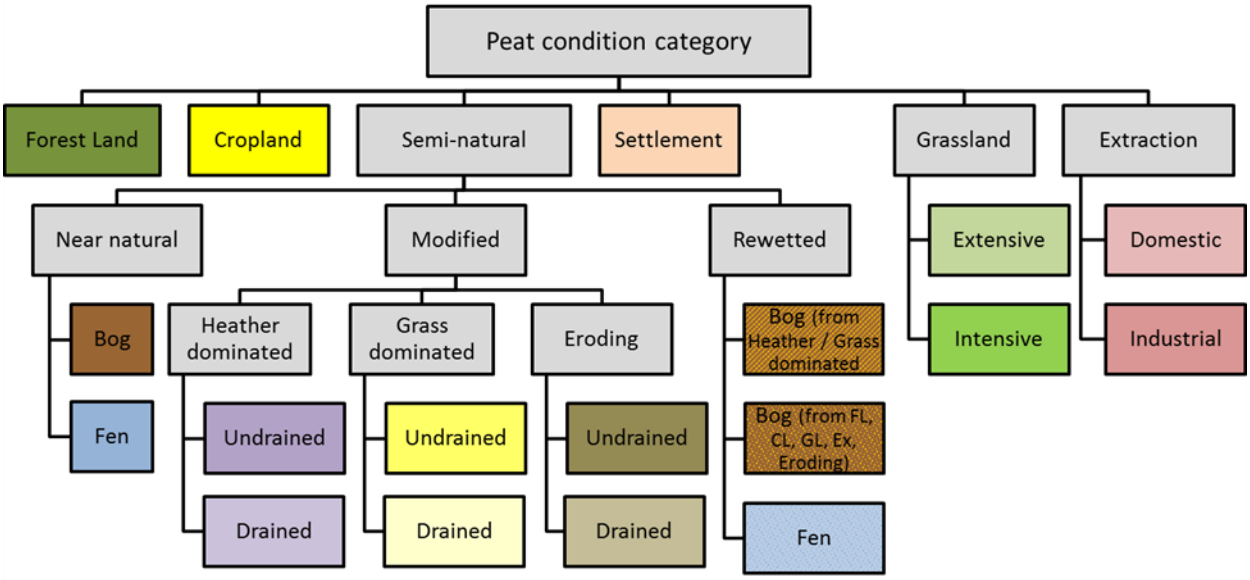
Previously, the UK’s LULUCF inventory reported limited emissions from peatlands, namely direct CO_2 and N_2O emissions arising from domestic and industrial extraction of peat, reservoir creation, conifer plantations on organic soils, and lowland drainage of cropland and agricultural grassland. Following the publication of the 2013 Supplement to the 2006 IPCC Guidelines, which provides methodology and default emission factors to allow calculation of GHG emissions and removals for a wider range of drained and rewetted peatlands (IPCC 2014), the UK elected to report Wetland Drainage and Rewetting (WDR) for the second commitment period of the Kyoto Protocol (KP). A BEIS-funded study on the Implementation of an Emission Inventory for UK Peatlands (Evans et. al. 2017) was undertaken to provide activity data and a UK-specific Tier 2 emissions reporting approach for UK peatlands. This section summarizes the main results used to estimate emissions from organic soils in the LULUCF inventory and full details are available in Evans et al. (2017) on the NAEI website.

A 3.4.6.1 Areas of organic soils

Peatland soils occur in all LULUCF land categories in the UK apart from 4F Other Land. Peatland condition categories comprised near-natural bog and fen, semi-natural peatlands affected by human activity (such as drainage, controlled burning and livestock grazing), cropland, extensive and intensive grassland, woodland, domestic and industrial peat extraction areas and active peatland restoration (rewetted) areas of bog and fen. This classification encompasses peat condition categories in the UK that were sufficiently well mapped to derive emission factors (**Figure A 3.7, Table A 3.4.28**). Detailed descriptions of the activity data obtained from unified peat extent and land use maps, including key assumptions in the assignment of peat areas to condition categories, are given in Evans et al. (2017). Updates to activity data since the publication of the Evans et al (2017) peatlands implementation report include: the addition of a Settlement peat condition category; amendment to the Eroded Bog category to include only the actively eroding (bare peat) component of the landscape, with areas of not actively eroding bog captured under Modified Bog areas; and separate Rewetted categories for rewetted semi-natural Modified Bog, and more intensively modified peatlands (e.g. Forest, Cropland, Intensive and Extensive Grassland, Peat Extraction, Eroding Modified Bog) (**Figure A 3.7**), as well as updates due to land use change (detailed below, **Table A 3.4.29**). The peatlands defined in **Figure A 3.7** have all been altered by human interventions and practices to some extent, with natural peatlands managed for their high conservation value (e.g. SSSIs, SACs). Thus, emissions and removals from all managed UK peatlands are reported *"regardless of whether they are anthropogenic or non-anthropogenic"* (IPCC 2014, Section 1.3, Chapter 1).

Figure A 3.7 Final land cover hierarchy used to derive a separate EFs for UK peatlands, amended from Evans et al (2017)

Grey cells represent higher-level categories encompassing two or more sub-categories. Note that there are separate rewetted bog categories for transitions from heavily modified peatlands (Forest Land, Cropland, Grassland, Extraction, Eroding bog) and Semi-natural peatlands (Heather dominated and Grass dominated bogs).



Changes in peat condition were associated with restoration (rewetting) of peatlands, which has largely occurred in the UK since 2000, changes in peat extraction, and forestry. Most large-scale peatland drainage occurred prior to 1990, however some new drainage has occurred due to wind farm or settlement developments, but to date it has not been possible to acquire data to report these effects. Similarly, land-use transitions between cropland and grassland, or change between intensive and extensive grassland on organic soils could not be reliably quantified due to an absence of spatially explicit data.

Changes in peat extraction site area were generated from Google Earth satellite imagery and applied to the baseline peat extraction areas (Evans et al. 2017) to give a time series of peat extraction area (see section 3.4.8). In contrast to the IPCC Tier 1 assumptions, fuel peat extraction was assumed to occur on nutrient-poor bog peat, and horticultural peat extraction on nutrient-rich fen peat, typical of UK practice (see Evans et al. 2017 for more detail).

Evans et al. (2017) reported spatial datasets of peatland restoration from 2000 to 2013. It was assumed that no rewetting activity took place before 2000 (other than peat extraction sites). An average rate of restoration was applied 2000 – 2013 due to limited temporal information. This annual rate has been extrapolated to the latest inventory year for England, Wales, and Northern Ireland, which is likely an underestimate given that funding for peatland restoration in the UK has increased in recent years. Efforts are underway to provide a reporting mechanism for recent rewetting activities. An annual timeseries of peatland restoration in Scotland 2013- latest inventory year was provided by Peatland Action, NatureScot. Estimates of changes in area of each peat condition due to rewetting between 1990 and 2019 are shown by UK administration in **Table A 3.4.27**.

Table A 3.4.26 Assignment of peat areas (kha) to condition categories for each UK administration in 1990 and 2019.

Country	England				Scotland		Wales		Northern Ireland		UK Total	
Peat category	Deep peat		Wasted peat		All	All	All	All	All	All	All	All
Year	1990	2019	1990	2019	1990	2019	1990	2019	1990	2019	1990	2019
Forest, D	47.76	49.22	12.67	13.49	332.68	356.86	9.51	9.21	26.82	30.97	429.43	459.74
Cropland, D	53.78	48.59	132.18	132.18	7.94	5.66	0.10	0.10	3.15	3.15	197.15	189.68
Eroding Modified Bog (bare peat), D	1.25	0.64	0.00	0.00	11.23	9.41	0.00	0.00	0.35	0.31	12.83	10.35
Eroding Modified Bog (bare peat), UD	6.63	6.53	0.00	0.00	29.59	28.62	0.03	0.03	0.61	0.56	36.86	35.74
Modified Bog (H.&G.dom), D	70.86	36.15	0.01	0.00	251.15	222.14	3.19	1.68	16.68	14.52	341.89	274.50
Modified Bog (H.&G.dom), UD	159.78	157.55	1.93	1.89	662.13	640.25	35.36	35.19	28.71	26.30	887.90	861.19
Extensive Grassland (combined bog + fen), D	3.49	0.18	0.52	0.52	31.65	33.59	8.97	2.49	5.40	4.42	50.04	41.20
Intensive Grassland, D	32.07	27.11	35.87	35.28	78.11	72.26	6.54	6.45	31.98	31.09	184.58	172.18
Near Natural Bog, UD	83.93	83.93	2.35	2.35	490.50	490.50	23.53	23.53	35.11	35.11	635.42	635.42
Near Natural Fen, UD	0.00	0.00	0.00	0.00	0.00	0.00	2.67	2.67	0.00	0.00	2.67	2.67
Extracted Domestic, D	4.26	4.25	0.14	0.14	44.90	44.65	0.00	0.00	91.84	87.54	141.14	136.58
Extracted Industrial, DI	6.91	2.13	0.00	0.00	2.89	2.86	0.00	0.00	0.52	0.93	10.33	5.91
Settlement, D	5.17	4.67	5.59	5.40	4.19	4.61	0.18	0.18	1.15	1.58	16.28	16.44
Rewetted Modified (Semi-natural) Bog, UD	0.00	34.03	0.00	0.00	0.00	20.71	0.00	1.49	0.00	0.78	0.00	57.02
Rewetted Bog, UD	0.15	3.88	0.00	0.00	0.02	13.36	0.00	4.68	0.36	4.93	0.53	26.85
Rewetted Fen, UD	10.18	27.35	0.00	0.00	0.00	1.52	0.00	2.37	0.03	0.53	10.21	31.78
Total	**486.22**	**486.22**	**191.25**	**191.25**	**1,946.99**	**1,946.99**	**90.09**	**90.09**	**242.72**	**242.72**	**2,957.26**	**2,957.26**

D= Drained, UD = Undrained, H.&G.dom = Heather and grass dominated

Table A 3.4.27 Estimated changes in area (kha) of each peat condition category due to land-use change, drainage and rewetting between 1990 and 2019

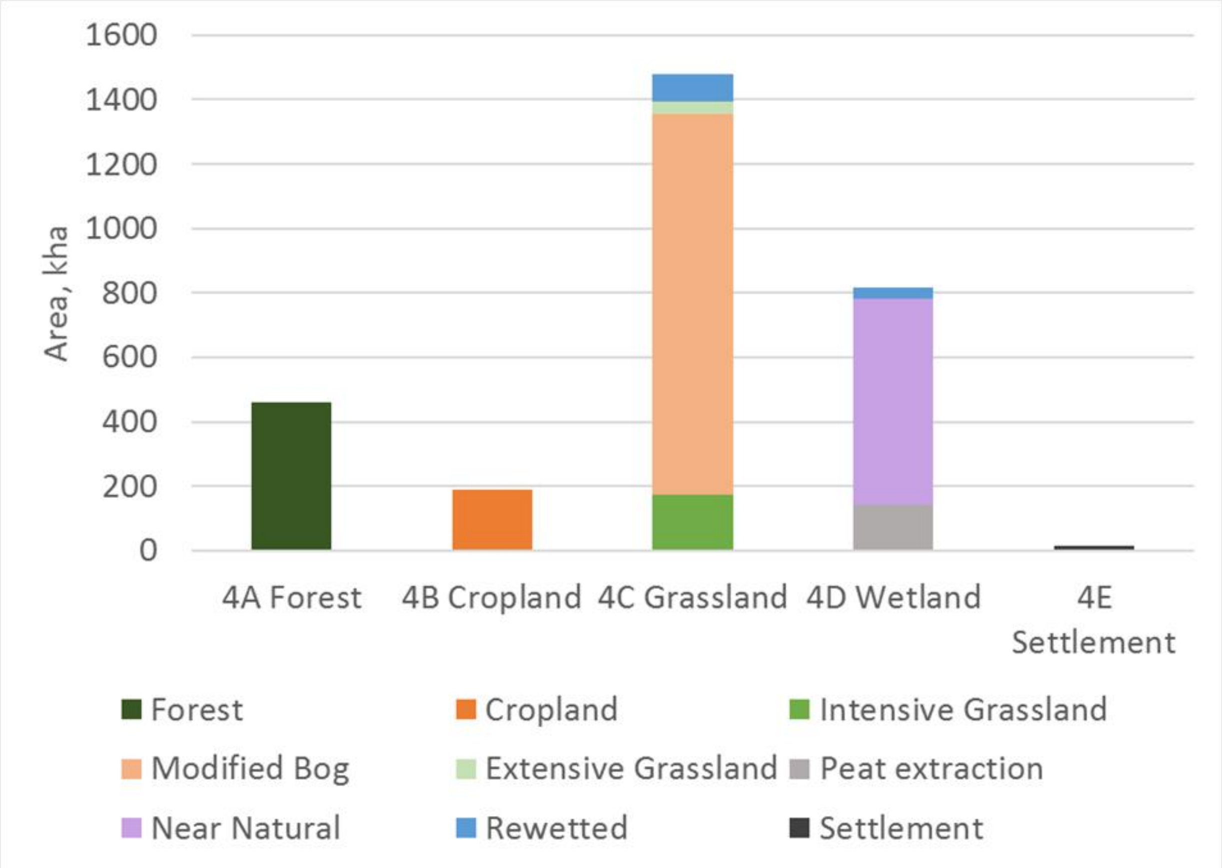
Tier 2 peat condition category	England Deep peat	England Wasted peat	Scotland	Wales	Northern Ireland	UK Total
Forest	1.460	0.819	24.177	-0.302	4.155	30.308

Tier 2 peat condition category	England Deep peat	England Wasted peat	Scotland	Wales	Northern Ireland	UK Total
Cropland	-5.193	0.000	-2.278	0.000	0.000	-7.471
Eroding Modified Bog (bare peat)	-0.703	-0.001	-2.796	-0.001	-0.097	-3.599
Modified Bog (Heather + Grass dominated)	-36.928	-0.041	-50.888	-1.678	-4.568	-94.103
Extensive Grassland (combined bog + fen)	-3.314	0.000	1.938	-6.476	-0.985	-8.838
Intensive Grassland	-4.965	-0.589	-5.857	-0.093	-0.892	-12.395
Near Natural Bog	0.000	0.000	0.000	0.000	0.000	0.000
Near Natural Fen	0.000	0.000	0.000	0.000	0.000	0.000
Extracted Domestic	-0.010	0.000	-0.245	0.000	-4.305	-4.560
Extracted Industrial	-4.780	-0.001	-0.036	0.000	0.404	-4.413
Settlement	-0.501	-0.187	0.413	0.004	0.430	0.159
Change in drained area	**-54.935**	**-0.001**	**-35.571**	**-8.547**	**-5.857**	**-104.912**
Rewetted Modified (Semi-natural) Bog	34.031	0.000	20.713	1.495	0.783	57.021
Rewetted Bog	3.732	0.000	13.334	4.679	4.574	26.319
Rewetted Fen	17.172	0.001	1.525	2.373	0.500	21.571
Change in rewetted area	**54.935**	**0.001**	**35.571**	**8.547**	**5.857**	**104.912**

The peat condition categories are assigned to the LULUCF land categories with the majority area falling under Grassland or Wetland (**Figure A 3.8**):

- 4A Forest Land: Forest;
- 4B Cropland: Cropland;
- 4C Grassland: Eroding Modified Bog, Modified Bog, Extensive Grassland, Intensive Grassland, Rewetted Modified Bog (from Modified Bog), Rewetted Bog or Fen (from Eroding Modified Bog, Intensive and Extensive Grassland);
- 4D Wetland: Near Natural Bog/Fen, Extracted Domestic, Extracted Industrial, Rewetted Bog or Fen (from Forest Land, Cropland, Extracted Domestic, Extracted Industrial and pre-1990 Rewetted Fen),
  4E Settlement: Settlement.

Figure A 3.8 Area of land-use sub-categories on organic soils in 2019 in the UK



A large area of the cropland organic soil area in England is classified as shallow, wasted peat: former deep peat that has been partly lost through agricultural activity. GHG emissions from wasted peatlands are not well quantified so it is assumed that wasted peat soils continue to emit at the same rate as deep peat, making these emissions estimates particularly uncertain. As such, the EFs for wasted peat are under review, with a BEIS-funded research project underway to measure GHG emissions from wasted peat in England, and emissions from these areas are likely to be revised in future inventories.

There is currently a significant area of bog in Northern Ireland that is classified as historic (i.e. inactive and pre-1990) domestic peat extraction (88 kha).This area is classified as semi-natural grassland in the Northern Ireland habitat surveys, so has been assigned to Article 3.4 Grazing Land Management activity rather than Article 3.4 Wetland Drainage and Rewetting in KP-LULUCF Domestic extraction.

A 3.4.6.2 Emission factors for organic soils

Tier 2 emission factors for the UK-relevant peat condition categories were developed by Evans et al. (2017). The EF literature review and meta analysis was updated in 2019 to include recent GHG flux measurement publications and generate the Tier 2 EFs given in **Table A 3.4.28**. Tier 2 EFs calculated from at least four different primary study locations were considered reliable enough to replace Tier 1 values (see detailed methods in Evans et al. 2017). Thus, where a Tier 1 EF is used in **Table A 3.4.28**, the Tier 2 EF for that category was not reliable enough to replace the Tier 1 value. A continued tier 3 approach for forestry carbon stock changes and fluxes on organic soils using the CARBINE model has been used, with updates to the areas of organic soils used in the model, documented in **Section A 3.4.1**. Other GHGs from forested peat (CO_2 from dissolved organic carbon (DOC) and particulate organic carbon (POC), CH_4, and N_2O) are estimated using the EFs in **Table A 3.4.28**. A Tier 2 approach was used for most peatland categories for Direct CO_2, CO_2 from POC, and Direct CH_4. Limited studies were available for Direct N_2O, CH_4 from ditches, and CO_2 from POC, thus a Tier 1 approach was adopted until more UK-specific flux data are available. Comparisons of the emission factors adopted for each UK peat condition category are given in **Figure A 3.9**-**Figure A 3.11**. Furthermore, updates to the tier 2 EFs developed by Evans et al. (2017) include EFs for Settlement, which uses the closest national condition category of drained organic soils assuming 50% garden (heather/shrub) using the EFs for Modified Bog, and 50% impermeable land (no emissions); amendment to the Eroded Modified Bog EF to represent emissions from actively Eroding Modified Bog (bare peat) only, with emissions from the not actively eroding bog captured by the EFs for Modified Bog; and an additional Rewetted EF for Rewetted Modified (Semi-natural Bog), described further in Section 3.4.6.3, which employs the EFs for Near Natural Bog.

Table A 3.4.28 Emission factors for peat condition types updated from Evans et al (2017). All fluxes are shown in $tCO_2e\ ha^{-1}\ yr^{-1}$. Note that a positive EF indicates net GHG emission, and a negative EF indicates net GHG removal.

Peat Condition	Drainage status	Direct CO_2	CO_2 from DOC	CO_2 from POC	Direct CH_4	CH_4 from Ditches	Direct N_2O	Total
Forest	Drained	2.52 to -1.79[c]	1.14[a]	0.3[b]	0.06[a]	0.14[a]	1.31[a]	**5.46 to 1.15**
Cropland	Drained	28.60[b]	1.14[a]	0.3[b]	0.02[b]	1.46[a]	6.09[a]	**37.61**
Eroding Modified Bog (bare peat)	Drained	6.18[b]	1.14[a]	5.0[b]	0.14[a]	0.68[a]	0.14[a]	**13.28**
	Undrained	6.18[b]	0.69[a]	5.0[b]	0.15[a]	0[a]	0.14[a]	**12.17**
Modified Bog (semi-natural Heather + Grass dominated)	Drained	0.13[b]	1.14[a]	0.3[b]	1.26[b]	0.66[a]	0.06[b]	**3.54**
	Undrained	0.13[b]	0.69[a]	0.1[b]	1.33[b]	0[a]	0.06[b]	**2.31**
Extensive Grassland (combined bog/fen)	Drained	6.96[b]	1.14[a]	0.3[b]	1.96[b]	0.66[a]	2.01[a]	**13.03**
Intensive Grassland	Drained	21.31[b]	1.14[a]	0.3[b]	0.68[b]	1.46[a]	2.67[b]	**27.54**
Rewetted Bog	Rewetted	-0.69[b]	0.88[a]	0.1[b]	3.59[b]	0.0[a]	0.04[b]	**3.91**
Rewetted Fen	Rewetted	4.27 [b]	0.88[a]	0.1[b]	2.81[b]	0.0[a]	0[a]	**8.05**
Rewetted Modified (Semi-natural) Bog	Rewetted	-3.54[b]	0.69[a]	0[b]	2.83[b]	0[a]	0[a]	**-0.02**
Near Natural Bog	Undrained	-3.54[b]	0.69[a]	0[b]	2.83[b]	0[a]	0[a]	**-0.02**
Near Natural Fen	Undrained	-5.41[b]	0.69[a]	0[b]	3.79[b]	0[a]	0[a]	**-0.93**
Extracted Domestic	Drained	10.27[a]	1.14[a]	1.01[b]	0.14[a]	0.68[a]	0.14[a]	**13.37**
Extracted Industrial	Drained	6.18[b]	1.14[a]	5.0[b]	0.14[a]	0.68[a]	0.14[a]	**13.28**
Settlement	Drained	0.07[b]	0.57[a]	0.15[b]	0.63 [b]	0.16[a]	0.03[b]	**1.61**

[a] Tier 1 default EF (IPCC 2014)
[b]Tier 2 EF (updated literature analysis in 2019 incorporating data from Evans et al. 2017)
[c]Tier 3 Forest Research CARBINE model implied EF for 1990 to 2019. The decreasing trend is due to an increase in age of forests on organic soils due to decreasing afforestation on organic soils.

Figure A 3.9 **Direct CO_2 emission factors (Tier 1, 2, 3) for UK peat condition types updated from Evans et al (2017) ± standard error. Note that an EF for Forest is not shown as the Tier 3 method employed results in a range of EFs for forests on organic soils, which is due to changes in the age of forests and differences in afforestation over time**

. (All fluxes are shown in tCO_2-C ha-1 yr-1. Note that a positive EF indicates net GHG emission, and a negative EF indicates net GHG removal)

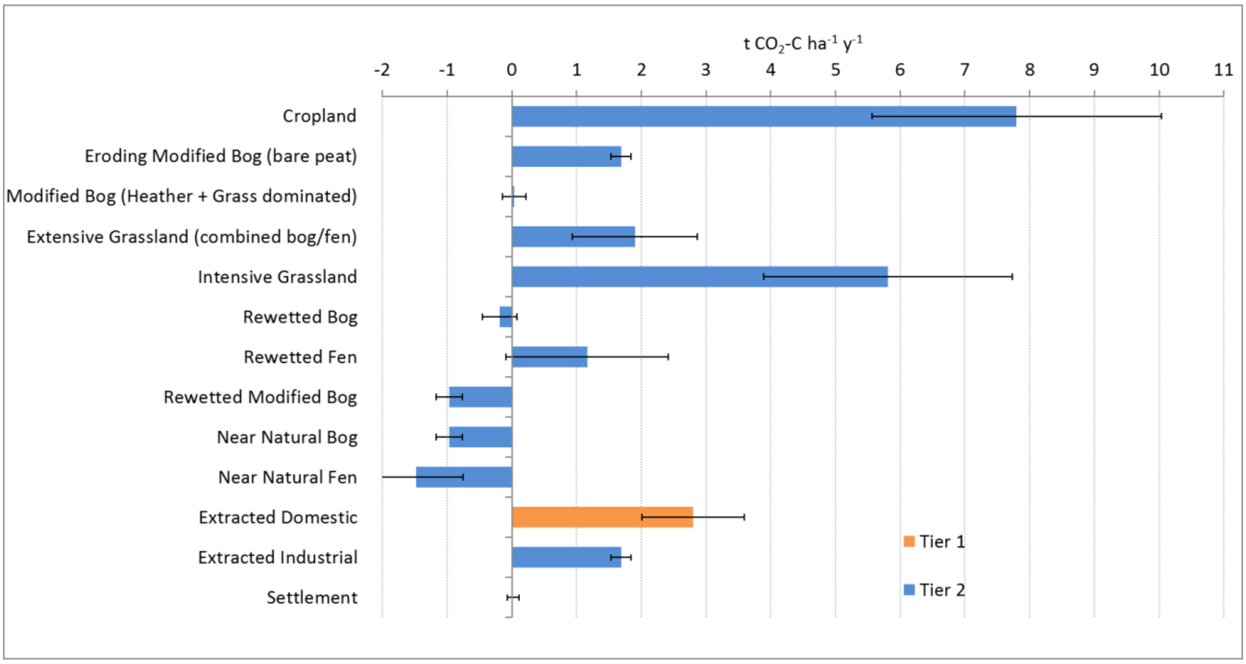


Figure A 3.10 Direct CH_4 emission factors (Tier 1 and 2) for UK peat condition types updated from Evans et al (2017) ± standard error. (All fluxes are shown in Kg CH_4 ha-1 yr-1)

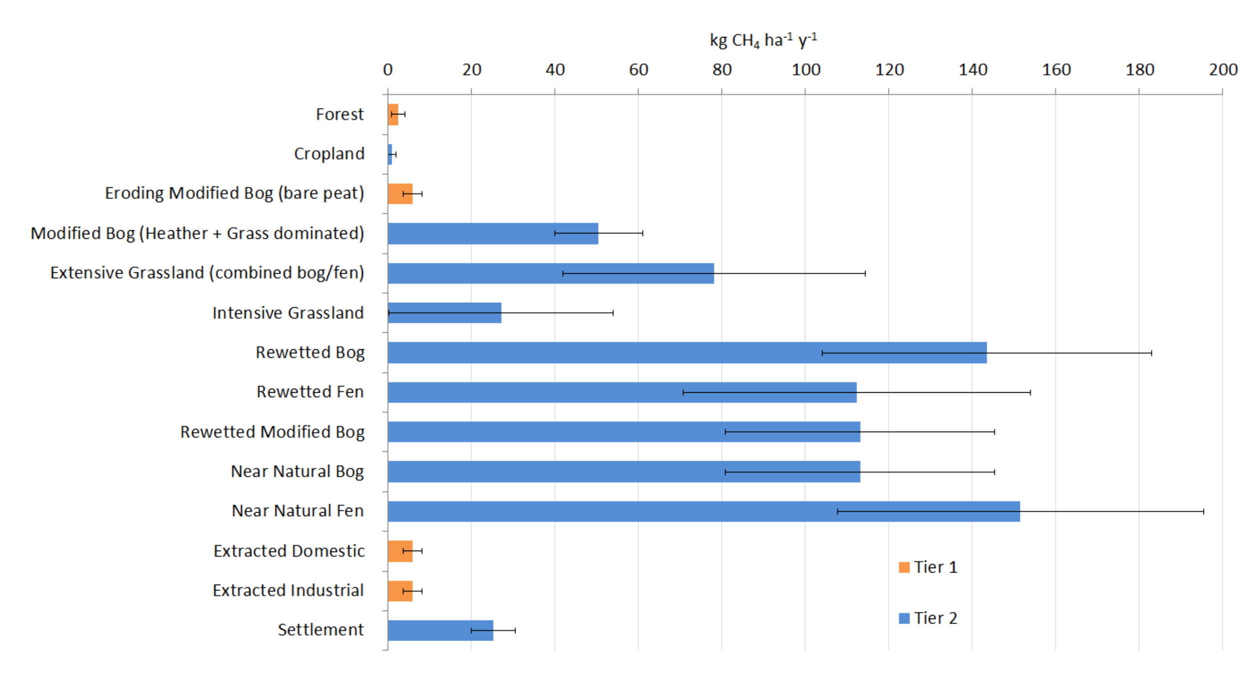
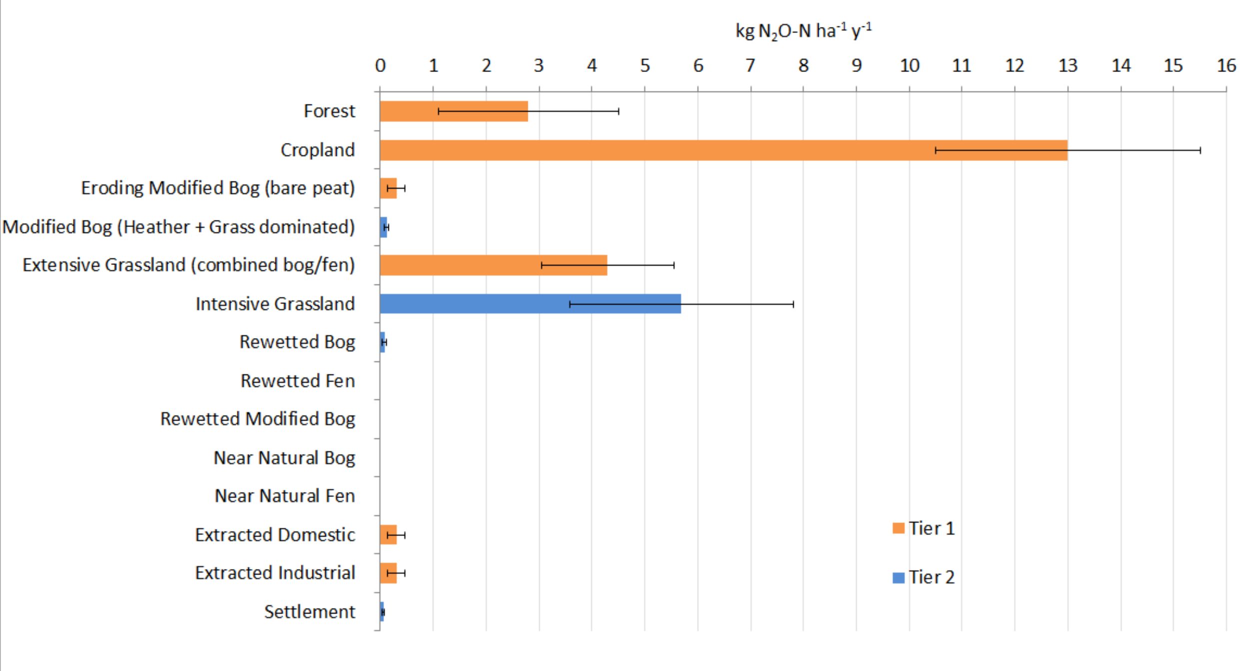


Figure A 3.11 Direct N_2O emission factors (Tier 1 and 2) for UK peat condition types updated from Evans et al (2017) ± standard error. (**All fluxes are shown in Kg N_2O-N ha^{-1} yr^{-1}**)



Off-site CO_2 emissions from fluvial DOC exported from drained areas were estimated following 2014 IPCC Tier 1 methodology which incorporated a large body of UK data. Tier 1 EFs for CO_2

from exported POC are not given in the Wetlands Supplement. However, Tier 2 emissions factors were estimated using flux data from Evans *et al* (2017) and the area of exposed peat associated with each land-use category based on the method outlined in Appendix 2.a.2 of the IPCC Wetlands Supplement. Indirect N_2O emissions associated with nitrate leaching from organic soils were not incorporated at this time due to caution given in the 2006 and 2014 IPCC guidance against double-counting of emissions from fertilisation. A BEIS-funded research project to measure emissions from wasted peat under cropland will help to assess indirect emissions from N_2O from organic soils.

A 3.4.6.3 Emissions from drainage and rewetting (4(II))

Large areas of UK peatlands, predominantly semi-natural heather- and grass-dominated bog, are modified by grazing and burning-management practices but remain undrained. As these habitats are a net source of GHG emissions (**Table A 3.4.6**), and no guidance is given in IPCC (2014) for modified undrained peatlands, Tier 2 emissions factors were developed to capture undrained peat condition categories.

Separate emissions factors were developed for rewetted semi-natural, heather and grass dominated bog (rewetted total EF = -0.02 tCO_2e ha^{-1} yr^{-1}), and more intensively modified peatlands, which includes forest, cropland, intensive/extensive grassland, extracted, and eroding modified bog, (total EFs of 3.91 and 8.05 tCO_2e ha^{-1} yr^{-1} for rewetted bog and fen, respectively) to take account of the different scale of damage to these lands, and the greater ease and effectiveness of rewetting of habitats that already have semi-natural vegetation and are functioning in a near-healthy state (**Table A 3.4.6**).

N_2O emissions from cropland and intensive grassland are calculated using the EFs in **Table A 3.4.28** and reported under the Agriculture sector category of 3.D- Agricultural Soils, as these agricultural land types are considered to be highly cultivated and this is consistent with the approach taken in the Agriculture sector. N_2O emissions from unintensive grassland on organic soils are reported under 4(II)/4.H to ensure completeness, as it is not possible to report these emissions in the 4(II)/4.C rows in the CRF tables.

A 3.4.6.4 Uncertainties

The uncertainties associated with the areas and emission factors from organic soils were assessed as part of the Evans et al. (2017) research and work to implement the results in the LULUCF inventory.

The uncertainties associated with areas were not quantifiable (as there were limited data sources available) so expert judgement was used to assign peatland condition classes to low, medium and high uncertainty: 10%, 30% and 60% respectively.

- Low uncertainty: rewetted Grassland, rewetted and near-natural Wetland;
- Medium uncertainty: drained Cropland, drained intensive Grassland, drained and undrained modified bog Grassland, industrial peat extraction on Wetland;
- High uncertainty: all condition classes on wasted peat, drained extensive grassland, domestic peat extraction on Wetland.

Uncertainties for the Tier 2 emission factors were calculated from the 95% confidence interval for CO_2, CH_4 and N_2O (see Evans et al. 2017), and taken from the IPCC 2013 guidance for Tier 1 factors. The combined uncertainties for organic soils by LULUCF category are included in **Table A 3.4.31**. The uncertainties for forest on organic soil are calculated as part of the overall Forest uncertainty, as this uses a Tier 3 model rather than an emission factor approach. Settlements on organic soils were not included in the Evans et al. 2017 research, but their uncertainty is assumed to be Medium/High based on expert judgement.

A 3.4.7 Emissions of N_2O due to disturbance associated with land use conversion and land management changes (4(III))

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 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 4A2, 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 and the BritPits online database[16]. Prior to the 2002 no Google Earth images are available, and peat extraction site areas have been estimated from other sources. **Table A 3.4.29** shows the sources of activity data used to estimate emissions from peat extraction.

[16] https://www.bgs.ac.uk/products/minerals/britpits.html

Table A 3.4.29 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)/BritPits database	Location of active peat extraction sites	England, Scotland, Wales, Northern Ireland	1984 - present	Online database is continuously updated
Google Earth	Land use images to estimate area of extraction sites identified from DMQ	UK	2002 - present	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 areas of peat extractions sites listed in the BritPits database were 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.

It is assumed that extraction areas continue to produce emissions while there is visible evidence of exposed peat soil from Google Earth satellite imagery, and do not convert back to functioning peatlands without restoration intervention. An extraction site is considered to have ceased emissions when there is visible evidence of the re-establishment of vegetation cover on the satellite imagery and evidence of rewetting (ditch blocking) from online documentation of the restoration works and communication with site managers.

Annual peat production in Great Britain (**Table A 3.4.30**) 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 3.4.30 Annual peat production, m^3 for England and Scotland (from Annual Minerals Raised Inquiry/Mineral Extraction in Great Britain reports)

Year	England Horticultural	England Fuel	Scotland Horticultural	Scotland 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	550,716	26,284
2006	856,000	1,000	712,000	24,000
2007	654,000	0	221,000	10,000
2008	496,000	0	243,000	21,000
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	146,000	20,000
2013	661,000	0	594,000	24,000
2014	294,000	0	501,000	32,000
2015*	567,100	0	425,372	22,528
2016*	567,100	0	425,372	22,528
2017*	567,100	0	425,372	22,528

Year	England Horticultural	England Fuel	Scotland Horticultural	Scotland Fuel
2018*	567,100	0	425,372	22,528
2019*	567,100	0	425,372	22,528

* Actual data not available 2015-2019. Volumes are 2005-2014 average except for Fuel peat in England which is assumed to be zero as there are no longer any sites licenced for this activity.

A 3.4.8.2 Estimation of emissions

Tier 1 and Tier 2 emission factors are used to estimate on-site emissions for CO_2, CH_4 and N_2O (see section 3.4.6.2).

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).

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 4D Wetlands remaining Wetlands). 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 1.995 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. The UK biomass carbon stock of shrubby grassland (10 t C/ha) was used for consistency with other parts of the LULUCF inventory.

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 extraction, conversion losses are assumed to be left as on-site harvest residue and enter the litter pool. 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 CARBINE model uses standard estimates for oven-dried wood density to derive biomass from the harvested volume (Lavers and Moore, 1983; Jenkins et al., 2011). Carbon content of all oven-dried wood is assumed to be 50% (Matthews, 1993). CARBINE assumes the wood of a tree species all has the same oven-dried wood density and carbon content, irrespective of which semi-finished wood product categories it is assigned to.

The proportions of wood produced which are allocated to different product categories are based on proportions derived from FAO data[17] (prior to 1994) and forestry commission data[18] (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 2013 Revised Supplementary Methods and Good Practice Guidance, taking into account the decay rate of wood products and the service life as influenced by socio-economic factors. The half-lives are: 35 years for sawn wood; 25 years for wood panels; 2 years for paper. Timber used as woodfuel is assumed to instantaneously oxidise.

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. 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 is undertaken for any updates in datasets for every inventory compilation cycle. This work builds on an MSc project to calculate LULUCF net emissions/removals for the OTs and CDs undertaken during 2007 (Ruddock 2007).

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

[18] https://www.forestresearch.gov.uk/tools-and-resources/statistics/statistics-by-topic/timber-statistics/uk-wood-production-and-trade-provisional-figures/

Gibraltar has a very small land area (6 km^2) with no agricultural land. The only area of woodland (dense Mediterranean scrub) occurs within the Upper Rock Nature Reserve/park, and is not managed for production[19]. The whole land area of Gibraltar is categorised as Settlement remaining Settlement and has not undergone any land use change since 1970. It is therefore estimated that there are no net LULUCF emissions from this territory.

An assessment of flooded land was undertaken for the Overseas Territories and Crown Dependencies. No flooded land areas exceed the area threshold of 1 km^2 used for the UK, so the area of Flooded Land remaining Flooded Land has been included with the Inland Water area in the Wetlands remaining Wetlands category.

Peat organic soils occur in the Falkland Islands and Isle of Man but not in the other Overseas Territories and Crown Dependencies. Emissions from the drainage and rewetting of organic soils on the Isle of Man will be reported in the next inventory submission. There is a longer term research project into organic soils and emissions in the Falkland Islands (funded through the UK Government Darwin Initiative project DPLUS083), the results of which will feed into the inventory in due course.

A small area of deforestation occurs in Guernsey, obtained from habitat surveys in 1999, 2010 and 2018. The change in forest cover is a result of the changed areas losing sufficient tree cover to be reclassified as dense scrub or parkland, rather than conversion to settlement land or agriculture, therefore changes in soil carbon stocks do not occur. Deforestation in the Cayman Islands arises from mangrove conversion to urban development (Jurn et al. 2018) and occurs on organic soils.

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 3.4.31**). This allowed Tier 1 level inventories to be constructed for the OT/CDs for all land use categories. The assumptions and factors used for the estimation of emissions are given in **Table A 3.4.32**. 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.

[19] https://www.gibraltar.gov.gi/new/sites/default/files/1/15/Upper_Rock_Nature_Reserve_Management_Action_Plan.pdf

Table A 3.4.31 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, 4D	2002-2018	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, 4D, 4E	1998/9, 2005, 2018	Guernsey Habitat Survey (199, 2010, 2018), Sustainable Guernsey 2005, 2009; Guernsey Facts and Figures 2018
Jersey	4A	1990-2010	FAO Global Forest Resources Assessment 2010: Jersey
	4B	1990 - 2018	Jersey Agricultural Statistics
	4A, 4B, 4C, 4D, 4E	2006, 2008, 2012, 2015	Jersey In Figures 2006-present
Falkland Islands	4A	1990-2011	Department of Mineral Resources, personal communication FAO Global Forest Resources Assessment 2010: Falkland Islands

Territory	LULUCF category	Time period	Reference
	4B, 4C	1991-present	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.
Cayman Islands	4A, 4B, 4C, 4D, 4E	2013	Cayman Island Compendium of Statistics- Land Cover 2013; Agricultural Land Capability of the Cayman Islands (1996)
	4E	1965-2013	Jurn et al. (2018); Information provided by Cayman Islands Government to Aether for GHGI (2017)
Bermuda	4A, 4B, 4D, 4E	1989-present	Bermuda Biodiversity Study[20], Bermuda Environmental Statistics Compendium

Table A 3.4.32 Assumptions and EFs 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	Cayman Islands	Bermuda
Soil C density, tC/ha	Mineral soil	95	95	95	87	35	47

[20] https://environment.bm/country-study

Land Use category	Sub-category	Isle of Man	Guernsey	Jersey	Falkland Islands	Cayman Islands	Bermuda
Forest land fluxes	Living biomass, DOM, Mineral soils, Organic soils	Tier 1 temperate oceanic forest and temperate oceanic plantation EFs used. All forest is on mineral soil. Area increased 1961-1990, but stable since. Gains and losses (thinning management) in living biomass are calculated, deadwood, litter and mineral soil CSC are assumed to be zero under Tier 1.	Tier 1 temperate oceanic forest and temperate oceanic plantation EFs used. All forest is on mineral soil. Area increased 2000-present. Gains in living biomass are calculated, deadwood, litter and mineral soil CSC are assumed to be zero under Tier 1.	Assumed in equilibrium	No forest on Falklands	Tier 1 tropical dry forest and tropical dry mangrove EFs used. All forest is on mineral soil, all mangrove is on organic soil. The forest area is stable 1990-2005. Assumed that any gains in biomass are lost in the same year, keeping the carbon stock changes in balance. Deadwood, litter and mineral and mangrove soil CSC are assumed to be zero under Tier 1	Tier 1 tropical dry forest and tropical dry mangrove EFs used. All forest is on mineral soil, all mangrove is on organic soil. Assumed that any gains in biomass are lost in the same year, keeping the carbon stock changes in balance. Deadwood, litter and mineral and mangrove soil CSC are assumed to be zero under Tier 1
	Wildfires	Use proxy rate of burning in UK forests (0.017% p.a.). Tier 1 EFs for “All other temperate forests”.	Use proxy rate of burning in UK forests (0.017% p.a.) Tier 1 EFs for “All other temperate forests”.	Use proxy rate of burning in UK forests (0.017% p.a.) Tier 1 EFs for “All other temperate forests”.	N/A	Use proxy rate of burning in Cuba forests (0.15% p.a.). Tier 1 EFs for “Primary tropical forest”.	No reported wildfires

Land Use category	Sub-category	Isle of Man	Guernsey	Jersey	Falkland Islands	Cayman Islands	Bermuda
Crop remaining crop	Living biomass	N/A. Only for perennial crops	Orchards only. 10 tC/ha	N/A. Only for perennial crops	N/A. Only for perennial crops	There is no land use data to distinguish the cropland within the man-modified area so it is included with the settlement area.	Agricultural land is predominantly cropland and the small area of agricultural grassland (dairy/forage) has been included here. Assumed stable with no net emissions
	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 Use category	Sub-category	Isle of Man	Guernsey	Jersey	Falkland Islands	Cayman Islands	Bermuda
Land converted to Crop	Living biomass	UK shrubby grass to crop values(5 tC/ha)	UK non-shrubby grass to crop value (2.2 tC/ha)	UK non-shrubby grass to crop value (2.2 tC/ha)	UK non-shrubby grassland to crop value (2.2 tC/ha)	There is no land use data to distinguish the cropland within the man-modified area so it is included with the settlement area.	N/A
	Dead organic matter	N/A	N/A	N/A	N/A		
	Mineral soils	Conversion from natural grassland (-1.7347 tC/ha). Crop F_{LU}=0.69, Crop F_i=0.92	Conversion from natural grassland (-0.95 tC/ha). Crop F_{LU}=0.8, Crop F_i=1	Conversion from natural grassland (-0.95 tC/ha). Crop F_{LU}=0.8, Crop F_i=1	N/A		
	Organic soils	N/A	N/A	N/A	Default (-5 tC/ha)		
	N_2O emissions	Default (0.001817 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	Cayman Islands	Bermuda
Grass remaining grass	Living biomass	N/A	N/A	N/A	N/A	The grassland area is stable 1990-2005. Biomass, dead organic matter and soil CSC are assumed to be zero under Tier 1.	Included with Cropland
	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		
	Wildfires	Use proxy rate of burning in UK grassland (0.070% p.a.). Tier 1 EFs for “Calluna heath (temperate)”	Use proxy rate of burning in UK grassland (0.070% p.a.). Tier 1 EFs for “Calluna heath (temperate)”	Use proxy rate of burning in UK grassland (0.070% p.a.). Tier 1 EFs for “Calluna heath (temperate)”	Use proxy rate of burning in UK grassland (0.070% p.a.) .Tier 1 EFs for “Calluna heath (temperate)”	Use proxy rate of burning in UK grassland (0.070% p.a.). Tier 1 EFs for “Tropical/sub-tropical grassland (mid-late dry season burn)”	No reported wildfires

Land Use category	Sub-category	Isle of Man	Guernsey	Jersey	Falkland Islands	Cayman Islands	Bermuda
Land converted to grass	Living biomass	UK crop to non-shrubby grass values (-2.2 tC/ha)	UK settlement to non-shrubby grass value (0 tC/ha), Forest to grass assume 120 t DM/ha in forest	Crop to Grassland: UK crop to non-shrubby grass value (-2.2 tC/ha) Settlement to Grassland: assume increase from 0 in glasshouses (2.8 tC/ha)	Use crop to non-shrubby grassland value (-2.2 tC/ha)	Only dry forest is converted to grassland. Tier 1 tropical dry grassland and tropical dry forest EFs are used	N/A
	Dead organic matter	N/A	Forest to grass assume 16 t DM/ha in forest	N/A	N/A	T1 tropical dy forest litter stocks, N/A for dead wood	N/A
	Mineral soils	Assume conversion from cropland (1.7347 tC/ha)	Assume conversion from settlement, assume same soil C as for cropland (0.95 tC/ha)	Cropland to Grassland: assume conversion from cropland (0.95 tC/ha) Settlement to Grassland: assume no change	N/A	Fmg- tropical moderately degraded factor (0.97)	N/A
	Organic soils	N/A	N/A	N/A	Default (-0.25 tC/ha)	N/A	N/A
	N_2O emissions	N/A	N/A	N/A	N/A	Tier 1 EFs with EF2 for tropical cropland/grassland	N/A

Land Use category	Sub-category	Isle of Man	Guernsey	Jersey	Falkland Islands	Cayman Islands	Bermuda
Wetlands remaining Wetlands	N/A	N/A	N/A	N/A	N/A	The area of inland water is stable 1990-2005. The tropical shrubland values (IPCC 2006) are used for mangroves.	There is a small area of protected peat marsh reported in the Biodiversity Study (assumed stable). Areas of fresh/brackish ponds are very small and have been included in Other Land.
Land converted to Wetlands	Living biomass losses	N/A	N/A	N/A	N/A	T1 tropical dry forest EFs for conversion to inland water	N/A
	Dead organic matter	N/A	N/A	N/A	N/A	Only dry forest is converted to flooded land. T1 tropical dry forest EFs for conversion to inland water	N/A
Settlements remaining Settlements	Living biomass, DOM, Mineral soils	N/A	N/A	N/A	N/A	It is assumed that any settlement area that existed before 1965 was on mineral soil. Any settlement area converted from mangrove post-1965 is assumed to be on organic soil. T1 EF for cultivated organic soils (IPCC 2013)	All settlement is assumed to be on mineral soil. Assumed stable.
	Organic soils	N/A	N/A	N/A	N/A		

Land Use category	Sub-category	Isle of Man	Guernsey	Jersey	Falkland Islands	Cayman Islands	Bermuda
Land converted to Settlements	Living biomass	UK values, shrubby grass to settlement (-7.2 tC/ha)	UK non-shrubby grass to settlement value (0 tC/ha)	Grassland to Settlement, UK non-shrubby grass to settlement value (0 tC/ha) Cropland to Settlement: use cropland to settlement value (-2.2 tC/ha)	Use shrubby grass to settlement value (-7.2 tC/ha)	Tier 1 EFs for tropical dry mangrove forest and tropical mangrove shrubland converted to settlement	Conversion to settlement is assumed to occur on forest land and agricultural land at an overall rate of 9.2 ha per year (Bermuda Biodiversity Study value for previous 10 years). Assume 41.6% paved over and 20% soil C lost, 27.3% turf grass with 117% change in soil C, 31.1% wooded with no change in soil C. Assume Crop F_{LU}=0.48 (long-term cultivated on tropical moist soil)
	Dead organic matter	N/A	N/A	N/A	N/A		

Land Use category	Sub-category	Isle of Man	Guernsey	Jersey	Falkland Islands	Cayman Islands	Bermuda
	Mineral soils	Default SOC = 95 tC/ha, assume conversion from grassland and all soil C lost (-4.75 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, Grassland to Settlement: assume 30% of land is paved over and the rest is turf grass (-1.14 tC/ha) Cropland to Settlement: assume 30% of land is paved over and the rest is turf grass (0.95 tC/ha)	N/A	N/A	
	Organic soils	N/A	N/A	N/A	Default - assume cropland (-5 tC/ha)	T1 EF for cultivated organic soils (IPCC 2013)	N/A
	N_2O emissions	Default (0.004976 t N_2O/ha)	Default (0.00119 t N_2O/ha)	Default (0.00119 t N_2O/ha)	N/A	Tier 1 EFs with EF2 for tropical cropland/grassland (for Wetland to Settlement) and EF2 for tropical forest for F2S	

Land Use category	Sub-category	Isle of Man	Guernsey	Jersey	Falkland Islands	Cayman Islands	Bermuda
Other land remaining other land	Living biomass, DOM, Mineral soils, Organic soils	N/A	N/A	N/A	N/A	Area assumed to remain constant over time	Area assumed to remain constant over time
Land converted to other land	Living biomass	N/A	Assume loss of grassland to standing water or cliff (-10 tC/ha)	Assumed loss of grassland to standing water (-2.8 t C/ha)	N/A	N/A	N/A
	Dead organic matter	N/A	N/A	N/A	N/A	N/A	N/A
	Mineral soils	N/A	Assume no change in soil stocks	N/A	N/A	N/A	N/A
	Organic soils	N/A	N/A	N/A	N/A	N/A	N/A
	N_2O emissions	N/A	0	N/A	N/A	N/A	N/A
Harvested wood products		N/A	N/A	N/A	N/A	Instantaneous oxidation assumed for any timber from deforestation.	N/A

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. This work was revisited in 2019/2020 (Henshall and Watterson 2020, not yet published), to re-assess the uncertainties and sensitivities associated with the forest land modelling and update the uncertainties for the non-forest parts of the LULUCF sector.

In 2010 parameterisation of the forest model was assessed as 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[21]). 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.

The updated uncertainty assessment of the Forest Land inventory and Harvested Wood Products (Henshall and Watterson 2020) (outputs derived from the CARBINE model) undertook a Monte Carlo analysis. The probability density functions (PDFs) assigned to the various CARBINE input parameters were based on information from the literature and expert judgement. A selection of 100 sets of input parameters were generated using Latin hypercube sampling, as this was considered to be the minimum number of model runs to get a reasonable estimate of the uncertainty considering the number of parameters adjusted.

The analysis of the carbon emissions/removals predicted by the model gave an uncertainty estimate at the 95% confidence interval of approximately 25% for both forest land and harvested wood products (rounded to the nearest 5%) in both the base year (1990) and the latest inventory year and 20% when both categories are considered in conjunction. This is smaller than what was assumed in the previous uncertainty analysis (around 40% uncertainty for those categories). While this may come in part from the improvement in the stratification of forest land obtained by the change of forest model, this is likely mostly a technical re-evaluation from a more up to date analysis of uncertainties range for the different parameters and the absence of characterisation of structural uncertainties in the model. In relative terms, carbon net emissions estimates for land converted to forest are assessed as considerably more uncertain (85% in the 1990 and 145% in 2018) than for forest remaining forest (20% in both 1990 and 2018).

In 2010 and the updated assessment the area undergoing land use change was assessed as being the single biggest uncertainty in the inventory. This uncertainty in the land use change areas is being addressed by the development of a new vector-based approach (see **Chapter 6**),

[21] 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.

combining multiple sources of land use data and potentially a more intensive use of raw data from remote sensing.

In general, the uncertainties for Tier 2 and Tier 3 activities have not changed significantly between the two uncertainty assessments (the uncertainties published with the IPCC default emission factors are the ones used for Tier 1 activities). The uncertainties in biomass carbon have changed, but these are small components of the LULUCF inventory so have little impact on overall uncertainties. Emissions from organic soils have been included for the first time and/or updated in the 1990-2019 submission, as described in **Section A 3.4.6**. A summary table of uncertainties in the LULUCF sector is shown in **Table A 3.4.33**.

Table A 3.4.33 Summary uncertainties for LULUCF sector activities

LULUCF sub-category	Variable	CO_2	CH_4	N_2O
4A.1 Forest remaining Forest	Forest soil and biomass	20%[a]		
4A.2 Land converted to Forest	Forest soil and biomass	86%[a]		
4A Forest Land/4(I)	Forest fertilisation			34%[a]
4A Forest Land/4(II)	Mineral soil drainage			140%[b]
4A Forest Land/4(II)	Organic soil drainage		95% [c]	97% [c]
4A Forest Land/4(III)	N_2O from land use change			135% [b]
4A Forest Land/4(V)	Biomass burning	54%[d]	54% [d]	54% [d]
4B Cropland	LUC mineral soil carbon change	31%[a]		
4B Cropland	LUC biomass carbon	80%[a]		
4B Cropland	Cropland management (soils and biomass)	12% [b]		
4B Cropland	Organic soils	52% [c]		
4B Cropland/4(II)	Organic soil drainage		91% [c]	71% [c]
4B Cropland/4(III)	N_2O from land use change			36%[a]
4B Cropland/4(V)	Biomass burning	54% [d]	54% [d]	54% [d]
4C Grassland	LUC mineral soil carbon change	43%[a]		
4C Grassland	LUC biomass carbon	64%[a]		
4C Grassland	Grassland management (biomass)	13% [b]		
4C Grassland	Organic soils	42% [c]		
4C Grassland/4(II)	Organic soil drainage		43% [c]	55% [c]
4C Grassland/4(III)	N_2O from land use change			135% [b]
4C Grassland/4(V)	Biomass burning	54% [d]	54% [d]	54% [d]

LULUCF sub-category	Variable	CO_2	CH_4	N_2O
4D Wetlands	Peat extraction offsite emissions	32%[a]		
4D Wetlands	Organic soils	49% [c]		
4D Wetlands/4(II)	Organic soil drainage		39% [c]	120% [c]
4D Wetlands	Flooded land biomass carbon	75% [b]		
4D Wetlands/4(V)	Biomass burning	54% [d]	54% [d]	54% [d]
4E Settlements	LUC mineral soil carbon change	28%[a]		
4E Settlements	LUC biomass carbon	33%[a]		
4E Settlements	Organic soils	60% [c]		
4E Settlements/4(II)	Organic soil drainage		60% [c]	60% [c]
4E Settlements/4(III)	N_2O from land use change			135% [b]
4E Settlements/4(V)	Biomass burning	54% [d]	54% [d]	54% [d]
4G HWP	Harvested wood products	19%[a]		
4	Indirect N_2O (atmospheric deposition)			240% [b]
4	Indirect N_2O (leaching)			163% [b]

[a] Updated uncertainty assessment (Henshall and Watterson, 2020); [b] IPCC default; [c] Analysis of uncertainties for the reporting of drainage and rewetting of peatlands recommended by Evans et al. 2017 (see Annex 3.4.6.4); [d] Uncertainty assessment 2012.

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**. This waste composition data is considered to be representative of current national circumstances, in absence of new data sources for the composition of mixed waste. 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 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 3.5.3**. The amounts of methane generated, recovered, used for power generation, flared, oxidised and emitted to the atmosphere 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%**
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	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%
Inert													100.00%
Commercial	5%	65%	37%		8%	76%							16.00%
Paper and Card	5%	65%	15%	15%	9%	61%							15.00%

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
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%
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%
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 (Mt) (1945 to 2019)

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						
1946	71.2	9.0	4.6	2.4	87.2	**1983**	77.1	8.5	4.6	2.6	92.8
1947	71.5	9.0	4.6	2.4	87.4	**1984**	77.2	8.5	4.6	2.6	92.8
1948	71.7	9.0	4.6	2.4	87.7	**1985**	77.2	8.4	4.6	2.6	92.8

Year	England	Scotland	Wales	Northern Ireland	Total	Year	England	Scotland	Wales	Northern Ireland	Total
1949	72.3	9.0	4.6	2.4	88.4	**1986**	77.3	8.4	4.6	2.6	92.9
1950	72.9	9.1	4.6	2.4	89.1	**1987**	77.3	8.3	4.6	2.6	92.9
1951	73.6	9.1	4.6	2.5	89.8	**1988**	77.4	8.3	4.6	2.6	92.9
1952	74.2	9.1	4.7	2.5	90.5	**1989**	77.4	8.3	4.6	2.6	92.9
1953	74.2	9.1	4.7	2.5	90.4	**1990**	77.7	8.3	4.7	2.6	93.3
1954	74.2	9.0	4.6	2.4	90.3	**1991**	77.7	11.3	4.7	2.6	96.3
1955	74.2	9.0	4.6	2.4	90.3	**1992**	77.7	12.2	4.7	2.6	97.2
1956	75.7	9.1	4.7	2.5	92.0	**1993**	77.6	14.0	4.6	2.6	98.8
1957	77.2	9.2	4.8	2.5	93.7	**1994**	77.6	15.9	4.6	2.6	100.7
1958	78.6	9.3	4.8	2.6	95.4	**1995**	81.8	15.0	4.9	2.8	104.5
1959	80.1	9.5	4.9	2.6	97.1	**1996**	80.7	15.0	4.8	2.8	103.3
1960	81.5	9.6	5.0	2.6	98.8	**1997**	81.1	14.0	4.8	2.8	102.7
1961	81.1	9.7	4.9	2.7	98.4	**1998**	75.0	11.9	4.5	2.6	93.9
1962	80.9	9.6	4.9	2.7	98.0	**1999**	69.3	10.9	4.1	2.4	86.6
1963	84.5	10.0	5.1	2.8	102.4	**2000**	67.4	11.2	4.0	2.3	84.9
1964	84.6	9.9	5.1	2.8	102.4	**2001**	71.4	8.9	4.2	2.4	86.9
1965	85.7	10.0	5.1	2.8	103.6	**2002**	66.8	8.2	3.9	2.3	81.3
1966	85.3	9.9	5.1	2.8	103.2	**2003**	65.4	7.9	3.8	2.2	79.4
1967	85.0	9.8	5.1	2.8	102.7	**2004**	64.9	7.8	3.8	2.2	78.7

Year	England	Scotland	Wales	Northern Ireland	Total	Year	England	Scotland	Wales	Northern Ireland	Total
1968	84.8	9.7	5.1	2.8	102.4	**2005**	60.0	7.1	3.5	2.0	72.6
1969	84.0	9.6	5.0	2.8	101.4	**2006**	61.7	7.1	4.0	2.0	74.8
1970	83.8	9.5	5.0	2.8	101.0	**2007**	60.7	7.4	3.2	1.9	73.2
1971	82.8	9.3	4.9	2.7	99.8	**2008**	53.9	6.1	2.9	1.6	64.5
1972	81.8	9.2	4.8	2.7	98.5	**2009**	44.0	4.7	2.5	1.1	52.3
1973	81.3	9.1	4.8	2.7	97.9	**2010**	43.6	4.6	2.3	1.0	51.4
1974	79.9	9.0	4.8	2.6	96.3	**2011**	44.7	4.7	2.2	1.0	52.5
1975	80.1	9.0	4.8	2.6	96.5	**2012**	41.8	4.5	2.2	1.1	49.6
1976	78.8	8.8	4.7	2.6	94.9	**2013**	41.1	4.1	2.2	1.1	48.4
1977	78.4	8.8	4.7	2.6	94.5	**2014**	41.3	4.1	1.5	1.3	48.2
1978	78.8	8.8	4.7	2.6	95.0	**2015**	43.9	4.2	1.3	1.6	51.0
1979	78.7	8.8	4.7	2.6	94.7	**2016**	44.7	3.7	2.0	1.9	52.3
1980	78.6	8.7	4.7	2.6	94.6	**2017**	45.4	3.8	1.8	1.7	52.7
1981	77.0	8.5	4.6	2.5	92.7	**2018**	44.1	3.7	1.40	1.5	50.7
1982	77.1	8.5	4.6	2.5	92.7	**2019**	45.9	3.0	1.1	1.0	51.3

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 Mt	Methane generated Kt	Methane captured kt	Methane captured %	Methane used for power generation kt	Methane used for power generation %	Methane flared kt	Methane flared %	Residual methane oxidised kt	Residual methane oxidised %	Methane emitted kt	Methane emitted %
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%
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	1065	42%	980	39%	85	3%	146	6%	1316	52%
2009	52.33	2,400	1112	46%	1015	42%	97	4%	127	5%	1159	48%
2010	51.38	2,278	1200	53%	1066	47%	134	6%	108	5%	971	43%
2011	52.54	2,159	1178	55%	1075	50%	103	5%	98	5%	883	41%

Year	Waste Landfilled Mt	Methane generated Kt	Methane captured kt	Methane captured %	Methane used for power generation kt	Methane used for power generation %	Methane flared kt	Methane flared %	Residual methane oxidised kt	Residual methane oxidised %	Methane emitted kt	Methane emitted %
2012	49.55	2,041	1124	55%	1042	51%	82	4%	92	4%	825	40%
2013	48.43	1,929	1144	59%	1035	54%	109	6%	78	4%	706	37%
2014	48.15	1,820	1142	63%	1007	55%	136	7%	68	4%	610	34%
2015	50.98	1,716	1065	62%	974	57%	90	5%	65	4%	587	34%
2016	52.31	1,627	1007	62%	941	58%	67	4%	62	4%	558	34%
2017	52.75	1,544	916	59%	857	56%	59	4%	63	4%	565	37%
2018	50.70	1,468	829	56%	783	53%	45	3%	64	4%	576	39%
2019	51.25	1,396	765	55%	725	52%	40	3%	63	5%	568	41%

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 3.5.5** 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	k value
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	Region: Europe: Western Climate: Wet Temperate
Jersey	N/A, all MSW is incinerated for energy from waste	N/A	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	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	Region: Europe: Western Climate: Wet Temperate
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: Caribbean Climate: Moist and wet tropical
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	Region: Caribbean Climate: Moist and wet tropical

Region	Methodology	Activity data	MCF	DOC	k value
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	Region: America: South Climate: Wet Temperate

A 3.5.2 Biological Treatment of Solid Waste (5B)

The annual amount of waste treated in the composting process (fresh weight) are reported in **Table A 3.5.6**. Fresh weight can be converted to dry mass is using the IPCC default a factor of 0.4 dry matter/fresh weight.

Table A 3.5.6 Activity Data: Inputs in the composting process

Year	Composting (Non-household) (Mg fw)	Composting (Household) (Mg fw)	MBT - Composting (Mg fw)
1990	-	181,322	-
1991	229,036	181,756	-
1992	458,072	182,146	-
1993	687,108	182,638	-
1994	916,144	183,213	-
1995	1,145,181	183,654	-
1996	1,374,217	184,132	-
1997	1,603,253	184,643	-
1998	1,832,289	185,364	-
1999	2,061,325	185,979	-
2000	2,290,361	186,676	-
2001	2,519,397	187,441	67,882
2002	2,748,433	187,373	62,537
2003	2,977,469	187,300	57,192
2004	3,206,506	238,235	37,179
2005	3,435,542	289,058	88,917
2006	3,664,578	339,909	110,618
2007	3,893,614	390,804	542,678
2008	3,720,016	441,622	629,269
2009	4,655,911	492,393	438,011
2010	4,802,584	496,077	1,282,060
2011	4,943,045	500,008	1,898,570
2012	5,271,802	503,005	1,719,118

Year	Composting (Non-household) (Mg fw)	Composting (Household) (Mg fw)	MBT - Composting (Mg fw)
2013	5,519,116	505,833	2,138,366
2014	6,223,475	509,350	2,439,341
2015	5,955,794	513,040	2,740,317
2016	6,285,774	517,007	3,041,292
2017	6,427,843	519,898	3,342,268
2018	5,934,485	522,778	3,643,244
2019	5,722,483	525,570	3,944,219

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

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	6,124	0
2001	6,187	16,970
2002	56,280	15,634
2003	56,280	14,298
2004	87,638	37,179
2005	197,540	17,783
2006	212,568	27,655

Year	Anaerobic digestion – non-agricultural residue (Mg)	Anaerobic digestion - MBT (Mg)
2007	232,605	40,847
2008	331,665	66,664
2009	642,869	365,570
2010	1,034,843	72,262
2011	1,629,109	104,815
2012	2,204,971	795,961
2013	3,350,116	600,692
2014	4,807,020	703,455
2015	6,373,511	806,218
2016	8,201,578	908,982
2017	9,167,997	1,011,745
2018	9,265,736	1,114,508
2019	9,353,485	1,217,272

A 3.5.3 Waste Incineration (5C)

Table A 3.5.8 Activity Data: UK Waste Incineration

Year	Municipal Waste Incineration[a] (Mt)	Clinical Waste Incineration (Mt)	Chemical Waste Incineration (Mt)	Sewage Sludge Incineration (Mt)
1990	2.093	0.350	0.290	0.075
1991	2.069	0.350	0.290	0.069
1992	1.945	0.330	0.290	0.072
1993	1.677	0.310	0.290	0.084
1994	1.148	0.290	0.289	0.072
1995	0.996	0.270	0.289	0.082
1996	1.062	0.250	0.288	0.088
1997	-	0.230	0.287	0.081
1998	-	0.236	0.287	0.185

Year	Municipal Waste Incineration[a] (Mt)	Clinical Waste Incineration (Mt)	Chemical Waste Incineration (Mt)	Sewage Sludge Incineration (Mt)
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	0.262	0.207
2004	-	0.182	0.240	0.212
2005	-	0.143	0.218	0.216
2006	-	0.105	0.199	0.220
2007	-	0.111	0.192	0.215
2008	-	0.115	0.167	0.192
2009	-	0.121	0.153	0.199
2010	-	0.114	0.159	0.231
2011	-	0.107	0.153	0.224
2012	-	0.107	0.154	0.209
2013	-	0.101	0.179	0.200
2014	-	0.103	0.184	0.174
2015	-	0.092	0.168	0.169
2016	-	0.093	0.173	0.148
2017	-	0.092	0.171	0.133
2018	-	0.092	0.139	0.112
2019	-	0.096	0.148	0.088

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 (kt)

Pollutant	Year	Chemical Waste Incineration	Accidental Fires	MSW Incineration[a]	Clinical Waste Incineration	Sewage Sludge Incineration	Total
CO_2	1990	368	NE	604	308	NA	1280
	1995	367	NE	365	238	NA	969
	2000	358	NE	NO	218	NA	577
	2005	335	NE	NO	126	NA	461
	2010	181	NE	NO	101	NA	281
	2015	157	NE	NO	81	NA	239
	2016	185	NE	NO	82	NA	267
	2017	182	NE	NO	81	NA	263
	2018	164	NE	NO	81	NA	244
	2019	161	NE	NO	84	NA	245
CH_4	1990	0.114	1.009	4.175	0.009	0.029	5.340
	1995	0.114	0.984	2.205	0.007	0.032	3.342
	2000	0.088	0.772	NO	0.006	0.076	0.941
	2005	0.068	0.708	NO	0.004	0.084	0.864
	2010	0.034	0.366	NO	0.003	0.090	0.493
	2015	0.028	0.279	NO	0.002	0.066	0.3375
	2016	0.028	0.283	NO	0.002	0.058	0.370
	2017	0.030	0.277	NO	0.002	0.052	0.361
	2018	0.028	0.271	NO	0.002	0.044	0.344
	2019	0.028	0.259	NO	0.002	0.034	0.324
N_2O	1990	0.029	NE	0.056	0.011	0.074	0.169
	1995	0.029	NE	0.026	0.008	0.081	0.145
	2000	0.029	NE	NO	0.007	0.192	0.228
	2005	0.022	NE	NO	0.004	0.214	0.240
	2010	0.016	NE	NO	0.003	0.229	0.248
	2015	0.017	NE	NO	0.003	0.167	0.187
	2016	0.017	NE	NO	0.003	0.146	0.166
	2017	0.017	NE	NO	0.003	0.131	0.151
	2018	0.014	NE	NO	0.003	0.110	0.127

Pollutant	Year	Chemical Waste Incineration	Accidental Fires	MSW Incineration[a]	Clinical Waste Incineration	Sewage Sludge Incineration	Total
	2019	0.015	NE	NO	0.003	0.087	0.105

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

Process stage	Process type	unit	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Total Sludge		kt tds	1634	1657	1682	1768	1666	1597	1659	1669	1688	1687
Population Equivalent		million	68.3	69.2	70.2	70.5	69.3	73.0	73.2	73.4	73.8	75.2
Additional Treatment	Digested	kt tds	400	432	467	795	823	657	673	660	635	545
	Advanced Digested	kt tds	102	109	117	331	374	454	556	615	683	819
	Composted	kt tds	7	8	8	15	24	7	18	14	2	4
Disposal route	Farmland	kt tds	508	547	590	1216	1282	1422	1434	1479	1548	1556
	Landfill	kt tds	160	153	110	131	35	7	9	8	0.4	4
	Incineration	kt tds	68	80	211	252	238	161	198	168	137	124
	Sea	kt tds	782	721	611	0	0	0	0	0	0	0
	Composted	kt tds	2	2	2	13	23	7	18	14	2	4
	Land Reclamation	kt tds	31	30	30	96	44	0	0	0	0	0
	Other	kt tds	84	124	129	61	44	0	0	0	0	0

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

Process stage	Process type	unit	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
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

Process stage	Process type	unit	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Additional Treatment	Digested[2]	kt/Mt tds	16.54	16.28	16.46	16.93	16.48	15.63	13.30	13.26	13.19	0.00
	Advanced Digested	kt/Mt tds	4.54	4.54	4.54	4.54	4.54	4.52	4.57	4.57	4.55	4.55
	Composted	kt/Mt tds	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	1.30	1.28	1.22	1.16	0.96
	Landfill	kt/Mt tds	15.09	15.09	15.09	15.09	15.09	15.09	15.09	15.09	15.09	15.09
	Incineration	kt/Mt tds	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	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
	Composted	kt/Mt tds	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	1.29	1.27	1.22	1.16	0.96
	Other[6]	kt/Mt tds	1.19	1.19	1.19	1.19	1.19	1.22	1.20	1.16	1.07	0.92
Total[7]		kt/Mt tds	29.81	28.54	30.98	13.47	13.48	11.68	10.94	10.87	10.58	10.50

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)

Process stage	Process type	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Mechanical treatment and storage[1]		4.41	4.47	4.54	4.77	4.50	4.31	4.48	4.51	4.56	4.55
Additional Treatment	Digested[2]	6.62	7.03	7.68	13.46	13.56	10.27	8.95	8.75	8.37	7.85
	Advanced Digested	0.46	0.50	0.53	1.50	1.70	2.06	2.55	2.81	3.11	3.72

Process stage	Process type	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
	Composted	0.07	0.08	0.08	0.15	0.24	0.07	0.18	0.14	0.02	0.04
Disposal route	Farmland[3]	0.68	0.73	0.79	1.71	1.81	1.84	1.84	1.81	1.79	1.49
	Landfill	2.41	2.30	1.66	1.97	0.53	0.10	0.14	0.12	0.01	0.05
	Incineration	-	-	-	-	-	-	-	-	-	-
	Sea[4]	33.92	31.99	36.63	-	-	-	-	-	-	-
	Composted	0.001	0.001	0.001	0.01	0.01	0.00	0.01	0.01	0.00	0.00
	Land Reclamation[5]	0.04	0.04	0.04	0.13	0.06	-	-	-	-	-
	Other[6]	0.10	0.15	0.15	0.07	0.05	-	-	-	-	-
Total[7]		48.72	47.29	52.11	23.81	22.46	18.66	18.14	18.14	17.85	17.70

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

Data	Unit	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Estimated population connected to private wastewater management systems	population (thousands)	1417.18	1440.63	1438.67	1465.29	1525.78	1577.77	1598.92	1605.40	1605.79	1606.95
BOD value applied	g/person/day	66.33	66.33	66.33	68.73	65.90	59.96	62.07	62.30	62.69	61.41

A 3.5.4.2 5D2 Industrial Wastewater Handling and Sludge Disposal

Table A 3.5.14 UK Industrial Wastewater Treatment Activity Data, total industrial product per sector (5D2)

Industry	Units	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Alcohol refining	Kilotonnes	407	407	395	551	487	573	489	614	516	669

Industry	Units	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Beer & malt	Kilotonnes	7,917	7,917	6,655	7,152	6,447	6,505	6,082	6,793	5,749	5,835
Coffee	Kilotonnes	0.4	0.4	63	74	80	83	84	81	86	85
Dairy Products	Kilotonnes	6,840	6,840	6,125	6,223	8,507	10,446	7,690	8,809	9,095	8,594
Fish processing	Kilotonnes	106	106	362	363	269	227	207	230	185	116
Iron and Steel manufacturing	Kilotonnes	214	214	177	98	293	810	580	109	99	99
Meat & Poultry	Kilotonnes	2,706	2,706	2,617	2,832	2,603	3,284	3,354	3,563	3,593	3,578
Organic chemicals	Kilotonnes	158	158	129	65	1,192	316	399	369	307	277
Petroleum Refineries	Kilotonnes	86,131	86,131	81,129	80,145	68,599	57,577	56,588	56,407	54,853	55,248
Nitrogen fertiliser	Kilotonnes	-	-	-	-	2,615	1,703	1,942	2,104	1,850	2,005
Plastics & resins	Kilotonnes	1,413	1,413	1,334	1,741	1,390	1,780	1,780	1,676	1,851	1,710
Pulp & Paper	Kilotonnes	8,590	8,590	8,138	7,349	8,207	6,822	7,182	8,017	5,967	6,219
Soap & detergents	Kilotonnes	202	202	248	278	291	259	306	326	285	302
Starch production	Kilotonnes	23	23	10	57	163	25	30	18	18	15
Sugar Refining	Kilotonnes	35	35	40	25	22	18	17	16	15	13
Vegetable Oils	Kilotonnes	302	302	288	346	411	574	419	433	397	287
Vegetables, Fruits & Juices	Kilotonnes	990	990	1,052	1,083	820	1,077	830	845	1,024	885
Wine & Vinegar	Kilotonnes	638	638	669	702	772	1,042	1,048	1,192	1,407	1,027

A 3.6 UK CROWN DEPENDENCIES AND OVERSEAS TERRITORIES

A 3.6.1 Overview of Data Sources

Fuel use data for Isle of Man, Guernsey and Jersey are assumed to be included in UK national energy statistics (see **Section 1.1.2.2**), so fuel thought to be used in these territories are split out from UK total consumption unless otherwise stated in **Section A 4.2.1**.

Activity data including fuel use data for other territories are obtained from government departments for those territories, specifically:

- The Cayman Islands Government Department of Environment Sustainable Development Unit;
- The Department of Energy Bermuda; and,
- The Falkland Islands Government Policy Unit.

Activity and emissions data estimates from LULUCF sources and sinks have been researched via the FAOSTAT database, to supplement data available from the OTs. The LULUCF data for Cayman Islands from FAOSTAT (FAO, 2018) indicates zero emissions, using Tier 1 methods. The data sources and methodologies used for other sectors are described in the main methodology sections of the NIR.

A 3.6.2 Activity and Emissions Data

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	2015	2016	2017	2018	2019
1. Energy	1.41	1.58	1.63	1.43	1.36	1.28	1.36	1.31	1.36	1.43
2. Industrial Processes and Product Use	0.00203	0.00698	0.0269	0.0531	0.0847	0.0844	0.0788	0.0735	0.0682	0.0681
3. Agriculture	0.179	0.185	0.186	0.128	0.155	0.145	0.15	0.146	0.144	0.144
4. LULUCF	-0.0338	-0.0364	-0.0323	-0.0233	-0.0181	-0.00612	-0.0264	-0.0295	-0.0326	-0.0332
5. Waste	0.114	0.116	0.119	0.119	0.105	0.0901	0.0878	0.0859	0.0838	0.0817
7. Other	-	-	-	-	-	-	-	-	-	-
Total	**1.67**	**1.85**	**1.93**	**1.71**	**1.68**	**1.60**	**1.65**	**1.59**	**1.63**	**1.69**

Table A 3.6.2 Isle of Man, Guernsey and Jersey ‑ Combustion activity data

Fuel	Fuel Unit	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Aviation spirit	TJ	122	136	185	202	107	54.6	42.8	30.3	28	17.8
Aviation turbine fuel	TJ	1,170	1,050	1,360	1,570	1,350	1,240	1,270	1,420	1,380	1,420
Burning oil	TJ	3,290	3,820	5,130	5,230	5,300	5,660	5,970	6,080	6,300	6,390
Coal	TJ	329	210	149	100	8.2	8.84	8.84	8.81	8.81	8.81
DERV	TJ	1,060	1,340	1,910	1,690	1,790	1,920	1,980	2,020	2,040	1,940
Fuel oil	TJ	6,350	7,850	5,910	1,060	1,210	812	1,050	452	884	1,700
Gas oil	TJ	2,340	2,480	2,310	2,580	1,690	1,210	1,250	1,240	1,220	1,230
LPG	TJ	384	443	1,530	819	736	554	529	501	515	478
MSW	TJ	268	374	479	866	795	1,050	1,100	1,040	1,080	1,070
Natural gas	TJ	-	-	-	3,370	4,020	3,590	4,050	3,980	4,000	4,010
Petrol	TJ	3,510	3,400	3,230	3,270	2,850	2,520	2,460	2,370	2,340	2,310
Urea consumption	Mt	-	-	-	-	0.000324	0.000746	0.000806	0.000835	0.00087	0.000849

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

Livestock Category	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Dairy	15,888	15,729	16,186	13,127	11,511	10,846	11,482	11,451	11,404	11,278
Non-dairy	28,663	28,333	29,176	16,770	28,821	26,643	26,397	24,601	24,131	23,429
Sheep	151,764	160,228	176,259	87,537	138,251	133,666	126,256	129,139	126,307	129,449
Pigs	4,854	5,411	4,609	1,148	4,086	2,861	2,449	2,364	2,378	2,344

Livestock Category	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Poultry	84,048	46,481	46,448	58,160	54,400	62,916	60,231	62,537	63,564	63,813
Goats	333	347	376	141	288	539	406	396	397	423
Horses	2,785	2,785	2,785	2,822	3,236	2,891	3,258	2,705	2,586	2,641

Table A 3.6.4 Isle of Man, Guernsey and Jersey - Total emissions from Agricultural Soils (Mt CO_2 equivalent)

Territory	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Isle of Man	0.0443	0.0447	0.0404	0.0293	0.0283	0.0260	0.0263	0.0258	0.0257	0.0256
Guernsey	0.0035	0.0036	0.0031	0.0027	0.0028	0.0029	0.0030	0.0030	0.0029	0.0029
Jersey	0.0091	0.0097	0.0094	0.0080	0.0078	0.0075	0.0073	0.0075	0.0075	0.0075

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	2015	2016	2017	2018	2019
1. Energy	1.23	1.25	1.40	1.59	1.58	1.69	1.51	1.65	1.67	1.71
2. Industrial Processes and Product Use	0.000361	0.00357	0.0186	0.0386	0.0525	0.0458	0.0426	0.0389	0.0353	0.0353
3. Agriculture	0.274	0.265	0.249	0.222	0.184	0.181	0.180	0.185	0.175	0.175
4. LULUCF	0.0937	0.0922	0.0998	0.100	0.238	0.134	0.136	0.137	0.138	0.129
5. Waste	0.115	0.100	0.0831	0.0833	0.128	0.109	0.107	0.111	0.115	0.119
7. Other	-	-	-	-	-	-	-	-	-	-
Total	**1.71**	**1.71**	**1.85**	**2.03**	**2.18**	**2.16**	**1.98**	**2.12**	**2.13**	**2.17**

Table A 3.6.6 Cayman Islands, Falklands Islands, and Bermuda - Combustion activity data

Fuel	Fuel Unit	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Aviation spirit	TJ	5.12	-	-	-	-	-	-	-	-	-
Aviation turbine fuel	TJ	1,190	544	601	825	1040	738	742	749	739	735
Burning oil	TJ	63.3	78.3	90.1	117	105	129	130	118	118	118
DERV	TJ	2,120	1,810	1,490	3,350	1,390	1,230	1,230	1,230	1,230	1,230
Fuel oil	TJ	1,970	2,060	3,600	4,140	4,270	4,300	4,600	5,110	4,500	4,550
Gas oil	TJ	5,670	6,360	6,120	6,740	7,750	8,130	7,560	8,080	8,610	8,940
LPG	TJ	260	290	321	370	379	414	441	443	461	489
MSW	TJ	0.931	453	453	453	426	362	412	435	465	461
Natural gas	TJ	1.5	1.86	2.14	2.8	3.32	3.65	3.46	3.52	3.52	3.52
Petrol	TJ	2,820	2,860	3,190	2,530	2,920	2,110	2,350	2,340	2,590	2,810
Urea consumption	kg	-	-	-	-	214,000	560,000	584,000	562,000	607,000	600,000
Lubricants	TJ	63.9	76.0	75.8	73.8	69.2	60.4	62.1	63.4	59.2	60.9
Petroleum waxes	kg	83,500	71,700	58,400	139,000	72,700	88,100	78,400	80,100	75,300	95,400

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

Livestock Category	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Dairy Cattle	2,161	1,862	1,911	1,145	868	675	634	647	598	598
Non-dairy Cattle	5,256	4,861	5,077	7,845	6,360	4,748	4,503	4,913	4,772	4,803

Livestock Category	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Sheep	739,999	717,571	669,905	580,864	478,625	482,131	479,752	490,213	462,245	462,245
Goats	405	867	1,286	1,704	2,251	1,812	2,031	2,337	2,546	2,689
Horses	2,217	2,069	1,703	1,417	1,269	1,223	1,252	1,244	1,221	1,221
Swine	1,116	1,174	1,376	1,384	1,233	1,058	1,234	1,301	1,485	1,582
Poultry	15,319	14,664	20,890	27,164	32,293	39,458	39,948	26,710	30,019	31,743
Deer	0	0	0	0	184	243	243	243	243	243

Table A 3.6.8 Cayman Islands, Falklands Islands, and Bermuda ‑ Total emissions from Agricultural Soils (Mt CO_2 equivalent)

Territory	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Bermuda	0.0007	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
Cayman Islands	0.0008	0.0010	0.0011	0.0013	0.0013	0.0012	0.0012	0.0011	0.0012	0.0012
Falkland Islands	0.1083	0.1045	0.0978	0.0860	0.0717	0.0715	0.0710	0.0727	0.0688	0.0688

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

Country	kg N applied
Cayman Islands	28,834
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	2015	2016	2017	2018	2019
1. Energy	0.218	0.215	0.241	0.277	0.287	0.337	0.332	0.308	0.297	0.287
2. Industrial Processes and Other Product Use	0.000467	0.0013	0.00301	0.006	0.00973	0.0118	0.0115	0.0108	0.01000	0.0101
3. Agriculture	-	-	-	-	-	-	-	-	-	-
4. LULUCF	-	-	-	-	-	-	-	-	-	-
5. Waste	0.00719	0.00872	0.0117	0.00145	0.0031	0.00173	0.00181	0.00184	0.00185	0.00183
Total	**0.225**	**0.225**	**0.256**	**0.284**	**0.3**	**0.35**	**0.346**	**0.321**	**0.309**	**0.299**

Table A 3.6.11 Gibraltar – Combustion activity data

Fuel	Fuel Unit	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Aviation spirit	TJ	-	-	-	-	-	-	-	-	-	-
Aviation turbine fuel	TJ	386	297	258	411	321	427	554	579	390	453
Clinical waste	Mt	-	-	-	-	0.00181	0.000306	0.000339	0.000356	0.000356	0.000356
DERV	TJ	82.4	67.8	141	330	348	492	492	492	490	489
Fuel oil	TJ	925	875	968	844	729	418	378	364	316	358
Gas oil	TJ	849	1010	1130	1420	1760	2570	2420	2050	2140	1430
LPG	TJ	384	384	384	384	384	384	384	404	404	428
MSW	TJ	109	126	160	-	-	-	-	-	-	-
Petrol	TJ	298	255	352	353	329	250	262	286	285	285

Fuel	Fuel Unit	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Aviation spirit	TJ	-	-	-	-	-	-	-	-	-	-
Petroleum waxes	Mt	0.0000297	0.0000206	0.0000147	0.0000348	0.0000184	0.0000233	0.0000205	0.0000208	0.0000194	0.0000236
Lubricants	TJ	22.7	21.8	19.1	18.5	17.5	16.0	16.3	16.5	15.3	15.1

Table A 3.6.12 Isle of Man, Guernsey and Jersey – Total Municipal Solid Waste activity data (Gg)

Territory	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Isle of Man	39.37	40.39	43.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Guernsey	56.7	56.7	56.7	56.7	35.0	29.5	28.3	27.2	27.2	4.16
Jersey	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table A 3.6.13 Cayman Islands, Falklands Islands, and Bermuda – Total Municipal Solid Waste activity data (Gg)

Territory	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Cayman Islands	34.0	34.0	34.0	144	94.1	63.0	102	106	108	136
Falklands Islands	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bermuda	64.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0

ANNEX 4: National Energy Balance

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.

The scope of the UK energy balance, as shown below, is fuel use in the United Kingdom and its Crown Dependencies (Jersey, Guernsey and the Isle of Man), as described in the NIR **Section 1.1.2.2**.

The fuel use estimates for Overseas Territories (OTs) are not included within DUKES, and are obtained through direct communications with the respective government contacts in each of the OTs.

Table A 4.1.1 UK Energy Balance for 2019 (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	1,508	-	56,762	-	37,771	13,761	20,407	-	-	130,209
Imports	4,426	623	57,134	36,380	44,548	5,491	-	2,111	-	150,712
Exports	-493	-8	-49,105	-22,664	-7,539	-385	-	-291	-	-80,485
Marine bunkers	-	-	-	-2,492	-	-	-	-	-	-2,492
Stock change*(4)*	+3	+112	-97	-579	-125	0	-	-	-	-685
Primary supply	**5,445**	**727**	**64,694**	**10,645**	**74,655**	**18,867**	**20,407**	**1,820**	**-**	**197,259**
Statistical difference*(5)*	-25	-0	+30	-34	-343	-	-	+30	-	-342
Primary demand	**5,469**	**727**	**64,664**	**10,679**	**74,998**	**18,867**	**20,407**	**1,790**	**-**	**197,602**
Transfers	-	+24	-379	+375	+454	-497	-7,154	+7,154	-	-23
Transformation	**-4,173**	**262**	**-64,285**	**63,401**	**-25,614**	**-11,420**	**-13,253**	**20,619**	**1,563**	**-32,899**
Electricity generation	-1,839	-513	-	-332	-23,271	-11,180	-13,253	20,619	-	-29,769
Major power producers	-1,830	-	-	-114	-21,076	-5,162	-13,253	17,568	-	-23,866
Autogenerators	-10	-513	-	-218	-2,196	-6,017	-	3,052	-	-5,902
Heat generation	-4	-1	-	-42	-2,343	-240	-	-	1,563	-1,067
Petroleum refineries	-	-	-64,689	64,264	-	-	-	-	-	-425

	Coal	Manufactured fuel(1)	Primary oils	Petroleum products	Natural gas(2)	Bioenergy & waste(3)	Primary electricity	Electricity	Heat sold	Total
Coke manufacture	-1,375	1,292	-	-	-	-	-	-	-	-83
Blast furnaces	-863	-646	-	-	-	-	-	-	-	-1,508
Patent fuel manufacture	-92	130	-	-46	-	-	-	-	-	-9
Other(7)	-	-	404	-443	-	-	-	-	-	-39
Energy industry use	**-**	**428**	**-**	**4,150**	**5,363**	**-**	**-**	**1,907**	**319**	**12,167**
Electricity generation	-	-	-	-	-	-	-	1,276	-	1,276
Oil and gas extraction	-	-	-	655	4,635	-	-	55	-	5,345
Petroleum refineries	-	-	-	3,495	179	-	-	364	319	4,356
Coal extraction	-	-	-	-	7	-	-	32	-	38
Coke manufacture	-	167	-	-	-	-	-	2	-	168
Blast furnaces	-	261	-	-	27	-	-	15	-	303
Patent fuel manufacture	-	-	-	-	-	-	-	-	-	-
Pumped storage	-	-	-	-	-	-	-	52	-	52
Other	-	-	-	-	516	-	-	113	-	628
Losses	**-**	**84**	**-**	**-**	**442**	**-**	**-**	**2,268**	**-**	**2,794**
Final consumption	**1,296**	**501**	**-**	**70,306**	**44,034**	**6,950**	**-**	**25,388**	**1,244**	**149,719**
Industry	**927**	**309**	**-**	**2,300**	**8,750**	**1,461**	**-**	**7,878**	**673**	**22,298**
Unclassified	-	-	-	1,307	1	188	-	-	-	1,497
Iron and steel	17	309	-	10	345	-	-	210	-	891

	Coal	Manufactured fuel(1)	Primary oils	Petroleum products	Natural gas(2)	Bioenergy & waste(3)	Primary electricity	Electricity	Heat sold	Total
Non-ferrous metals	16	-	-	8	259	-	-	336	-	619
Mineral products	394	-	-	180	1,202	277	-	528	-	2,582
Chemicals	34	-	-	123	1,719	117	-	1,287	223	3,502
Mechanical engineering etc	7	-	-	0	954	2	-	550	1	1,513
Electrical engineering etc	3	-	-	1	270	-	-	527	-	801
Vehicles	32	-	-	208	524	-	-	393	-	1,158
Food, beverages etc	40	-	-	120	1,740	64	-	986	16	2,967
Textiles, leather etc	39	-	-	43	244	-	-	229	-	554
Paper, printing etc	56	-	-	32	389	478	-	875	0	1,831
Other industries	285	-	-	40	686	335	-	1,837	433	3,615
Construction	3	-	-	227	417	-	-	119	-	767
Transport *(6)*	**11**	**-**	**-**	**54,448**	**-**	**1,737**	-	**469**	**-**	**56,665**
Air	-	-	-	13,681	-	-	-	-	-	13,681
Rail	11	-	-	688	-	-	-	438	-	1,137
Road	-	-	-	39,141	-	1,737	-	32	-	40,909
National navigation	-	-	-	938	-	-	-	-	-	938
Pipelines	-	-	-	-	-	-	-	-	-	-
Other	**358**	**142**	-	**6,315**	**34,882**	**3,751**	**-**	**17,041**	**571**	**63,062**
Domestic	337	142	-	2,554	26,650	2,449	-	8,927	269	41,328

	Coal	Manufactured fuel(1)	Primary oils	Petroleum products	Natural gas(2)	Bioenergy & waste(3)	Primary electricity	Electricity	Heat sold	Total
Public administration	13	-	-	745	3,178	41	-	1,526	78	5,581
Commercial	4	-	-	1,654	4,116	1,128	-	6,226	221	13,349
Agriculture	-	-	-	924	93	133	-	362	4	1,515
Miscellaneous	5	-	-	438	846	-	-	-	-	1,289
Non energy use	-	**50**	-	**7,244**	**401**	-	-	-	-	**7,695**

(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.

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

(5) Primary supply minus primary demand.

(6) See paragraphs 5.21 regarding electricity use in transport and 6.44-6.49 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, 2020), 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

Category	IPCC Fuel Name	NAEI Fuel Name
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

Category	IPCC Fuel Name	NAEI Fuel Name
Gaseous	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 (DUKES; BEIS, 2020). This annual publication gives detailed sectoral energy consumption broken down by fuel type, and covering the entire time period of the inventory. In many cases, these data are used directly in the inventory without modification. However, there are instances where the activity data used are not based directly on DUKES, instead utilising alternative data sources which provide supplementary information to the allocation of fuel to individual sectors and sources. 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 (e.g. to account for energy use in OTs)
- 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 to environmental or industry regulators).
- 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 coal use within the GHG inventory is consistent with the DUKES total and in most cases, coal use at the sectoral level is also consistent with the DUKES data. However, there are several instances where operator-reported data, either via trade associations such as the Mineral Products Association, or through EU ETS, indicates slight differences from the DUKES statistics. In those cases the Inventory Agency deviates from DUKES to ensure higher accuracy for those source categories. Overall, however, the DUKES demand total is regarded as complete and accurate and therefore the 1A2gviii Other Industrial Combustion is used as the 'residual' source category, to deliver exact reconciliation between GHGI activity and the DUKES demand total. **Table A 4.2.2** below presents the comparison between UK 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	Activity (Mt)	GHGI	IPCC Sector	Activity (Mt)	Difference	Comment
Major power producers	2.890	Power Stations	1A1ai	2.890	0.000	
Autogenerators	0.016	Autogenerators (inc. exports to grid)	1A2b	0.016	0.000	
Heat generation	0.006	n/a	n/a	0.000	0.006	GHGI doesn't report 'heat generation' separate from other fuel use. This fuel use is included within 'Other' and 'Industry'.
Coke manufacture	1.809	Coke manufacture	1A1ci, 1B1b	1.749	0.060	Operator data used in preference to DUKES
Blast furnaces	1.135	Blast furnaces	1B1b	1.135	0.000	

DUKES Category	Activity (Mt)	GHGI	IPCC Sector	Activity (Mt)	Difference	Comment
Patent fuel manufacture	0.144	Solid smokeless fuel production	1B1b	0.144	0.000	
Coal extraction	0.000	Collieries - combustion	1A1ciii	0.000	0.000	
Other industries	1.426	Other industrial combustion	1A2gviii	0.575		NAEI other industry used to reconcile overall consumption to DUKES total.
Iron and steel	0.000	Iron and steel - combustion plant	1A2a	0.027		
Non-ferrous metals	0.000	Non-ferrous metal (combustion)	1A2b	0.027		
Minerals	0.000	Cement and lime processes	1A2f	0.649		Cement and lime sector data from MPA and EU ETS used in preference to DUKES
Chemicals	0.000	Chemicals (combustion)	1A2c	0.054		
food beverages	0.000	Food & drink, tobacco (combustion)	1A2e	0.059		
Paper printing	0.000	Pulp, Paper and Print (combustion)	1A2d	0.097		
TOTAL industry	1.426	**TOTAL industry**	∑1A2	1.488	-0.062	Some operator data used, also some re-allocation of heat generation data.
Rail	0.015	Rail transport	1A3c	0.015	0.000	
Domestic	0.492	Domestic combustion	1A4bi	0.492	0.000	
Public Administration	0.019	Public sector combustion	1A4ai	0.022	-0.004	Small reallocation from DUKES ‘heat-generation’ category.
Commercial	0.005	Miscellaneous industrial/commercial combustion	1A4ci	0.012	0.000	
Miscellaneous	0.007					
Agriculture	0.000	Agriculture (mobile & stationary combustion)	1A4ai	0.000	0.000	
TOTAL (all)	7.963	**TOTAL (all)**		**7.963**	**0.000**	**Fully reconciled to DUKES demand total.**

Notes: Rows are shaded to help illustrate reconciliation between sectors.

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 and Colliery Methane use in the latest year (TJ net)

DUKES Category	Activity (TJ net)	GHGI	IPCC Sector	Activity (TJ net)	Difference	Comment
NATURAL GAS						
Major power producers	796,304	Power Stations (UK)	1A1ai	796,304		
		Power Stations (CDs)	1A1ai	3,086	- 3,086	Isle of Man gas use is additional, as it is not reported within DUKES
Oil and gas extraction	175,119	Upstream Oil/Gas production	1A1cii	175,119	0	
Coal extraction	255	Collieries - combustion	1A1ciii	255	-	
Blast furnaces	1,019	Blast furnaces	1A2a	1,019	-	
Other	19,481	Gas production	1A1ciii	21,060	- 1,578	Gas use to drive international gas interconnector pipelines are excluded from DUKES; they are added from EU ETS data.
Petroleum refineries	17,168	Petroleum Refineries	1A1b	42,258		Re-allocation in the GHGI of gas use from autogeneration to the refinery sector
Autogenerators	82,065	Autogeneration (inc. exports to grid)	1A2gviii	57,962		
	1,040	Railways - stationary combustion	1A4ai	53		
	100,274			100,274	0	Reconciled over these sources.
Agriculture	3,645	Agriculture - stationary combustion	1A4ci	3,645		
Commercial	170,990	Miscellaneous industrial/commercial combustion	1A4ai	202,948		
Miscellaneous	31,958					
Domestic	1,006,895	Domestic combustion	1A4bi	1,007,824		
Public Administration	136,500	Public sector combustion	1A4ai	136,500		
Subtotal	**1,349,988**	*Subtotal*		1,350,917	- 929	Domestic gas use on the Isle of Man is additional, as it is not included in DUKES
Iron and steel	14,538	Iron and steel - combustion plant	1A2a	15,554		
Non-ferrous metals	10,618	Non-Ferrous Metal (combustion)	1A2b	10,618		
Chemicals	83,948	Chemicals (combustion)	1A2c	83,948		

DUKES Category	Activity (TJ net)	GHGI	IPCC Sector	Activity (TJ net)	Difference	Comment
Paper, printing, etc.	20,188	Pulp, Paper and Print (combustion)	1A2d	20,188		
Food, beverages, etc.	70,822	Food & drink, tobacco (combustion)	1A2e	70,822		
		Cement processes	1A2f	4,754		
Other	175,491	Other industrial combustion	1A2gviii	149,121		
Subtotal	**375,605**	*Subtotal*		**355,005**	20,600	Reduced to account for greater NEU implied by alternative NAEI data sources
NEU	15,148	Ammonia production	2B1	27,533		
		Other NEU (non-emissive)	n/a	8,215		
Subtotal	15,148			35,748	-20,600	Offset by industrial combustion reductions
Losses	16,688	Losses			16,688	GHGI doesn't report a 'losses' category in energy units, but directly reports gas transporter estimates of leakage in mass of methane terms.
TOTAL	**2,848,840**		**TOTAL**	**2,838,786**	**10,054**	GHGI allocation for combusted gas is higher than DUKES due to the addition of gas use in the Isle of Man and at gas interconnectors.
COLLIERY METHANE						
Autogenerators	888	Collieries - combustion	1A1ciii	888	0	
Unclassified industry	18	Other industrial combustion	1A2gviii	18	0	
TOTAL	**906**		**TOTAL**	**906**	0	Exact reconciliation

Notes: Rows are shaded to help illustrate reconciliation between sectors. Note that DUKES activity data is originally in gross energy terms. Reconciliation has been calculated by net terms using a net/gross ratio derived from sources external to DUKES (i.e. from information provided by the GB's gas network operators).

A 4.2.1.3 Fuel Oil

For shipping, a major research project was completed in 2017 and the results were incorporated from the 2018 submission onwards. The estimated total fuel oil consumption derived from this research is greater than as reported for shipping 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 oil use in latest year (Mtonnes)

DUKES Category	Activity (Mt)	GHGI	IPCC Sector	Activity (Mt)	Difference	Comment
Major power producers	0.060	Power Stations	1A1ai	0.101	-0.041	EU ETS data used for AD for UK power stations. For CDs, local datasets are used

DUKES Category	Activity (Mt)	GHGI	IPCC Sector	Activity (Mt)	Difference	Comment
Autogenerators	0.016	Autogenerators (inc. exports to grid)	1A2gviii	0.000	0.016	Fuel reallocated to iron and steel works and other industry on the basis of data provided by BEIS
Oil gas extraction	0.052	Upstream Oil/Gas production	1A1ciii	0.000	0.052	Fuel oil allocated to oil and gas extraction in DUKES is reallocated to other industrial combustion
Petroleum refineries	0.126	Refineries - combustion	1A1b	0.126	0.000	
Other industries	0.094	Other industrial combustion	1A2gviii	0.114		Calculated as a residual, to account for differences (e.g. from EU ETS) in power stations, and allocation of autogeneration
Iron and steel	0.008	Iron and steel - combustion plant	1A2a	0.016	-0.008	Increased to account for share of autogeneration and to include fuel allocated to blast furnaces
Non-ferrous metals	0.000	Non-ferrous metal (combustion)	1A2b	0.000	0.000	
Chemicals	0.027	Chemicals (combustion)	1A2c	0.027	0.000	
food beverages	0.004	Food & drink, tobacco (combustion)	1A2e	0.004		
Paper printing	0.001	Pulp, Paper and Print (combustion)	1A2d	0.001		
TOTAL industry	0.136	TOTAL industry	∑1A2	0.163		
National navigation	0.006	Shipping - coastal	1A3d	0.163	-0.157	Bottom-up shipping methodology implies greater fuel use than is available in the sum of national navigation and marine bunkers in DUKES
		Shipping between UK and CDs	1A3d	0.000	0.000	DUKES doesn't report at this level of data resolution
		Other domestic shipping	1A3d	0.009	-0.009	
		Fishing vessels	1A4ciii	0.009	-0.009	
Marine bunkers	0.731	Marine bunkers	Memo item	0.722	0.009	
Public Administration	0.032	Public sector combustion	1A4ai	0.032	0.000	
Commercial	0.065	Miscellaneous industrial/commercial combustion	1A4ai	0.070	0.000	
Miscellaneous	0.005					
Agriculture	0.017	Agriculture (mobile & stationary combustion)	1A4ci	0.017	0.000	

DUKES Category	Activity (Mt)	GHGI	IPCC Sector	Activity (Mt)	Difference	Comment
TOTAL (all sectors)	1.246	TOTAL (all sectors)		1.412	-0.166	Higher overall reported FO use in the GHGI due to shipping estimates.

notes: Rows are shaded to help illustrate reconciliation between sectors.

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 economic 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.

In addition to off-road mobile machinery, gas oil allocations are also required for other sources such as vessels on the UK's inland waterways (Walker et al, 2011). Research into fuel use on inland waterways indicates that not all vessels with diesel engines use gas oil, but that some also use road diesel; this may also apply to 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; the research indicated 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.

To address these issues, an inventory improvement task was commissioned (Murrells et al., 2011), to develop an inventory methodology that is retained in the current submission.

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.

As with fuel oil, the introduction of the results of a major research project into the shipping sector in the 2018 submission, 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 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	Activity (Mt)	GHGI	IPCC Sector	Activity (Mt)	Difference	Comment
Major power producers	0.047	Power Stations	1A1ai	0.049	-0.002	EU ETS data used for UK power stations. Local data used for CDs.
Autogenerators	0.040	Autogenerators (inc. exports to grid)	1A2gviii	0.000	0.040	Fuel reallocated to iron and steel works and other industries on the basis of data provided by BEIS
Oil gas extraction	0.554	Upstream Oil/Gas production	1A1ciii	0.554	0.000	
Petroleum refineries	0.000	Refineries - combustion	1A1b	0.000	0.000	
Other industries	1.216	Other industrial combustion	1A2gviii	0.044		Calculated as a residual to accommodate bottom-up estimates in other sectors.
Iron and steel	0.000	Iron and steel - combustion plant	1A2a	0.002		Data provided by operators
Non-ferrous metals	0.007	Non-ferrous metal (combustion)	1A2b	0.000		
Mineral products	0.000	Cement production	1A2f	0.005		Data provided by cement operators
Chemicals	0.088	Chemicals (combustion)	1A2c	0.004		GHGI estimates for AD in several 1A2 stationary

DUKES Category	Activity (Mt)	GHGI	IPCC Sector	Activity (Mt)	Difference	Comment
Food, beverages	0.030	Food & drink, tobacco (combustion)	1A2e	0.002		combustion sectors are lower than DUKES, to accommodate estimates for off-road machinery.
Paper printing	0.030	Pulp, Paper and Print (combustion)	1A2d	0.001		
		Off-road industrial machinery	1A2gvii	1.777		Inventory Agency estimates. No such DUKES categories.
		Aircraft - support vehicles	1A3eii	0.190		
TOTAL industry (inc. heat generation)	1.370	TOTAL industry	∑1A2, 1A3eii	2.025	-0.654	Many sector re-allocations but overall GHG allocates more gas oil to industrial sources, to cover mobile machinery use.
Road	23.802	Road transport		23.321	0.480	Reduced to offset consumption from off-road DERV applications
Rail	0.635	Rail transport	1A3c	0.513	0.121	Inventory Agency estimates
National navigation	0.858	Inland and small vessels, and domestic shipping	1A3d	1.427		Bottom-up shipping methodology implies more use of gas oil than in DUKES; additional some categories are inventory estimates and additional to DUKES (e.g. motorboats and inland-goods carrying vessels)
		Fishing vessels	1A4ciii	0.152	-0.152	Bottom-up shipping methodology provides estimates for fishing: no such DUKES category.
		Naval shipping	1A5b	0.171	-0.171	Inventory Agency estimates; no such DUKES category.
Marine bunkers	1.599	Marine bunkers	Memo item	0.000	1.599	Bunker reporting of gas oil is regarded by BEIS to be accurate, hence retained.
Domestic	0.165	Domestic combustion	1A4bi	0.165	0.000	
		Off-road domestic machinery	1A4bii	0.011	-0.011	Inventory Agency estimates; no such DUKES category.
Public Administration	0.304	Public sector combustion	1A4ai	0.019	0.285	Fuel use offset to account for to inventory estimates of various off-road machinery and vehicles
Commercial	0.549	Miscellaneous industrial/commercial combustion	1A4ai	0.035	0.775	Fuel use offset to account for to inventory estimates of various off-road machinery and vehicles
Miscellaneous	0.261					
Agriculture	0.406	Agriculture (stationary combustion)	1A4ci	0.000	0.406	Fuel use offset to account for to inventory estimates of various off-road machinery and vehicles
		Agriculture (mobile combustion)	1A4cii	1.301	-1.301	Inventory Agency estimates

DUKES Category	Activity (Mt)	GHGI	IPCC Sector	Activity (Mt)	Difference	Comment
TOTAL (all sectors)	30.589	TOTAL (all sectors)		29.742	0.846	Overall the GHGI reports more gas oil use than DUKES, due to the shipping research and fuel use in OTs.

Notes: Rows are shaded to help illustrate reconciliation between sectors

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 (Mt)

DUKES Category	Activity (Mt)	GHGI	IPCC Sector	Activity (Mt)	Difference	Comment
Liquefied Petroleum Gas (LPG) – ***in DUKES this fuel is reported as propane and butane***						
Petroleum refineries	0.006	Refineries - combustion	1A1b	0.006	0.000	
	-	Combustion at gas separation plants	1A1cii	0.015	- 0.015	GHGI reports LPG use at gas separation plants based on operator data; no such DUKES category.
Iron and steel	0.001	Iron and steel - combustion plant	1A2a	0.001		Several re-allocations from DUKES to accommodate other data. Overall a higher GHGI allocation to industry, lower allocation to ‘other’ sources such as commercial, but reconciles to DUKES across industry and ‘other’ combustion, together.
Food, beverages, etc.	0.056	Food & drink, tobacco (combustion)	1A2e	0.644		
Other industry	0.131	Other industrial combustion	1A2gviii			
Subtotal industry	0.188	*Subtotal industry*		0.645	- 0.457	
Agriculture	0.082	Agriculture - stationary combustion	1A4ci	-		
Commercial / Miscellaneous	0.357	Miscellaneous/Commercial combustion	1A4ai	-		
Domestic	0.246	Domestic combustion	1A4bi	0.246		
Public administration	0.018	Public sector combustion	1A4bi	-		
Subtotal other	0.703	*Subtotal other*		0.246	0.457	
Road transport	0.061	Road transport	1A3bv	0.061	0.000	
TOTAL (LPG)	**0.958**	**TOTAL (LPG)**		**0.974**	**-0.015**	GHGI is slightly higher due to the addition of estimates for LPG

DUKES Category	Activity (Mt)	GHGI	IPCC Sector	Activity (Mt)	Difference	Comment
						use in gas separation plant
Other Petroleum Gases (OPG) – *includes Refinery Fuel Gas (RFG). In DUKES, reported as Ethane, Other gases and Naphtha.*						
Petroleum refineries	2.016	Refineries - combustion	1A1b	2.212	- 0.195	Refinery (and on-site refinery autogen) AD derived from EU ETS and deviates from DUKES
Autogeneration	0.135				0.135	
Subtotal	2.151	*Subtotal*		2.212	- 0.060	
Unclassified industry	0.117	Chemicals (combustion)	2B8g	1.033	- 0.916	Use of process off-gases as fuel in petrochemical plant are added to the GHGI, from EU ETS reporting. In DUKES these materials are reported (correctly) as Non Energy Use process feedstocks, other than a small component of naphtha reported as unclassified industry use.
TOTAL (OPG)	**2.268**	**TOTAL (OPG)**		**3.244**	**-0.977**	GHGI fuel use a lot higher than DUKES due to the reporting of activity and emissions from process off-gases, from NEU materials in DUKES.

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: Comparison of Emission Estimates Using Atmospheric Observations

This Annex describes the verification of the reported UK emissions through comparison with UK emissions estimated through the use of atmospheric observations and modelling.

A 6.1 MODELLING APPROACH USED FOR COMPARISON WITH THE UK GHGI

Comparison of the UK GHGI (Greenhouse Gas Inventory) with emission estimates made using atmospheric observations 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 HFCs for refrigeration.

In order to provide a comparison to the UK GHGI, BEIS (UK government department of Business, Energy and Industrial Strategy) supported the establishment and maintenance of a high-quality remote observation station at **Mace Head (MHD)** on the west coast of Ireland as part of the Advanced Global Atmospheric Gases Experiment (AGAGE) (Prinn *et al.*, 2018). 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, 2014, Stanley *et al.* 2018, Stavert *et al*. 2019).

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 (decommissioned in 2015). Two additional stations, **Heathfield (HFD)** in Southern England and **Bilsdale (BSD)** in North Yorkshire, were established through the NERC GAUGE (Global And UK Greenhouse gas Experiment) programme. BSD replaced TTA in 2015 in the UK DECC network and is funded by BEIS. HFD is supported by the National Physical Laboratory (NPL). Methane (CH_4), carbon dioxide (CO_2), nitrous oxide (N_2O) and sulphur hexafluoride (SF_6) are measured at all stations across the UK DECC network. The hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) are measured at MHD and TAC, and nitrogen trifluoride (NF_3) is only measured at MHD.

With permission of the data providers, observations were also obtained from:

- **Carnsore Point (CSP)** on the east coast of Ireland (2005-2010), funded by the Irish Environmental Protection Agency
- **Weybourne (WAO)** in East Anglia, England (2013-2020) supported by the University of East Anglia and the National Centre for Atmospheric Sciences

- **Cabauw (CBW)** in the Netherlands (1993-2019) supported by the Netherlands Organisation for applied scientific research (TNO), funded by the Dutch Ministry of Infrastructure and Water Management
- **Jungfraujoch (JFJ)** in the Swiss Alps (2007-2020) supported by the Federal Office for the Environment (FOEN) through the project HALCLIM/CLIMGAS-CH, by the International Foundation High Altitude Research Stations Jungfraujoch and Gornergrat (HFSJG), and by the Swiss Federal Laboratories for Materials Science and Technology (Empa)
- **Monte Cimone (CMN)** in the Italian Apennine mountains (2007-2020) supported by the University of Urbino
- **Taunus (TOB)** in central Germany (2013 - 2020) supported by the Goethe University Frankfurt

For the global hemispheric concentration analysis, data were kindly provided for the **Cape Grim observatory (CGO)** in Tasmania, Australia by CSIRO (The Commonwealth Scientific and Industrial Research Organisation, an Australian Government agency).

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 each station at the time of each observation. Estimates of UK emissions are made by firstly estimating the underlying background trend (Northern Hemisphere, mid-latitude, atmospheric concentrations with the short-term impact of regional pollution removed from the data) and secondly by modelling where the air has passed over on route to the observation stations at a regional scale. 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 distribution that most accurately reproduces the observations (Manning *et al.* 2003, 2011 and Arnold *et al.* 2017).

For each reported gas, the Northern and Southern (estimated using observations from Cape Grim) Hemisphere background concentrations and the UK emission estimates are presented. InTEM uses all of the available observations. Two-year inversion windows are used up until 2013 due to the paucity of UK observations prior to this date. Each inversion is performed for a two year period and then the period is incremented by one-year e.g. 1989 – 1990, 1990 – 1991 etc., from which a median for each year is estimated. From 2013, with the additional data from the other stations, the inversion time window was shortened to one year or smaller (1 month for CH_4, N_2O and SF_6).

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 InTEM estimates of UK emissions using the atmospheric observations are compared to the reported GHGI estimates. For each gas the InTEM estimated geographical distribution is presented as an average for 2017-2020. For CH_4 and N_2O this is shown as seasonal averages for 2017-2020. The time-series of UK emissions from 1990 are given showing the comparison between the GHGI and InTEM (2-year and 1-year or monthly) estimates. The uncertainty of the InTEM estimates are calculated through the Bayesian framework. The GHGI uncertainties have been linearly interpolated between the reported 1990 and 2019 values given in this report. All of the comparisons have been made in units of CO_2-equivalence using the latest scientific values for global warming potential (GWP) over a 100-year timeframe (WMO ozone assessment [Montzka et. al., 2018] and where necessary the IPCC 5th assessment [Myhre et. al., 2013]).

A 6.2 METHANE

Figure A 6.1 Background Northern Hemisphere annual concentrations of methane estimated from Mace Head, Ireland observations are shown in red, background Southern Hemisphere annual concentrations from Cape Grim, Tasmania are shown in blue.

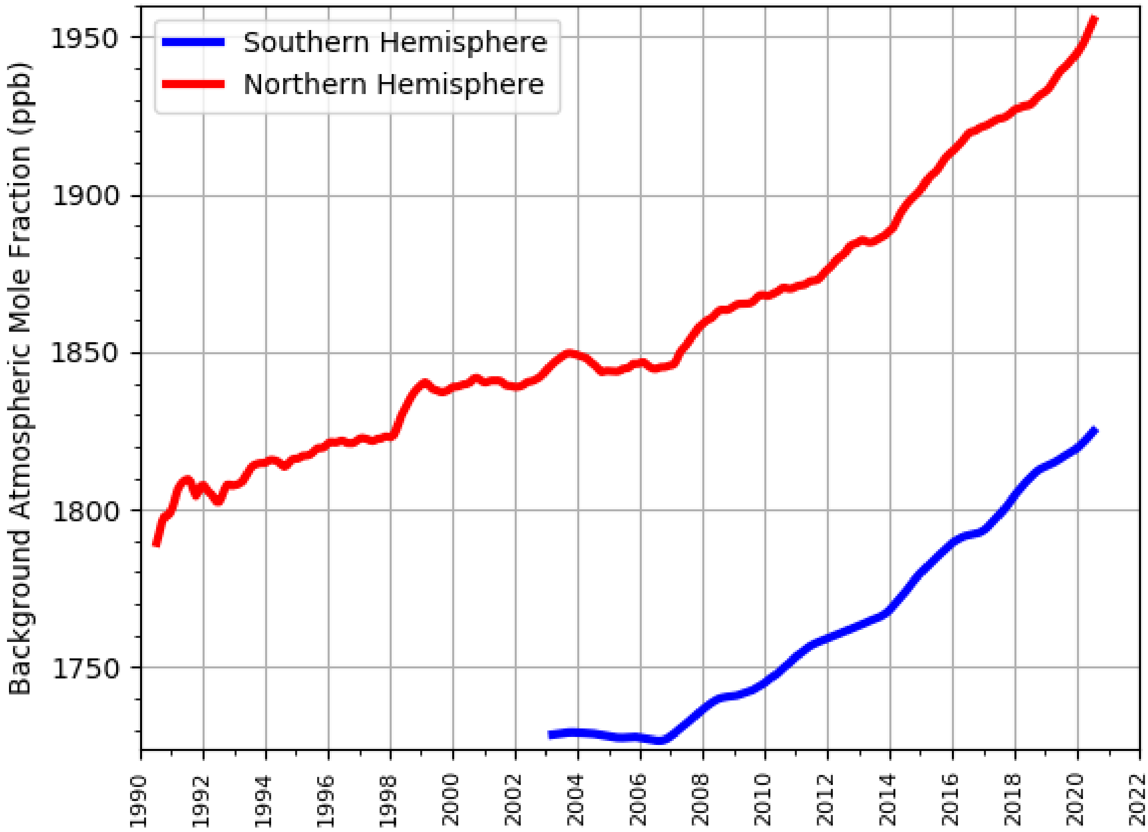


Figure A 6.1 shows the background atmospheric concentration of methane from 1990 onwards. As with all of the background plots for each different gas, it shows how the overall atmospheric concentration of the gas in question is changing as a result of global emissions and atmospheric loss processes. For CH_4, the underlying background trend is positive. In 2020, the NH concentration grew by 15 ppb, the SH by 8 ppb.

The emission estimates made for the UK using the InTEM methodology are compared to the GHGI emission estimates for the period 1990 onwards and shown in **Figure A 6.2**. It is important to note that although the UK GHGI methane emissions are estimated to have fallen over the last 29 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 InTEM 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 emissions at some of the stations, observations taken when local emissions are thought to be significant (low boundary layer heights, low wind speeds, stable atmospheres) have been removed from the InTEM analysis.

Figure A 6.2 Verification of the UK emission inventory estimates for methane in Tg CO_2-eq yr[-1] from 1990. GHGI estimates are shown in black. InTEM 2-year estimates are shown in blue (±1σ). InTEM 1-month, annualised, estimates are shown in orange (±1σ).

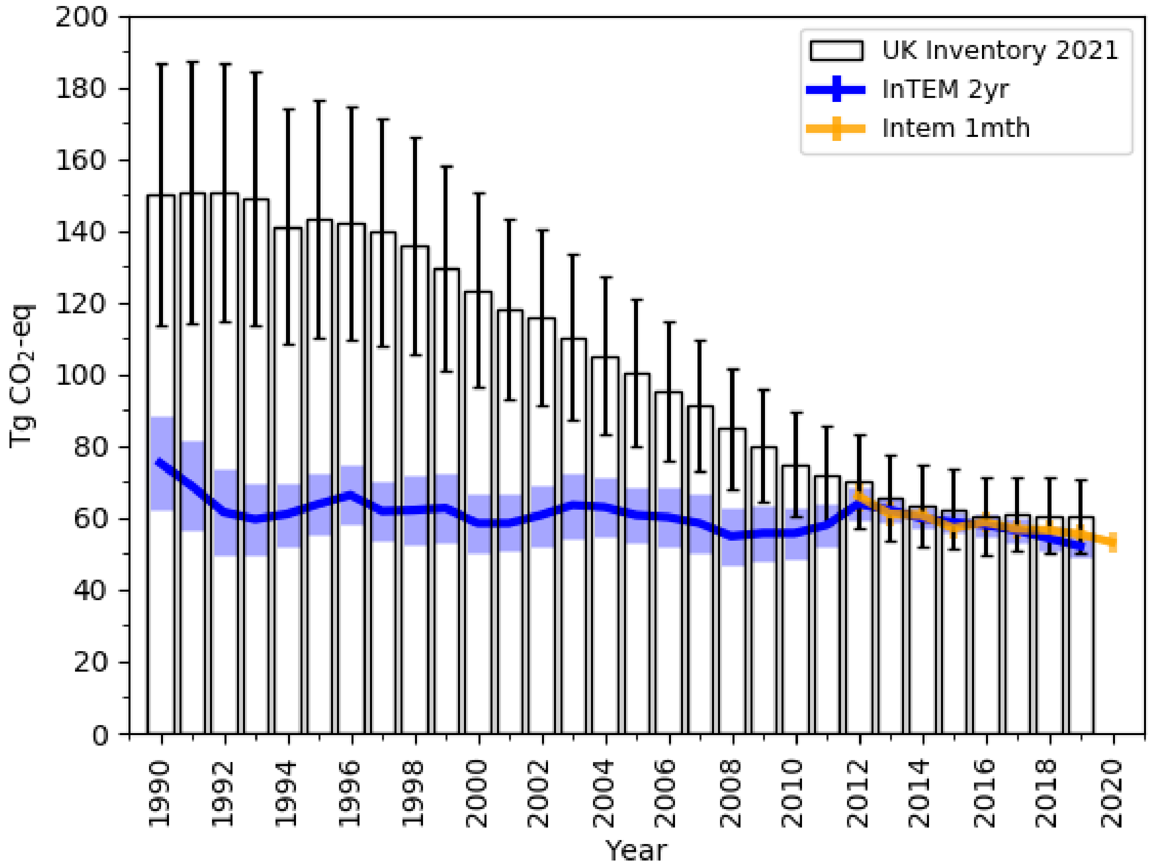
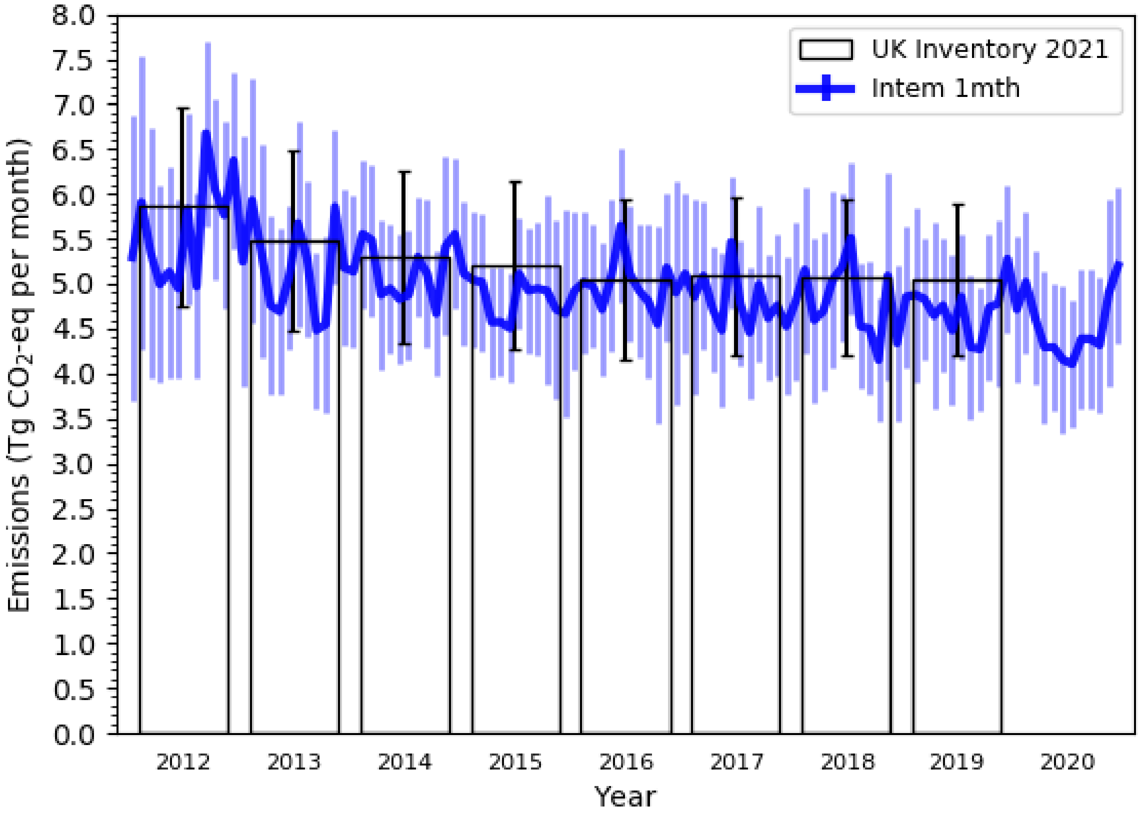
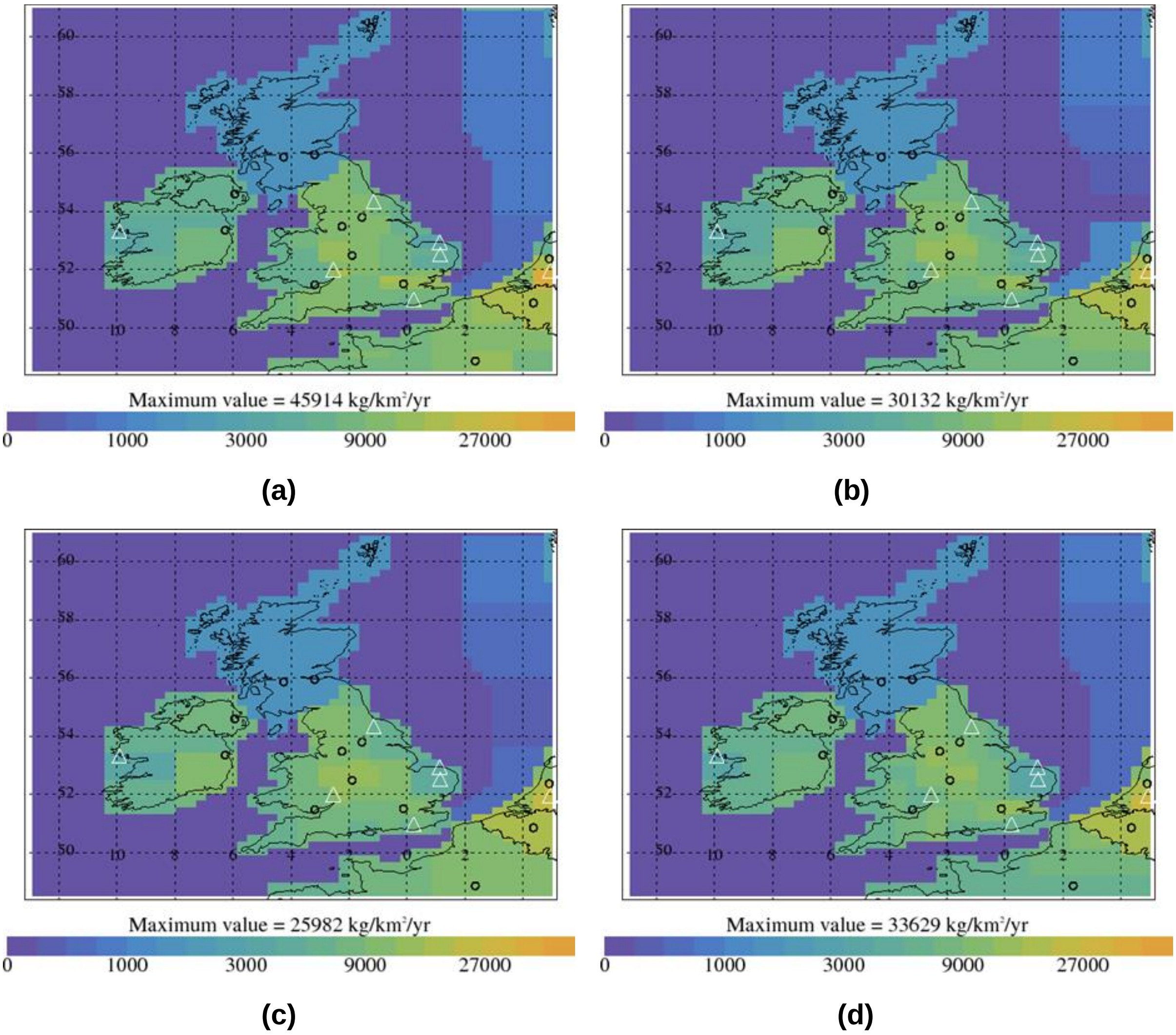


Figure A 6.3 Verification of the UK emission inventory estimates for methane in Tg CO_2-eq month^{-1} from 2012. GHGI estimates are shown in black. InTEM 1-month estimates are shown in blue (±1σ).



The UK GHGI trend is monotonically downwards whereas the InTEM estimates, after an initial fall, shows only a very slight downward trend. Prior to 2012 the InTEM estimate is based only on MHD and CBW observations, from 2012 onwards observations from MHD, TAC, RGL, HFD, TTA, BSD, WAO and CBW are available and show a slow decline. The InTEM 1-month estimates (**Figure A 6.3**) using all observations do not show a strong seasonal cycle in UK methane emissions. **Figure A 6.4** shows the geographical distribution of methane emissions as estimated from InTEM per season, Winter (Dec-Feb), Spring (Mar-May), Summer (Jun-Jul) and Autumn (Sep-Nov). Scotland is poorly resolved due to the paucity of observations after 2015.

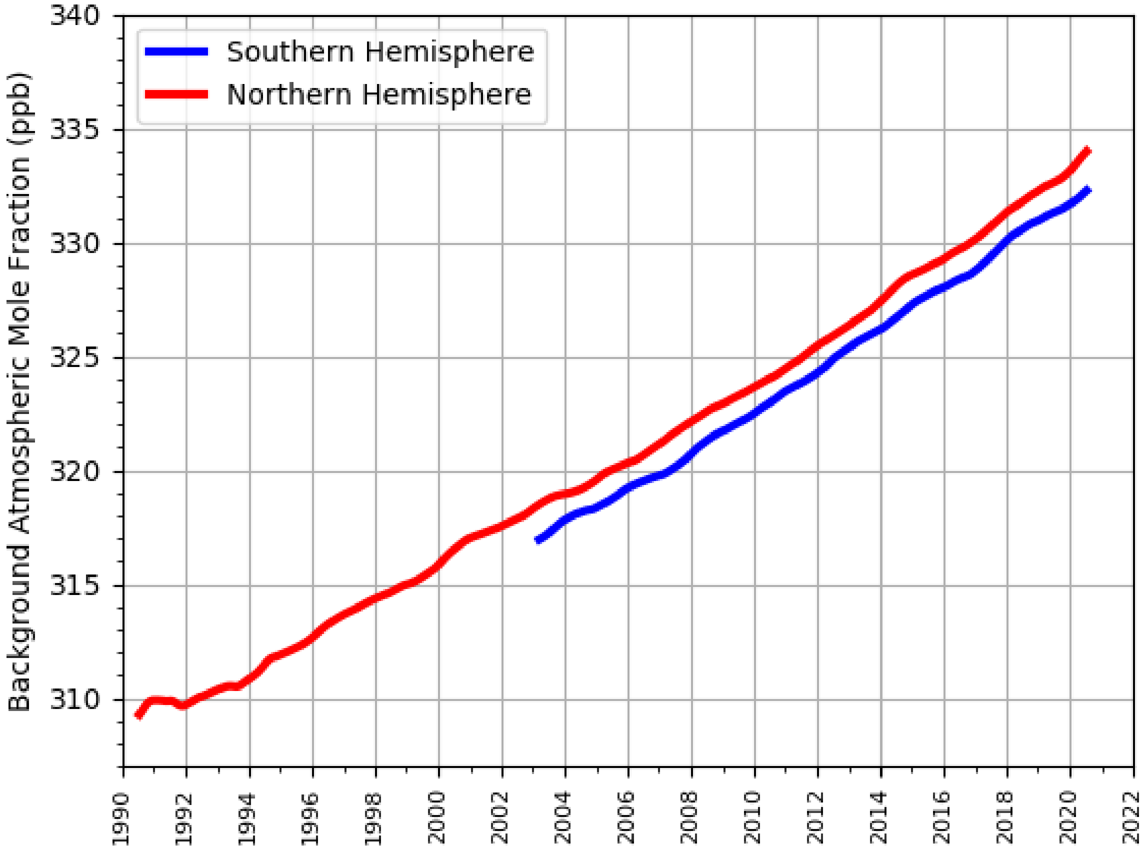
Figure A 6.4 **Four-year average CH_4 InTEM emission estimates (kg $km^{-2}yr^{-1}$ of gas) 2017-2020 by season: (a) winter (b) spring (c) summer (d) autumn. The observation stations are shown as white triangles. Major cities are shown as black circles.**



A 6.3 NITROUS OXIDE

Figure A 6.5 shows the Hemisphere background atmospheric concentration of nitrous oxide (N_2O) from 1990 onwards. The background trend is monotonic and positive. The Northern Hemispheric background concentration is increasing by ~1 ppb yr^{-1}.

Figure A 6.5 Background Northern Hemisphere annual concentrations of nitrous oxide estimated from Mace Head, Ireland observations are shown in red, background Southern Hemisphere annual concentrations from Cape Grim, Tasmania are shown in blue.



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 6.6 **Verification of the UK emission inventory estimates for nitrous oxide in Tg CO_2-eq yr^{-1} from 1990. GHGI estimates are shown in black. InTEM 2-year estimates are shown in blue (±1σ), InTEM 1-month, annualised, estimates are shown in orange (±1σ).**

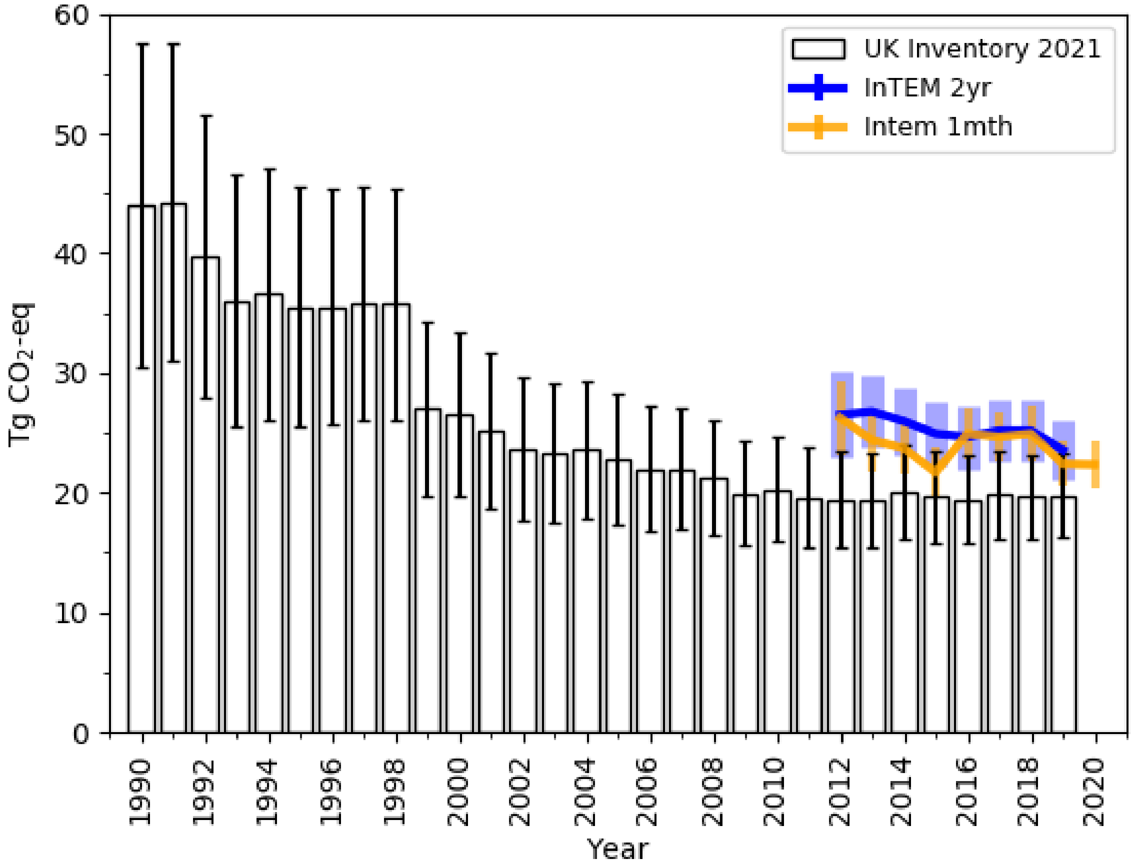


Figure A 6.6 shows the InTEM and GHGI emission estimates comparison for nitrous oxide for the UK. The annual InTEM estimates are 5-8 Tg CO_2-eq higher than those reported by the GHGI, although the 1σ uncertainties just overlap. The InTEM estimates are showing a decline in UK emissions (2012-2020) whereas the GHGI is relatively flat 2012-2019. The GHGI estimates show a sharp decline (~9 Tg CO_2-eq) 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 that they cut their emissions of N_2O by 90%, from 12 Tg CO_2-eq yr^{-1} to around 1.6 Tg CO_2-eq yr^{-1}. The improved network of observations from 2012 onwards allows a very strong seasonal cycle (1.8 Tg CO_2-eq mth^{-1}) in UK emissions to be highlighted. **Figure A 6.7** shows there is a peak in UK emissions in spring-summer (~2.9 Tg CO_2-eq mth^{-1}) and a minimum in the winter months (~1.1 Tg CO_2-eq mth^{-1}), aligned with the traditional fertiliser application period. There is however a strong year-to-year variability in this seasonal pattern demonstrating the impact of varying meteorology on the emissions of N_2O. The spatial pattern of emissions in each month is show in **Figure A 6.8**.

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 coincidental with the activity ultimately responsible for generating the nitrous oxide e.g. the nitrous oxide or its precursors may be transported from its source, for example by rivers, prior to its release to the atmosphere.

Figure A 6.7 Verification of the UK emission inventory estimates for nitrous oxide in Tg CO_2-eq month^{-1} from 2012. GHGI estimates are shown in black. InTEM 1-month estimates are shown in blue (±1σ).

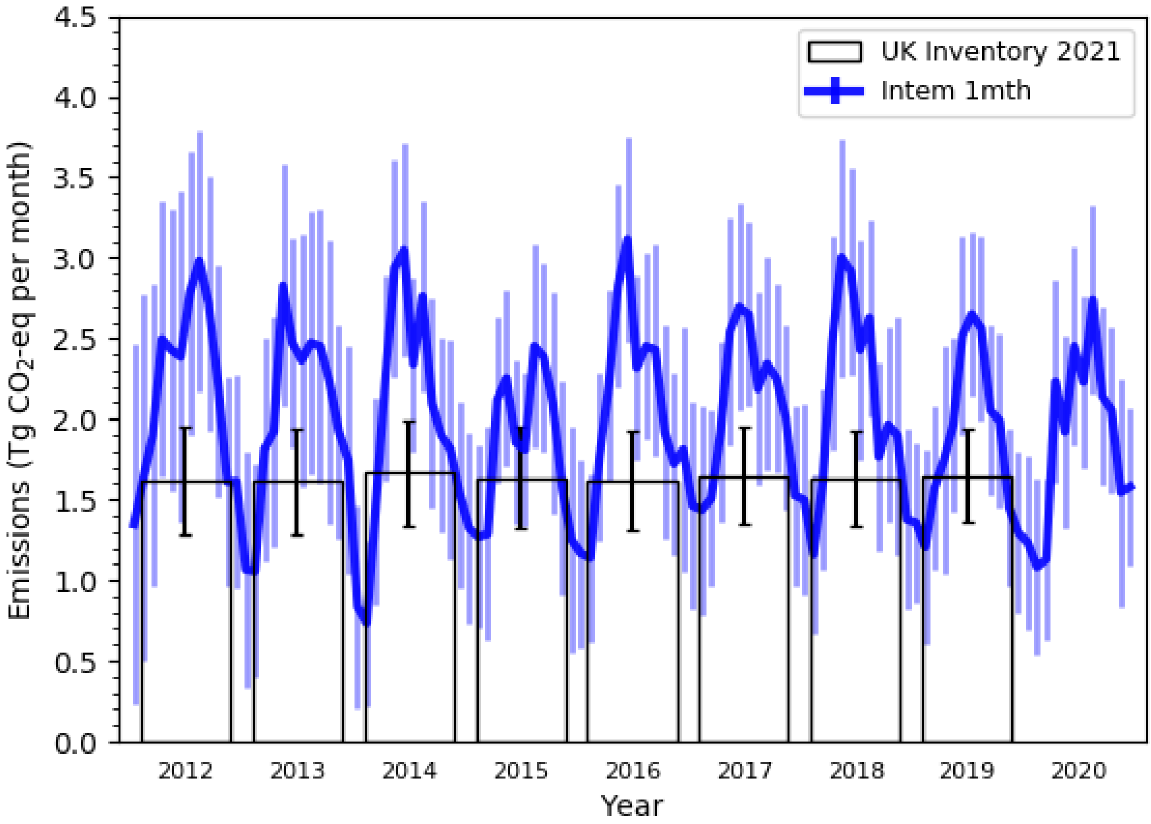
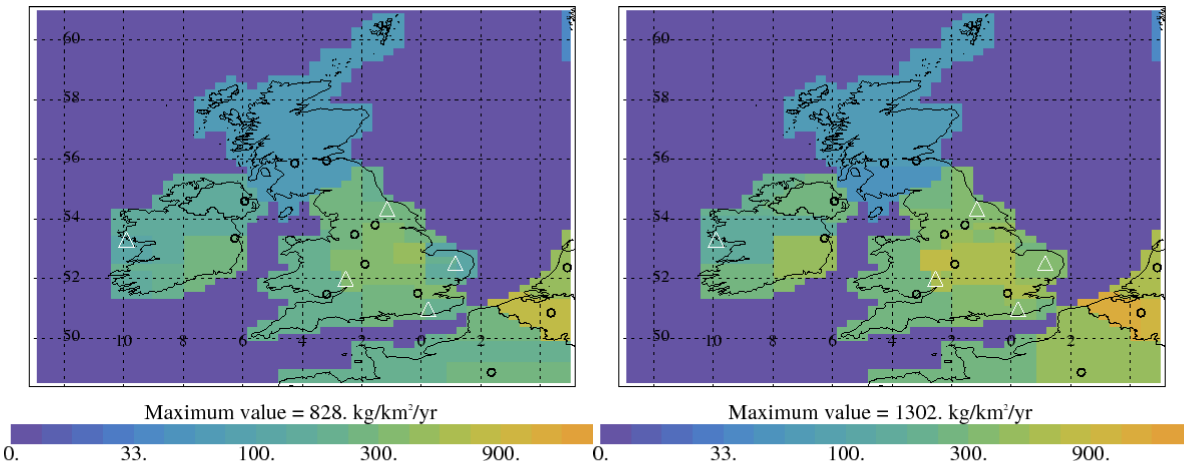
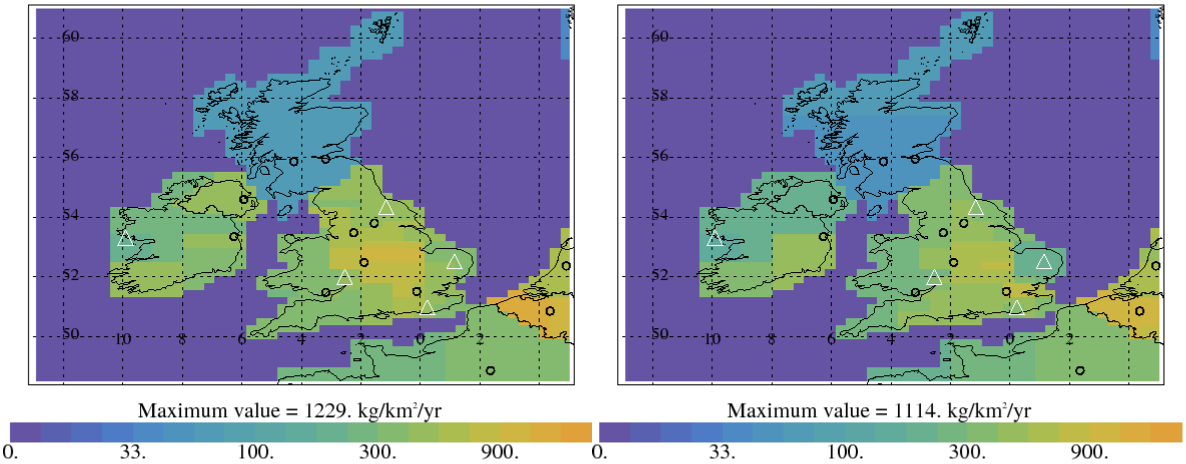


Figure A 6.8 Four-year average N_2O InTEM emission estimates (kg km^{-2}yr^{-1} of gas) 2017-2020 by season: (a) winter (b) spring (c) summer (d) autumn. The observation stations are shown as white triangles. Major cities are shown as black circles.



(a) (b)



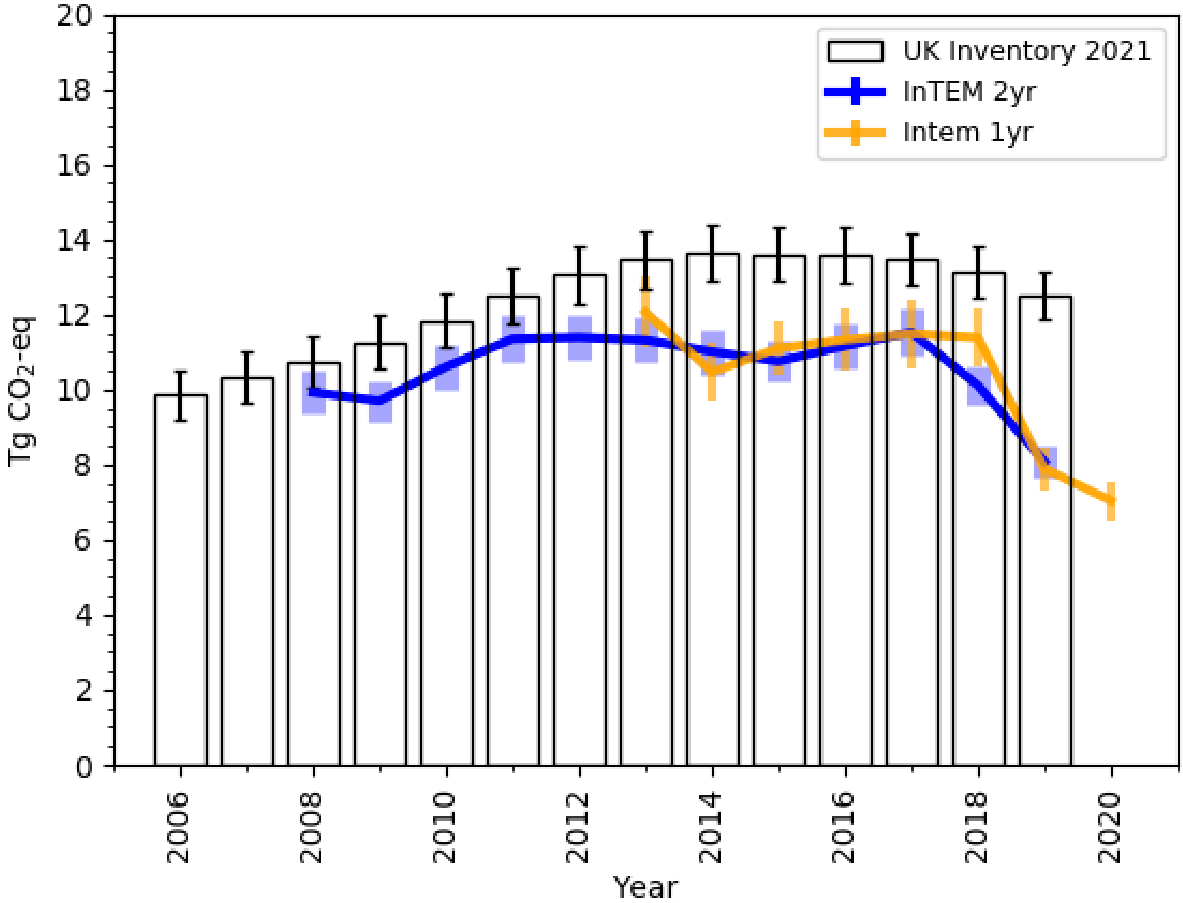
(c) **(d)**

A 6.4 HYDROFLUOROCARBONS

Figure A 6.9 shows the sum of all the HFCs, (HFC-125, HFC-134a, HFC-143a, HFC-152a, HFC-23, HFC-32, HFC-227ea, HFC-245fa, HFC-365mfc and HFC-43-10mee) in Tg CO_2-eq yr^{-1}. The GHGI is shown in black and InTEM annualised 2-year in blue and the 1-year in orange. The total InTEM HFC is consistently lower than the GHGI, with the best agreement between 2008-2012. From 2013 the InTEM estimate remains largely flat before dropping sharply from 2018 to 2020 in the 1-year data. The largest discrepancy between the model estimate and the GHGI is in 2019, with an approximate difference > 4 Tg CO_2-eq yr^{-1}. Note, the GHGI reports uncertainty for the HFCs collectively, they are not available for the individual gases.

There is a notable drop in the InTEM HFC estimates in 2019 and to a smaller extent in 2020. Only a small decline is estimated in the GHGI in 2019. The UK is committed to phasing down the use of HFCs to 21% by 2030, based on the average use between 2009-2012. Comparison of the total InTEM UK HFC emissions in 2020 with the average from 2009-2012 shows a drop of 34.6%, indicating good progress toward the target of a 79% decrease by 2030.

Figure A 6.9 **Sum of UK HFC emission estimates (HFC-125, HFC-134a, HFC-143a, HFC-152a, HFC-23, HFC-32, HFC-227ea, HFC-245fa, HFC-365mfc and HFC-43-10mee) in Tg CO_2-eq yr^{-1} from the GHGI (black) and InTEM, annualised 2-year inversion (blue) and 1-year inversion (orange). Note HFC-43-10mee (< 0.2 Tg CO_2-eq yr^{-1}) included from 2011 when the observations start. The uncertainty bars represent ±1σ.**



A 6.4.1 HFC-134a

Figure A 6.10 shows the Hemisphere background atmospheric concentration of HFC-134a from 1995 onwards. The background trend is monotonic and positive, in 2020 the Northern Hemisphere background increased by ~5 ppt.

Figure A 6.10 **Background Northern Hemisphere annual concentrations of HFC-134a estimated from Mace Head, Ireland observations are shown in red, background Southern Hemisphere annual concentrations from Cape Grim, Tasmania are shown in blue.**

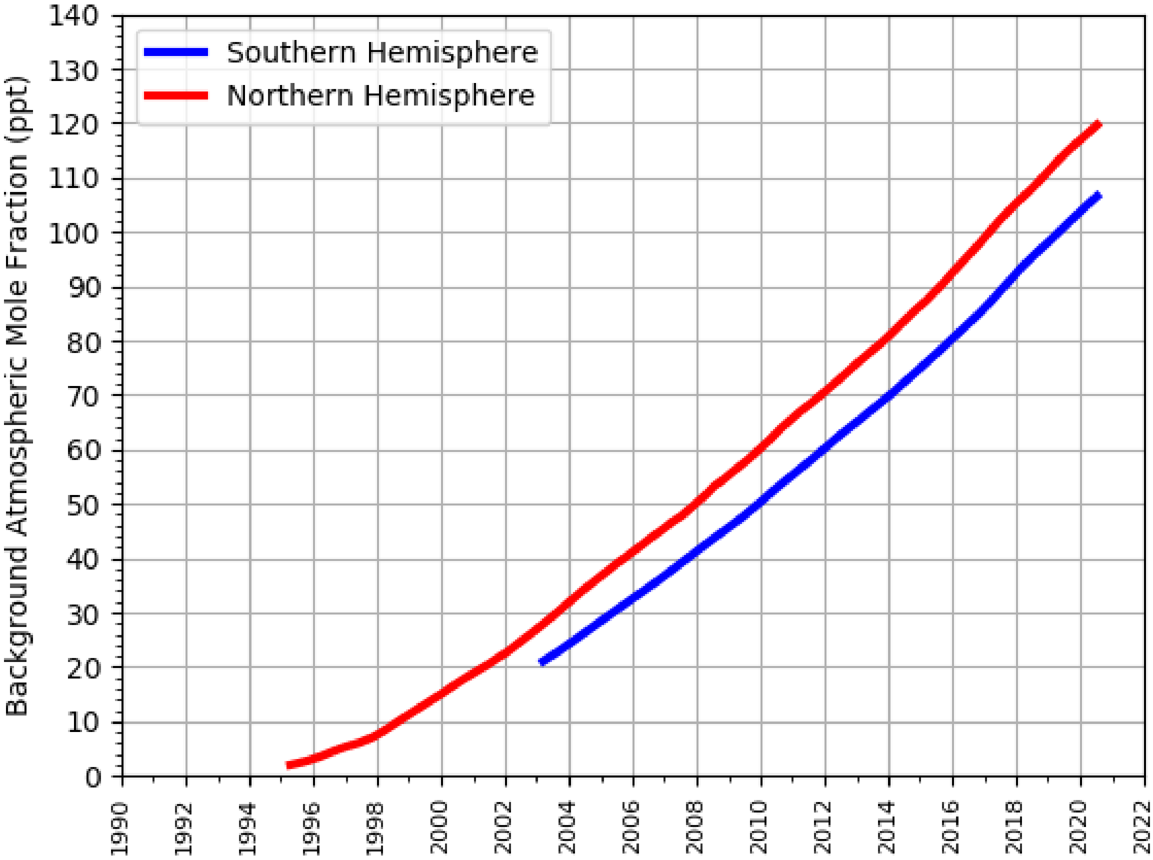


Figure A 6.11 Verification of the UK emission inventory estimates for HFC-134a in Tg CO_2-eq yr^{-1} from 1990. GHGI estimates are shown in black. InTEM 2-year estimates are shown in blue (±1σ), InTEM 1-year estimates are shown in orange (±1σ).

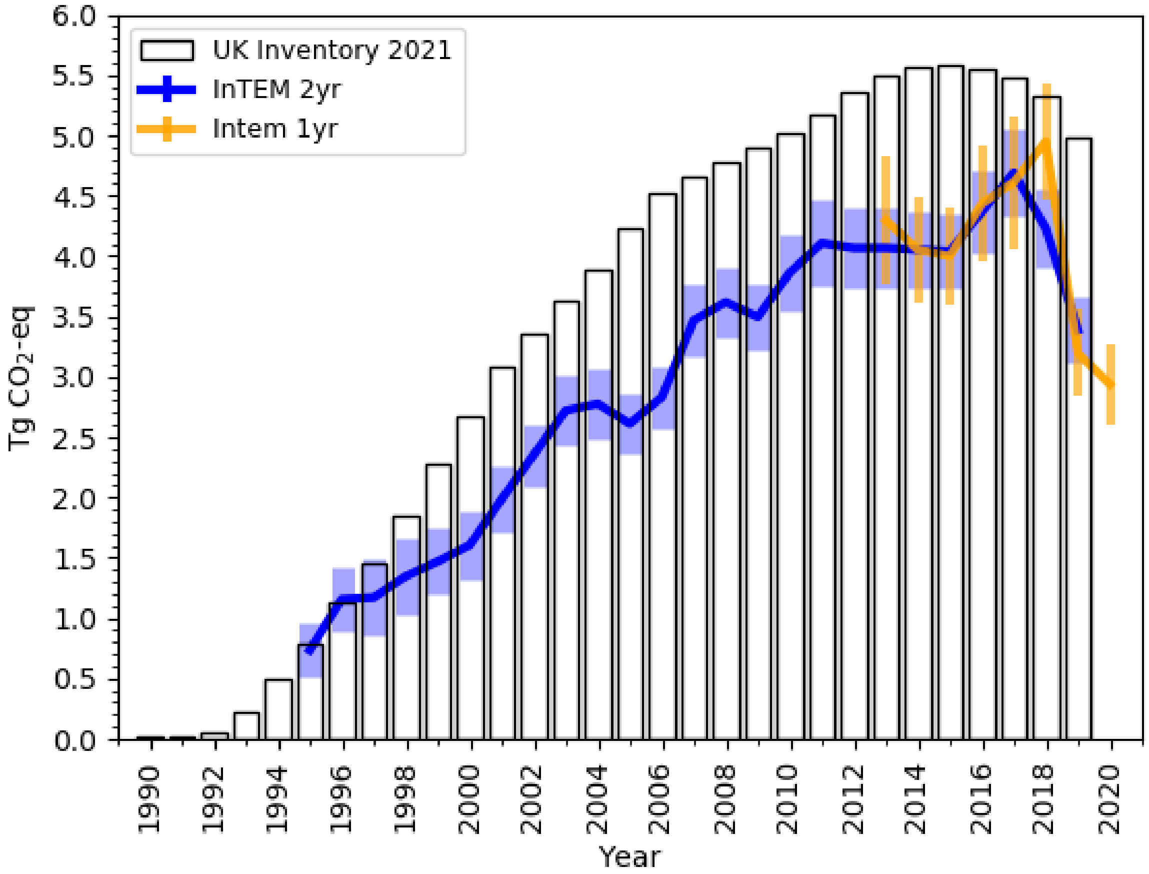


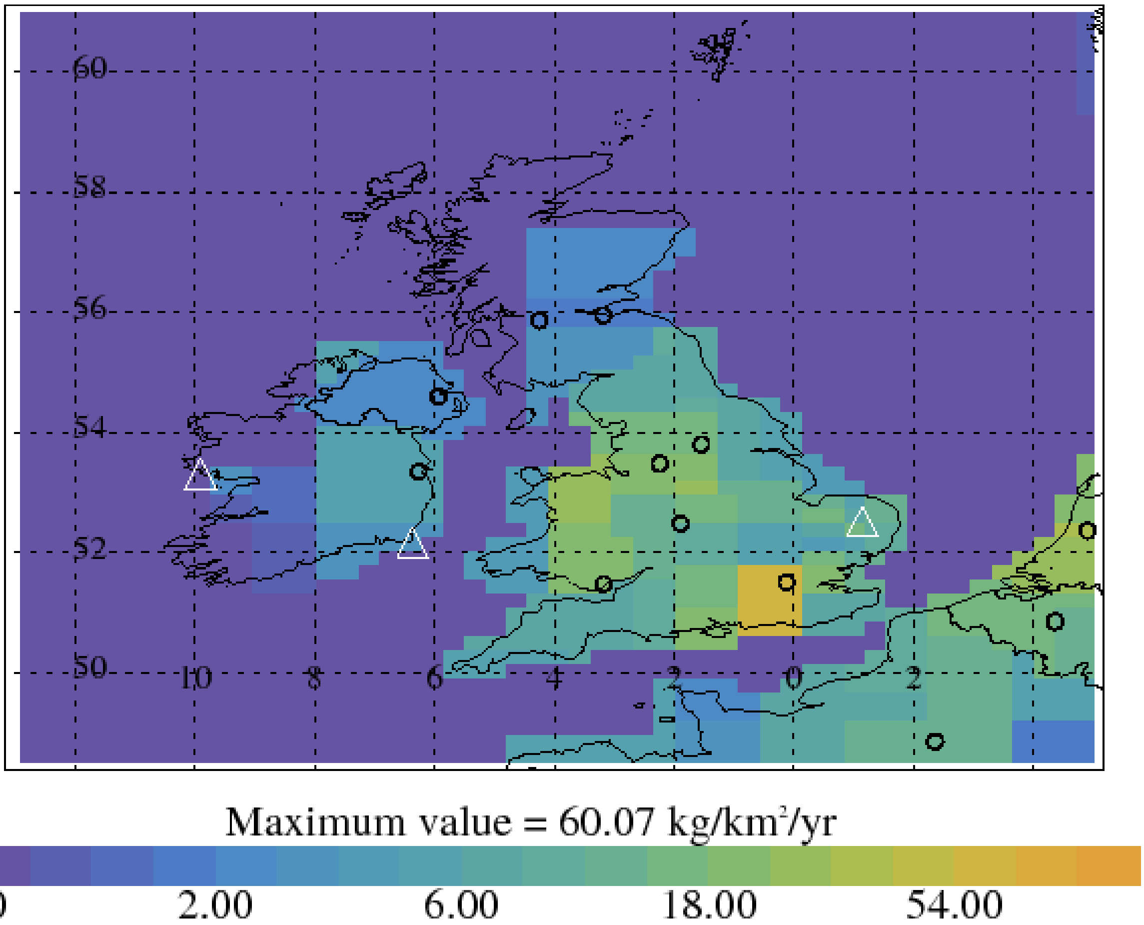
Figure A 6.11 shows the InTEM and GHGI emission estimates for the UK for HFC-134a for the period 1990 onwards. The GHGI shows a stronger increase in emission compared to the InTEM estimates. The InTEM estimates have risen at about 70% of the rate of the GHGI. Throughout the time series the trend agreement between the GHGI and InTEM is good but the InTEM estimates are consistently lower than the GHGI estimates, with the difference well outside the InTEM uncertainty range, except for the 1-year estimate in 2018. From 2018, the InTEM 1-year estimate drops sharply and is approximately 40% lower than the GHGI in 2019 and continues to drop in 2020. Since the implementation of phase three of the EU MAC directive (2006), on 1st January 2017, the use of fluorinated greenhouse gases with $GWPs_{100}$ higher than 150 (mainly HFC-134a) in all new models of cars and light vans sold in the EU has been banned. The impact of this policy is seen both in InTEM and the GHGI, with InTEM implying a more rapid phase-out is occurring than originally thought.

It must be noted that the agreement between InTEM and the GHGI is significantly improved compared to similar comparisons in the UK submissions in previous years. This is a direct result of the implementation of the new RAHCP model in the GHGI.

Figure A 6.12 shows the spatial InTEM emissions estimate for HFC-134a over the UK in kg $km^{-2}yr^{-1}$, for a four-year average over 2017-2020. The variable grid resolution of InTEM produces a patchwork of different resolutions dependant on source signal at the measurement site. For

HFC-134a, the highest emissions are generally focused on the more populated areas, with the highest emission region appearing over London and in the south of the UK.

Figure A 6.12 Four-year average HFC-134a InTEM emission estimates (kg km^{-2}yr^{-1}) 2017-2020. The observation stations are shown as white triangles. Major cities are shown as black circles.



A 6.4.2 HFC-125

Figure A 6.13 Background Northern Hemisphere annual concentrations of HFC-125 estimated from Mace Head, Ireland observations are shown in red, background Southern Hemisphere annual concentrations from Cape Grim, Tasmania are shown in blue.

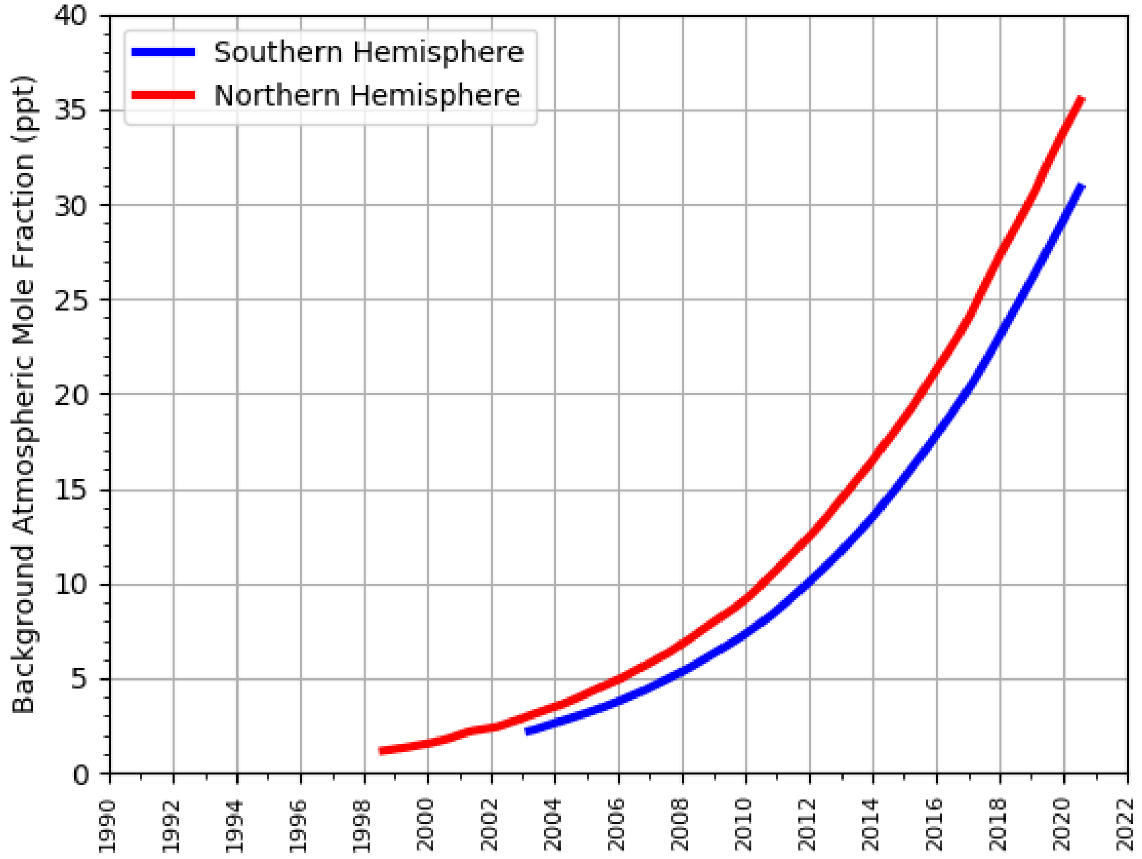


Figure A 6.13 shows the Hemispheric background atmospheric concentrations of HFC-125 from 1998 onwards. The background trend is monotonic and exponentially increasing, in 2020 the Northern Hemisphere background increased by 3.2 ppt.

InTEM emission estimates for the UK for HFC-125 for the period 1999 onwards are shown in **Figure A 6.14** . Both the InTEM and UK GHGI estimates suggest that the emissions of HFC-125 from the UK increased significantly from the 1990s. The InTEM estimates are slightly higher than the GHGI from 1999-2004, but from 2005-2013 there is excellent agreement. From 2014-2018, the model estimate remains fairly flat, whilst the GHGI continues to rise, and the agreement is less good. In 2019 the 1-year InTEM estimate drops sharply, and is significantly lower than the 2019 GHGI value. It must be noted that the agreement between InTEM and the GHGI is significantly improved compared to similar comparisons in the UK submissions in previous years. This is a direct result of the implementation of the new RAHCP model in the GHGI.

Figure A 6.14 Verification of the UK emission inventory estimates for HFC-125 in Tg CO_2-eq yr^{-1} from 1990. GHGI estimates are shown in black. InTEM 2-year estimates are shown in blue (±1 σ), InTEM 1-year estimates are shown in orange (±1 σ).

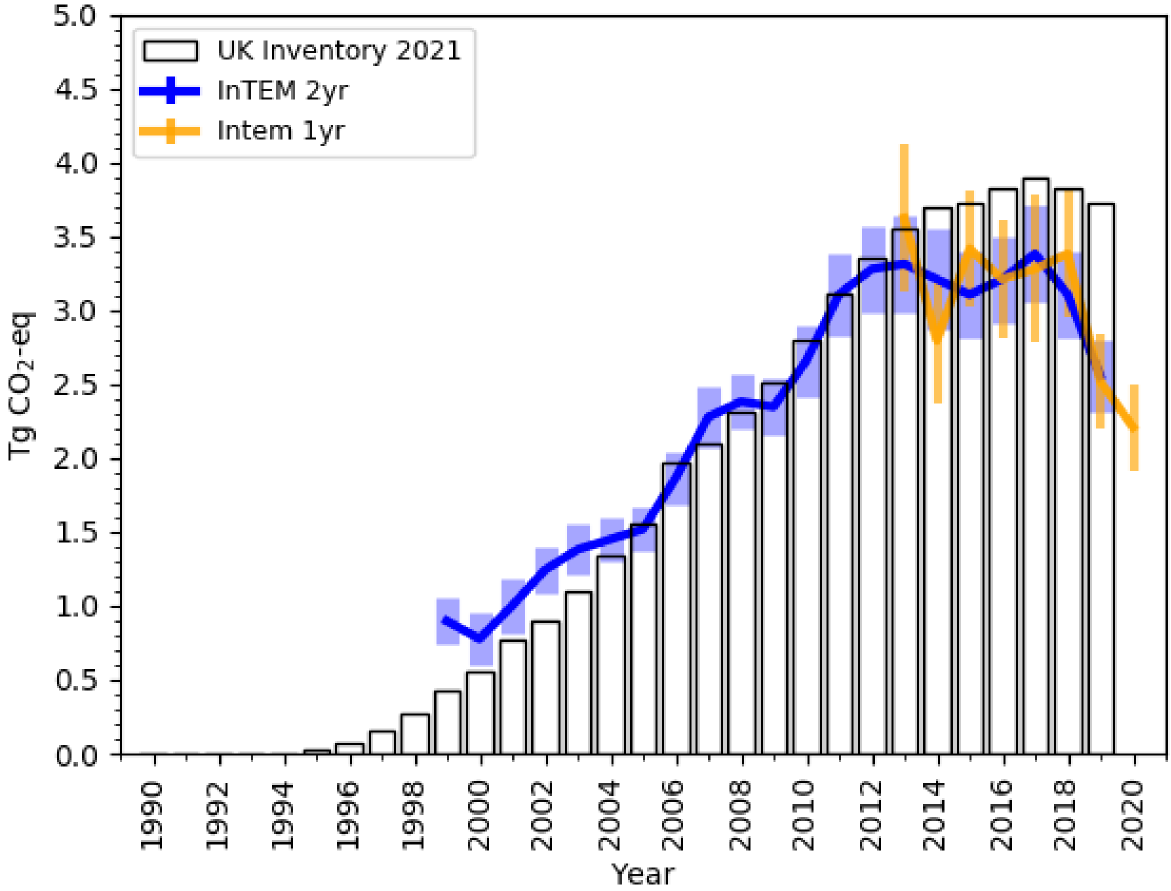
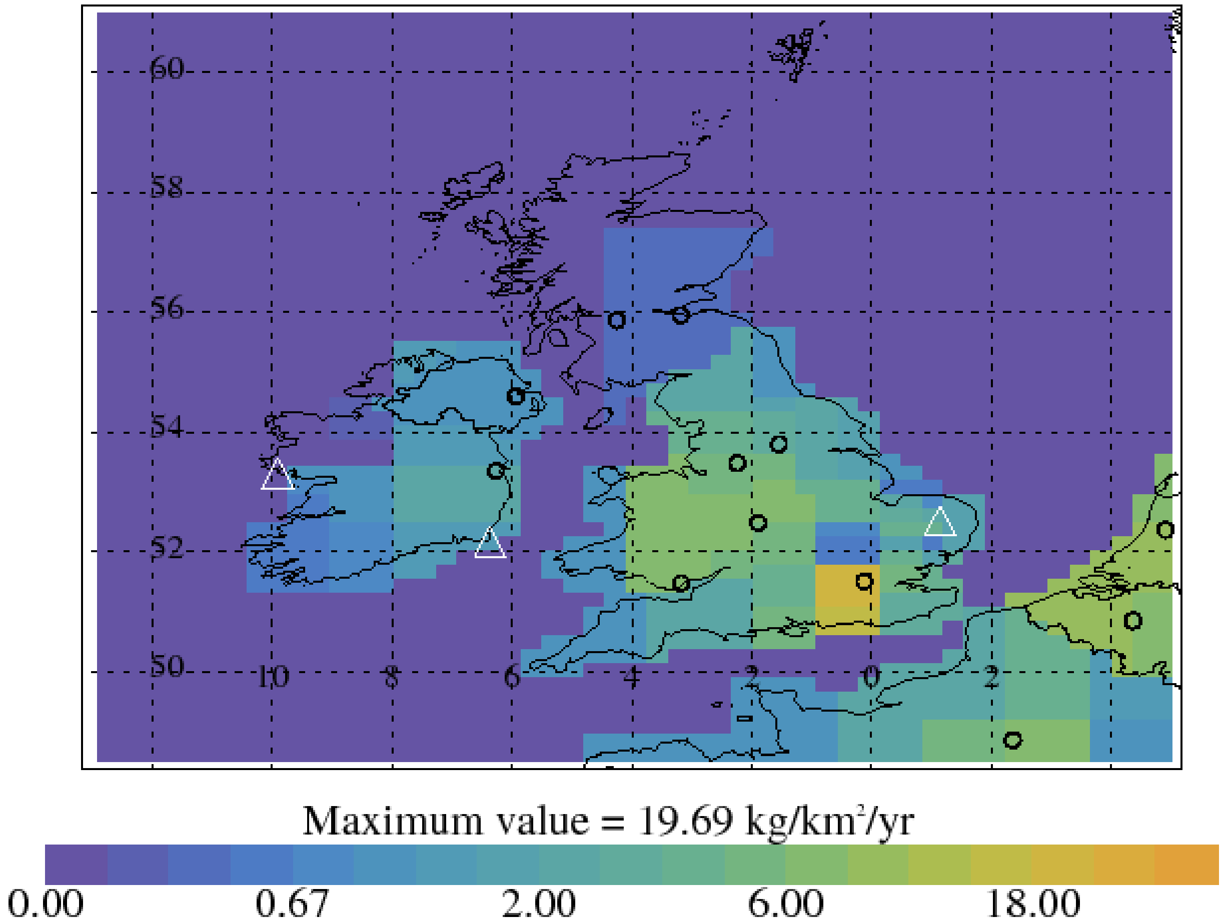


Figure A 6.15 shows the spatial InTEM emissions estimate for HFC-125 over the UK in kg $km^{-2}yr^{-1}$, for a four-year average over 2017-2020. Similarly to HFC-134a, the highest emissions are generally focused on the more populated areas, with the highest emission region appearing over London and in the south of the UK.

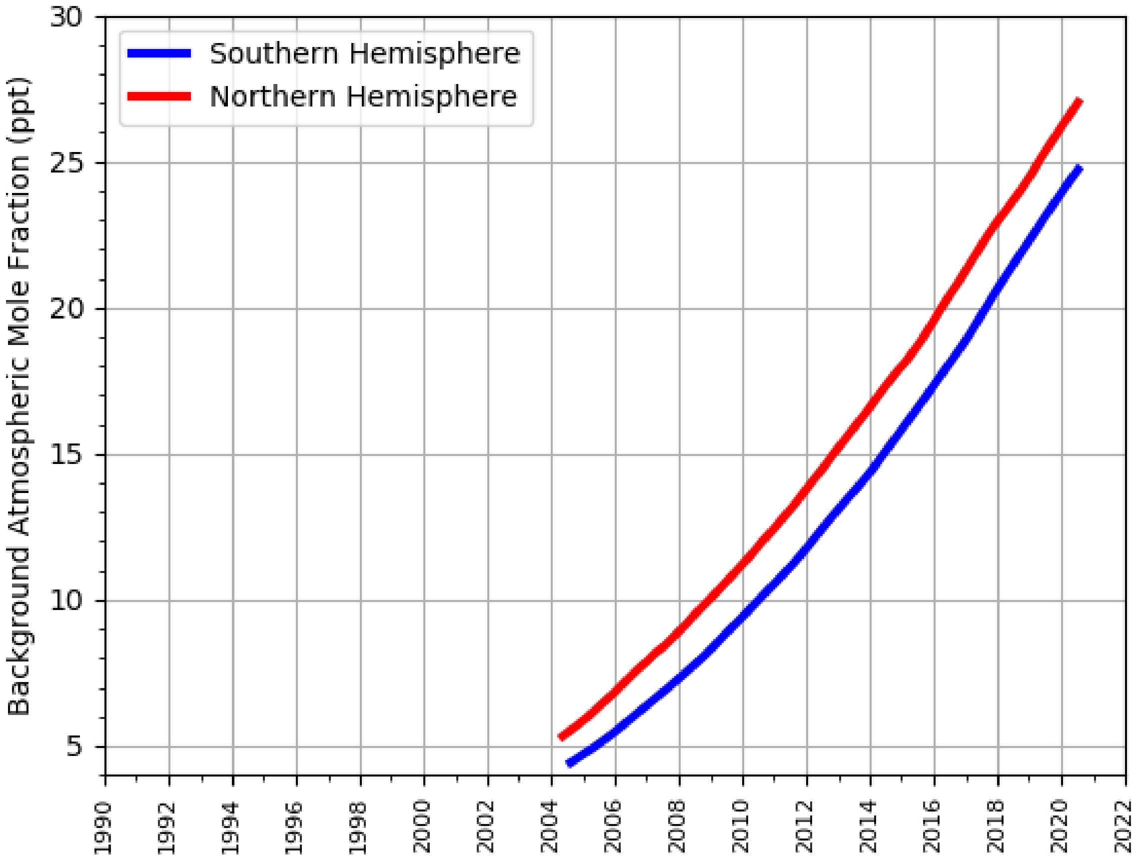
Figure A 6.15 **Four-year average HFC-125 InTEM emission estimates (kg km^{-2}yr^{-1}) 2017-2020. The observation stations are shown as white triangles. Major cities are shown as black circles.**



A 6.4.3 HFC-143a

Figure A 6.16 shows the Hemispheric background atmospheric concentrations of HFC-143a from 2004 onwards. The hemispheric background trend is positive, in 2020 the Northern Hemisphere background increased by 1.6 ppt.

Figure A 6.16 Background Northern Hemisphere annual concentrations of HFC-143a estimated from Mace Head, Ireland observations are shown in red, background Southern Hemisphere annual concentrations from Cape Grim, Tasmania are shown in blue.



InTEM emission estimates for the UK for HFC-143a for the period 2004 onwards are shown in **Figure A 6.17** and are compared to the GHGI estimates. UK emissions, as estimated by the GHGI, have increased year-on-year from the early 1990s until a peak in 2012-2013, and thereafter a gradual decline. The InTEM estimates show reasonable agreement with the GHGI, though is slightly higher from 2005-2011. InTEM follows the slope of the declining GHGI very closely and is just slightly lower from 2012-2017. After 2017 the InTEM model estimate drops much more rapidly than the GHGI and is approximately 60% of the GHGI by 2019. On visual inspection it appears that there is a two-year shift between the two independent estimates. It must be noted that the agreement between InTEM and the GHGI is significantly improved compared to similar comparisons in the UK submissions in previous years. This is a direct result of the implementation of the new RAHCP model in the GHGI.

Figure A 6.17 **Verification of the UK emission inventory estimates for HFC-143a in Tg CO_2-eq yr^{-1} from 1990. GHGI estimates are shown in black. InTEM 2-year estimates are shown in blue (±1σ), InTEM 1-year estimates are shown in orange (±1σ).**

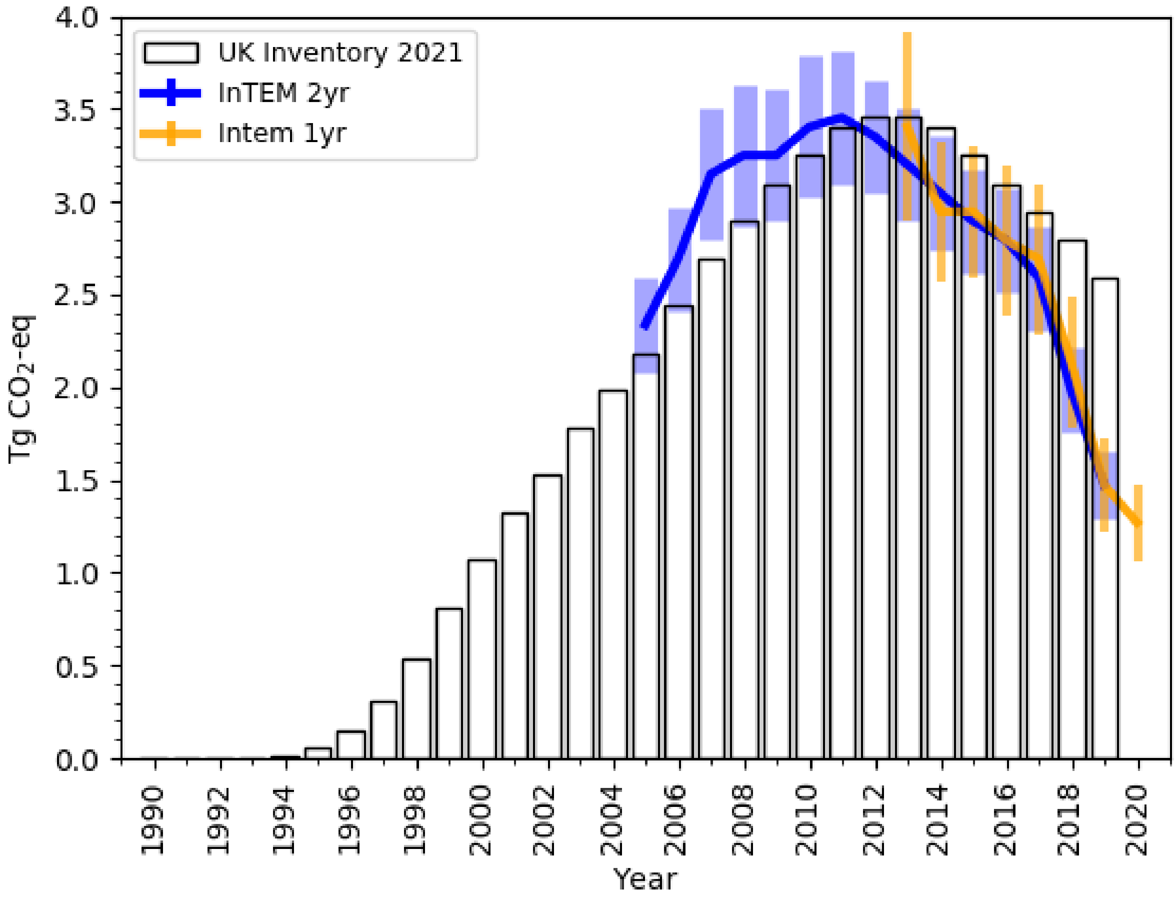
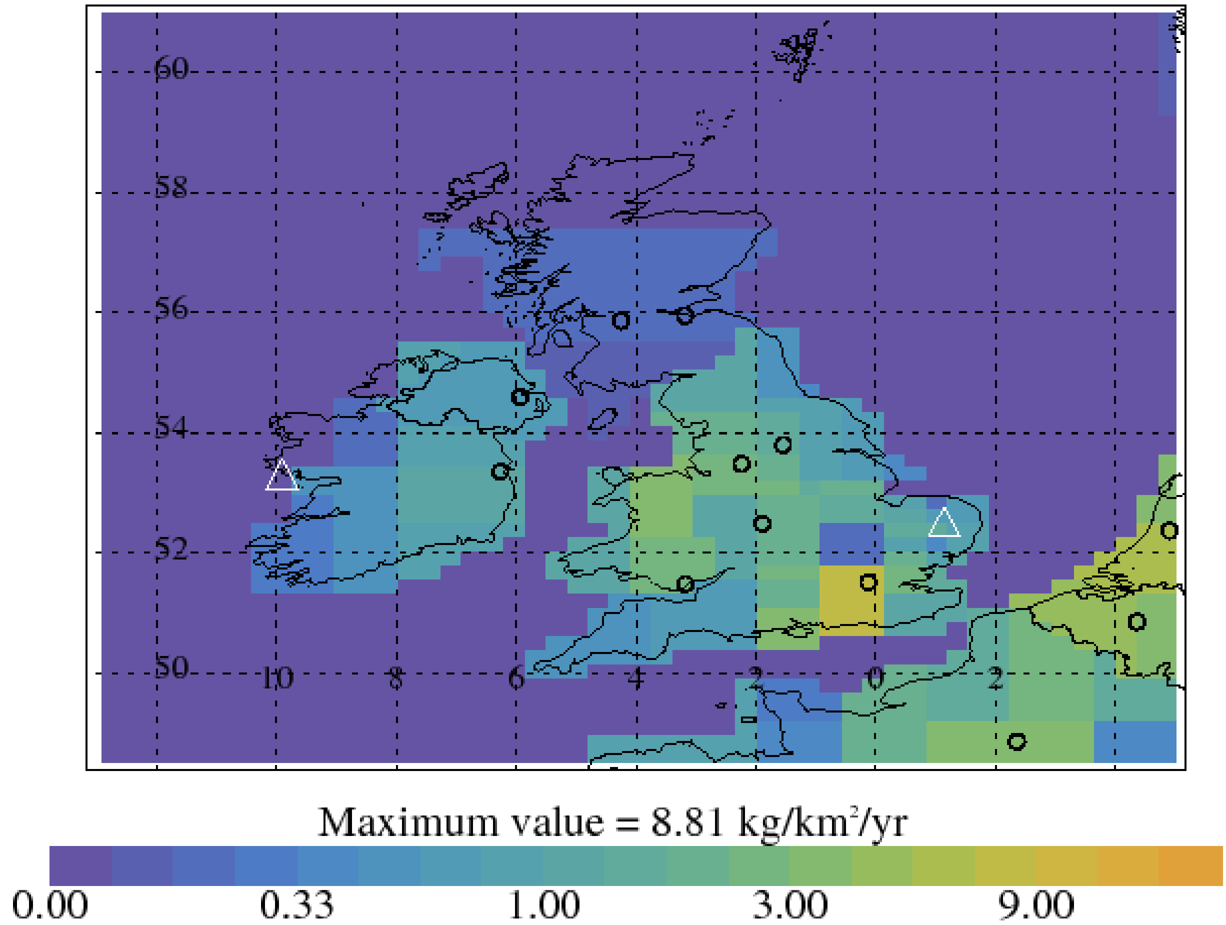


Figure A 6.18 shows the spatial InTEM emissions estimate for HFC-143a over the UK in kg $km^{-2}yr^{-1}$, for a four-year average over 2017-2020. The highest emissions are generally focused in populated regions, with the highest emission area appearing over London and in the south of the UK.

Figure A 6.18 Four-year average HFC-143a InTEM emission estimates (kg km−2yr−1) 2017-2020. The observation stations are shown as white triangles. Major cities are shown as black circles.



A 6.4.4 HFC-23

Figure A 6.19 shows the hemispheric background atmospheric concentrations of HFC-23 from 2008 onwards. The background trend is monotonic and positive, in 2020 the Northern Hemispheric background increased by 1.1 ppt.

InTEM emission estimates for the UK for HFC-23 from 2009 are higher than the emissions estimated by the GHGI for this period, although the InTEM uncertainties are large and mostly extend down to zero (**Figure A 6.20**). From the observations it is clear that some intermittent emissions of HFC-23 occur in the UK.

Figure A 6.19 Background Northern Hemisphere annual concentrations of HFC-23 estimated from Mace Head, Ireland observations are shown in red, background Southern Hemisphere annual concentrations from Cape Grim, Tasmania are shown in blue.

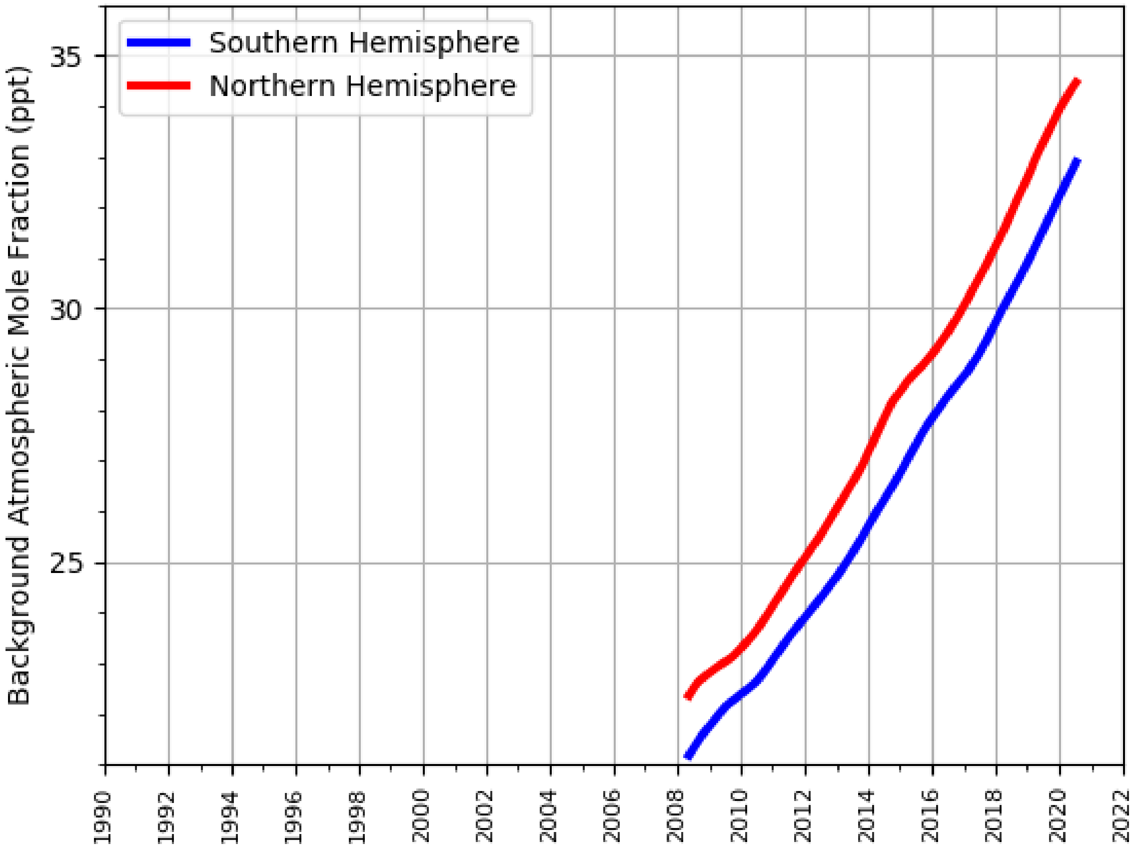
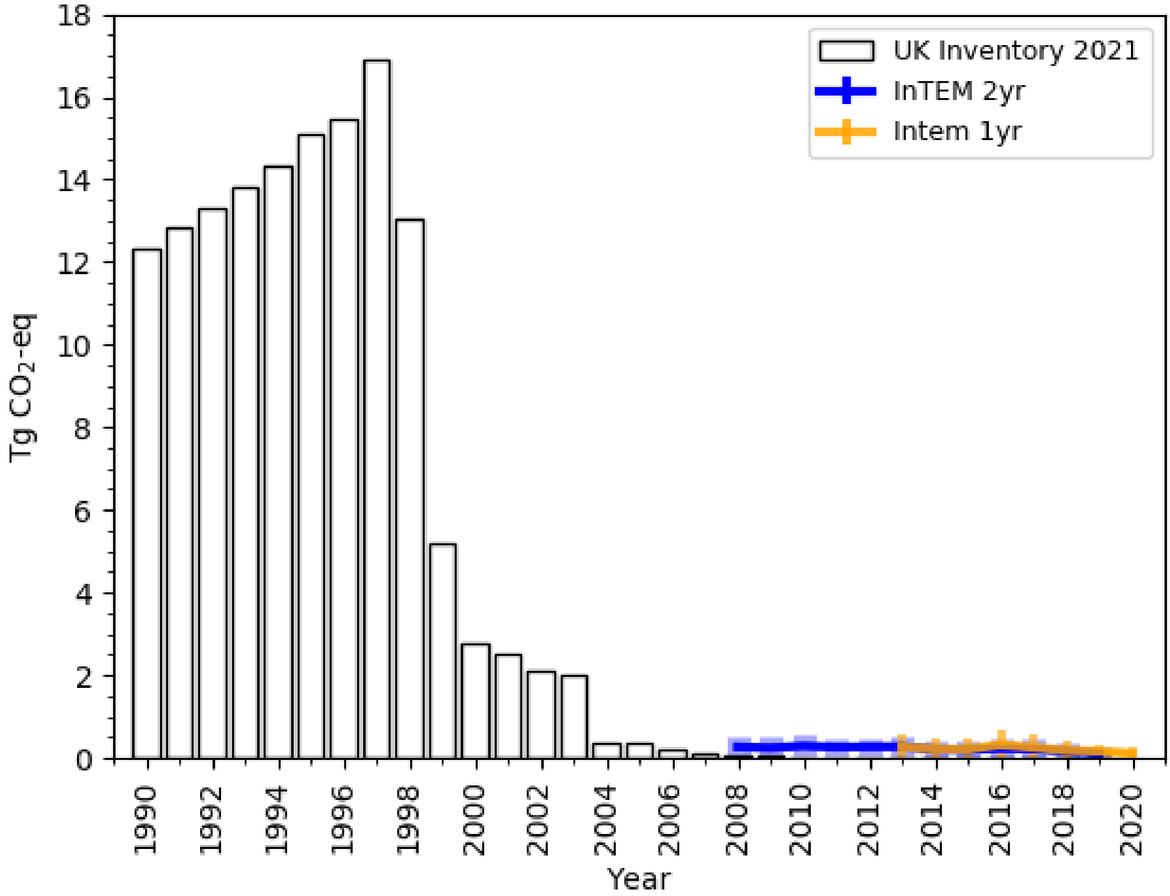


Figure A 6.20 **Verification of the UK emission inventory estimates for HFC-23 in Tg CO_2-eq yr^{-1} from 1990. GHGI estimates are shown in black. InTEM 2-year estimates are shown in blue (±1 σ), 1-year estimates are shown in orange (±1 σ). The second plot is plotted with an expanded y-axis from 2004.**



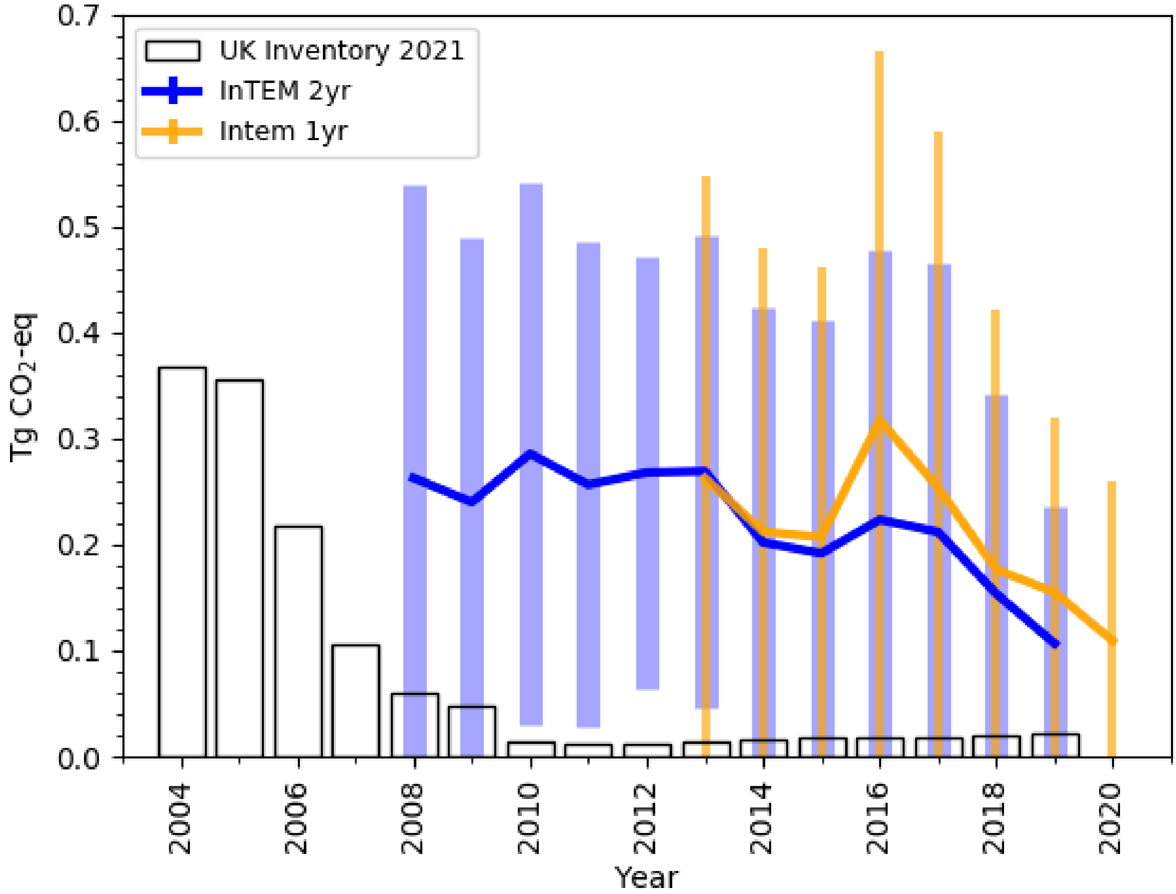

UK Inventory 2021
InTEM 2yr
Intem 1yr
Tg CO2-eq
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2004
2006
2008
2010
2012
2014
2016
2018
2020
Year

Figure A 6.21 **Four-year average HFC-23 InTEM emission estimates (kg km−2yr−1) 2017-2020. The observation stations are shown as white triangles. Major cities are shown as black circles.**

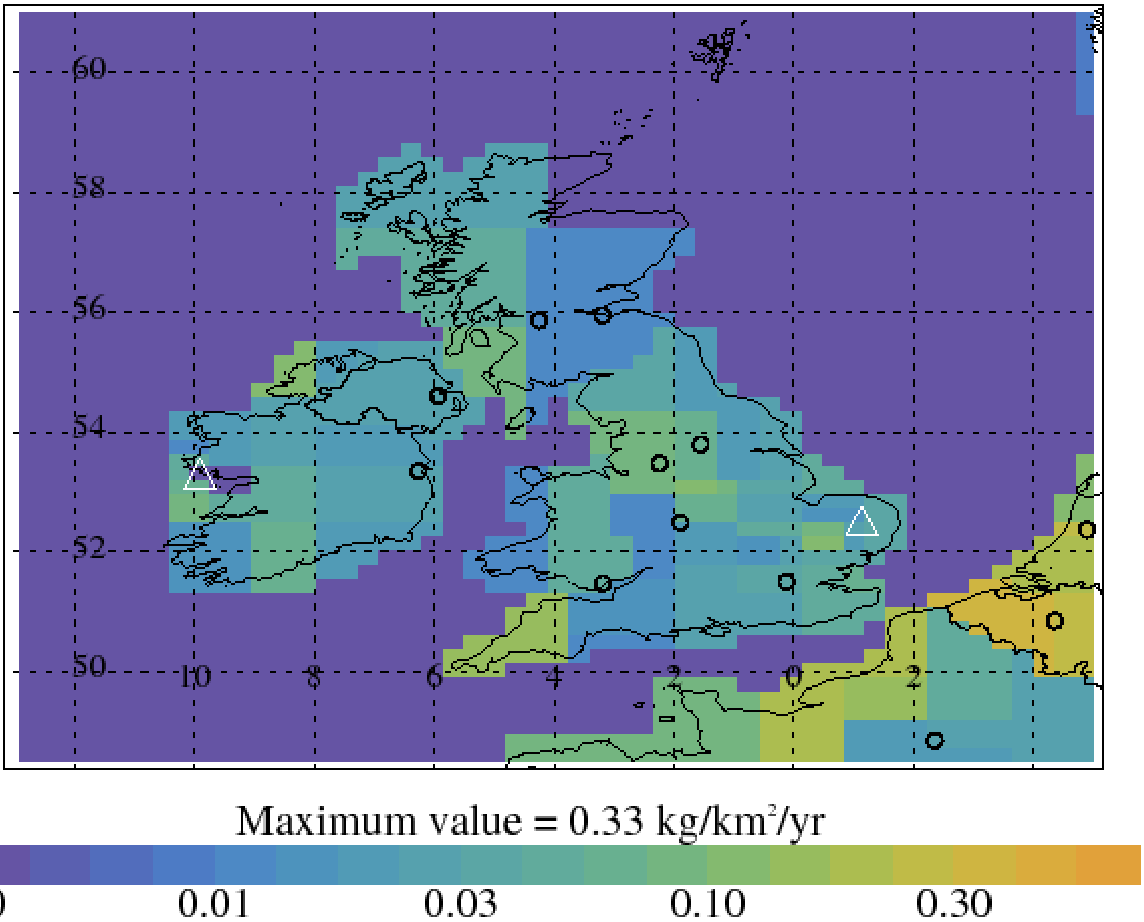
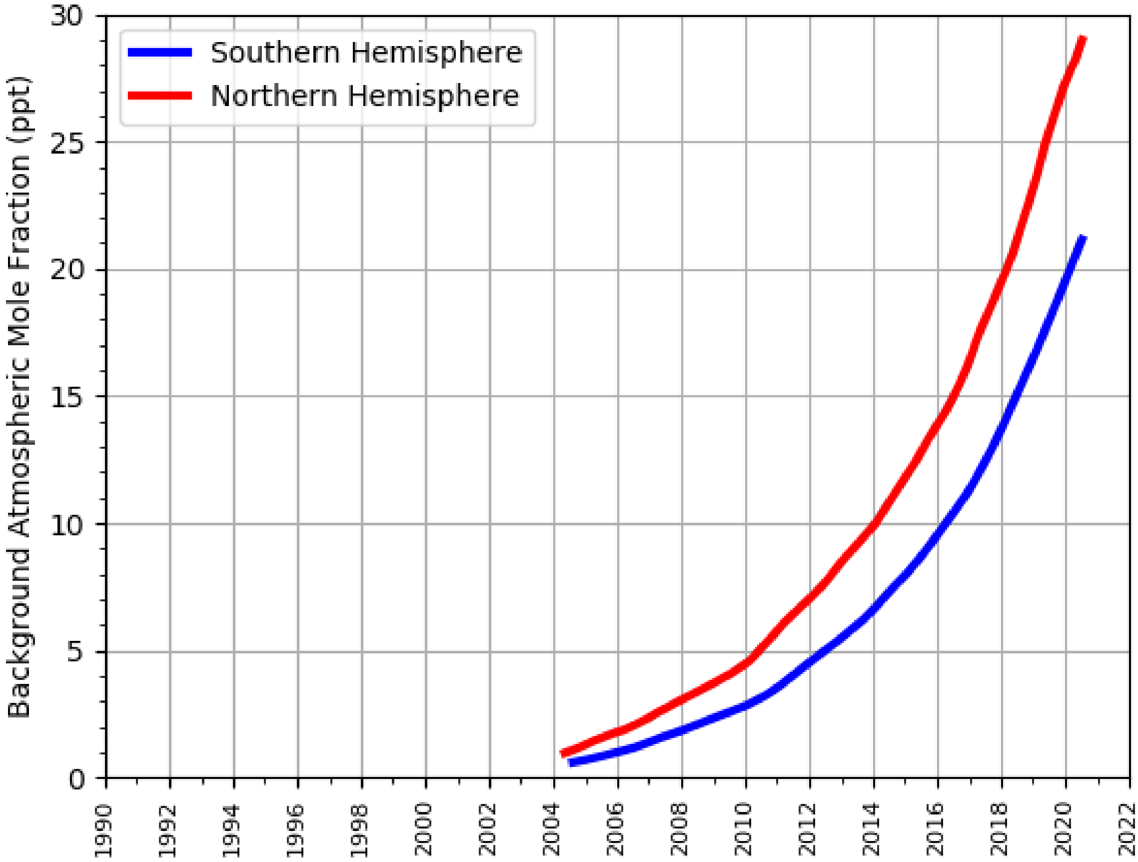


Figure A 6.21 shows the spatial InTEM emissions estimate for HFC-23 over the UK in kg km^{-2}yr^{-1}, for a four-year average over 2017-2020. The levels of HFC-23 are fairly uniform over the UK. Higher emissions are indicated on the parts of the French coast, Belgium and the Netherlands.

A 6.4.5 HFC-32

Figure A 6.22 shows the hemispheric background atmospheric concentration of HFC-32 from 2004 onwards. The background trend is monotonic and positive, in 2020 the Northern Hemispheric background increased by 3.5 ppt.

Figure A 6.22 **Background Northern Hemisphere annual concentrations of HFC-32 estimated from Mace Head, Ireland observations are shown in red, background Southern Hemisphere annual concentrations from Cape Grim, Tasmania are shown in blue.**



InTEM emission estimates for the UK for HFC-32 for 2005 onwards are shown in **Figure A 6.23** The InTEM emission estimates match the GHGI estimates extremely well up until 2013. From 2014-2018 the agreement is less good with the InTEM estimates lower than the GHGI. From 2018 InTEM decreases, however in contrast, the GHGI continues to rise in 2019. It must be noted that the agreement between InTEM and the GHGI is significantly improved compared to similar comparisons in the UK submissions in previous years. This is a direct result of the implementation of the new RAHCP model in the GHGI.

Figure A 6.23 **Verification of the UK emission inventory estimates for HFC-32 in Tg CO_2-eq yr^{-1} from 1990. GHGI estimates are shown in black. InTEM 2-year estimates are shown in blue (±1 σ), 1-year estimates are shown in orange (±1 σ).**

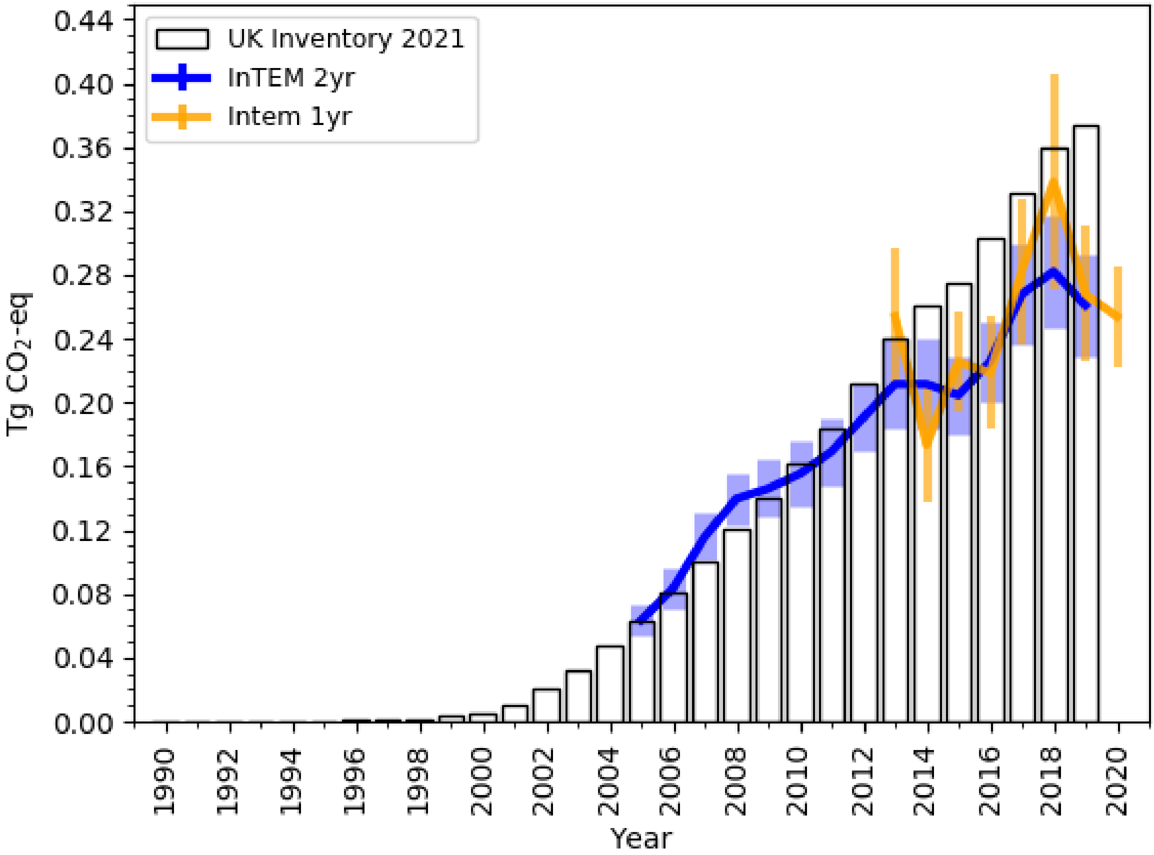
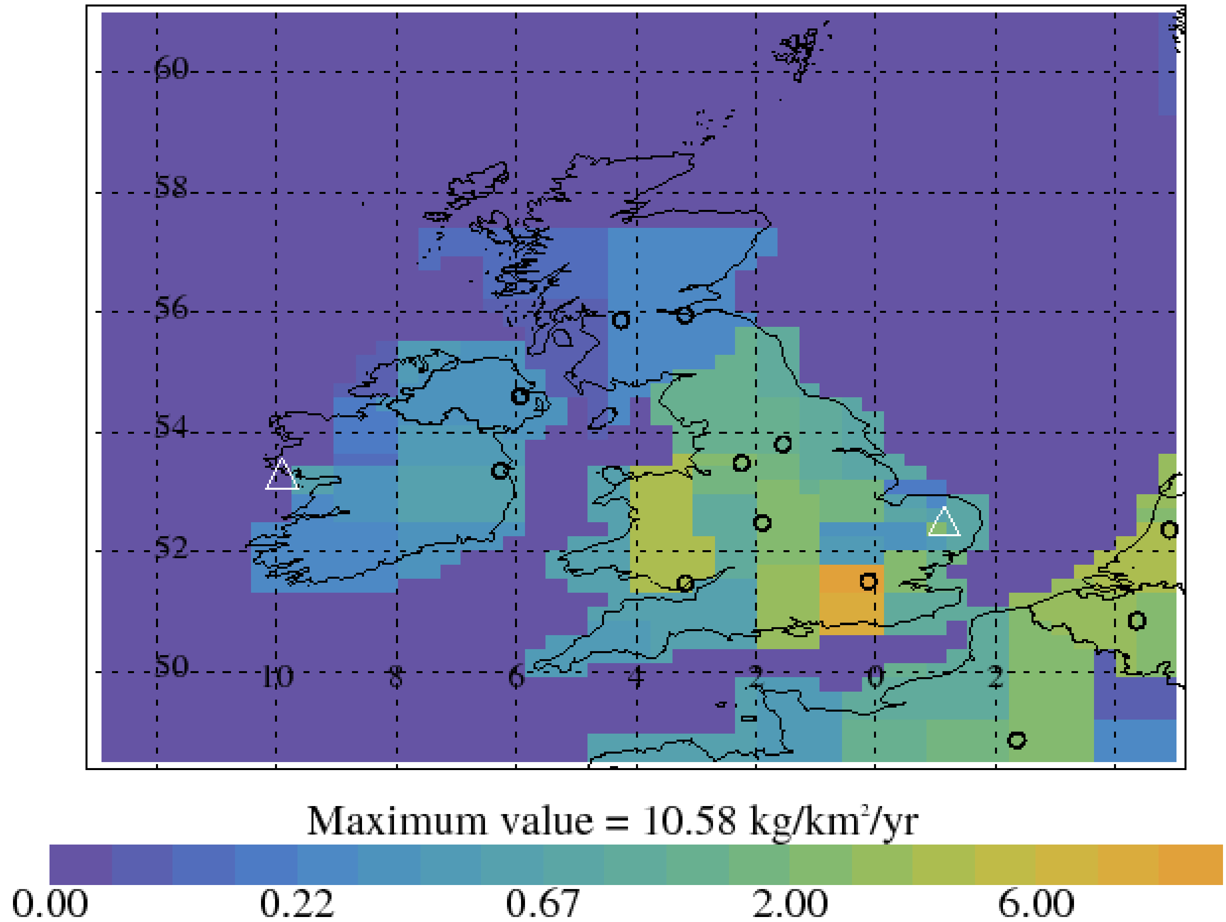


Figure A 6.24 shows the spatial InTEM emissions estimate for HFC-32 over the UK in kg $km^{-2}yr^{-1}$, for a four-year average over 2017-2020. The highest emissions are generally focused on the more populated areas, with the highest emission region appearing over London and in the south of the UK.

Figure A 6.24 **Four-year average HFC-32 InTEM emission estimates (kg km^{-2}yr^{-1}) 2017-2020. The observation stations are shown as white triangles. Major cities are shown as black circles.**



A 6.4.6 HFC-227ea

Figure A 6.25 shows the hemispheric background atmospheric concentrations of HFC-227ea from 2007 onwards. There is a positive trend in the background; in 2020 the Northern Hemispheric baseline increased by 0.16 ppt.

The GHGI estimates (**Figure A 6.26**) are significantly (~3 times) higher than those estimated by InTEM. The InTEM estimates start to decline from 2018 similar, in trend, to that estimated by the GHGI albeit more slowly.

Figure A 6.25 Background Northern Hemisphere annual concentrations of HFC-227ea estimated from Mace Head, Ireland observations are shown in red, background Southern Hemisphere annual concentrations from Cape Grim, Tasmania are shown in blue.

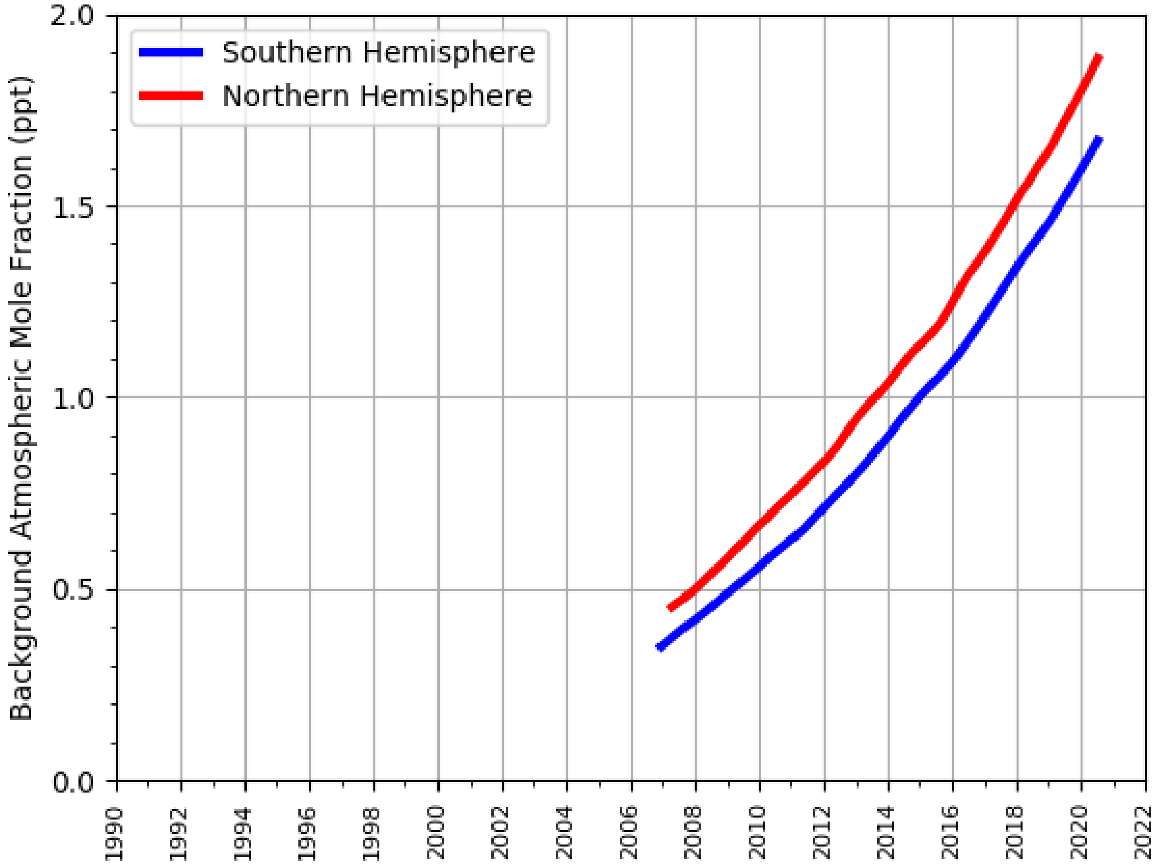


Figure A 6.26 Verification of the UK emission inventory estimates for HFC-227ea in Tg CO_2-eq yr^{-1} from 1990. GHGI estimates are shown in black. InTEM 2-year estimates are shown in blue (±1 σ), InTEM 1-year estimates are shown in orange (±1 σ).

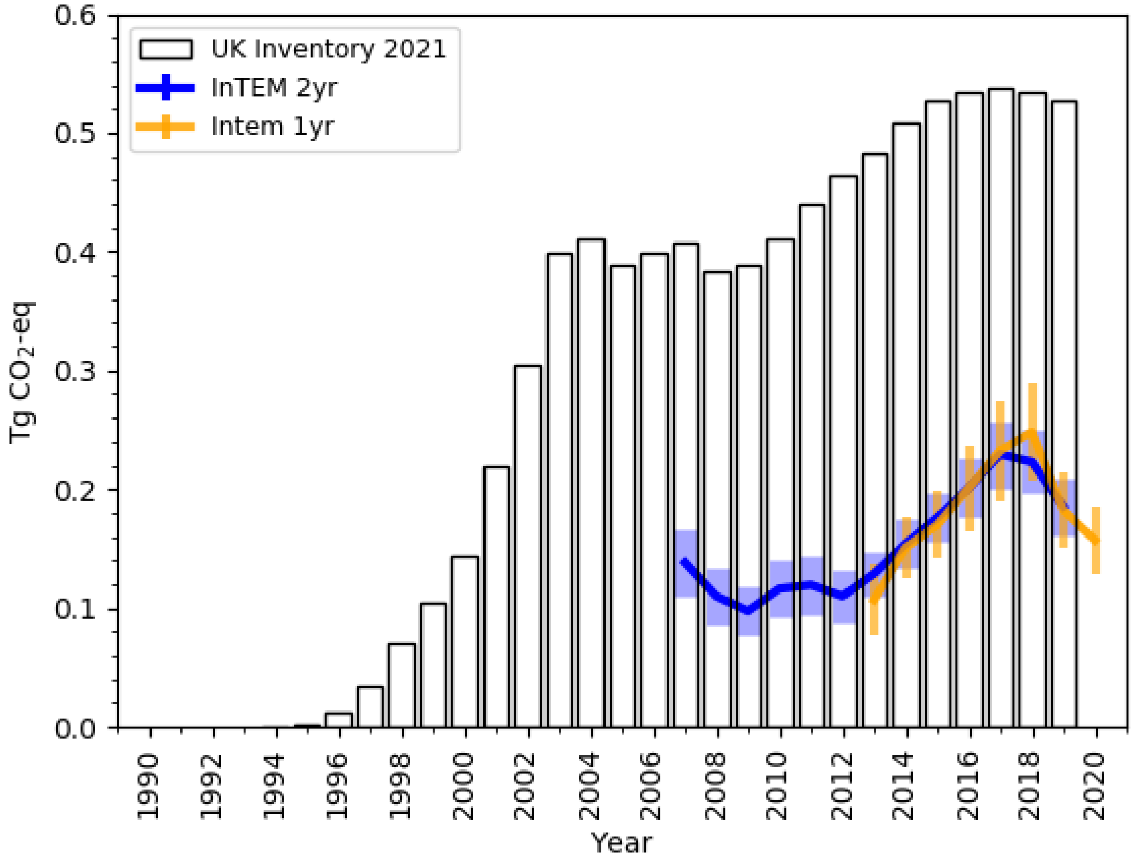


Figure A 6.27 **Four-year average HFC-227ea InTEM emission estimates (kg km^{-2}yr^{-1}) 2017-2020. The observation stations are shown as white triangles. Major cities are shown as black circles.**

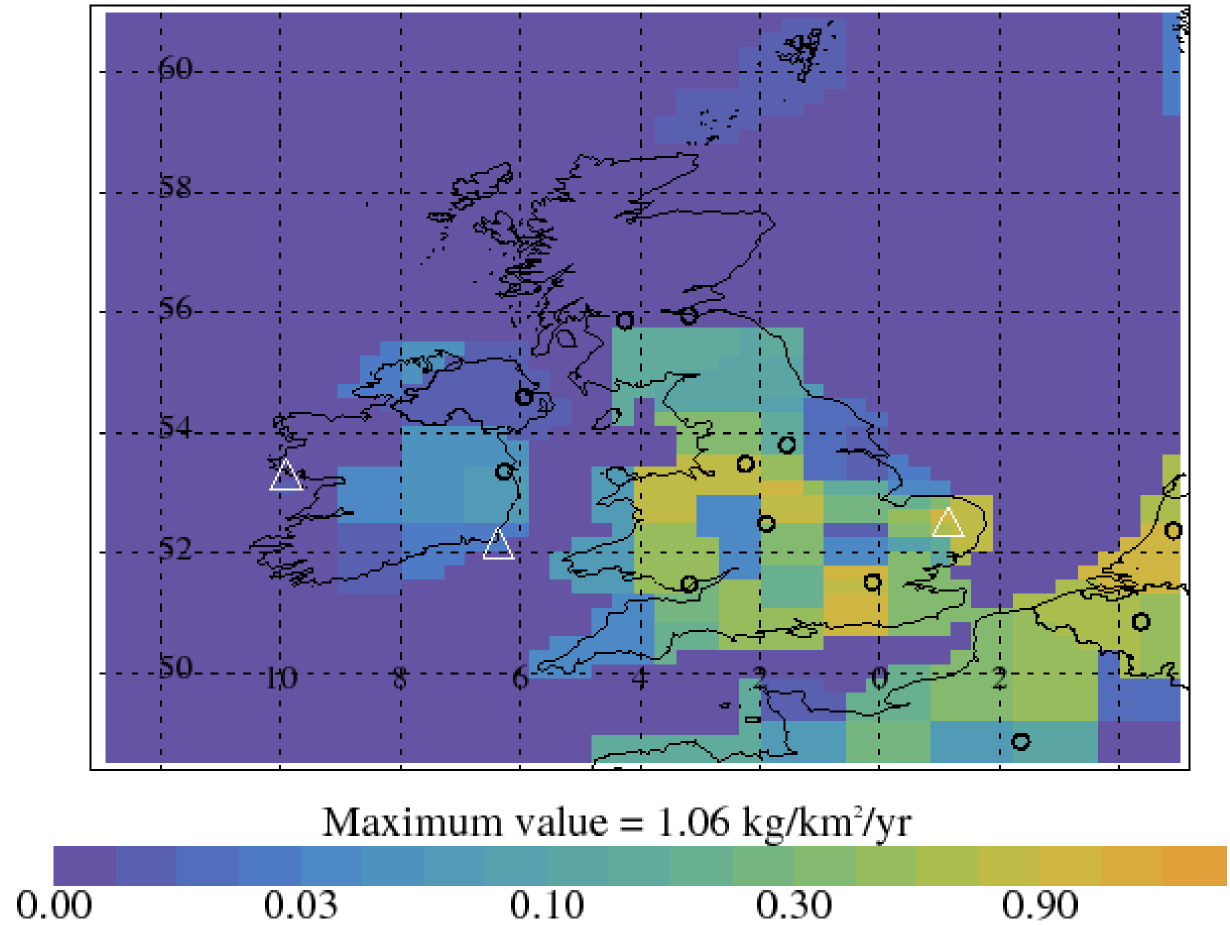


Figure A 6.27 shows the spatial InTEM emissions estimate for HFC-227ea over the UK in kg km^{-2}yr^{-1}, for a four-year average over 2017-2020. The geographic distribution appears to largely follow population with the notable exception of the area around TAC. This could be due to local emissions near to the station and is worthy of further investigation.

A 6.4.7 HFC-365mfc

Figure A 6.28 shows the hemispheric background atmospheric concentration of HFC-365mfc from 2004 onwards. There was a positive trend in the hemispheric backgrounds up until 2019 but no growth was estimated in the Northern Hemisphere in 2020.

The GHGI (**Figure A 6.29**) shows a sharp decline in emissions in 2008 and the InTEM 2-year estimates show a similar response. Post-2011 the GHGI estimates rising UK emissions, a trend initially reproduced by InTEM, however the InTEM estimates then show a sharp decline starting in 2016.

Figure A 6.28 Background Northern Hemisphere annual concentrations of HFC-365mfc estimated from Mace Head, Ireland observations are shown in red, background Southern Hemisphere annual concentrations from Cape Grim, Tasmania are shown in blue.

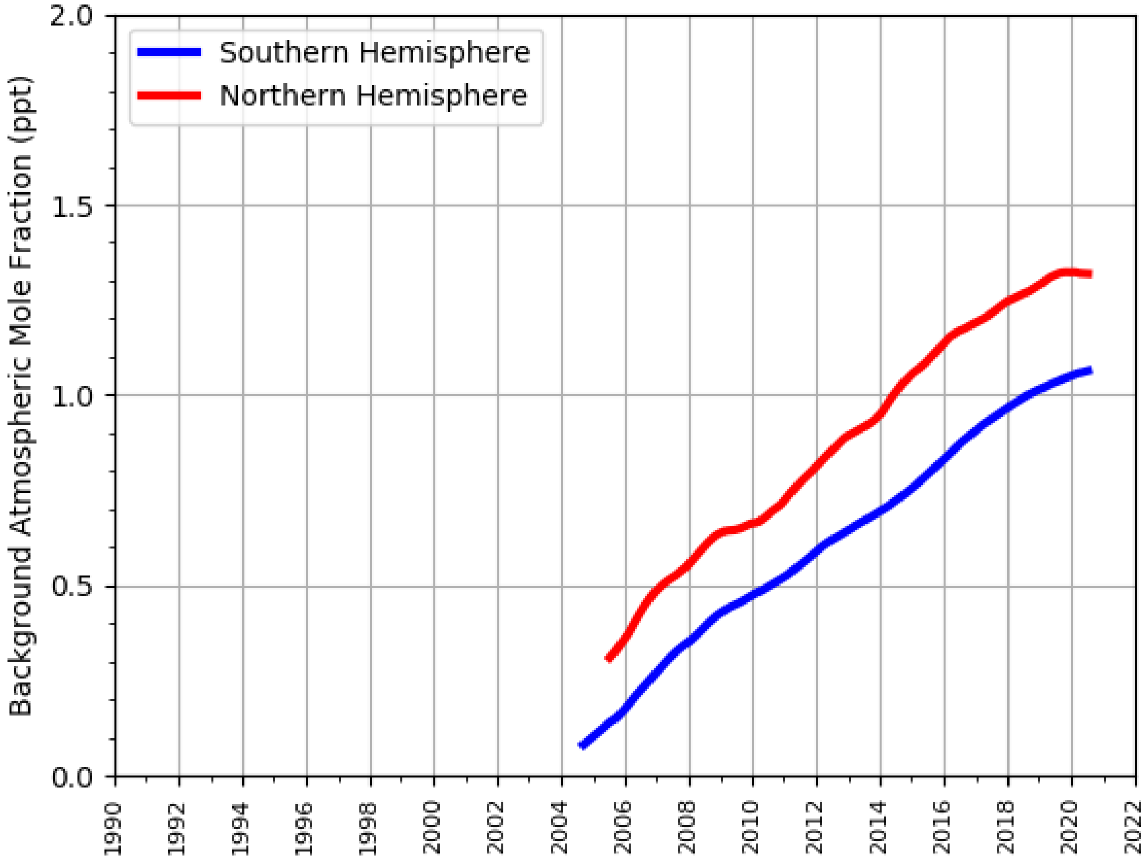


Figure A 6.29 **Verification of the UK emission inventory estimates for HFC-365mfc in Tg CO_2-eq yr^{-1} from 1990. GHGI estimates are shown in black. InTEM 2-year estimates are shown in blue (±1 σ), InTEM 1-year estimates are shown in orange (±1 σ).**

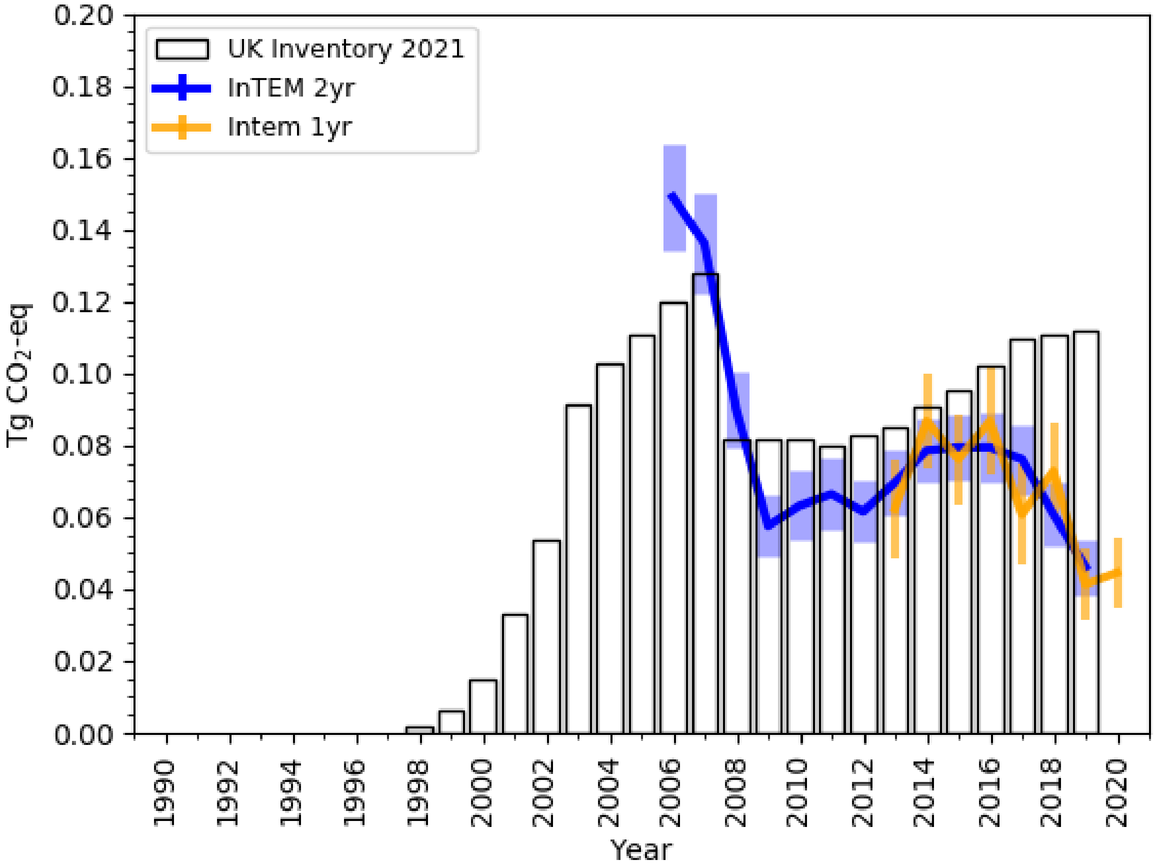


Figure A 6.30 **Four-year average HFC-365mfc InTEM emission estimates (kg km^{-2}yr^{-1}) 2017-2020. The observation stations are shown as white triangles. Major cities are shown as black circles.**

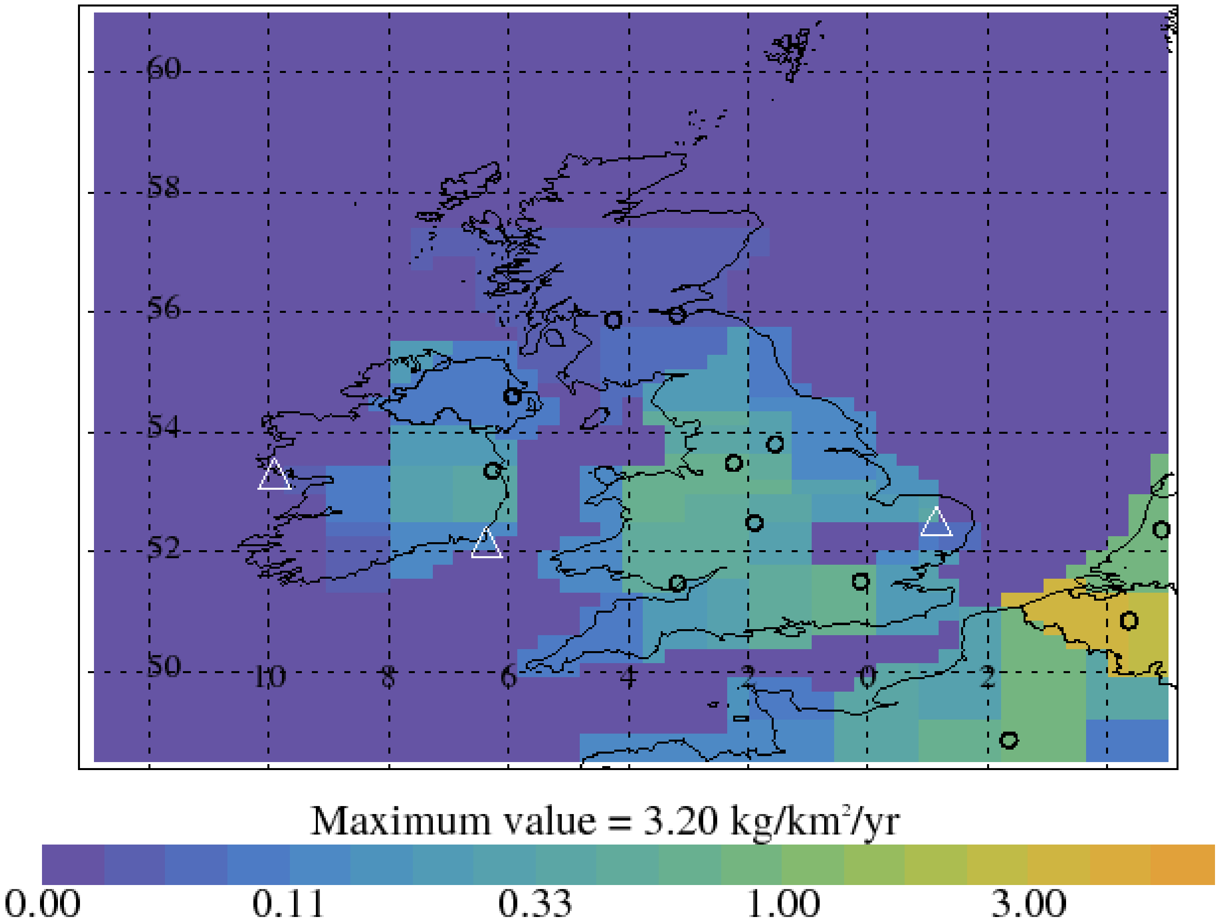


Figure A 6.30 shows the spatial InTEM emissions estimate for HFC-365mfc over the UK in kg km^{-2}yr^{-1}, for a four-year average over 2017-2020. The levels of HFC-365mfc emission are relatively uniform over England and Wales. Higher emissions are indicated on the near continent in Belgium.

A 6.4.8 HFC-245fa

Figure A 6.31 shows the hemispheric background atmospheric concentrations of HFC-245fa from 2007 onwards. There is a positive trend in the background; in 2020 the Northern Hemispheric background increased by 0.15 ppt.

The InTEM estimates (**Figure A 6.32**) have significant uncertainty and are consistently lower than the GHGI estimates, with the exception of 2008. The GHGI estimates show a significant decline in 2008 and then a steady annual increase. The InTEM estimates show a strong rise in emissions starting 2014 but then starts to decline from 2018 in contrast to the GHGI.

Figure A 6.31 Background Northern Hemisphere annual concentrations of HFC-245fa estimated from Mace Head, Ireland observations are shown in red, background Southern Hemisphere annual concentrations from Cape Grim, Tasmania are shown in blue.

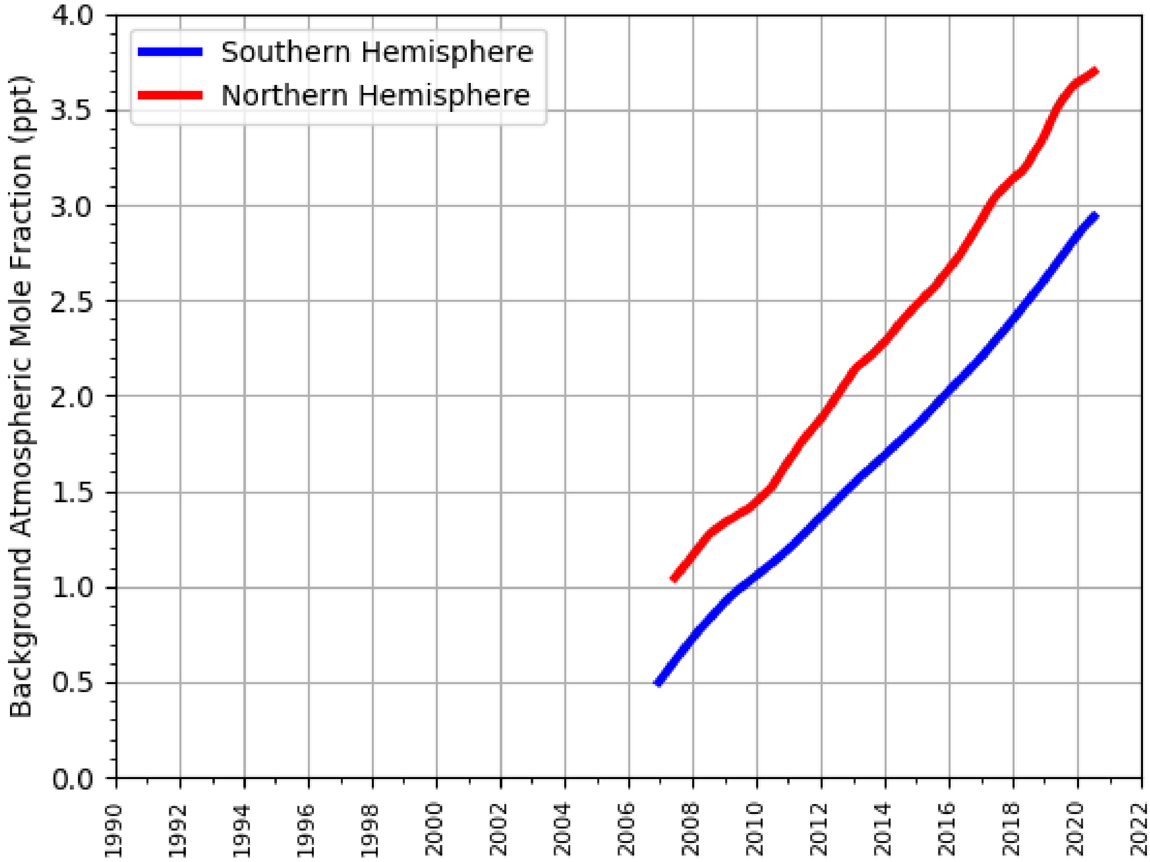


Figure A 6.32 Verification of the UK emission inventory estimates for HFC-245fa in Tg CO_2-eq yr^{-1} from 1990. GHGI estimates are shown in black. InTEM 2-year estimates are shown in blue (±1 σ). InTEM 1-year estimates are shown in orange (±1 σ).

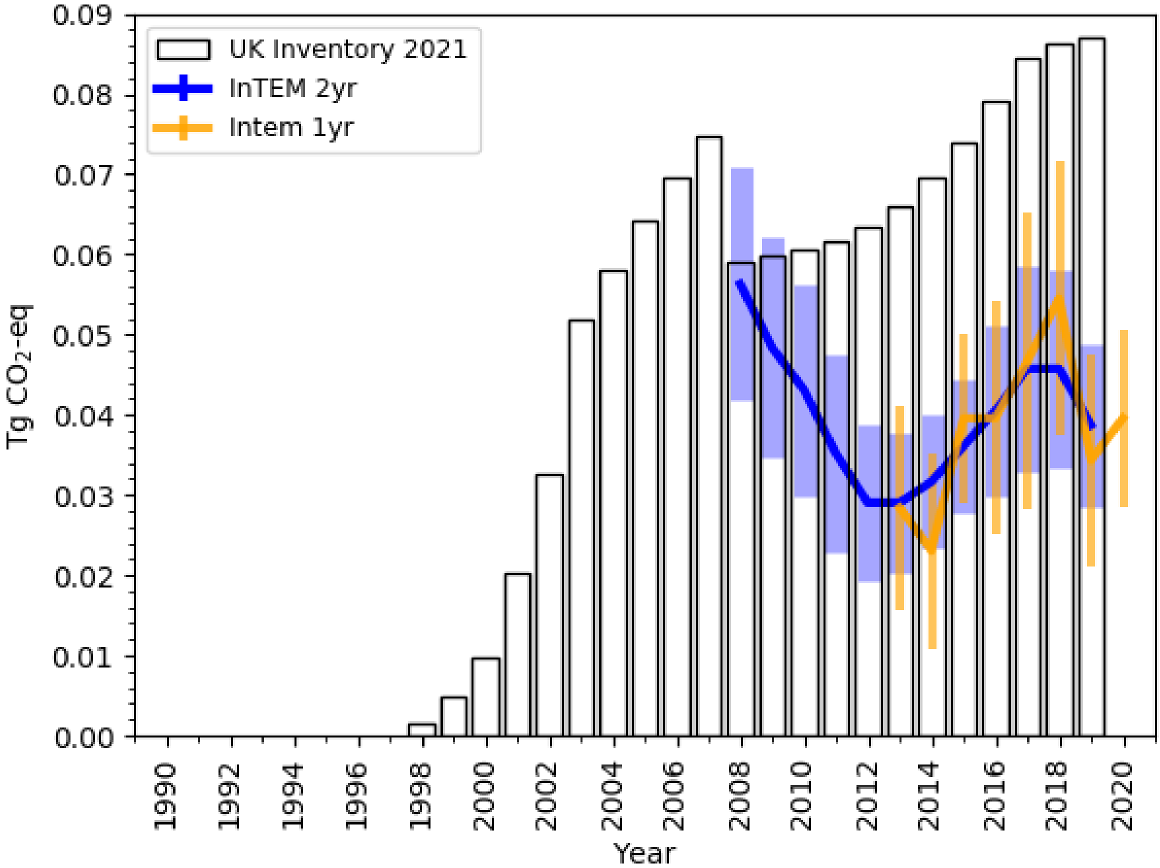
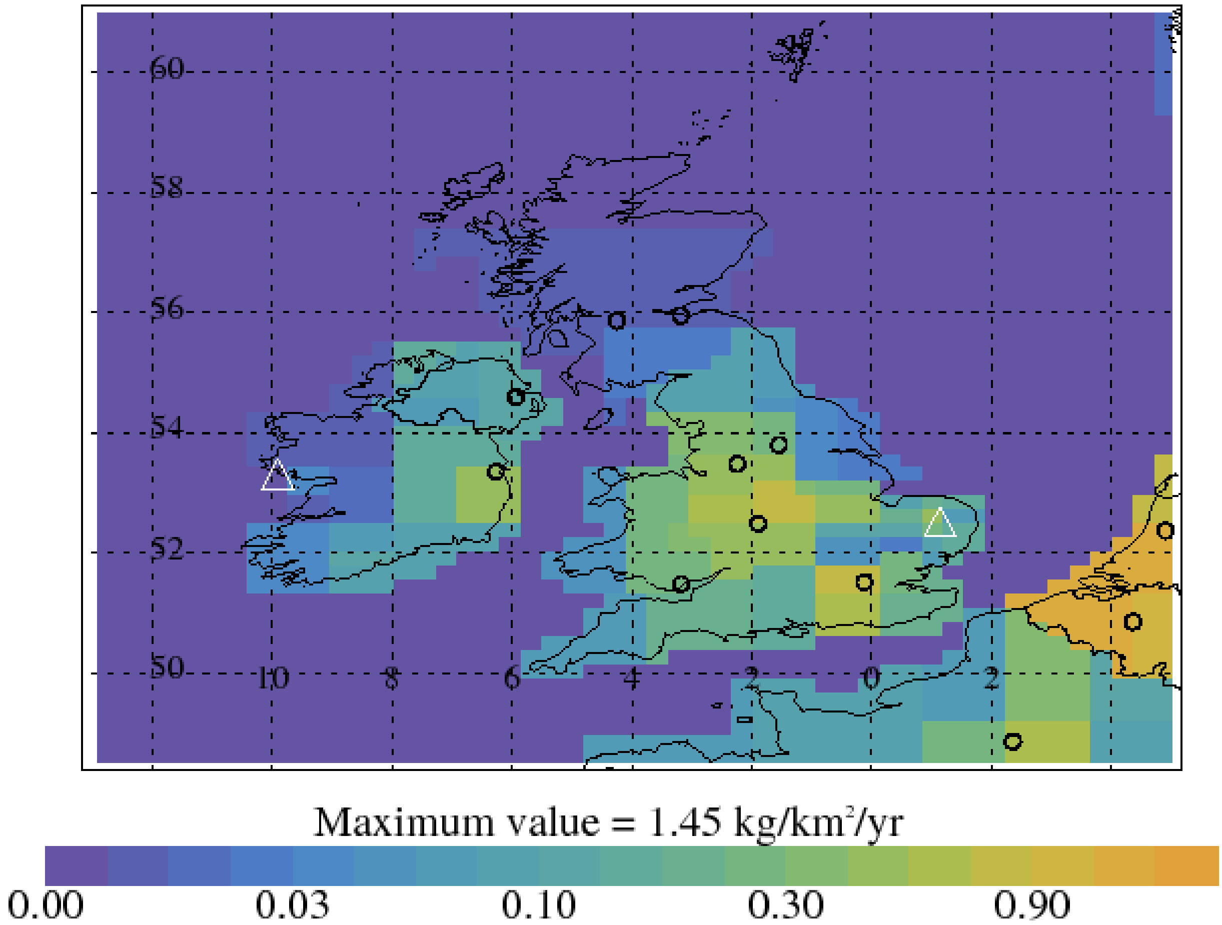


Figure A 6.33 shows the spatial InTEM emissions estimate for HFC-245fa over the UK in kg $km^{-2}yr^{-1}$, for a four-year average over 2017-2020. HFC-245fa follows the distribution of population over the UK. Higher emissions are indicated in Belgium and the Netherlands.

Figure A 6.33 Four-year average HFC-245fa InTEM emission estimates (kg km^{-2}yr^{-1}) 2017-2020. The observation stations are shown as white triangles. Major cities are shown as black circles.



A 6.4.9 HFC-152a

Figure A 6.34 Background Northern Hemisphere annual concentrations of HFC-152a estimated from Mace Head, Ireland observations are shown in red, background Southern Hemisphere annual concentrations from Cape Grim, Tasmania are shown in blue.

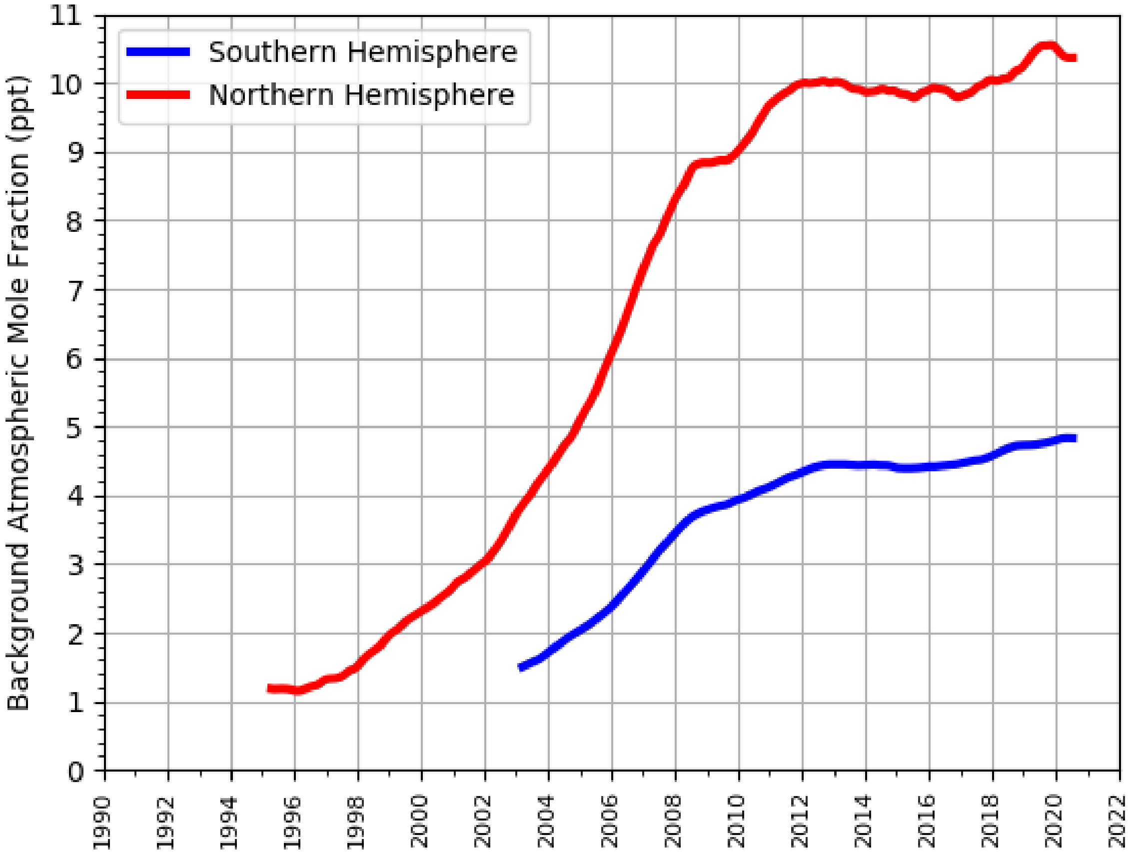


Figure A 6.34 shows the background atmospheric concentration of HFC-152a from 1995 onwards. The Northern Hemispheric background concentration shows a strong rise from the mid-1990s until 2008, then a much-reduced annual increase until 2012. From 2012-2017 a small decline is observed (Simmonds et al, 2016), followed by a rise, peaking in 2019. The Northern and Southern Hemispheric differences are exacerbated for this gas because of its relatively short atmospheric lifetime (1.6 years).

Figure A 6.35 **Verification of the UK emission inventory estimates for HFC-152a Tg CO_2-eq yr^{-1} from 1990. GHGI estimates are shown in black. InTEM 2-year estimates are shown in blue (±1σ), InTEM 1-year estimates are shown in orange (±1σ).**

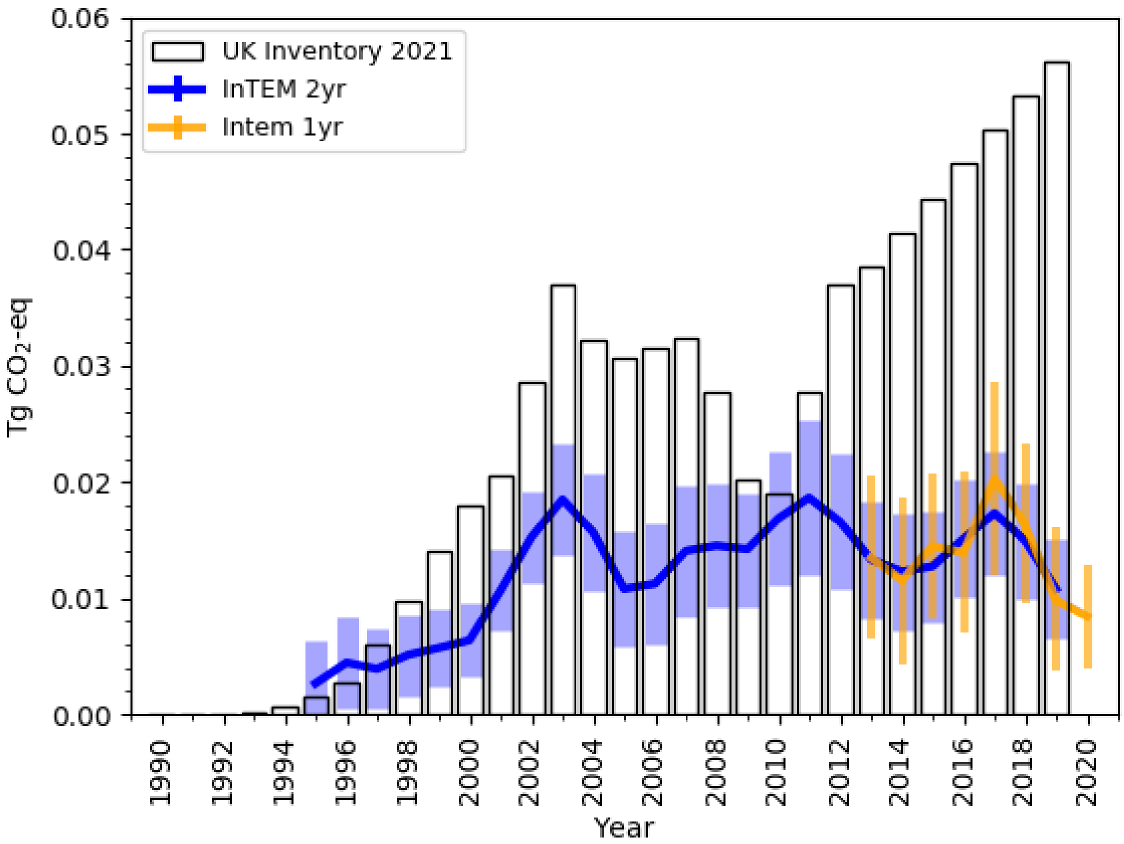
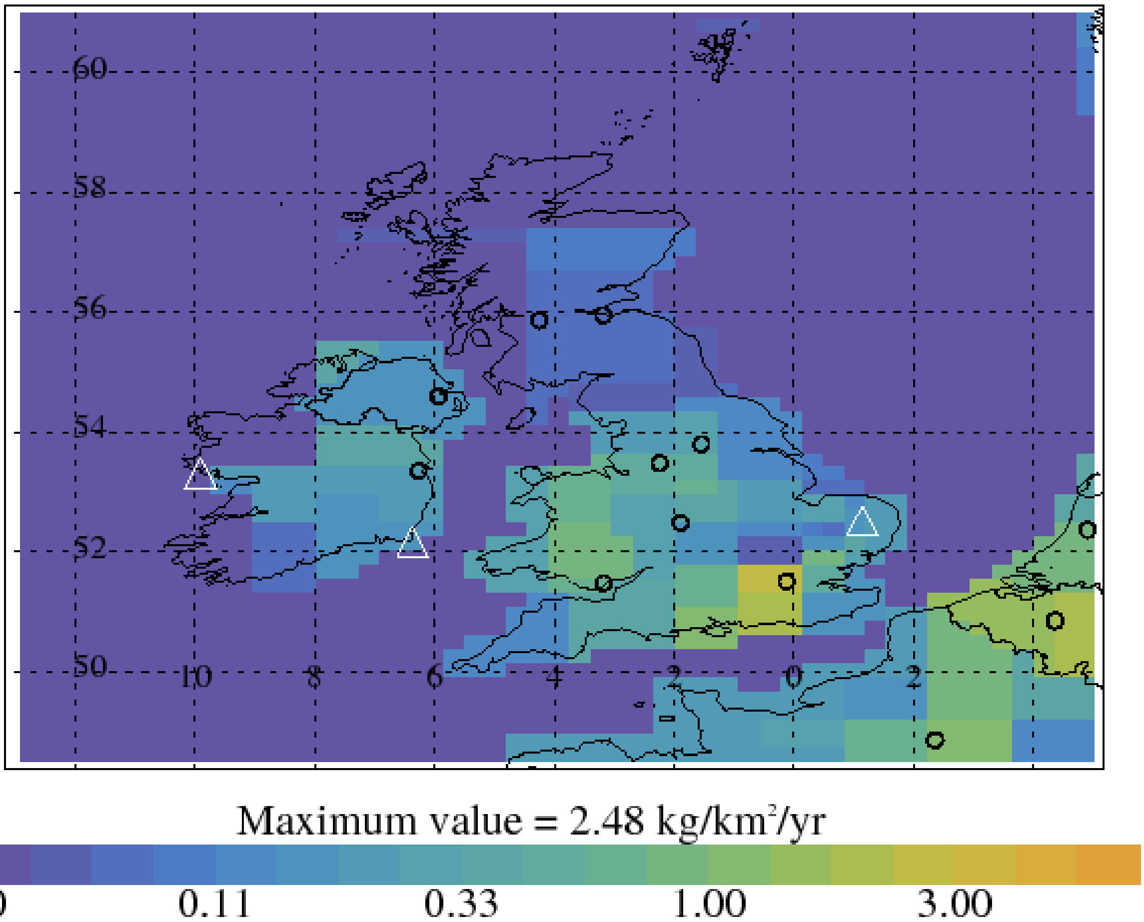


Figure A 6.35 shows the InTEM and the GHGI emission estimates for the UK for HFC-152a for the period 1990 onwards. Between 1999-2008 and from 2012 onwards the GHGI estimates are significantly larger than those estimated through inverse modelling. It is also interesting to note the positive trend from 2011 until 2019 in the UK GHGI conflicts with a much flatter InTEM trend followed by a sharp decline from 2017 to 2020. The InTEM estimate is < 20% of the GHGI in 2019.

Figure A 6.36 shows the spatial InTEM emissions estimate for HFC-152a over the UK in kg $km^{-2}yr^{-1}$, for a four-year average over 2017-2020. Similarly to HFC-134a, the highest emissions are generally focused on the more populated areas, with the highest emission region appearing over London and in the south of the UK.

Figure A 6.36 **Four-year average HFC-152a InTEM emission estimates (kg km^{-2}yr^{-1}) 2017-2020. The observation stations are shown as white triangles. Major cities are shown as black circles.**



A 6.4.10 HFC-43-10mee

Figure A 6.37 shows the hemispheric background atmospheric concentration of HFC-43-10mee from 2011 onwards. There is a positive trend in the background, in 2020 the Northern Hemispheric baseline concentration increased by 0.01 ppt.

As estimated by both methods, the UK emissions of this gas are small (**Figure A 6.38**). The GHGI estimates are initially in agreement with those estimated by InTEM, but the GHGI then has a small rise in 2015 and 2016, just as the InTEM emission drops sharply to a low point in 2015 and 2016, before rising back up until 2019, before dropping sharply in 2020. Throughout the InTEM uncertainty estimate is large relative to the emission. The spatial distribution is shown in **Figure A 6.39** and is largely distributed by population.

Figure A 6.37 **Background Northern Hemisphere annual concentrations of HFC-43-10mee estimated from Mace Head, Ireland observations are shown in red, background Southern Hemisphere annual concentrations from Cape Grim, Tasmania are shown in blue.**

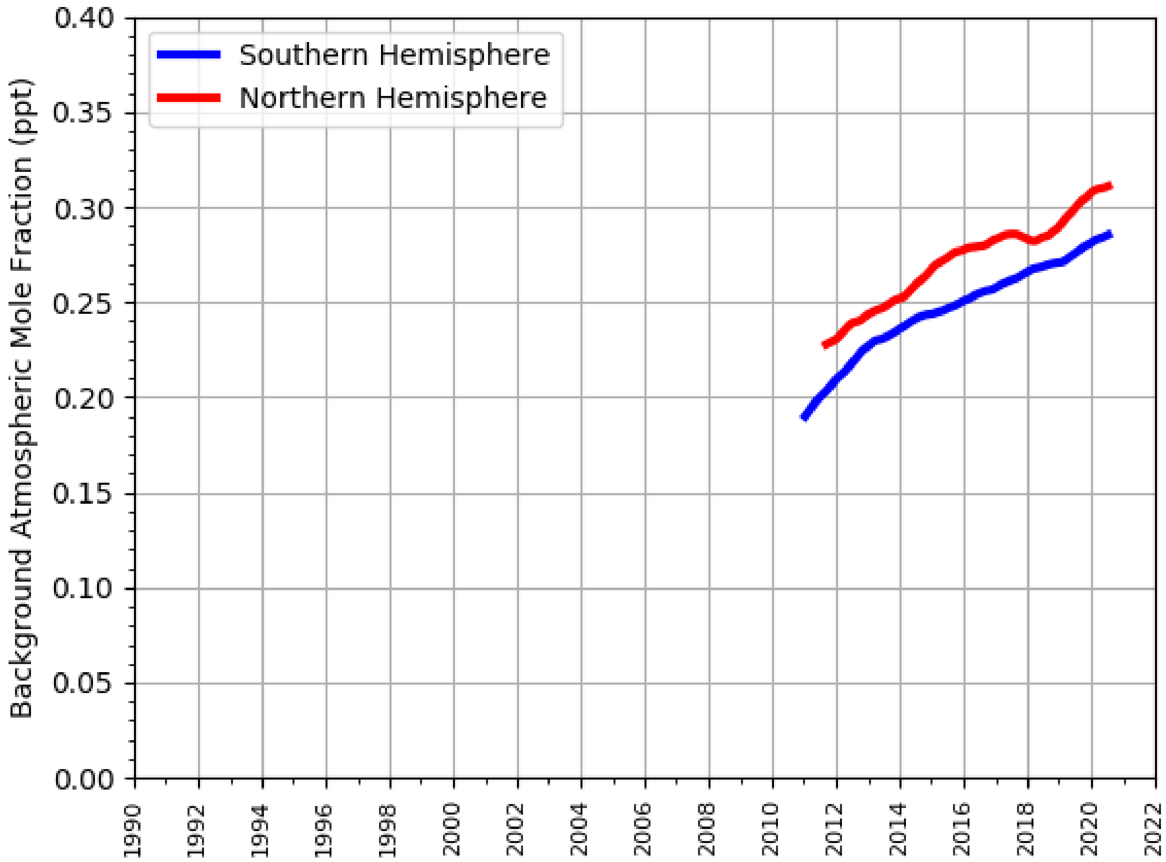


Figure A 6.38 **Verification of the UK emission inventory estimates for HFC-43-10mee in Tg CO_2-eq yr^{-1} from 1990. GHGI estimates are shown in black. InTEM 2-year estimates are shown in blue (±1 σ), InTEM 1-year estimates are shown in orange (±1 σ).**

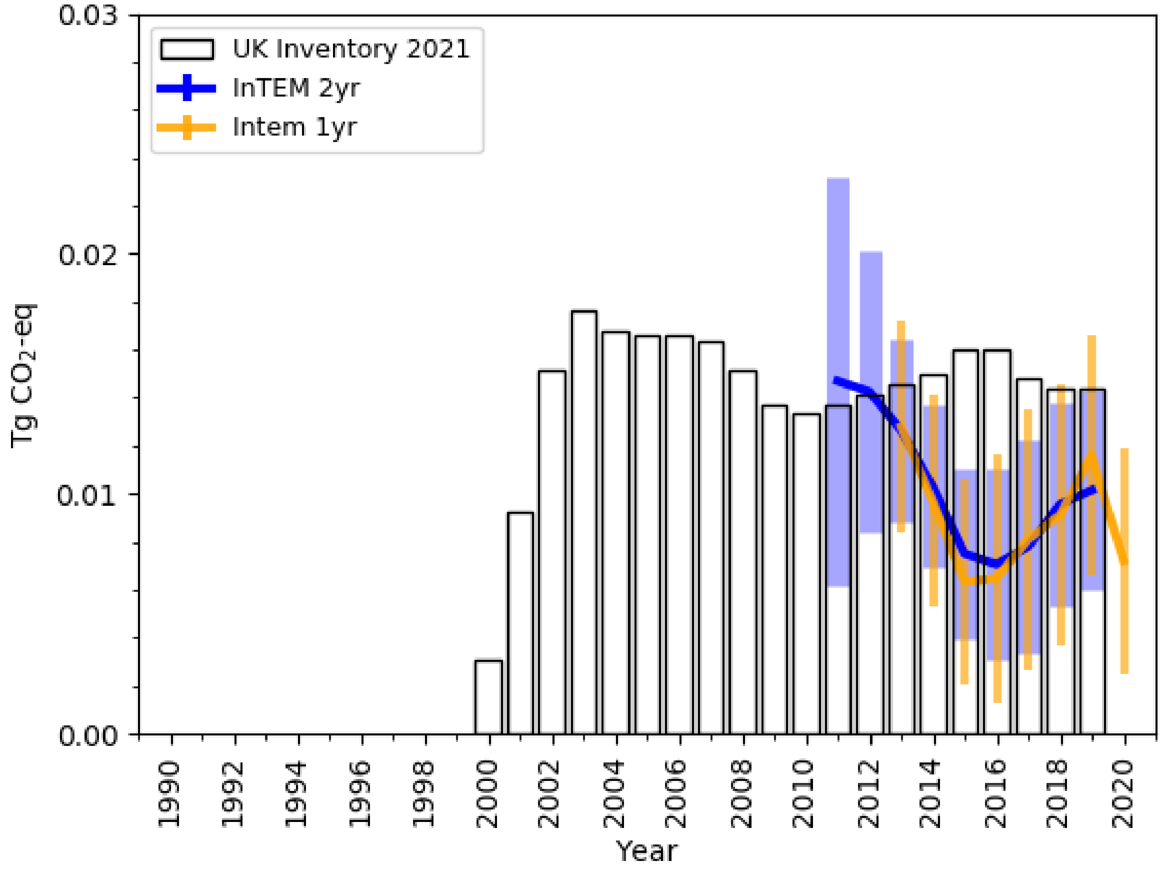
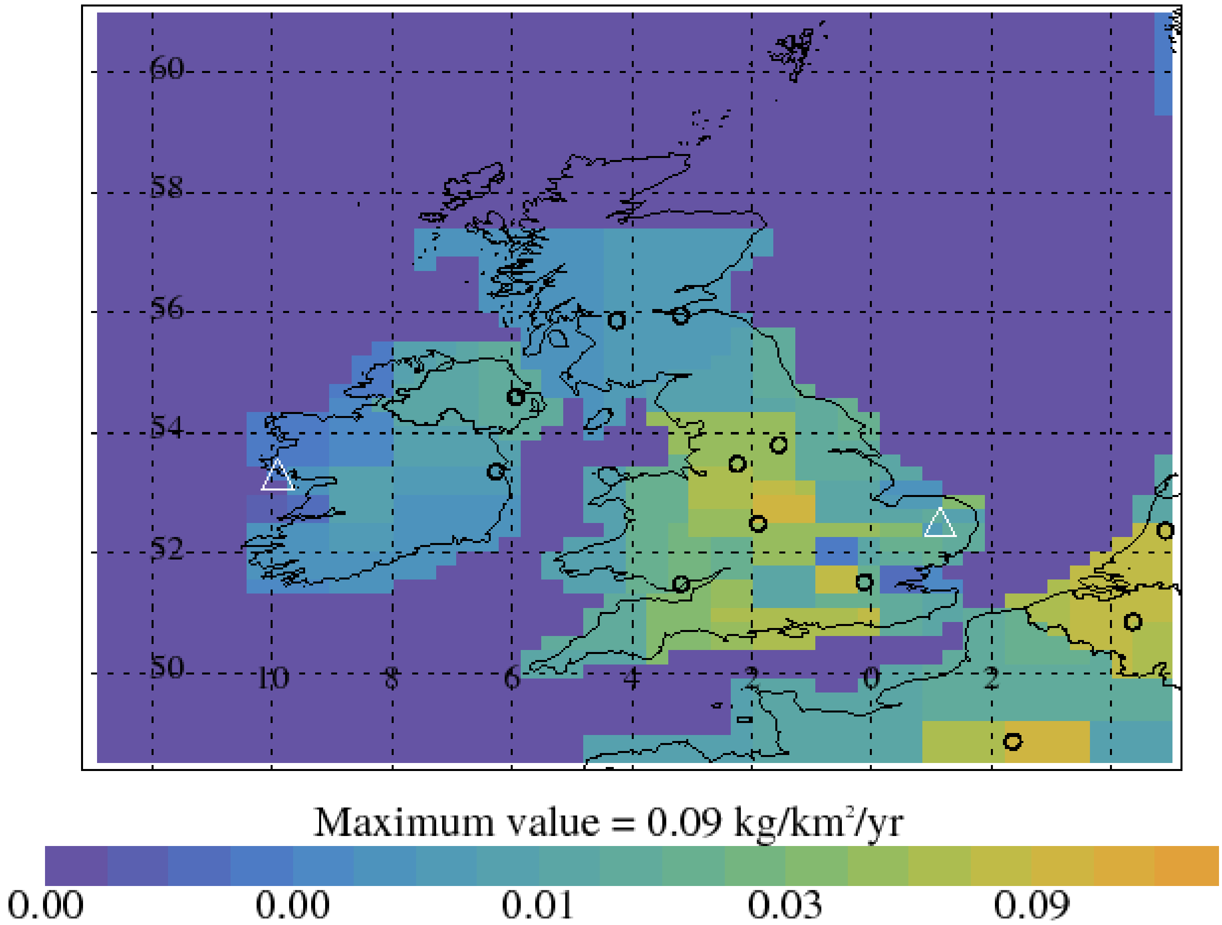


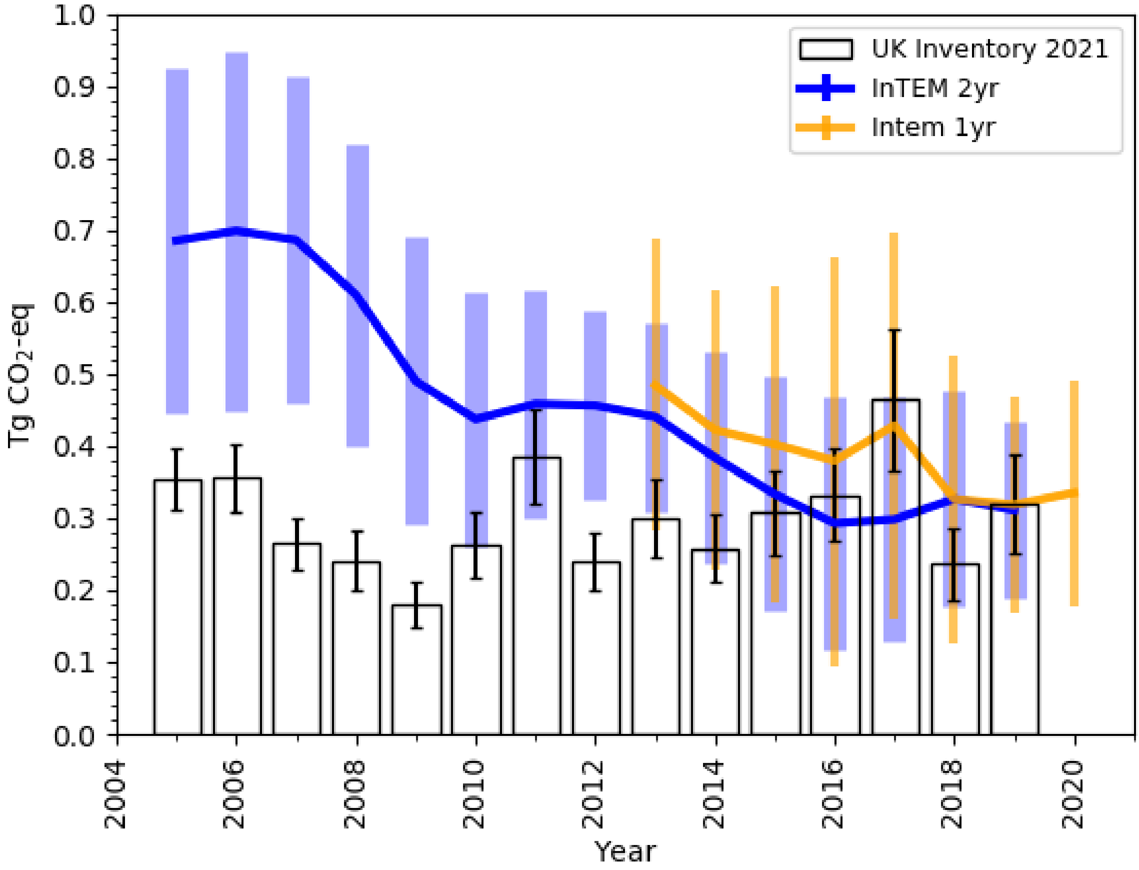
Figure A 6.39 **Four-year average HFC-43-10mee InTEM emission estimates (kg km^{-2}yr^{-1}) 2017-2020. The observation stations are shown as white triangles. Major cities are shown as black circles.**



A 6.5 PERFLUOROCARBONS

Figure A 6.40 shows the sum of all UK emissions of PFCs, (PFC-14, PFC-116, PFC-218, PFC-318) in Tg CO_2-eq yr^{-1}. The GHGI is shown in black and InTEM annualised 2-year in blue and the 1-year in orange. The InTEM PFC estimate is considerably higher than the GHGI until 2011 when the agreement starts to improve. The agreement in 2019 between the two independent estimates is extremely good. Note, the GHGI reports uncertainty for the PFCs collectively, they are not available for the individual gases.

Figure A 6.40 Sum of UK PFC emission estimates (PFC-14, PFC-116, PFC-218, PFC-318) in Tg CO_2-eq yr^{-1} from the GHGI (black) and InTEM, annualised 2-year inversion (blue) and 1-year inversion (orange). The uncertainty bars represent 1-σ.



A 6.5.1 PFC-14

Figure A 6.41 shows the hemispheric background atmospheric concentrations of PFC-14 from 2004 onwards. The background trend is positive, in 2020 the Northern Hemispheric background concentration increased by 0.9 ppt.

The drop in emissions in 2012 in the GHGI (**Figure A 6.42**) reflects the closure of a large aluminium production plant in the UK. The InTEM uncertainty ranges are large and the estimates are approximately double the GHGI from 2005 to 2010. InTEM estimates then gradually fall more in line with the GHGI although the estimated uncertainties are still large and generally extend down to zero, probably because the majority of emissions come from intermittently emitting point sources. Overall there is good agreement between the GHGI and the InTEM estimates in the last few years.

Figure A 6.41 Background Northern Hemisphere annual concentrations of PFC-14 estimated from Mace Head, Ireland observations are shown in red, background Southern Hemisphere annual concentrations from Cape Grim, Tasmania are shown in blue.

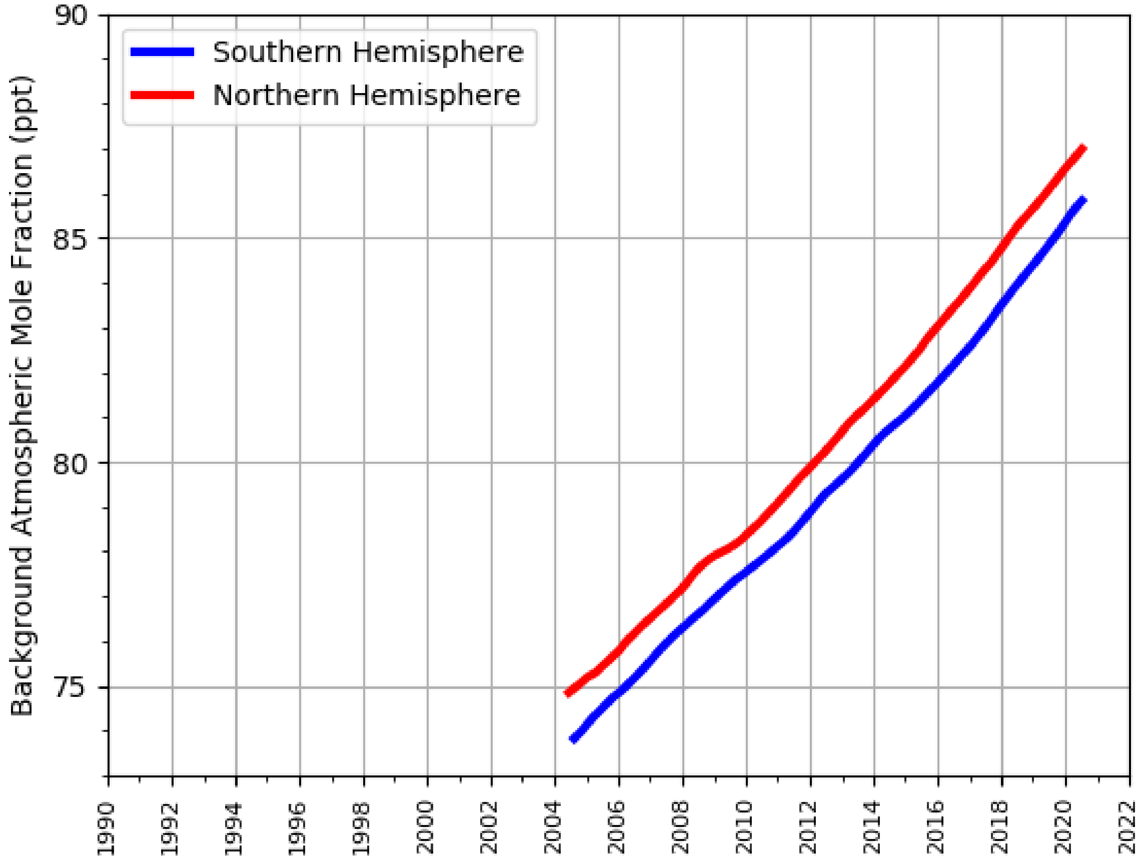


Figure A 6.42 Verification of the UK emission inventory estimates for PFC-14 in Tg CO_2-eq yr^{-1} from 1990. GHGI estimates are shown in black. InTEM 2-year estimates are shown in blue (±1 σ), InTEM 1-year estimates are shown in orange (±1 σ).

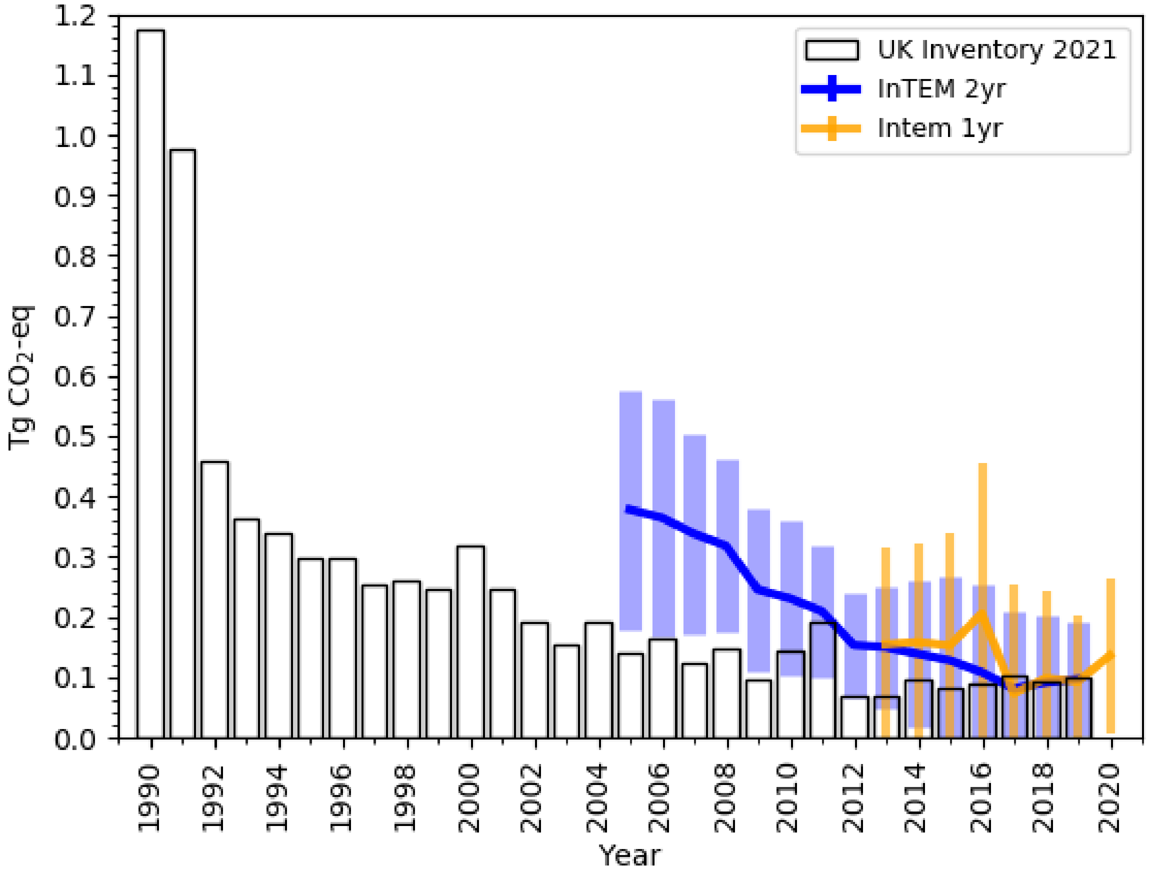


Figure A 6.43 **Four-year average PFC-14 InTEM emission estimates (kg km^{-2}yr^{-1}) 2017-2020. The observation stations are shown as white triangles. Major cities are shown as black circles.**

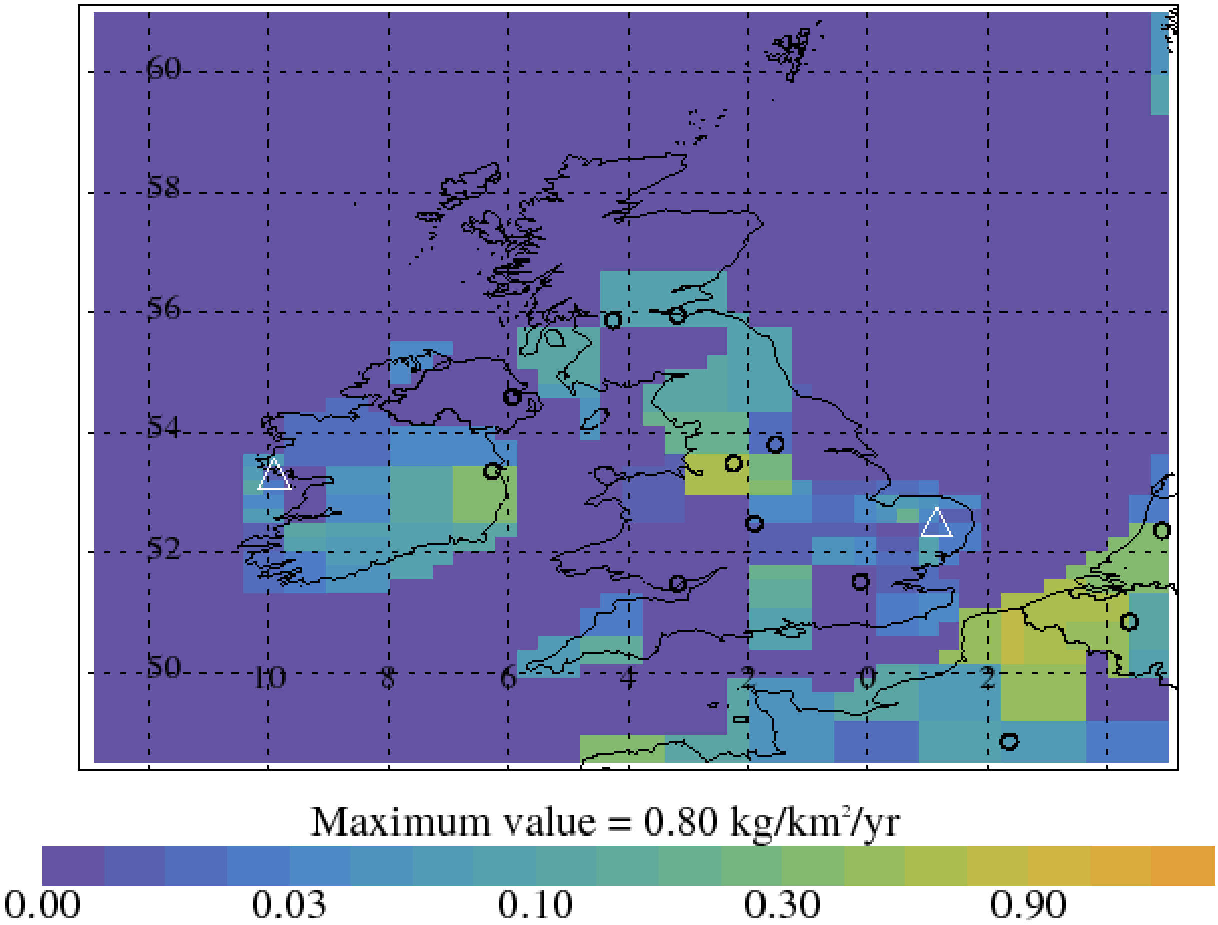


Figure A 6.43 shows the spatial InTEM emissions estimate for PFC-14 over the UK in kg km^{-2}yr^{-1}, for a four-year average over 2017-2020. The spatial distribution of PFC-14 shows sources in the NW of England, around Dublin and on the near-continent.

A 6.5.2 PFC-116

Figure A 6.44 shows the hemispheric background atmospheric concentrations of PFC-116 from 2004 onwards. The background trend is monotonic and positive and in 2020 the Northern Hemispheric background concentration increased by 0.1 ppt.

The UK InTEM estimates have large uncertainties that generally overlap with the GHGI estimates (**Figure A 6.45**). The 2017-2020 geographical spread (**Figure A 6.46**) shows the most significant sources are around the Cork area in southern Republic of Ireland, around Belfast, Northern Ireland, and the NW of England.

Figure A 6.44 Background Northern Hemisphere annual concentrations of PFC-116 estimated from Mace Head, Ireland observations are shown in red, background Southern Hemisphere annual concentrations from Cape Grim, Tasmania are shown in blue.

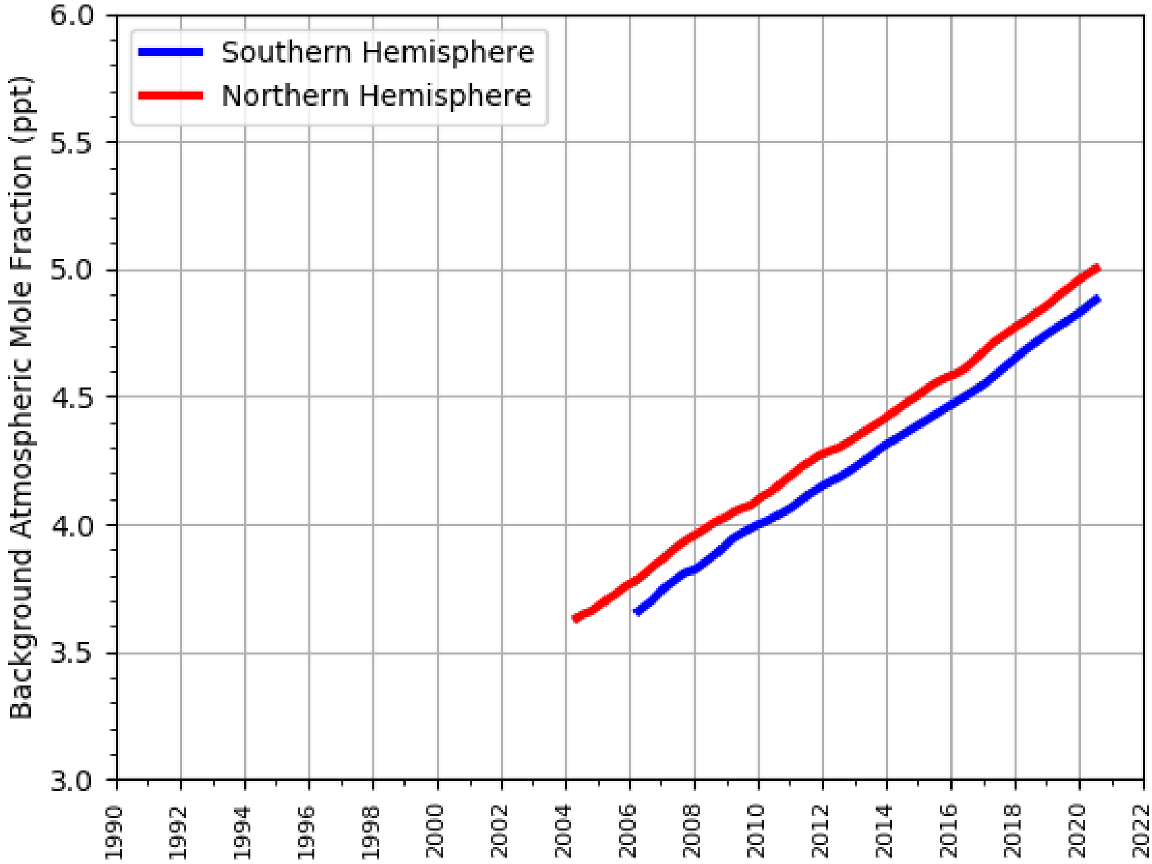


Figure A 6.45 Verification of the UK emission inventory estimates for PFC-116 in Tg CO_2-eq yr^{-1} from 1990. GHGI estimates are shown in black. InTEM 2-year estimates are shown in blue (±1 σ), InTEM 1-year estimates are shown in orange (±1 σ).

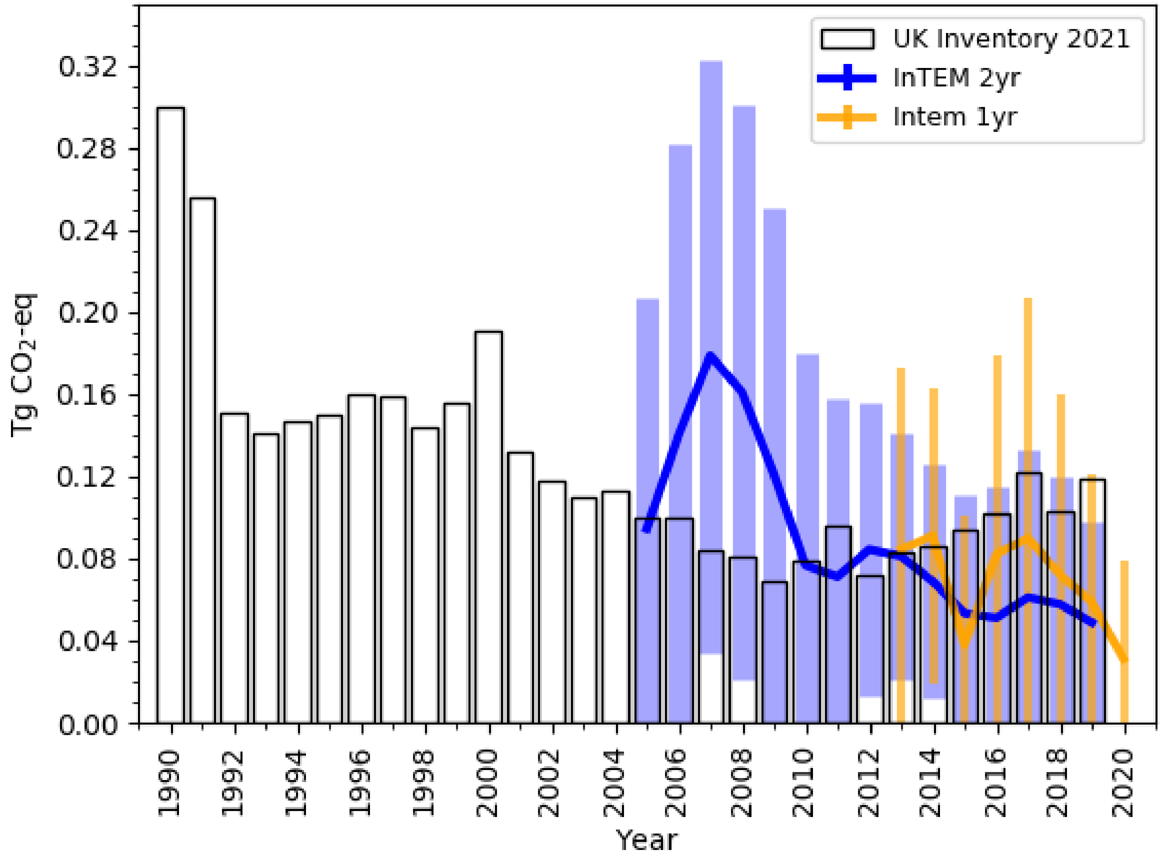
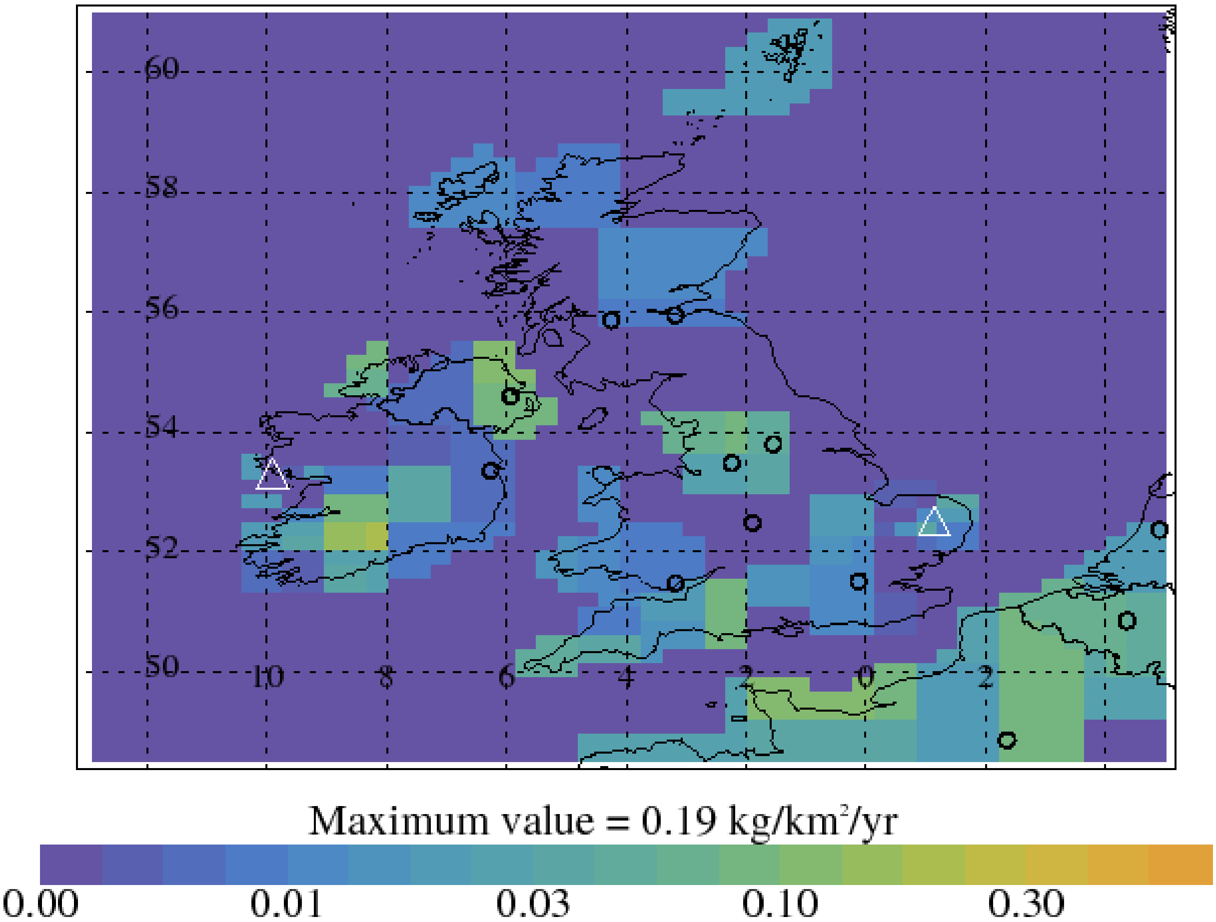


Figure A 6.46 Four-year average PFC-116 InTEM emission estimates (kg km^{-2}yr^{-1}) 2017-2020. The observation stations are shown as white triangles. Major cities are shown as black circles.



A 6.5.3 PFC-218

Figure A 6.47 shows the hemispheric background atmospheric concentrations of PFC-218 from 2004 onwards. The background trend is monotonic and positive and in 2020 the Northern Hemispheric background concentration increased by 0.02 ppt.

The InTEM estimates are generally higher than those reported in the GHGI (**Figure A 6.48**) with a notable exception being 2017. Both estimates show a strong year-to-year variability. The very clear fall in UK GHGI emissions between 2005 and 2008 is replicated by the InTEM estimates. The 2017-2020 geographical distribution of emissions (**Figure A 6.49**) shows that the most significant source is clearly in the NW of England, the home of the UK's only PFC-218 production facility.

Figure A 6.47 **Background Northern Hemisphere annual concentrations of PFC-218 estimated from Mace Head, Ireland observations are shown in red, background Southern Hemisphere annual concentrations from Cape Grim, Tasmania are shown in blue.**

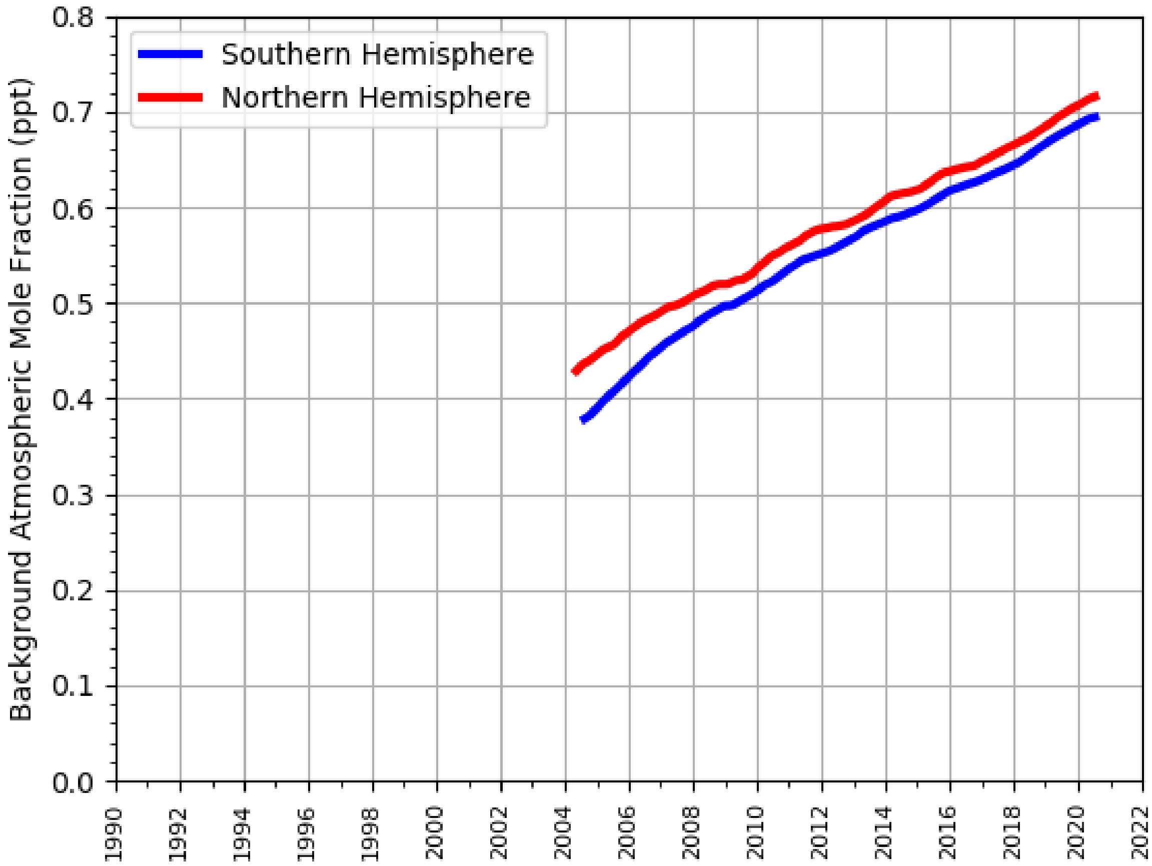


Figure A 6.48 **Verification of the UK emission inventory estimates for PFC-218 in Tg CO_2-eq yr^{-1} from 1990. GHGI estimates are shown in black. InTEM 2-year estimates are shown in blue (±1 σ), InTEM 1-year estimates are shown in orange (±1 σ).**

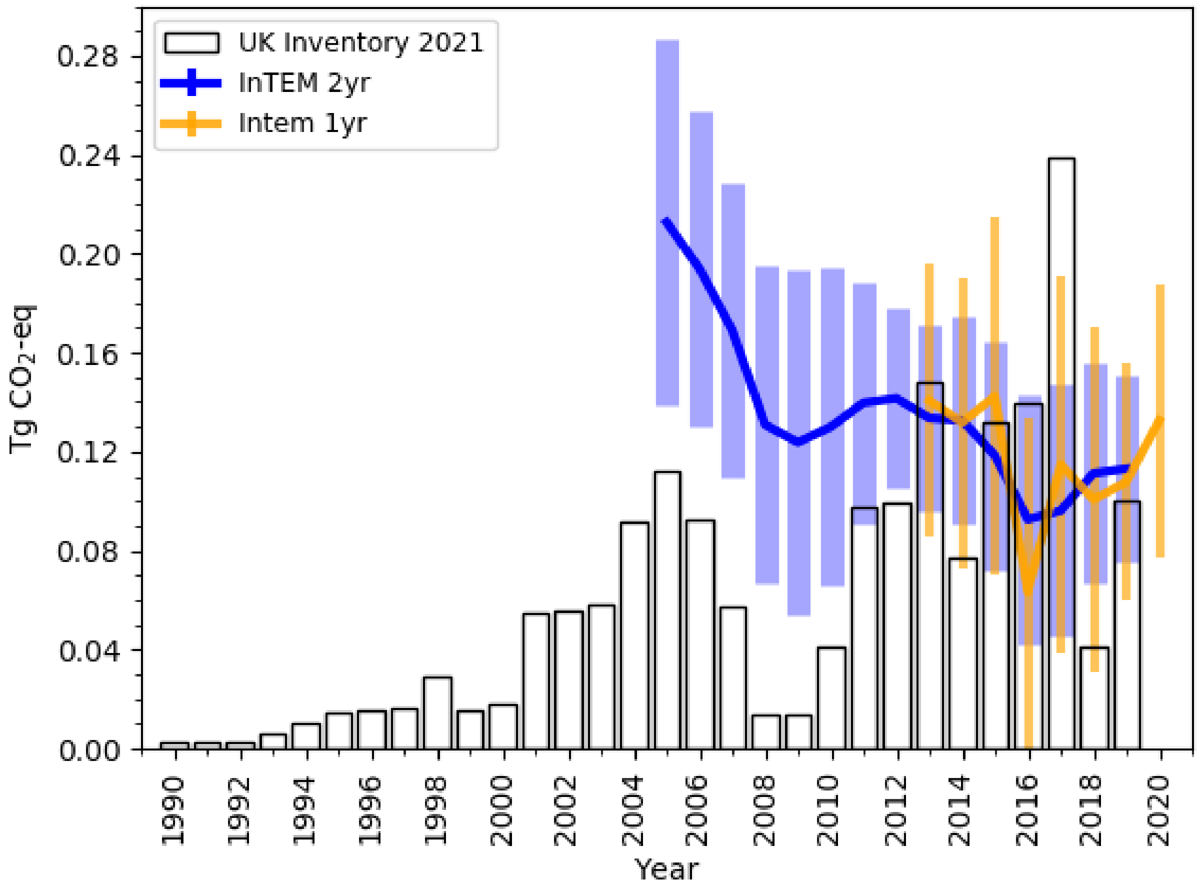
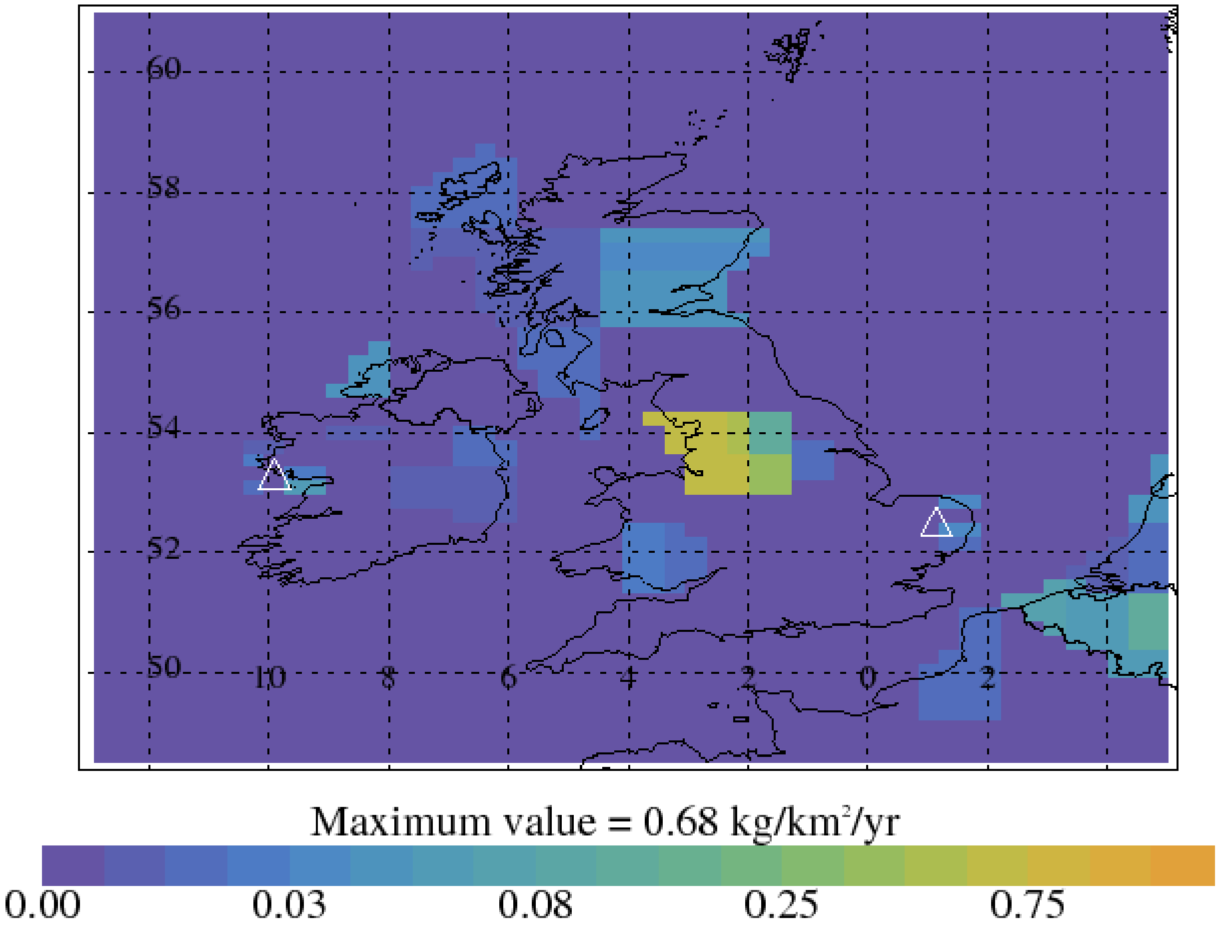


Figure A 6.49 **Four-year average PFC-218 InTEM emission estimates (kg km^{-2}yr^{-1}) 2017-2020. The observation stations are shown as white triangles. Major cities are shown as black circles.**



A 6.5.4 PFC-318

Figure A 6.50 shows the hemispheric background atmospheric concentrations of PFC-318 from 2011 onwards. The background trend is monotonic and positive and in 2020 the Northern Hemisphere background concentration increased by 0.07 ppt.

The UK InTEM estimates are on average >40 Gg CO_2-eq yr^{-1} significantly higher than emissions reported in the GHGI at ~0.07 Gg CO_2-eq yr^{-1} (**Figure A 6.51**). However, the InTEM estimated quantities have large uncertainties sometimes extending down to zero emissions. Considering the recent geographical spread of emissions (**Figure A 6.52**) the most significant source in the region is the Netherlands.

Figure A 6.50 Background Northern Hemisphere annual concentrations of PFC-318 estimated from Mace Head, Ireland observations are shown in red, background Southern Hemisphere annual concentrations from Cape Grim, Tasmania are shown in blue.

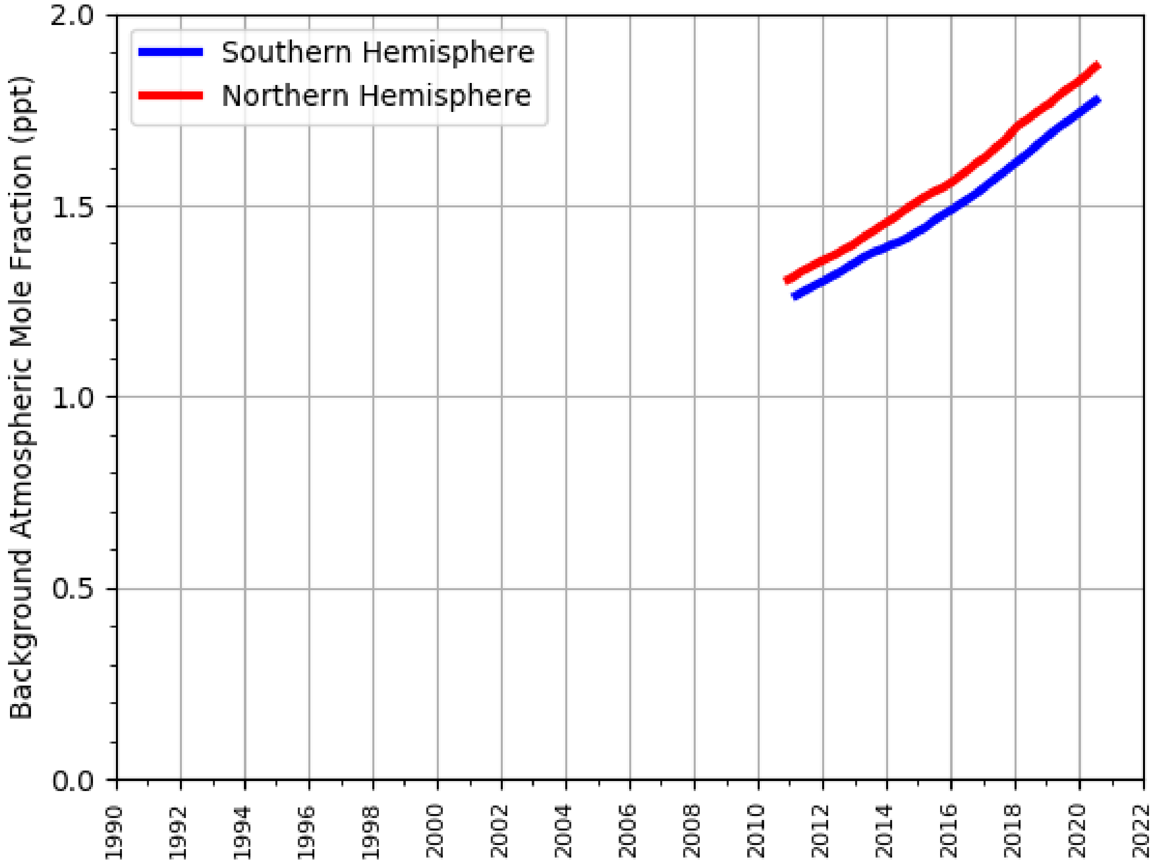


Figure A 6.51 Verification of the UK emission inventory estimates for PFC-318 in Tg CO_2-eq yr^{-1} from 1990. GHGI estimates are shown in black although they are too small to be visible on this scale. InTEM 2-year estimates are shown in blue (±1 σ) and InTEM 1-year estimates are shown in orange (±1 σ).

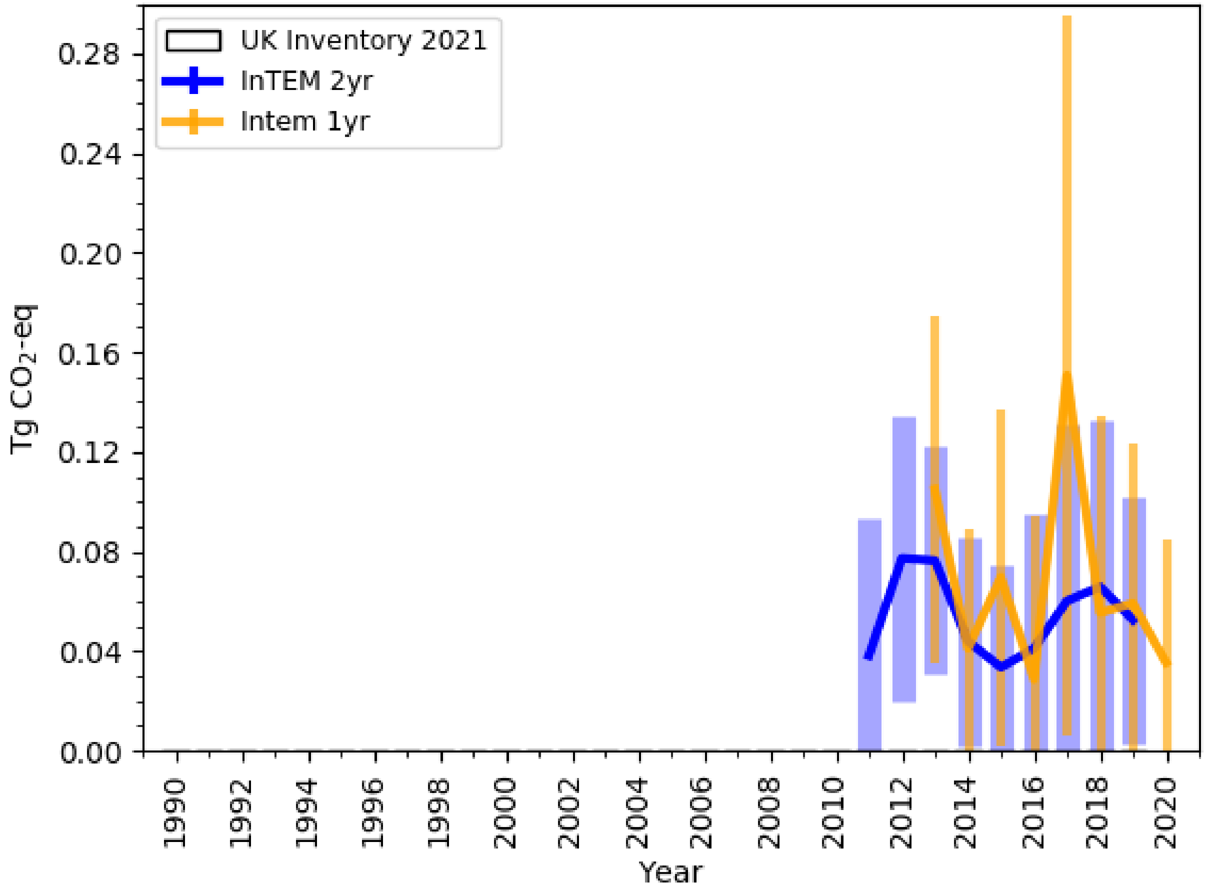
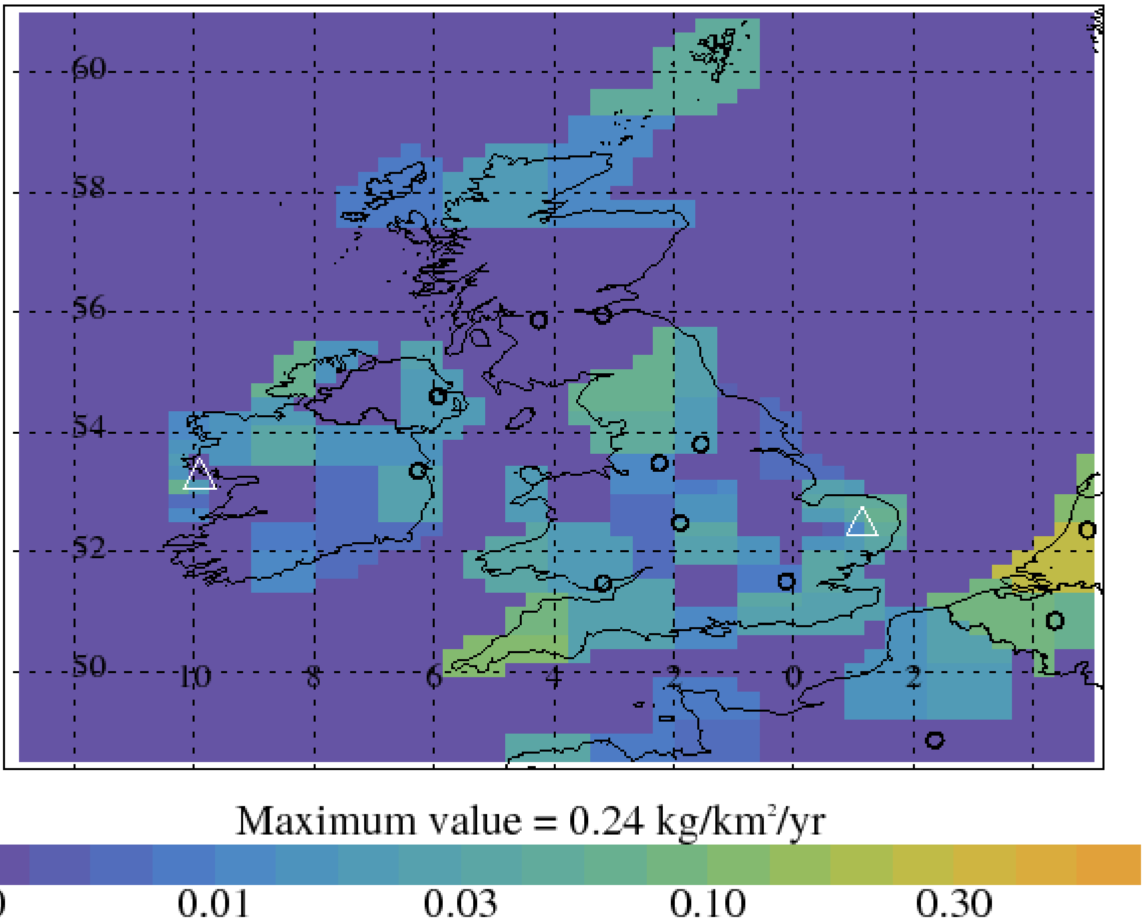


Figure A 6.52 Four-year average PFC-318 InTEM emission estimates (kg km^{-2}yr^{-1}) 2017-2020. The observation stations are shown as white triangles. Major cities are shown as black circles.



A 6.6 SULPHUR HEXAFLUORIDE

Figure A 6.53 Background Northern Hemisphere annual concentrations of SF_6 estimated from Mace Head, Ireland observations are shown in red, background Southern Hemisphere annual concentrations from Cape Grim, Tasmania are shown in blue.

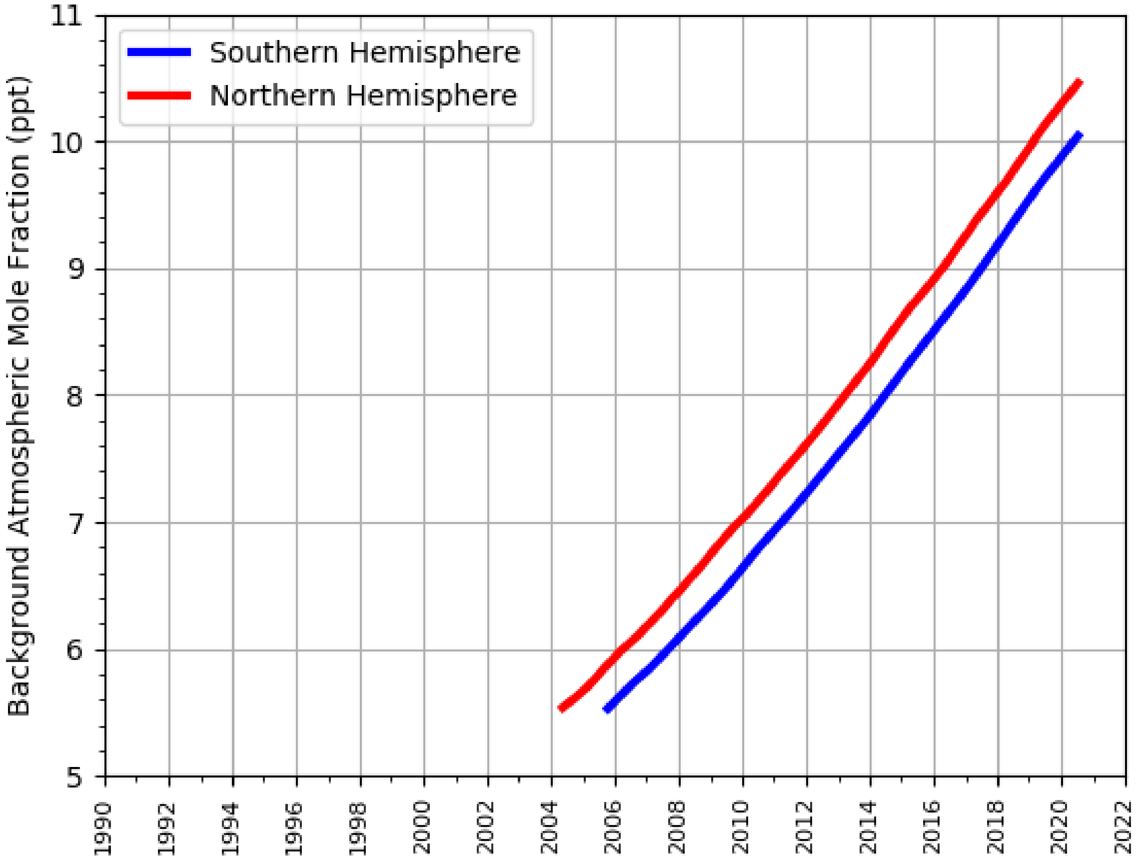
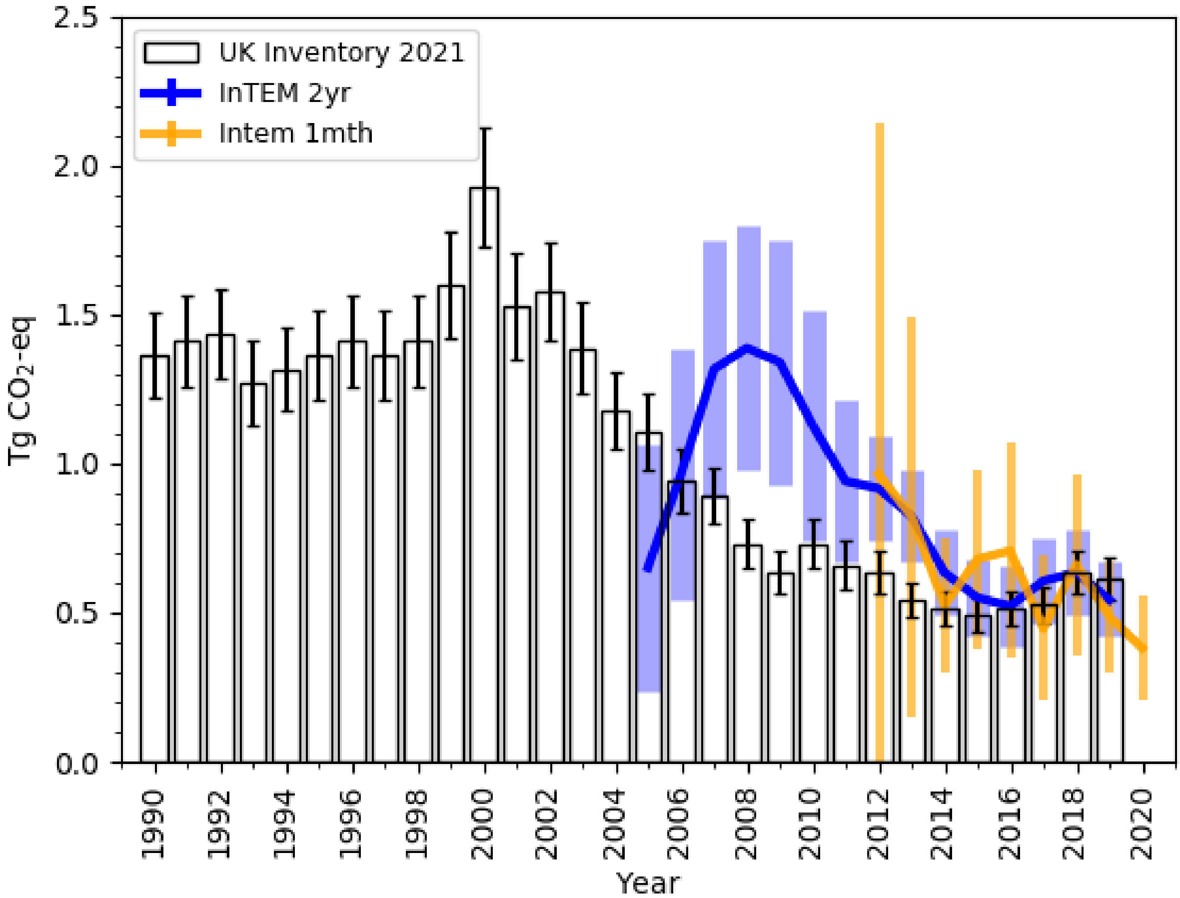


Figure A 6.53 shows the hemispheric background atmospheric concentrations of sulphur hexafluoride (SF_6) from 2004 onwards. The background trend is monotonic and positive and in 2020 the Northern Hemispheric background concentration increased by 0.32 ppt.

Figure A 6.54 Verification of the UK emission inventory estimates for SF_6 in Tg CO_2-eq yr-1 from 1990. GHGI estimates are shown in black. InTEM 2-year estimates are shown in blue (±1 σ), InTEM 1-month, annualised, estimates are shown in orange (±1 σ).



The UK 2-yr InTEM estimates (**Figure A 6.54**) show a rise from 2005 until 2008 and then a decline until 2016. From 2005 until 2009 the GHGI shows a steady decline from ~1.2 Tg CO_2-eq yr^{-1} to ~0.7 Tg CO_2-eq yr^{-1}, a small rise in 2010 and then a slow decline up to 2015 and a rise until 2018. For the 1-mth annualised InTEM estimates there is a general decline in emissions across the time-series from 2012, although there are years with enhanced emissions such as 2016. Looking at the monthly emissions (**Figure A 6.55**) such elevations appear to be linked to specific events in individual months e.g. Dec 2016. There is no evidence of a strong seasonal cycle in UK SF_6 emissions, although there are months with very elevated estimated emissions. The observations themselves reveal some very large, short-lived, pollution events that are worthy of further investigation. The estimated spatial distribution of emissions 2017-2020 from InTEM is shown in **Figure A 6.56**. The emissions do not appear to be distributed by population or from a single emission source. The main reported sources of emissions in the UK are from use in high-voltage switchgear which is widespread across the UK.

Figure A 6.55 Verification of the UK emission inventory estimates for SF_6 in Tg CO_2-eq yr^{-1} from 2012. GHGI estimates are shown in black. InTEM 1-month estimates are shown in blue (±1 σ).

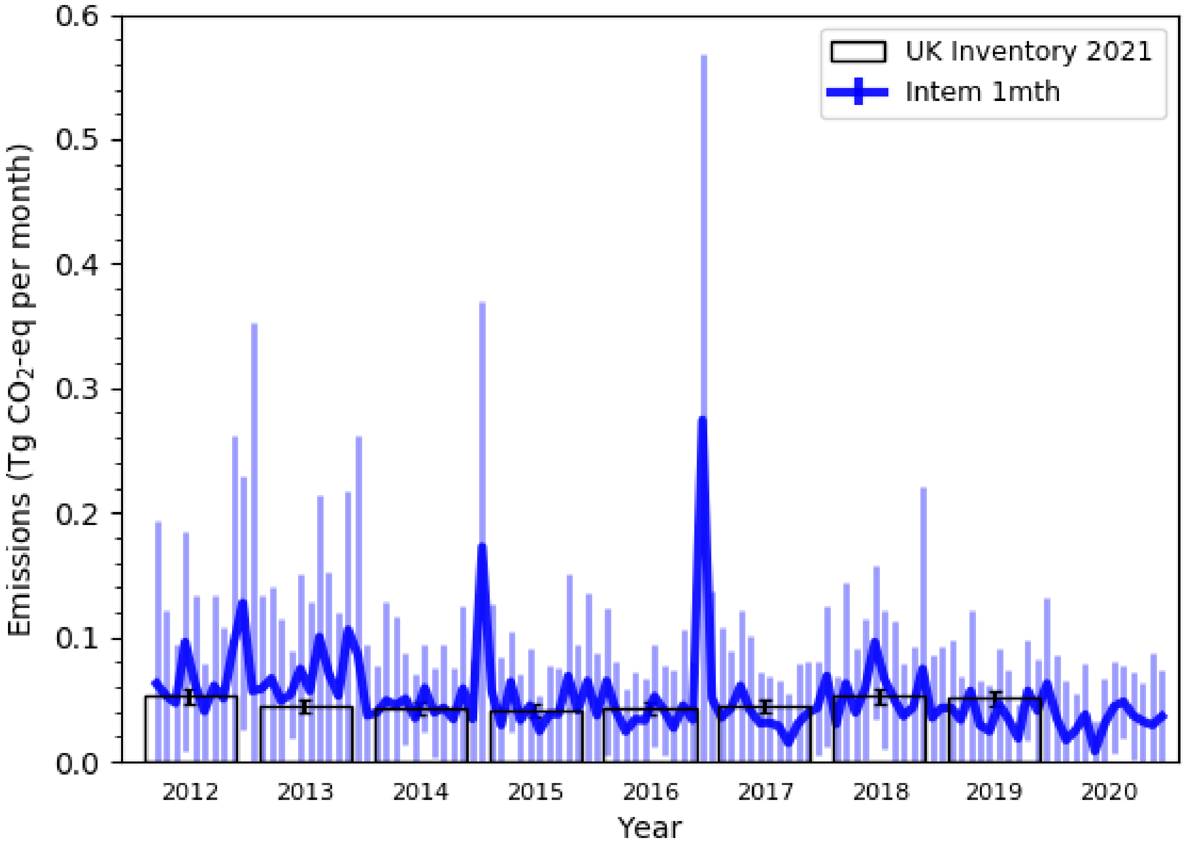
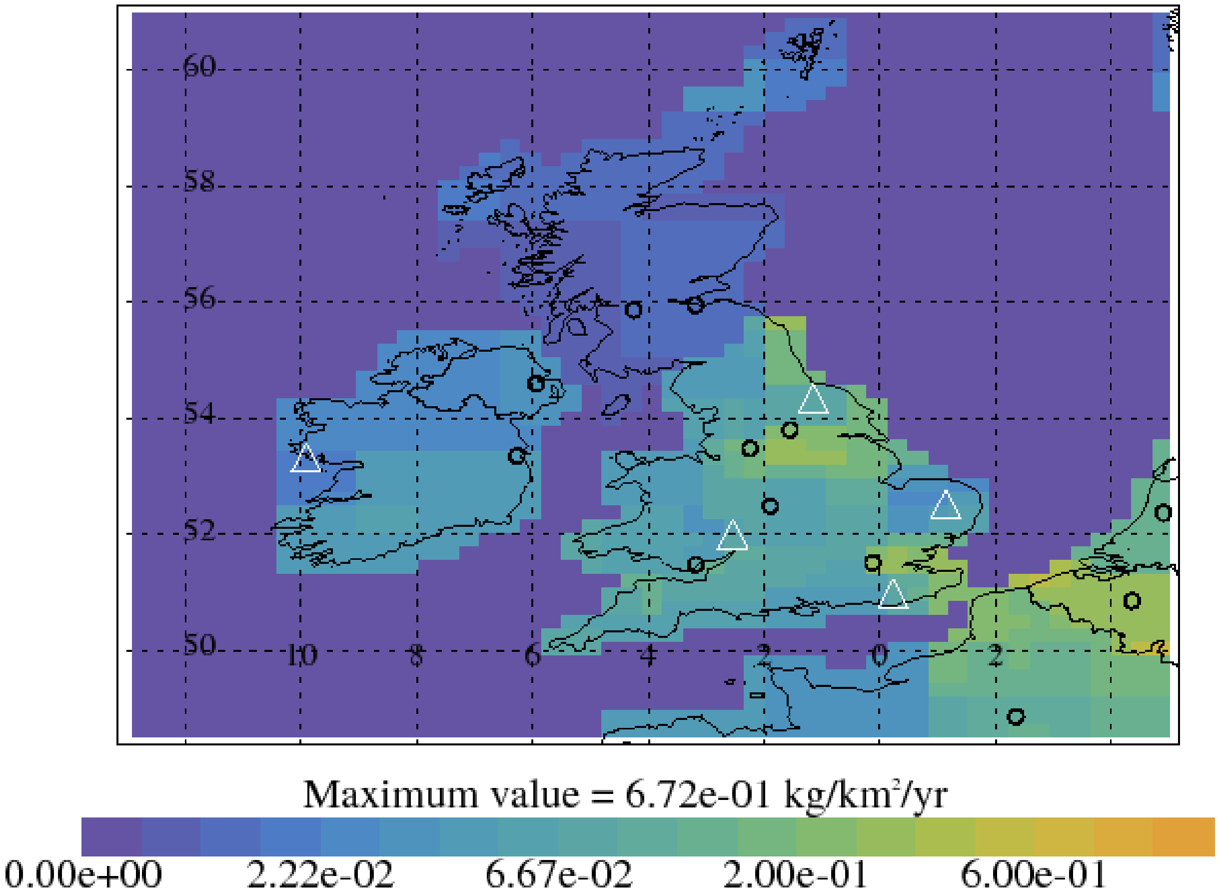


Figure A 6.56 Four-year average SF_6 InTEM emission estimates (kg $km^{-2}yr^{-1}$ of gas) 2017-2020. The observation stations are shown as white triangles. Major cities are shown as black circles.



A 6.7 NITROGEN TRIFLUORIDE

Figure A 6.57 shows the hemispheric background atmospheric concentrations of nitrogen trifluoride (NF_3) from 2014 onwards. The background trend is monotonic and positive and the Northern Hemispheric atmospheric concentration increased by 0.26 ppt in 2020.

NF_3 is only measured at MHD and JFJ. The InTEM emission estimates for the UK are ~8 Gg CO_2-eq yr^{-1} (**Figure A 6.58**) but with uncertainties that extends down to zero. The GHGI estimate for 2019 is 0.6 Gg CO_2-eq yr^{-1}.

Figure A 6.57 Background Northern Hemisphere annual concentrations of NF_3 estimated from Mace Head, Ireland observations are shown in red, background Southern Hemisphere annual concentrations from Cape Grim, Tasmania are shown in blue.

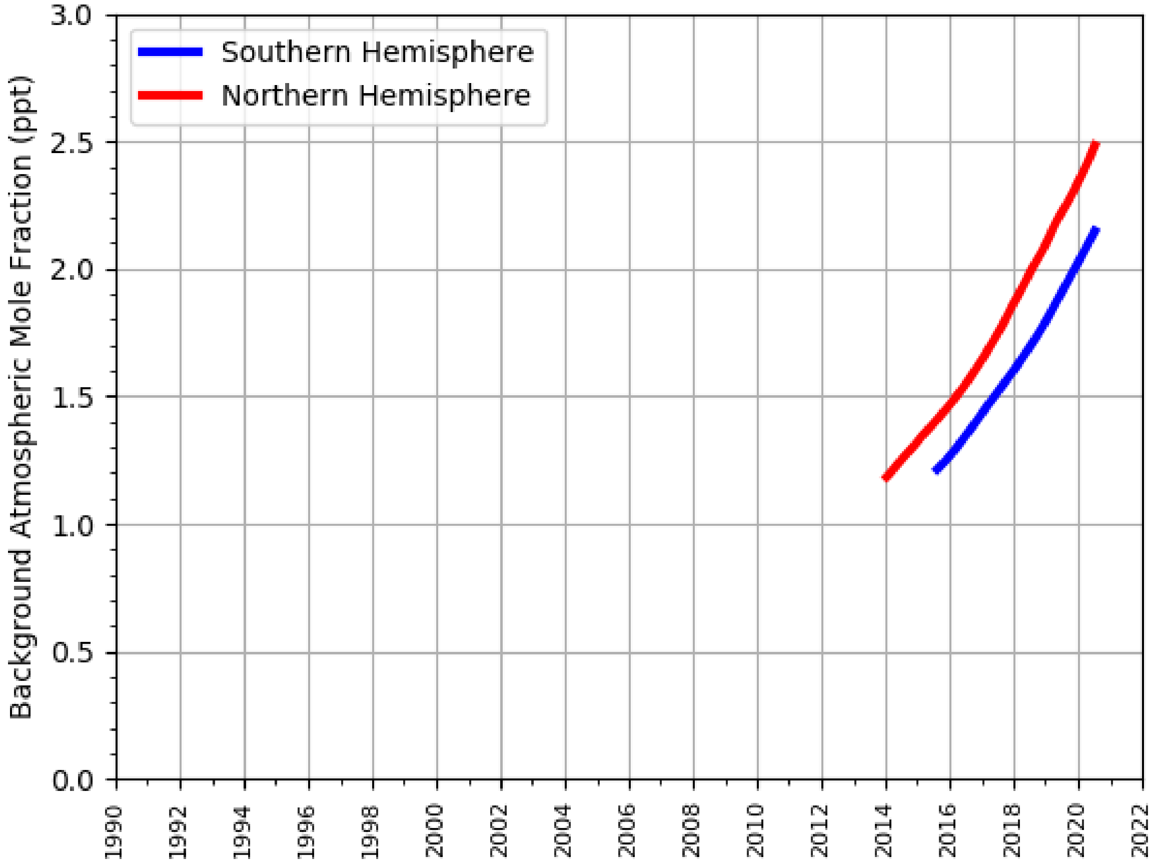
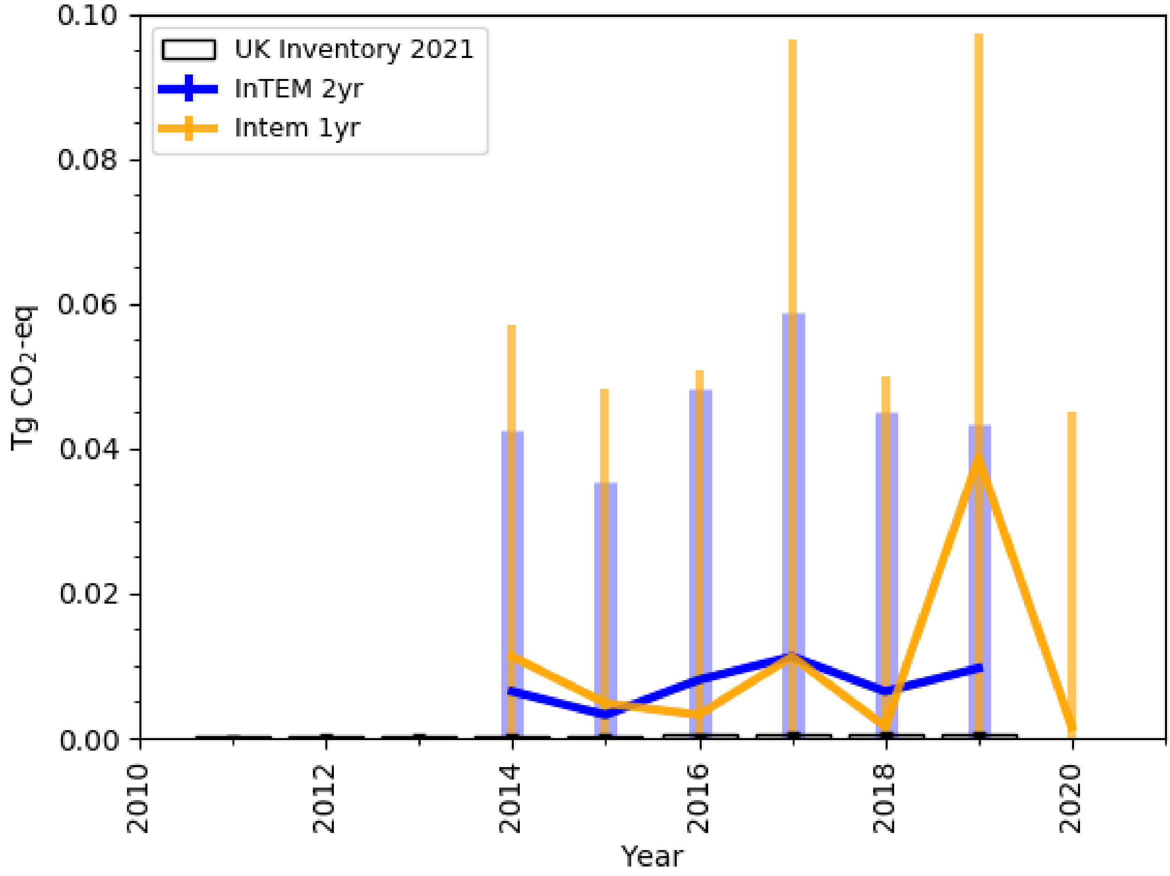


Figure A 6.58 **Verification of the UK emission inventory estimates for NF_3 in Tg CO_2-eq yr^{-1} from 1990. GHGI estimates are shown in black. InTEM 2-year estimates are shown in blue (±1 σ), InTEM 1-year estimates are shown in orange (±1 σ).**



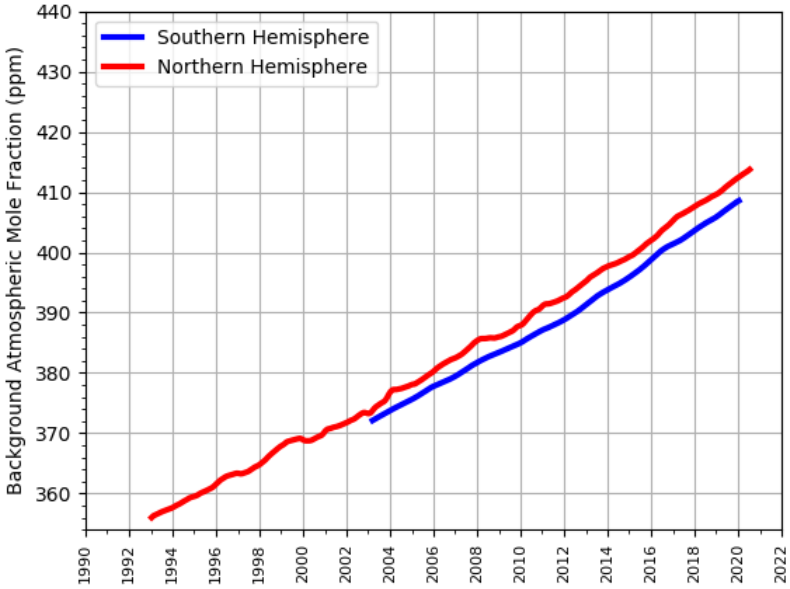
A 6.8 CARBON DIOXIDE

High precision, high frequency measurements of carbon dioxide (CO_2) are made across the UK DECC network. The Northern Hemisphere background trend is positive; in 2020 it increased by 2.6 ppm up from 2.5 ppm in 2019. The background has a strong seasonal cycle due to the influence of the biosphere with a maximum in early spring and a minimum in late summer.

The CO_2 observed has three principle components:

1. Northern hemisphere background (**Figure A 6.59**).
2. Anthropogenic (man-made)
3. Non-anthropogenic (natural)

Figure A 6.59 Background Northern Hemisphere annual concentrations of CO_2 estimated from Mace Head, Ireland observations are shown in red, background Southern Hemisphere annual concentrations from Cape Grim, Tasmania are shown in blue.



Since plants both produce CO_2 through respiration and absorb CO_2 through photosynthesis, the CO_2 flux from vegetation has a strong diurnal and seasonal cycle and switches from production to absorption 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 ignored. It is difficult to use CO_2 measurements directly in an inversion to estimate anthropogenic emissions because (a) it is not possible to distinguish between biogenic and anthropogenic CO_2, and (b) 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 (say 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 2018 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 2018 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	Factors	Activity	Emissions	Comments
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 1B2	Upstream oil and gas production – Gas oil, natural gas, LPG, OPG			✓	
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			✓	

Category	Sub-categories	Factors	Activity	Emissions	Comments
2B8g	Ethylene & other petrochemicals			✓	
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 data has been available on an annual basis since this time across major UK industrial plants.

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[22] 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

[22] 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 1990-2019 inventory cycle, the Inventory Agency has updated and extended the EU ETS analysis conducted for inventory compilation, using the 2019 EU ETS dataset, which is the sixth year of reporting under the Phase III EU ETS scope. This annex presents a comprehensive review of the thirteen 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 all offshore oil and gas installations from EU ETS data since 2011, 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 four 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 tileries. 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.

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 2020, 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 latest year of data, 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 2019 EU ETS data had to be allocated to DUKES' sectors, and all of the fuel data for 2019 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 2019 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, 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 2020 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 2019, as published within DUKES (published in July 2020).

The EU ETS data for offshore oil and gas installations was provided in May 2020 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 7.3 EU ETS DATA COVERAGE

The coverage of the EU ETS data has changed over the 14 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-present) 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 **Table A 7.4.1**. The number of sites in each sector which are included in the ETS dataset for 2005 and 2019 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 7.3.1 Numbers of installations included in the EU ETS data

Sector	EU ETS installations in 2005	Total installations in 2005	EU ETS installations in 2019	Total installations in 2019
Power stations (fossil fuel, > 75MWe)	60	60	48	48
Power stations (fossil fuel, < 75MWe)	23	27	31	35
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	13	13
Refineries	12	12	6	6
Combustion – iron & steel industry	11	200[a]	22	200a
Combustion – other industry	171	5000[a]	447	5000a
Combustion – commercial sector	28	1000[a]	100	1000a
Combustion – public sector	169	1000[a]	103	1000a

Sector	EU ETS installations in 2005	Total installations in 2005	EU ETS installations in 2019	Total installations in 2019
Glassworks (flat, special, container & fibre)	6	32	23	23
Brickworks	18	80[b]	48	48
Soda ash & titanium dioxide	0	4	4	4

[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 2019.

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 2019, 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 2019. 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 7.4 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 7.4.1 Activity and Emissions Data

A 7.4.1.1 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 7.4.1** 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 7.4.1 Refinery Emissions Data Comparison and Revision to OPG Activity

Year	Best Operator Data[1] kt C	Refinery emissions total (if based on DUKES) kt C	Additional emissions assumed from OPG kt C	Additional emissions assumed from Pet Coke kt C
2000	3,467	4,718	-	-
2001	3,669	4,665	-	-
2002	4,118	5,244	-	-
2003	4,052	5,084	-	-
2004	3,980	4,925	74	-
2005	5,007	5,275	-	150
2006	4,910	4,674	160	76
2007	4,857	4,729	77	50
2008	4,709	4,348	240	121
2009	4,492	4,000	366	126
2010	4,632	4,349	207	76
2011	4,739	4,490	249	-
2012	4,287	4,299	-	-
2013	4,002	3,852	148	2
2014	3,678	3,558	120	-
2015	3,682	3,610	26	47
2016	3,708	3,497	155	56
2017	3,698	3,511	174	12
2018	3,559	3,412	128	19
2019	3,444	3,361	81	2

[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 5422 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 7.4.1.2 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 2019, with estimates for 2003 to 2007 derived by interpolation between the EU ETS 2008 data and the DUKES 2002 data.

A 7.4.1.3 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 Devolved Administrations 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 2019, 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 compressors, 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 7.4.1.4 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 EU ETS, 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 1990-2019 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 gases and other residues.

A 7.4.1.5 Industrial Processes

The EU ETS dataset contains data on several 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 2005-2019 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 2005-2019 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 7.4.2 Implied Emission Factors

A 7.4.2.1 Power Stations

Table A 7.4.2 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 7.4.2 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	615.0
2007		100	614.7
2008		100	612.4
2009		100	607.2
2010		100	609.0
2011		100	608.9
2012		100	611.7
2013		100	612.5
2014		100	611.8
2015		100	607.9
2016		94	612.3
2017		100	613.0
2018		100	601.4

Year	Fuel	% Tier 3	Average Carbon Emission Factor (Tier 3 only)
2019		100	608.9
2005	Fuel oil / Waste oil[s]	59	860.3
2006		66	873.0
2007		68	871.1
2008		91	869.5
2009		94	872.7
2010		95	873.3
2011		94	875.0
2012		96	873.4
2013		93	871.3
2014		92	871.8
2015		89	872.8
2016		91	876.9
2017		88	877.1
2018		81	874.2
2019		89	873.8
2005	Natural gas	52	1.443
2006		76	1.465
2007		95	1.464
2008		97	1.467
2009		100	1.464
2010		99	1.460
2011		99	1.456
2012		100	1.461
2013		99	1.464
2014		100	1.461
2015		100	1.462

Year	Fuel	% Tier 3	Average Carbon Emission Factor (Tier 3 only)
2016		99	1.462
2017		99	1.466
2018		99	1.465
2019		99	1.463
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 onwards		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 petroleum coke 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 7.4.2.2 Crude Oil Refineries

Table A 7.4.3 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 7.4.3 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	860.9
2006		65	873.8
2007		78	877.2
2008		91	871.6
2009		91	876.2
2010		97	878.2
2011		85	45.3
2012		82	887.1
2013		95	874.3
2014		96	875.8
2015		61	876.7
2016		66	876.1
2017		25	860.9
2018		65	873.8
2019		78	877.2
2005	OPG	56	1.494
2006		54	1.468

Year	Fuel	% Tier 3	Average Carbon Emission Factor (Tier 3 sites only)
2007		65	1.587
2008		78	1.482
2009		78	1.494
2010		79	1.509
2011		68	1.433
2012		61	1.463
2013		77	1.493
2014		64	1.508
2015		62	1.492
2016		61	1.470
2017		66	1.481
2018		70	1.476
2019		73	1.463
2005	Natural Gas	n/a	-
2006		43	1.460
2007		45	1.462
2008		98	1.475
2009		98	1.480
2010		97	1.465
2011		81	1.375
2012		63	1.442
2013		89	1.459
2014		87	1.459
2015		87	1.465
2016		81	1.456
2017		84	1.462
2018		87	1.462
2019		87	1.459

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 2011-2019 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 2013-2019. 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 7.4.2.3 Integrated Steelworks & Coke Ovens

Table A 7.4.4 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 7.4.4 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	6.873
2007		90	6.920
2008		92	6.945
2009		92	7.029
2010		100	6.949
2011		94	6.990
2012		96	6.815
2013		91	6.766

Year	Fuel	% Tier 3	Average Carbon Emission Factor (Tier 3 sites only)
2014		91	6.776
2015		100	7.653
2016		100	7.578
2017		90	7.219
2018		100	7.426
2019		100	7.587
2005	Coke oven gas	0	n/a
2006		0	n/a
2007		0	n/a
2008		53	1.093
2009		96	1.140
2010		96	1.117
2011		96	1.089
2012		96	1.094
2013		96	1.103
2014		100	1.143
2015		100	1.216
2016		48	1.659
2017		100	1.068
2018		100	1.133
2019		72	1.094
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
2013		27	1.447

Year	Fuel	% Tier 3	Average Carbon Emission Factor (Tier 3 sites only)
2014		23	1.445
2015		0	n/a
2016		12	1.445
2017		33	1.446
2018		33	1.456
2019		35	1.436
2005	Fuel oil	0	n/a
2006		0	n/a
2007		0	n/a
2008		84	878
2009		89	885
2010		83	888
2011		88	889
2012		67	877
2013		33	846
2014		30	845
2015		32	845
2016		0	n/a
2017		0	n/a
2018		0	n/a
2019		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 7.4.2.4 Cement Kilns

Table A 7.4.5 summarises EU ETS data for the major fuels burnt at cement kilns.

Table A 7.4.5 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		99	658.3
2010		100	637.7
2011		100	645.8
2012		100	662.4
2013		100	694.2
2014		100	673.9
2015		100	675.3
2016		98	682.1
2017		100	683.3
2018		100	663.5
2019		100	664.1
2005	Petroleum coke	0	n/a
2006		100	820.8
2007		100	830.2
2008		100	819.1
2009		71	796.8
2010		57	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
2017		100	823.1
2018		100	798.1

Year	Fuel	% Tier 3	Average Carbon Emission Factor (Tier 3 sites only)
2019		100	782.0

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 7.4.6**.

Table A 7.4.6 Comparison of Cement Sector Carbon Dioxide Emissions* within the UK GHGI and the EU ETS

	2008	2010	2015	2016	2017	2018	2019
GHGI CO_2 emissions (kt)	8,298	5,791	6,566	6,820	6,571	6,529	6,638
Sum of EU ETS CO_2 emissions (kt)	8,259	5,792	6,543	6,800	6,560	6,517	6,613
EU ETS / GHGI	99.5%	100.0%	99.7%	99.7%	99.8%	99.8%	99.6%

*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 7.4.2.5 Lime Kilns

Table A 7.4.7 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 7.4.7 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
2017		100	677.1
2018		100	683.7
2019		100	655.3

*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 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 7.4.8 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 7.4.8** 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 7.4.8 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
2017		196.0
2018		196.3
2019		195.1

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 7.4.2.6 Other Industrial Combustion

Table A 7.4.9 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, with the exception of 2010. 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 7.3** 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 7.4.9 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	603.0	648.6
2007		99	615.7	662.9
2008		94	598.6	656.8
2009		92	595.4	668.8
2010		88	576.5	674.5
2011		91	589.0	653.7
2012		90	599.2	653.9
2013		95	653.4	653.5
2014		98	654.3	651.5
2015		100	645.8	652.4
2016		100	624.9	651.1
2017		100	647.4	651.5
2018		100	653.1	651.5
2019		100	640.7	651.5
2005	Fuel oil	48	864.7	879.0
2006		74	865.3	879.0
2007		50	872.3	879.0
2008		35	871.4	879.0
2009		39	871.3	879.0
2010		40	873.0	879.0
2011		51	874.2	879.0
2012		49	875.1	879.0
2013		44	871.3	879.0
2014		48	875.0	879.0
2015		55	872.1	879.0
2016		63	876.2	879.0

Year	Fuel	% Tier 3	Average Carbon Emission Factor (Tier 3 sites only)	GHGI Carbon Emission Factor
2017		65	880.0	879.0
2018		70	872.3	879.0
2019		88	875.5	879.0
2005	Natural gas	16	1.593	1.477
2006		37	1.470	1.476
2007		42	1.466	1.476
2008		29	1.496	1.475
2009		43	1.499	1.473
2010		40	1.503	1.472
2011		39	1.466	1.469
2012		40	1.469	1.469
2013		43	1.473	1.473
2014		42	1.472	1.472
2015		42	1.480	1.470
2016		41	1.474	1.463
2017		43	1.483	1.465
2018		35	1.477	1.465
2019		39	1.480	1.460

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 (2005-2019) 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[23]. 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[24]), 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. Since then, the independent Committee on Climate Change (CCC) has been set up to advise the UK Government on setting, monitoring and achieving UK carbon budgets. In June 2019, a legally binding target to achieve net zero greenhouse gas emissions across the UK economy by 2050 was set[25].

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 2021 UK GHG emissions statistical release included an update of the UK's performance against the second carbon budget[26]. Note that performance against the first carbon budget was set in May 2014[27], updated inventories do not update the first carbon budget or our performance against it.

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[23] https://www.gov.uk/government/collections/final-uk-greenhouse-gas-emissions-national-statistics

[24] 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.

[25] https://www.legislation.gov.uk/ukdsi/2019/9780111187654

[26] https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2019

[27] https://www.gov.uk/government/statistics/final-statement-for-the-first-carbon-budget-period

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	2015	2016	2017	2018	2019
Energy supply	278.0	237.9	221.5	231.3	207.1	145.0	121.5	111.5	104.3	95.8
Business	113.8	111.3	113.5	105.3	89.3	82.9	80.5	80.9	80.4	77.9
Transport	128.1	129.7	133.3	136.0	124.5	123.5	125.9	126.1	124.4	122.2
Public	13.5	13.3	12.1	11.2	9.5	8.0	8.1	7.7	8.1	7.9
Residential	80.1	81.7	89.0	85.9	87.8	67.6	68.9	66.6	70.2	69.2
Agriculture	53.1	52.4	50.1	48.3	45.2	46.0	46.0	46.4	45.8	46.3
Industrial processes	59.9	50.9	27.2	20.6	12.7	12.7	10.6	11.0	10.2	10.4
LULUCF28	18.0	14.7	12.0	8.3	6.0	5.7	5.3	5.0	5.6	5.9
Waste management	64.7	67.4	61.1	47.3	28.3	19.2	18.6	19.0	19.1	19.0
Total	809.1	759.3	719.8	694.2	610.5	510.5	485.4	474.2	468.1	454.8

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	2015	2016	2017	2018	2019
CO_2	608.3	571.2	569.4	568.3	508.0	418.3	395.1	382.9	377.7	365.1
CH_4	133.9	127.7	110.4	89.6	66.9	55.8	54.1	54.6	54.3	54.0
N_2O	49.6	39.9	29.8	25.8	22.8	22.0	21.8	22.3	22.1	22.2
HFCs	14.4	18.6	7.8	9.1	11.8	13.6	13.6	13.5	13.1	12.5
PFCs	1.7	0.6	0.6	0.4	0.3	0.3	0.4	0.5	0.3	0.3
SF_6	1.3	1.3	1.9	1.1	0.7	0.5	0.5	0.5	0.6	0.6
NF_3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	809.1	759.3	719.8	694.2	610.5	510.5	485.4	474.2	468.1	454.8

[28] 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 2019.

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[29.].

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 1990-2019, 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[30] 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.

29 See page 84 of UNFCCC Guidelines contained in FCCC/CP/1999/7 available at: http://unfccc.int/resource/docs/cop5/07.pdf

30 An 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.

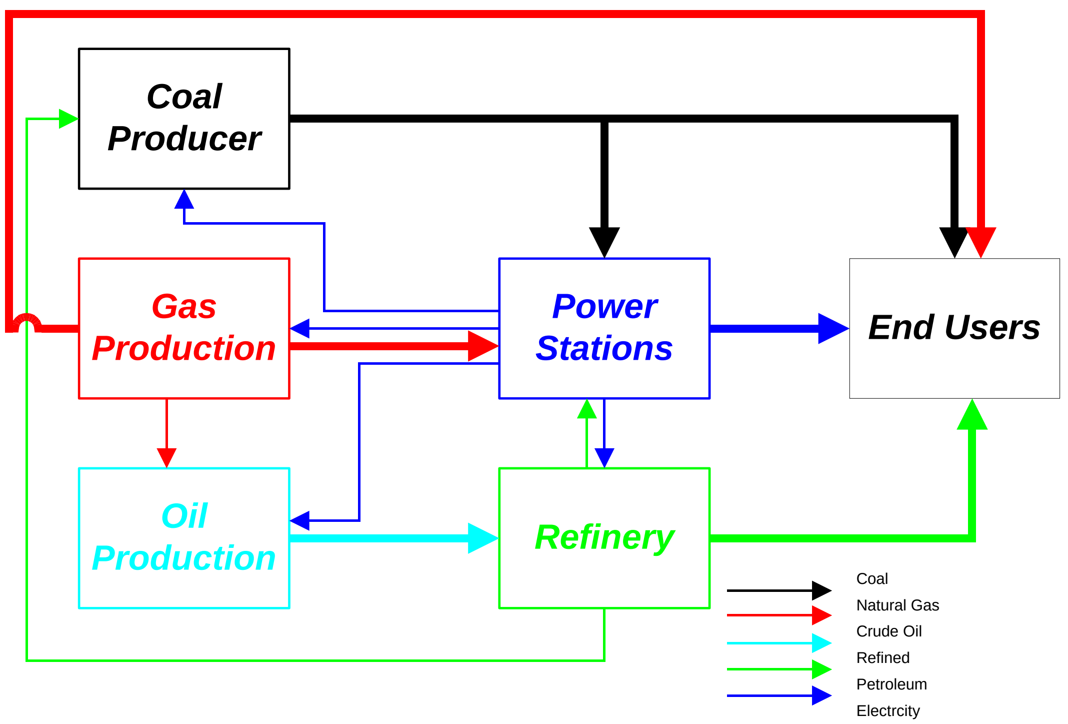
- Emissions in the **road transport** end user category include:
  1. Direct emissions from motor vehicle exhausts.
  2. A portion of indirect emissions from: refineries producing motor fuels, including refining, storage, flaring and extraction of oil; the distribution and supply of motor fuels; and 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. Therefore, in the process of reallocating emissions to the end user, emissions are allocated from one to the other and then are 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[31] 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 Annex were calculated for a convergence at 0.001%) the process continues at Step 2. If this percentage matches or is less than the predetermined value, the calculation is finished.

Convergence occurs 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

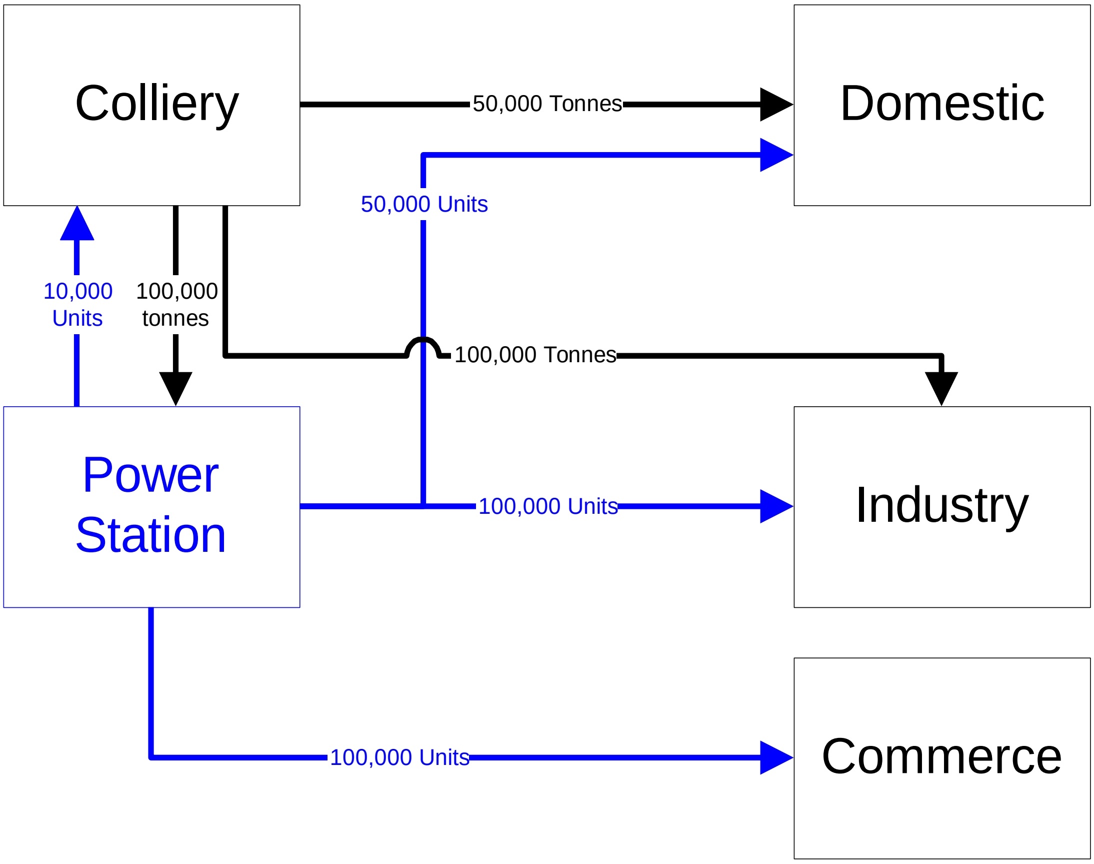
The following example illustrates the methodology used to calculate emissions according to end users. The units in this example are arbitrary.

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.

[31] 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		
	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 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 26,923 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

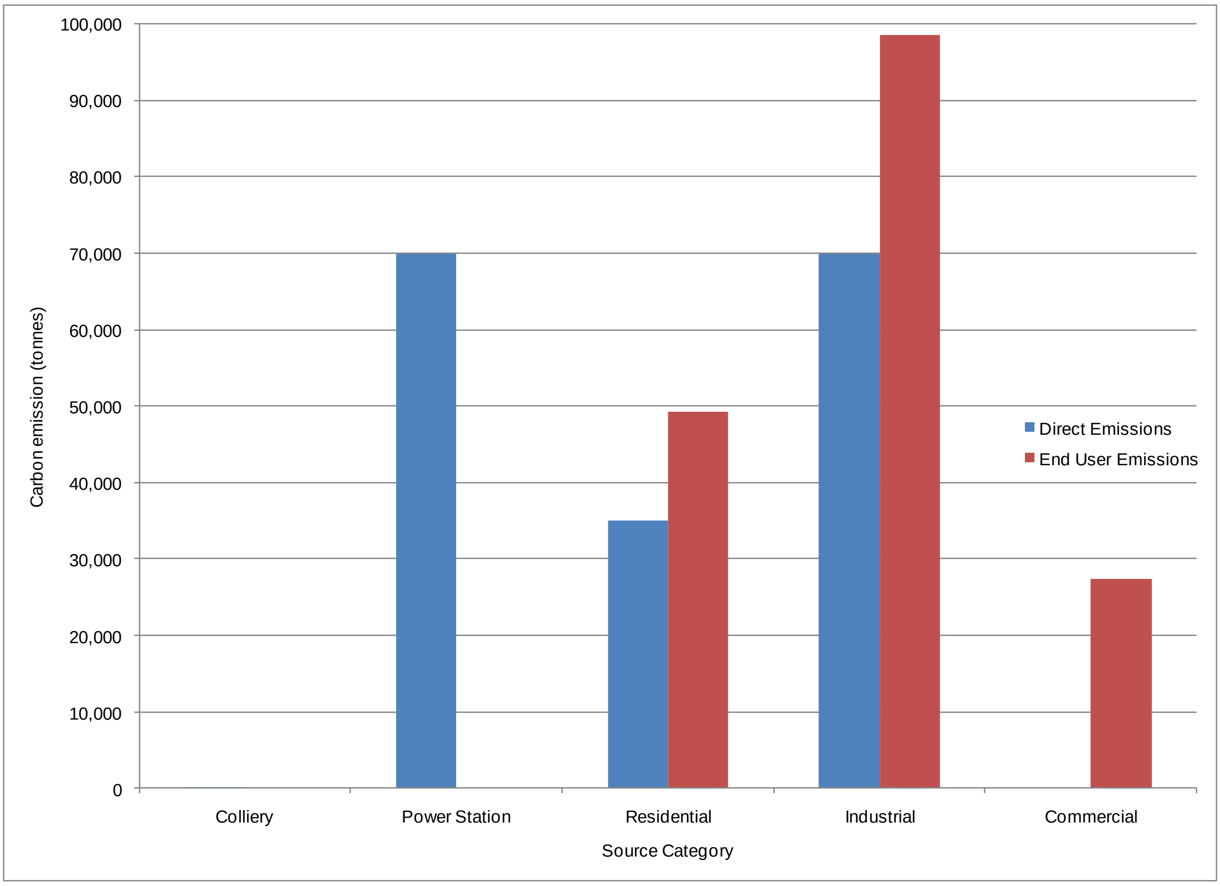


Figure A 9.3 compares the quantities of direct and end user carbon emitted from each sector at the end of the end user calculation. The direct emissions of carbon are from the combustion of coal in the sectors. The direct and end user emissions are from two distinct calculations and must be considered 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 - Onshore Oil Loading	
	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	
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

End user group	Emission sources to be reallocated to end users	Fuels used for redistribution
	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	Lubricants
	Petrol terminals – storage	LNG
	Petrol terminals – tanker loading	LPG
	Petroleum processes	Naphtha
	Refineries – combustion	OPG
	Refineries – drainage	Petrol
	Refineries – flares	Petroleum coke
	Refineries – general	Refinery miscellaneous
	Refineries – process	Vaporising oil
	Refineries – road/rail loading	
	Refineries – tankage	
	Sea going vessel loading	
	Ship purging	
6. Solid Smokeless Fuels	Solid Smokeless fuel production	Solid Smokeless Fuels
7. Town gas	Town gas manufacture	Town Gas
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

National Communication Category	IPCC Sector	Source Name	Activity Name
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
	3A1a	Enteric	Dairy - Dairy Cows
	3A1b	Enteric	Other cattle - Beef females for slaughter
			Other cattle - Bulls for breeding
			Other cattle - Cereal fed bull
			Other cattle - Cows
			Other cattle - Dairy Calves Female
			Other cattle - Dairy In Calf Heifers
			Other cattle - Dairy Replacements Female
			Other cattle - Heifers for breeding
			Other cattle - Steers
	3A2	Enteric	Sheep - Ewe
			Sheep - Lamb
			Sheep - Ram
	3A3	Enteric	Pig - Boar

National Communication Category	IPCC Sector	Source Name	Activity Name
			Pig - Fattening Pig < 20 kg
			Pig - Fattening Pig > 80 kg
			Pig - Fattening Pig 20 to 80 kg
			Pig - Gilt
			Pig - Sow
	3A4	Enteric	Deer
			Goats
			Agricultural Horses
			Domestic Horses
			Professional Horses
	3B11a	Excreta	Dairy - Dairy Cows
		Managed Manure	Dairy - Dairy Cows
		Digestate	Dairy - Dairy Cows
	3B11b	Excreta	Other cattle - Beef females for slaughter
			Other cattle - Bulls for breeding
			Other cattle - Cereal fed bull
			Other cattle - Cows
			Other cattle - Dairy Calves Female
			Other cattle - Dairy In Calf Heifers
			Other cattle - Dairy Replacements Female
			Other cattle - Heifers for breeding
			Other cattle - Steers
		Managed Manure	Other cattle - Beef females for slaughter

National Communication Category	IPCC Sector	Source Name	Activity Name
			Other cattle - Bulls for breeding
			Other cattle - Cereal fed bull
			Other cattle - Cows
			Other cattle - Dairy Calves Female
			Other cattle - Dairy In Calf Heifers
			Other cattle - Dairy Replacements Female
			Other cattle - Heifers for breeding
			Other cattle - Steers
		Digestate	Other cattle - Beef females for slaughter
			Other cattle - Bulls for breeding
			Other cattle - Cereal fed bull
			Other cattle - Cows
			Other cattle - Dairy Calves Female
			Other cattle - Dairy In Calf Heifers
			Other cattle - Dairy Replacements Female
			Other cattle - Heifers for breeding
			Other cattle - Steers
	3B12	Excreta	Sheep - Ewe
			Sheep - Lamb
			Sheep - Ram
		Managed Manure	Sheep - Ewe
			Sheep - Lamb

National Communication Category	IPCC Sector	Source Name	Activity Name
			Sheep - Ram
	3B13	Excreta	Pig - Boar
			Pig - Fattening Pig < 20 kg
			Pig - Fattening Pig > 80 kg
			Pig - Fattening Pig 20 to 80 kg
			Pig - Gilt
			Pig - Sow
		Managed Manure	Pig - Boar
			Pig - Fattening Pig < 20 kg
			Pig - Fattening Pig > 80 kg
			Pig - Fattening Pig 20 to 80 kg
			Pig - Gilt
			Pig - Sow
		Digestate	Pig - Boar
			Pig - Fattening Pig < 20 kg
			Pig - Fattening Pig > 80 kg
			Pig - Fattening Pig 20 to 80 kg
			Pig - Gilt
			Pig - Sow
	3B14	Excreta	Deer
			Goats
			Poultry - Broilers
			Poultry - Laying Hens

National Communication Category	IPCC Sector	Source Name	Activity Name
			Poultry - Other
			Poultry - Turkeys
			Agricultural Horses
			Domestic Horses
			Professional Horses
		Managed Manure	Deer
			Goats
			Poultry - Broilers
			Poultry - Laying Hens
			Poultry - Other
			Poultry - Turkeys
			Agricultural Horses
			Domestic Horses
			Professional Horses
		Digestate	Poultry - Broilers
			Poultry - Laying Hens
			Poultry - Other
			Poultry - Turkeys
	3B21a	Dairy - Dairy Cows - Direct	Housing
	3B21b	Other cattle - Beef females for slaughter - Direct	Housing
		Other cattle - Bulls for breeding - Direct	Housing
		Other cattle - Cereal fed bull - Direct	Housing
		Other cattle - Cows - Direct	Housing
		Other cattle - Dairy Calves Female - Direct	Housing
		Other cattle - Dairy In Calf Heifers - Direct	Housing
		Other cattle - Dairy Replacements Female - Direct	Housing

National Communication Category	IPCC Sector	Source Name	Activity Name
		Other cattle - Heifers for breeding - Direct	Housing
		Other cattle - Steers - Direct	Housing
	3B22	Sheep - Ewe - Direct	Storage
		Sheep - Lamb - Direct	Storage
		Sheep - Ram - Direct	Storage
	3B23	Pig - Boar - Direct	Housing
		Pig - Fattening Pig < 20 kg - Direct	Housing
		Pig - Fattening Pig > 80 kg - Direct	Housing
		Pig - Fattening Pig 20 to 80 kg - Direct	Housing
		Pig - Gilt - Direct	Housing
		Pig - Sow - Direct	Housing
	3B24	Poultry - Broilers - Direct	Housing
		Poultry - Laying Hens - Direct	Housing
		Poultry - Other - Direct	Housing
		Poultry - Turkeys - Direct	Housing
		Agricultural Horses - Direct	Housing
		Deer - Direct	Housing
		Domestic Horses - Direct	Housing
		Goats - Direct	Housing
		Professional Horses - Direct	Housing
	3B25	Dairy - Dairy Cows - Indirect Deposition	Housing
			Storage
			Yarding
		Dairy - Dairy Cows - Indirect Leach	Storage
		Other cattle - Beef females for slaughter - Indirect Deposition	Housing
			Storage

National Communication Category	IPCC Sector	Source Name	Activity Name
			Yarding
		Other cattle - Beef females for slaughter - Indirect Leach	Storage
		Other cattle - Bulls for breeding - Indirect Deposition	Housing
			Storage
			Yarding
		Other cattle - Bulls for breeding - Indirect Leach	Storage
		Other cattle - Cereal fed bull - Indirect Deposition	Housing
			Storage
			Yarding
		Other cattle - Cereal fed bull - Indirect Leach	Storage
		Other cattle - Cows - Indirect Deposition	Housing
			Storage
			Yarding
		Other cattle - Cows - Indirect Leach	Storage
		Other cattle - Dairy Calves Female - Indirect Deposition	Housing
			Storage
			Yarding
		Other cattle - Dairy Calves Female - Indirect Leach	Storage
		Other cattle - Dairy In Calf Heifers - Indirect Deposition	Housing
			Storage
			Yarding
		Other cattle - Dairy In Calf Heifers - Indirect Leach	Storage
		Other cattle - Dairy Replacements Female - Indirect Deposition	Housing
			Storage
			Yarding

National Communication Category	IPCC Sector	Source Name	Activity Name
		Other cattle - Dairy Replacements Female - Indirect Leach	Storage
		Other cattle - Heifers for breeding - Indirect Deposition	Housing
			Storage
			Yarding
		Other cattle - Heifers for breeding - Indirect Leach	Storage
		Other cattle - Steers - Indirect Deposition	Housing
			Storage
			Yarding
		Other cattle - Steers - Indirect Leach	Storage
		Pig - Boar - Indirect Deposition	Housing
			Storage
		Pig - Boar - Indirect Leach	Storage
		Pig - Fattening Pig < 20 kg - Indirect Deposition	Housing
			Storage
		Pig - Fattening Pig < 20 kg - Indirect Leach	Storage
		Pig - Fattening Pig > 80 kg - Indirect Deposition	Housing
			Storage
		Pig - Fattening Pig > 80 kg - Indirect Leach	Storage
		Pig - Fattening Pig 20 to 80 kg - Indirect Deposition	Housing
			Storage
		Pig - Fattening Pig 20 to 80 kg - Indirect Leach	Storage
		Pig - Gilt - Indirect Deposition	Housing
			Storage
		Pig - Gilt - Indirect Leach	Storage
		Pig - Sow - Indirect Deposition	Housing

National Communication Category	IPCC Sector	Source Name	Activity Name
			Storage
		Pig - Sow - Indirect Leach	Storage
		Poultry - Broilers - Indirect Deposition	Housing
			Storage
		Poultry - Broilers - Indirect Leach	Storage
		Poultry - Laying Hens - Indirect Deposition	Housing
			Storage
		Poultry - Laying Hens - Indirect Leach	Storage
		Poultry - Other - Indirect Deposition	Housing
			Storage
		Poultry - Other - Indirect Leach	Storage
		Poultry - Turkeys - Indirect Deposition	Housing
			Storage
		Poultry - Turkeys - Indirect Leach	Storage
		Sheep - Ewe - Indirect Deposition	Housing
			Storage
		Sheep - Ewe - Indirect Leach	Storage
		Sheep - Lamb - Indirect Deposition	Housing
			Storage
		Sheep - Lamb - Indirect Leach	Storage
		Sheep - Ram - Indirect Deposition	Housing
			Storage
		Sheep - Ram - Indirect Leach	Storage
		Agricultural Horses - Indirect Deposition	Housing
			Storage
		Agricultural Horses - Indirect Leach	Storage

National Communication Category	IPCC Sector	Source Name	Activity Name
		Dairy - Dairy Cows - Digestate Indirect Deposition	Storage
		Deer - Indirect Deposition	Housing
			Storage
		Deer - Indirect Leach	Storage
		Domestic Horses - Indirect Deposition	Housing
			Storage
		Domestic Horses - Indirect Leach	Storage
		Goats - Indirect Deposition	Housing
			Storage
		Goats - Indirect Leach	Storage
		Other cattle - Beef females for slaughter - Digestate Indirect Deposition	Storage
		Other cattle - Bulls for breeding - Digestate Indirect Deposition	Storage
		Other cattle - Cereal fed bull - Digestate Indirect Deposition	Storage
		Other cattle - Cows - Digestate Indirect Deposition	Storage
		Other cattle - Dairy Calves Female - Digestate Indirect Deposition	Storage
		Other cattle - Dairy In Calf Heifers - Digestate Indirect Deposition	Storage
		Other cattle - Dairy Replacements Female - Digestate Indirect Deposition	Storage
		Other cattle - Heifers for breeding - Digestate Indirect Deposition	Storage
		Other cattle - Steers - Digestate Indirect Deposition	Storage
		Pig - Boar - Digestate Indirect Deposition	Storage
		Pig - Fattening Pig < 20 kg - Digestate Indirect Deposition	Storage
		Pig - Fattening Pig > 80 kg - Digestate Indirect Deposition	Storage
		Pig - Fattening Pig 20 to 80 kg - Digestate Indirect Deposition	Storage

National Communication Category	IPCC Sector	Source Name	Activity Name
		Pig - Gilt - Digestate Indirect Deposition	Storage
		Pig - Sow - Digestate Indirect Deposition	Storage
		Poultry - Broilers - Digestate Indirect Deposition	Storage
		Poultry - Laying Hens - Digestate Indirect Deposition	Storage
		Poultry - Other Poultry - Digestate Indirect Deposition	Storage
		Poultry - Turkeys - Digestate Indirect Deposition	Storage
		Professional Horses - Indirect Deposition	Housing
			Storage
		Professional Horses - Indirect Leach	Storage
	3D11	Arable - Direct	Ammonium Nitrate Application
			Ammonium Sulphate and Diammonium Phosphate Application
			Calcium Ammonium Nitrate Application
			Other Nitrogen Including Compounds Application
			Urea Ammonium Nitrate Application
			Urea Application
		Grass - Direct	Ammonium Nitrate Application
			Ammonium Sulphate and Diammonium Phosphate Application
			Calcium Ammonium Nitrate Application
			Other Nitrogen Including Compounds Application
			Urea Ammonium Nitrate Application
			Urea Application
	3D12a	Dairy - Dairy Cows - Direct	Spreading

National Communication Category	IPCC Sector	Source Name	Activity Name
		Other cattle - Beef females for slaughter - Direct	Spreading
		Other cattle - Bulls for breeding - Direct	Spreading
		Other cattle - Cereal fed bull - Direct	Spreading
		Other cattle - Cows - Direct	Spreading
		Other cattle - Dairy Calves Female - Direct	Spreading
		Other cattle - Dairy In Calf Heifers - Direct	Spreading
		Other cattle - Dairy Replacements Female - Direct	Spreading
		Other cattle - Heifers for breeding - Direct	Spreading
		Other cattle - Steers - Direct	Spreading
		Pig - Boar - Direct	Spreading
		Pig - Fattening Pig < 20 kg - Direct	Spreading
		Pig - Fattening Pig > 80 kg - Direct	Spreading
		Pig - Fattening Pig 20 to 80 kg - Direct	Spreading
		Pig - Gilt - Direct	Spreading
		Pig - Sow - Direct	Spreading
		Poultry - Broilers - Direct	Spreading
		Poultry - Laying Hens - Direct	Spreading
		Poultry - Other - Direct	Spreading
		Poultry - Turkeys - Direct	Spreading
		Sheep - Ewe - Direct	Spreading
		Sheep - Lamb - Direct	Spreading
		Sheep - Ram - Direct	Spreading
		Agricultural Horses - Direct	Spreading
		Deer - Direct	Spreading
		Domestic Horses - Direct	Spreading
		Goats - Direct	Spreading

National Communication Category	IPCC Sector	Source Name	Activity Name
		Professional Horses - Direct	Spreading
	3D12b	Sewage Sludge Cake - Direct	Spreading
		Sewage Sludge Liquid - Direct	Spreading
	3D13	Dairy - Dairy Cows - Direct	Grazing
		Other cattle - Beef females for slaughter - Direct	Grazing
		Other cattle - Bulls for breeding - Direct	Grazing
		Other cattle - Cereal fed bull - Direct	Grazing
		Other cattle - Cows - Direct	Grazing
		Other cattle - Dairy Calves Female - Direct	Grazing
		Other cattle - Dairy In Calf Heifers - Direct	Grazing
		Other cattle - Dairy Replacements Female - Direct	Grazing
		Other cattle - Heifers for breeding - Direct	Grazing
		Other cattle - Steers - Direct	Grazing
		Pig - Boar - Direct	Grazing
		Pig - Fattening Pig < 20 kg - Direct	Grazing
		Pig - Fattening Pig > 80 kg - Direct	Grazing
		Pig - Fattening Pig 20 to 80 kg - Direct	Grazing
		Pig - Gilt - Direct	Grazing
		Pig - Sow - Direct	Grazing
		Poultry - Broilers - Direct	Grazing
		Poultry - Laying Hens - Direct	Grazing
		Poultry - Other - Direct	Grazing
		Poultry - Turkeys - Direct	Grazing
		Sheep - Ewe - Direct	Grazing
		Sheep - Lamb - Direct	Grazing
		Sheep - Ram - Direct	Grazing

National Communication Category	IPCC Sector	Source Name	Activity Name
		Agricultural Horses - Direct	Grazing
		Deer - Direct	Grazing
		Domestic Horses - Direct	Grazing
		Goats - Direct	Grazing
		Professional Horses - Direct	Grazing
	3D14	Arable - Direct	Ammonium Nitrate Residue
			Ammonium Sulphate and Diammonium Phosphate Residue
			Calcium Ammonium Nitrate Residue
			No Nitrogen Fertiliser Applied Residue
			Other Nitrogen Including Compounds Residue
			Urea Ammonium Nitrate Residue
			Urea Residue
		Grass - Direct	Ammonium Nitrate Residue
			Ammonium Sulphate and Diammonium Phosphate Residue
			Calcium Ammonium Nitrate Residue
			No Nitrogen Fertiliser Applied Residue
			Other Nitrogen Including Compounds Residue
			Urea Ammonium Nitrate Residue
			Urea Residue
	3D15	Cropland management	Mineralisation
	3D16	Managed Histosols	Land area

National Communication Category	IPCC Sector	Source Name	Activity Name
	3D21	Arable - Indirect Deposition	Ammonium Nitrate Application
			Ammonium Sulphate and Diammonium Phosphate Application
			Calcium Ammonium Nitrate Application
			Other Nitrogen Including Compounds Application
			Urea Ammonium Nitrate Application
			Urea Application
		Dairy - Dairy Cows - Indirect Deposition	Grazing
			Spreading
		Grass - Indirect Deposition	Ammonium Nitrate Application
			Ammonium Sulphate and Diammonium Phosphate Application
			Calcium Ammonium Nitrate Application
			Other Nitrogen Including Compounds Application
			Urea Ammonium Nitrate Application
			Urea Application
		Other cattle - Beef females for slaughter - Indirect Deposition	Grazing
			Spreading
		Other cattle - Bulls for breeding - Indirect Deposition	Grazing
			Spreading
		Other cattle - Cereal fed bull - Indirect Deposition	Grazing
			Spreading
		Other cattle - Cows - Indirect Deposition	Grazing
			Spreading

National Communication Category	IPCC Sector	Source Name	Activity Name
		Other cattle - Dairy Calves Female - Indirect Deposition	Grazing
			Spreading
		Other cattle - Dairy In Calf Heifers - Indirect Deposition	Grazing
			Spreading
		Other cattle - Dairy Replacements Female - Indirect Deposition	Grazing
			Spreading
		Other cattle - Heifers for breeding - Indirect Deposition	Grazing
			Spreading
		Other cattle - Steers - Indirect Deposition	Grazing
			Spreading
		Pig - Boar - Indirect Deposition	Grazing
			Spreading
		Pig - Fattening Pig < 20 kg - Indirect Deposition	Grazing
			Spreading
		Pig - Fattening Pig > 80 kg - Indirect Deposition	Grazing
			Spreading
		Pig - Fattening Pig 20 to 80 kg - Indirect Deposition	Grazing
			Spreading
		Pig - Gilt - Indirect Deposition	Grazing
			Spreading
		Pig - Sow - Indirect Deposition	Grazing
			Spreading
		Poultry - Broilers - Indirect Deposition	Grazing
			Spreading
		Poultry - Laying Hens - Indirect Deposition	Grazing

National Communication Category	IPCC Sector	Source Name	Activity Name
			Spreading
		Poultry - Other - Indirect Deposition	Grazing
			Spreading
		Poultry - Turkeys - Indirect Deposition	Grazing
			Spreading
		Sheep - Ewe - Indirect Deposition	Grazing
			Spreading
		Sheep - Lamb - Indirect Deposition	Grazing
			Spreading
		Sheep - Ram - Indirect Deposition	Grazing
			Spreading
		Agricultural Horses - Indirect Deposition	Grazing
			Spreading
		Crop Digestates - Indirect Deposition	Spreading
		Dairy - Dairy Cows - Digestate Indirect Deposition	Spreading
		Deer - Indirect Deposition	Grazing
			Spreading
		Domestic Horses - Indirect Deposition	Grazing
			Spreading
		Food Digestates - Indirect Deposition	Spreading
		Goats - Indirect Deposition	Grazing
			Spreading
		Other cattle - Beef females for slaughter - Digestate Indirect Deposition	Spreading
		Other cattle - Bulls for breeding - Digestate Indirect Deposition	Spreading
		Other cattle - Cereal fed bull - Digestate Indirect Deposition	Spreading

National Communication Category	IPCC Sector	Source Name	Activity Name
		Other cattle - Cows - Digestate Indirect Deposition	Spreading
		Other cattle - Dairy Calves Female - Digestate Indirect Deposition	Spreading
		Other cattle - Dairy In Calf Heifers - Digestate Indirect Deposition	Spreading
		Other cattle - Dairy Replacements Female - Digestate Indirect Deposition	Spreading
		Other cattle - Heifers for breeding - Digestate Indirect Deposition	Spreading
		Other cattle - Steers - Digestate Indirect Deposition	Spreading
		Other organic residue Digestates - Indirect Deposition	Spreading
		Pig - Boar - Digestate Indirect Deposition	Spreading
		Pig - Fattening Pig < 20 kg - Digestate Indirect Deposition	Spreading
		Pig - Fattening Pig > 80 kg - Digestate Indirect Deposition	Spreading
		Pig - Fattening Pig 20 to 80 kg - Digestate Indirect Deposition	Spreading
		Pig - Gilt - Digestate Indirect Deposition	Spreading
		Pig - Sow - Digestate Indirect Deposition	Spreading
		Poultry - Broilers - Digestate Indirect Deposition	Spreading
		Poultry - Laying Hens - Digestate Indirect Deposition	Spreading
		Poultry - Other Poultry - Digestate Indirect Deposition	Spreading
		Poultry - Turkeys - Digestate Indirect Deposition	Spreading
		Professional Horses - Indirect Deposition	Grazing
			Spreading
		Sewage Sludge Cake - Indirect Deposition	Spreading
		Sewage Sludge Liquid - Indirect Deposition	Spreading
	3D22	Arable - Indirect Leach	Ammonium Nitrate Application

National Communication Category	IPCC Sector	Source Name	Activity Name
			Ammonium Sulphate and Diammonium Phosphate Application
			Calcium Ammonium Nitrate Application
			Other Nitrogen Including Compounds Application
			Urea Ammonium Nitrate Application
			Urea Application
		Arable - Residue Indirect Leach	Ammonium Nitrate Application
			Ammonium Sulphate and Diammonium Phosphate Application
			Calcium Ammonium Nitrate Application
			No Nitrogen Fertiliser Applied
			Other Nitrogen Including Compounds Application
			Urea Ammonium Nitrate Application
			Urea Application
		Cropland management	Mineralisation - indirect leach
		Dairy - Dairy Cows - Indirect Leach	Grazing
			Spreading
		Grass - Indirect Leach	Ammonium Nitrate Application
			Ammonium Sulphate and Diammonium Phosphate Application
			Calcium Ammonium Nitrate Application
			Other Nitrogen Including Compounds Application
			Urea Ammonium Nitrate Application

National Communication Category	IPCC Sector	Source Name	Activity Name
			Urea Application
		Grass - Residue Indirect Leach	Ammonium Nitrate Application
			Ammonium Sulphate and Diammonium Phosphate Application
			Calcium Ammonium Nitrate Application
			No Nitrogen Fertiliser Applied
			Other Nitrogen Including Compounds Application
			Urea Ammonium Nitrate Application
			Urea Application
		Other cattle - Beef females for slaughter - Indirect Leach	Grazing
			Spreading
		Other cattle - Bulls for breeding - Indirect Leach	Grazing
			Spreading
		Other cattle - Cereal fed bull - Indirect Leach	Grazing
			Spreading
		Other cattle - Cows - Indirect Leach	Grazing
			Spreading
		Other cattle - Dairy Calves Female - Indirect Leach	Grazing
			Spreading
		Other cattle - Dairy In Calf Heifers - Indirect Leach	Grazing
			Spreading
		Other cattle - Dairy Replacements Female - Indirect Leach	Grazing
			Spreading
		Other cattle - Heifers for breeding - Indirect Leach	Grazing

National Communication Category	IPCC Sector	Source Name	Activity Name
			Spreading
		Other cattle - Steers - Indirect Leach	Grazing
			Spreading
		Pig - Boar - Indirect Leach	Grazing
			Spreading
		Pig - Fattening Pig < 20 kg - Indirect Leach	Grazing
			Spreading
		Pig - Fattening Pig > 80 kg - Indirect Leach	Grazing
			Spreading
		Pig - Fattening Pig 20 to 80 kg - Indirect Leach	Grazing
			Spreading
		Pig - Gilt - Indirect Leach	Grazing
			Spreading
		Pig - Sow - Indirect Leach	Grazing
			Spreading
		Poultry - Broilers - Indirect Leach	Grazing
			Spreading
		Poultry - Laying Hens - Indirect Leach	Grazing
			Spreading
		Poultry - Other - Indirect Leach	Grazing
			Spreading
		Poultry - Turkeys - Indirect Leach	Grazing
			Spreading
		Sheep - Ewe - Indirect Leach	Grazing
			Spreading
		Sheep - Lamb - Indirect Leach	Grazing

National Communication Category	IPCC Sector	Source Name	Activity Name
			Spreading
		Sheep - Ram - Indirect Leach	Grazing
			Spreading
		Agricultural Horses - Indirect Leach	Grazing
			Spreading
		Crop Digestates - Indirect Leach	Spreading
		Dairy - Dairy Cows - Digestate Indirect Leach	Spreading
		Deer - Indirect Leach	Grazing
			Spreading
		Domestic Horses - Indirect Leach	Grazing
			Spreading
		Food Digestates - Indirect Leach	Spreading
		Goats - Indirect Leach	Grazing
			Spreading
		Other cattle - Beef females for slaughter - Digestate Indirect Leach	Spreading
		Other cattle - Bulls for breeding - Digestate Indirect Leach	Spreading
		Other cattle - Cereal fed bull - Digestate Indirect Leach	Spreading
		Other cattle - Cows - Digestate Indirect Leach	Spreading
		Other cattle - Dairy Calves Female - Digestate Indirect Leach	Spreading
		Other cattle - Dairy In Calf Heifers - Digestate Indirect Leach	Spreading
		Other cattle - Dairy Replacements Female - Digestate Indirect Leach	Spreading
		Other cattle - Heifers for breeding - Digestate Indirect Leach	Spreading
		Other cattle - Steers - Digestate Indirect Leach	Spreading
		Other organic residue Digestates - Indirect Leach	Spreading

National Communication Category	IPCC Sector	Source Name	Activity Name
		Pig - Boar - Digestate Indirect Leach	Spreading
		Pig - Fattening Pig < 20 kg - Digestate Indirect Leach	Spreading
		Pig - Fattening Pig > 80 kg - Digestate Indirect Leach	Spreading
		Pig - Fattening Pig 20 to 80 kg - Digestate Indirect Leach	Spreading
		Pig - Gilt - Digestate Indirect Leach	Spreading
		Pig - Sow - Digestate Indirect Leach	Spreading
		Poultry - Broilers - Digestate Indirect Leach	Spreading
		Poultry - Laying Hens - Digestate Indirect Leach	Spreading
		Poultry - Other Poultry - Digestate Indirect Leach	Spreading
		Poultry - Turkeys - Digestate Indirect Leach	Spreading
		Professional Horses - Indirect Leach	Grazing
			Spreading
		Sewage Sludge Cake - Indirect Leach	Spreading
		Sewage Sludge Liquid - Indirect Leach	Spreading
	3F11_Field_burning	Field burning	Wheat residue
	3F12_Field_burning	Field burning	Barley residue
	3F14_Field_burning	Field burning	Oats residue
	3F5_Field_burning	Field burning	Linseed residue
	3G1_Liming - limestone	Liming	Limestone
	3G2_Liming - dolomite	Liming	Dolomite
	3H	Fertiliser Application	Urea Application
	non-IPCC	Agriculture - stationary combustion	Electricity
	3D12c	Beef females for slaughter - Digestate Direct	Spreading
		Boar - Digestate Direct	Spreading
		Broilers - Digestate Direct	Spreading

National Communication Category	IPCC Sector	Source Name	Activity Name
		Bulls for breeding - Digestate Direct	Spreading
		Cereal fed bull - Digestate Direct	Spreading
		Cows - Digestate Direct	Spreading
		Crop Digestates - Direct	Spreading
		Dairy Calves Female - Digestate Direct	Spreading
		Dairy Cows - Digestate Direct	Spreading
		Dairy In Calf Heifers - Digestate Direct	Spreading
		Dairy Replacements Female - Digestate Direct	Spreading
		Fattening Pig < 20 kg - Digestate Direct	Spreading
		Fattening Pig > 80 kg - Digestate Direct	Spreading
		Fattening Pig 20 to 80 kg - Digestate Direct	Spreading
		Food Digestates - Direct	Spreading
		Gilt - Digestate Direct	Spreading
		Heifers for breeding - Digestate Direct	Spreading
		Laying Hens - Digestate Direct	Spreading
		Other organic residue Digestates - Direct	Spreading
		Other Poultry - Digestate Direct	Spreading
		Sow - Digestate Direct	Spreading
		Steers - Digestate Direct	Spreading
		Turkeys - Digestate Direct	Spreading
Business	**1A2a_Iron_and_steel**	Blast furnaces	Blast furnace gas
			Coke oven gas
			LPG
			Natural gas
		Iron and steel - combustion plant	Blast furnace gas
			Coal

National Communication Category	IPCC Sector	Source Name	Activity Name
			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
	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

National Communication Category	IPCC Sector	Source Name	Activity Name
			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	Biogas
			Natural gas
		Other industrial combustion	Biomass
			Burning oil
			Coal
			Coke
			Coke oven gas
			Colliery methane
			Fuel oil
			Gas oil
			LPG

National Communication Category	IPCC Sector	Source Name	Activity Name
			Lubricants
			Natural gas
			OPG
			Petroleum coke
			SSF
			Waste solvent
			Wood
	1A4ai_Commercial/Institutional	Miscellaneous industrial/commercial combustion	Coal
			Fuel oil
			Gas oil
			MSW
			Natural gas
		Heat supply	Landfill 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
	2D1_Lubricant_Use	Industrial engines	Lubricants
	2E1_Integrated_circuit_or_semiconductor	Electronics - HFC	Non-fuel combustion
		Electronics - NF_3	Non-fuel combustion
	2F1a_Commercial_refrigeration	All sources	All activities
	2F1b_Domestic_refrigeration	All sources	All activities
	2F1c_Industrial_refrigeration	All sources	All activities
	2F1d_Transport_refrigeration	All sources	All activities
	2F1e_Mobile_air_conditioning	All sources	All activities
	2F1f_Stationary_air_conditioning	All sources	All activities

National Communication Category	IPCC Sector	Source Name	Activity Name
	2F2a_Closed_foam_blowing_agents	Closed foams	Halocarbon bank: HFC-134a
			Halocarbon used for manufacturing: HFC-134a
			Halocarbon bank: HFC-152a
			Halocarbon used for manufacturing: HFC-152a
			Halocarbon bank: HFC-227ea
			Halocarbon in products at disposal: HFC-227ea
			Halocarbon used for manufacturing: HFC-227ea
			Halocarbon bank: HFC-245fa
			Halocarbon in products at disposal: HFC-245fa
			Halocarbon used for manufacturing: HFC-245fa
			Halocarbon bank: HFC-365mfc
			Halocarbon in products at disposal: HFC-365mfc
			Halocarbon used for manufacturing: HFC-365mfc
	2F2b_Open_foam_blowing_agents	One Component Foams	Non-fuel combustion
	2F3_Fire_Protection	Firefighting	Halocarbon bank: C4F10
			Halocarbon in products at disposal: C4F10
			Halocarbon used for manufacturing: C4F10
			Halocarbon bank: HFC-227ea

National Communication Category	IPCC Sector	Source Name	Activity Name
			Halocarbon in products at disposal: HFC-227ea
	2F5_Solvents	Precision cleaning	Halocarbon use: HFC-43-10mee
	2F6b_Other_Applications:Contained-Refrigerant_containers	Transport and distribution of refrigerants	Halocarbon bank: HFC-125
			Halocarbon bank: HFC-134a
			Halocarbon bank: HFC-143a
			Halocarbon bank: HFC-32
	2F6b_Other_Applications:Contained-Refrigerant_Processing	F-gas handling	Non-fuel combustion
	2G1_Electrical_equipment	Electrical insulation	Halocarbon bank: SF_6
	2G2_Military_applications	Airborne Warning And Control Systems	Active Aircraft
	2G2_Particle_accelerators	Particle accelerators	Halocarbon use: SF_6
	2G2e_Electronics_and_shoes	Electronics - PFC	Non-fuel combustion
		Electronics - SF_6	Non-fuel combustion
		Sporting goods	Non-fuel combustion
	2G2e_Tracer_gas	Tracer gas	Halocarbon use: SF_6
	2G3a_Medical aplications	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
	2D3_Other_NEU	Non Energy Use: petroleum coke	Petroleum coke

National Communication Category	IPCC Sector	Source Name	Activity Name
Energy Supply	**1A1ai_Public_Electricity&Heat_Production**	Power stations	Burning oil
			Coal
			Fuel oil
			Gas oil
			Natural gas
			Petroleum coke
	1A1b_Petroleum_Refining	Refineries - combustion	Natural gas
	1A1ci_Manufacture_of_solid_fuels	Coke production	Natural gas
		Solid smokeless fuel production	Coke
	1A1cii_Oil_and_gas_extraction	Upstream Gas Production - fuel combustion	Gas oil
		Upstream oil and gas production - combustion at gas separation plant	LPG
			OPG
		Upstream Oil Production - fuel combustion	Natural gas
	1A1ciii_Other_energy_industries	Collieries - combustion	Natural gas
		Gas production	LPG
		Nuclear fuel production	Natural gas
	1B1b_Solid_Fuel_Transformation	Coke production	Coal
		Solid smokeless fuel production	Coal
			Petroleum coke
	non-IPCC	Collieries - combustion	Electricity
		Gas production	Electricity
		Refineries - combustion	Electricity
Exports	**Aviation_Bunkers**	Aircraft - international cruise	Aviation spirit
			Aviation turbine fuel
		Aircraft - international take off and landing	Aviation spirit
			Aviation turbine fuel

National Communication Category	IPCC Sector	Source Name	Activity Name
		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
		Aircraft engines	Lubricants
	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
			Burning oil
			Coke
			DERV
			Electricity

National Communication Category	IPCC Sector	Source Name	Activity Name
			Fuel oil
			Lubricants
			Petrol
			SSF
Industrial processes	**2A1_Cement_Production**	Cement - decarbonising	Clinker production
	2A2_Lime_Production	Lime production - decarbonising	Limestone
	2A3_Glass_production	Glass - general	Dolomite
			Limestone
			Soda ash
			Glass-making additives
	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
	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

National Communication Category	IPCC Sector	Source Name	Activity Name
	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
	2A4b_Other_uses_of_Soda_Ash	Non Energy Use: chemical feedstock	Soda ash
		Other emissive applications of Soda Ash	Soda ash
	2A4d_Other_process_uses_of_carbonates:_Other	Bread baking	Sodium Bicarbonate
		Flue Gas Treatment (neutralisation)	Sodium Bicarbonate
		Other emissive applications of Sodium Bicarbonate	Sodium Bicarbonate
		Unknown applications of Sodium Bicarbonate	Sodium Bicarbonate

National Communication Category	IPCC Sector	Source Name	Activity Name
Land use, land use change and forestry	**4_Indirect_N_2O_Emissions**	LULUCF Indirect N_2O - Atmospheric Deposition	Non-fuel combustion
		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
	4B1_Cropland Remaining Cropland	Cropland remaining Cropland - Biomass Burning - Wildfires	Biomass
		Cropland remaining Cropland - Living biomass carbon stock change	Non-fuel combustion
		Cropland remaining Cropland - Soils 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
	4D_Wetlands_Emissions_from_Drainage	Wetlands - Drainage and rewetting and other management of organic and mineral soils	Non-fuel combustion
	4D1_Wetlands remaining wetlands	Peat Extraction Remaining Peat Extraction - Carbon stock change	Non-fuel combustion
		Other Wetlands Remaining Other Wetlands - Carbon stock change	Non-fuel combustion
	4D2_Land converted to Wetlands	Cropland converted to Other Wetlands - Carbon stock change	Non-fuel combustion
		Forest Land converted to Other Wetlands - Biomass Burning - Controlled Burning	Biomass
	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
	4G_Harvested Wood Products	HWP Produced and Consumed Domestically - Carbon stock change	Non-fuel combustion

National Communication Category	IPCC Sector	Source Name	Activity Name
		HWP Produced and Exported - Carbon stock change	Non-fuel combustion
	4C2_Cropland_converted_to_Grassland	Cropland converted to Grassland - Carbon stock change	Non-fuel combustion
	4D2_Grassland_converted_to_Wetlands_Flooded_Land	Grassland converted to flooded land - Carbon stock change	Non-fuel combustion
	4C2_Settlements_converted_to_Grassland	Settlements converted to Grassland - Carbon stock change	Non-fuel combustion
	4A2_Grassland_converted_to_Forest_Land	Grassland converted to Forest Land - Carbon stock change	Non-fuel combustion
		Grassland converted to Forest Land - Direct N_2O emissions from N Mineralization/Immobilization	Non-fuel combustion
	4A2_Settlements_converted_to_Forest_Land	Settlements converted to Forest Land - Carbon stock change	Non-fuel combustion
		Settlements converted to Forest Land - Direct N_2O emissions from N Mineralization/Immobilization	Non-fuel combustion
	4A2_Cropland_converted_to_Forest_Land	Cropland converted to Forest Land - Carbon stock change	Non-fuel combustion
		Cropland converted to Forest Land - Direct N_2O emissions from N Mineralization/Immobilization	Non-fuel combustion
	4B2_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_Settlements_converted_to_Cropland	Settlements converted to Cropland - Carbon stock change	Non-fuel combustion
	4B2_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
		Forest Land converted to Cropland - Direct N_2O emissions from N Mineralization/Immobilization	Non-fuel combustion
	4C2_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
	4D2_Forest_Land_converted_to_Wetlands	Forest Land converted to Other Wetlands - Carbon stock change	Non-fuel combustion

National Communication Category	IPCC Sector	Source Name	Activity Name
	4D2_Land_converted_to_Wetlands_Peat_Extraction	Land converted for Peat Extraction - Carbon stock change	Non-fuel combustion
	4E2_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_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_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
	4E_Settlements_Emissions_from_Drainage	Settlements - Drainage and rewetting and other management of organic and mineral soils	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
Public	**1A4ai_Commercial/Institutional**	Public sector combustion	Burning oil
			Coal
			Coke
			Fuel oil
			Gas oil
			Natural gas
		Heat supply	Sewage gas
	non-IPCC	Public sector combustion	Electricity
Residential	**1A4bi_Residential_stationary**	Domestic combustion	Anthracite
			Burning oil
			Charcoal
			Coal
			Coke

National Communication Category	IPCC Sector	Source Name	Activity Name
			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	Halocarbon bank: HFC-134a
			Halocarbon bank: HFC-227ea
	2F4b_Aerosols:Other	Aerosols other than metered dose inhalers	Halocarbon bank: HFC-134a
			Halocarbon bank: HFC-152a
	2G3b_N_2O_from_product_uses:_Other	Recreational use of N_2O	Process emission
	5B1a_composting_municipal_solid_waste	Composting (at household)	Biological waste
	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

National Communication Category	IPCC Sector	Source Name	Activity Name
			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
		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

National Communication Category	IPCC Sector	Source Name	Activity Name
		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 biofuels use	Biodiesel
			Bio-MTBE
		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
		Motorboats / workboats (e.g. canal boats, dredgers, service boats, tourist boats, river boats)	DERV
			Gas oil
			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

National Communication Category	IPCC Sector	Source Name	Activity Name
	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
	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
Grand Total			

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	2015	2016	2017	2018	2019
Agriculture	56.9	56.9	55.5	52.8	51.1	47.7	48.0	47.7	48.0	47.3	47.7
Business	248.2	247.7	217.8	215.2	208.4	181.9	146.2	131.0	126.1	122.1	115.0
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	9.2	9.2	13.1	12.9	16.8	15.9	11.9	11.9	12.0	11.4	11.2
Industrial Processes	65.4	63.2	53.6	29.3	21.4	13.5	13.2	11.1	11.4	10.7	10.9
Land Use, Land Use Change and Forestry	18.0	18.0	14.7	12.0	8.3	6.0	5.7	5.3	5.0	5.6	5.9
Public	31.5	31.5	28.9	24.3	22.4	19.1	14.5	13.3	12.2	12.3	11.7
Residential	171.7	171.3	157.1	158.5	162.4	156.2	113.4	106.2	99.9	100.8	96.9
Transport	146.6	146.6	151.1	153.7	156.1	141.9	138.4	140.3	140.6	138.7	136.4
Waste Management	64.7	64.7	67.4	61.1	47.3	28.3	19.2	18.6	19.0	19.1	19.0
Total greenhouse gas emissions	812.2	809.1	759.3	719.8	694.2	610.5	510.5	485.4	474.2	468.1	454.8

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	2015	2016	2017	2018	2019
Agriculture	10.0	10.0	9.4	8.0	8.8	7.8	7.4	7.4	7.2	7.2	7.4
Business	229.7	229.7	203.3	203.0	195.2	166.7	130.0	115.2	110.3	106.6	100.0
Energy Supply	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

End user category	Base Year	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Exports	8.4	8.4	12.2	12.2	16.1	15.2	11.4	11.3	11.4	10.8	10.6
Industrial Processes	20.9	20.9	19.0	18.1	16.8	11.2	12.5	10.4	10.6	10.1	10.2
Land Use, Land Use Change and Forestry	10.3	10.3	7.1	4.6	1.1	-1.0	-1.2	-1.6	-1.9	-1.4	-1.0
Public	29.2	29.2	27.1	23.3	21.7	18.5	14.1	12.9	11.9	12.0	11.4
Residential	156.2	156.2	145.3	149.3	154.6	149.1	107.5	100.8	94.6	95.6	92.0
Transport	142.4	142.4	146.8	150.3	153.6	140.1	136.4	138.4	138.5	136.6	134.3
Waste Management	1.3	1.3	1.0	0.6	0.5	0.3	0.2	0.3	0.3	0.2	0.2
Total greenhouse gas emissions	608.3	608.3	571.2	569.4	568.3	508.0	418.3	395.1	382.9	377.7	365.1

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	2015	2016	2017	2018	2019
Agriculture	29.3	29.3	28.8	28.1	26.8	25.2	25.7	25.6	25.7	25.2	25.3
Business	15.5	15.5	11.7	7.4	4.8	3.7	2.7	2.3	2.3	2.2	2.1
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	0.5	0.4	0.4	0.5	0.5	0.5
Industrial Processes	2.1	2.1	1.7	1.1	0.5	0.4	0.2	0.2	0.2	0.1	0.2
Land Use, Land Use Change and Forestry	4.7	4.7	4.7	4.7	4.8	4.8	4.8	4.8	4.8	4.9	4.9
Public	2.1	2.1	1.7	0.9	0.6	0.5	0.4	0.3	0.3	0.3	0.3

End user category	Base Year	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Residential	14.4	14.4	10.7	6.7	4.9	4.5	3.6	3.2	3.1	3.2	3.1
Transport	2.6	2.6	2.2	1.5	1.0	0.8	0.6	0.6	0.7	0.7	0.7
Waste Management	62.5	62.5	65.4	59.3	45.6	26.6	17.4	16.6	17.0	17.2	17.0
Total greenhouse gas emissions	133.9	133.9	127.7	110.4	89.6	66.9	55.8	54.1	54.6	54.3	54.0

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	2015	2016	2017	2018	2019
Agriculture	17.6	17.6	17.3	16.6	15.5	14.7	14.9	14.8	15.1	14.9	15.0
Business	1.5	1.5	1.4	1.2	1.3	1.2	1.2	1.1	1.1	1.2	1.1
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 Processes	23.9	23.9	14.4	5.4	3.1	1.5	0.3	0.3	0.3	0.3	0.3
Land Use, Land Use Change and Forestry	3.0	3.0	2.9	2.7	2.4	2.2	2.1	2.1	2.1	2.1	2.1
Public	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Residential	0.7	0.7	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4
Transport	1.6	1.6	2.2	1.9	1.5	1.1	1.3	1.3	1.4	1.4	1.4
Waste Management	1.0	1.0	1.1	1.2	1.2	1.5	1.6	1.6	1.7	1.7	1.7
Total greenhouse gas emissions	49.6	49.6	39.9	29.8	25.8	22.8	22.0	21.8	22.3	22.1	22.2