Annexes

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A1 ANNEX 1: Key Categories

This Annex was updated in the 2010 NIR to include the new information required for reporting under the Kyoto Protocol (decision 15/CMP.1). The table below contains the information that Annex 1 must contain, and the locations of this information in the Annex[1]. The text in italics refers to the elements which are required under the Kyoto Protocol.

Requirements	**Locations of the relevant information in this Annex**
Description of methodology used for identifying key categories, *including KP-LULUCF*	See sections immediately below "*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 Good Practice Guidance.
Tables 7.A1 - 7.A3 of the IPCC good practice guidance	The data requested in these Good Practice Guidance tables, including and excluding LULUCF, are provided in **Table A1.1.1** to **Table A1.1.14**.
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 A1.2.1**.

A1.1 DESCRIPTION OF METHODOLOGY USED FOR IDENTIFYING KEY CATEGORIES

General approach used to identify Key Categories

Up to and including the 2007 NIR this Annex referred to key sources. The NIR now refers to key categories, or key source categories, rather than key sources. "Key categories" is the terminology used in the IPCC's Good Practice Guidance (2000) and the word category is used, rather than source, to avoid any potential confusion with sources and corresponding sinks of carbon.

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 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 set out in Section 7.2 of the IPCC Good Practice Guidance (2000) (*Determining national key source categories*) to determine the key source categories.

[1] 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 results of the key source category analysis with and without LULUCF, for the base year and the latest reported year, are summarised by sector and gas in **Table A 1.1.11** to **Table A 1.1.14**. A trend cannot be calculated for the base year alone, and so **Table A 1.1.11** and **Table A 1.1.12** only contain key source categories identified by the level of overall percentage uncertainty in the inventory.

The key category analysis is based on the level analysis and trend analysis which are part of the Approach 1 uncertainty analysis. The Approach 1 uncertainty analysis is an error propagation approach, as described in Section 3.2.3.1 of the IPCC 2006 Guidelines. This analysis has been performed using the data shown in **Table A 7.6.1** to **Table A 7.6.4** using the same categorisation and the same estimates of uncertainty. The table indicates whether a key category arises from the level assessment or the trend assessment. The factors that make a source a key category are:

- A high contribution to the total;
- A high contribution to the trend; and
- High uncertainty.

For example, transport fuel (1A3b) is a key category for carbon dioxide because it is large; landfill methane (6A) is key because it is large, has a high uncertainty and shows a significant trend.

Both the level and the trend assessments have been completed, following the procedure set out in the IPCC Good Practice Guidance (2000). The emission estimates were taken from the current inventory. Following IPCC good practice, a qualitative assessment of the inventory is underway and the cement sector is included as key category, after a recommendation from a UNFCCC Expert Review Team. Initial indications are that we do not expect further additional sources categories to be identified following this qualitative assessment, but this will be kept under review.

The results of the level assessment with and without LULUCF for the base year, 1990, and the latest reported year are shown in **Table A 1.1.1** to **Table A 1.1.6**. 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 total uncertainty in the final column after this sorting process.

The results of the trend assessment with and without LULUCF for the base year to the latest reported year, and, 1990 to the latest reported year, are shown in **Table A 1.1.7** to **Table A 1.1.10**. The key source categories are highlighted by the shaded cells in the table. The trend parameter was calculated using 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 95% of the total uncertainty in the final column after this sorting process.

In the level assessments, the production of nitric and adipic acid are key categories in the UK inventory for the base year and 1990. For the latest inventory year, only the production of nitric acid is a key category. The emissions from nitric acid production are currently associated with a very high uncertainty, but this is under review. The uncertainties assigned to the Activity Data (AD) and Emission Factors (EFs) are: 2B2 Nitric acid production, AD 10%, EF 230%; 2B3 Adipic acid production, AD 0.5%, EF 15%. The uncertainty associated with N_2O emissions released from nitric acid production dominates the overall uncertainty of N_2O emissions in sector 2B. In 2011, the manufacturer of nitric acid was contacted and they provided estimates of uncertainty associated with the emissions from the production of nitric acid. These new estimates indicate that uncertainty is higher for the base year and significantly lower in the latest reported year. These estimates of uncertainties have been incorporated in the Monte Carlo analysis only as it has the ability to reflect temporal differences, and consideration will be given to including this information in the Approach 1 analysis in the next NIR.

Any methodological improvements to the uncertainty analysis are discussed in **Annex 7**.

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

Three categories are considered to be key: Article 3.3 Afforestation and Reforestation (CO_2), Article 3.3 Deforestation (CO_2) and Article 3.4 Forest Management (CO_2). These have been assessed according to the IPCC good practice guidance for LULUCF section 5.4.4.

Article 3.3 Afforestation and Reforestation (CO_2): The associated UNFCCC category 5A (-10 569 Gg CO_2) is a key category although the AR component (forest planted since 1990) is not key on its own (i.e. its category contribution (-2 959 Gg CO_2) is smaller than the smallest UNFCCC key category (1A Coal)). Removals from this category are also predicted to increase over time as a result of tree planting schemes partially focussed on climate change mitigation.

Article 3.3 Deforestation (CO_2): The associated UNFCCC categories (5B, 5C and 5E) are key categories (12 116, -8 541 and 6 216 Gg CO_2 respectively). However, the Deforestation category contribution (710 Gg CO_2) to these UNFCCC categories is smaller than the smallest UNFCCC key category (1A Coal). The data used in the calculation of deforestation emissions are the most uncertain of the data sources in the KP-LULUCF inventory and are a priority for improvement.

Article 3.4 Forest Management (CO_2): The associated UNFCCC category 5A is a key category (-10 569 Gg CO_2). The Forest Management category contribution (-7 498 Gg CO_2) is also greater than other categories in the UNFCCC key category.

These categories are the priority for improvement in the KP-LULUCF inventory, and there is ongoing development (described in **Chapters 7 and 11**).

Using the uncertainty analysis to plan improvements in the preparation of the inventory
The uncertainty analysis should be used to prioritise and plan improvements. The approach the UK takes to achieve this is described in **Chapter 1**, **Section 1.2.2.4**.

Table A 1.1.1 Key Category Analysis for the base year based on level of emissions (including LULUCF)

IPCC category	Source category	Gas	Base year emissions Gg CO2 equiv. 1990 & 1995	Year Y emissions Gg CO2 equiv. 2010	Combined uncertainty range as a % of source category	Level Parameter (used to order sources)	Level / Sum(Level)*100 %	Cumulative %
4D	Agricultural Soils	N2O	32825.07	26385.59	424.00	0.17973	53.82760	
6A	Solid Waste Disposal	CH4	43143.47	14767.00	48.38	0.02696	8.07324	61.90085
1A(stationary)	Oil	CO2	92867.52	53505.95	15.13	0.01815	5.43518	67.33602
1A1&1A2&1A4&1A5	Other Combustion	N2O	4829.07	3122.22	195.00	0.01216	3.64193	70.97795
2B	Nitric Acid Production	N2O	3903.85	1316.57	230.22	0.01161	3.47587	74.45382
4B	Manure Management	N2O	2053.05	1750.56	414.00	0.01098	3.28726	77.74108
5B	Cropland	CO2	15732.05	12115.71	50.01	0.01016	3.04281	80.78389
1A3b	Auto Fuel	CO2	108564.64	111579.17	4.48	0.00628	1.88196	82.66585
6B	Wastewater Handling	N2O	1164.86	1151.57	401.12	0.00603	1.80711	84.47295
5C	Grassland	CO2	-6261.11	-8541.00	70.01	0.00566	1.69522	86.16817
4A	Enteric Fermentation	CH4	18694.63	15385.93	20.00	0.00483	1.44605	87.61423
5E	Settlements	CO2	7011.87	6216.22	50.01	0.00453	1.35620	88.97043
2B	Adipic Acid Production	N2O	20737.34	0.00	15.01	0.00402	1.20370	90.17413
5A	Forest Land	CO2	-12155.07	-10568.81	25.02	0.00393	1.17619	91.35031
2	Industrial Processes	HFC	15327.65	14314.07	19.03	0.00377	1.12788	92.47819
1A	Coal	CO2	247785.08	114863.47	1.08	0.00345	1.03213	93.51033
1B1	Mining & Solid Fuel Transformation	CH4	18281.71	1799.47	100.77	0.00307	0.92018	94.43050
1A3b	Auto Fuel	N2O	1179.78	847.95	170.02	0.00259	0.77579	95.20629
1B2	Production, Refining & Distribution of Oil & Natu	CH4	10322.92	5191.29	25.61	0.00225	0.67454	95.88082
1A	Natural Gas	CO2	108956.17	197884.94	1.51	0.00213	0.63768	96.51850
4B	Manure Management	CH4	3585.62	2679.30	30.00	0.00139	0.41603	96.93453
1A	All Fuel	CH4	2077.99	1069.03	50.00	0.00134	0.40185	97.33637
1B	Oil & Natural Gas	CO2	5777.84	4388.43	17.09	0.00128	0.38185	97.71822
2B5	NEU	CO2	1562.92	1969.82	53.85	0.00109	0.32551	98.04373
5G	Other	CO2	-1727.33	-3985.06	30.02	0.00067	0.20053	98.24426
2A7	Fletton Bricks	CO2	539.42	530.66	72.80	0.00051	0.15188	98.39614
5B	Cropland	N2O	781.56	622.48	50.01	0.00050	0.15116	98.54730
1A3a	Aviation Fuel	CO2	1580.55	1990.63	20.27	0.00041	0.12391	98.67121
1A3b	Auto Fuel	CH4	634.83	71.41	50.08	0.00041	0.12295	98.79417
1A3	Other Diesel	N2O	191.40	282.12	140.01	0.00035	0.10364	98.89781
6C	Waste Incineration	CO2	1227.50	292.01	21.19	0.00034	0.10060	98.99840
2	Industrial Processes	SF6	1239.30	689.99	20.02	0.00032	0.09598	99.09438
5D	Wetlands	CO2	481.73	263.02	50.01	0.00031	0.09317	99.18756
4F	Field Burning	N2O	77.60	0.00	231.35	0.00023	0.06944	99.25699
2A1	Cement Production	CO2	7295.26	3792.01	2.42	0.00023	0.06818	99.32518
1A	Combined Fuel	CO2	801.51	867.86	21.21	0.00022	0.06576	99.39094
1A4	Peat	CO2	475.59	47.44	31.62	0.00019	0.05817	99.44910
4F	Field Burning	CH4	265.51	0.00	55.90	0.00019	0.05740	99.50650
2B	Ammonia Production	CO2	1431.17	978.43	10.11	0.00019	0.05597	99.56247
6B	Wastewater Handling	CH4	287.21	347.89	50.01	0.00019	0.05555	99.61802
2C1	Iron&Steel Production	CO2	2309.27	1747.34	6.12	0.00018	0.05465	99.67267
1A	Lubricant	CO2	386.90	225.28	30.07	0.00015	0.04499	99.71766
6C	Waste Incineration	N2O	47.90	47.25	230.11	0.00014	0.04263	99.76029
6C	Waste Incineration	CH4	134.43	6.25	50.49	0.00009	0.02625	99.78654
2A2	Lime Production	CO2	1206.41	233.70	5.10	0.00008	0.02379	99.81033
2A3	Limestone & Dolomite use	CO2	1125.28	920.77	5.10	0.00007	0.02219	99.83252
1B	Solid Fuel Transformation	CO2	856.42	219.64	6.01	0.00007	0.01992	99.85244
2B	Chemical Industry	CH4	169.43	73.50	28.28	0.00006	0.01853	99.87097
1B2	Oil & Natural Gas	N2O	42.40	46.17	111.16	0.00006	0.01823	99.88920
1A3d	Marine Fuel	CO2	2123.33	2264.57	2.20	0.00006	0.01809	99.90729
2	Industrial Processes	PFC	461.81	220.47	10.05	0.00006	0.01795	99.92524
1A	Other (waste)	CO2	212.42	1660.57	21.19	0.00006	0.01741	99.94264
1A3	Other Diesel	CO2	1613.78	2370.91	2.20	0.00005	0.01375	99.95639
1A3d	Marine Fuel	N2O	16.56	17.64	170.01	0.00004	0.01089	99.96728
1A3a	Aviation Fuel	N2O	15.56	19.60	171.17	0.00003	0.01030	99.97758
2A7	Fletton Bricks	CH4	23.60	5.63	101.98	0.00003	0.00931	99.98689
2C	Iron & Steel	N2O	11.11	6.72	118.00	0.00002	0.00507	99.99196
2C	Iron & Steel Production	CH4	16.36	11.81	50.00	0.00001	0.00316	99.99512
1B1	Coke Oven Gas	N2O	2.08	1.38	118.00	0.00000	0.00095	99.99607
5E2	Land converted to settlements	CH4	9.96	8.30	20.02	0.00000	0.00077	99.99684
1A3a	Aviation Fuel	CH4	3.30	1.11	53.85	0.00000	0.00069	99.99753
1A3	Other Diesel	CH4	3.11	3.78	50.03	0.00000	0.00060	99.99813
5A	Forest Land	N2O	5.57	1.92	20.02	0.00000	0.00043	99.99856
1A3d	Marine Fuel	CH4	1.85	3.91	50.03	0.00000	0.00036	99.99892
5A	Forest Land	CH4	4.30	8.17	20.02	0.00000	0.00033	99.99925
5D	Wetlands	N2O	3.98	0.50	20.02	0.00000	0.00031	99.99956
5C2	Land converted to grassland	CH4	3.90	11.74	20.02	0.00000	0.00030	99.99986
5E2	Land converted to settlements	N2O	1.01	0.84	20.02	0.00000	0.00008	99.99994
5C2	Land converted to grassland	N2O	0.40	1.19	20.02	0.00000	0.00003	99.99997
5B	Cropland	CH4	0.14	0.39	50.01	0.00000	0.00003	100.00000
1A3c	Coal	CO2	0.00	49.62	6.01	0.00000	0.00000	100.00000
1A4	Combined Fuel	CO2	0.00	0.00	21.21	0.00000	0.00000	100.00000
2A4	Soda Ash Use	CO2	0.00	0.00	15.13	0.00000	0.00000	100.00000
1A3c	Coal	CH4	0.00	0.99	50.00	0.00000	0.00000	100.00000
1A3c	Coal	N2O	0.00	0.12	118.00	0.00000	0.00000	100.00000
4G	OvTerr Agriculture N2O (all)	N2O	0.00	0.00	50.99	0.00000	0.00000	100.00000
5G	Other	N2O	0.00	0.00	50.01	0.00000	0.00000	100.00000
		Sum -->	774,364.31	590,177.13		0.3339	100.00	

Table A 1.1.2 Key Category Analysis for the base year based on level of emissions (excluding LULUCF)

IPCC category	Source category	Gas	Base year emissions Gg CO2 equiv. 1990 & 1995	Year Y emissions Gg CO2 equiv. 2010	Combined uncertainty range as a % of source category	Level Parameter (used to order sources)	Level / Sum(Level)*100 %	Cumulative %
4D	Agricultural Soils	N2O	32825.07	26385.59	424.00	0.18064	58.32919	
6A	Solid Waste Disposal	CH4	43143.47	14767.00	48.38	0.02709	8.74841	67.07760
1A(stationary)	Oil	CO2	92867.52	53505.95	15.13	0.01824	5.88972	72.96732
1A1&1A2&1A4&1A5	Other Combustion	N2O	4829.07	3122.22	195.00	0.01222	3.94650	76.91382
2B	Nitric Acid Production	N2O	3903.85	1316.57	230.22	0.01166	3.76655	80.68038
4B	Manure Management	N2O	2053.05	1750.56	414.00	0.01103	3.56217	84.24255
1A3b	Auto Fuel	CO2	108564.64	111579.17	4.48	0.00632	2.03935	86.28190
6B	Wastewater Handling	N2O	1164.86	1151.57	401.12	0.00606	1.95823	88.24013
4A	Enteric Fermentation	CH4	18694.63	15385.93	20.00	0.00485	1.56699	89.80712
2B	Adipic Acid Production	N2O	20737.34	0.00	15.01	0.00404	1.30436	91.11148
2	Industrial Processes	HFC	15327.65	14314.07	19.03	0.00379	1.22220	92.33369
1A	Coal	CO2	247785.08	114863.47	1.08	0.00346	1.11845	93.45214
1B1	Mining & Solid Fuel Transformation	CH4	18281.71	1799.47	101.94	0.00309	0.99713	94.44927
1A3b	Auto Fuel	N2O	1179.78	847.95	170.02	0.00260	0.84066	95.28993
1B2	Production, Refining & Distribution of Oil & Natu	CH4	10322.92	5191.29	25.90	0.00226	0.73095	96.02088
1A	Natural Gas	CO2	108956.17	197884.94	1.51	0.00214	0.69101	96.71189
4B	Manure Management	CH4	3585.62	2679.30	30.00	0.00140	0.45082	97.16270
1A	All Fuel	CH4	2077.99	1069.03	50.00	0.00135	0.43545	97.59816
1B	Oil & Natural Gas	CO2	5777.84	4388.43	17.09	0.00128	0.41378	98.01194
2B5	NEU	CO2	1562.92	1969.82	53.85	0.00109	0.35273	98.36467
2A7	Fletton Bricks	CO2	539.42	530.66	72.80	0.00051	0.16458	98.52925
1A3a	Aviation Fuel	CO2	1580.55	1990.63	20.27	0.00042	0.13427	98.66352
1A3b	Auto Fuel	CH4	634.83	71.41	50.08	0.00041	0.13324	98.79676
1A3	Other Diesel	N2O	191.40	282.12	140.01	0.00035	0.11231	98.90907
6C	Waste Incineration	CO2	1227.50	292.01	21.19	0.00034	0.10901	99.01808
2	Industrial Processes	SF6	1239.30	689.99	20.02	0.00032	0.10401	99.12208
4F	Field Burning	N2O	77.60	0.00	231.35	0.00023	0.07524	99.19733
2A1	Cement Production	CO2	7295.26	3792.01	2.42	0.00023	0.07389	99.27121
1A	Combined Fuel	CO2	801.51	867.86	21.21	0.00022	0.07126	99.34247
1A4	Peat	CO2	475.59	47.44	31.62	0.00020	0.06303	99.40550
4F	Field Burning	CH4	265.51	0.00	55.90	0.00019	0.06220	99.46770
2B	Ammonia Production	CO2	1431.17	978.43	10.11	0.00019	0.06065	99.52836
6B	Wastewater Handling	CH4	287.21	347.89	50.01	0.00019	0.06020	99.58855
2C1	Iron&Steel Production	CO2	2309.27	1747.34	6.12	0.00018	0.05922	99.64777
1A	Lubricant	CO2	386.90	225.28	30.07	0.00015	0.04875	99.69652
6C	Waste Incineration	N2O	47.90	47.25	230.11	0.00014	0.04620	99.74272
6C	Waste Incineration	CH4	134.43	6.25	50.49	0.00009	0.02844	99.77116
2A2	Lime Production	CO2	1206.41	233.70	5.10	0.00008	0.02578	99.79694
2A3	Limestone & Dolomite use	CO2	1125.28	920.77	5.10	0.00007	0.02405	99.82099
1B	Solid Fuel Transformation	CO2	856.42	219.64	6.01	0.00007	0.02158	99.84257
2B	Chemical Industry	CH4	169.43	73.50	28.28	0.00006	0.02008	99.86266
1B2	Oil & Natural Gas	N2O	42.40	46.17	111.16	0.00006	0.01975	99.88241
1A3d	Marine Fuel	CO2	2123.33	2264.57	2.20	0.00006	0.01960	99.90201
2	Industrial Processes	PFC	461.81	220.47	10.05	0.00006	0.01945	99.92146
1A	Other (waste)	CO2	212.42	1660.57	21.19	0.00006	0.01886	99.94032
1A3	Other Diesel	CO2	1613.78	2370.91	2.20	0.00005	0.01489	99.95521
1A3d	Marine Fuel	N2O	16.56	17.64	170.01	0.00004	0.01180	99.96702
1A3a	Aviation Fuel	N2O	15.56	19.60	171.17	0.00003	0.01116	99.97818
2A7	Fletton Bricks	CH4	23.60	5.63	101.98	0.00003	0.01009	99.98826
2C	Iron & Steel	N2O	11.11	6.72	118.00	0.00002	0.00549	99.99376
2C	Iron & Steel Production	CH4	16.36	11.81	50.00	0.00001	0.00343	99.99718
1B1	Coke Oven Gas	N2O	2.08	1.38	118.00	0.00000	0.00103	99.99822
1A3a	Aviation Fuel	CH4	3.30	1.11	53.85	0.00000	0.00074	99.99896
1A3	Other Diesel	CH4	3.11	3.78	50.03	0.00000	0.00065	99.99961
1A3d	Marine Fuel	CH4	1.85	3.91	50.03	0.00000	0.00039	100.00000
1A3c	Coal	CO2	0.00	49.62	6.01	0.00000	0.00000	100.00000
1A4	Combined Fuel	CO2	0.00	0.00	21.21	0.00000	0.00000	100.00000
2A4	Soda Ash Use	CO2	0.00	0.00	15.13	0.00000	0.00000	100.00000
5A	Forest land	CO2	0.00	0.00	25.02	0.00000	0.00000	100.00000
5B	Cropland	CO2	0.00	0.00	50.01	0.00000	0.00000	100.00000
5C	Grassland	CO2	0.00	0.00	70.01	0.00000	0.00000	100.00000
5D	Wetlands	CO2	0.00	0.00	50.01	0.00000	0.00000	100.00000
5E	Settlements	CO2	0.00	0.00	50.01	0.00000	0.00000	100.00000
5G	Other	CO2	0.00	0.00	30.02	0.00000	0.00000	100.00000
1A3c	Coal	CH4	0.00	0.99	50.00	0.00000	0.00000	100.00000
5A	Forest land	CH4	0.00	0.00	20.02	0.00000	0.00000	100.00000
5B	Cropland	CH4	0.00	0.00	50.01	0.00000	0.00000	100.00000
5C2	Land converted to grassland	CH4	0.00	0.00	20.02	0.00000	0.00000	100.00000
5E2	Land converted to settlements	CH4	0.00	0.00	20.02	0.00000	0.00000	100.00000
1A3c	Coal	N2O	0.00	0.12	118.00	0.00000	0.00000	100.00000
4G	OvTerr Agriculture N2O (all)	N2O	0.00	0.00	50.99	0.00000	0.00000	100.00000
5A	Forest land	N2O	0.00	0.00	20.02	0.00000	0.00000	100.00000
5B	Cropland	N2O	0.00	0.00	50.01	0.00000	0.00000	100.00000
5C2	Land converted to grassland	N2O	0.00	0.00	20.02	0.00000	0.00000	100.00000
5D	Wetlands	N2O	0.00	0.00	20.02	0.00000	0.00000	100.00000
5E2	Land converted to settlements	N2O	0.00	0.00	20.02	0.00000	0.00000	100.00000
5G	Other	N2O	0.00	0.00	50.01	0.00000	0.00000	100.00000
		Sum -->	770,471.37	594,021.50		0.3097	100.00	

Table A 1.1.3 Key Category Analysis for 1990 based on level of emissions (including LULUCF)

IPCC category	Source category	Gas	Emissions Gg CO2 equiv. 1990	Year Y emissions Gg CO2 equiv. 2010	Combined uncertainty range as a % of source category	Level Parameter (used to order sources)	Level / Sum(Level)*100 %	Cumulative %
4D	Agricultural Soils	N2O	32825.07	26385.59	424.00	0.18048	53.97320	
6A	Solid Waste Disposal	CH4	43143.47	14767.00	48.38	0.02707	8.09508	62.06828
1A(stationary)	Oil	CO2	92867.52	53505.95	15.13	0.01822	5.44988	67.51816
1A1&1A2&1A4&1A5	Other Combustion	N2O	4829.07	3122.22	195.00	0.01221	3.65178	71.16994
2B	Nitric Acid Production	N2O	3903.85	1316.57	230.22	0.01165	3.48527	74.65521
4B	Manure Management	N2O	2053.05	1750.56	414.00	0.01102	3.29615	77.95136
5B	Cropland	CO2	15732.05	12115.71	50.01	0.01020	3.05104	81.00240
1A3b	Auto Fuel	CO2	108564.64	111579.17	4.48	0.00631	1.88705	82.88945
6B	Wastewater Handling	N2O	1164.86	1151.57	401.12	0.00606	1.81199	84.70144
5C	Grassland	CO2	-6261.11	-8541.00	70.01	0.00568	1.69981	86.40125
4A	Enteric Fermentation	CH4	18694.63	15385.93	20.00	0.00485	1.44997	87.85122
5E	Settlements	CO2	7011.87	6216.22	50.01	0.00455	1.35987	89.21108
2B	Adipic Acid Production	N2O	20737.34	0.00	15.01	0.00404	1.20695	90.41804
5A	Forest Land	CO2	-12155.07	-10568.81	25.02	0.00394	1.17937	91.59741
1A	Coal	CO2	247785.08	114863.47	1.08	0.00346	1.03493	92.63233
1B1	Mining & Solid Fuel Transformation	CH4	18281.71	1799.47	101.19	0.00309	0.92267	93.55500
2	Industrial Processes	HFC	11385.62	14314.07	19.03	0.00281	0.84007	94.39507
1A3b	Auto Fuel	N2O	1179.78	847.95	170.02	0.00260	0.77788	95.17295
1B2	Production, Refining & Distribution of Oil & Natu	CH4	10322.92	5191.29	25.71	0.00226	0.67636	95.84931
1A	Natural Gas	CO2	108956.17	197884.94	1.51	0.00214	0.63940	96.48872
4B	Manure Management	CH4	3585.62	2679.30	30.00	0.00139	0.41715	96.90587
1A	All Fuel	CH4	2077.99	1069.03	50.00	0.00135	0.40293	97.30880
1B	Oil & Natural Gas	CO2	5777.84	4388.43	17.09	0.00128	0.38288	97.69168
2B5	NEU	CO2	1562.92	1969.82	53.85	0.00109	0.32639	98.01807
5G	Other	CO2	-1727.33	-3985.06	30.02	0.00067	0.20107	98.21914
2A7	Fletton Bricks	CO2	539.42	530.66	72.80	0.00051	0.15229	98.37143
5B	Cropland	N2O	781.56	622.48	50.01	0.00051	0.15157	98.52300
1A3a	Aviation Fuel	CO2	1580.55	1990.63	20.27	0.00042	0.12424	98.64725
1A3b	Auto Fuel	CH4	634.83	71.41	50.08	0.00041	0.12329	98.77053
1A3	Other Diesel	N2O	191.40	282.12	140.01	0.00035	0.10392	98.87446
6C	Waste Incineration	CO2	1227.50	292.01	21.19	0.00034	0.10087	98.97532
5D	Wetlands	CO2	481.73	263.02	50.01	0.00031	0.09342	99.06875
2	Industrial Processes	SF6	1029.95	689.99	20.02	0.00027	0.07998	99.14873
4F	Field Burning	N2O	77.60	0.00	231.35	0.00023	0.06963	99.21836
2A1	Cement Production	CO2	7295.26	3792.01	2.42	0.00023	0.06837	99.28673
1A	Combined Fuel	CO2	801.51	867.86	21.21	0.00022	0.06594	99.35266
1A4	Peat	CO2	475.59	47.44	31.62	0.00020	0.05832	99.41098
4F	Field Burning	CH4	265.51	0.00	55.90	0.00019	0.05756	99.46854
2B	Ammonia Production	CO2	1431.17	978.43	10.11	0.00019	0.05612	99.52466
6B	Wastewater Handling	CH4	287.21	347.89	50.01	0.00019	0.05570	99.58036
2C1	Iron&Steel Production	CO2	2309.27	1747.34	6.12	0.00018	0.05480	99.63516
2	Industrial Processes	PFC	1401.60	220.47	10.05	0.00018	0.05462	99.68979
1A	Lubricant	CO2	386.90	225.28	30.07	0.00015	0.04511	99.73490
6C	Waste Incineration	N2O	47.90	47.25	230.11	0.00014	0.04275	99.77764
6C	Waste Incineration	CH4	134.43	6.25	50.49	0.00009	0.02632	99.80396
2A2	Lime Production	CO2	1206.41	233.70	5.10	0.00008	0.02386	99.82782
2A3	Limestone & Dolomite use	CO2	1125.28	920.77	5.10	0.00007	0.02225	99.85007
1B	Solid Fuel Transformation	CO2	856.42	219.64	6.01	0.00007	0.01997	99.87004
2B	Chemical Industry	CH4	169.43	73.50	28.28	0.00006	0.01858	99.88862
1B2	Oil & Natural Gas	N2O	42.40	46.17	111.16	0.00006	0.01828	99.90690
1A3d	Marine Fuel	CO2	2123.33	2264.57	2.20	0.00006	0.01813	99.92503
1A	Other (waste)	CO2	212.42	1660.57	21.19	0.00006	0.01746	99.94249
1A3	Other Diesel	CO2	1613.78	2370.91	2.20	0.00005	0.01378	99.95627
1A3d	Marine Fuel	N2O	16.56	17.64	170.01	0.00004	0.01092	99.96719
1A3a	Aviation Fuel	N2O	15.56	19.60	171.17	0.00003	0.01033	99.97752
2A7	Fletton Bricks	CH4	23.60	5.63	101.98	0.00003	0.00933	99.98685
2C	Iron & Steel	N2O	11.11	6.72	118.00	0.00002	0.00508	99.99194
2C	Iron & Steel Production	CH4	16.36	11.81	50.00	0.00001	0.00317	99.99511
1B1	Coke Oven Gas	N2O	2.08	1.38	118.00	0.00000	0.00095	99.99606
5E2	Land converted to settlements	CH4	9.96	8.30	20.02	0.00000	0.00077	99.99683
1A3a	Aviation Fuel	CH4	3.30	1.11	53.85	0.00000	0.00069	99.99752
1A3	Other Diesel	CH4	3.11	3.78	50.03	0.00000	0.00060	99.99813
5A	Forest Land	N2O	5.57	1.92	20.02	0.00000	0.00043	99.99856
1A3d	Marine Fuel	CH4	1.85	3.91	50.03	0.00000	0.00036	99.99892
5A	Forest Land	CH4	4.30	8.17	20.02	0.00000	0.00033	99.99925
5D	Wetlands	N2O	3.98	0.50	20.02	0.00000	0.00031	99.99956
5C2	Land converted to grassland	CH4	3.90	11.74	20.02	0.00000	0.00030	99.99986
5E2	Land converted to settlements	N2O	1.01	0.84	20.02	0.00000	0.00008	99.99994
5C2	Land converted to grassland	N2O	0.40	1.19	20.02	0.00000	0.00003	99.99997
5B	Cropland	CH4	0.14	0.39	50.01	0.00000	0.00003	100.00000
1A3c	Coal	CO2	0.00	49.62	6.01	0.00000	0.00000	100.00000
1A4	Combined Fuel	CO2	0.00	0.00	21.21	0.00000	0.00000	100.00000
2A4	Soda Ash Use	CO2	0.00	0.00	15.13	0.00000	0.00000	100.00000
1A3c	Coal	CH4	0.00	0.99	50.00	0.00000	0.00000	100.00000
1A3c	Coal	N2O	0.00	0.12	118.00	0.00000	0.00000	100.00000
4G	OvTerr Agriculture N2O (all)	N2O	0.00	0.00	50.99	0.00000	0.00000	100.00000
5G	Other	N2O	0.00	0.00	50.01	0.00000	0.00000	100.00000
		Sum -->	771,152.71	590,177.13		0.3344	100.00	

Table A 1.1.4 Key Category Analysis for 1990 based on level of emissions (excluding LULUCF)

IPCC category	Source category	Gas	Emissions Gg CO2 equiv. 1990	Year Y emissions Gg CO2 equiv. 2010	Combined uncertainty range as a % of source category	Level Parameter (used to order sources)	Level / Sum(Level)*100 %	Cumulative %
4D	Agricultural Soils	N2O	32825.07	26385.59	424.00	0.18140	58.50020	
6A	Solid Waste Disposal	CH4	43143.47	14767.00	48.38	0.02721	8.77406	67.27425
1A(stationary)	Oil	CO2	92867.52	53505.95	15.13	0.01832	5.90699	73.18124
1A1&1A2&1A4&1A5	Other Combustion	N2O	4829.07	3122.22	195.00	0.01227	3.95807	77.13932
2B	Nitric Acid Production	N2O	3903.85	1316.57	230.22	0.01171	3.77760	80.91691
4B	Manure Management	N2O	2053.05	1750.56	414.00	0.01108	3.57261	84.48953
1A3b	Auto Fuel	CO2	108564.64	111579.17	4.48	0.00634	2.04533	86.53485
6B	Wastewater Handling	N2O	1164.86	1151.57	401.12	0.00609	1.96398	88.49883
4A	Enteric Fermentation	CH4	18694.63	15385.93	20.00	0.00487	1.57158	90.07041
2B	Adipic Acid Production	N2O	20737.34	0.00	15.01	0.00406	1.30819	91.37860
1A	Coal	CO2	247785.08	114863.47	1.08	0.00348	1.12173	92.50033
1B1	Mining & Solid Fuel Transformation	CH4	18281.71	1799.47	102.37	0.00310	1.00005	93.50038
2	Industrial Processes	HFC	11385.62	14314.07	19.03	0.00282	0.91053	94.41092
1A3b	Auto Fuel	N2O	1179.78	847.95	170.02	0.00261	0.84313	95.25405
1B2	Production, Refining & Distribution of Oil & Natu	CH4	10322.92	5191.29	26.01	0.00227	0.73309	95.98713
1A	Natural Gas	CO2	108956.17	197884.94	1.51	0.00215	0.69303	96.68017
4B	Manure Management	CH4	3585.62	2679.30	30.00	0.00140	0.45214	97.13231
1A	All Fuel	CH4	2077.99	1069.03	50.00	0.00135	0.43673	97.56904
1B	Oil & Natural Gas	CO2	5777.84	4388.43	17.09	0.00129	0.41499	97.98403
2B5	NEU	CO2	1562.92	1969.82	53.85	0.00110	0.35377	98.33780
2A7	Fletton Bricks	CO2	539.42	530.66	72.80	0.00051	0.16506	98.50286
1A3a	Aviation Fuel	CO2	1580.55	1990.63	20.27	0.00042	0.13467	98.63753
1A3b	Auto Fuel	CH4	634.83	71.41	50.08	0.00041	0.13363	98.77115
1A3	Other Diesel	N2O	191.40	282.12	140.01	0.00035	0.11264	98.88379
6C	Waste Incineration	CO2	1227.50	292.01	21.19	0.00034	0.10933	98.99312
2	Industrial Processes	SF6	1029.95	689.99	20.02	0.00027	0.08669	99.07981
4F	Field Burning	N2O	77.60	0.00	231.35	0.00023	0.07547	99.15528
2A1	Cement Production	CO2	7295.26	3792.01	2.42	0.00023	0.07410	99.22938
1A	Combined Fuel	CO2	801.51	867.86	21.21	0.00022	0.07147	99.30085
1A4	Peat	CO2	475.59	47.44	31.62	0.00020	0.06321	99.36406
4F	Field Burning	CH4	265.51	0.00	55.90	0.00019	0.06239	99.42645
2B	Ammonia Production	CO2	1431.17	978.43	10.11	0.00019	0.06083	99.48727
6B	Wastewater Handling	CH4	287.21	347.89	50.01	0.00019	0.06037	99.54765
2C1	Iron&Steel Production	CO2	2309.27	1747.34	6.12	0.00018	0.05939	99.60704
2	Industrial Processes	PFC	1401.60	220.47	10.05	0.00018	0.05921	99.66625
1A	Lubricant	CO2	386.90	225.28	30.07	0.00015	0.04889	99.71514
6C	Waste Incineration	N2O	47.90	47.25	230.11	0.00014	0.04633	99.76147
6C	Waste Incineration	CH4	134.43	6.25	50.49	0.00009	0.02853	99.79000
2A2	Lime Production	CO2	1206.41	233.70	5.10	0.00008	0.02586	99.81586
2A3	Limestone & Dolomite use	CO2	1125.28	920.77	5.10	0.00007	0.02412	99.83997
1B	Solid Fuel Transformation	CO2	856.42	219.64	6.01	0.00007	0.02165	99.86162
2B	Chemical Industry	CH4	169.43	73.50	28.28	0.00006	0.02014	99.88176
1B2	Oil & Natural Gas	N2O	42.40	46.17	111.16	0.00006	0.01981	99.90157
1A3d	Marine Fuel	CO2	2123.33	2264.57	2.20	0.00006	0.01966	99.92123
1A	Other (waste)	CO2	212.42	1660.57	21.19	0.00006	0.01892	99.94015
1A3	Other Diesel	CO2	1613.78	2370.91	2.20	0.00005	0.01494	99.95508
1A3d	Marine Fuel	N2O	16.56	17.64	170.01	0.00004	0.01183	99.96692
1A3a	Aviation Fuel	N2O	15.56	19.60	171.17	0.00003	0.01119	99.97811
2A7	Fletton Bricks	CH4	23.60	5.63	101.98	0.00003	0.01012	99.98823
2C	Iron & Steel	N2O	11.11	6.72	118.00	0.00002	0.00551	99.99374
2C	Iron & Steel Production	CH4	16.36	11.81	50.00	0.00001	0.00344	99.99718
1B1	Coke Oven Gas	N2O	2.08	1.38	118.00	0.00000	0.00103	99.99821
1A3a	Aviation Fuel	CH4	3.30	1.11	53.85	0.00000	0.00075	99.99896
1A3	Other Diesel	CH4	3.11	3.78	50.03	0.00000	0.00065	99.99961
1A3d	Marine Fuel	CH4	1.85	3.91	50.03	0.00000	0.00039	100.00000
1A3c	Coal	CO2	0.00	49.62	6.01	0.00000	0.00000	100.00000
1A4	Combined Fuel	CO2	0.00	0.00	21.21	0.00000	0.00000	100.00000
2A4	Soda Ash Use	CO2	0.00	0.00	15.13	0.00000	0.00000	100.00000
5A	Forest land	CO2	0.00	0.00	25.02	0.00000	0.00000	100.00000
5B	Cropland	CO2	0.00	0.00	50.01	0.00000	0.00000	100.00000
5C	Grassland	CO2	0.00	0.00	70.01	0.00000	0.00000	100.00000
5D	Wetlands	CO2	0.00	0.00	50.01	0.00000	0.00000	100.00000
5E	Settlements	CO2	0.00	0.00	50.01	0.00000	0.00000	100.00000
5G	Other	CO2	0.00	0.00	30.02	0.00000	0.00000	100.00000
1A3c	Coal	CH4	0.00	0.99	50.00	0.00000	0.00000	100.00000
5A	Forest land	CH4	0.00	0.00	20.02	0.00000	0.00000	100.00000
5B	Cropland	CH4	0.00	0.00	50.01	0.00000	0.00000	100.00000
5C2	Land converted to grassland	CH4	0.00	0.00	20.02	0.00000	0.00000	100.00000
5E2	Land converted to settlements	CH4	0.00	0.00	20.02	0.00000	0.00000	100.00000
1A3c	Coal	N2O	0.00	0.12	118.00	0.00000	0.00000	100.00000
4G	OvTerr Agriculture N2O (all)	N2O	0.00	0.00	50.99	0.00000	0.00000	100.00000
5A	Forest land	N2O	0.00	0.00	20.02	0.00000	0.00000	100.00000
5B	Cropland	N2O	0.00	0.00	50.01	0.00000	0.00000	100.00000
5C2	Land converted to grassland	N2O	0.00	0.00	20.02	0.00000	0.00000	100.00000
5D	Wetlands	N2O	0.00	0.00	20.02	0.00000	0.00000	100.00000
5E2	Land converted to settlements	N2O	0.00	0.00	20.02	0.00000	0.00000	100.00000
5G	Other	N2O	0.00	0.00	50.01	0.00000	0.00000	100.00000
		Sum -->	767,259.76	594,021.50		0.3101	100.00	

Table A 1.1.5 Key Category Analysis for the latest reported year based on level of emissions (including LULUCF)

IPCC category	Source category	Gas	Emissions Gg CO2 equiv. 1990	Year Y emissions Gg CO2 equiv. 2010	Combined uncertainty range as a % of source category	Level Parameter (used to order sources)	Level / Sum(Level)*100 %	Cumulative %
4D	Agricultural Soils	N2O	32825.07	26385.59	424.00	0.18956	58.49079	
1A(stationary)	Oil	CO2	92867.52	53505.95	15.13	0.01372	4.23324	62.72403
4B	Manure Management	N2O	2053.05	1750.56	414.00	0.01228	3.78907	66.51310
6A	Solid Waste Disposal	CH4	43143.47	14767.00	48.38	0.01211	3.73548	70.24858
1A1&1A2&1A4&1A5	Other Combustion	N2O	4829.07	3122.22	195.00	0.01032	3.18312	73.43170
5B	Cropland	CO2	15732.05	12115.71	50.01	0.01027	3.16781	76.59952
5C	Grassland	CO2	-6261.11	-8541.00	70.01	0.01013	3.12611	79.72563
1A3b	Auto Fuel	CO2	108564.64	111579.17	4.48	0.00847	2.61473	82.34036
6B	Wastewater Handling	N2O	1164.86	1151.57	401.12	0.00783	2.41502	84.75538
5E	Settlements	CO2	7011.87	6216.22	50.01	0.00527	1.62531	86.38069
4A	Enteric Fermentation	CH4	18694.63	15385.93	20.00	0.00521	1.60884	87.98953
2B	Nitric Acid Production	N2O	3903.85	1316.57	230.22	0.00514	1.58466	89.57419
1A	Natural Gas	CO2	108956.17	197884.94	1.51	0.00507	1.56561	91.13980
2	Industrial Processes	HFC	11385.62	14314.07	19.03	0.00461	1.42387	92.56367
5A	Forest land	CO2	-12155.07	-10568.81	25.02	0.00448	1.38250	93.94618
1A3b	Auto Fuel	N2O	1179.78	847.95	170.02	0.00244	0.75376	94.69994
1A	Coal	CO2	247785.08	114863.47	1.08	0.00210	0.64679	95.34673
5G	Other	CO2	-1727.33	-3985.06	30.02	0.00203	0.62539	95.97212
2B5	NEU	CO2	1562.92	1969.82	53.85	0.00180	0.55460	96.52672
1B2	Production, Refining & Distribution of Oil & Natural Gas	CH4	10322.92	5191.29	17.08	0.00150	0.46353	96.99025
4B	Manure Management	CH4	3585.62	2679.30	30.00	0.00136	0.42024	97.41049
1B	Oil & Natural Gas	CO2	5777.84	4388.43	17.09	0.00127	0.39206	97.80255
1A	All Fuel	CH4	2077.99	1069.03	50.00	0.00091	0.27946	98.08202
1A3a	Aviation Fuel	CO2	1580.55	1990.63	20.27	0.00068	0.21096	98.29298
1A3	Other Diesel	N2O	191.40	282.12	140.01	0.00067	0.20651	98.49949
2A7	Fletton Bricks	CO2	539.42	530.66	72.80	0.00065	0.20198	98.70147
1A	Other (waste)	CO2	212.42	1660.57	21.19	0.00060	0.18396	98.88544
5B	Cropland	N2O	781.56	622.48	50.01	0.00053	0.16275	99.04819
1B1	Mining & Solid Fuel Transformation	CH4	18281.71	1799.47	13.06	0.00040	0.12288	99.17107
1A	Combined Fuel	CO2	801.51	867.86	21.21	0.00031	0.09625	99.26732
6B	Wastewater Handling	CH4	287.21	347.89	50.01	0.00029	0.09096	99.35828
2	Industrial Processes	SF6	1029.95	689.99	20.02	0.00023	0.07224	99.43052
5D	Wetlands	CO2	481.73	263.02	50.01	0.00022	0.06877	99.49929
6C	Waste Incineration	N2O	47.90	47.25	230.11	0.00018	0.05684	99.55613
2C1	Iron&Steel Production	CO2	2309.27	1747.34	6.12	0.00018	0.05590	99.61203
2B	Ammonia Production	CO2	1431.17	978.43	10.11	0.00017	0.05173	99.66376
2A1	Cement Production	CO2	7295.26	3792.01	2.42	0.00016	0.04791	99.71167
1A	Lubricant	CO2	386.90	225.28	30.07	0.00011	0.03541	99.74708
6C	Waste Incineration	CO2	1227.50	292.01	21.19	0.00010	0.03235	99.77943
1A3	Other Diesel	CO2	1613.78	2370.91	2.20	0.00009	0.02730	99.80673
1B2	Oil & Natural Gas	N2O	42.40	46.17	111.16	0.00009	0.02683	99.83356
1A3d	Marine Fuel	CO2	2123.33	2264.57	2.20	0.00008	0.02607	99.85964
2A3	Limestone & Dolomite use	CO2	1125.28	920.77	5.10	0.00008	0.02455	99.88418
1A3b	Auto Fuel	CH4	634.83	71.41	50.08	0.00006	0.01870	99.90288
1A3a	Aviation Fuel	N2O	15.56	19.60	171.17	0.00006	0.01754	99.92042
1A3d	Marine Fuel	N2O	16.56	17.64	170.01	0.00005	0.01568	99.93610
2	Industrial Processes	PFC	1401.60	220.47	10.05	0.00004	0.01158	99.94768
2B	Chemical Industry	CH4	169.43	73.50	28.28	0.00004	0.01087	99.95855
1A4	Peat	CO2	475.59	47.44	31.62	0.00003	0.00784	99.96639
1B	Solid Fuel Transformation	CO2	856.42	219.64	6.01	0.00002	0.00691	99.97330
2A2	Lime Production	CO2	1206.41	233.70	5.10	0.00002	0.00623	99.97953
2C	Iron & Steel	N2O	11.11	6.72	118.00	0.00001	0.00414	99.98367
2C	Iron & Steel Production	CH4	16.36	11.81	50.00	0.00001	0.00309	99.98676
2A7	Fletton Bricks	CH4	23.60	5.63	101.98	0.00001	0.00300	99.98976
6C	Waste Incineration	CH4	134.43	6.25	50.49	0.00001	0.00165	99.99141
1A3c	Coal	CO2	0.00	49.62	6.01	0.00001	0.00156	99.99297
5C2	Land converted to grassland	CH4	3.90	11.74	20.02	0.00000	0.00123	99.99420
1A3d	Marine Fuel	CH4	1.85	3.91	50.03	0.00000	0.00102	99.99523
1A3	Other Diesel	CH4	3.11	3.78	50.03	0.00000	0.00099	99.99621
5E2	Land converted to settlements	CH4	9.96	8.30	20.02	0.00000	0.00087	99.99708
5A	Forest land	CH4	4.30	8.17	20.02	0.00000	0.00086	99.99794
1B1	Coke Oven Gas	N2O	2.08	1.38	118.00	0.00000	0.00085	99.99879
1A3a	Aviation Fuel	CH4	3.30	1.11	53.85	0.00000	0.00031	99.99910
1A3c	Coal	CH4	0.00	0.99	50.00	0.00000	0.00026	99.99936
5A	Forest land	N2O	5.57	1.92	20.02	0.00000	0.00020	99.99956
5C2	Land converted to grassland	N2O	0.40	1.19	20.02	0.00000	0.00012	99.99968
5B	Cropland	CH4	0.14	0.39	50.01	0.00000	0.00010	99.99979
5E2	Land converted to settlements	N2O	1.01	0.84	20.02	0.00000	0.00009	99.99988
1A3c	Coal	N2O	0.00	0.12	118.00	0.00000	0.00007	99.99995
5D	Wetlands	N2O	3.98	0.50	20.02	0.00000	0.00005	100.00000
1A4	Combined Fuel	CO2	0.00	0.00	21.21	0.00000	0.00000	100.00000
2A4	Soda Ash Use	CO2	0.00	0.00	15.13	0.00000	0.00000	100.00000
4F	Field Burning	CH4	265.51	0.00	55.90	0.00000	0.00000	100.00000
2B	Adipic Acid Production	N2O	20737.34	0.00	15.01	0.00000	0.00000	100.00000
4F	Field Burning	N2O	77.60	0.00	231.35	0.00000	0.00000	100.00000
4G	OvTerr Agriculture N2O (all)	N2O	0.00	0.00	50.99	0.00000	0.00000	100.00000
5G	Other	N2O	0.00	0.00	50.01	0.00000	0.00000	100.00000
		Sum -->	771,152.71	590,177.13		0.32	100.00	

Table A 1.1.6 Key Category Analysis for the latest reported year based on level of emissions (excluding LULUCF)

IPCC category	Source category	Gas	Emissions Gg CO2 equiv. 1990	Year Y emissions Gg CO2 equiv. 2010	Combined uncertainty range as a % of source category	Level Parameter (used to order sources)	Level / Sum(Level)*100 %	Cumulative %
4D	Agricultural Soils	N2O	32825.07	26385.59	424.00	0.18834	65.10709	
1A(stationary)	Oil	CO2	92867.52	53505.95	15.13	0.01363	4.71210	69.81918
4B	Manure Management	N2O	2053.05	1750.56	414.00	0.01220	4.21768	74.03686
6A	Solid Waste Disposal	CH4	43143.47	14767.00	48.38	0.01203	4.15803	78.19489
1A1&1A2&1A4&1A5	Other Combustion	N2O	4829.07	3122.22	195.00	0.01025	3.54319	81.73807
1A3b	Auto Fuel	CO2	108564.64	111579.17	4.48	0.00842	2.91050	84.64857
6B	Wastewater Handling	N2O	1164.86	1151.57	401.12	0.00778	2.68821	87.33678
4A	Enteric Fermentation	CH4	18694.63	15385.93	20.00	0.00518	1.79083	89.12760
2B	Nitric Acid Production	N2O	3903.85	1316.57	230.22	0.00510	1.76391	90.89151
1A	Natural Gas	CO2	108956.17	197884.94	1.51	0.00504	1.74271	92.63422
2	Industrial Processes	HFC	11385.62	14314.07	19.03	0.00458	1.58494	94.21916
1A3b	Auto Fuel	N2O	1179.78	847.95	170.02	0.00243	0.83902	95.05818
1A	Coal	CO2	247785.08	114863.47	1.08	0.00208	0.71995	95.77813
2B5	NEU	CO2	1562.92	1969.82	53.85	0.00179	0.61733	96.39547
1B2	Production, Refining & Distribution of Oil & Natural Gas	CH4	10322.92	5191.29	17.08	0.00149	0.51596	96.91143
4B	Manure Management	CH4	3585.62	2679.30	30.00	0.00135	0.46778	97.37921
1B	Oil & Natural Gas	CO2	5777.84	4388.43	17.09	0.00126	0.43641	97.81562
1A	All Fuel	CH4	2077.99	1069.03	50.00	0.00090	0.31108	98.12669
1A3a	Aviation Fuel	CO2	1580.55	1990.63	20.27	0.00068	0.23483	98.36152
1A3	Other Diesel	N2O	191.40	282.12	140.01	0.00066	0.22987	98.59140
2A7	Fletton Bricks	CO2	539.42	530.66	72.80	0.00065	0.22483	98.81622
1A	Other (waste)	CO2	212.42	1660.57	21.19	0.00059	0.20477	99.02099
1B1	Mining & Solid Fuel Transformation	CH4	18281.71	1799.47	13.06	0.00040	0.13678	99.15777
1A	Combined Fuel	CO2	801.51	867.86	21.21	0.00031	0.10714	99.26491
6B	Wastewater Handling	CH4	287.21	347.89	50.01	0.00029	0.10125	99.36616
2	Industrial Processes	SF6	1029.95	689.99	20.02	0.00023	0.08041	99.44657
6C	Waste Incineration	N2O	47.90	47.25	230.11	0.00018	0.06327	99.50984
2C1	Iron&Steel Production	CO2	2309.27	1747.34	6.12	0.00018	0.06222	99.57207
2B	Ammonia Production	CO2	1431.17	978.43	10.11	0.00017	0.05758	99.62964
2A1	Cement Production	CO2	7295.26	3792.01	2.42	0.00015	0.05333	99.68297
1A	Lubricant	CO2	386.90	225.28	30.07	0.00011	0.03942	99.72239
6C	Waste Incineration	CO2	1227.50	292.01	21.19	0.00010	0.03601	99.75840
1A3	Other Diesel	CO2	1613.78	2370.91	2.20	0.00009	0.03039	99.78879
1B2	Oil & Natural Gas	N2O	42.40	46.17	111.16	0.00009	0.02987	99.81866
1A3d	Marine Fuel	CO2	2123.33	2264.57	2.20	0.00008	0.02902	99.84768
2A3	Limestone & Dolomite use	CO2	1125.28	920.77	5.10	0.00008	0.02732	99.87500
1A3b	Auto Fuel	CH4	634.83	71.41	50.08	0.00006	0.02081	99.89582
1A3a	Aviation Fuel	N2O	15.56	19.60	171.17	0.00006	0.01952	99.91534
1A3d	Marine Fuel	N2O	16.56	17.64	170.01	0.00005	0.01745	99.93279
2	Industrial Processes	PFC	1401.60	220.47	10.05	0.00004	0.01289	99.94569
2B	Chemical Industry	CH4	169.43	73.50	28.28	0.00003	0.01210	99.95778
1A4	Peat	CO2	475.59	47.44	31.62	0.00003	0.00873	99.96651
1B	Solid Fuel Transformation	CO2	856.42	219.64	6.01	0.00002	0.00769	99.97420
2A2	Lime Production	CO2	1206.41	233.70	5.10	0.00002	0.00694	99.98113
2C	Iron & Steel	N2O	11.11	6.72	118.00	0.00001	0.00461	99.98575
2C	Iron & Steel Production	CH4	16.36	11.81	50.00	0.00001	0.00344	99.98918
2A7	Fletton Bricks	CH4	23.60	5.63	101.98	0.00001	0.00334	99.99253
6C	Waste Incineration	CH4	134.43	6.25	50.49	0.00001	0.00184	99.99436
1A3c	Coal	CO2	0.00	49.62	6.01	0.00001	0.00174	99.99610
1A3d	Marine Fuel	CH4	1.85	3.91	50.03	0.00000	0.00114	99.99724
1A3	Other Diesel	CH4	3.11	3.78	50.03	0.00000	0.00110	99.99834
1B1	Coke Oven Gas	N2O	2.08	1.38	118.00	0.00000	0.00095	99.99928
1A3a	Aviation Fuel	CH4	3.30	1.11	53.85	0.00000	0.00035	99.99963
1A3c	Coal	CH4	0.00	0.99	50.00	0.00000	0.00029	99.99992
1A3c	Coal	N2O	0.00	0.12	118.00	0.00000	0.00008	100.00000
1A4	Combined Fuel	CO2	0.00	0.00	21.21	0.00000	0.00000	100.00000
2A4	Soda Ash Use	CO2	0.00	0.00	15.13	0.00000	0.00000	100.00000
5A	Forest land	CO2	0.00	0.00	25.02	0.00000	0.00000	100.00000
5B	Cropland	CO2	0.00	0.00	50.01	0.00000	0.00000	100.00000
5C	Grassland	CO2	0.00	0.00	70.01	0.00000	0.00000	100.00000
5D	Wetlands	CO2	0.00	0.00	50.01	0.00000	0.00000	100.00000
5E	Settlements	CO2	0.00	0.00	50.01	0.00000	0.00000	100.00000
5G	Other	CO2	0.00	0.00	30.02	0.00000	0.00000	100.00000
4F	Field Burning	CH4	265.51	0.00	55.90	0.00000	0.00000	100.00000
5A	Forest land	CH4	0.00	0.00	20.02	0.00000	0.00000	100.00000
5B	Cropland	CH4	0.00	0.00	50.01	0.00000	0.00000	100.00000
5C2	Land converted to grassland	CH4	0.00	0.00	20.02	0.00000	0.00000	100.00000
5E2	Land converted to settlements	CH4	0.00	0.00	20.02	0.00000	0.00000	100.00000
2B	Adipic Acid Production	N2O	20737.34	0.00	15.01	0.00000	0.00000	100.00000
4F	Field Burning	N2O	77.60	0.00	231.35	0.00000	0.00000	100.00000
4G	OvTerr Agriculture N2O (all)	N2O	0.00	0.00	50.99	0.00000	0.00000	100.00000
5A	Forest land	N2O	0.00	0.00	20.02	0.00000	0.00000	100.00000
5B	Cropland	N2O	0.00	0.00	50.01	0.00000	0.00000	100.00000
5C2	Land converted to grassland	N2O	0.00	0.00	20.02	0.00000	0.00000	100.00000
5D	Wetlands	N2O	0.00	0.00	20.02	0.00000	0.00000	100.00000
5E2	Land converted to settlements	N2O	0.00	0.00	20.02	0.00000	0.00000	100.00000
5G	Other	N2O	0.00	0.00	50.01	0.00000	0.00000	100.00000
		Sum -->	767,259.76	594,021.50		0.29	100.00	

Table A 1.1.7 Key Category Analysis based on trend in emissions (from base year to latest reported year, including LULUCF)

IPCC category	Source category	Gas	Base year emissions Gg CO2 equiv. 1990 & 1995	Year Y emissions Gg CO2 equiv. 2010	Combined uncertainty range as a % of source category	Trend Parameter (used to order sources)	Trend / Sum(Trend)*100 %	Cumulative %
4D	Agricultural Soils	N2O	32825.07	26385.59	424.00	0.05468	49.48703	
2B	Nitric Acid Production	N2O	3903.85	1316.57	230.22	0.01954	17.68764	67.17468
6B	Wastewater Handling	N2O	1164.86	1151.57	401.12	0.00944	8.53920	75.71387
6A	Solid Waste Disposal	CH4	43143.47	14767.00	48.38	0.00943	8.53195	84.24582
4B	Manure Management	N2O	2053.05	1750.56	414.00	0.00708	6.40864	90.65446
1A1&1A2&1A4&1A5	Other Combustion	N2O	4829.07	3122.22	195.00	0.00472	4.27071	94.92516
1A(stationary)	Oil	CO2	92867.52	53505.95	15.13	0.00088	0.79581	95.72097
1A3	Other Diesel	N2O	191.40	282.12	140.01	0.00059	0.53736	96.25833
2B5	NEU	CO2	1562.92	1969.82	53.85	0.00050	0.45432	96.71265
5E	Settlements	CO2	7011.87	6216.22	50.01	0.00048	0.43887	97.15152
1B1	Mining & Solid Fuel Transformation	CH4	18281.71	1799.47	13.06	0.00046	0.41316	97.56468
1A3b	Auto Fuel	N2O	1179.78	847.95	170.02	0.00033	0.29786	97.86254
1A	All Fuel	CH4	2077.99	1069.03	50.00	0.00029	0.25890	98.12145
1A3b	Auto Fuel	CH4	634.83	71.41	50.08	0.00023	0.20809	98.32954
2	Industrial Processes	HFC	15327.65	14314.07	19.03	0.00021	0.19171	98.52125
1B2	Production, Refining & Distribution of Oil & Natural Gas	CH4	10322.92	5191.29	17.08	0.00017	0.15467	98.67593
1A	Other (waste)	CO2	212.42	1660.57	21.19	0.00015	0.13539	98.81131
2A7	Fletton Bricks	CO2	539.42	530.66	72.80	0.00014	0.12747	98.93878
1A3b	Auto Fuel	CO2	108564.64	111579.17	4.48	0.00013	0.11656	99.05535
6C	Waste Incineration	N2O	47.90	47.25	230.11	0.00013	0.11441	99.16976
4A	Enteric Fermentation	CH4	18694.63	15385.93	20.00	0.00010	0.09158	99.26134
1A3a	Aviation Fuel	CO2	1580.55	1990.63	20.27	0.00007	0.06498	99.32632
6B	Wastewater Handling	CH4	287.21	347.89	50.01	0.00007	0.06491	99.39123
1A4	Peat	CO2	475.59	47.44	31.62	0.00007	0.06338	99.45461
5B	Cropland	CO2	15732.05	12115.71	50.01	0.00007	0.06321	99.51783
6C	Waste Incineration	CO2	1227.50	292.01	21.19	0.00006	0.05813	99.57596
1A	Natural Gas	CO2	108956.17	197884.94	1.51	0.00006	0.05291	99.62887
5D	Wetlands	CO2	481.73	263.02	50.01	0.00006	0.05240	99.68127
6C	Waste Incineration	CH4	134.43	6.25	50.49	0.00005	0.04934	99.73061
1A3a	Aviation Fuel	N2O	15.56	19.60	171.17	0.00005	0.04561	99.77623
1B2	Oil & Natural Gas	N2O	42.40	46.17	111.16	0.00004	0.03446	99.81069
1A3d	Marine Fuel	N2O	16.56	17.64	170.01	0.00003	0.02918	99.83987
2A7	Fletton Bricks	CH4	23.60	5.63	101.98	0.00003	0.02585	99.86572
1A	Combined Fuel	CO2	801.51	867.86	21.21	0.00003	0.02327	99.88899
2	Industrial Processes	SF6	1239.30	689.99	20.02	0.00002	0.02054	99.90953
1A	Coal	CO2	247785.08	114863.47	1.08	0.00002	0.01727	99.92680
5B	Cropland	N2O	781.56	622.48	50.01	0.00001	0.01349	99.94029
1A	Lubricant	CO2	386.90	225.28	30.07	0.00001	0.01266	99.95295
4B	Manure Management	CH4	3585.62	2679.30	30.00	0.00001	0.00968	99.96263
2B	Chemical Industry	CH4	169.43	73.50	28.28	0.00001	0.00895	99.97158
2C	Iron & Steel	N2O	11.11	6.72	118.00	0.00001	0.00490	99.97648
2A2	Lime Production	CO2	1206.41	233.70	5.10	0.00000	0.00359	99.98007
1B	Solid Fuel Transformation	CO2	856.42	219.64	6.01	0.00000	0.00315	99.98322
2	Industrial Processes	PFC	461.81	220.47	10.05	0.00000	0.00267	99.98589
2B	Ammonia Production	CO2	1431.17	978.43	10.11	0.00000	0.00231	99.98820
2A1	Cement Production	CO2	7295.26	3792.01	2.42	0.00000	0.00208	99.99028
1A3d	Marine Fuel	CH4	1.85	3.91	50.03	0.00000	0.00126	99.99154
1A3	Other Diesel	CO2	1613.78	2370.91	2.20	0.00000	0.00111	99.99265
1B	Oil & Natural Gas	CO2	5777.84	4388.43	17.09	0.00000	0.00089	99.99354
1A3a	Aviation Fuel	CH4	3.30	1.11	53.85	0.00000	0.00082	99.99436
1A3	Other Diesel	CH4	3.11	3.78	50.03	0.00000	0.00071	99.99507
5C2	Land converted to grassland	CH4	3.90	11.74	20.02	0.00000	0.00071	99.99577
1A3d	Marine Fuel	CO2	2123.33	2264.57	2.20	0.00000	0.00063	99.99640
1B1	Coke Oven Gas	N2O	2.08	1.38	118.00	0.00000	0.00059	99.99699
1A3c	Coal	CH4	0.00	0.99	50.00	0.00000	0.00050	99.99749
5A	Forest land	CH4	4.30	8.17	20.02	0.00000	0.00040	99.99789
1A3c	Coal	CO2	0.00	49.62	6.01	0.00000	0.00036	99.99825
2A3	Limestone & Dolomite use	CO2	1125.28	920.77	5.10	0.00000	0.00033	99.99858
2C	Iron & Steel Production	CH4	16.36	11.81	50.00	0.00000	0.00033	99.99891
1A3c	Coal	N2O	0.00	0.12	118.00	0.00000	0.00033	99.99923
5D	Wetlands	N2O	3.98	0.50	20.02	0.00000	0.00020	99.99944
5A	Forest land	N2O	5.57	1.92	20.02	0.00000	0.00019	99.99962
5B	Cropland	CH4	0.14	0.39	50.01	0.00000	0.00015	99.99977
2C1	Iron&Steel Production	CO2	2309.27	1747.34	6.12	0.00000	0.00010	99.99987
5C2	Land converted to grassland	N2O	0.40	1.19	20.02	0.00000	0.00007	99.99994
5E2	Land converted to settlements	CH4	9.96	8.30	20.02	0.00000	0.00006	99.99999
5E2	Land converted to settlements	N2O	1.01	0.84	20.02	0.00000	0.00001	100.00000
1A4	Combined Fuel	CO2	0.00	0.00	21.21	0.00000	0.00000	100.00000
2A4	Soda Ash Use	CO2	0.00	0.00	15.13	0.00000	0.00000	100.00000
5A	Forest land	CO2	-12155.07	-10568.81	25.02	0.00000	0.00000	100.00000
5C	Grassland	CO2	-6261.11	-8541.00	70.01	0.00000	0.00000	100.00000
5G	Other	CO2	-1727.33	-3985.06	30.02	0.00000	0.00000	100.00000
4F	Field Burning	CH4	265.51	0.00	55.90	0.00000	0.00000	100.00000
2B	Adipic Acid Production	N2O	20737.34	0.00	15.01	0.00000	0.00000	100.00000
4F	Field Burning	N2O	77.60	0.00	231.35	0.00000	0.00000	100.00000
4G	OvTerr Agriculture N2O (all)	N2O	0.00	0.00	50.99	0.00000	0.00000	100.00000
5G	Other	N2O	0.00	0.00	50.01	0.00000	0.00000	100.00000
		Sum -->	774,364.31	590,177.13		0.11	100.00	

Table A 1.1.8 Key Category Analysis based on the trend in emissions (from base year to latest reported year, excluding LULUCF)

IPCC category	Source category	Gas	Base year emissions Gg CO2 equiv. 1990 & 1995	Year Y emissions Gg CO2 equiv. 2010	Combined uncertainty range as a % of source category	Trend Parameter (used to order sources)	Trend / Sum(Trend)*100 %	Cumulative %
4D	Agricultural Soils	N2O	32825.07	26385.59	424.00	0.04231	43.84539	
2B	Nitric Acid Production	N2O	3903.85	1316.57	230.22	0.01960	20.30373	64.14912
6A	Solid Waste Disposal	CH4	43143.47	14767.00	48.38	0.00945	9.79626	73.94538
6B	Wastewater Handling	N2O	1164.86	1151.57	401.12	0.00891	9.22752	83.17289
4B	Manure Management	N2O	2053.05	1750.56	414.00	0.00628	6.50274	89.67564
1A1&1A2&1A4&1A5	Other Combustion	N2O	4829.07	3122.22	195.00	0.00499	5.16972	94.84536
1A(stationary)	Oil	CO2	92867.52	53505.95	15.13	0.00090	0.93743	95.78279
1A3	Other Diesel	N2O	191.40	282.12	140.01	0.00058	0.59676	96.37955
2B5	NEU	CO2	1562.92	1969.82	53.85	0.00048	0.50182	96.88137
1B1	Mining & Solid Fuel Transformation	CH4	18281.71	1799.47	13.06	0.00045	0.47080	97.35217
1A3b	Auto Fuel	N2O	1179.78	847.95	170.02	0.00039	0.40316	97.75534
1A	All Fuel	CH4	2077.99	1069.03	50.00	0.00029	0.30153	98.05687
1A3b	Auto Fuel	CH4	634.83	71.41	50.08	0.00023	0.23719	98.29406
2	Industrial Processes	HFC	15327.65	14314.07	19.03	0.00020	0.20448	98.49854
1B2	Production, Refining & Distribution of Oil & Natural Gas	CH4	10322.92	5191.29	17.08	0.00017	0.18016	98.67870
1A	Other (waste)	CO2	212.42	1660.57	21.19	0.00015	0.15205	98.83075
2A7	Fletton Bricks	CO2	539.42	530.66	72.80	0.00013	0.13763	98.96838
1A3b	Auto Fuel	CO2	108564.64	111579.17	4.48	0.00012	0.12671	99.09509
6C	Waste Incineration	N2O	47.90	47.25	230.11	0.00012	0.12359	99.21868
4A	Enteric Fermentation	CH4	18694.63	15385.93	20.00	0.00008	0.08803	99.30670
1A4	Peat	CO2	475.59	47.44	31.62	0.00007	0.07223	99.37893
1A3a	Aviation Fuel	CO2	1580.55	1990.63	20.27	0.00007	0.07177	99.45070
6B	Wastewater Handling	CH4	287.21	347.89	50.01	0.00007	0.07156	99.52226
6C	Waste Incineration	CO2	1227.50	292.01	21.19	0.00006	0.06648	99.58873
1A	Natural Gas	CO2	108956.17	197884.94	1.51	0.00006	0.05900	99.64773
6C	Waste Incineration	CH4	134.43	6.25	50.49	0.00005	0.05617	99.70390
1A3a	Aviation Fuel	N2O	15.56	19.60	171.17	0.00005	0.05038	99.75429
1B2	Oil & Natural Gas	N2O	42.40	46.17	111.16	0.00004	0.03771	99.79199
1A3d	Marine Fuel	N2O	16.56	17.64	170.01	0.00003	0.03186	99.82385
2A7	Fletton Bricks	CH4	23.60	5.63	101.98	0.00003	0.02956	99.85341
1A	Combined Fuel	CO2	801.51	867.86	21.21	0.00002	0.02544	99.87886
2	Industrial Processes	SF6	1239.30	689.99	20.02	0.00002	0.02409	99.90294
1A	Coal	CO2	247785.08	114863.47	1.08	0.00002	0.01999	99.92293
4B	Manure Management	CH4	3585.62	2679.30	30.00	0.00002	0.01734	99.94027
1A	Lubricant	CO2	386.90	225.28	30.07	0.00001	0.01493	99.95521
2B	Chemical Industry	CH4	169.43	73.50	28.28	0.00001	0.01034	99.96555
2C	Iron & Steel	N2O	11.11	6.72	118.00	0.00001	0.00582	99.97136
1B	Oil & Natural Gas	CO2	5777.84	4388.43	17.09	0.00000	0.00437	99.97574
2A2	Lime Production	CO2	1206.41	233.70	5.10	0.00000	0.00410	99.97983
1B	Solid Fuel Transformation	CO2	856.42	219.64	6.01	0.00000	0.00360	99.98344
2	Industrial Processes	PFC	461.81	220.47	10.05	0.00000	0.00310	99.98654
2B	Ammonia Production	CO2	1431.17	978.43	10.11	0.00000	0.00289	99.98943
2A1	Cement Production	CO2	7295.26	3792.01	2.42	0.00000	0.00242	99.99185
1A3d	Marine Fuel	CH4	1.85	3.91	50.03	0.00000	0.00141	99.99326
1A3	Other Diesel	CO2	1613.78	2370.91	2.20	0.00000	0.00124	99.99449
1A3a	Aviation Fuel	CH4	3.30	1.11	53.85	0.00000	0.00094	99.99543
1A3	Other Diesel	CH4	3.11	3.78	50.03	0.00000	0.00078	99.99621
1B1	Coke Oven Gas	N2O	2.08	1.38	118.00	0.00000	0.00072	99.99694
1A3d	Marine Fuel	CO2	2123.33	2264.57	2.20	0.00000	0.00069	99.99762
1A3c	Coal	CH4	0.00	0.99	50.00	0.00000	0.00056	99.99818
2C	Iron & Steel Production	CH4	16.36	11.81	50.00	0.00000	0.00045	99.99863
1A3c	Coal	CO2	0.00	49.62	6.01	0.00000	0.00041	99.99904
1A3c	Coal	N2O	0.00	0.12	118.00	0.00000	0.00037	99.99941
2A3	Limestone & Dolomite use	CO2	1125.28	920.77	5.10	0.00000	0.00031	99.99972
2C1	Iron&Steel Production	CO2	2309.27	1747.34	6.12	0.00000	0.00028	100.00000
1A4	Combined Fuel	CO2	0.00	0.00	21.21	0.00000	0.00000	100.00000
2A4	Soda Ash Use	CO2	0.00	0.00	15.13	0.00000	0.00000	100.00000
5A	Forest land	CO2	0.00	0.00	25.02	0.00000	0.00000	100.00000
5B	Cropland	CO2	0.00	0.00	50.01	0.00000	0.00000	100.00000
5C	Grassland	CO2	0.00	0.00	70.01	0.00000	0.00000	100.00000
5D	Wetlands	CO2	0.00	0.00	50.01	0.00000	0.00000	100.00000
5E	Settlements	CO2	0.00	0.00	50.01	0.00000	0.00000	100.00000
5G	Other	CO2	0.00	0.00	30.02	0.00000	0.00000	100.00000
4F	Field Burning	CH4	265.51	0.00	55.90	0.00000	0.00000	100.00000
5A	Forest land	CH4	0.00	0.00	20.02	0.00000	0.00000	100.00000
5B	Cropland	CH4	0.00	0.00	50.01	0.00000	0.00000	100.00000
5C2	Land converted to grassland	CH4	0.00	0.00	20.02	0.00000	0.00000	100.00000
5E2	Land converted to settlements	CH4	0.00	0.00	20.02	0.00000	0.00000	100.00000
2B	Adipic Acid Production	N2O	20737.34	0.00	15.01	0.00000	0.00000	100.00000
4F	Field Burning	N2O	77.60	0.00	231.35	0.00000	0.00000	100.00000
4G	OvTerr Agriculture N2O (all)	N2O	0.00	0.00	50.99	0.00000	0.00000	100.00000
5A	Forest land	N2O	0.00	0.00	20.02	0.00000	0.00000	100.00000
5B	Cropland	N2O	0.00	0.00	50.01	0.00000	0.00000	100.00000
5C2	Land converted to grassland	N2O	0.00	0.00	20.02	0.00000	0.00000	100.00000
5D	Wetlands	N2O	0.00	0.00	20.02	0.00000	0.00000	100.00000
5E2	Land converted to settlements	N2O	0.00	0.00	20.02	0.00000	0.00000	100.00000
5G	Other	N2O	0.00	0.00	50.01	0.00000	0.00000	100.00000
		Sum -->	770,471.37	594,021.50		0.10	100.00	

Table A 1.1.9 Key Category Analysis based on trend in emissions (from 1990 to latest reported year, including LULUCF)

IPCC category	Source category	Gas	Emissions Gg CO2 equiv. 1990	Year Y emissions Gg CO2 equiv. 2010	Combined uncertainty range as a % of source category	Trend Parameter (used to order sources)	Trend / Sum(Trend)*100 %	Cumulative %
gory								
4D	Agricultural Soils	N2O	32825.07	26385.59	424.00	0.05031	47.41899	
2B	Nitric Acid Production	N2O	3903.85	1316.57	230.22	0.01961	18.48260	65.90158
6A	Solid Waste Disposal	CH4	43143.47	14767.00	48.38	0.00946	8.91620	74.81778
6B	Wastewater Handling	N2O	1164.86	1151.57	401.12	0.00926	8.73267	83.55045
4B	Manure Management	N2O	2053.05	1750.56	414.00	0.00680	6.41393	89.96438
1A1&1A2&1A4&1A5	Other Combustion	N2O	4829.07	3122.22	195.00	0.00483	4.55119	94.51557
1A(stationary)	Oil	CO2	92867.52	53505.95	15.13	0.00089	0.83950	95.35507
1A3	Other Diesel	N2O	191.40	282.12	140.01	0.00059	0.55486	95.90993
2B5	NEU	CO2	1562.92	1969.82	53.85	0.00050	0.46822	96.37815
5E	5E LULUCF	CO2	7011.87	6216.22	50.01	0.00047	0.44358	96.82172
1B1	Mining & Solid Fuel Transformation	CH4	18281.71	1799.47	13.06	0.00046	0.43058	97.25230
2	Industrial Processes	HFC	11385.62	14314.07	19.03	0.00045	0.42307	97.67537
1A3b	Auto Fuel	N2O	1179.78	847.95	170.02	0.00035	0.33153	98.00690
1A	All Fuel	CH4	2077.99	1069.03	50.00	0.00029	0.27198	98.27888
1A3b	Auto Fuel	CH4	634.83	71.41	50.08	0.00023	0.21689	98.49577
1B2	Production, Refining & Distribution of Oil & Natural Gas	CH4	10322.92	5191.29	17.08	0.00017	0.16249	98.65826
1A	Other (waste)	CO2	212.42	1660.57	21.19	0.00015	0.14036	98.79862
2A7	Fletton Bricks	CO2	539.42	530.66	72.80	0.00014	0.13032	98.92894
1A3b	Auto Fuel	CO2	108564.64	111579.17	4.48	0.00013	0.11945	99.04839
6C	Waste Incineration	N2O	47.90	47.25	230.11	0.00012	0.11699	99.16538
4A	Enteric Fermentation	CH4	18694.63	15385.93	20.00	0.00010	0.09003	99.25541
1A3a	Aviation Fuel	CO2	1580.55	1990.63	20.27	0.00007	0.06697	99.32238
6B	Wastewater Handling	CH4	287.21	347.89	50.01	0.00007	0.06685	99.38923
1A4	Peat	CO2	475.59	47.44	31.62	0.00007	0.06606	99.45529
6C	Waste Incineration	CO2	1227.50	292.01	21.19	0.00006	0.06066	99.51595
5D	5D LULUCF	CO2	481.73	263.02	50.01	0.00006	0.05514	99.57109
1A	Natural Gas	CO2	108956.17	197884.94	1.51	0.00006	0.05472	99.62581
6C	Waste Incineration	CH4	134.43	6.25	50.49	0.00005	0.05140	99.67721
1A3a	Aviation Fuel	N2O	15.56	19.60	171.17	0.00005	0.04701	99.72422
5B	5B LULUCF	CO2	15732.05	12115.71	50.01	0.00004	0.03950	99.76372
1B2	Oil & Natural Gas	N2O	42.40	46.17	111.16	0.00004	0.03540	99.79912
1A3d	Marine Fuel	N2O	16.56	17.64	170.01	0.00003	0.02995	99.82907
2A7	Fletton Bricks	CH4	23.60	5.63	101.98	0.00003	0.02698	99.85605
1A	Combined Fuel	CO2	801.51	867.86	21.21	0.00003	0.02389	99.87994
1A	Coal	CO2	247785.08	114863.47	1.08	0.00002	0.01810	99.89804
2	Industrial Processes	PFC	1401.60	220.47	10.05	0.00002	0.01796	99.91600
1A	Lubricant	CO2	386.90	225.28	30.07	0.00001	0.01336	99.92936
5B	5B LULUCF	N2O	781.56	622.48	50.01	0.00001	0.01270	99.94207
4B	Manure Management	CH4	3585.62	2679.30	30.00	0.00001	0.01218	99.95424
2B	Chemical Industry	CH4	169.43	73.50	28.28	0.00001	0.00938	99.96362
2	Industrial Processes	SF6	1029.95	689.99	20.02	0.00001	0.00822	99.97184
2C	Iron & Steel	N2O	11.11	6.72	118.00	0.00001	0.00518	99.97702
2A2	Lime Production	CO2	1206.41	233.70	5.10	0.00000	0.00374	99.98077
1B	Solid Fuel Transformation	CO2	856.42	219.64	6.01	0.00000	0.00329	99.98405
2B	Ammonia Production	CO2	1431.17	978.43	10.11	0.00000	0.00249	99.98655
2A1	Cement Production	CO2	7295.26	3792.01	2.42	0.00000	0.00218	99.98873
1B	Oil & Natural Gas	CO2	5777.84	4388.43	17.09	0.00000	0.00204	99.99077
1A3d	Marine Fuel	CH4	1.85	3.91	50.03	0.00000	0.00130	99.99207
1A3	Other Diesel	CO2	1613.78	2370.91	2.20	0.00000	0.00115	99.99322
1A3a	Aviation Fuel	CH4	3.30	1.11	53.85	0.00000	0.00085	99.99408
5C2	5C2 LULUCF	CH4	3.90	11.74	20.02	0.00000	0.00073	99.99481
1A3	Other Diesel	CH4	3.11	3.78	50.03	0.00000	0.00073	99.99554
1A3d	Marine Fuel	CO2	2123.33	2264.57	2.20	0.00000	0.00065	99.99619
1B1	Coke Oven Gas	N2O	2.08	1.38	118.00	0.00000	0.00063	99.99682
1A3c	Coal	CH4	0.00	0.99	50.00	0.00000	0.00051	99.99733
5A	5A LULUCF	CH4	4.30	8.17	20.02	0.00000	0.00041	99.99774
1A3c	Coal	CO2	0.00	49.62	6.01	0.00000	0.00037	99.99812
2C	Iron & Steel Production	CH4	16.36	11.81	50.00	0.00000	0.00037	99.99848
1A3c	Coal	N2O	0.00	0.12	118.00	0.00000	0.00034	99.99882
2A3	Limestone & Dolomite use	CO2	1125.28	920.77	5.10	0.00000	0.00032	99.99915
5D	5D LULUCF	N2O	3.98	0.50	20.02	0.00000	0.00021	99.99936
5A	5A LULUCF	N2O	5.57	1.92	20.02	0.00000	0.00020	99.99956
2C1	Iron&Steel Production	CO2	2309.27	1747.34	6.12	0.00000	0.00016	99.99971
5B	5B LULUCF	CH4	0.14	0.39	50.01	0.00000	0.00015	99.99986
5C2	5C2 LULUCF	N2O	0.40	1.19	20.02	0.00000	0.00007	99.99994
5E2	5E2 LULUCF	CH4	9.96	8.30	20.02	0.00000	0.00006	99.99999
5E2	5E2 LULUCF	N2O	1.01	0.84	20.02	0.00000	0.00001	100.00000
1A4	Combined Fuel	CO2	0.00	0.00	21.21	0.00000	0.00000	100.00000
2A4	Soda Ash Use	CO2	0.00	0.00	15.13	0.00000	0.00000	100.00000
5A	5A LULUCF	CO2	-12155.07	-10568.81	25.02	0.00000	0.00000	100.00000
5C	5C LULUCF	CO2	-6261.11	-8541.00	70.01	0.00000	0.00000	100.00000
5G	5G LULUCF	CO2	-1727.33	-3985.06	30.02	0.00000	0.00000	100.00000
4F	Field Burning	CH4	265.51	0.00	55.90	0.00000	0.00000	100.00000
2B	Adipic Acid Production	N2O	20737.34	0.00	15.01	0.00000	0.00000	100.00000
4F	Field Burning	N2O	77.60	0.00	231.35	0.00000	0.00000	100.00000
4G	OvTerr Agriculture N2O (all)	N2O	0.00	0.00	50.99	0.00000	0.00000	100.00000
5G	5G LULUCF	N2O	0.00	0.00	50.01	0.00000	0.00000	100.00000
		Sum -->	771,152.71	590,177.13		0.11	100.00	

Table A 1.1.10 Key Category Analysis based on trend in emissions (from 1990 to latest reported year, excluding LULUCF)

IPCC category	Source category	Gas	Emissions Gg CO2 equiv. 1990	Year Y emissions Gg CO2 equiv. 2010	Combined uncertainty range as a % of source category	Trend Parameter (used to order sources)	Trend / Sum(Trend)*100 %	Cumulative %
4D	Agricultural Soils	N2O	32825.07	26385.59	424.00	0.03800	41.20952	
2B	Nitric Acid Production	N2O	3903.85	1316.57	230.22	0.01966	21.32027	62.52979
6A	Solid Waste Disposal	CH4	43143.47	14767.00	48.38	0.00949	10.28761	72.81740
6B	Wastewater Handling	N2O	1164.86	1151.57	401.12	0.00874	9.47531	82.29271
4B	Manure Management	N2O	2053.05	1750.56	414.00	0.00600	6.51008	88.80279
1A1&1A2&1A4&1A5	Other Combustion	N2O	4829.07	3122.22	195.00	0.00510	5.52820	94.33100
1A(stationary)	Oil	CO2	92867.52	53505.95	15.13	0.00092	0.99328	95.32428
1A3	Other Diesel	N2O	191.40	282.12	140.01	0.00057	0.61915	95.94343
2B5	NEU	CO2	1562.92	1969.82	53.85	0.00048	0.51961	96.46303
1B1	Mining & Solid Fuel Transformation	CH4	18281.71	1799.47	13.06	0.00045	0.49309	96.95612
2	Industrial Processes	HFC	11385.62	14314.07	19.03	0.00043	0.46945	97.42557
1A3b	Auto Fuel	N2O	1179.78	847.95	170.02	0.00041	0.44618	97.87174
1A	All Fuel	CH4	2077.99	1069.03	50.00	0.00029	0.31824	98.18999
1A3b	Auto Fuel	CH4	634.83	71.41	50.08	0.00023	0.24844	98.43842
1B2	Production, Refining & Distribution of Oil & Natural Gas	CH4	10322.92	5191.29	17.08	0.00018	0.19015	98.62858
1A	Other (waste)	CO2	212.42	1660.57	21.19	0.00015	0.15841	98.78699
2A7	Fletton Bricks	CO2	539.42	530.66	72.80	0.00013	0.14127	98.92826
1A3b	Auto Fuel	CO2	108564.64	111579.17	4.48	0.00012	0.13041	99.05868
6C	Waste Incineration	N2O	47.90	47.25	230.11	0.00012	0.12688	99.18556
4A	Enteric Fermentation	CH4	18694.63	15385.93	20.00	0.00008	0.08606	99.27162
1A4	Peat	CO2	475.59	47.44	31.62	0.00007	0.07564	99.34726
1A3a	Aviation Fuel	CO2	1580.55	1990.63	20.27	0.00007	0.07431	99.42158
6B	Wastewater Handling	CH4	287.21	347.89	50.01	0.00007	0.07404	99.49562
6C	Waste Incineration	CO2	1227.50	292.01	21.19	0.00006	0.06971	99.56532
1A	Natural Gas	CO2	108956.17	197884.94	1.51	0.00006	0.06131	99.62663
6C	Waste Incineration	CH4	134.43	6.25	50.49	0.00005	0.05881	99.68544
1A3a	Aviation Fuel	N2O	15.56	19.60	171.17	0.00005	0.05217	99.73761
1B2	Oil & Natural Gas	N2O	42.40	46.17	111.16	0.00004	0.03890	99.77651
1A3d	Marine Fuel	N2O	16.56	17.64	170.01	0.00003	0.03284	99.80935
2A7	Fletton Bricks	CH4	23.60	5.63	101.98	0.00003	0.03100	99.84035
1A	Combined Fuel	CO2	801.51	867.86	21.21	0.00002	0.02624	99.86660
1A	Coal	CO2	247785.08	114863.47	1.08	0.00002	0.02106	99.88765
2	Industrial Processes	PFC	1401.60	220.47	10.05	0.00002	0.02059	99.90825
4B	Manure Management	CH4	3585.62	2679.30	30.00	0.00002	0.02053	99.92878
1A	Lubricant	CO2	386.90	225.28	30.07	0.00001	0.01583	99.94461
2B	Chemical Industry	CH4	169.43	73.50	28.28	0.00001	0.01088	99.95549
2	Industrial Processes	SF6	1029.95	689.99	20.02	0.00001	0.01016	99.96565
2C	Iron & Steel	N2O	11.11	6.72	118.00	0.00001	0.00618	99.97183
1B	Oil & Natural Gas	CO2	5777.84	4388.43	17.09	0.00001	0.00584	99.97767
2A2	Lime Production	CO2	1206.41	233.70	5.10	0.00000	0.00429	99.98196
1B	Solid Fuel Transformation	CO2	856.42	219.64	6.01	0.00000	0.00378	99.98574
2B	Ammonia Production	CO2	1431.17	978.43	10.11	0.00000	0.00312	99.98887
2A1	Cement Production	CO2	7295.26	3792.01	2.42	0.00000	0.00256	99.99142
1A3d	Marine Fuel	CH4	1.85	3.91	50.03	0.00000	0.00146	99.99289
1A3	Other Diesel	CO2	1613.78	2370.91	2.20	0.00000	0.00128	99.99417
1A3a	Aviation Fuel	CH4	3.30	1.11	53.85	0.00000	0.00099	99.99516
1A3	Other Diesel	CH4	3.11	3.78	50.03	0.00000	0.00081	99.99596
1B1	Coke Oven Gas	N2O	2.08	1.38	118.00	0.00000	0.00078	99.99674
1A3d	Marine Fuel	CO2	2123.33	2264.57	2.20	0.00000	0.00071	99.99745
1A3c	Coal	CH4	0.00	0.99	50.00	0.00000	0.00058	99.99803
2C	Iron & Steel Production	CH4	16.36	11.81	50.00	0.00000	0.00050	99.99853
1A3c	Coal	CO2	0.00	49.62	6.01	0.00000	0.00042	99.99896
1A3c	Coal	N2O	0.00	0.12	118.00	0.00000	0.00038	99.99934
2C1	Iron&Steel Production	CO2	2309.27	1747.34	6.12	0.00000	0.00036	99.99970
2A3	Limestone & Dolomite use	CO2	1125.28	920.77	5.10	0.00000	0.00030	100.00000
1A4	Combined Fuel	CO2	0.00	0.00	21.21	0.00000	0.00000	100.00000
2A4	Soda Ash Use	CO2	0.00	0.00	15.13	0.00000	0.00000	100.00000
5A	Forest land	CO2	0.00	0.00	25.02	0.00000	0.00000	100.00000
5B	Cropland	CO2	0.00	0.00	50.01	0.00000	0.00000	100.00000
5C	Grassland	CO2	0.00	0.00	70.01	0.00000	0.00000	100.00000
5D	Wetlands	CO2	0.00	0.00	50.01	0.00000	0.00000	100.00000
5E	Settlements	CO2	0.00	0.00	50.01	0.00000	0.00000	100.00000
5G	Other	CO2	0.00	0.00	30.02	0.00000	0.00000	100.00000
4F	Field Burning	CH4	265.51	0.00	55.90	0.00000	0.00000	100.00000
5A	Forest land	CH4	0.00	0.00	20.02	0.00000	0.00000	100.00000
5B	Cropland	CH4	0.00	0.00	50.01	0.00000	0.00000	100.00000
5C2	Land converted to grassland	CH4	0.00	0.00	20.02	0.00000	0.00000	100.00000
5E2	Land converted to settlements	CH4	0.00	0.00	20.02	0.00000	0.00000	100.00000
2B	Adipic Acid Production	N2O	20737.34	0.00	15.01	0.00000	0.00000	100.00000
4F	Field Burning	N2O	77.60	0.00	231.35	0.00000	0.00000	100.00000
4G	OvTerr Agriculture N2O (all)	N2O	0.00	0.00	50.99	0.00000	0.00000	100.00000
5A	Forest land	N2O	0.00	0.00	20.02	0.00000	0.00000	100.00000
5B	Cropland	N2O	0.00	0.00	50.01	0.00000	0.00000	100.00000
5C2	Land converted to grassland	N2O	0.00	0.00	20.02	0.00000	0.00000	100.00000
5D	Wetlands	N2O	0.00	0.00	20.02	0.00000	0.00000	100.00000
5E2	Land converted to settlements	N2O	0.00	0.00	20.02	0.00000	0.00000	100.00000
5G	Other	N2O	0.00	0.00	50.01	0.00000	0.00000	100.00000
		Sum -->	767,259.76	594,021.50		0.09	100.00	

Table A 1.1.11 Key Source Category Analysis summary for the base year (including LULUCF)

Quantitative Method Used: Approach 1 (Error propagation approach)

A		B	C	D	E
IPCC Source Categories		Gas	Category Key Source Category	If Column C is Yes, Criteria for Identification	Comments
1A	Coal	CO2		Level	
1A(stationary)	Oil	CO2		Level	
1A	Natural Gas	CO2			
1A	Other (waste)	CO2			
1A	Lubricant	CO2			
1A3a	Aviation Fuel	CO2			
1A3b	Auto Fuel	CO2		Level	
1A3d	Marine Fuel	CO2			
1A3	Other Diesel	CO2			
1A4	Peat	CO2			
1B	Solid Fuel Transformation	CO2			
1B	Oil & Natural Gas	CO2			
2A1	Cement Production	CO2		Qualitative	
2A2	Lime Production	CO2			
2A3	Limestone & Dolomite use	CO2			
2A4	Soda Ash Use	CO2			
2A7	Fletton Bricks	CO2			
2B	Ammonia Production	CO2			
2C1	Iron&Steel Production	CO2			
5A	5A LULUCF	CO2		Level	
5B	5B LULUCF	CO2		Level	
5C	5C LULUCF	CO2		Level	
5E	5E LULUCF	CO2		Level	
5G	5G LULUCF	CO2			
6C	Waste Incineration	CO2			
7C	Other	CO2			
1A	All Fuel	CH4			
1A3a	Aviation Fuel	CH4			
1A3b	Auto Fuel	CH4			
1A3d	Marine Fuel	CH4			
1A3	Other Diesel	CH4			
1B1	Mining & Solid Fuel Transformation	CH4		Level	
1B2	Oil & Natural Gas	CH4			
2A7	Fletton Bricks	CH4			
2B	Chemical Industry	CH4			
2C	Iron & Steel Production	CH4			
4A	Enteric Fermentation	CH4		Level	
4B	Manure Management	CH4			
4F	Field Burning	CH4			
5C2	5C2 LULUCF	CH4			
5E2	5E2 LULUCF	CH4			
6A	Solid Waste Disposal	CH4		Level	high uncertainty
6B	Wastewater Handling	CH4			
6C	Waste Incineration	CH4			
1A1&1A2&1A4&1A	Other Combustion	N2O		Level	
1A3a	Aviation Fuel	N2O			
1A3b	Auto Fuel	N2O		Level	
1A3d	Marine Fuel	N2O			
1A3	Other Diesel	N2O			
1B1	Coke Oven Gas	N2O			
1B2	Oil & Natural Gas	N2O			
2B	Adipic Acid Production	N2O		Level	
2B	Nitric Acid Production	N2O		Level	
2C	Iron & Steel	N2O			
4B	Manure Management	N2O		Level	high uncertainty
4D	Agricultural Soils	N2O		Level	high uncertainty
4F	Field Burning	N2O			
5C2	5C2 LULUCF	N2O			
5E2	5E2 LULUCF	N2O			
6B	Wastewater Handling	N2O		Level	
6C	Waste Incineration	N2O			
2	Industrial Processes	HFC		Level	
2	Industrial Processes	PFC			
2	Industrial Processes	SF6			

Table A 1.1.12 Key Source Category Analysis summary for the base year (excluding LULUCF)

Quantitative Method Used: Approach 1 (Error propagation approach)					
A		B	C	D	E
IPCC Source Categories		Gas	Category Key Source Category	If Column C is Yes, Criteria for Identification	Comments
1A	Coal	CO2		Level	
1A(stationary)	Oil	CO2		Level	
1A	Natural Gas	CO2			
1A	Other (waste)	CO2			
1A	Lubricant	CO2			
1A3a	Aviation Fuel	CO2			
1A3b	Auto Fuel	CO2		Level	
1A3d	Marine Fuel	CO2			
1A3	Other Diesel	CO2			
1A4	Peat	CO2			
1B	Solid Fuel Transformation	CO2			
1B	Oil & Natural Gas	CO2			
2A1	Cement Production	CO2		Qualitative	
2A2	Lime Production	CO2			
2A3	Limestone & Dolomite use	CO2			
2A4	Soda Ash Use	CO2			
2A7	Fletton Bricks	CO2			
2B	Ammonia Production	CO2			
2C1	Iron&Steel Production	CO2			
5A	5A LULUCF	CO2			
5B	5B LULUCF	CO2			
5C	5C LULUCF	CO2			
5E	5E LULUCF	CO2			
5G	5G LULUCF	CO2			
6C	Waste Incineration	CO2			
7C	Other	CO2			
1A	All Fuel	CH4			
1A3a	Aviation Fuel	CH4			
1A3b	Auto Fuel	CH4			
1A3d	Marine Fuel	CH4			
1A3	Other Diesel	CH4			
1B1	Mining & Solid Fuel Transformation	CH4		Level	
1B2	Oil & Natural Gas	CH4			
2A7	Fletton Bricks	CH4			
2B	Chemical Industry	CH4			
2C	Iron & Steel Production	CH4			
4A	Enteric Fermentation	CH4		Level	
4B	Manure Management	CH4			
4F	Field Burning	CH4			
5C2	5C2 LULUCF	CH4			
5E2	5E2 LULUCF	CH4			
6A	Solid Waste Disposal	CH4		Level	high uncertainty
6B	Wastewater Handling	CH4			
6C	Waste Incineration	CH4			
1A1&1A2&1A4&1A	Other Combustion	N2O		Level	
1A3a	Aviation Fuel	N2O			
1A3b	Auto Fuel	N2O		Level	
1A3d	Marine Fuel	N2O			
1A3	Other Diesel	N2O			
1B1	Coke Oven Gas	N2O			
1B2	Oil & Natural Gas	N2O			
2B	Adipic Acid Production	N2O		Level	
2B	Nitric Acid Production	N2O		Level	
2C	Iron & Steel	N2O			
4B	Manure Management	N2O		Level	high uncertainty
4D	Agricultural Soils	N2O		Level	high uncertainty
4F	Field Burning	N2O			
5C2	5C2 LULUCF	N2O			
5E2	5E2 LULUCF	N2O			
6B	Wastewater Handling	N2O		Level	
6C	Waste Incineration	N2O			
2	Industrial Processes	HFC		Level	
2	Industrial Processes	PFC			
2	Industrial Processes	SF6			

Table A 1.1.13 Key Source Category Analysis summary for the latest reported year (including LULUCF)

Quantitative Method Used: Approach 1 (Error propagation approach)

A IPCC Source Categories		B Gas	C Category Key Source Category	D If Column C is Yes, Criteria for Identification	E Comments
1A	Coal	CO2		Level	
1A(stationary)	Oil	CO2		Level, Trend	
1A	Natural Gas	CO2		Level	
1A	Other (waste)	CO2			
1A	Lubricant	CO2			
1A3a	Aviation Fuel	CO2			
1A3b	Auto Fuel	CO2		Level	
1A3d	Marine Fuel	CO2			
1A3	Other Diesel	CO2			
1A4	Peat	CO2			
1B	Solid Fuel Transformation	CO2			
1B	Oil & Natural Gas	CO2			
2A1	Cement Production	CO2		Qualitative	
2A2	Lime Production	CO2			
2A3	Limestone & Dolomite use	CO2			
2A4	Soda Ash Use	CO2			
2A7	Fletton Bricks	CO2			
2B	Ammonia Production	CO2			
2C1	Iron&Steel Production	CO2			
5A	5A LULUCF	CO2		Level	
5B	5B LULUCF	CO2		Level	
5C	5C LULUCF	CO2		Level	
5E	5E LULUCF	CO2		Level	
5G	5G LULUCF	CO2			
6C	Waste Incineration	CO2			
7C	Other	CO2			
1A	All Fuel	CH4			
1A3a	Aviation Fuel	CH4			
1A3b	Auto Fuel	CH4			
1A3d	Marine Fuel	CH4			
1A3	Other Diesel	CH4			
1B1	Mining & Solid Fuel Transformation	CH4			
1B2	Oil & Natural Gas	CH4			
2A7	Fletton Bricks	CH4			
2B	Chemical Industry	CH4			
2C	Iron & Steel Production	CH4			
4A	Enteric Fermentation	CH4		Level	
4B	Manure Management	CH4			
4F	Field Burning	CH4			
5C2	5C2 LULUCF	CH4			
5E2	5E2 LULUCF	CH4			
6A	Solid Waste Disposal	CH4		Level, Trend	high uncertainty
6B	Wastewater Handling	CH4			
6C	Waste Incineration	CH4			
1A1&1A2&1A4&1A	Other Combustion	N2O		Level, Trend	
1A3a	Aviation Fuel	N2O			
1A3b	Auto Fuel	N2O		Level	
1A3d	Marine Fuel	N2O			
1A3	Other Diesel	N2O			
1B1	Coke Oven Gas	N2O			
1B2	Oil & Natural Gas	N2O			
2B	Adipic Acid Production	N2O			
2B	Nitric Acid Production	N2O		Level, Trend	
2C	Iron & Steel	N2O			
4B	Manure Management	N2O		Level, Trend	high uncertainty
4D	Agricultural Soils	N2O		Level, Trend	high uncertainty
4F	Field Burning	N2O			
5C2	5C2 LULUCF	N2O			
5E2	5E2 LULUCF	N2O			
6B	Wastewater Handling	N2O		Level, Trend	
6C	Waste Incineration	N2O			
2	Industrial Processes	HFC		Level	
2	Industrial Processes	PFC			
2	Industrial Processes	SF6			

Table A 1.1.14 Key Source Category Analysis summary for the **latest reported year** (excluding LULUCF)

Quantitative Method Used: Approach 1 (Error propagation approach)					
A IPCC Source Categories		B Gas	C Category Key Source Category	D If Column C is Yes, Criteria for Identification	E Comments
1A	Coal	CO2			
1A(stationary)	Oil	CO2		Level, Trend	
1A	Natural Gas	CO2		Level	
1A	Other (waste)	CO2			
1A	Lubricant	CO2			
1A3a	Aviation Fuel	CO2			
1A3b	Auto Fuel	CO2		Level	
1A3d	Marine Fuel	CO2			
1A3	Other Diesel	CO2			
1A4	Peat	CO2			
1B	Solid Fuel Transformation	CO2			
1B	Oil & Natural Gas	CO2			
2A1	Cement Production	CO2		Qualitative	
2A2	Lime Production	CO2			
2A3	Limestone & Dolomite use	CO2			
2A4	Soda Ash Use	CO2			
2A7	Fletton Bricks	CO2			
2B	Ammonia Production	CO2			
2C1	Iron&Steel Production	CO2			
5A	5A LULUCF	CO2			
5B	5B LULUCF	CO2			
5C	5C LULUCF	CO2			
5E	5E LULUCF	CO2			
5G	5G LULUCF	CO2			
6C	Waste Incineration	CO2			
7C	Other	CO2			
1A	All Fuel	CH4			
1A3a	Aviation Fuel	CH4			
1A3b	Auto Fuel	CH4			
1A3d	Marine Fuel	CH4			
1A3	Other Diesel	CH4			
1B1	Mining & Solid Fuel Transformation	CH4			
1B2	Oil & Natural Gas	CH4			
2A7	Fletton Bricks	CH4			
2B	Chemical Industry	CH4			
2C	Iron & Steel Production	CH4			
4A	Enteric Fermentation	CH4		Level	
4B	Manure Management	CH4			
4F	Field Burning	CH4			
5C2	5C2 LULUCF	CH4			
5E2	5E2 LULUCF	CH4			
6A	Solid Waste Disposal	CH4		Level, Trend	high uncertainty
6B	Wastewater Handling	CH4			
6C	Waste Incineration	CH4			
1A1&1A2&1A4&1A	Other Combustion	N2O		Level, Trend	
1A3a	Aviation Fuel	N2O			
1A3b	Auto Fuel	N2O		Level	
1A3d	Marine Fuel	N2O			
1A3	Other Diesel	N2O			
1B1	Coke Oven Gas	N2O			
1B2	Oil & Natural Gas	N2O			
2B	Adipic Acid Production	N2O			
2B	Nitric Acid Production	N2O		Level, Trend	
2C	Iron & Steel	N2O			
4B	Manure Management	N2O		Level, Trend	high uncertainty
4D	Agricultural Soils	N2O		Level, Trend	high uncertainty
4F	Field Burning	N2O			
5C2	5C2 LULUCF	N2O			
5E2	5E2 LULUCF	N2O			
6B	Wastewater Handling	N2O		Level, Trend	
6C	Waste Incineration	N2O			
2	Industrial Processes	HFC		Level	
2	Industrial Processes	PFC			
2	Industrial Processes	SF6			

A1.2 TABLE NIR 3, AS CONTAINED IN THE ANNEX TO DECISION 6/CMP.3

Table A 1.2.1 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[2]. The table is consistent with the data submitted in the UK's CRF submission in file <KP-GBR-2012-2010-v1.1.xls>.

Table A 1.2.1 Table NIR 3. Summary overview for Key Categories for Land Use, Land-Use Change and Forestry Activities under the Kyoto Protocol

KEY CATEGORIES OF EMISSIONS AND REMOVALS	GAS	CRITERIA USED FOR KEY CATEGORY IDENTIFICATION			COMMENTS(3)
		Associated category in UNFCCC inventory(1) is key (indicate which category)	Category contribution is greater than the smallest category considered key in the UNFCCC inventory (1), (4) (including LULUCF)	Other(2)	
Specify key categories according to the national level of disaggregation used(1)					
Afforestation and Reforestation	CO_2	Conversion to Forest Land	No	Associated UNFCCC category (5A) is key	The Afforestation and Reforestation category contribution is smaller than the smallest UNFCCC key category but the associated UNFCCC category (5A Forest Land) is a key category. Therefore this is a key category (IPCC good practice guidance for LULUCF section 5.4.4).

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

KEY CATEGORIES OF EMISSIONS AND REMOVALS	GAS	CRITERIA USED FOR KEY CATEGORY IDENTIFICATION			COMMENTS[3]
		Associated category in UNFCCC inventory[1] is key (indicate which category)	Category contribution is greater than the smallest category considered key in the UNFCCC inventory [1], [4] (including LULUCF)	Other[2]	
Deforestation	CO_2	Conversion to Grassland; conversion to Settlements	No	Associated UNFCCC category (5B, 5C and 5E) are key)	The Deforestation category contribution is smaller than the smallest UNFCCC key category but the associated UNFCCC categories (5B Cropland, 5C Grassland and 5E Settlements) are key categories. Therefore this is a key category (IPCC good practice guidance for LULUCF section 5.4.4).
Forest Management	CO_2	Conversion to Forest Land	Yes	Associated UNFCCC category (5A) is key	The associated UNFCCC inventory category is a key category and the Forest Management category contribution is greater than the smallest UNFCCC key category.

(1) See section 5.4 of the IPCC good practice guidance for LULUCF
(2) This should include qualitative consideration as per Section 5.4.3 of the IPCC Good Practice Guidance for LULUCF or any other criteria
(3) Describe the criteria identifying the category as key
(4) If the emissions or removals of the category exceed the emissions of the smallest category identified as key in the UNFCCC inventory (including LULUCF), Parties should indicate YES. If not, Parties should indicate NO

A2 ANNEX 2: Detailed Discussion of Methodology and Data for Estimating CO_2 Emissions from Fossil Fuel Combustion

Methodology for estimating CO_2 emissions from fossil fuel combustion is discussed together with the methodologies for other emissions in **Annex 3**. This is because the underlying methodology for such estimates applies to a range of pollutants and not just CO_2.

A3 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 – presented in **Section A3.3** onwards.

A3.1 FUELS DATA

The fuels data are taken from DUKES - the Digest of UK Energy Statistics (DECC, 2011), so the fuel definitions and the source categories used in the NAEI reflect those in DUKES. Categories used in the inventory for non-combustion sources generally reflect the availability of data on emissions from these sources.

IPCC Guidelines (IPCC, 1997a) lists fuels that should be considered when reporting emissions. **Table A 3.1.1** lists the fuels that are used in the GHGI and indicates how they relate to the fuels reported in the NAEI. In most cases the mapping is obvious but there are a few cases where some explanation is required.

Aviation Fuels

UK energy statistics report consumption of aviation turbine fuel and this is mapped onto jet kerosene in the GHGI. Aviation turbine fuel includes fuel that is described as jet gasoline using IPCC terminology.

Coal

The IPCC Guidelines (IPCC, 1997a) classify coal as anthracite, coking coal, other bituminous coal and sub-bituminous coal. In mapping the UK fuel statistics to these categories it is assumed that only the coal used in coke ovens is coking coal; and the rest is reported as either coal or anthracite. Most coal used in the UK is bituminous coal; anthracite is reported separately in UK energy statistics.

Coke Oven Coke

Gas works coke is no longer manufactured in the UK so all coke and coke breeze consumption is reported as coke oven coke.

Colliery Methane

The IPCC Guidelines do not refer to colliery methane but significant use is made of it as a fuel in the UK so emissions are included in the GHGI.

Orimulsion

Orimulsion® is an emulsion of bitumen and water and was burnt in some power stations in the UK, however its use has now been discontinued

Slurry

This is a slurry of coal and water used in some power stations.

Sour Gas

Unrefined natural gas is used as a fuel on offshore platforms and in some power stations. It has a higher carbon and sulphur content than mains gas.

Wastes used as fuel

The following wastes are used for power generation: municipal solid waste, scrap tyres, poultry litter, meat and bone meal, landfill gas, sewage gas, and waste oils. Some waste oils and scrap tyres are burnt in cement kilns. Further waste oils are burnt by other industrial sectors and it is assumed that some lubricants consumed in the UK are destroyed (burnt) in engines[3].

3 11% in 2011 for lubricants burnt in all types of engines - this is made up of 6.6% burnt in road vehicle engines, 3.7% burnt in marine engines and the remaining 1.0% split between agricultural, industrial and aircraft engines.

Table A 3.1.1 Mapping of fuels used in IPCC and the NAEI

	IPCC	NAEI
Category	**Subcategory**	**Subcategory**
Liquid	Motor Gasoline Aviation Gasoline Jet Kerosene Other Kerosene Gas/Diesel Oil Residual Fuel Oil Orimulsion Liquefied Petroleum Gas Naphtha Petroleum Coke Refinery Gas Other Oil: Other Other Oil: Other Lubricants	Petrol Aviation Spirit Aviation Turbine Fuel[1] (ATF) Burning Oil Gas Oil/ DERV Fuel Oil Orimulsion Liquefied Petroleum Gas (LPG) Naphtha Petroleum Coke Other Petroleum Gas (OPG) Refinery Miscellaneous Waste Oils Lubricants
Solid	Anthracite Coking Coal Coal Coal Coke Oven Coke Patent Fuel Coke Oven Gas Blast Furnace Gas	Anthracite Coal[2] Coal Slurry[3] Coke Solid Smokeless Fuel (SSF) Coke Oven Gas Blast Furnace Gas
Gas	Natural Gas Natural Gas Colliery Methane[5]	Natural Gas Sour Gas[4] Colliery Methane
Other Fuels	Municipal Solid Waste Industrial Waste: Scrap Tyres	Municipal Solid Waste Scrap Tyres
Biomass	Wood/Wood Waste Other Solid Biomass: Straw Other Solid Biomass: Poultry Litter, Meat & Bone Meal Landfill Gas Sludge Gas	Wood Straw Poultry Litter, Meat & bone meal Landfill Gas Sewage Gas

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 Not referred to in IPCC Guidelines (IPCC, 1997a) but included in GHGI.

A3.2 NAEI SOURCE CATEGORIES AND IPCC EQUIVALENTS

Table A 3.2.1 to **Table A 3.2.7** relate the IPCC source categories to the equivalent NAEI base categories. In most cases it is possible to obtain a precise mapping of an NAEI source category to a specific IPCC source category. In some cases the relevant NAEI source category does not correspond exactly to the IPCC source category and in a few cases an equivalent NAEI source category is not estimated or is defined quite differently. As a result, total annual emissions given in the NAEI and GHGI differ slightly. The source categories responsible for the differences between the GHGI and the NAEI are Land Use, Land Use Change and Forestry sources.

Table A 3.2.1 to **Table A 3.2.7** refer to NAEI base categories.

Table A 3.2.1 Mapping of IPCC Source Categories to NAEI Source Categories – fuel combustion

IPCC Source Category	NAEI Source Category
1A1a Public Electricity and Heat Production	Power Stations
1A1b Petroleum Refining	Refineries (Combustion)
1A1ci Manufacture of Solid Fuels	SSF Production Coke Production
1A1cii Other Energy Industries	Collieries Gas Production Gas Separation Plant (Combustion) Offshore Own Gas Use Production of Nuclear Fuel Town Gas Production
1A2a Iron and Steel	Iron and Steel (Combustion) Iron and Steel (Sinter Plant) Iron and Steel (Blast Furnaces)
1A2b Non-Ferrous Metals	Non-Ferrous Metals
1A2c Chemicals	Chemicals Ammonia (Combustion)
1A2d Pulp, Paper and Print	Pulp, Paper and Print
1A2e Food Processing, Beverages, Tobacco	Food Processing, Beverages, Tobacco
1A2fi Other	Other Industry (Combustion) Cement (Fuel Combustion) Cement (Non-decarbonising) Lime Production (Combustion) Autogenerators
1A2fii Other (Off-road Vehicles and Other Machinery)	Other Industry Off-road
1A3a Civil Aviation	Domestic Aviation
1A3b Road Transportation	Road Transport
1A3c Railways	Railways (Freight) Railways (Intercity) Railways (Regional)
1A3di International Marine	International Marine
1A3dii Internal Navigation	Coastal Shipping
1A3e Other Transport	Aircraft Support
1A4a Commercial/Institutional	Miscellaneous Public Services Railways (Stationary Sources)
1A4bi Residential	Domestic
1A4bii Residential Off-road	Domestic, House & Garden
1A4ci Agriculture/Forestry/Fishing (Stationary)	Agriculture
1A4cii Agriculture/Forestry/Fishing (Off-road Vehicles and Other Machinery)	Agriculture Power Units
1A4ciii Agriculture/Forestry/Fishing (Fishing)	Fishing
1A5a Other: Stationary	No comparable category-included in 1A4a
1A5b Other: mobile	Aircraft Military Shipping Naval

Table A 3.2.2 Mapping of IPCC Source Categories to NAEI Source Categories (Fugitive emissions from fuels)

IPCC Source Category	NAEI Source Category
1B1a Coal Mining i Mining activities	Deep-Mined Coal
1B1a Coal Mining ii Post mining activities	Coal Storage & Transport
1B1a Coal Mining ii Surface Mines	Open-Cast Coal
1B1b Solid Fuel Transformation	Coke Production (Fugitive) SSF Production (Fugitive) Flaring (Coke Oven Gas)
1B1c Other	Not Estimated
1B2a Oil i Exploration	Oil Production - Offshore Well Testing
1B2a Oil ii Production	Oil Production – Process Emissions
1B2a Oil iii Transport	Oil Production – Offshore Oil Loading Oil Production – Onshore Oil Loading
1B2a Oil iv Refining/Storage	Refineries (drainage) Refineries (tankage) Refineries (Process) Oil Production - Oil Terminal Storage Petroleum Processes
1B2a Oil vi Other	Not Estimated
1B2a Oil v Distribution of oil products	Petrol Stations (Petrol Delivery) Petrol Stations (Vehicle Refuelling) Petrol Stations (Storage Tanks) Petrol Stations (Spillages) Petrol Terminals (Storage) Petrol Terminals (Tanker Loading) Refineries (Road/Rail Loading)
1B2b i Natural Gas Exploration	Gas production – offshore well testing
1B2b ii Natural Gas. Production/Processing	Gas production – gas terminal storage Gas production – process emissions
1B2b iii Transmission	IE
1B2b iv Distribution	Gas Leakage
1B2b v Other leakage	Gas Leakage
1B2ci Venting: Oil	Oil production – gas venting
1B2cii Venting: Gas	Gas production – gas venting
1B2ci Flaring: Oil	Oil production – gas flaring Refineries (Flares)
1B2cii Flaring: Gas	Gas production – gas flaring

Table A 3.2.3 Mapping of IPCC Source Categories to NAEI Source Categories (Industrial Processes)

IPCC Source Category	NAEI Source Category
2A1 Cement Production	Cement (Decarbonising)
2A2 Lime Production	Lime Production (Decarbonising)
2A3 Limestone and Dolomite Use	Glass Production: Limestone and Dolomite Iron and Steel (Blast Furnace): Limestone and Dolomite Power Stations (FGD)
2A4 Soda Ash Production and Use	Glass Production: Soda Ash

IPCC Source Category	NAEI Source Category
2A5 Asphalt Roofing	Not Estimated
2A6 Road Paving with Asphalt	Road Construction
2A7 Other	Brick Manufacture (Fletton) Glass (continuous filament glass fibre) Glass (glass wool)
2B1 Ammonia Production	Ammonia Feedstock
2B2 Nitric Acid Production	Nitric Acid Production
2B3 Adipic Acid Production	Adipic Acid Production
2B4 Carbide Production	
2B5 Other	Sulphuric Acid Production Chemical Industry Chemical Industry (Carbon Black) Chemical Industry (Ethylene) Chemical Industry (Methanol) Chemical Industry (Nitric Acid Use) Chemical Industry (Pigment Manufacture) Chemical Industry (Reforming) Chemical Industry (Sulphuric Acid Use) Coal, tar and bitumen processes Solvent and Oil recovery Ship purging
2C1 Iron and Steel	Iron and Steel (other) Iron and Steel (Basic Oxygen Furnace) Iron and Steel (Electric Arc Furnace) Iron and Steel Flaring (Blast Furnace Gas) Rolling Mills (Hot & Cold Rolling)
2C2 Ferroalloys Productions	No Comparable Source Category
2C3 Aluminium Production	Non-Ferrous Metals (Aluminium Production)
2C4 SF6 Used in Aluminium and Magnesium Foundries	SF_6 Cover Gas
2C5 Other	Non-Ferrous Metals (other non-ferrous metals) Non-Ferrous Metals (primary lead/zinc) Non-Ferrous Metals (secondary Copper) Non-Ferrous Metals (secondary lead)
2D1 Pulp and Paper	Wood Products Manufacture

IPCC Source Category	NAEI Source Category
2D2 Food and Drink	Brewing (barley malting, fermentation, wort boiling) Bread Baking Cider Manufacture Other Food (animal feed; cakes, biscuits, cereals; coffee, malting, margarine and other solid fats; meat, fish and poultry; sugar) Spirit Manufacture (barley malting, casking distillation, fermentation, maturation, spent grain drying) Wine Manufacture
2E1 Halocarbon & SF6 By-Product Emissions 2E2 Halocarbon & SF6 Fugitive Emissions	Halocarbons Production (By-Product and Fugitive)
2E3 Halocarbon & SF6 Other	Not Occurring
2F1 Refrigeration & Air Conditioning Equipment	Commercial Refrigeration Domestic Refrigeration Industrial Refrigeration Mobile Air Conditioning Refrigerated Transport Stationary Air Conditioning
2F2 Foam Blowing	Foams
2F3 Fire Extinguishers	Fire Fighting
2F2 Aerosols	Metered Dose Inhalers Aerosols (Halocarbons)
2F5 Solvents	Precision Cleaning
2F9a One Component Foams	One Component Foams
2F9 Semiconductors, Electrical and Production of Trainers	Electronics Training Shoes Electrical Insulation

Table A 3.2.4 Mapping of IPCC Source Categories to NAEI Source Categories

IPCC Source Category	NAEI Source Category
3A Paint Application	Decorative paint (retail decorative) Decorative paint (trade decorative) Industrial Coatings (automotive) Industrial Coatings (agriculture & construction) Industrial Coatings (aircraft) Industrial Coatings (Drum) Industrial Coatings (coil coating) Industrial Coatings (commercial vehicles) Industrial Coatings (high performance) Industrial Coatings (marine) Industrial Coatings (metal and plastic) Industrial Coatings (metal packaging) Industrial Coatings (vehicle refinishing) Industrial Coatings (wood)

IPCC Source Category	NAEI Source Category
3B Degreasing & Dry Cleaning	Dry Cleaning Surface Cleaning Leather Degreasing
3C Chemical Products, Manufacture & Processing	Coating Manufacture (paint) Coating Manufacture (ink) Coating Manufacture (glue) Film Coating Leather coating Other Rubber Products Tyre Manufacture Textile Coating
3D Other	Aerosols (Car care, Cosmetics & toiletries, household products) Agrochemicals Use Industrial Adhesives Paper Coating Printing Other Solvent Use Non Aerosol Products (household, automotive, cosmetics & toiletries, domestic adhesives, paint thinner) Seed Oil Extraction Wood Impregnation

Table A 3.2.5 Mapping of IPCC Source Categories to NAEI Source Categories (Agriculture)

IPCC Source Category	NAEI Source Category
4A1 Enteric Fermentation: Cattle	Dairy Cattle Enteric Other Cattle Enteric
4A2 Enteric Fermentation: Buffalo	Not Occurring
4A3 Enteric Fermentation: Sheep	Sheep Enteric
4A4 Enteric Fermentation: Goats	Goats Enteric
4A5 Enteric Fermentation: Camels & Llamas	Not Occurring
4A6 Enteric Fermentation: Horses	Horses Enteric
4A7 Enteric Fermentation: Mules & Asses	Not Occurring
4A8 Enteric Fermentation: Swine	Pigs Enteric
4A9 Enteric Fermentation: Poultry	Not Occurring
4A10 Enteric Fermentation: Other: Deer	Deer Enteric
4B1 Manure Management: Cattle	Dairy Cattle Wastes Other Cattle Wastes
4B2 Manure Management: Buffalo	Not Occurring
4B3 Manure Management: Sheep	Sheep Wastes
4B4 Manure Management: Goats	Goats Wastes
4B5 Manure Management: Camels & Llamas	Not Occurring
4B6 Manure Management: Horses	Horses Wastes
4B7 Manure Management: Mules & Asses	Not Occurring
4B8 Manure Management: Swine	Pigs Wastes

IPCC Source Category	NAEI Source Category
4B9 Manure Management: Poultry	Broilers Wastes Laying Hens Wastes Other Poultry
4B10 Manure Management: Other: Deer	Deer Wastes
4B11 Anaerobic Lagoons	Not Occurring
4B13 Liquid Systems	Manure Liquid Systems
4B13 Solid Storage and Dry Lot	Manure Solid Storage and Dry Lot
4B14 Other	Manure Other
4C Rice Cultivation	Not Occurring
4D 1 Agricultural Soils: Direct Soil Emissions 4D 2 Agricultural Soils: Animal Emissions 4D 4 Agricultural Soils: Indirect Emissions	Agricultural Soils Fertiliser Agricultural Soils Crops
4E Prescribed Burning of Savannahs	Not Occurring
4F1 Field Burning of Agricultural Residues: Cereals	Barley Residue Wheat Residue Oats Residue
4F5 Field Burning of Agricultural Residues: Other: Linseed	Linseed Residue
4G Other	Not Estimated

Emissions and removals from the LULUCF sector in this NIR are reported used the reporting nomenclature specified in the LULUCF Good Practice Guidance and agreed at the 9th Conference of Parties for reporting to the UNFCCC. These reporting categories are very different to those previously used, and to the NAEI source categories, which are based on NFR codes. **Table A 3.2.6** summarises the categories used, and which NAEI categories they correspond to.

Table A 3.2.6 Mapping of IPCC Source Categories to NAEI Source Categories (Land Use, Land Use Change and Forestry)

IPCC Source Category	NAEI Source Category
5A Forest Land (Biomass Burning - wildfires)	Not Reported
5A Forest Land (Drainage of soils)	Not Reported
5A1 Forest Land Remaining Forest Land	Not Reported
5A2 Forest Land (N fertilisation)	Not Reported
5A2 Land Converted to Forest Land	Not Reported
5B Cropland (Biomass Burning - controlled)	Not Reported
5B Liming	4D1 Liming of Agricultural Soils
5B1 Cropland Remaining Cropland	Not Reported
5B2 Land Converted to Cropland	Not Reported
5C Grassland (Biomass burning - controlled)	Not Reported
5C Liming	4D1 Liming of Agricultural Soils
5C1 Grassland Remaining Grassland	Not Reported
5C2 Land converted to grassland	Not Reported
5D Wetlands (Biomass burning - controlled)	Not Reported
5D1 Wetlands remaining wetlands	Not Reported
5D2 Land converted to wetlands	Not Reported
5E Settlements (Biomass burning - controlled)	Not Reported
5E1 Settlements remaining settlements	Not Reported
5E2 Land converted to settlements	Not Reported

IPCC Source Category	NAEI Source Category
5F Other land (Biomass burning - controlled)	Not Reported
5F1 Other land remaining other land	Not Reported
5F2 Land converted to other land	Not Reported
5G Other (Harvested wood)	Not Reported
No relevant category	5B Deforestation

Table A 3.2.7 Mapping of IPCC Source Categories to NAEI Source Categories (Waste)

IPCC Source Category	NAEI Source Category
6A1 Managed Waste Disposal on Land	Landfill
6A2 Unmanaged Waste Disposal on Land	Not Occurring
6A3 Other	Not Occurring
6B1 Industrial Wastewater 6B2 Domestic and Commercial Wastewater 6B3 Other	Sewage Sludge Disposal
6C Waste Incineration	Incineration: MSW Incineration: Sewage Sludge Incineration: Clinical Incineration: Cremation
6D Other Waste	Not estimated

A3.3 ENERGY (CRF SECTOR 1)

The previous two sections defined the fuels and source categories used in the NAEI and the GHGI. This section describes the methodology used to estimate the emissions arising from fuel combustion for energy. These sources correspond to IPCC Table 1A.

There is little continuous monitoring of emissions performed in the UK; hence information is rarely available on actual emissions over a specific period of time from an individual emission source. In any case, emissions of CO_2 from fuel are probably estimated more accurately from fuel consumption data.

The majority of emissions are estimated from other information such as fuel consumption, distance travelled or some other statistical data related to the emissions. Estimates for a particular source sector are calculated by applying an emission factor to an appropriate statistic. This is as follows:

$$\text{Total Emission} = \text{Emission Factor} \times \text{Activity Statistic}$$

Emission factors are typically derived from measurements on a number of representative sources and the resulting factor applied to the UK environment.

For the indirect gases, emissions data are sometimes available for individual sites from databases such as the Environment Agency's Pollution Inventory (PI). Hence the emission for a particular sector can be calculated as the sum of the emissions from these point sources. That is:

$$\text{Emission} = \Sigma \ \text{Point Source Emissions}$$

However it is still necessary to make an estimate of the fuel consumption associated with these point sources, so that the emissions from non-point sources can be estimated from fuel consumption data without double counting. In general the point source approach is only applied to emissions of indirect greenhouse gases for well-defined point sources (e.g. power stations, cement kilns, coke ovens, refineries). Direct greenhouse gas emissions and most non-industrial sources are estimated using emission factors.

A3.3.1 Basic Combustion Module

For the pollutants and sources discussed in this section the emission results from the combustion of fuel. The activity statistics used to calculate the emission are fuel consumption statistics taken from DECC (2011). A file of the fuel combustion data used in the inventory is provided on a CD ROM attached to this report. Emissions are calculated according to the following equation:

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

where

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

The pollutants estimated in this way are as follows:

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

The sources covered by this module are:

- Domestic;
- Miscellaneous;
- Public Service;
- Refineries (Combustion);
- Iron & Steel (Combustion);
- Iron & Steel (Blast Furnaces);
- Iron & Steel (Sinter Plant);
- Non-Ferrous Metals;
- Chemicals;
- Pulp, Paper and Print;
- Food Processing, Beverages, Tobacco
- Other Industry (Combustion);
- Autogenerators;
- Gas Production;
- Collieries;
- Production of Nuclear Fuel;
- Coastal Shipping;
- Fishing;

- Inland waterways;
- Agriculture;
- Ammonia (Combustion);
- Railways (Stationary Sources);
- Aircraft Military; and
- Shipping Naval.

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

For the estimation of CO and NO_x emissions from industrial, commercial/institutional and domestic sources the methodology allows for source/fuel combinations to be further broken down by a) thermal input of combustion devices; b) type of combustion process e.g. boilers, furnaces, turbines etc. Different emission factors are applied to these subdivisions of the source/fuel combination. Most of these emission factors are taken from literature sources, predominantly from US EPA, (2005), EMEP/CORINAIR (2003), and Walker *et al*, (1985). Some emissions data reported in the Pollution Inventory (Environment Agency, 2011) are also used to generate emission factors.

Table A 3.3.1 to **Table A 3.3.4** list the emission factors used in this module. Emission factors are expressed in terms of kg pollutant/tonne for solid and liquid fuels, and g/TJ gross for gases. This differs from the IPCC approach, which expresses emission factors as tonnes pollutant/TJ based on the *net calorific value* of the fuel. For gases the NAEI factors are based on the *gross calorific value* of the fuel. This approach is used because the gas consumption data in DECC (2011) are reported in terms of energy content on a gross basis. The tables are grouped into solid, liquid, gas and biomass/other based on the IPCC definitions of the fuels.

For most of the combustion source categories, the emission is estimated from fuel consumption data reported in DUKES and an emission factor appropriate to the type of combustion e.g. commercial gas fired boiler. However the DUKES category 'Other Industries' covers a range of sources and types, so the Inventory disaggregates this category into a number of sub-categories, namely:

- Other Industry;
- Other Industry Off-road;
- Ammonia Feedstock (natural gas only);
- Ammonia (Combustion) (natural gas only);
- Cement (Combustion); and
- Lime Production (non-decarbonising).

Thus the GHGI category Other Industry refers to stationary combustion in boilers and heaters by industries not covered elsewhere (including glass, ceramics & bricks, textiles & engineering sectors) In previous inventory submissions this also included non-ferrous metals; chemicals; pulp, paper and print and food processing, beverages and tobacco, however following UNFCCC recommendation these sources have now been disaggregated into the relevant IPCC sector where possible. Other categories are estimated by more complex methods discussed in the sections indicated. For certain industrial processes (e.g. Lime production, cement production and ammonia production), the methodology is discussed in **Section A3.4** as the estimation of the fuel consumption is closely related to the details of the process. However, for these processes, where emissions arise from fuel combustion for energy production, these are *reported* under IPCC Table 1A. The fuel consumption of Other Industry is estimated so that the total fuel consumption of these sources is consistent with DUKES (DECC, 2011).

According to IPCC 1996 Revised Guidelines, electricity generation by companies primarily for their own use is autogeneration, and the emissions produced should be reported under the industry concerned. However, most National Energy Statistics (including the UK) report emissions from electricity generation as a separate category. The UK inventory attempts to report as far as possible according to the IPCC methodology. Hence autogenerators would be reported in the relevant sector where they can be identified e.g. iron and steel (combustion), refineries (combustion). In some cases the autogenerator cannot be identified from the energy statistics so it would be classified as other industry (combustion). This means that the split between iron and steel (combustion) and other industry (combustion) may be uncertain. Also, for certain sectors, data on fuel deliveries are used in preference to data on fuel consumption because deliveries will include autogeneration whereas consumption does not.

In 2004, an extensive review of carbon factors in the UK GHG inventory was carried out (Baggott *et al*., 2004). This review covered over 90% of carbon emissions in the UK and focused on obtaining up-to-date carbon factors and oxidation factors for use in the inventory. The methods used to derive the carbon factors are described below.

In the UK, power stations and the cement industry are important users of coal. The carbon contents of coal used by these two industries are obtained directly from industry representatives or from EU ETS data and this ensures that the inventory contains emissions of CO_2 that are estimated as accurately as possible.

The cement industry imports most of the coal it uses from abroad, and the coal burnt is considered to be 100% oxidised due to the high operating temperatures of cement kilns.

The carbon contents of fuels used by other industry sectors are not requested annually, but a time series is updated each year by scaling the carbon contents to the GCVs presented in the latest version of the Digest of UK Energy Statistics (DECC, 2011). The carbon content of a fuel is closely correlated with the calorific value and so using calorific values as a proxy provides a good estimate of the changing carbon contents.

The major liquid fuel carbon factors in the inventory have been from the UK Petroleum Institute Association (UKPIA). During the review in 2004, UKPIA undertook fuel analysis and provided carbon emission factors for the following fuels:

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

- Butane.

UKPIA advise whether these factors are still valid each year.

For the cement sector, industry carbon factors are used for most fuels.

Natural gas factors are provided by the UK gas network distributors. These data are derived from extensive measurements which are carried out by the various network distributors and data are provided to us each year.

In the 2009 GHGI, carbon factors from the EUETS were introduced for certain sector and fuel combinations and EU-ETS factors have continued to be used in subsequent GHGIs. The sectors are listed below for which EUETS data is used:

  - Power Stations
  - Autogenerators
  - Refineries
  - Lime kilns
  - Other industrial combustion

EUETS factors are not used for all years or all fuels for the sectors above; further information on the use of EU ETS data within the inventory is included in **Annex 11.** Where EUETS factors are not used, carbon factors remained the same as in previous inventories and as described in the carbon factors review from 2004.

Implied emission factors (IEFs) for carbon are partly driven by the carbon emission factors and so there is some variability across the time series due to changes in UK factors. Updating carbon emission factors each year can cause large inter-annual changes in carbon implied emission factors (IEFs). One approach to avoid this, which has been suggested by an UNFCCC Expert Review Team, is to use regression analysis and derive the CEFs from the best fit line. We have considered this approach and discussed with UK DECC. For the moment, the UK continues to update CEFs on an annual basis because it considers that this approach provides the most accurate estimates of carbon emissions in a given year.

For gas in sector 1A1, the carbon IEFs for gas are high in relation to other Member States of the European Union. This is because sour gas has been used in the UK ESI sector from 1992 onwards, and sour gas has a much greater IEF than natural gas. The increase in the CO_2 IEF between 1991 and 1992 is explained by the commissioning of Peterhead power station in Scotland.

Table A 3.3.1 Emission Factors for the Combustion of Liquid Fuels for 2010

Fuel	Source	Units	C[aj]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
ATF	Aircraft Military	kg/t	859[a]	0.103[g]	0.1[g]	8.5[g]	8.2[g]	1.1[g]	0.84[g]
Burning Oil	Domestic	kg/t	859[a]	0.462[g]	0.0277[g]	3.23[l]	1.85[l]	0.047[f]	0.51[z]
Burning Oil	Other Industry	kg/t	859[a]	0.0924[g]	0.0277[g]	3.33[l]	0.19[l]	0.028[e]	0.51[z]
Burning Oil	Public Service, Railways (Stationary)	kg/t	859[a]	0.462[g]	0.0277[g]	0	0	0.047[f]	0.51[z]
Burning Oil	Miscellaneous	kg/t	859[a]	0.462[g]	0.0277[g]	0	0	0.047[f]	0.51[z]
Gas Oil	Cement	kg/t	870[a]	0.0910[g]	0.0273[g]	NE	NE	NE	NE
Gas Oil	Domestic	kg/t	870[a]	0.455[g]	0.0273[g]	3.19[l]	1.82[l]	0.047[f]	1.44[z]
Gas Oil	Fishing, Coastal Shipping, Naval, International Marine	kg/t	870[a]	0.05[ap]	0.08 [ap]	57.97, 64.44, 69.33, 69.33[av]	7.4[ap]	2.04, 2.82, 2.74, 2.74[av]	2.02, 20.36, 20.5, 20.5[av]
Gas Oil	Iron&Steel	kg/t	870[a]	0.0910[g]	0.0273[g]	15.31[l]	5.93[l]	0.028[f]	1.44[z]
Gas Oil	Refineries	kg/t	870[a]	0.136[g]	0.0273[g]	4.53[k]	0.24[i]	0.028[f]	1.44[z]
Gas Oil	Other Industry	kg/t	870[a]	0.0910[g]	0.0273[g]	5.29[l]	1.14[l]	0.028[f]	1.44[z]
Gas Oil	Public Service	kg/t	870[a]	0.455[g]	0.0273[g]	2.44[l]	0.38[l]	0.047[f]	1.44[z]
Gas Oil	Miscellaneous	kg/t	870[a]	0.455[g]	0.0273[g]	1.22[l]	0.157[l]	0.047[f]	1.44[z]
Fuel Oil	Agriculture	kg/t	879[a]	0.433[g]	0.026[g]	7.69[l]	0.31[l]	0.138[f]	14.84[z]
Fuel Oil	Cement	kg/t	879[a]	0.087[g]	0.026[g]	NE	NE	NE	NE
Fuel Oil	Public Service	kg/t	879[a]	0.433[g]	0.026[g]	6.93[l]	0.80[l]	0.138[f]	14.84[z]
Fuel Oil	Miscellaneous	kg/t	879[a]	0.433[g]	0.026[g]	0.96[l]	0.03[l]	0.138[f]	14.84[z]
Fuel Oil	Coastal Shipping, International Marine	kg/t	879[a]	0.05[ap]	0.08[ap]	70.57, 77.71[av]	7.4[ap]	3.517, 2.924[av]	53.96, 53.92[av]
Fuel Oil	Domestic	kg/t	879[a]	0.433[g]	0.026[g]	0[ap]	0[ap]	0.138[f]	14.84[z]
Fuel Oil	Iron&Steel	kg/t	879[a]	0.087[g]	0.026[g]	6.67	0.85[l]	0.034[f]	14.84[z]
Fuel Oil	Railways (Stationary)	kg/t	879[a]	0.433[g]	0.026[g]	6.93[l]	0.80[l]	0.138[f]	14.84[z]
Fuel Oil	Other Industry	kg/t	879[a]	0.087[g]	0.026[g]	8.26[l]	1.27[l]	0.034[f]	14.84[z]
Fuel Oil	Refineries (Combustion)	kg/t	878[at]	0.130[g]	0.026[g]	2.87[ag]	0.77[ag]	0.034[f]	30.12[ag]
Lubricants	Other Industry	kg/t	865[x]	0.091[e]	0.027[e]	4.53[k]	0.25[f]	0.133[f]	11.41[x]

Fuel	Source	Units	C[aj]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Petrol	Refineries	kg/t	855[a]	0.138[an]	0.028[g]	4.62[k]	0.24[e]	0.028[e]	0.01[z]
Naphtha	Refineries (Combustion)	kg/t	854[a]	0.129[g]	0.026 [g]	4.62[k]	0.24 [i]	0.028 [f]	0.2[ax]
Waste oils	Cement (Combustion)	kg/t	C	C	C	C	C	C	C
Waste solvent	Cement (Combustion	kg/t	C	C	C	C	C	C	C
Petroleum Coke	Domestic	kg/t	837 [ay]	NE	NE	3.95[az]	158[az]	4.9[az]	142.4[az]
Petroleum Coke	Refineries	kg/t	930[at]	0.107[g]	0.281[w]	5.38[ag]	1.48[ag]	0.054[k]	27.15[ag]
Petroleum Coke	Cement Production –Combustion	kg/t	C	C	C	C	C	C	C
Petroleum Coke	Other Industry	kg/t	C	C	C	C	C	C	C
LPG	Domestic	g/GJ Gross	16227[a]	0.895[f]	0.100[g]	62.19[f]	8.89[f]	3.78[f]	0
LPG	I&Sak, Other Industry, Refineries,	g/GJ Gross	16227[a]	0.895[f]	0.100[g]	62.19[f]	15.11[f]	3.78[f]	0
LPG	Gas Production – combustion at gas separation plant	g/GJ Gross	16227[a]	52.42[aw]	4.416[aw]	148.24[aw]	65.70[aw]	4.12[aw]	0.73[aw]
OPG	Gas production	g/GJ Gross	14333[at]	1.000[g]	NE	70.00[k]	2.37[i]	3.78[f]	0
OPG	Refineries (Combustion)	g/GJ Gross	14333[at]	1.000[g]	NE	70.81[ag]	14.13[z]	3.78[f]	0
OPG	Other Industry	g/GJ Gross	14333[at]	5.000[g]	0.100[g]	70.00[k]	2.37[i]	3.78[f]	0
OPG	Gas production – combustion at gas separation plant	g/GJ Gross	14333[at]	52.42[aw]	4.416[aw]	148.24[aw]	65.70[aw]	4.12[aw]	0.73[aw]

Note: Emission factors on an energy basis are presented in CD-ROM/excel file which accompanies this report.

Table A 3.3.2 Emission Factors for the Combustion of Solid fuels for 2010

Fuel	Source	Units	C[aj]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Coal	Agriculture	Kg/tonne	639.1[ao]	0.011[o]	0.146[w]	4.75[l]	8.25[l]	0.05[o]	17.0[aa]
Coal	Collieries	Kg/tonne	675.7[ao]	0.011[o]	0.148[w]	4.75[l]	8.25[l]	0.05[o]	21.7[aa]
Coal	Domestic	Kg/tonne	667.8[ao]	15.7[o]	0.122[w]	2.34[l]	159.96[l]	14.00[o]	17.8[aa]
Coal	Iron and Steel (Combustion)	Kg/tonne	693.8[ao]	0.011[o]	0.237[w]	1.23	0.53	0.05[o]	17.0[aa]
Coal	Lime Production (Combustion)	Kg/tonne	635.1[ao]	0.011[o]	0.214[w]	45.29[v]	8.25[v]	0.05[o]	17.0[aa]
Coal	Miscellaneous	Kg/tonne	611.6[ao]	0.011[o]	0.147[w]	5.60[l]	8.58[l]	0.05[o]	17.0[aa]
Coal	Public Service	Kg/tonne	611.6[ao]	0.011[o]	0.147[w]	4.47[l]	7.00[l]	0.05[o]	17.0[aa]
Coal	Other Industry	Kg/tonne	657.2[ao]	0.011[o]	0.214[w]	4.28[l]	1.97[l]	0.05[o]	17.0[aa]
Coal	Railways	Kg/tonne	726.8[ao]	0.011[o]	0.147[m]	4.47[l]	7.00[l]	0.05[o]	17.0[aa]
Coal	Autogenerators	Kg/tonne	599.9[at]	0.020[o]	0.066[w]	5.12[l]	1.53[l]	0.03[o]	17.0[aa]
Coal	Cement production (combustion)	Kg/tonne	C	C	C	C	C	C	C
Anthracite	Domestic	Kg/tonne	819.1[ao]	2[o]	0.142[w]	3.47[k]	208.2[k]	1.7[o]	15.2[aa]
Coke	Agriculture	Kg/tonne	852.4[r]	0.011[p]	0.150[w]	0	0	0.05[p]	19[ab]
Coke	SSF Production	Kg/tonne	852.4[r]	0.011[p]	0.230[w]	NE	NE	0.05[p]	19[ab]
Coke	Domestic	Kg/tonne	852.4[r]	5.8[o]	0.117[w]	3.04[l]	118.6[l]	4.9[o]	15.2[aa]
Coke	I&Sak (Sinter Plant)	Kg/tonne	852.4[r]	1.41[ae]	0.230[w]	13.47[ae]	296.4[ae]	0.48[ae]	20.5[ae]
Coke	I&Sak (Combustion)	Kg/tonne	852.4[r]	0.011[p]	0.230[w]	0.87[l]	226[l]	0.05[p]	19[ab]
Coke	Other Industry	Kg/tonne	852.4[r]	0.011[p]	0.230[w]	0	0	0.05[p]	19[ab]
Coke	Railways	Kg/tonne	852.4[r]	0.011[p]	0.150[w]	0	0	0.05[p]	19[ab]
Coke	Miscellaneous; Public Service	Kg/tonne	852.4[r]	0.011[p]	0.150[w]	0	0	0.05[p]	19[ab]
Peat	Domestic	Kg/tonne	370.0[g]	4.17[g]	0.056[g]	0.70[g]	69.5[g]	7.07[g]	NE

Fuel	Source	Units	C^{aj}	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
SSF	Miscellaneous; Public Service	Kg/tonne	766.3[n]	0.011[o]	0.155[w]	4.89[k]	48.9[k]	0.05[p]	19[ab]
SSF	Domestic	Kg/tonne	774.2[n]	5.8[o]	0.120[w]	3.26[k]	130.4[k]	4.9[o]	16[ab]
SSF	Other Industry	Kg/tonne	766.3[n]	0.011[o]	0.237[w]	4.89[k]	48.9[k]	0.05[p]	19[ab]
Blast Furnace Gas	Coke Production	g/GJ Gross	81354[r]	112.01[k]	2.00[k]	79.0[k]	39.5[k]	5.60[k]	0
Blast Furnace Gas	I&Sak (Combustion), I&Sak (Flaring)	g/GJ Gross	81354[r]	112.01[k]	2.00[k]	79.0[k]	39.5[k]	5.60[k]	0
Blast Furnace Gas	Blast Furnaces	g/GJ Gross	81354[r]	112.01[k]	2.00[k]	37.0[k]	39.5[k]	5.60[k]	0
Coke Oven Gas	Other Sources	g/GJ Gross	11215[r]	57.25[k]	2.00[k]	80.5[k]	40.0[k]	4.35[k]	402.9[v]
Coke Oven Gas	I&Sak Blast Furnaces	g/GJ Gross	11215[r]	57.25[k]	2.00[k]	80.5[k]	40.0[k]	4.35[k]	402.9[v]
Coke Oven Gas	Coke Production	g/GJ Gross	11215[r]	57.25[k]	2.00[k]	384.2[k]	40.0[k]	4.35[k]	402.9[v]

Note: Emission factors on an energy basis are presented in CD-ROM/Excel file which accompanies this submission.

Table A 3.3.3 Emission Factors for the Combustion of Gaseous Fuels 2010 (g/GJ gross)

Fuel	Source	C[aj]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Natural Gas	Agriculture	13952[r]	5.0[g]	0.10[g]	39.2[l]	2.13[l]	2.23[f]	0
Natural Gas	Miscellaneous	13952[r]	5.0[g]	0.10[g]	52.4	11.17	2.23[f]	0
Natural Gas	Public Service	13952[r]	5.0[g]	0.10[g]	57.9[l]	13.92[l]	2.23[f]	0
Natural Gas	Coke Production, SSF Prodn[al],	13952[r]	1.0[g]	0.10[g]	175.0[k]	2.37[l]	2.23[f]	0
Natural Gas	Refineries	13908[at]	1.0[g]	0.10[g]	70.0[k]	2.37[l]	2.23[f]	0
Natural Gas	Blast Furnaces	13952[r]	5.0[g]	0.10[g]	23.1[v]	2.37[l]	2.23[f]	0
Natural Gas	Domestic	13952[r]	5.0[g]	0.10[g]	22.2[l]	30.8[l]	2.23[f]	0
Natural Gas	Gas Prodn[al],	13952[r]	1.0[g]	0.10[g]	74.7[l4]	17.4[l]	2.23[f]	0
Natural Gas	Oil Prodn[al]	16188[aw]	18.3[aw]	3.92[aw]	192.3[aw]	61.6[aw]	0.86[aw]	9.13[aw]
Natural Gas	I&S[ak]	13952[r]	5.0[g]	0.10[g]	176.7[l]	172.9[l]	2.23[f]	0
Natural Gas	Railways	13952[r]	5.0[g]	0.10[g]	89.4[l]	33.8[l]	2.23[f]	0
Natural Gas	Other Industry	13952[r]	5.0[g]	0.10[g]	139.9[l]	74.4[l]	2.23[f]	0
Natural Gas	Nuclear Fuel Prodn[al], Collieries	13952[r]	1.0[g]	0.10[g]	139.9[l]	74.4[l]	2.23[f]	0
Natural Gas	Autogenerators	13952[r]	5.0[g]	0.10[g]	61.9[l]	20.6[l]	2.23[f]	0
Natural Gas	Ammonia (Combustion)	13952[r]	5.0[g]	0.10[g]	157.2[d]	NE	2.23[f]	0
Colliery Methane	Other Industry, collieries	17145[a]	5.0[s]	0.10[g]	70.0[k]	2.37[i]	2.23[f]	0
Colliery Methane	Coke Production, Gas Production	17145[a]	1.0[s]	0.10[g]	70.0[k]	2.37[i]	2.23[f]	0

Table A 3.3.4 Emission Factors for the Combustion of other fuels and biomass 2010

Fuel	Source	Units	C[aj]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
MSW	Miscellaneous	Kg/tonne	75[ah]	2.85[g]	0.038[g]	0.84[v]	0.098[v]	0.0049[v]	0.028[v]
Scrap tyres	Cement (combustion)	Kg/tonne	C	C	C	C	C	C	C
Waste	Cement (combustion)	Kg/tonne	C	C	C	C	C	C	C
Straw	Agriculture	Kg/tonne	440[g]	4.7[g]	0.06[g]	1.5[k]	79[g]	9.5[k]	
Wood	Domestic	Kg/tonne	387[g]	4.17[g]	0.06[g]	0.7[k]	69.5[k]	23.6[k]	0.11[f]
Wood	Other industry	Kg/tonne	381[g]	0.41[g]	0.05[g]	2.06[k]	68.5[k]	0.39[k]	0.13[f]
Sewage Gas	Public Services	g/GJ Gross	27406[g]	5.0[g]	0.10[g]	239.8[bb]	7.1[f]	2.42[f]	0
Landfill Gas	Miscellaneous	g/GJ Gross	27406[g]	5.0[g]	0.10[g]	239.8[ba]	122.4[f]	3.62[f]	0

Footnotes to **Tables A 3.3.1** to **A 3.3.4**:

a	Carbon Factor Review (2004), Review of Carbon Emission Factors in the UK Greenhouse Gas Inventory. Report to UK Defra. Baggott, SL, Lelland, A, Passant and Watterson, JW, and selected recent updates to the factors presented in this report.
b	CORINAIR (1992)
b+	Derived from CORINAIR(1992) assuming 30% of total VOC is methane
c	Methane facto r estimated as 12% of total hydrocarbon emission factor taken from EMEP/CORINAIR(1996) based on speciation in IPCC (1997c)
d	Based on operator data: GrowHow (2011), Invista (2011), BP Chemicals (2011)
e	As for gas oil
f	USEPA (2005)
g	IPCC (1997c)
h	EMEP (1990)
i	Walker *et al* (1985)
j	As for fuel oil.
k	EMEP/CORINAIR (2003)
l	AEA estimate based on disaggregation of UK fuel use by sector and device type with application of literature-based emission factors or data reported in the Pollution Inventory for each disaggregated sector/device combination (2009)
m	USEPA (1997)
n	British Coal (1989)
o	Brain *et al,* (1994)
p	As for coal
r	AEA Energy & Environment estimate based on carbon balance
s	As for natural gas
t	EMEP/CORINAIR (1996)
u	IPCC (2000)
v	Emission factor derived from emissions reported in the Pollution Inventory (Environment Agency, 2011)
w	Fynes *et al* (1994)
x	Passant (2005)
y	UKPIA (1989)
z	Emission factor derived from data supplied by UKPIA (2006, 2007, 2008, 2009, 2010, 2011)
aa	Emission factor for 2005 based on data provided by UK Coal (2005), Scottish Coal (2006), Celtic Energy (2006), Tower (2006), Betwys (2000)
ab	Munday (1990)
ac	Estimated from THC data in CRI (Environment Agency, 1997) assuming 3.% methane split given in EMEP/CORINAIR (1996)
ad	EMEP/CORINAIR (1999)
ae	AEA estimate based on data from Environment Agency (2005) and Corus (2005)
af	UKPIA (2004)
ag	AEA estimate based on data from Environment Agency (2005), UKPIA, DUKES, and other sources
ah	Royal Commission on Environmental Pollution (1993)
aj	Emission factor as mass carbon per unit fuel consumption
ak	I&S = Iron and Steel
al	Prodn = Production
am	As for SSF
an	As for burning oil
ao	AEA estimate based on carbon factors review
ap	EMEP/CORINAIR
aq	AEA estimate
ar	Directly from annual fuel sulphur concentration data
as	Based on sulphur content of pet coke used in Drax trials (Drax Power Ltd, 2008)
at	Based on factors presented in EU-ETS returns
au	Data supplied directly by the British Cement Association (BCA)

av	UK Ship Emissions Inventory (Entec, 2010)
aw	EEMS 2008 to 2010, DECC Oil and Gas
ax	UKPIA, Pers. Comm., 2000
ay	Loader *et al* (2008)
az	As for domestic wood
ba	Amec, (2011)
bb	As for landfill gas
C	Confidential
NE	Not estimated
NA	Not available
IE	Included elsewhere
1	These are the factors used the latest inventory year. The corresponding time series of emission factors and calorific values may are available electronically [on the CD accompanying this report]. Note that all carbon emission factors used for Natural Gas include the CO_2 already present in the gas prior to combustion.

A3.3.2 Conversion of Energy Activity Data and Emission Factors

The NAEI database stores activity data in Mtonnes for solid and liquid fuels and Mtherms (gross) for gaseous fuels. Emission factors are in consistent units namely: ktonnes/Mtonne for solid and liquid fuels and ktonnes/Mtherm (gross) for gaseous fuels. For some sources emission factors are taken from IPCC and CORINAIR sources and it is necessary to convert them from a net energy basis to a gross energy basis. For solid and liquid fuels:

$$H_n = m\, h_g\, f$$

and for gaseous fuels:

$$H_n = H_g\, f$$

where:

H_n	Equivalent energy consumption on net basis	(kJ)
m	Fuel consumption	(kg)
h_g	Gross calorific value of fuel	(kJ/kg)
f	Conversion factor from gross to net energy consumption	(-)
H_g	Energy Consumption on gross basis	(kJ)

In terms of emission factors:

$$e_m = e_n\, h_g\, f$$

or

$$e_g = e_n\, f$$

where:

e_m	Emission factor on mass basis	(kg/kg)
e_n	Emission factor on net energy basis	(kg/kJ net)
e_g	Emission factor on gross energy basis	(kg/kJ gross)

The gross calorific values of fuels used in the UK are tabulated in DECC, (2011). The values of the conversion factors used in the calculations are given in **Table A 3.3.5.**

Table A 3.3.5 Conversion Factors for Gross to Net Energy Consumption

Fuel	Conversion Factor
Other Gaseous Fuels	0.9
Solid and Liquid Fuels	0.95
LPG and OPG	0.92
Blast Furnace Gas	1.0

The values given for solid, liquid and other gaseous fuels are taken from IPCC Guidelines (IPCC, 1997c). The value used for LPG is based on the calorific value for butane, the major constituent of LPG (Perry *et al*, 1973). Blast furnace gas consists mainly of carbon monoxide and carbon dioxide. Since little hydrogen is present, the gross calorific value and the net calorific values will be the same.

A3.3.3 Energy Industries (1A1)

A3.3.3.1 Electricity Generation

The NAEI category Power Stations is mapped onto 1A1 Electricity and Heat Production, and this category reports emissions from electricity generation by companies whose main business is producing electricity (Major Power Producers) and hence excludes autogenerators. Activity data for this category are taken from fuel consumption data in the annual publication *The Digest of UK Energy Statistics* (DECC, 2011) in conjunction with site-specific fuel use data obtained directly from plant operators. Coal and natural gas data from DUKES are very close to the category definition (i.e. exclude autogenerators) but fuel oil data does contain a small contribution from transport undertakings and groups of factories. From 1999 onwards, the fuel oil consumption reported within DUKES has been significantly lower than that estimated from returns from the power generators. In the inventory, the fuel oil use data from the power station operators are used; if the DUKES data were to be used, the emission factors implied by the data reported to UK environmental regulators (EA, SEPA, NIDoE) would be impossibly high. A correction is applied to the Other Industry (Combustion) category in the NAEI to ensure that total UK fuel oil consumption corresponds to that reported in DUKES[4].

4 Making use, from 2000 onwards, of supplementary data from DECC because of a revision to the DUKES reporting format.

Table A 3.3.6 Emission Factors for Power Stations in 2010 [A time series of carbon emission factors can be found in the background energy tables on the accompanying CD, or in the Excel tables accompanying the report on the NAEI website]

Source	Unit	CO_2[1]	CH_4	N_2O	NO_X	CO	NMVOC	SO_2
Coal	Kt/Mt	610[s]	0.02[e]	0.063[l]	4.31[n]	0.69[n]	0.018[n]	4.07[n]
Petroleum Coke	Kt/Mt	605[a]	0.107[q]	0.087[r]	3.05[n]	7.49[n]	0.015[n]	10.00[n]
Fuel Oil	Kt/Mt	873[s]	0.130[h]	0.026[h]	11.72[n]	1.49[n]	0.049[n]	8.35[n]
Gas Oil	Kt/Mt	870[a]	0.136[h]	0.0273[h]	13.08[n]	1.68[n]	0.341[n]	8.10[n]
Natural gas	Kt/Mth	1.460[s]	0.000106[h]	1.06E-05[h]	0.0036[n]	0.0011[n]	0.000123[n]	5.32E-05[n]
MSW	Kt/Mt	75[d]	0.285[h]	0.038[h]	0.84[o]	0.098[o]	0.00492[o]	0.0268[o]
Sour gas	Kt/Mth	1.931[c]	0.000106[h]	1.06E-05[h]	0	0	0	0
Poultry Litter	Kt/Mt	NE	0.284[h]	0.0379[j]	0.999[n]	0.401[o]	0.0495[o]	0.263[n]
Sewage Gas	Kt/Mth	NE	0.000106[h]	1.06E-05[h]	0.0253[k]	0.000749[k]	0.000255[k]	NE
Waste Oils	Kt/Mt	864.8[b]	NE	NE	11.72[n]	1.49[n]	0.049[n]	8.35[n]
Landfill gas	Kt/Mth	NE	0.000106[h]	1.06E-05[h]	0.0253[k]	0.0129[k]	0.000382[k]	NE
Wood	Kt/Mt	NE	0.279	0.0372	1.445	12.17	0.283	0.010

Footnotes to **Table A 3.3.6** (Emission Factors for Power Stations)

1 Emission factor as mass carbon/ unit fuel consumption
a Baggott *et al* (2004) - Review of Carbon Emission Factors in the UK Greenhouse Gas Inventory. Report to UK Defra. Baggott, SL, Lelland, A, Passant and Watterson, JW Plus selected updates.
(UKPIA (2004)-Liquid Fuels, Transco (2008) – Natural Gas, Quick (2004) and AEP(2004) – Power Station Coal). Note that all carbon emission factors used for Natural Gas include the CO_2 already present in the gas prior to combustion.
b Passant, N.R., Emission factors programme Task 1 – Summary of simple desk studies (2003/4), AEA Technology Plc, Report No AEAT/ENV/R/1715/Issue 1, March 2004
c Stewart et al (1996) Emissions to Atmosphere from Fossil Fuel Power Generation in the UK, AEAT-0746, ISBN 0-7058-1753-3
d RCEP (Royal Commission on Environmental Protection) 17th Report - Incineration of Waste, 1993. Recently photosynthesised carbon **is excluded** from the carbon EF for MSW used in the GHG inventory, and is assumed to be 75% of total carbon. This indicates a total carbon EF of 300 kg/t.
e Brain (1994)
f Stewart *et al* (1996) estimated from total VOC factor assuming 27.2% is methane after USEPA(1997)
g CORINAIR (1992)
h IPCC (1997c)
i EMEP/CORINAIR (1996)
j IPCC (1997)
k USEPA (2004)
l Fynes *et al* (1994)
m Stewart (1997)
n Based on reported emissions data from the EA Pollution Inventory (Environment Agency, 2011), SEPA's Scottish Pollutant Release inventory (SEPA, 2011), NI DoE's Inventory of Sources and Releases list (NI DoE, 2011) and direct communications with plant operators (Pers. Comms., 2011)
o Environment Agency (2011)
p USEPA (1997)
q IPCC (2006)
r Based on Fynes, G. & Sage, P.W (1994)
s Based on EU-ETS data
NE Not Estimated

The emission factors used for Power Stations are shown in **Table A 3.3.6**. National emission estimates for SO_2, NO_x, CO and NMVOC are based on estimates for each power station provided by the process operators to UK regulators (EA, SEPA, NIDoE, all 2011). These emission estimates are reported on a power station basis and comprise emissions from more than one fuel in many cases (for example, those from coal fired plant will include emissions from oil used to light up the boilers). It is necessary to estimate emissions by fuel in order to fulfil IPCC and UNECE reporting requirements. Therefore, the reported emissions are allocated across the different fuels burnt at each station. Plant-specific fuel use data are obtained directly from operators, or obtained from EU ETS data held by UK regulators, or estimated from carbon emissions in a few cases where no other data are available. The allocation of reported emissions of a given pollutant across fuels is achieved as follows:

- Emissions from the use of each fuel at each power station are calculated using the reported fuel use data and a set of literature-based emission factors to give 'default emission estimates';

- For each power station, the 'default emission estimates' for the various fuels are summed, and the percentage contribution that each fuel makes to this total is calculated; and
- The reported emission for each power station is then allocated across fuels by assuming each fuel contributes the same percentage of emissions as in the case of the 'default emission estimates'.

From 1991 to 1997 some UK power stations burnt orimulsion, an emulsion of bitumen and water. DTI (1998) gives the UK consumption of orimulsion. This fuel was only used by the electricity supply industry so these data were used in the category power stations. The carbon content of the fuel was taken from the manufacturer's specification (BITOR, 1995). The emissions of NO_x, SO_2, NMVOC and CO were taken from Environment Agency (1998) but emission factors for methane and N_2O were derived from those of heavy fuel oil but adjusted on the basis of the gross calorific value. The CO emission factor is based on measured data. This fuel is no longer used.

Electricity has been generated from the incineration of municipal solid waste (MSW) to some extent from before 1990, though generation capacity increased markedly in the mid-1990s owing to construction and upgrading of incinerators to meet regulations which came into force at the end of 1996. Data are available (DECC, 2011) on the amount of waste used in heat and electricity generation and the emissions from the incinerators (Environment Agency, 2011). Since 1997, all MSW incinerators have generated electricity so emissions are no longer reported under the waste incineration category.

In addition to MSW combustion, the inventory reports emissions from the combustion of scrap tyres. The carbon content of tyres is assumed to be the same as for those used in the cement industry; data are supplied for this source annually (MPA, 2011). IPCC default factors based on oil are used. In 2000, the tyre-burning plant closed down.

Also included are emissions from four plants that were designed to burn poultry litter, a plant burning wood, and a plant burning straw. In 2000 one of the poultry litter plants was converted to burn meat and bone meal. A number of large coal-fired power stations co-fire small quantities of biofuels. Most co-firing is with solid fuels such as short-rotation coppice (SRC), and these fuels were included in the GHGI for the first time for the 2008 version of the inventory.

Carbon emissions for poultry litter, straw and wood/SRC are not included in the UK total since these derive from biomass, but emissions are reported for information in the CRF. Emissions of CH_4, N_2O, CO, NO_x, SO_2, and NMVOC are also estimated. Emission factors are based on Environment Agency (2011) data and IPCC (1997) defaults for biomass. Fuel use data are provided directly by the operators of three poultry litter plant and have been estimated for the fourth poultry litter plant and the wood and straw-burning plant either by using EU ETS data or, where that is not available, based on information published on the internet by the operators of the power stations. There is considerable variation in emission factors for different sites due to the variability of fuel composition.

Emission estimates are made from the generation of electricity from landfill gas and sewage gas (DECC, 2011). It is assumed that the electricity from this source is fed into the public supply or sold into non-waste sectors and hence classified as public power generation. The gases are normally used to power reciprocating gas (or dual-fuel engines), which may be part of combined heat and power schemes. Emission factors for landfill gas and sewage gas burnt in reciprocating engines have not been found so those for these gases burnt in gas turbines have been used instead (USEPA, 2008). DECC (2011) reports the energy for electricity production and for heat production separately. The emissions for electricity generation are allocated to 'Public Power' whilst those for heat production are reported under 'Miscellaneous' for landfill gas and 'Public Services' for sewage gas. These emission sources have previously been allocated to 1A4 although it was felt they would be more appropriate in 1A1a, this has been corrected for the 2012 submission. The carbon emissions are not included in the UK total as they are derived from biomass, but emissions are reported for information in the CRF.

A3.3.3.2 Petroleum Refining

The NAEI category refinery (combustion) is mapped onto the IPCC category 1A1b Petroleum Refining. The emission factors used are shown in **Table A 3.3.1**. Included in this category is an emission from the combustion of petroleum coke. This emission arises from the operation of fluidized bed catalytic crackers. During the cracking processes coke is deposited on the catalyst degrading its performance. The catalyst must be continuously regenerated by burning off the coke. The hot flue gases from the regeneration stage are used as a source of heat for the process. Since the combustion provides useful energy and the estimated amount of coke consumed is reported (DECC, 2011), the emissions are reported under 1A1b Petroleum Refining rather than as a fugitive emission under 1B2. However, comparing the EU ETS operator returns for this sector with the reported fuel use in DUKES implies a carbon content of greater than 100% for this fuel. Therefore the emissions are based on the EU ETS total, and the activity data is calculated based on the reported emission and an emission factor (UKPIA, 2011). For other pollutants and fuels, emission factors are all based on either operator reported data (UKPIA, 2011) or IPCC (1997) defaults for oil. The NAEI definition of Refinery (Combustion) includes all combustion sources: refinery fuels, electricity generation in refineries and fuel oils burnt in the petroleum industry.

A3.3.3.3 Manufacture of Solid Fuels

The mappings used for these categories are given in **Sections A3.1-3.2** and emission factors for energy consumption in these industries are given in **Table A 3.3.1 - Table A 3.3.4**. The fuel consumption for these categories are taken from DECC (2011). The emissions from these sources (where it is clear that the fuel is being burnt for energy production) are calculated as in the base combustion module and reported in IPCC Table 1A Energy. Where the fuel is used as a feedstock resulting in it being transformed into another fuel, which may be burnt elsewhere, a more complex treatment is needed. The approach used by the NAEI is to perform a carbon balance over solid smokeless fuel (SSF) production and a separate carbon balance over coke production, sinter production, blast furnaces and basic oxygen furnaces. This procedure ensures that there is no double counting of carbon and is consistent with IPCC guidelines. No town gas was manufactured in the UK over the period covered by these estimates so this is not considered.

The transformation processes involved are:

Solid Smokeless Fuel Production

coal → SSF + carbon emission

Coke Production/Sinter production/Blast furnaces/Basic oxygen furnaces (simplified)

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

Carbon emissions from each process can be estimated by comparing the carbon inputs and outputs of each stage of the transformation. The carbon content of the primary fuels are fixed based on the findings of the 2004 UK carbon factor review, as is the carbon content of coke oven gas, blast furnace gas, pig iron, and steel.

The carbon contents of coke, coke breeze, and basic oxygen furnace gas are allowed to vary in order to enable the carbon inputs and outputs to be balanced. The calculations are so arranged that the total carbon emission corresponds to the carbon content of the input fuels in accordance with IPCC Guidelines.

In the case of SSF production, the carbon content of both input (coal) and output (SSF) are held constant with the difference being treated as an emission of carbon from the process (since the carbon content of the input is always greater than the output). This procedure has been adopted because it has been assumed that some carbon would be emitted in the form of gases, evolved during the production process, and possibly used as a fuel for the transformation process. However, all emissions of carbon are currently reported under 1B1b since it is not clear whether there is any use of process gases as a fuel. It is recommended that SSF manufacturers be contacted to check whether these emissions would be better reported under 1A1c. DUKES does report a small consumption of natural gas by SSF manufacturers in some years. It is assumed that this must be burnt to provide heat for transformation processes and so emissions of carbon from this gas are reported under 1A1c. Small quantities of coke are also consumed in 1997-2002 and these are also currently treated as a fuel burnt by SSF manufacturers. However, this seems unlikely and it is recommended that, for the next version of the inventory, this coke is treated as being incorporated into the SSF and the carbon released when the SSF is burnt.

Petroleum coke is known to be used as a domestic smokeless fuel, however DUKES does not include any consumption data for SSF manufacture in its commodity balance tables and the SSF production figures in DUKES are therefore assumed to exclude petroleum coke. The consumption of petroleum coke by the domestic sector is instead estimated and reported separately to domestic consumption of SSF. Emissions of carbon are reported under 1A4b.

In reporting emissions from coke ovens and SSF manufacturing processes, emissions arising from fuel combustion for energy are reported under 1A1ci Manufacture of Solid Fuels, whilst emissions arising from the transformation process are reported under 1B1b Solid Fuel Transformation. In the case of blast furnaces, energy emissions are reported under 1A2a Iron and Steel and process emissions under 2C1 Iron and Steel Production. We recommend some changes to the treatment of emissions from blast furnaces and other sources in the steel industry in the next version of the inventory (see **Section 1.14.2**).

A3.3.3.4 Other Energy Industries

Section A3.2 shows the NAEI source categories mapped onto 1A1cii Other Energy Industries. All these emissions are treated according to the base combustion module using emission factors given in **Table A 3.3.1 - Table A 3.3.4**. However, the treatment of gas oil use on offshore installations is anomalous. The fuel use for this sector is not explicitly available within the gas oil commodity balance table in DUKES. Therefore it is assumed to be included elsewhere within the commodity balance, and therefore included in the UK national total.

The estimation of emissions from natural gas, LPG and OPG used as a fuel in offshore installations and onshore terminals is discussed in **Section A3.3.8.** These emissions are reported in category 1A1cii, but the methodology used in their estimation is closely linked to the estimation of offshore fugitive emissions.

A3.3.4 Manufacturing Industries and Construction (1A2)

A3.3.4.1 Other Industry

In the NAEI, the autogenerators category reports emissions from electricity generation by companies primarily for their own consumption. The Inventory makes no distinction between electricity generation and combined heat and power or heat plants. Hence CHP systems where the electricity is fed into the public supply are classified as power stations and CHP systems where the electricity is used by the generator are classified as autogeneration. The autogenerators category is mapped onto the IPCC category 1A2f Other Industry. The IPCC 1A1 category also refers to CHP plant and heat plant.

Following a UNFCCC recommendation, this year for the first time emissions for manufacturing industries and construction have been fully disaggregated to categories 1A2a-f. Full details of the changes made to activity data in order to implement these improvements are given below.

A3.3.4.1.1 Coal

There were two parts to the work to finalise a coal use time series in the industry sector. Firstly, some inconsistencies have been identified in the coal consumption time series in the Digest of UK Energy Statistics (DUKES); secondly, the disaggregation of emissions within the existing 1A2f sector.

Time series inconsistencies

Total industrial coal use within the GHG inventory is consistent with the DUKES total. However, there is an apparent step change in the amount of fuel allocated to other industries within DUKES between 1999 and 2000. In addition, between 1997 and 1999, the total coal use allocated to 1A2f is less than the independent estimates for cement and lime production used within the inventory. Cement and lime production would fall into the 1A2f category for IPCC reporting.

Further investigation has been done into these inconsistencies and a new time series of coal consumption is to be adopted for the inventory. These investigations included reviewing existing fuel and carbon emissions data. Nickel and Vanadium emissions were also considered, since petroleum coke can contain very high levels of these metals – this meant assumptions could be made about how much of the fuel used in each sector is coal as opposed to petroleum coke.

Various data for the cement industry have been reviewed (for example clinker production and CO_2 emissions data, see below) to assess if there are any factors that would support the DUKES time series for coal over the period 1996-2000. DUKES reports a similar level of coal usage by the industry sector in 1996 and 2000, but much lower usage in 1997-1999, with usage in 1999 at about half the level in 1996 and 2000. Since the cement industry is the largest industrial user of coal, this suggests a significant change in the cement sector between 1997 and 1999.

Existing estimates of cement industry fuel use are from the Mineral Products Association (MPA) (formerly the British Cement Association (BCA)), who has provided data for the year 1990 and then 2000 onwards; figures are interpolated between 1990 and 2000.

The key parameters which govern coal use are:

1) Choice of fuel: Coal and petroleum coke are known to be the main choice of fuel for cement kilns across Europe. IPC permits from the early 1990s confirm that almost all UK kilns were then fired with coal, or a mixture of coal and petroleum coke. BCA estimate that almost all energy input in 1990 was coal, with a big increase in petroleum coke use by 2000. It is assumed that there is a steady trend in between 1990 and 2000 i.e. petroleum coke use growing each successive year. For the DUKES time series to be correct there would have to be a substantial swing from coal to petroleum coke in 1997 and an equally substantial swing back to coal in 2000. Fuel grade petroleum coke has to be imported and DUKES shows a sharp decrease in imports[5] over the period 1996-1999, with imports in 2000 at the same level as in 1999. So the trends there, while suggesting that trends in petroleum coke use in cement kilns may not follow a straight line, also don't provide much evidence of a change in petroleum coke use that is consistent with DUKES' coal data.
2) Clinker production: Energy is required to produce clinker; the inventory team have clinker production data for all years from the BCA or the British Geological Survey (BGS). The general trend from 1996 to 2000 was a slow increase in production, which contradicts the DUKES time series.
3) Energy intensity: there are four main process routes to make clinker, referred to as wet, semi-wet, semi-dry and dry. More energy is needed for wet processes than dry. The UK has a mixture of these processes but it is mostly dry. There was a slight increase in the wet capacity in 2000 due to the start of operations at the 'new' Rugby works, after closure of the old works and the Chinnor works in 1999, these both being wet processes as well. By the end of 2009 all of the UK works were dry processes apart from Rugby (wet) and South Ferriby (semi-dry). Estimates have been made of the UK plant capacity and these show that there was no major upheaval or change over the period of interest, just a small increase in the % of capacity which was of the wet type.

Most of the evidence is consistent with a gradually changing industry as opposed to the step changes seen in the time series compiled from the DUKES data between 1997 and 2000. Therefore, the existing estimates for coal used by the cement sector have been retained and the time series for the rest of the industry sector has been built around these. Although the lime sector has not been reviewed in detail, it is known that there have been no closures over that period and there is no evidence to support any major changes in that industry either, so again existing estimates for the lime sector have been retained.

It has also been considered that other users within the 1A2f sector will also burn coal e.g. a number of brickworks. The DUKES data for 1996 and 2000 suggest that 'other' 1A2f processes used substantial amounts of coal in those years.

[5] Note that imports may not just be fuel grade coke: anode grade coke could also be imported in some/all years (this type of coke is manufactured at the Conoco refinery in the UK but it is not clear if that supplies all UK demand for anode grade coke).

Disaggregation of 1A2f

For the period 1990-1996, fuel consumption data have been used for sectors 1A2a-1A2f directly from DUKES. These are also used from 2000 onwards. In the intervening years, these figures have been interpolated; keeping the industry sector total the same as DUKES and using a 1A2f total which is consistent with the independent cement and lime industry emissions data. The new 1A2 proposed use data are presented in **Table A 3.3.8**.
The proposed time series has been provided to the DUKES team for comment.

A3.3.4.1.2 Natural Gas

Fuel consumption data for 1A2a-1A2e are taken directly from DUKES figures. 1A2f makes up the rest of the industry sector and the fuel consumption total is consistent with that in DUKES. One small modification is to add the non-energy use estimate from DUKES into the industry total, and then take out the NAEI independent estimate for non-energy use, provided to the NAEI by plant operators. 1A2f also contains emissions from the cement and lime industry. The provisional 1A2 natural gas use data are presented in **Table A 3.3.10**.

A3.3.4.1.3 Fuel Oil

Fuel consumption data for 1A2a-1A2e are taken directly from DUKES figures. 1A2f makes up the rest of the industry sector and the fuel consumption total is consistent with that in DUKES. The provisional 1A2 fuel oil use data are presented in **Table A 3.3.12**.

A3.3.4.1.4 Gas Oil

Allocation of gas oil across other inventory sectors complicates the disaggregation of gas oil use across 1A2. Gas oil use is reallocated to cover rail and off-road machinery; industrial off-road machinery is all allocated to 1A2f (with smaller allocations for off road machinery in agriculture, house and garden and aircraft support vehicles). A provisional time series of gas oil use is presented in **Table A 3.3.14**.

This time series has been developed alongside improvements task 5. More detail of this task can be found in **Section A3.3.4.2** and full descriptions of the changes made to gas oil use within the inventory can be found in the accompanying report, Murrells *et al* (2011).

As part of the improvements task 5; estimates were made of the amount of gas oil used in stationary combustion within the manufacturing industries and construction sector. DUKES fuel use data were then used as a proxy to disaggregate 1A2b-e. The remaining gas oil use is allocated to 1A2f along with independent fuel use estimates for off-road machinery and the cement industry. The proposed 1A2 gas oil consumption data are presented in **Table A 3.3.14.**

A3.3.4.1.5 Electricity

Electricity consumption data are used for the end user version of the UK, DA and LA inventories. Electricity consumption data for 1A2a-1A2e are taken directly from DUKES figures. 1A2f makes up the rest of the industry sector and the electricity consumption total is consistent with that in DUKES. The new 1A2 electricity consumption data are presented in **Table A 3.3.16**.

Coal:

Table A 3.3.7 1990-2009 Coal consumption data from 2011 submission (kt)

Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1A2a Iron and Steel	12	9	6	13	14	8	3	1	9	17	3	1	0	0	0	0	1	75	69	60
1A2f Other industrial combustion	7727	7938	8055	7327	6688	6130	5106	4896	4366	4125	3748	3993	3958	3906	3667	3586	3587	3671	3796	3448
Total	7739	7947	8061	7340	6702	6138	5109	4897	4375	4142	3751	3995	3959	3906	3667	3586	3588	3746	3865	3508

Table A 3.3.8 1990-2009 Coal consumption data for 2012 submission (kt)

Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1A2a Iron and Steel	12	9	6	13	14	8	3	1	4	7	3	1	-	-	-	-	1	75	69	60
1A2b Non-ferrous metals	79	296	275	298	262	230	282	114	90	157	73	71	105	71	48	57	79	53	50	45
1A2c Chemicals	1,134	1,263	1,210	1,015	1,009	841	891	499	280	322	174	333	360	376	357	399	397	413	410	364
1A2d Pulp, paper and print	688	827	930	950	799	472	267	179	47	73	166	151	165	153	158	148	148	151	156	131
1A2e Food processing, beverages and tobacco	505	616	640	632	569	463	384	282	125	132	104	100	74	72	65	50	49	57	63	72
1A2f Other industrial combustion	5,321	4,936	5,000	4,432	4,049	4,124	3,282	3,822	3,829	3,450	3,231	3,338	3,254	3,234	3,039	*2,930*	*2,920*	*2,982*	*3,118*	*2,841*
Total	7,739	7,947	8,061	7,340	6,702	6,138	5,109	4,897	4,375	4,142	3,751	3,994	3,958	3,906	3,667	3,585	3,593	3,730	3,866	3,512

Note: Highlighted cells *in italics* show where DUKES data have been revised from previous year

Natural Gas:

Table A 3.3.9 1990-2009 Natural Gas consumption data from 2011 submission Mth

Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1A2a Iron and Steel	463	428	474	531	693	697	738	714	704	765	335	310	314	375	370	335	321	288	274	201
1A2f Other industrial combustion	4,798	4,607	4,188	4,268	4,649	5,012	5,554	5,963	6,282	6,669	7,618	7,310	6,940	6,953	6,581	6,460	6,185	5,986	6,110	5,281
Total	5,262	5,035	4,662	4,799	5,342	5,708	6,293	6,677	6,986	7,434	7,953	7,619	7,254	7,328	6,951	6,795	6,506	6,274	6,385	5,481

Table A 3.3.10 1990-2009 Natural Gas consumption data for 2012 submission Mth

Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1A2a Iron and Steel	463	428	474	531	693	697	738	714	704	765	335	310	314	375	370	335	321	288	274	201
1A2b Non-ferrous metals	154	154	129	140	154	146	165	158	189	189	201	193	179	163	116	115	113	105	109	92
1A2c Chemicals	1,024	713	828	1,268	1,495	1,471	1,554	1,656	1,674	1,854	1,992	1,959	1,789	1,772	1,730	1,523	1,449	1,381	1,480	1,162
1A2d Pulp, paper and print	399	401	391	354	443	503	542	472	486	547	675	628	598	599	535	670	623	581	616	541
1A2e Food processing, beverages and tobacco	678	646	680	615	701	832	928	911	930	986	1,051	1,045	1,021	1,008	1,008	895	854	829	879	761
1A2f Other industrial combustion	2,542	2,693	2,159	1,891	1,855	2,060	2,366	2,766	3,003	3,093	3,699	3,484	3,352	3,411	3,191	3,223	3,104	3,087	*3,040*	2,652
Total	5,262	5,035	4,661	4,799	5,342	5,708	6,293	6,677	6,986	7,434	7,953	7,619	7,254	7,328	6,951	6,761	6,464	6,271	6,400	5,409

Note: Highlighted cells i*n italics* show where DUKES data have been revised from previous year

Fuel Oil:

Table A 3.3.11 1990-2009 Fuel Oil consumption data from 2011 submission (kt)

Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1A2a Iron and Steel	113	155	151	311	274	254	82	116	233	344	274	315	250	133	152	128	118	162	121	149
1A2f Other industrial combustion	4,009	5,150	5,100	4,350	3,697	2,639	2,221	1,348	1,132	574	518	806	370	327	499	547	448	574	379	363
Total	4,121	5,305	5,251	4,661	3,971	2,893	2,303	1,464	1,366	919	792	1,121	620	460	651	675	566	736	500	512

Table A 3.3.12 1990-2009 Fuel Oil consumption data for 2012 submission (kt)

Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1A2a Iron and Steel	113	155	151	311	274	254	82	116	233	344	274	315	250	*133*	152	*130*	118	*159*	121	*152*
1A2b Non-ferrous metals	32	54	55	38	51	39	25	27	17	16	10	35	34	24	24	*24*	*29*	26	26	*26*
1A2c Chemicals	1,312	1,495	1,509	1,429	1,212	799	656	494	425	137	219	149	109	87	*93*	*101*	*91*	96	88	*68*
1A2d Pulp, paper and print	226	274	307	263	267	189	147	101	84	71	47	99	49	38	32	*36*	*38*	36	35	*34*
1A2e Food processing, beverages and tobacco	791	799	798	742	645	495	442	320	246	240	154	188	97	74	66	*52*	*50*	63	62	*45*
1A2f Other industrial combustion	1,648	2,528	2,431	1,878	1,522	1,117	951	406	360	110	87	334	82	103	*284*	*573*	*340*	*357*	*185*	*83*
Total	4,121	5,305	5,251	4,661	3,971	2,893	2,303	1,464	1,366	919	792	1,121	620	460	651	915	666	736	516	408

Note: Highlighted cells *in italics* show where DUKES data have been revised from previous year

Gas Oil:

Table A 3.3.13 1990-2009 Gas Oil consumption data from 2011 submission (kt)

Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1A2a Iron and Steel	146	139	130	139	136	129	138	143	31	13	69	1	2	2	2	0	0	0	0	0
1A2f Other industrial combustion	3,043	2,959	2,947	2,965	2,996	2,899	3,022	2,857	3,281	3,040	3,013	3,263	2,863	2,673	2,648	3,097	2,776	2,712	2,588	2,116
Total	3,189	3,098	3,077	3,104	3,132	3,028	3,160	3,000	3,312	3,053	3,082	3,264	2,864	2,675	2,650	3,097	2,776	2,712	2,588	2,116

Table A 3.3.14 1990-2009 Gas Oil consumption data for 2012 submission (kt)

Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1A2a Iron and Steel	11	10	12	13	17	17	18	17	17	18	8	7	7	9	8	12	11	6	4	3
1A2b Non-ferrous metals	10	10	10	9	8	6	8	6	6	5	6	9	4	1	2	4	2	1	1	1
1A2c Chemicals	68	69	66	64	53	44	52	42	44	25	28	31	13	6	7	17	9	6	4	3
1A2d Pulp, paper and print	15	16	15	15	12	10	12	10	10	5	5	8	4	1	2	*9*	2	2	1	1
1A2e Food processing, beverages and tobacco	67	69	67	64	53	45	53	43	44	28	32	46	21	10	17	44	22	14	10	9
1A2f Other industrial combustion	3,097	3,016	2,973	2,958	2,885	2,779	2,909	2,757	2,777	2,572	2,600	2,697	2,362	2,148	2,148	*2,517*	*2,167*	*2,259*	*2,077*	*1,648*
Total	3,268	3,191	3,143	3,122	3,028	2,901	3,051	2,875	2,897	2,653	2,680	2,799	2,411	2,175	2,183	2,604	2,214	2,288	2,097	1,665

Note: Highlighted cells *in italics* show where DUKES data have been revised from previous year

Electricity – used for the End Users Inventory:

Table A 3.3.15 1990-2009 Electricity consumption data from 2011 submission

Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1A2a Iron and Steel	7863	7601	7086	7713	8224	8108	8665	8391	8282	8486	7868	7768	4144	4489	4480	4033	4871	3983	3774	2713
1A2f Other industrial combustion	83037	81958	78522	80016	78773	81986	83820	85103	84659	86635	89448	89253	92699	94018	94114	92502	92860	97005	94022	85013
Total	90900	89559	85608	87729	86997	90094	92485	93494	92941	95121	97316	97021	96843	98507	98594	96535	97731	100988	97796	87725

Table A 3.3.16 1990-2009 Electricity consumption data for 2012 submission

Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1A2a Iron and Steel	7863	7601	7086	7713	8224	8108	8665	8391	8282	8486	7868	7768	4144	4489	4480	4033	4871	3983	3774	2713
1A2b Non-ferrous metals	3764	3836	3716	3503	3948	3912	3926	3461	3718	3767	4112	4157	*4212*	*4363*	*4133*	4355	4429	4283	*4326*	*4059*
1A2c Chemicals	14555	13712	14098	14923	14598	14787	14921	14771	14514	14874	15249	14410	*14731*	*14281*	*13411*	12190	13102	17018	*17472*	*15729*
1A2d Pulp, paper and print	7138	7140	6662	7540	7609	7856	7708	8374	8230	8215	8139	8572	*9250*	*9390*	*9519*	9735	9661	9475	*10690*	*9162*
1A2e Food processing, beverages and tobacco	10361	10233	10136	10577	9627	9609	10527	10730	10652	10519	10324	10216	*10428*	*10337*	*10367*	10387	10621	10718	*10939*	*9782*
1A2f Other industrial combustion	47219	47037	43910	43473	42991	45822	46738	47767	47545	49260	51624	51898	*51598*	*51567*	*52310*	55835	*55025*	*55261*	*55790*	*50123*
Total	90900	89559	85608	87729	86997	90094	92485	93494	92941	95121	97316	97021	94363	94427	94220	96535	97709	100738	102991	91568

Note: Highlighted cells i*n italics* show where DUKES data have been revised from previous year

A3.3.4.2 Treatment of Gas Oil in the inventory

Gas oil is used in both off-road transport and machinery diesel engines, and as a fuel for stationary combustion. The varied use of this fuel complicates the means of allocating consumption across the wide range of sectors that use the fuel in the inventory. DUKES provides a breakdown of gas oil consumption in different industry and other sectors, but with high uncertainty and DUKES is unable to distinguish between use of the fuel for stationary combustion and off-road machinery, a distinction which is necessary for the inventory.

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

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

In light of this, Task 5 of the 2011 UK GHG Inventory Improvement Programme aimed to address the allocation of gas oil and DERV in the GHGI (Murrells et al., 2011). The methodology outlined in Murrells et al. (2011) has been used in the compilation of the 2010 inventory, and is summarised here.

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

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

The study also considered the allocation of gas oil given in DUKES to different industry and other sectors and how these can be mapped to inventory reporting categories. The detailed bottom-up method is used to estimate gas oil consumption by different off-road machinery and marine vessel types. Independent sources were used to estimate gas oil used by the rail sector while data provided by industrial sites reporting under emission trading schemes

(EU-ETS) were used to derive an allocation of gas oil consumption by stationary combustion sources in different industry, commercial and other sectors. Also, the UK energy statistics now include an allocation of gas oil for consumption by the oil and gas sector, but since only a partial time series was made available, the study included making estimates of gas oil for this category back to 1990.

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

- A revised estimate of the amount of DERV used to power small off-road machinery;
- An estimate of the amount of gas oil, DERV and petrol used to power vessels on inland waterways;
- An overall, revised figure of 0.35 Mtonnes of DERV and 0.35 Mtonnes petrol used by non-road transport emission sources, representing 1.7% and 2.2% of all DERV and petrol consumed in the UK, respectively, in 2009. This implies that 1.9% of all CO_2 emissions arising from consumption of petrol and DERV are due to non-road transport sources;
- The allocation of gas oil to inland waterways led to a re-evaluation of gas oil used across different marine sectors, leading to a re-assignment of 0.132 Mtonnes of gas oil previously assigned to international shipping to domestic UK marine activities in 2009. This increases the CO_2 emissions assigned to domestic marine activities (shipping, fishing, naval and inland waterways) that are included in the UK totals by 0.42 $MtCO_2$ and to reduce the amount allocated to the international bunkers as a Memo Item by the same amount. This increase is 0.09% of the UK total emissions of CO_2 in 2009. In 1990, the re-evaluation increases CO_2 emissions from all domestic marine activities by 0.29 $MtCO_2$, equivalent to 0.05% of UK total CO_2 emissions in 1990;
- A revised allocation of gas oil consumption across all inventory sectors, including that used for stationary combustion in industry and the public sector, consistent with EU-ETS data and consumption by off-road machinery for all years between 1990 and 2010.

Table A 3.3.17 shows the revised allocation of gas oil in the GHGI between 1998 and 2010. Further details of the re-allocation are given in the inventory improvement report by Murrells *et al* (2011). The report considers the uncertainties in the sector allocations and makes recommendations on how these can be improved based on current activities known to be taking place in the UK to understand the allocation of gas oil across some sectors.

Table A 3.3.17 Allocation of gas oil consumption to sectors in the 2010 GHGI

Mtonnes		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Electricity generation		0.069	0.071	0.144	0.033	0.045	0.044	0.092	0.178	0.213	0.089	0.089	0.080	0.050
Cement		0.011	0.011	0.011	0.013	0.014	0.009	0.009	0.011	0.009	0.004	0.010	0.007	0.007
Oil and gas extraction		0.525	0.497	0.480	0.511	0.488	0.460	0.427	0.475	0.430	0.404	0.472	0.450	0.490
Marine	Inland waterways	0.099	0.098	0.099	0.097	0.098	0.098	0.100	0.102	0.103	0.104	0.103	0.097	0.099
	Naval	0.270	0.297	0.291	0.267	0.243	0.273	0.302	0.271	0.265	0.274	0.271	0.270	0.275
	Fishing	0.005	0.004	0.004	0.004	0.004	0.004	0.005	0.005	0.004	0.004	0.004	0.004	0.004
	Domestic shipping	0.181	0.181	0.169	0.163	0.170	0.166	0.168	0.172	0.163	0.388	0.378	0.359	0.341
	International shipping	1.824	1.481	1.489	1.645	1.233	1.440	1.343	1.258	1.686	1.073	0.929	0.925	0.862
Rail		0.503	0.504	0.504	0.528	0.539	0.546	0.569	0.581	0.580	0.594	0.604	0.601	0.610
Stationary combustion	Domestic	0.191	0.161	0.147	0.193	0.202	0.163	0.160	0.141	0.171	0.173	0.164	0.131	0.165
	Iron and steel	0.017	0.018	0.008	0.007	0.007	0.009	0.008	0.012	0.011	0.006	0.004	0.003	0.004
	Miscellaneous industrial/commercial	0.193	0.138	0.136	0.145	0.089	0.080	0.076	0.129	0.090	0.065	0.051	0.045	0.048
	Other industrial combustion	0.947	0.655	0.747	0.738	0.346	0.373	0.356	0.635	0.268	0.147	0.097	0.082	0.095
	Public sector	0.262	0.170	0.165	0.148	0.065	0.042	0.047	0.100	0.061	0.037	0.025	0.022	0.025
Off-road machinery	Industrial	2.084	2.084	2.084	2.089	2.093	1.984	2.001	2.151	1.970	2.136	1.986	1.573	1.538
	Agriculture&Forestry	1.428	1.400	1.359	1.336	1.331	1.321	1.250	1.264	1.177	1.130	1.113	1.140	1.148
	Airports	0.099	0.105	0.112	0.113	0.117	0.124	0.134	0.142	0.146	0.150	0.146	0.138	0.133
Non-energy use		0.760	0.844	0.936	0.411	0.205	0.287	0.249	0.229	0.259	0.238	0.201	0.143	0.142
Total Consumption		**9.467**	**8.721**	**8.886**	**8.441**	**7.293**	**7.422**	**7.295**	**7.857**	**7.604**	**7.016**	**6.647**	**6.068**	**6.035**

A3.3.5 Transport (1A3)

A3.3.5.1 Aviation

A3.3.5.1.1 Overview of method to estimate emissions from civil aviation

In accordance with the agreed guidelines, the UK inventory contains estimates for both domestic and international civil aviation. Emissions from international aviation are recorded as a memo item, and are not included in national totals. Emissions from both the Landing and Take-Off (LTO) phase and the Cruise phase are estimated. The method used to estimate emissions from military aviation can be found towards the end of this section on aviation.

In 2004, the simple method previously used to estimate emissions from aviation overestimated fuel use and emissions from domestic aircraft because only two aircraft types were considered and the default emission factors used applied to older aircraft. It is clear that more smaller modern aircraft are used on domestic and international routes. Emissions from international aviation were correspondingly underestimated. A summary of the more detailed approach now used is given below, and a full description is given in Watterson *et al.* (2004).

The current method estimates emissions from the number of aircraft movements broken down by aircraft type at each UK airport, and so complies with the IPCC Tier 3 specification. Emissions of a range of pollutants are estimated in addition to the reported greenhouse gases. In comparison with earlier methods used to estimate emissions from aviation, the current approach is much more detailed and reflects differences between airports and the aircraft that use them. Emissions from additional sources (such as aircraft auxiliary power units) are also now included.

This method utilises data from a range of airport emission inventories compiled in the last few years by AEA. This work includes the RASCO study (23 regional airports, with a 1999 case calculated from CAA movement data) carried out for the Department for Transport (DfT), and the published inventories for Heathrow, Gatwick and Stansted airports, commissioned by BAA and representative of the fleets at those airports. Emissions of NOx and fuel use from the Heathrow inventory have been used to verify the results of this study.

In 2006, the Department for Transport (DfT) published its report “Project for the Sustainable Development of Heathrow” (PSHD). This laid out recommendations for the improvement of emission inventories at Heathrow and lead to a revised inventory for Heathrow for 2002. For departures, the PSDH made recommendations for revised thrust setting at take-off and climb-out as well as revised cut-back heights. In 2007, these recommendations for Heathrow were incorporated into the UK inventory and in the 2008 inventory they were incorporated into the UK inventory for all airports, along with further recommendations relating to: the effects of aircraft speed on take-off emissions; engine spool-up at take-off; the interpolation to intermediate thrust settings; hold times; taxiing thrust and times; engine deterioration and APU emission indices and running times.

For arrivals, the PSDH made recommendations for revised reverse thrust setting and durations along with revised landing-roll times. In 2007, these recommendations for Heathrow were incorporated into the UK inventory and in the 2008 inventory they were incorporated into the UK inventory for all airports, along with further recommendations relating to: the interpolation to intermediate thrust settings; approach thrusts and times; taxiing thrust and times; engine deterioration and APU emission indices and running times.

Since publication of the PSDH report, inventories at Gatwick and Stansted have been updated. These inventories incorporated many of the recommendations of the PSDH and have been used as a basis for the 2008 inventory.

For the 2009 inventory flights between the UK and overseas territories were included as domestic aviation. Previous inventories included flights from the UK to overseas territories as international aviation, recorded as a memo item. Flights from overseas territories to the UK were not included in previous inventories.

For the 2010 inventory all flights originating from the overseas territories, irrespective of destination, have been included in the inventory as have return flights from oil rigs. These changes have been made in response to recommendations from the UNFCCC's Expert Review of the UK's inventory in 2010.

Separate estimates have been made for emissions from the LTO cycle and the cruise phase for both domestic and international aviation. For the LTO phase, fuel consumed and emissions per LTO cycle are based on detailed airport studies and engine-specific emission factors (from the ICAO database). For the cruise phase, fuel use and emissions are estimated using distances (based on great circles) travelled from each airport for a set of representative aircraft.

In the current UK inventory there is a noticeable reduction in emissions from 2005 to 2006 despite a modest increase in aircraft movements and kilometres flown. This is attributable to the propagation of more modern aircraft into the fleet. From 2006 to 2007 there is a further reduction in emissions, which is attributable to both a modest decrease in aircraft movements and kilometres flown and the propagation of more modern aircraft into the fleet. In 2008, and again in 2009, there are reductions in both emissions and aircraft movements, in line with the economic downturn.

A3.3.5.1.2 Emission Reporting Categories for Civil Aviation

Table A 3.3.18 below shows the emissions included in the emission totals for the domestic and international civil aviation categories currently under the UNFCCC, the EU NECD and the LRTAP Convention. Note the reporting requirements to the LRTAP Convention have altered recently – the table contains the most recent reporting requirements

Table A 3.3.18 Components of Emissions Included in Reported Emissions from Civil Aviation

	EU NECD	LRTAP Convention	EU-MM/UNFCCC
Domestic aviation (landing and take-off cycle [LTO])	Included in national total	Included in national total	Included in national total
Domestic aviation (cruise)	Not included in national total	Not included in national total	Included in national total
International aviation (LTO)	Included in national total	Included in national total	Not included in national total
International aviation (cruise)	Not included in national total	Not included in national total	Not included in national total

Notes

Emissions from the LTO cycle include emissions within a 1000 m ceiling of landing.

A3.3.5.1.3 Aircraft Movement Data (Activity Data)

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

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

  Flights between the UK and overseas territories are considered to be international in the CAA aircraft movement data, but these have been reclassified as domestic aviation.

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

  The CAA data have been supplemented with data from overseas territories, supplied by DfT.

  A summary of aircraft movement data is given in **Table A 3.3.19** Flights between the UK and overseas territories are included in domestic.

- **Inland Deliveries of Aviation Turbine Fuel and Aviation Spirit**
  Total inland deliveries of aviation spirit and aviation turbine fuel to air transport are given in DUKES (DECC 2011). This is the best approximation of aviation bunker fuel consumption available and is assumed to cover international, domestic and military use, excluding casual uplift (see below).

- **Consumption of Aviation Turbine Fuel and Aviation Spirit by the Military**
  Historically, total consumption by military aviation has been given in ONS (1995) and MOD (2005a) and was assumed to be aviation turbine fuel. A revised, but consistent time series of military aviation fuel was provided by the Safety, Sustainable Development and Continuity Division of the Defence Fuels Group of the MoD (MoD, 2009 and 2010) covering each financial year from 2003/04 to 2009/10. In 2011 the MoD revised their methodology for calculating fuel consumption, which provided revised data for 2008/09 onwards (MoD 2011). The new data also included estimates of aviation spirit and fuel classed as “Casual Uplift”. The latter is drawn from commercial airfields world-wide and assumed not to be included in DUKES.

  Adjustments were made to the data to derive figures on a calendar year basis.

Table A 3.3.19 Aircraft Movement Data

	International LTOs (000s)	Domestic LTOs (000s)	International Aircraft, Gm flown	Domestic Aircraft, Gm flown
1990	469.62	367.81	654.15	114.21
1991	454.57	335.27	643.25	106.58
1992	491.80	351.97	725.80	111.69
1993	502.90	362.83	737.68	116.63
1994	519.22	342.45	811.29	111.59
1995	540.74	355.42	851.62	115.64
1996	570.15	366.32	892.50	120.65

	International LTOs (000s)	Domestic LTOs (000s)	International Aircraft, Gm flown	Domestic Aircraft, Gm flown
1997	595.78	377.38	969.19	125.89
1998	632.18	383.30	1053.96	132.72
1999	666.83	387.90	1120.39	136.25
2000	713.04	398.40	1193.15	142.70
2001	720.51	414.16	1208.59	153.50
2002	712.98	415.33	1200.17	152.65
2003	729.00	423.56	1251.83	155.59
2004	762.36	458.69	1356.88	166.59
2005	804.39	484.29	1448.79	177.51
2006	831.40	486.48	1517.07	179.36
2007	857.85	480.82	1572.29	175.79
2008	844.41	467.96	1558.33	172.23
2009	776.37	417.48	1441.29	156.38
2010	736.93	390.92	1396.04	145.40

Notes

Gm Giga metres, or 10^9 metres

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

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

A3.3.5.1.4 Emission factors used

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

Table A 3.3.20 Carbon Dioxide and Sulphur Dioxide Emission Factors for Civil and Military Aviation for 2010 (kg/t)

Fuel	CO_2	SO_2
Aviation Turbine Fuel	859	0.84
Aviation Spirit	853	0.84

Notes

Carbon and sulphur contents of fuels provided by UKPIA (2011)
Carbon emission factor as kg carbon/tonne
Military aviation only uses ATF

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

Table A 3.3.21 Average Non-CO2 Emission Factors for Civil and Military Aviation - 2010

	Fuel	Units	CH_4	N_2O	NO_x	CO	NMVOC
Civil aviation							
Domestic LTO	AS	kt/Mt	1.54	0.10	3.83	1072.52	12.55
Domestic Cruise	AS	kt/Mt	-	0.10	7.40	2.49	0.20
Domestic LTO	ATF	kt/Mt	0.18	0.10	12.62	8.58	1.65
Domestic Cruise	ATF	kt/Mt	-	0.10	14.24	2.43	0.49
International LTO	AS	kt/Mt	1.91	0.10	1.93	1260.27	15.54
International Cruise	AS	kt/Mt	-	0.10	6.81	0.79	0.01
International LTO	ATF	kt/Mt	0.13	0.10	13.90	8.93	1.21
International Cruise	ATF	kt/Mt	-	0.10	14.11	1.17	0.52
Military aviation	ATF	kt/Mt	-	0.10	7.40	2.49	0.20

Notes

AS – Aviation Spirit

ATF – Aviation Turbine Fuel

Use of all aviation spirit assigned to the LTO cycle

A3.3.5.1.5 Method used to estimate emissions from the LTO cycle – civil aviation – domestic and international

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

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

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

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

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

A3.3.5.1.6 Method used to estimate emissions in the cruise – civil aviation – domestic and international

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

A3.3.5.1.7 Estimating emissions of the indirect and non-greenhouse gases

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

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

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

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

Where:

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

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

A3.3.5.1.8 Estimating emissions of the direct greenhouse gases

Estimates of CO_2 were derived from estimates of fuel consumed in the cruise (see equation above) and LTO cycle and the carbon contents of the aviation fuels. The amount of fuel used in the LTO cycle is calculated as the product of the duration (seconds) of the operation, the engine fuel flow rate at the appropriate thrust setting (kg fuel per second).

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

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

A3.3.5.1.9 Classification of domestic and international flights

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

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

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

Flights to the Channel Islands and the Isle of Man are considered to be within the UK in the CAA aircraft movement data.

Flights between the UK and overseas territories are considered to be international in the CAA aircraft movement data, but have been reclassified as domestic aviation since the 2009 inventory. Flights between overseas territories (obtained from the DfT data) have been classed as domestic aviation. Other flights originating from the overseas territories have been classed as international.

By following the IPCC Good Practice Guidance (IPCC, 2000), it is necessary to know whether passengers or freight are put down before deciding whether the whole journey is considered as an international flight or consisting of a (or several) domestic flight(s) and an international flight. We feel the consequence of the difference between CAA and IPCC definitions will have a small impact on total emissions.

The CAA definitions above are also used by the CAA to generate national statistics of international and domestic aircraft movements. Therefore, the aircraft movement data used in this updated aviation methodology are consistent with national statistical datasets on aircraft movements.

A3.3.5.1.10 Overview of method to estimate emission from military aviation

LTO data are not available for military aircraft movements, so a simple approach is used to estimate emissions from military aviation. A first estimate of military emissions is made using military fuel consumption data and IPCC (1997) and EMEP/CORINAIR (1999) cruise defaults shown in Table 1 of EMEP/CORINAIR (1999) (see **Table A 3.3.21)**. The EMEP/CORINAIR (1999) factors used are appropriate for military aircraft. The military fuel data include fuel consumption by all military services in the UK. It also includes fuel shipped to overseas garrisons, casual uplift at civilian airports.

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

A3.3.5.1.11 Fuel reconciliation

The estimates of aviation fuels consumed in the commodity balance table in the DECC publication DUKES are the national statistics on fuel consumption, and IPCC guidance states that national total emissions must be on the basis of fuel sales. Therefore, the estimates of emissions have been re-normalised based on the results of the comparison between the fuel consumption data in DUKES and the estimate of fuel consumed produced from the civil aviation emissions model, having first scaled up the emissions and fuel consumption to account for air-taxi and non-ATMs. The scaling is done separately for each airport to reflect the different fractions of air-taxi and non-ATMs at each airport and the different impacts on domestic and international emissions. The aviation fuel consumptions presented in DECC DUKES include the use of both civil and military fuel, and the military fuel use must be subtracted from the DUKES total to provide an estimate of the civil aviation consumption. This estimate of civil aviation fuel consumption has been used in the fuel reconciliation. Emissions from flights originating from the overseas territories have been excluded from the fuel reconciliation process as the fuel associated with these flights is not included in DUKES. Emissions will be re-normalised each time the aircraft movement data is modified or data for another year added.

A3.3.5.1.12 Geographical coverage of aviation emission estimates

According to the IPCC Guidelines, "inventories should include greenhouse gas emissions and removals taking place within national (including administered) territories and offshore areas over which the country has jurisdiction." IPCC, (1997); (IPPC Reference Manual, Overview, Page 5).

The national estimates of aviation fuels consumed in the UK are taken from DECC DUKES. The current (and future) methods used to estimate emissions from aviation rely on these data, and so the geographical coverage of the estimates of emissions will be determined by the geographical coverage of DUKES.

UK DECC has confirmed that the coverage of the energy statistics in DUKES is England, Wales, Scotland and Northern Ireland plus any oil supplied from the UK to the Channel Islands and the Isle of Man. This clarification was necessary since this information cannot be gained from UK trade statistics.

DECC have confirmed estimates in DUKES exclude Gibraltar and the other UK overseas territories. The DECC definition accords with that of the "economic territory of the United Kingdom" used by the UK Office for National Statistics (ONS), which in turn accords with the definition required to be used under the European System of Accounts (ESA95).

A3.3.5.2 Railways

The UK GHGI reports emissions from both stationary and mobile sources. The inventory source "*railways (stationary)*" comprises emissions from the combustion of burning oil, fuel oil and natural gas by the railway sector. The natural gas emission derives from generation plant used for the London Underground. These stationary emissions are reported under 1A4a Commercial/Institutional in the IPCC reporting system. These emissions are based on fuel consumption data from DECC (2011). Emission factors are reported in **Table A 3.3.1** to **Table A 3.3.4**. Most of the electricity used by the railways for electric traction is supplied from the public distribution system, so the emissions arising from its generation are reported under 1A1a Public Electricity.

Emissions are reported from the consumption of coal used to power steam trains and from gas oil. Coal consumption data has been obtained from DUKES. Estimates have been made across the time-series from 1990-2010 and are believed to be due to consumption by heritage trains. Emission factors for greenhouse gases from coal consumption are reported in **Table A 3.3.1** to **Table A 3.3.4**. For the air pollutants, US EPA emission factors for hand-stoked coal-fired boilers are used to estimate emissions from coal-fired steam trains.

The UK GHGI reports emissions from trains that run on gas oil in three categories: freight, intercity and regional. Emissions from diesel trains are reported under the IPCC category 1A3c Railways. Emission estimates are based on train kilometres travelled and gas oil consumption by the railway sector.

Gas oil consumption by passenger trains was calculated utilising data provided by the Association of Train Operating Companies (ATOC) and the Office of Rail Regulation (ORR). Data from these two sources are consistent for years after 2007. As no data from ATOC/ORR were available for 2010, fuel consumption for this year was estimated on the basis of the trend in train kilometres from 2009 to 2010. In this year's inventory gas oil consumption data for years before 2005 were re-scaled using train km data to bring consistency with the more recent trends in the ATOC/ORR fuel consumption data. Revisions were also made to the split between Intercity and regional trains to bring consistency with total passenger train km from the ORR published in the National Rail Trends Yearbook (NRTY).

Gas oil consumption by freight trains was also calculated utilising data provided by ORR for 2005-2009. These data were consistent with figures from ATOC. As no data from ATOC/ORR were available for 2010, fuel consumption for this year was estimated on the basis of the trend in train tonne kilometres from 2009 to 2010. For years prior to 2005, fuel consumption was scaled using net tonne kilometre trends data taken from ORR's NRTY.

In 2010, the estimated fuel consumption in both passenger and freight rail showed a slight increase in comparison to 2009 as a consequence of increased train kilometres travelled.

Carbon dioxide, sulphur dioxide and nitrous oxide emissions are calculated using fuel-based emission factors and the total fuel consumed as provided in the National Rail Trends Yearbook. Emissions of CO, NMVOC, NO_x, PM and methane are based on the train kilometre estimates and emission factors for different train types. The fuel consumption is distributed according to:

- Train kilometre data taken from the National Rail Trends Yearbook (2011) http://www.rail-reg.gov.uk/server/show/nav.2026 ;
- Assumed mix of locomotives for each category; and,
- Fuel consumption factors for different types of locomotive (LRC (1998), BR (1994) and Hawkins & Coad (2004)).

The emission factors shown in **Table A 3.3.22** are aggregate implied factors for diesel trains in 2010, so that all factors are reported on the common basis of fuel consumption.

No revisions have been made to any of the emission factors, which are provided in terms of g/km. However, compared with the last version of the inventory, the implied emission factors on a per fuel consumed basis differ slightly for pollutants other than CO_2 and SO_2. This is because emissions are estimated using train kilometre data, but then divided by the fuel consumed to derive an implied emission factor in terms of kt/Mt fuel. Therefore, if the fuel consumed changes this will impact on the implied emission factor in terms of kt/Mt fuel. In this case, the fuel consumption estimates have been modified slightly from previous years due to more accurate data becoming available and this therefore has a knock on effect on the implied emission factors per fuel consumed.

The emission factor for SO_2 has decreased from 1.68 kt/ Mt fuel in 2009 to 1.44 kt/ Mt fuel in 2010 in line with UKPIA's Table of the Sulphur content (UKPIA, 2011) showing a reduction in the sulphur content of gas oil.

Table A 3.3.22 Diesel Railway Emission Factors for 2010 (kt/Mt fuel)

	C[1]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Freight	870	0.2	1.2	114.3	12.7	6.4	1.44
Intercity	870	0.2	1.2	40.6	13.5	4.1	1.44
Regional	870	0.4	1.2	33.1	36.8	6.4	1.44

1 Emission factors expressed as ktonnes carbon per Mtonne fuel

A3.3.5.3 Road Transport

Emissions from road transport are calculated either from a combination of total fuel consumption data and fuel properties or from a combination of drive related emission factors and road traffic data.

A3.3.5.3.1 Improvements in the 2010 inventory

There have been a number of improvements made to the road transport inventory and the key changes are summarised as follows:

- Revised 2009 vehicle km activity data for Northern Ireland as provided by the Department for Regional Development.
- Use of Automatic Number Plate Recognition (ANPR) data and Regional Vehicle Licensing Statistics (DVLA) to define the petrol and diesel car mix by road type and by Devolved Administrations. The ANPR and DVLA data were also used to define fleet composition (in terms of age mix/ Euro standard) for cars, LGVs and HGVs.
- Removed previous assumptions made on the early uptake of Euro 4 petrol cars as these appear to have been overly optimistic. Their date of introduction is now based on the mandatory date set in the European emissions directive.
- Assumptions on the split in vehicle km for HGVs by vehicle weight class have been updated using information provided by DfT's Road Freight Statistics. This is to improve how the emission factors for different HGV vehicle weight classes are utilised.
- Updated the composition of bus fleet as operated by Transport for London (TfL)
- Revised assumptions on how the London Low Emission Zone (LEZ) scheme affects emissions from HGVs. It was previously assumed that the LEZ for HGVs would affect all pollutants from 2008 onwards through increased uptake of newer vehicles; however, it is now assumed that only Particulate Matter (PM) emissions would be affected as vehicles are achieving the LEZ requirement via retrofit of particulate traps. Other indirect GHG pollutant emissions are assumed not to be affected by the scheme
- Revised figures from DfT on average mpg fuel efficiency of different sizes of HGVs between 2006 and 2009.

- Time series revision of DfT's Bus Services Operators Grant (BSOG) data on the average fuel efficiency of local bus services, to take account of the fuel consumption for journeys to and from the start and end of a bus route.
- Updated N_2O emission factors for HGVs and buses as provided in the EMEP/CORINAIR Emissions Guidebook 2009 (June 2010). The new N_2O emission factors for heavy duty vehicles are now provided by Euro Standard, vehicle weight and road type (instead of a constant value used in the past).
- Revised trip length for calculating cold start N_2O emissions from petrol cars.
- Re-allocation of more petrol and DERV to off-road and inland waterways sectors across all years following a major review on the allocation of these fuels across a range of sectors described elsewhere in this report Annex. For 2009, an extra 89 kt petrol was re-allocated from road transport to off-road and inland waterways (0.5% of all petrol) and an extra 336 kt DERV was re-allocated from road transport to off-road and inland waterways (1.7% of all DERV).
- Revised emission factors for NO_x for all vehicle types (except motorcycles) and emission degradation methodology for light duty vehicles based on latest version of COPERT 4 (v8.1).

For CO_2, these changes have affected the distribution of fuel consumption and hence CO_2 emissions between vehicle types. Total CO_2 emissions from road transport in all years are also slightly different (1% less) compared to the 2009 inventory, due to the re-allocation of more petrol and DERV to off-road and inland waterways sectors. It should be noted that estimates of fuel consumption calculated for individual types of vehicles are normalised so the total adds up to the DUKES figures for petrol and diesel consumption (corrected for off-road consumption). For other pollutants where emissions are not directly related to fuel consumption, the changes in methods, activity data and emission factors alter the total emissions for road transport reported in each year.

A3.3.5.3.2 Fuel-based emissions

Emissions of carbon dioxide and sulphur dioxide from road transport are calculated from the consumption of petrol and diesel fuels and the sulphur content of the fuels consumed. Data on petrol and diesel fuels consumed by road transport in the UK are taken from the Digest of UK Energy Statistics published by the DECC and corrected for consumption by off-road vehicles and the very small amount of fuel consumed by the Crown Dependencies included in DUKES (emissions from the Crown Dependencies are calculated elsewhere).

In 2010, 14.99 Mtonnes of petrol and 20.87 Mtonnes of diesel fuel (DERV) were consumed in the UK. Petrol consumption has gone down while diesel consumption has increased as compared with 2009. It was estimated that of this, around 2.5% of petrol was consumed by inlands waterways and off-road vehicles and machinery and 0.4% used in the Crown Dependencies, leaving 14.55 Mtonnes of petrol consumed by road vehicles in the UK in 2010. Around 1.8% of road diesel is estimated to be used by inland waterways and off-road vehicles and machinery (the bulk of these use gas oil), and 0.2% used in the Crown Dependencies, leaving 20.46 Mtonnes of diesel consumed by road vehicles in the UK in 2010.

According to figures in DUKES (DECC, 2011), 0.106 Mtonnes of LPG were used for transport in 2010, a small reduction from 0.107 Mtonnes the previous year.

Since 2005, there has been a rapid growth in consumption of biofuels in the UK. These are not included in the totals presented above for petrol and diesel which according to DECC refer only to mineral-based fuels (fossil fuels). According to statistics in DUKES and from HMRC (2011), 0.50 Mtonnes bioethanol and 0.93 Mtonnes biodiesel were consumed in the UK in 2010. On a volume basis, this represents about 3.1% of all petrol and 4.1% of all diesel sold in the UK, respectively, and on an energy basis it is estimated that consumption of bioethanol and biodiesel displaced around 0.300 Mtonnes of mineral-based petrol (about 2.0% of total petrol that would have been consumed) and 0.808 Mtonnes of mineral-based diesel (about 3.9% of total diesel that would have been consumed). The CO_2 emissions arising from consumption of these fuels are not included in the national totals.

Emissions of CO_2, expressed as kg carbon per tonne of fuel, are based on the carbon content (by mass) of the fuel; emissions of SO_2 are based on the sulphur content of the fuel. Values of the fuel-based emission factors for CO_2 and SO_2 from consumption of petrol and diesel fuels are shown in **Table A 3.3.23**. Values for SO_2 vary annually as the sulphur-content of fuels change, and are shown in **Table A 3.3.23** for 2010 fuels based on data from UKPIA (2011).

Table A 3.3.23 Fuel-Based Emission Factors for Road Transport (kg/tonne fuel)

Fuel	C[a]	SO_2[b]
Petrol	855	0.012
Diesel	863	0.015

a Emission factor in kg carbon/tonne, based on UKPIA (2005)
b 2010 emission factor calculated from UKPIA (2011) – figures on the weighted average sulphur-content of fuels delivered in the UK in 2010

Emissions of CO_2 and SO_2 can be broken down by vehicle type based on estimated fuel consumption factors and traffic data in a manner similar to the traffic-based emissions described below for other pollutants.

To distribute fuel consumption, hence emissions, between different vehicle types, a combination of data sources and approaches were used making best use of all available information.

Fuel consumption factors for petrol and diesel vehicles

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

For cars, LGVs and motorcycles, the speed-related fuel consumption factors in g fuel/km were used in combination with average speed, fleet composition and vehicle km data for different road types as described below. The fleet-average fuel consumption factors calculated for these vehicle types grouped into their respective Euro emission standards are shown in **Table A 3.3.24** for average speeds on urban, rural and motorway roads. The different emission standards are described in a later section.

Table A 3.3.24 Fuel Consumption Factors for Light Vehicles (in g fuel/km)

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

For HGVs, the DfT provide statistics from a survey of haulage companies on the average miles per gallon (mpg) fuel efficiency of different sizes of lorries (DfT, 2011a). A time-series of mpg figures from 1989 to 2010 is provided by the road freight statistics and these can be converted to g fuel per kilometre fuel consumption factors. The figures will reflect the operations of haulage companies in the UK in terms of vehicle load factor and typical driving cycles, e.g. distances travelled at different speeds on urban, rural and motorway roads. The shape of the DfT/TRL speed-related functions based on test cycle measurements of more limited samples of vehicles are then used to define the variation, relative to the averaged value, in fuel consumption factor with speed and hence road type. The mpg factors for 2006 to 2009 have been revised by DfT and are used in the latest inventory.

Table A 3.3.25 presents the fleet-averaged fuel consumption factors for rigid and articulated HGVs from 1990-2010 for urban, rural and motorway conditions based on the road freight statistics published in DfT (2011a). The factors in this table are slightly different from the factors in the corresponding table last year partly due to the revisions in the mpg factors, but also because of revised assumptions on the distribution of vehicle km by different weight classes of HGVs which affects the factors in all years.

Table A 3.3.25 Average fuel consumption factors for HGVs (in g fuel/km) in the fleet based on DfT's road freight statistics

g fuel/km	Rigid HGVs			Artic HGVs		
	urban	rural	m-way	urban	rural	m-way
1990	272.4	217.7	231.5	438.8	337.1	343.6
1991	276.6	221.0	235.1	437.2	335.9	342.4
1992	277.0	221.4	235.4	433.9	333.3	339.8
1993	266.9	213.5	227.0	412.1	316.7	322.8
1994	259.0	207.8	221.1	405.1	311.6	317.6
1995	263.3	212.2	225.9	395.5	304.6	310.5
1996	258.2	209.0	222.8	388.1	299.3	305.1
1997	256.3	208.4	222.3	387.2	299.2	304.9
1998	245.1	200.5	214.1	370.8	287.2	292.7
1999	249.8	205.4	219.6	370.3	287.3	292.8
2000	247.8	204.8	219.2	370.2	287.7	293.2
2001	259.8	214.2	228.8	375.4	292.0	297.6
2002	252.9	208.4	222.3	373.2	290.0	295.6
2003	262.7	216.1	230.0	378.3	293.7	299.4
2004	253.8	208.5	221.7	365.0	283.1	288.6
2005	250.6	204.9	217.3	360.9	279.7	285.1
2006	261.7	213.0	225.4	363.4	281.4	286.9
2007	269.9	218.4	230.5	365.9	283.1	288.6
2008	279.4	225.9	238.3	379.7	293.5	299.3
2009	281.6	227.9	240.6	381.1	294.3	300.1
2010	285.1	229.8	242.3	384.9	296.9	302.7

For buses and coaches, the principal data source used was figures from DfT on the Bus Service Operators Grant system (BSOG). This is an audited subsidy, directly linked to the fuel consumed on local bus services. From BSOG financial figures, DfT were able to calculate the costs and hence quantity of fuel (in litres) used for local bus services going back to 1996 and using additional bus km data were able to derive implied fuel consumption factors for local service buses (DfT, 2011b). DfT believe this provides a relatively robust estimation of fuel consumption on local bus services and would be based on a larger evidence base than the DfT/TRL speed-related functions which are derived from a relatively small sample of buses and coaches tested. In the 2010 inventory, DfT has revised the whole time series of BSOG data to take account of fuel consumption on local bus services that were carried out on dead mileage, i.e. mileage to and from the start and end of a bus route. This had been omitted previously and the revised BSOG data now represent lower fuel consumption factors compared to the factors used in the last year's inventory. In terms of trend, the BSOG data continue to imply an increase in the average fuel consumption factor for local buses, i.e. a reduction in fuel efficiency over the period from 1998/9 to 2009/20010.

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

The BSOG data are provided on a financial year basis, the most recent being for 2009/10. The financial year figures were used to represent the factors for the earlier calendar year. Hence, the 2009/10 figures were used for the 2009 calendar year and superceded estimates for 2009 made last year when these data were not available. As there are no corresponding BSOG data to use for 2010, factors were estimating based on trends in the average fuel consumption factor for urban buses implied by DfT/TRL speed functions for different bus classes and the change in the bus fleet between 2009 and 2010. This produced a fuel efficiency scaling factor that could be applied to the factor for 2009.

Table A 3.3.26 presents the fleet-averaged fuel consumption factor for buses and coaches from 1990-2010 for urban, rural and motorway conditions based on this method. The revised BSOG factors lead to a reduction in the factors compared with those shown in the corresponding table last year.

Table A 3.3.26 Average fuel consumption factors for buses and coaches (in g fuel/km) in the fleet based on DfT's BSOG data

g fuel/km	Urban	Rural	Motorway
1990	268.9	167.8	190.9
1991	268.9	167.8	190.9
1992	268.9	167.8	190.9
1993	268.2	167.5	190.5
1994	265.0	165.7	189.0
1995	260.8	163.3	187.0
1996	255.9	160.7	184.8
1997	255.3	160.9	185.8
1998	255.1	161.5	187.4
1999	264.5	168.2	195.9

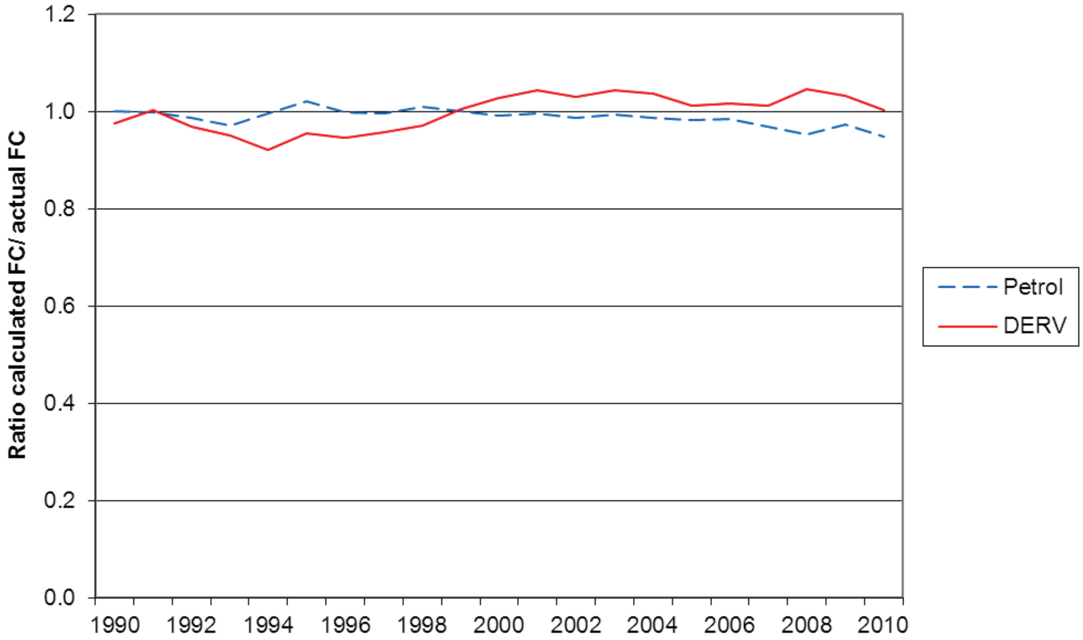
g fuel/km	Urban	Rural	Motorway
2000	277.0	176.7	206.4
2001	278.3	177.9	208.4
2002	290.0	186.1	219.0
2003	303.9	195.0	229.8
2004	309.5	198.6	234.1
2005	324.4	208.1	245.6
2006	319.2	204.7	241.6
2007	327.6	209.7	247.7
2008	340.7	217.8	257.3
2009	340.1	217.0	256.6
2010	340.2	216.7	256.5

Fuel reconciliation and normalisation
A model is used to calculate total petrol and diesel consumption by combining these factors with relevant traffic data (discussed in **Section A3.3.5.3.1**.). These "bottom-up" calculated estimates of petrol and diesel consumption are then compared with DECC figures for total fuel consumption in the UK published in DUKES, adjusted for the small amount of consumption by, inland waterways, off-road machinery and consumption in the Crown Dependencies. Consumption of petrol and diesel by these off-road machinery were revised this year following a major review on the allocation of these fuels across a range of sectors described elsewhere in this report Annex. This review highlighted the greater consumption of road fuels for small and intermittently used machinery and vessels than had been previously assumed.

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

Figure A 3.3.1 shows the ratio of model calculated fuel consumption to the figures in DUKES based on total fuel sales of petrol and diesel in the UK, allowing for off-road consumption. For a valid comparison with DUKES, the amount of petrol and diesel displaced by biofuel consumption has been used to correct the calculated consumption of petrol and diesel. The ratio fluctuates just above and below the 1 line, but the difference is never higher than 8%. In 2010, the bottom-up method underestimates petrol consumption by 5.2% and over-estimates diesel consumption by 0.2%. This is considered well within the uncertainty of the factors used to derive the bottom-up estimates.

Figure A 3.3.1 Ratio of calculated consumption of petrol and diesel fuel based on traffic movement and fuel consumption factors summed for different vehicle types to the DUKES figures for these fuels based on fuel sales in the UK.



The normalisation process introduces uncertainties into the fuel consumption and hence CO_2 emission estimates for individual vehicle classes even though the totals for road transport are known with high accuracy.

For petrol, the fuel consumption calculated for each vehicle type consuming petrol is scaled up or down by the same proportion to make the total petrol consumption align with DUKES. So for example, the fuel consumption estimated for petrol cars, LGVs and motorcycles are all increased by 5.2% to align with fuel sales in 2010. Cars consume the vast majority of this fuel, so the DUKES figures provide a relatively accurate description of the trends in fuel consumption and CO_2 emissions by petrol cars. A small residual is consumed by petrol LGVs and motorcycles, so their estimates are susceptible to fairly high levels of uncertainty introduced by the normalisation process.

For diesel, a number of different vehicle classes (cars, LGVs, HGVs and buses) all consume similar amounts of fuel. Either the fuel consumption for all diesel vehicles can be scaled to align with DUKES, as carried out for petrol normalisation, or consumption for specific vehicle types can be adjusted to bring the total in line with DUKES. Because all vehicle types make a similar contribution to diesel consumption, adjusting the calculated figures for all vehicle types by scaling can lead to distorted trends in the figures for specific vehicle types over a time-series. After discussions with officials at DfT, it was decided to retain the consumption for cars, LGVs and buses at the values calculated by the bottom-up approach and use HGVs to "carry the burden" of bringing the total diesel consumption in line with DUKES (DfT, 2009a). There were two main reasons for this. First, because HGVs are the largest overall consumer of diesel, this approach of correcting for the difference between calculated diesel consumption and fuel sales figures from DUKES has a smaller effect on HGVs than other vehicle classes. A second reason is that a rationale can be given for HGVs leading to the overestimation of diesel consumption compared with sales since 1998 on the basis of "fuel tourism" effects. This is where vehicles consume fuel on UK roads that was purchased abroad. In this case, the fuel would not appear in the UK sales figures, but would be represented in consumption figures calculated from traffic movement data. Given the recent price differential between diesel sold in the UK and the rest of Europe and the amount of cross-border haulage operations, HGVs are believed to make a larger contribution to potential fuel tourism effects than any other class of vehicle. Furthermore, DfT were able to provide some data to back up this hypothesis. This included DfT estimates of the amount of fuel purchased abroad by UK vehicles and the kilometres travelled in the UK by foreign vehicles (DfT, 2009a). The 2009 figures suggested the total amount of fuel purchased abroad (and therefore not contributing to UK fuel sales in DUKES) by HGVs operating in the UK could be around 550 ktonnes compared with a gap of around 652 ktonnes in the estimate of total diesel consumption and the figures based on fuel sales in DUKES. This is at least consistent with a theory indicating HGV fuel tourism contributing to the gap and partial justification for adjusting the bottom-up estimated diesel consumption for HGVs to bring the total diesel consumption in line with DUKES. However, it is important to recognise that other factors including modelling uncertainty will also be playing a factor.

Emissions from LPG consumption
Total CO_2 emissions from vehicles running on LPG are estimated on the basis of national figures (from DUKES) on the consumption of this fuel by road transport. The CO_2 emissions from LPG consumption cannot be broken down by vehicle type because there are no reliable figures available on the total number of vehicles or types of vehicles running on this fuel. This is unlike vehicles running on petrol and diesel where the DfT has statistics on the numbers and types of vehicles registered as running on these fuels. It is believed that many vehicles running on LPG are cars and vans converted by their owners and that these conversions are not necessarily reported to vehicle licensing agencies. Figures from DUKES suggest that the consumption of LPG is around 0.3% of the total amount of petrol and diesel consumed by road transport and vehicle licensing data suggest less than 0.5% of all light duty vehicles run on LPG.

Emissions of CO_2 from LPG consumption are calculated from total consumption figures and carbon factors for LPG fuel.

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

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

A3.3.5.3.3 Traffic-based emissions

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

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

Hot exhaust emissions

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

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

Vehicle and fuel type

Emissions are calculated for vehicles of the following types:

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

Total emission rates are calculated by multiplying emission factors in g/km with annual vehicle kilometre figures for each of these vehicle types on different types of roads.

Vehicle kilometres by road type

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

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

DfT estimates annual vehicle kilometres (vkm) for the road network in Great Britain by vehicle type on roads classified as trunk, principal and minor roads in built-up areas (urban) and non-built-up areas (rural) and motorways (DfT, 2011c). DfT provides a consistent time series of vehicle km data by vehicle and road types going back to 1993 for the 2010 inventory, taking into account any revisions to historic data. Additional information discussed later was used to provide the breakdown in vkm for cars by fuel type.

Vehicle kilometre data for Northern Ireland by vehicle type and road class were provided by the Department for Regional Development (DRD), Northern Ireland, Road Services (DRDNI, 2011a). These provided a consistent time-series of vehicle km data for all years up to 2010. Data for 2009 has been revised slightly in particularly for the buses and coaches activity on rural and motorway, with an overall 15% reduction in total buses and coaches vkm compared with the 2009 data used in the 2009 inventory. Additional information is provided by DRDNI about the split between cars and LGVs and the petrol/diesel car split for cars and LGVs in the traffic flow based on further interrogation by DRDNI of licensing data (DRDNI, 2011b).

The Northern Ireland data have been combined with the DfT data for Great Britain to produce a time-series of total UK vehicle kilometres by vehicle and road type from 1970 to 2010 as shown in **Table A 3.3.27**.

Table A 3.3.27 UK vehicle km by road vehicles

Billion vkm		**1990**	**1995**	**2000**	**2005**	**2008**	**2009**	**2010**
Petrol cars	urban	142.2	137.9	135.6	122.6	110.2	108.7	102.6
	rural	141.0	133.9	134.0	127.5	115.4	113.7	109.2
	m-way	49.2	48.3	52.9	48.8	42.7	43.3	41.6
Diesel cars	urban	5.8	17.2	26.2	41.7	53.1	54.5	56.1
	rural	6.2	18.1	28.7	48.4	64.4	65.3	67.2
	m-way	2.8	8.5	14.6	25.2	33.3	33.3	33.6
Petrol LGVs	urban	11.1	7.5	4.2	1.9	1.6	1.4	1.3
	rural	11.4	8.3	5.0	2.3	2.0	1.8	1.6
	m-way	3.9	3.2	2.0	0.9	0.8	0.7	0.6
Diesel LGVs	urban	5.7	10.2	15.6	21.7	23.6	23.0	23.4
	rural	6.1	11.5	18.9	26.2	30.0	29.3	29.8
	m-way	2.0	4.4	7.4	10.5	11.6	11.5	11.4
Rigid HGVs	urban	4.5	3.7	3.9	4.1	3.7	3.4	3.3
	rural	7.1	6.8	7.2	7.5	7.3	6.7	6.6
	m-way	3.7	3.7	4.2	4.2	4.2	4.0	4.1
Artic HGVs	urban	1.1	1.1	1.1	1.0	0.9	0.9	0.8
	rural	4.3	4.7	5.1	5.3	5.6	5.0	5.0
	m-way	4.7	6.0	7.4	7.9	8.0	7.3	7.5
Buses	urban	2.4	2.9	3.0	3.2	3.2	3.2	3.2
	rural	1.7	1.5	1.7	1.5	1.6	1.6	1.6

Billion vkm		1990	1995	2000	2005	2008	2009	2010
	m-way	0.6	0.5	0.5	0.5	0.5	0.4	0.5
M/cycle	urban	3.3	1.9	2.3	3.0	2.7	2.8	2.6
	rural	2.0	1.6	2.0	2.2	2.1	2.1	1.8
	m-way	0.3	0.3	0.4	0.4	0.5	0.4	0.4
Total		**423.4**	**443.9**	**484.0**	**518.6**	**528.8**	**524.3**	**515.9**

<u>Vehicle speeds by road type</u>
Vehicle speed data are used to calculate emission factors from the emission factor-speed relationships available for different pollutants. Average speed data for traffic in a number of different areas were taken from the following main sources: Transport Statistics Great Britain (DfT, 2009b) provided averages of speeds in Central, Inner and Outer London surveyed at different times of day during 1990 to 2008. Speeds data from other DfT's publications such as 'Road Statistics 2006: Traffic, Speeds and Congestion' (DfT, 2007a) and 2008 national road traffic and speed forecasts (DfT, 2008a) were used to define speeds in other urban areas, rural roads and motorways. Where new information is not available, previous NAEI assumptions were maintained or road speed limits used for the vehicles expected to observe these on the type of road concerned. **Table A 3.3.28** shows the speeds used in the previous and 2010 inventory for light duty vehicles, HGVs and buses. DfT confirmed these data were still valid for 2010.

Table A 3.3.28 Average Traffic Speeds in Great Britain

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

<u>Vehicle fleet composition: by age, size, technology and fuel type</u>

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

One of the main improvements made in the 2010 inventory is the application of Automatic Number Plate Recognition (ANPR) data provided by DfT (2011d, pers comm) for defining the UK's vehicle fleet composition on the road. The ANPR data has been collected annually (since 2007) over 256 sites in the UK on different road types (urban and rural major/minor roads, and motorways) and regions. Measurements are made at each site on one weekday (8am-2pm and 3pm-9pm) and one half weekend day (either 8am-2pm or 3pm-9pm) each year in June and are currently available for 2007, 2008, 2009 and 2010. There are approximately 1.4-1.7 million observations recorded from all the sites each year, and they cover various vehicle and road characteristics such as fuel type, age of vehicle (which can be associated with its Euro standard), engine sizes, vehicle weight and road types.

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

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

As the ANPR data are only available between 2007 and 2010, it was necessary to estimate the road-type variations in the fleet for years before the ANPR became available (2007) otherwise a step-change would be introduced in the emission time-series. For the petrol/diesel mix of the GB car fleet as a whole, this was done by extrapolating the 2007 ANPR data back to 1990 based on the rate of change in the proportion of diesel vehicles as indicated by the DfT Vehicle Licensing Statistics. The result was then further adjusted by the DVLA data to define the variation of the petrol/diesel mix by the DA regions. The ANPR data confirmed that there is a preferential use of diesel cars on motorways, as was previously assumed in the inventory, but that preferential usage of diesel cars also extended to urban roads as well, although not to the extent as seen on motorways. The net result was an increase in diesel car km on urban roads, but less on motorways than had been previously assumed. For Northern Ireland, the ANPR data for 2010 show that there was no major difference in the proportion of diesel cars observed on different road types and that the proportion was similar to that implied by the licensing data; as a result, it is assumed that there is no preferential use of diesel cars, and the petrol/diesel mix in car km should follow the proportion as indicated by the licensing statistics provided by DRDNI. This leads to the vehicle km data for petrol and diesel cars on different road types in the UK shown in **Table A 3.3.27.**

The age of a vehicle determines the type of emission regulation that applied when it was first registered. These have successively entailed the introduction of tighter emission control technologies, for example three-way catalysts and better fuel injection and engine management systems. **Table A 3.3.29** shows the regulations that have come into force up to 2010 for each vehicle type. The year 2010 saw the introduction of Euro 5 standards for cars and small vans. The date into service is taken to be roughly the mid-point of the Directive’s implementation dates for Type-Approval and New Registrations.

Table A 3.3.29 Vehicles types and regulation classes

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

In previous years, the inventory was developed using licensing data to define the age mix of the national fleet and data from travel surveys that showed how annual mileage changes with vehicle age. This was used to split the vehicle km figures by age and Euro classification. The new ANPR data provided direct evidence on the age mix of vehicles on the road and how this varied on different road types and thus obviated the need to rely on licensing data and assumptions about changing mileage with age. The information tended to show that the diesel car, LGV and HGV fleet observed on the road was rather newer than inferred from the licensing records and mileage surveys. However, this information was only available for 2007-2010 and it was important to consider how the trends observed in these limited years of ANPR data availability could be rolled back to earlier years. This was done by developing a pollutant and vehicle specific factor for each road type reflecting the relative difference in the fleet mix on each road type defined by the ANPR data compared with the GB average between 2007-2010 and its impact on emissions. This factor is extrapolated to a value of 1 in 1990 because in this year all vehicles meet pre-Euro 1 standard, and hence differences in the age of the fleet on different road types or DA countries have no effect on emissions. This factor is then combined with a DA-specific "driver" derived from trends in licensing data to account for the relative differences in the fleet in each DA country compared with the GB average. An overall year-, vehicle-, road-, DA- and pollutant-specific factor is then applied to GB average emission factors calculated in the fleet model.

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

The DfT/TRL emission factors cover three engine size ranges for cars: <1400cc, 1400-2000cc and >2000cc. The vehicle licensing statistics have shown that there has been a growing trend in the sales of bigger and smaller engine-sized cars in recent years, in particular for diesel cars at the expense of medium-sized cars. The inventory uses the proportion of cars by engine size varying each year from 2000 onwards based on the vehicle licensing data (DfT, 2011e). In addition, the relative mileage done by different size of vehicles was factored into the ratios, this is to take account of the fact that larger cars do more annual mileage than smaller cars (DfT, 2008b).

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

Assumptions on the split in vehicle km for HGVs by vehicle weight class have been updated. Previously the assumptions do not vary with time. However, DfT Road Freight Statistics (DfT, 2011a) show that there has been a gradual reduction in traffic activity for the rigid HGVs below 7.5 tonnes, while there has been an increase in traffic activity for rigid HGVs over 25 tonnes over the period 2000 to 2010. For artic HGVs, the dominant group continues to be those over 33 tonnes, and traffic activity from the below 33 tonnes category have been decreasing over time. These trends have now been reflected in the 2010 inventory.

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

Assumptions on the split in vehicle km for buses by vehicle weight class are based on licensing information and correlations between vehicle weight class and number of seats and whether it is single- or double-decker. It is assumed that 31% of buses are <15t and the remaining are 15-18t.

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

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

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

It was previously assumed that a proportion of all new petrol cars sold in the UK would meet Euro 4 standards prior to the mandatory date required by the Directive i.e. in year 2006 for new registrations (DfT, 2004). However, this assumption has been updated in the 2010 inventory with Euro 4 petrol cars only introduced from year 2006 onwards as set by the Directive. This is in light of the recent study by King’s College and AEA (Carslaw et al., 2011) indicating on the basis of ANPR data and manufacturers’ information a lower proportion of Euro 4 cars on the road than previously implied by the inventory.

Freight haulage operators have used incentives to upgrade the engines in their HGVs or retrofit them with particle traps. DETR estimated that around 4,000 HGVs and buses were retrofitted with particulate traps in 2000, and this would rise to 14,000 vehicles by the end of

2005 (DETR, 2000). This was accounted for in the inventory for its effects on NO_x, CO and VOC emissions.

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

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

The specific features of the fleet of buses operated by Transport for London (TfL) in London were taken into account. Information from TfL on the Euro standard mix of their fleet of buses was used. Based on information from DfT, it is assumed that approximately 75-80% of all bus km in London are done by TfL buses, the remainder being done by non-TfL buses having the composition of the national bus fleet, except in 2008 and 2009 where the fleet is modified to be compliant with the LEZ.

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

Hot Emission Factors
The emission factors for different pollutants were mostly taken from the database of vehicle emission factors released by DfT/TRL in 2009 (Boulter et al., 2009) or from EMEP Emissions Inventory Guidebooks.

Greenhouse gases: N_2O and CH_4
The emission factors for N_2O for all vehicle types are based on the recommendation of the Emissions Inventory Guidebook (EEA, 2010) derived from the COPERT 4 methodology "*Computer Programme to Calculate Emissions from Road Transport*". The DfT/TRL review recommended these emission factors continue to be used for the UK inventory.

For N_2O emissions from petrol cars and LGVs, emission factors are provided for different Euro standards and driving conditions (urban, rural, highway) with adjustment factors that take into account the vehicle's accumulated mileage and the fuel sulphur content; both of these tend to increase emission factors. For diesel cars and LGVs, bulk emission factors are provided for different Euro standards and road types, with no fuel and mileage effects. The factors for motorcycles make no distinction between different Euro standards and road types. In the latest version of Emissions Inventory Guidebook (EEA, 2010), the factors for HGVs and buses have been updated and are provided for different Euro standards, weight classes and driving conditions, instead of a constant factor for all Euro standards and road types as published in the previous guidebook (EEA, 2007).

Table A 3.3.35 summarises the N_2O emission factor for all vehicle types and road conditions in mg/km; the factors for petrol cars and LGVs are shown for zero accumulated mileage, but the inventory takes account of the increase in emissions with mileage. For the latest Euro 3 and 4 cars, emission factors in urban areas increase by around 15% over 50,000km, while for rural and motorway conditions, emission factors increase by as much as 38% over this distance, though starting from a smaller base. The age-mileage functions provided by TRL are used to work out the accumulated mileage effects in the calculation of N_2O emission factors.

N_2O emissions were a problem with early generation petrol cars fitted with three-way catalysts, being formed as a by-product on the catalyst surface during the NO_x reduction process. Emission factors have been declining with successive Euro standards since the first generation of catalysts for Euro 1, presumably due to better catalyst formulations as well as reductions in fuel sulphur content.

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

Table A 3.3.36 summarises the CH_4 emission factor for all vehicle types and road conditions in mg/km.

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

Emissions of CH_4 and N_2O from consumption of LPG were calculated from vehicle km data and emission factors (expressed as g of pollutant per km) available from DfT/TRL covering all types of light duty vehicles (cars and LGVs). The problem was estimating the kilometres travelled by LPG vehicles. Consumption of LPG is relatively small in the UK (0.3% of all road fuels) and there are no reliable data on the number or types of vehicles running on LPG as some vehicles have been converted and conversions are not always logged with the vehicle licensing agency. It is estimated that around 0.5% of all light duty vehicles run on LPG. As information on the type of LPG vehicles travelling in the UK is not available, it has been assumed that all vehicles using LPG are LGVs and this assumption then allows the kilometres travelled by LPG LGVs to be calculated from fuel efficiency factors for vehicles using this fuel taken from DfT/TRL combined with the total LPG consumption given in DUKES. The LPG kilometres were then combined with the g/km emission factors for CH_4 and N_2O provided by TRL/DfT assuming the fleet composition of LPG vehicles in terms of the mix of Euro standards was the same as for diesel LGVs.

Based on this approach, **Table A 3.3.30** shows fleet-averaged emission factors for vehicles using LPG in the UK in 2010 for each main road type.

Table A 3.3.30 Fleet-weighted emission factors for light duty vehicles running on LPG in 2010

g/km	Urban	Rural	Motorway
CH_4	0.0351	0.0195	0.0178
N_2O	0.0106	0.0040	0.0022

As emissions arise from the unintended combustion of lubricants in the engine, then all exhaust emission factors will include the contribution of lubricants as well the main fuel to the pollutant emissions when the vehicles were tested. Hence, the emissions of CH_4 and N_2O (and other air pollutants) from lubricants are included implicitly in the hot exhaust emissions for each vehicle and fuel type. Treating emissions of these pollutants separately would lead to a double count.

Air pollutants and Indirect GHGs: Regulated pollutants NO_x, CO, NMVOCs

Emission factors for NO_x have been revised as recent evidence has shown that there is lack of consistency between the trends in the road transport NO_x emissions inventory and trends in ambient roadside concentrations of NO_x (Carslaw et al., 2011). Moreover, the previous emission factors for some vehicle classes do not seem to reflect real-world NO_x emissions, especially for more modern diesel vehicles (Euro 3+).

NO_x emission factors from the COPERT 4 v8.1 model (published in May 2011) are adopted in the 2010 inventory. The COPERT 4 v8.1 factors are based on new sources of information on vehicle emissions emerged since the TRL/DfT emission factors were developed. The development of COPERT 4 model is coordinated by the European Environment Agency and is used widely by other Member States to calculate emissions from road transport. The latest version of the COPERT model is available for download from http://www.emisia.com/copert/. The COPERT NO_x emission factors are represented as equations relating emission factor in g/km to average speed. These baseline emission factors correspond to a fleet of average mileage in the range of 30,000 to 60,000 kilometres. For petrol cars and LGVs, COPERT provides additional correction factors to take account of degradation in emissions with accumulated mileage. Detailed methodology of emission degradation is provided in the 2009 EMEP/EEA Emissions Inventory Guidebook (EEA, 2010). In addition, there are separate emission functions available for Euro V HDVs equipped with Selective Catalytic Reduction (SCR) and Exhaust Gas Recirculation (EGR) systems for NO_x control. According to European Automobile Manufacturers' association (ACEA), around 75% of Euro V HDVs sold in 2008 and 2009 are equipped with SCR systems, and this is recommended to be used if the country has no other information available (it is not expect that the UK situation will vary from this European average).

The TRL/DfT (Boulter et al., 2009) emission factors for total hydrocarbons (THC) and CO are continued to be used in the 2010 inventory, and are also represented as equations relating emission factor in g/km to average speed. The TRL/DfT emission factors are provided for an extensive range of vehicle types, sizes and Euro standards and are based on emission test data for in-service vehicles. The factors are presented as a series of emission factor-speed relationships for vehicles normalised to an accumulated mileage of 50,000 kilometres. Scaling factors are provided to take account of degradation in emissions with accumulated mileage – for some vehicle classes, emission factors actually improved with mileage, but most deteriorated. Scaling factors are also provided to take into account the effects of fuel quality since some of the measurements would have been made during times when available fuels were of inferior quality than they are now, particularly in terms of sulphur content. These fuel scaling factors are also applied to the COPERT NO_x emission factors.

Tables A 3.3.37-39 summarise the baseline COPERT NO_x emission factors (before any degradation corrections to the petrol LDVs factors and normalised to current fuels) and the TRL/DfT's CO and THC emission factors (normalised to 50,000km accumulated mileage and current fuels) for all vehicle types under typical urban, rural and motorway road conditions in g/km. The factors have been averaged according to the proportion of different vehicle sizes in the UK fleet based on vehicle licensing statistics. Factors for NMVOCs are derived by subtracting the calculated g/km factors for CH_4 from the corresponding THC emission factors.

The speed-emission factor equations were used to calculate emission factor values for each vehicle type and Euro emission standard at each of the average speeds of the road and area types shown in **Table A 3.3.28**. The calculated values were averaged to produce single emission factors for the three main road classes described earlier (urban, rural single carriageway and motorway/dual carriageway), weighted by the estimated vehicle kilometres on each of the detailed road types taken from DfT.

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

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

The emission factors used for NMVOCs, NO_x and CO are already adjusted to take account of improvements in fuel quality for conventional petrol and diesel, mainly due to reductions in the fuel sulphur content of refinery fuels. An additional correction was also made to take account of the presence of biofuels blended into conventional fossil fuel. Uptake rates of biofuels were based on the figures from HMRC (2011) and it was assumed that all fuels were consumed as weak (typically 5%) blends with fossil fuel. The effect of biofuel (bioethanol and biodiesel) on exhaust emissions was represented by a set of scaling factors given by Murrells and Li (2008). A combined scaling factor was applied to the emission factors according to both the emission effects of the biofuel and its uptake rates each year. The effects on these pollutants are generally rather small for these weak blends.

Account was taken of some heavy duty vehicles in the fleet being fitted with pollution abatement devices, perhaps to control particulate matter emissions (PM), or that otherwise lead to reductions in NO_x, CO and NMVOC emissions beyond that required by Directives. Emissions from buses were scaled down according to the proportion fitted with oxidation catalysts or diesel particulate filters (DPFs) and the effectiveness of these measures in reducing emissions from the vehicles. The effectiveness of these measures in reducing emissions from a Euro II bus varies for each pollutant and is shown in **Table A 3.3.31**.

Table A 3.3.31 Scale Factors for Emissions from a Euro II Bus Running on Fitted with an Oxidation Catalyst or DPF

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

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

Euro II HGVs equipped with DPFs have their emissions reduced by the amounts shown in **Table A 3.3.32**.

Table A 3.3.32 Scale Factors for Emissions from a Euro II HGV Fitted with a DPF

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

Cold-Start Emissions

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

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

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

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

Cold start emissions are calculated from the formula:

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

where

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

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

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

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

where

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

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

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

This methodology was used to estimate annual UK cold start emissions of NO_x, CO and NMVOCs from petrol and diesel cars and LGVs. Emissions were calculated separately for each Euro standard of petrol cars. Cold start emissions data are not available for heavy-duty vehicles, but these are thought to be negligible (Boulter, 1996).

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

Cold start emissions of N_2O were estimated using a method provided by the COPERT 4 methodology for the Emissions Inventory Guidebook (EEA, 2007). The method is simpler in the sense that it uses a mg/km emission factor to be used in combination with the distances travelled with the vehicle not fully warmed up, i.e. under "cold urban" conditions. For petrol cars and LGVs, a correction is made to the cold start factor that takes into account the vehicle's accumulated mileage and the fuel sulphur content, in the same way as for the hot exhaust emission. The cold start factors in mg/km for N_2O emissions from light duty vehicles are shown in **Table A 3.3.33**. There are no cold start factors for HGVs and buses.

Table A 3.3.33 Cold Start Emission Factors for N_2O (in mg/km)

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

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

Evaporative Emission

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

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

i) Diurnal Loss

This arises from the increase in the volatility of the fuel and expansion of the vapour in the fuel tank due to the diurnal rise in ambient temperature. Evaporation through "tank breathing" will occur each day for all vehicles with gasoline fuel in the tank, even when stationary.

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

iii) Running Loss
These are evaporative losses that occur while the vehicle is in motion.

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

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

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

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

The method also requires additional information on the number of cars with carburettor and/or fuel return systems. Both these systems lead to higher emissions, the latter because fuel vapour being returned to the fuel tank is warm and therefore heats the fuel in the tank. Data are not available in the UK on the number of cars running with either of these systems, but it was assumed that all pre-Euro 1 cars would be with carburettor and that all Euro 1 onward cars would use fuel injection, but with fuel return systems, hence having high emission factors. The latter is a conservative assumption as some modern cars with fuel injection might be using returnless fuel systems and hence have lower emissions, but it was not possible to know this as there is no association with the car's Euro class.

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

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

The COPERT 4 methodology is based on knowledge of fuel vapour pressure (levels most appropriate for the region in the summer and winter seasons) and climatic conditions (ranges of ambient temperatures most applicable to the region in the summer and winter seasons). Based on the information on seasonal fuel volatility received annually from UKPIA (2011), the COPERT 4 emission factors adopted for summer days were those associated with 70 kPa vapour pressure petrol and cooler summer temperature conditions and those adopted for winter days were those associated with 90 kPa vapour pressure petrol and milder winter temperature conditions characteristic of the UK climate.

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

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

An implied emission factor based on the population, composition of the fleet and trips made in 2010 is shown for petrol cars and motorcycles in **Table A 3.3.34**. The units are in g per vehicle per day.

Table A 3.3.34 Fleet-average emission factor for evaporative emissions of NMVOCs in 2010

g/vehicle.day	2010
Petrol cars	0.94
Motorcycles	1.63

Table A 3.3.35 N_2O Emission Factors for Road Transport (in mg/km)

N_2O(mg/km)	Standard	Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	10.0	6.5	6.5
	Euro 1	21.3	13.8	6.9
	Euro 2	10.7	3.4	1.8
	Euro 3	1.4	0.6	0.5
	Euro 4	1.8	0.6	0.5
	Euro 5	1.8	0.6	0.5
Diesel cars	Pre-Euro 1	0.0	0.0	0.0
	Euro 1	2.0	4.0	4.0
	Euro 2	4.0	6.0	6.0
	Euro 3	9.0	4.0	4.0
	Euro 4	9.0	4.0	4.0
	Euro 5	9.0	4.0	4.0
Petrol LGVs	Pre-Euro 1	10.0	6.5	6.5
	Euro 1	22.0	13.8	6.9
	Euro 2	16.3	9.3	5.8
	Euro 3	10.5	4.6	4.6
	Euro 4	0.8	1.3	1.3
Diesel LGV	Pre-Euro 1	0.0	0.0	0.0
	Euro 1	2.0	4.0	4.0
	Euro 2	4.0	6.0	6.0
	Euro 3	9.0	4.0	4.0
	Euro 4	9.0	4.0	4.0
Rigid HGVs	Pre-Euro I	30.0	30.0	30.0
	Euro I	10.4	8.6	6.1
	Euro II	10.0	8.6	5.7
	Euro III	4.9	4.9	3.7
	Euro IV	10.6	12.9	10.6
	Euro V	27.6	37.1	31.3
Artic HGVs	Pre-Euro I	30.0	30.0	30.0
	Euro I	17.6	14.7	10.8
	Euro II	17.6	14.7	9.8
	Euro III	8.8	8.8	6.8
	Euro IV	18.6	22.9	18.8
	Euro V	47.9	65.1	54.5
Buses	Pre-Euro I	30.0	30.0	30.0
	Euro I	11.7	11.2	7.0
	Euro II	11.7	11.2	6.0
	Euro III	5.7	5.7	4.0
	Euro IV	12.4	13.1	11.4
	Euro V	32.2	35.2	33.6

N_2O(mg/km)	Standard	Urban	Rural	Motorway
Mopeds, <50cc, 2st	Pre-Euro 1	1.0		
	Euro 1	1.0		
	Euro 2	1.0		
	Euro 3	1.0		
Motorcycles, >50cc, 2st	Pre-Euro 1	2.0	2.0	
	Euro 1	2.0	2.0	
	Euro 2	2.0	2.0	
	Euro 3	2.0	2.0	
Motorcycles, >50cc, 4st	Pre-Euro 1	2.0	2.0	2.0
	Euro 1	2.0	2.0	2.0
	Euro 2	2.0	2.0	2.0
	Euro 3	2.0	2.0	2.0

Table A 3.3.36 Methane Emission Factors for Road Transport (in mg/km)

mg CH4/km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	73.0	21.8	57.7
	Euro 1	15.0	5.2	20.9
	Euro 2	15.8	9.6	9.7
	Euro 3	5.0	4.1	7.2
	Euro 4	1.3	1.0	1.8
	Euro 5	1.3	1.0	1.8
Diesel cars	Pre-Euro 1	12.3	10.2	10.0
	Euro 1	6.1	6.3	6.2
	Euro 2	2.9	1.7	1.2
	Euro 3	1.4	1.1	1.1
	Euro 4	1.0	0.8	0.7
	Euro 5	1.0	0.8	0.7
Petrol LGVs	Pre-Euro 1	73.0	21.8	57.7
	Euro 1	15.0	5.2	20.9
	Euro 2	15.8	9.6	9.7
	Euro 3	5.0	4.1	7.2
	Euro 4	1.3	1.0	1.8
Diesel LGV	Pre-Euro 1	11.8	4.0	22.0
	Euro 1	6.7	1.7	5.8
	Euro 2	2.9	1.7	1.2
	Euro 3	2.2	0.6	1.0
	Euro 4	1.5	0.4	0.7
Rigid HGVs	Pre-Euro I	185.5	50.2	43.6
	Euro I	85.0	23.0	20.0
	Euro II	54.4	20.0	18.6
	Euro III	47.6	21.4	18.2
	Euro IV	2.6	1.6	1.2
	Euro V	2.3	1.4	1.1
Artic HGVs	Pre-Euro I	381.8	174.5	152.7
	Euro I	175.0	80.0	70.0
	Euro II	112.0	69.6	65.1
	Euro III	98.0	74.4	63.7
	Euro IV	5.3	5.6	4.2
	Euro V	4.7	5.0	3.8
Buses & coaches	Pre-Euro I	381.8	174.5	152.7
	Euro I	175.0	80.0	70.0

mg CH4/km		Urban	Rural	Motorway
	Euro II	113.8	52.0	45.5
	Euro III	103.3	47.2	41.3
	Euro IV	5.3	5.6	4.2
	Euro V	4.7	5.0	3.8
Mopeds, <50cc, 2st	Pre-Euro 1	219.0		
	Euro 1	43.8		
	Euro 2	24.1		
	Euro 3	19.7		
Motorcycles, >50cc, 2st	Pre-Euro 1	150.0	150.0	
	Euro 1	99.0	106.5	
	Euro 2	30.0	31.5	
	Euro 3	12.0	13.5	
Motorcycles, >50cc, 4st	Pre-Euro 1	200.0	200.0	200.0
	Euro 1	127.9	138.6	148.7
	Euro 2	126.7	93.1	107.1
	Euro 3	76.2	32.6	31.8

Table A 3.3.37 NOx Emission Factors for Road Transport (in g/km), before degradation correction for petrol cars and LGVs[6]

g NOx (as NO2 eq)/km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	2.11	2.66	3.58
	Euro 1	0.26	0.31	0.59
	Euro 2	0.14	0.16	0.19
	Euro 3	0.07	0.06	0.06
	Euro 4	0.05	0.03	0.02
	Euro 5	0.04	0.02	0.01
Diesel cars	Pre-Euro 1	0.57	0.53	0.74
	Euro 1	0.57	0.58	0.74
	Euro 2	0.60	0.56	0.79
	Euro 3	0.69	0.67	0.86
	Euro 4	0.48	0.44	0.72
	Euro 5	0.35	0.31	0.52
Petrol LGVs	Pre-Euro 1	2.82	3.34	3.97
	Euro 1	0.41	0.42	0.61
	Euro 2	0.14	0.14	0.21
	Euro 3	0.09	0.09	0.13
	Euro 4	0.04	0.04	0.06
Diesel LGV	Pre-Euro 1	1.29	0.81	2.08

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

g NOx (as NO2 eq)/km		Urban	Rural	Motorway
	Euro 1	1.05	1.01	1.50
	Euro 2	1.05	1.01	1.50
	Euro 3	0.88	0.85	1.26
	Euro 4	0.72	0.68	1.02
Rigid HGVs	Pre-Euro I	8.65	7.89	7.91
	Euro I	5.92	5.45	5.51
	Euro II	6.40	5.77	5.76
	Euro III	5.01	4.45	4.42
	Euro IV	3.47	3.19	2.86
	Euro V	2.77	1.34	0.81
Artic HGVs	Pre-Euro I	13.95	11.17	10.07
	Euro I	9.79	7.87	7.13
	Euro II	10.42	8.36	7.59
	Euro III	8.35	6.72	6.14
	Euro IV	5.74	4.81	3.59
	Euro V	3.83	1.94	1.27
Buses & coaches	Pre-Euro I	10.84	9.31	8.64
	Euro I	7.26	6.00	6.42
	Euro II	7.85	6.47	7.00
	Euro III	6.14	4.66	5.33
	Euro IV	4.21	3.35	3.85
	Euro V	3.35	2.16	1.91
Mopeds, <50cc, 2st	Pre-Euro 1	0.03		
	Euro 1	0.03		
	Euro 2	0.01		
	Euro 3	0.01		
Motorcycles, >50cc, 2st	Pre-Euro 1	0.03	0.04	
	Euro 1	0.04	0.05	
	Euro 2	0.05	0.06	
	Euro 3	0.02	0.04	
Motorcycles, >50cc, 4st	Pre-Euro 1	0.22	0.45	0.57
	Euro 1	0.23	0.44	0.57
	Euro 2	0.13	0.31	0.66
	Euro 3	0.07	0.16	0.34

Table A 3.3.38 CO Emission Factors for Road Transport (in g/km) normalised to 50,000 km accumulated mileage (where applicable)

g CO/km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	9.77	6.85	5.53
	Euro 1	2.42	1.64	3.13
	Euro 2	0.53	0.69	1.82
	Euro 3	0.23	0.62	1.58
	Euro 4	0.42	0.71	1.56
	Euro 5	0.34	0.58	1.29
Diesel cars	Pre-Euro 1	0.58	0.43	0.36
	Euro 1	0.32	0.22	0.18
	Euro 2	0.19	0.12	0.08
	Euro 3	0.06	0.04	0.02
	Euro 4	0.05	0.03	0.02
	Euro 5	0.04	0.02	0.01
Petrol LGVs	Pre-Euro 1	11.69	8.17	6.69
	Euro 1	3.10	3.25	4.81
	Euro 2	0.10	1.15	3.12
	Euro 3	0.41	0.77	2.22
	Euro 4	0.41	0.77	2.22
Diesel LGV	Pre-Euro 1	0.71	0.77	0.95
	Euro 1	0.55	0.46	0.43
	Euro 2	0.59	0.62	0.76
	Euro 3	0.17	0.13	0.12
	Euro 4	0.14	0.10	0.09
Rigid HGVs	Pre-Euro I	2.14	1.96	2.06
	Euro I	1.38	1.30	1.37
	Euro II	1.17	1.12	1.18
	Euro III	1.04	0.96	0.98
	Euro IV	0.57	0.50	0.55
	Euro V	0.08	0.07	0.07
Artic HGVs	Pre-Euro I	2.49	2.26	2.39
	Euro I	2.17	1.98	2.10
	Euro II	1.80	1.69	1.83
	Euro III	1.91	1.74	1.86
	Euro IV	0.34	0.31	0.34
	Euro V	0.13	0.12	0.13
Buses & coaches	Pre-Euro I	2.72	1.89	1.50
	Euro I	1.68	1.11	1.24
	Euro II	1.33	0.87	1.13
	Euro III	1.46	0.92	1.22
	Euro IV	0.13	0.08	0.09
	Euro V	0.13	0.09	0.09
Mopeds, <50cc, 2st	Pre-Euro 1	13.80		
	Euro 1	5.60		
	Euro 2	1.30		
	Euro 3	1.30		
Motorcycles, >50cc, 2st	Pre-Euro 1	16.08	23.67	
	Euro 1	10.61	15.62	
	Euro 2	8.39	12.35	

g CO/km		Urban	Rural	Motorway
	Euro 3	4.63	6.82	
Motorcycles, >50cc, 4st	Pre-Euro 1	16.59	22.01	25.84
	Euro 1	10.08	17.56	15.74
	Euro 2	5.27	8.98	9.51
	Euro 3	2.91	4.96	5.25

Table A 3.3.39 THC Emission Factors for Road Transport (in g/km) normalised to 50,000 km accumulated mileage (where applicable). NMVOC emission factors are derived by subtracting methane factors from the THC factors

g HC/km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	1.242	0.847	0.644
	Euro 1	0.124	0.091	0.115
	Euro 2	0.045	0.041	0.051
	Euro 3	0.020	0.020	0.027
	Euro 4	0.014	0.010	0.013
	Euro 5	0.013	0.009	0.012
Diesel cars	Pre-Euro 1	0.124	0.093	0.076
	Euro 1	0.072	0.048	0.035
	Euro 2	0.054	0.039	0.031
	Euro 3	0.020	0.013	0.010
	Euro 4	0.018	0.015	0.013
	Euro 5	0.018	0.015	0.013
Petrol LGVs	Pre-Euro 1	1.444	0.935	0.669
	Euro 1	0.190	0.128	0.151
	Euro 2	0.037	0.038	0.057
	Euro 3	0.028	0.028	0.039
	Euro 4	0.014	0.014	0.019
Diesel LGV	Pre-Euro 1	0.160	0.136	0.124
	Euro 1	0.083	0.057	0.042
	Euro 2	0.082	0.076	0.085
	Euro 3	0.034	0.025	0.024
	Euro 4	0.029	0.022	0.021
Rigid HGVs	Pre-Euro I	0.993	0.836	0.894
	Euro I	0.397	0.355	0.364
	Euro II	0.254	0.225	0.231
	Euro III	0.225	0.200	0.205
	Euro IV	0.011	0.010	0.010
	Euro V	0.011	0.010	0.010
Artic HGVs	Pre-Euro I	0.711	0.609	0.651
	Euro I	0.676	0.589	0.629
	Euro II	0.430	0.372	0.398
	Euro III	0.370	0.322	0.344
	Euro IV	0.018	0.016	0.017
	Euro V	0.019	0.016	0.017
Buses & coaches	Pre-Euro I	1.014	0.676	0.409
	Euro I	0.589	0.413	0.431
	Euro II	0.384	0.271	0.273

g HC/km		Urban	Rural	Motorway
	Euro III	0.346	0.245	0.270
	Euro IV	0.018	0.012	0.013
	Euro V	0.018	0.012	0.014
Mopeds, <50cc, 2st	Pre-Euro 1	13.910		
	Euro 1	2.730		
	Euro 2	1.560		
	Euro 3	1.200		
Motorcycles, >50cc, 2st	Pre-Euro 1	7.407	8.113	
	Euro 1	2.341	3.273	
	Euro 2	1.243	1.738	
	Euro 3	0.777	1.084	
Motorcycles, >50cc, 4st	Pre-Euro 1	1.527	1.218	1.726
	Euro 1	0.853	0.753	0.807
	Euro 2	0.381	0.439	0.577
	Euro 3	0.238	0.275	0.362

A3.3.5.4 Navigation

The UK GHGI provides emission estimates for coastal shipping, naval shipping, international marine and fishing. Coastal shipping is reported within IPCC category 1A3dii National Navigation. Emissions from fishing vessels are reported separately under the IPCC category 1A4ciii. Emissions from international shipping are reported as a Memo Item for information purposes under IPCC category 1A3di International Marine. Emissions from naval shipping are reported under 1A5.

A new method was used to estimate coastal and international marine emissions for the 2009 inventory, and has been used for the 2010 inventory. The method is centred around a procedure developed by Entec under contract to Defra for calculating fuel consumption and emissions from shipping activities around UK waters using a bottom-up procedure based on detailed shipping movement data for different vessel types, fuels and journeys (Entec, 2010). The approach represents a Tier 2 method for estimating emissions from water-borne navigation in the IPCC Guidelines for national greenhouse gas inventories and was the first time such an approach had been feasible for the UK inventory. Previous emission estimates for coastal and international marine were based on total deliveries of fuel oil, marine diesel oil and gas oil to marine bunkers and for national navigation given in national energy statistics (DUKES, 2011). This led to very erratic time series trends in fuel consumption and emissions which bear little resemblance to other activity statistics associated with shipping such as port movement data. The total fuel delivery statistics given in DUKES (marine bunker plus national navigation) are believed to be an accurate representation of the amount of fuel made available for marine consumption, but there is more uncertainty in the ultimate distribution and use of the fuels for domestic and international shipping consumption.

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

According to IPCC emission reporting guidelines, emissions from domestic coastal shipping are included in national totals, whereas emissions for international marine are not, but are reported as a Memo item for information. To meet the overall requirements of IPCC Guidelines for reporting emissions from shipping, the method adopted for the UK inventory uses the results from Entec for coastal shipping based on movement data for domestic journeys while at the same time using an estimation for international marine that retains consistency with total marine fuels data reported in DUKES. Emissions from naval shipping continue to be based on fuel consumption data reported by the MoD. Estimates of emissions from inland waterways have not previously been included explicitly in the inventory, but are reported for the first time in this year's inventory. To maintain the overall marine fuel balance, the fuel allocated to international shipping has been revised.

The overall approach can be summarised as follows:

- Fuel consumption and emissions for domestic journeys are taken from the Entec study based on detailed movement data for 2007. Entec provided an uplift to their bottom-up estimates to take account of missing vessel movements
- Fuel consumption and emissions for fishing vessels are taken from the Entec study and reported separately under 1A4ciii

- Estimates for domestic shipping fuel consumption and emissions backcast to 1990 and forecast to 2010 are used
- Fuel consumption and emissions are calculated separately for naval shipping from data provided by the MoD
- Fuel consumption and emissions are calculated separately for inland waterways from estimates of vessel population and activities
- A reconciliation with fuels data in DUKES is made whereby the **difference** between the sum of the currently reported fuel deliveries for marine bunkers and national navigation in DUKES and the sum of the fuel consumption estimate for domestic shipping taken from Entec, and the fuel consumption estimates for naval shipping and the UK's inland waterways **is assigned to international shipping**.

Details in the approach are given in the following sections, including the new methodology for inland waterways. Further details of the bottom-up methodology for estimating fuel consumption and emissions based on shipping vessel movements are given in the Entec (2010) report.

Estimation for Domestic Shipping Emissions in 2007

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

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

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

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

- Bulk carrier
- Container ship
- General cargo
- Passenger
- Ro-Ro cargo
- Tanker
- Fishing
- Other

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

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

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

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

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

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

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

The Entec study considered only fuel consumption and CO_2 emissions and emissions of NO_x, SO_2, PM and NMVOCs, but did not cover other greenhouse gases, CH_4 and N_2O. For

NO_x, the factors took into account limits on emissions from engines installed on ships constructed or converted after 1 January 2000, as required to meet the NO_x Technical Code of the MARPOL agreement. As the age of the engine is identified in the LMIU dataset, an average factor for engines in 2007 could be determined. Emission factors for SO_2 depend on the sulphur content of the fuel. Entec made the following assumptions for each fuel based on current limits and data from IVL:

Table A 3.3.40 Sulphur content of fuel

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

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

For pollutants not covered in the Entec (2010) study, including CH_4 and N_2O, emission factors in units g/kg fuel were taken from the EMEP/CORINAIR guidebook.

The detailed Tier 2 approach used by Entec is able to distinguish fuel consumption and emissions between domestic movements from one UK port to another and UK international movements between a UK port and a port overseas. This enables the emissions to be allocated to the IPCC category 1A3dii Domestic Water-borne Navigation separate from 1A3di International Water-borne Navigation (International bunkers), according to IPCC Source Categories:

Table A 3.3.41 Allocation of emissions to IPCC Source Categories

1A3di International Water-borne Navigation (International bunkers)	Emissions from fuels used by vessels of all flags that are engaged in international water-borne navigation. The international navigation may take place at sea, on inland lakes and waterways and in coastal waters. Includes emissions from journeys that depart in one country and arrive in a different country.
1A3dii Domestic Water-borne Navigation	Emissions from fuels used by vessels of all flags that depart and arrive in the same country

Emissions from domestic navigation (1A3dii) are included in the national totals, emissions from international navigation (1A3dii) are not included in national totals, but are reported as a Memo item for information.

Fishing was one of the vessel categories treated by Entec, so this enables emissions from fishing vessels to be reported separately under the IPCC category 1A4ciii.

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

Estimating the Time Series in Domestic Shipping Emissions from 1990

The LMIU data used by Entec only covered vessel movements during the 2007 calendar year. Applying the same approach to other years required considerable additional time and resources, so an alternative approach was used based on proxy data to develop a consistent time series in emissions back to 1990 and forward to 2010 from the 2007 base year emissions. The variables that were considered were:

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

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

- All ports traffic data based on tonnes cargo for domestic and international movements was assigned as an indicator for the bulk carrier, general cargo and tanker vessel categories. Trends were available from 1990-2010.
- All ports main unitised statistics reported as number of units for domestic and international movements was assigned as an indicator for the container ship and Ro-Ro cargo vessel categories. Trends were available from 1990-2010
- International and domestic sea passenger movements reported as number of passengers was assigned to the passenger vessel category

A time-series of tonnes fish landed in the UK provided in UK Sea Fisheries Statistics by the Marine Management Organisation was used for the fishing vessels category (MMO, 2010).

The Entec (2010) report shows the trends in each of the relevant statistics relative to the 2007 base year level. Figure 13.1 in that report shows that before 2007, all statistics were showing a growth in the level of activity from 1990 with the exception of three. These were trends in ports traffic (tonnes cargo) for domestic movements, international sea passenger numbers and fish landings which showed declining activity. However, in the period between 2007 and 2009, almost all statistics showed a decreasing level of activity. Between 2009 and 2010, some of these statistics showed an increase, while others showed a decreasing trend, but overall led to a decreasing trend in fuel consumption.

It was assumed that 2007 heralded the introduction of marine gas oil and marine diesel oil consumption by vessels that had previously used residual fuel oil in the SECA around UK coasts. Thus in years between 1990-2006, all vessels except fishing and those in the 'other' category were assumed to be using fuel oil for their main engine. It was also assumed that passenger vessels outside the SECA started to use MDO in 2007 in order to comply with the SCMF Directive having previously been using fuel oil. However, other vessels outside the SECA were assumed to continue to be using fuel oil across the 1990-2010 time-series.

Overall, this implies a large decrease in fuel oil consumption accompanied by a large increase in MDO/MGO consumption in 2007.

As far as changes in emission factors are concerned, the main consideration was in changes in factors for NO_x and SO_2 over time. The issue for NO_x was the proportion of pre- and post-2000 engines installed on ships since engines installed after January 2000 must comply with the NO_x Technical Code. For each year, an estimated engine replacement rate was used to estimate the proportion of pre- and post-2000 engines in the fleet and from this a weighted NO_x emission factor was derived. It was assumed that emission factors were constant in years before 2000.

SO_2 factors are based on the sulphur content of each type of fuel. Prior to 2007, such figures were based on assumptions from CONCAWE and Entec (2005). Entec (2010) assumed that the sulphur content of marine gas oil fell from 0.2% to 0.1% in 2008/2009. This assumption was maintained for 2010.

Estimation of International Shipping Emissions from 1990

The study by Entec provided a time-series in fuel consumption and emissions from vessels involved in international movements, i.e. those arriving at UK ports from overseas and those leaving UK ports to voyage overseas. However, when adding the estimates of fuel consumption from international movements to fuel consumed by domestic movements (UK port-to-UK port), the sum is different to the total fuel supplied to international marine bunkers and consumed by national navigation in DUKES. This is illustrated in **Table A 3.3.42** which shows the total fuel consumed by domestic and international vessel movements in 2007 according to the Entec methodology compared with the total consumption statistics (national navigation plus marine bunkers) in DUKES for 2007 for fuel oil and gas oil. Note that DUKES makes no separation between marine diesel oil and marine gas oil, so the figures here and in the inventory for gas oil refer to the combined amounts for both these types of fuel.

Table A 3.3.42 Total consumption of marine fuels for domestic and international shipping calculated by the Entec method compared with figures for national navigation and marine bunkers in DUKES for 2007. The DUKES figure for gas oil has consumption by military vessels excluded

Mt fuel	Entec	DUKES
Gas oil	4.34	1.57
Fuel oil	1.00	2.04

The totals differ markedly. One reason for that is the Entec “international” category includes fuel consumed by vessels arriving at UK ports that purchased their fuel overseas and so would not be included in the DUKES marine bunkers supply. However, in reporting emissions from international shipping movements as a Memo item, the UK is only responsible for emissions from fuel supplied by the UK’s bunker fuels market. Another issue is the international bunker fuels market itself and how the figures in DUKES for marine bunkers relate to actual consumption by international shipping movements starting in the UK. International fuel bunkering may be affected by variations in international marine fuel prices such that it is conceivable that fuel tankering occurs to a greater or lesser extent each year. This may explain why the trend in total marine fuel consumption implied by DUKES since 1990 is more erratic than trends in shipping movements implied by port statistics.

All these factors can lead to potential differences in the total domestic plus international fuel consumption calculated from a method based on vessel movements from fuel statistics in DUKES. Moreover, DECC acknowledged that there is uncertainty with refineries who submit data to DUKES as to where the fuel ultimately gets used, i.e. whether for domestic shipping activities or for international marine fuel bunkers. So not only could the total fuel consumed be different, but these uncertainties could allocate the incorrect amounts of the DUKES marine fuels to domestic (national navigation) and international (marine bunkers) consumption. The key point is that for emission reporting under IPCC guidelines, the UK is only responsible for emissions from the fuel it supplies, whatever it is used for, but an accurate estimate is required of the amount of fuel used for domestic shipping consumption because emissions arising from this are accounted for in the UK inventory totals. Therefore, to retain overall consistency with national energy statistics and the requirements of inventory reporting under IPCC Guidelines it was decided at a meeting with stakeholders (Defra, DECC, DfT and Entec) in July 2010 to adopt an approach for the inventory whereby the figures for domestic shipping would be taken directly from the Entec study (described above), but the figures for international shipping would be based on the residual fuel consumption, i.e. the difference between the total fuel deliveries statistic in DUKES and the Entec figure for domestic shipping, after further correcting for consumption of fuel by military shipping. Correction for military consumption is necessary because the figures in DUKES include consumption by naval shipping, but these are not included in Entec's estimates for domestic or international movements, and are also reported as a separate source category in the inventory as described below.

A further adaptation of the approach was made in this year's inventory to account for consumption of gas oil by inland waterways which in last year's inventory would have been captured in the residual assigned to international shipping. Discussions with the DUKES team during a study on the allocation of gas oil across sectors (Murrells et al., 2011) revealed that it is likely that gas oil supplied by marinas and filling points along rivers is included in the DUKES figures for national navigation.

Thus for fuel consumption across the time series:

International shipping fuel consumption = (total DUKES fuel consumption – Entec domestic shipping fuel consumption – naval fuel consumption – inland waterways fuel consumption)

This implies that the total marine fuel consumption by all marine activities covered in the GHGI is considered a "closed" system, in other words, the sum of consumption across all the different marine activities (international shipping, domestic shipping, fishing, naval and inland waterways) is consistent with the total amount of gas oil used for consumption as given in DUKES for marine bunkers and national navigation. The approach also implies a different domestic/international split to that implied by DUKES. The proportion of fuel consumption (hence emissions) allocated to domestic shipping is considerably smaller than that implied in DUKES as can be seen in Table A3.3.43.

However, the significance of including inland waterways in this year's inventory is that less fuel and hence CO_2 emissions are reported to international shipping as an inventory Memo item compared with the 2009 inventory, and more is included in the UK national totals. This table differs from the corresponding table in last year's inventory report by including inland waterway fuel consumption in the GHGI figure for domestic gas oil consumption, reducing the residual assigned to international consumption. Nevertheless, even with this change the proportion of fuel assigned to domestic consumption is still considerably lower than the figure implied by DUKES.

Table A 3.3.43 Consumption of marine fuels by domestic and international shipping calculated by the inventory approach on the basis of Entec figures for domestic movements and inventory estimates of inland waterway activities compared with figures for national navigation (domestic) and marine bunkers (international) in DUKES for 2007. ***The DUKES figure for gas oil (international) has consumption by military vessels excluded.***

Mt fuel		GHGI	DUKES
Gas oil	Domestic	0.496	0.942
	International	1.073	0.627
	Total	1.569	1.569
	% domestic	32%	60%
Fuel oil	Domestic	0.103	0.569
	International	1.936	1.471
	Total	2.040	2.040
	% domestic	5%	28%

Following this revised approach, emissions for international shipping (1A3di) were calculated by multiplying the residual fuel consumption calculated above with an implied emission factor for international vessel movements. The implied emission factors were derived from the Entec study by dividing the Entec emission estimates for international vessel movement by their associated fuel consumption for each fuel type. This effectively means the inventory does capture the types of vessels, engines, speeds and activities used for international movements in Entec's inventory even though the overall movements, fuel consumption and hence emissions are different.

This approach was used to estimate international shipping fuel consumption and emissions for all years back to 1990.

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

DUKES derive marine fuel delivery statistics from the information reported monthly to DECC's oil data reporting system. This delivery information is sourced from the accounting departments of refineries. Up to 2010, the inventory team had noted erratic behaviour in the time-series trends for domestic and marine bunkers reported in DUKES which could not be explained. The inventory team had received many enquiries as to this erratic behaviour in the inventory resulting from use of these data from parts of UK government including the marine divisions of the UK Department for Transport who could not reconcile these trends with their own port movement and other statistics. In 2009, the UK's Department for Environment (Defra) commissioned Entec to undertake a detailed bottom-up estimate of air quality pollutant emissions from shipping based on detailed shipping movement data. This highlighted inconsistencies in the split between fuel consumed for international shipping and national navigation calculated in this study with the figures in DUKES. This led to a series of meetings to resolve this discrepancy and suggest a way forward for the inventory.

The initial meeting in March 2009 involved officials from DECC, Defra, DfT, the UK Petroleum Industry Association (UKPIA), Entec and the inventory team. Minutes of the meeting were recorded. It became apparent that the UK Petroleum Industry Association (UKPIA) and the DECC DUKES team did not have confidence in the way responders to the returns had decided to make the allocation for marine bunkers and national navigation, but there was confidence in the total marine fuels made available for consumption. This was expressed in a series of communications to the inventory team after the initial meeting. UKPIA supported the idea that a split based on a bottom-up, vessel movements basis was a better option and the DUKES team at DECC did not object to this proposal.

The UK's inventory team withheld any changes to the methodology until full agreement had been reached across all Parties. Further meetings involving the same Parties were held in 2010 following further developments of the Entec work. A final meeting was held in July 2010 at which a new method for the inventory based on the Entec studies was proposed for domestic shipping, with the balance of marine fuels (from the total given in DUKES) assigned to international bunkers. Minutes of this meeting were recorded and presentations and related material circulated to all Parties. This included a full analysis and explanation of the impacts to the inventory of making the methodology change. Partial agreement in principle was reached at the meeting to use the proposed method for later confirmation. This was recorded in the Minutes and full agreement was later agreed in an email from DECC circulated to Defra, DfT and the inventory team on 11th October 2010. The new method was then adopted for the 2009 version of the inventory published in early 2011 and was described in the UK's 2011 National Inventory Report methodology annex.

The inventory team has regular contact with the DUKES team who are regularly reviewing their data collection systems. The DUKES team need to consider any potential changes to their reporting in future in the context of their wider oil reporting system used.

Estimation of Domestic and International Shipping Emissions from 1970-1990

For years prior to 1990, the implied emission factors and fuel types used for navigation are assumed to be the same as for 1990. Implied emission factors in g/kg fuel were developed for domestic, international and fishing vessels for gas oil and fuel oil.

The method for estimating fuel consumption by domestic, fishing and international shipping prior to 1990 is based on the relative share of these movement types in 1990 itself which was assumed to remain constant in all previous years. The 1990 share was applied to the total fuel consumption figures given in DUKES for each year back to 1970 (after deducting consumption by military vessels).

Summary of fuel consumption and emission factors for domestic and international shipping

Table A 3.3.44 summarises the time-series in fuel consumption for domestic and international shipping derived from this method for fuel oil and gas oil (marine diesel oil plus marine gas oil combined) since 1990. Figures for fishing which are reported as a separate source category in the inventory are also shown. Fuel consumption by inland waterways are not included in this table.

Table A 3.3.44 Fuel consumption for domestic coastal and international shipping derived from inventory method

Year	Fuel Consumption (Mt)				
	Gas oil			Fuel oil	
	Domestic (excl. fishing)	Fishing	International	Domestic	International
1990	0.171	0.006	1.614	0.346	1.132

1991	0.169	0.005	1.674	0.342	1.065
1992	0.166	0.006	1.700	0.335	1.095
1993	0.164	0.006	1.616	0.332	1.143
1994	0.174	0.006	1.545	0.352	0.951
1995	0.181	0.006	1.378	0.368	1.196
1996	0.182	0.006	1.602	0.370	1.259
1997	0.178	0.005	1.531	0.361	1.570
1998	0.181	0.005	1.824	0.371	1.417
1999	0.181	0.004	1.481	0.374	0.877
2000	0.169	0.004	1.489	0.347	0.630
2001	0.163	0.004	1.645	0.334	0.541
2002	0.170	0.004	1.233	0.351	0.460
2003	0.166	0.004	1.440	0.342	0.576
2004	0.168	0.005	1.343	0.343	0.935
2005	0.172	0.005	1.258	0.356	1.164
2006	0.163	0.004	1.686	0.337	1.480
2007	0.388	0.004	1.073	0.103	1.936
2008	0.378	0.004	0.929	0.100	2.458
2009	0.359	0.004	0.925	0.094	2.208
2010	0.341	0.004	0.862	0.088	1.855

Table A 3.3.45 shows the implied emission factors for each pollutant, for both domestic and international vessel movements and fishing in 2010. The units are in g/kg fuel and are implied by the figures in the Entec study.

Table A 3.3.45 2010 Inventory Implied Emission Factors

Fuel	Source	CH_4	N_2O	CO_2
		g/kg	g/kg	g/kg
Gas Oil	Domestic (excl. fishing)	0.05	0.08	870
	Fishing	0.05	0.08	870
	International	0.05	0.08	870
Fuel Oil	Domestic	0.05	0.08	879
	International	0.05	0.08	879

Fuel	Source	NO_X	SO_2	VOC	CO
		g/kg	g/kg	g/kg	g/kg
Gas Oil	Domestic (excl. fishing)	64.44	20.36	2.82	7.40
	Fishing	57.97	2.02	2.04	7.40
	International	69.33	20.50	2.74	7.40
Fuel Oil	Domestic	70.57	53.96	3.52	7.40
	International	77.71	53.92	2.92	7.40

The UNFCCC Expert Review Team has previously commented that the UK does not include CH_4 and N_2O emissions from lubricants for this sector. However, as emissions arise from the unintended combustion of lubricants in the engine, then all exhaust emission factors will include the contribution of lubricants as well the main fuel to the pollutant emissions when the engines were tested. Hence, the emissions of CH_4 and N_2O (and other air pollutants) from lubricants are included implicitly in the emissions for each vessel and fuel type. Treating emissions of these pollutants separately would lead to a double count.

Emissions from military shipping

Emissions from military shipping are reported separately under NFR code 1A5b. Emissions are calculated using a time-series of naval fuel consumption data (naval diesel and marine gas oil) provided directly by the Sustainable Development and Continuity Division of the Defence Fuels Group of the MoD (MoD, 2011). Data are provided on a financial year basis so adjustments were made to derive figures on a calendar year basis.

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

Consistency with marine fuels data submitted to IEA/EUROSTAT

In response to feedback from the Expert Review Team, the inventory agency has confirmed with the UK national energy statistics team at DECC that the UK allocations of marine bunker fuels reported within DUKES are consistent with the data submitted to EUROSTAT and the IEA across the full time-series. Note, however, that the UK inventory memo item estimates for international shipping deviate from the reported DUKES (and IEA/EUROSTAT) data due to reallocation of some of the bunker fuels to military shipping based on data from the Defence Fuels Group of the MoD; these emissions are included in national inventory estimates and not in the Memo Item (International bunkers) estimate.

Furthermore, the shipping methodology described above leads to a different domestic/international split in fuel use allocation for marine fuels compared with the allocations in the national energy statistics (DUKES) and submissions to IEA/EUROSTAT.

Emissions from Inland Waterways

For the first time, emissions from inland waterways have been included in the 2010 inventory. Although this is a new source in the inventory, it does not represent an overall increase in CO_2 emissions, but it does re-allocate some emissions that were assigned to international shipping to a maritime sector that is included in national totals.

Emissions from vessels used on inland waterways were previously not reported in the UK GHGI because there are no national fuel consumption statistics on the amount of fuel used by this sector in DUKES. However as all fuel consumed by all sources in the UK was captured by the inventory, emissions from inland waterways were effectively captured, but were misallocated to other sectors using the same types of fuels.
The IPCC Guidelines (IPCC, 2006) indicate that emissions from inland waterways are a sub-set of the NFR category 1A3d Waterborne Navigation which also covers shipping. In the UK, all emissions from inland waterways are included in domestic totals whereas in some other countries, vessels on inland waterways could be classed as international since they pass between countries.

The IPCC Guidelines specify that category 1A3d should include not only fuel used for marine shipping, but also for passenger vessels, ferries, recreational watercraft, other inland watercraft, and other gasoline-fuelled watercraft. The Guidelines recommend national energy statistics be used to calculate emissions, but if these are unavailable then emissions should be estimated from surveys of fuel suppliers, vessel movement data or equipment (engine) counts and passenger and cargo tonnage counts.

The methodology applied to derive emissions from the inland waterways sector for the 2010 inventory uses the 2007 and 2009 EMEP/EEA Emissions Inventory Guidebooks (EMEP, 2007, 2009a). The inland waterways class is divided into four categories and sub-categories:

01. Sailing Boats with auxiliary engines;
02. Motorboats / Workboats (e.g. dredgers, canal, service, tourist, river boats);
    a. recreational craft operating on inland waterways;
    b. recreational craft operating on coastal waterways;
    c. workboats;
03. Personal watercraft i.e. jet ski; and
04. Inland goods carrying vessels.

Details of the approach used are given in the report by Walker et al (2011). A bottom-up approach was used based on estimates of the population and usage of different types of craft and the amounts of different types of fuels consumed. Estimates of both population and usage were made for the baseline year of 2008 for each type of vessel used on canals, rivers and lakes and small commercial, service and recreational craft operating in estuaries / occasionally going to sea. For this, data were collected from stakeholders, including the British Waterways, DfT, Environment Agency, Maritime and Coastguard Agency (MCGA), and Waterways Ireland.

The methodology used to estimate the total amount of each fuel consumed by the inland waterways sector follows that described in the EMEP/EEA Emissions inventory guidebook (EMEP, 2009b) where emissions from individual vessel types are calculated using the following equation:

$$E = \sum_i N \times HRS \times HP \times LF \times EFi$$

where:
E = mass of emissions of pollutant i or fuel consumed during inventory period,
N = source population (units),
HRS = annual hours of use,
HP = average rated horsepower,
LF = typical load factor,
EFi = average emissions of pollutant i or fuel consumed per unit of use (e.g. g/kWh).

The method requires:

- a categorisation of the types of vessels and the fuel that they use (petrol, DERV or gas oil);
- numbers for each type of vessel, together with the number of hours that each type of vessel is used;
- data on the average rated engine power for each type of vessel, and the fraction of this (the load factor) that is used on average to propel the boat;
- g/kWh fuel consumption factors and fuel-based emission factors.

A key assumption made is that privately owned vessels with diesel engines used for recreational purposes use DERV while only commercial and service craft and canal boats use gas oil (Walker et al., 2011). Some smaller vessels also run on petrol engines. As a result, around 90 ktonnes of DERV and 90 ktonnes of petrol previously assigned to the road transport sector for 2009 in last year's inventory are now allocated to inland waterways.

Walker at al. (2011) and Murrells et al. (2011) draw attention to the potential overlap between the larger vessels using the inland waterways and the smaller vessels in the shipping sectors (namely tugboats and chartered and commercial fishing vessels), and the judgement and assumptions made to try to avoid such an overlap.

As it was only possible to estimate population and activities for one year (2008), proxy statistics were used to estimate activities for different groups of vessels for other years in the time series 1990 – 2010:

- Private leisure craft – ONS Social Trends 41: Expenditure, Table 1, Volume of household expenditure on "Recreation and culture"; http://www.ons.gov.uk/ons/rel/social-trends-rd/social-trends/social-trends-41/index.html;
- Commercial passenger/tourist craft – Visit England, Visitor Attractions Trends in England 2010, Annual Report Visitor numbers. Table 9.1 Trends in the number of visits to UK attractions 1989-2010, Total England Attractions; http://www.visitengland.org/Images/Final%20report_tcm30-27368.pdf
- Service craft (tugs etc.) – DfT Maritime Statistics, Port traffic trends. Table 1.3 - Foreign and domestic traffic, by port: 1965 - 2009, United Kingdom and Great Britain Total (supplementary spreadsheet); http://www2.dft.gov.uk/pgr/statistics/datatablespublications/maritime/compendium/maritimestatistics2009.html; and
- Freight – DfT Waterborne Freight in the United Kingdom, Table 1.1: Waterborne transport within the United Kingdom, 1990 – 2009; Goods lifted - UK inland waters traffic - Non-seagoing traffic - Internal http://www2.dft.gov.uk/pgr/statistics/datatablespublications/maritime/waterborne/waterbornefreight2009.html

One of these four proxy data sets was assigned to each of the detailed vessel types covered in the inventory and used to define the trends in their fuel consumption from the 2008 base year estimate.

Table A 3.3.46 shows the trend in fuel consumption by inland waterways from 1990-2010 developed for the inventory this year. **Table A 3.3.47** provides emission factors for each pollutant, assumed for all vessel types operating on the UK's inland waterways in 2010. More detail regarding the vessels and their fuel type can be found in the report by Walker et al., 2011.

Table A 3.3.46 Fuel consumption for inland waterways derived from inventory method

Year	Fuel Consumption (kt)					
	Gas Oil		Diesel		Petrol	
	Motorboats / workboats	Inland goods-carrying vessels	Sailing boats with auxiliary engines	Motorboats / workboats	Motorboats / workboats	Personal watercraft
1990	86.2	3.82	0.59	27.6	22.0	11.2
1991	86.5	3.44	0.62	28.8	22.6	11.7

1992	86.9	3.76	0.68	31.5	24.1	12.8
1993	88.4	4.07	0.74	34.3	25.5	13.9
1994	92.8	4.52	0.80	37.0	27.0	15.0
1995	94.3	4.20	0.85	39.8	28.5	16.1
1996	94.9	3.63	0.91	42.5	29.9	17.2
1997	95.2	3.06	0.97	45.3	31.1	18.3
1998	95.8	2.74	1.03	48.0	32.2	19.4
1999	95.5	2.74	1.09	50.7	33.6	20.5
2000	96.1	2.74	1.15	53.5	34.8	21.6
2001	94.5	2.71	1.21	56.2	35.9	22.8
2002	96.0	2.52	1.30	60.4	38.7	24.4
2003	96.4	2.02	1.39	64.6	41.0	26.1
2004	98.8	1.65	1.48	68.8	43.2	27.8
2005	100.2	2.16	1.57	72.9	45.2	29.5
2006	101.1	2.26	1.66	77.1	47.6	31.2
2007	101.7	2.14	1.75	81.3	49.9	32.9
2008	100.3	2.35	1.84	85.5	52.2	34.6
2009	94.6	2.08	1.93	89.6	54.8	36.3
2010	97.0	2.35	1.93	89.6	55.1	36.3

Table A 3.3.47 2010 Inventory Emission Factors

Fuel	CH_4	N_2O	CO_2
	g/kg	g/kg	g/kg
DERV	0.05	0.08	863
Gas Oil	0.05	0.08	870
Petrol	1.7	0.08	855

Fuel	NO_X	SO_2	VOC	CO
	g/kg	g/kg	g/kg	g/kg
DERV	42.5	0.0148	4.72	10.9
Gas Oil	42.5	1.442	4.72	10.9
Petrol	9.0	0.012	50.0	300.0

A3.3.6 Other Sectors (1A4)

The mapping of NAEI categories to 1A4 Other Sectors is shown in **Section A3.2**. For most sources, the estimation procedure follows that of the base combustion module using DECC reported fuel use data and emission factors from **Table A 3.3.1**. The NAEI category public service is mapped onto 1A4a Commercial and Institutional. This contains emissions from stationary combustion at military installations, which should be reported under 1A5a Stationary. Also included are stationary combustion emissions from the railway sector, including generating plant dedicated to railways. Also included in 1A4 are emissions from the ‘miscellaneous’ sector, which includes emissions from the commercial sector and some service industries.

Emissions from 1A4b Residential and 1A4c Agriculture/Forestry/Fishing are disaggregated into those arising from stationary combustion and those from off-road vehicles and other machinery. The estimation of emissions from off-road sources is discussed in **Section A3.3.7.1** below. Emissions from fishing vessels are now reported under 1A4c, the revised shipping methodology (described in **Section A3.3.3.4)** has allowed the separate reporting of this source (previously reported under coastal shipping, 1A3d).

A3.3.7 Other (1A5)

Emissions from military aircraft and naval vessels are reported under 1A5b Mobile. The method of estimation is discussed in **Sections A3.3.5.1** and **A3.3.5.4** with emission factors given **Table A 3.3.1**. Note that military stationary combustion is included under 1A4a Commercial and Institutional due to a lack of more detailed data. Emissions from off-road sources are estimated and are reported under the relevant sectors, i.e. Other Industry, Residential, Agriculture and Other Transport. The methodology of these estimates is discussed in **Section A3.3.7.1**.

A3.3.7.1 Estimation of Other Off-Road Sources

Emissions are estimated for 77 different types of portable or mobile equipment powered by diesel or petrol driven engines. These range from machinery used in agriculture such as tractors and combine harvesters; industry such as portable generators, forklift trucks and air compressors; construction such as cranes, bulldozers and excavators; domestic lawn mowers; aircraft support equipment. In the inventory they are grouped into four main categories:

- domestic house & garden
- agricultural power units (includes forestry)
- industrial off-road (includes construction and quarrying)
- aircraft support machinery.

The mapping of these categories to the appropriate IPCC classes is shown in **Section A3.2**. Aircraft support is mapped to Other Transport and the other categories map to the off-road vehicle subcategories of Residential, Agriculture and Manufacturing Industries and Construction.

Emissions are calculated from a bottom-up approach using machinery- or engine-specific emission factors in g/kWh based on the power of the engine and estimates of the UK population and annual hours of use of each type of machinery.

The emission estimates are calculated using a modification of the methodology given in EMEP/ CORINAIR (1996). Emissions are calculated using the following equation for each machinery class:

$$E_j = N_j \,.\, H_j \,.\, P_j \,.\, L_j \,.\, W_j.(1 + Y_j \,.\, a_j /2).\, e_j$$

where

E_j	=	Emission of pollutant from class j	(kg/y)
N_j	=	Population of class j.	
H_j	=	Annual usage of class j	(hours/year)
P_j	=	Average power rating of class j	(kW)
L_j	=	Load factor of class j	(-)

Y_j	=	Lifetime of class j	(years)
W_j	=	Engine design factor of class j	(-)
a_j	=	Age factor of class j	(y^{-1})
e_j	=	Emission factor of class j	(kg/kWh)

For petrol-engined sources, evaporative NMVOC emissions are also estimated as:

$$E_{vj} = N_j \cdot H_j \cdot e_{vj}$$

where

E_{vj}	=	Evaporative emission from class j	kg
evj	=	Evaporative emission factor for class j	kg/h

The population, usage and lifetime of different types of off-road machinery were updated following a study carried out by AEA on behalf of the Department for Transport (Netcen, 2004a). This study researched the current UK population, annual usage rates, lifetime and average engine power for a range of different types of diesel-powered non-road mobile machinery. Additional information including data for earlier years were based on research by Off Highway Research (2000) and market research polls amongst equipment suppliers and trade associations by Precision Research International on behalf of the former DoE (Department of the Environment) (PRI, 1995, 1998). Usage rates from data published by Samaras *et al* (1993, 1994) were also used.

The population and usage surveys and assessments were only able to provide estimates on activity of off-road machinery for years up to 2004. These are one-off studies requiring intensive resources and are not updated on an annual basis. There are no reliable national statistics on population and usage of off-road machinery nor figures from DECC on how these fuels, once they are delivered to fuel distribution centres around the country, are ultimately used. Therefore, other activity drivers were used to estimate activity rates for the four main off-road categories from 2005-2010.

For industrial and construction machinery, a set of four drivers is used. Each of the individual machinery types is mapped to one of these four drivers depending on the typical industry sector in which the machinery type is usually used. The four categories and drivers used are described in **Table A 3.3.48**.

For domestic house and garden machinery, trends in number of households are used (CLG, 2010), for airport machinery, statistics on number of terminal passengers at UK airports are used (CAA, 2011), and for agricultural off road machinery, the trends in gas oil allocated to agriculture in DUKES (DECC, 2011) are used.
A simple turnover model is used to characterise the population of each machinery type by age (year of manufacture/sale). For older units, the emission factors used came mostly from EMEP/CORINAIR (1996) though a few of the more obscure classes were taken from Samaras & Zierock (1993). The load factors were taken from Samaras (1996). Emission factors for garden machinery, such as lawnmowers and chainsaws were updated following a review by Netcen (2004b). For equipment whose emissions are regulated by Directive 2002/88/EC or 2004/26/EC, the emission factors for a given unit were taken to be the maximum permitted by the directive at the year of manufacture. The emission regulations are quite complex in terms of how they apply to different machinery types. Each of the 77 different machinery types was mapped to the relevant regulation in terms of implementation date and limit value.

The methodology follows the Tier 3 methodology described in the latest EMEP/CORINAIR emission inventory guidebook (EMEP/CORINAIR, 2009).

Table A 3.3.48 Activity drivers used for off-road machinery in the industry and construction sector.

Category	Driver source	Machinery types
Construction	ONS construction statistics. The value of all new work (i.e. excluding repair and maintenance work) at constant (2005) prices and seasonally adjusted. Taken from the Construction Statistics Annual 2011. http://www.ons.gov.uk/ons/rel/construction/construction-statistics/no--12--2011-edition/construction-statistics-annual-report-2011.pdf	generator sets <5 kW
		generator sets 5-100 kW
		asphalt pavers
		tampers /rammers
		plate compactors
		concrete pavers
		rollers
		scrapers
		paving equip
		surfacing equip
		trenchers
		concrete /industrial saws
		cement & mortar mixers
		cranes
		graders
		rough terrain forklifts
Quarrying	Data on UK production of minerals, taken from UK Minerals Yearbook data, BGS 2011.	bore/drill rigs
		off highway trucks*
		crushing/processing equip
Construction and Quarrying	Growth driver based on the combination of the quarrying and construction drivers detailed above.	excavators
		loaders with pneumatic tyres
		bulldozers
		tracked loaders
		tracked bulldozers
		tractors/loaders
		crawler tractors
		off highway tractors
		dumpers /tenders
General Industry	Based on an average of growth indices for all industrial sectors, taken from data supplied by DECC for use in energy and emissions projections.	generator sets 100-1000KW
		pumps
		air compressors
		gas compressors
		welding equip
		pressure washers
		aerial lifts
		forklifts*
		sweepers/ scrubbers
		other general industrial equip
		other material handling equip

Aggregated emission factors for the four main off-road machinery categories in 2010 are shown in **Table 3.3.49** by fuel type. The fleet-average (aggregated) emission factors for most machinery types are lower than in the 2009 inventory because of the expiry of old machinery and penetration of new machinery into the fleet. Factors for SO_2 are changed due to changes in the sulphur content of fuels. For industrial off-road machinery, some machinery types with diesel engines previously assumed to be using gas oil are now assumed to be using DERV, following a study into the use of gas oil in the UK (see **Section A3.3.4.2**). This study leads to a re-allocation of 0.25 Mtonnes DERV previously assigned to road transport in 2009 to industrial off-road machinery, mainly small machinery types used on an irregular basis, such as small portable generators and small cement and mortar mixers.

Table A 3.3.49 Aggregate Emission Factors for Off-Road Source Categories in 2010 (t/kt fuel)

Source	Fuel	C[2]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2[3]
Domestic House&Garden	DERV	863	0.16	1.31	47.96	4.34	2.57	0.01
Domestic House&Garden	Petrol	855	0.91	0.03	3.62	667.85	49.52	0.01
Agricultural Power Units	Gas oil	870	0.16	1.32	24.73	16.57	4.55	1.44
Agricultural Power Units	Petrol	855	2.17	0.02	1.45	716.32	248.58	0.01
Industrial Off-road	DERV	863	0.17	1.46	41.99	18.83	7.07	0.01
Industrial Off-road	Gas oil	870	0.17	1.46	41.99	18.83	7.07	1.44
Industrial Off-road	Petrol	855	3.76	0.05	6.24	1034.72	39.33	0.01
Aircraft Support	Gas oil	870	0.16	1.34	26.62	12.52	4.93	1.44

1 Emission factors reported are for 2010
2 Emission factor as kg carbon/t, UKPIA (2004)
3 Based on sulphur content of fuels in 2009 from UKPIA (2011).

The emission factors used for carbon were the standard emission factors for DERV, gas oil and petrol given in **Table A 3.3.1.**

A3.3.8 Fugitive Emissions From fuels (1B)

A3.3.8.1 Solid Fuels (1B1)

A3.3.8.1.1 Coal Mining

Emissions for IPCC categories 1B1ai Underground Mines-mining, 1B1ai Underground Mines-post-mining and 1B1aii Surface Mines are calculated from saleable coal production statistics reported by DECC (2011). Licensed mines referred to privately owned mines and were generally smaller and shallower than previously nationalised mines. The distinction was sufficiently marked to allow the use of a separate emission factor. Data on the shallower licensed mines are supplied by Barty (1995) up to 1994. Following privatisation, the distinction between licensed mines and deep mines no longer exists and all domestically produced coal that is not open-cast is assumed to be deep mined. For 1995, data from 1994 were used but in subsequent years the distinction has been abandoned. The emission factors used are shown in **Table A 3.3.50**.

Table A 3.3.50 Methane Emission Factors for Coal Mining (kg/t coal)

Year	Deep Mined	Coal Storage & Transport[a]	Licensed Mine[c]	Open Cast[c]
1990	10.0[a]	1.16	1.36	0.34
1991	10.2[a]	1.16	1.36	0.34
1992	11.0[a]	1.16	1.36	0.34
1993	13.1[b,d]	1.16	1.36	0.34
1994	13.0[b,d]	1.16	1.36	0.34
1995	13.0[b,d]	1.16	1.36	0.34
1996	13.4[b,d]	1.16	1.36	0.34
1997	13.4[b,d]	1.16	1.36	0.34
1998	13.4[b]	1.16	-	0.34
1999	13.5[b]	1.16	-	0.34
2000	14.0[b]	1.16	-	0.34
2001	12.6[b]	1.16	-	0.34
2002	13.5[b]	1.16	-	0.34
2003	11.7[b]	1.16	-	0.34
2004	13.7[b]	1.16	-	0.34
2005	12.6[b]	1.16	-	0.34
2006	10.6[b]	1.16	-	0.34
2007	7.45[b]	1.16	-	0.34
2008	7.61[b]	1.16	-	0.34
2009	8.46[b]	1.16	-	0.34
2010	7.53[b]	1.16	-	0.34

a Bennet *et al* (1995)
b Factor based on UK Coal Mining Ltd data
c Williams (1993)
d Based on 1998 factor from UK Coal Mining Ltd. (in m^3/tonne) extrapolated back from 1998 to 1993 as no other data are available

The licensed and open cast factors are taken from Williams (1993). The deep mined factors for 1990 -1992 and the coal storage factor are taken from Bennet *et al* (1995). This was a study on deep mines which produced estimates of emissions for the period 1990-93. This was a period over which significant numbers of mines were being closed, hence the variation in emission factors. The emission factors for 1998-2010 are based on operator's measurements of the methane extracted by the mine ventilation systems. The mines surveyed cover around 90% of deep mined production. No time series data are available for 1993-97, so the 1998 factor was used. Methane extracted is either emitted to atmosphere or utilised for energy production. Methane is not flared for safety reasons. The factors reported in **Table A 3.3.50** refer to emissions and exclude the methane utilised. The coal storage and transport factor is only applied to deep mined coal production.

The activity data for the coal mining emissions are reported in the CRF tables attached as a CD to this report. The number of active deep mines reported is defined as the number of mines producing at any one time during the period (Coal Authority, 2005). Hence, this would include large mines as well as small ones or those that only produced for part of the year. The colliery methane utilisation data are taken from DUKES (DECC, 2011).

Emissions of methane from closed coal mines were first included in the 2006 GHG inventory submission. These estimates were calculated in two studies by White Young Green, one considering historical emissions (1990 to 2004), and the other considering projections (2005 onwards). In 2011, DECC commissioned a study to update this work (WSP, 2011), to reflect known changes in the mining industry (e.g. mines that closed earlier or remained open longer than projected). The results of this study are included in the 2012 inventory submission.

The main change in emissions results from the better understanding of methane recovery, which has now been subtracted from the gross emission. Emissions from the combustion of colliery methane are included within the energy sector (1A).

The original study into closed coal mine emissions was conducted during 2005. The estimation method for both historic and projected methane emissions from UK coal mines comprised two separate sets of calculations to estimate emissions from (1) coal mines that had been closed for some years, and (2) methane emissions from mines that had recently closed or were forecast to close over 2005 to 2009. The 2005 study derived emission estimates for the years 1990 to 2050 using a relationship between emissions and the quantity of the underlying methane gas within the abandoned mine workings, including site-specific considerations of the most appropriate decay model for the recently closed mines. The new study carried out in 2011 uses the same methods, with updated data for actual mine closure dates. The study also included benchmarking of UK specific estimates with other inventories to ensure that the method used remains appropriate for the UK.

Methane emissions from closed mines reach the surface through many possible flow paths: vents, old mine entries, diffuse emission through fractured and permeable strata. Direct measurement of the total quantity of gas released from abandoned mines is not practical. Emission estimates for 1990 to 2050 have been calculated using a relationship between emission and the quantity of the underlying methane gas within the abandoned mine workings.

Methane reserves have been calculated for all UK coalfields that are not totally flooded from 1990 with projections to 2050. The gas reserves are calculated by totalling all the gas quantities in individual seems likely to have been disturbed by mining activity. To enable calculation of the reserves over time, it has been necessary to calculate the rises in water levels in the abandoned mines due to water inflow. As workings become flooded they cease to release significant amounts of methane to the surface.

Monitoring has been carried out to measure methane emission from vents and more diffuse sources. Monitoring of vents involved measurement of the flows and concentrations of the gas flowing out of the mine. Monitoring of more diffuse sources required collection of long-term gas samples to measure any increases in background atmospheric methane level in the locality.

Methane flows measured by both methods showed a general increase with the size of the underlying gas reserve. The data indicated an emission of 0.74% of the reserve per year as a suitable factor to apply to the methane reserve data in order to derive methane emission estimates for abandoned UK coalfields for 1990 to 2050.

A3.3.8.1.2 Solid Fuel Transformation

Fugitive emissions from solid fuel transformation processes are reported in IPCC category 1B1b. The IPCC Revised 1996 Guidelines do not provide any methodology for such estimates, hence emissions are largely based on default emission factors. Combustion emissions from these processes have already been discussed in **Section A3.3.3**.

In a coke oven, coal is transformed into coke and coke oven gas. The coke oven gas is used as a fuel to heat the coke oven or elsewhere on the site. The coke may be used elsewhere as a fuel or as a reducing agent in metallurgical processes. A carbon balance is performed over the coke oven on the fuels input and the fuels produced as described in **Section A3.3.1**.

Process emissions of other pollutants from coke ovens are estimated either on the basis of total production of coke or the coal consumed. Emission factors are given in **Table A 3.3.51**.

Emissions of carbon from solid smokeless fuel production are calculated using a mass balance approach, described previously in **Section A3.3.1**. A similar mass balance is carried out for SO_2. For emissions of other pollutants, a mass balance approach is not used. Emissions of other pollutants from SSF plant are estimated on the basis of total production of SSF. The emission factors used are given in **Table A 3.3.51** and are based on US EPA (2010) factors for coke ovens. There are a number of processes used in the UK ranging from processes similar to coking to briquetting of anthracite dust and other smokeless fuels. Given the range of processes in use, these estimates will be very uncertain. It is possible that some emissions from SSF manufacture could arise from the combustion of gases produced during SSF manufacturing processes e.g. gases evolved from retorts used to manufacture some fuels. However, this combustion is not identified in the energy statistics and so emissions from SSF manufacture are treated as fugitive and reported under 1B1b. The only exceptions to this are emissions from the use of natural gas and coke by SSF manufacture which are treated as energy uses and emissions reported under 1A1c. As already stated elsewhere, it is recommended that coke use be included in the transformation calculations for the next version of the inventory so that emissions are reported under 1B1b.

Table A 3.3.51 Emission Factors Used for Coke and Solid Smokeless Fuel Production

	Units	CH_4	CO	NO_x	SO_2	NMVOC
Coke	kt/Mt coke made	0.0802[a]	2.18[c]	-	2.58[c]	0.0274[e]
Coke	kt/Mt coal consumed	-	-	0.02[b]		-
SSF	kt/Mt SSF made	0.0802[a]	0.02[c]	0.0220[c]	-	0.0178[a]
SSF	kt/Mt coal consumed	-	-	-	3.20[d]	-

a EIPPCB, (2000)
b USEPA (2004)
c Factor for 2010 based on Environment Agency (2011)
d Based on mass balance.
e Derived from benzene emission factor assuming a VOC/benzene ratio of 3.9:2.195, which is based on emission factors suggested by Corus, 2000

A3.3.8.2 Oil and Natural Gas (1B2)

This source category covers emissions which occur during the production, transportation, or use of liquid and gaseous fuels but which are not due to the combustion of those fuels to support a productive activity. Emissions occur from oil and gas production facilities, gas and oil terminals, gas processing facilities, oil refineries, gas transmission networks, and storage and distribution of petrol.

The EEMS Reporting System

Emissions from upstream oil and gas production facilities, including onshore terminals, are estimated based on operator reporting via the Environmental Emissions Monitoring System (EEMS), regulated by the DECC Offshore Inspectorate and developed in conjunction with the trade association Oil & Gas UK (formerly the UK Offshore Operators' Association, UKOOA). The EEMS data provides a detailed inventory of point source emissions estimates, based on operator returns for the years 1995-2010. Additional data on CO_2 emissions from some offshore combustion processes has become available via the National Allocation Plan and annual operator emission estimates for sites participating in the EU Emission Trading System. In recent years these EUETS data have been used by operators to update their EEMS emission estimates for combustion processes, ensuring consistency between EEMS and EUETS, and by the Inventory Agency as a useful Quality Check on time-series consistency of carbon emission factors.

Development of the EEMS Quality Assurance System

The EEMS dataset continues to develop in quality; the quality system in place, developed by the regulatory body (DECC) in conjunction with the trade association (UK Oil & Gas), is now based on an online reporting system with controls over data entry, together with guidance notes provided to operators to provide estimation methodology options and emission factors for specific processes. The online reporting system was introduced for the 2006 data submission, and several glitches in the system were evident during the compilation of the 1990-2006 GHGI. Many of these issues have now been resolved by the DECC Offshore Inspectorate, although in the latest dataset from plant operators there remain some gaps in reported emissions. This indicates that the EEMS reporting quality system requires further development to ensure that operators report a consistent and comprehensive series of emissions data, with time-series consistency a key factor. Where a site intermittently reports emissions from a specific process source, these gaps ought to be identified and rectified “at source”. The inventory agency has worked through many of the data inconsistencies in the EEMS dataset with the DECC team, to identify where gaps in data provision require provisional estimates to be used for the UK GHGI reporting system.

Reference Sources for Emission Estimates, 1990-1995

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

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

Other Data Sources: Onshore Terminal Emissions

Emission estimates for onshore oil and gas terminals are also based on annual emissions data reported by process operators under the EEMS system, regulated by DECC. These onshore sites also report emissions data to the UK environmental regulatory agencies (the Environment Agency of England & Wales and the Scottish Environmental Protection Agency) under IPC/IPPC regulations. Emissions data for Scottish plant are available for 2002 and 2004 onwards, whilst in England & Wales the Pollution Inventory of the Environment Agency holds emissions data from industrial plant from around 1995 onwards. For some terminals, occasional data gaps are evident in the EEMS data, most notably for methane and NMVOC emissions from oil loading activities. In these instances, the emission estimates reported under IPC/IPPC are used to provide an indication of the level of emissions in that year, but the longer time-series of the EEMS data for Scottish sites has led the Inventory Agency to use the EEMS data as the primary data source for these terminals.

UK GHGI Compilation: Method Development and Quality Control
For the EEMS reporting cycle for 2006 data, a new online system of operator reporting was implemented by DECC. After initial teething problems with this new system, the data quality and completeness in annual returns from operators has improved, and there is an industry-regulator panel of experts that manages the development of the EEMS reporting system and underlying guidance.

Data reporting problems such as perceived gaps and inconsistencies are resolved by the DECC Offshore Inspectorate and the Inventory Agency through direct consultation with installation operators. Data quality checks on installation data in the current inventory cycle identified several outliers in implied emission factors and time-series inconsistencies for specific sites, and these have been reviewed with the DECC regulators to resolve the data for the national inventory. The Inventory Agency agreed the following actions with DECC (Livingston, 2011):

- Oil Production: gas flaring, 2009: revised operator data for carbon dioxide emissions for one platform;
- Oil Production: gas combustion, 2009: revised operator data for carbon dioxide emissions for two sites;
- Oil Production and Gas Production: gas oil use, full inventory time series: revision to UK energy statistics to allocate gas oil to the upstream oil and gas sector has re-allocated emissions of all GHGs from IPCC sector 1A2f (other industry) to 1A1c (Other energy industries). No overall change in total gas oil activity data or emissions.

The inventory compilation method was overhauled in the 1990-2007 submission, to take advantage of developments in the EEMS dataset from the DECC Offshore Inspectorate, which enabled greater access to reported activity data that have been used to calculate the emissions for the following sources:

- Gas flaring
- Gas combustion
- Well testing
- 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.]

Some significant revisions to emissions data reporting methodology were made in the 1990-2007 data compilation, following discussion with the DECC Offshore Inspectorate, and the DECC Energy Statistics team. There are two reporting systems from upstream oil & gas processing in the UK; the EEMS system provides emissions data to the DECC Oil & Gas team, whilst the Petroleum Processing Reporting System (PPRS) is used to report data to the DECC Energy Statistics team as part of the wider system of regulation of oil & gas extraction and production permitting system. These data reported via the PPRS include data on gas flaring & venting volumes at offshore and onshore installations, and have previously been used as the “activity data” within the UK GHGI. The EEMS system meets an environmental emissions reporting requirement, whilst the PPRS meets other regulatory licensing reporting requirements. Whilst the two systems might be expected to reflect similar trends in activities, where reported activities coincide (such as gas flaring and venting), consultation with the DECC teams has indicated that the two systems are largely independent.

Further to this, the development of the EEMS dataset has enabled greater access to reported activity data that have been used to calculate the emissions. These EEMS-derived activity data enable greater analysis of the oil & gas emissions and related emission factors. In the compilation of the 1990-2007 inventory data, where previously the EEMS emissions were reported alongside the PPRS activity data (e.g. in the case of gas flaring and venting), the EEMS-derived activity data are now used. In most cases, this has led to an improvement in data transparency and easier query of Implied Emission Factor trends. However, the EEMS activity data are only available back to 1997. Where necessary, therefore, the activity data back to 1990 have been extrapolated using the PPRS time-series to provide the indicative trend. It is these data (that are collected independently of the EEMS environmental data) that are used to extrapolate the activity data back to 1990, whilst the emission estimates are retained from the 1998 UKOOA study. Hence the reported Implied Emission Factors from 1990-1996 inclusive are an artefact of the method that uses the best available data but cannot be derived using a consistent approach across the time series due to the data limitations in the early part of the time series.

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

Data Reconciliation with UK Energy Statistics across Reporting Categories

The data reported from the EEMS system must be reconciled with the UK Energy Statistics and integrated into the NAEI without double-counting emissions. The gas oil consumption by offshore installations is now reported separately in the UK Energy Statistics for the first time, whereas previously the gas oil estimates for the oil & gas sector were included within the “other industries” category in DUKES (DECC, 2011).

In the NAEI, upstream oil and gas emissions are estimated in the following categories each with its own methodology:

- Oil & Gas Production: Flaring
- Oil & Gas Production: Well testing
- Oil & Gas Production: Venting
- Oil & Gas Production: Process Emissions (including fugitive emissions)
- Offshore Oil Loading
- Onshore Oil Loading
- Oil Terminal Storage
- Oil and Gas Production: Fuel combustion (reported under 1A1c Other Energy Industries)
- Gas Separation Plant (Combustion) (reported under 1A1c Other Energy Industries)

The mapping of these sources to IPCC categories is described in **Section A3.2**. Activity data are reported in the CRF Background Table 1B2, however in most cases these data are not used to calculate the emissions, but are provided for comparison with other inventories.

During 2010, analysis was completed in consultation with oil and gas industry regulators and operators to allocate each installation to either the oil or gas industry, in order that separate emission estimates may be derived from the EEMS dataset and reported in the appropriate IPCC sectors. For installations where oil and gas are co-produced in associated terminals, regulator information has been used to assess whether the site is predominantly an oil or a gas production installation. This improvement has led to much more detailed reporting of emissions, greater transparency of emission estimates and will also improve the accuracy of the UK GHG emission estimates by end user categories, as the emissions from upstream oil and upstream gas industry can now be managed separately. This development means that the following IPCC sectors are used in the UK inventory (whereas previously the gas production estimates were combined with the equivalent oil production IPCC sectors):

- 1B2bi: Gas Production and Processing
- 1B2cii: Gas Production: Venting
- 1B2cii: Gas Production: Flaring

For the years 1990 to 1997 inclusive, the installation-specific EEMS data were not available (1990-2005) or are not regarded as a good quality dataset (1996, 1997). The allocation of sites to oil and gas industries does not therefore provide an improvement to the detail or transparency of the estimates in the early part of the time series. This is unfortunate, but the data simply do not exist to generate any more accurate, detailed estimates. In order to present a plausible trend in overall emissions for the oil and gas sectors back to 1990, a relatively simplistic approach has been adopted to divide the industry estimates between oil and gas back to 1990.

For flaring, gas consumption and well testing emissions the oil:gas ratio of activity data in 1998 has been used to extrapolate back the activities to 1990, retaining the previous emission factors for the “oil and gas” sources.

For process and fugitive sources, oil storage and venting emissions, where the EEMS data are simply presented as emissions data without any underlying activity and emission factor information, the estimates for the early part of the time series are simply based on the oil:gas ratio (for each pollutant) from 1998.

A3.3.8.2.1 Oil & Gas Production: Flaring

This includes flaring from offshore platforms and onshore terminals. Flaring emission data for CO_2, SO_2, NO_x, CO, NMVOC, and CH_4 are taken from the EEMS dataset (DECC, 2011). Data from 1995-2010 are based on detailed operator returns, whilst 1990-1994 data are calculated from extrapolation of total emissions data and the use of 1997 data splits between sources. N_2O emissions are based on operator information from 1999-2010, and on emission factors and production throughput data for 1990-1998.

The activity data and implied emission factors are given below in **Table 3.3.52 and Table 3.3.53**. The implied emission factors for 1997-2010 are reported as kg pollutant per kg gas flared and are calculated from emissions and activity data reported annually by operators via the EEMS reporting system. The data for 1990-1996 are estimated based on reported emission totals and extrapolated activity data.

Table A 3.3.52 Oil Production Flaring: Activity Data & Implied Emission Factors

Year	Activity Data	CO_2	CH_4	NO_x	CO	NMVOC	SO_2	N_2O
	ktonnes	kg/kg	kg/kg	kg/kg	kg/kg	kg/kg	kg/kg	kg/kg
2010	1326	2.65	0.0097	0.0014	0.0060	0.0089	0.00018	0.00007
2009	1306	2.62	0.0092	0.0013	0.0065	0.0090	0.00016	0.00007
2008	1304	2.59	0.0089	0.0012	0.0062	0.0087	0.00027	0.00007
2007	1502	2.59	0.0098	0.0014	0.0067	0.0081	0.00011	0.00008
2006	1406	2.58	0.0100	0.0013	0.0068	0.0076	0.00014	0.00008
2005	1624	2.65	0.0096	0.0013	0.0067	0.0083	0.00016	0.00008
2004	1420	2.66	0.0099	0.0013	0.0067	0.0071	0.00022	0.00008
2003	1424	2.66	0.0103	0.0013	0.0068	0.0069	0.00017	0.00008
2002	1606	2.67	0.0100	0.0016	0.0068	0.0073	0.00016	0.00008
2001	1765	2.64	0.0101	0.0013	0.0068	0.0072	0.00022	0.00008
2000	1689	2.54	0.0115	0.0012	0.0066	0.0068	0.00019	0.00008
1999	1820	2.66	0.0107	0.0016	0.0068	0.0080	0.00028	0.00009
1998	2008	2.70	0.0104	0.0014	0.0070	0.0093	0.00014	0.00008
1997	1996	2.70	0.0104	0.0015	0.0073	0.0093	0.00013	0.00008
1996	2388	2.27	0.0097	0.0013	0.0069	0.0090	0.00013	0.00007
1995	2246	2.39	0.0100	0.0013	0.0073	0.0095	0.00014	0.00008
1994	3087	1.47	0.0067	0.0008	0.0056	0.0079	0.00004	0.00005
1993	2315	1.85	0.0090	0.0011	0.0071	0.0103	0.00005	0.00006
1992	2321	1.72	0.0098	0.0011	0.0068	0.0101	0.00005	0.00005
1991	2381	1.56	0.0095	0.0010	0.0064	0.0097	0.00005	0.00005
1990	2627	1.43	0.0091	0.0009	0.0058	0.0085	0.00004	0.00005

Note that an estimate of NMVOC emissions from refinery flares is also reported in 1B2ci Venting and Flaring: Oil. This is based on estimates supplied by UKPIA (2011).

Table A 3.3.53 Gas Production Flaring: Activity Data & Implied Emission Factors

Year	Activity Data	CO_2	CH_4	NO_x	CO	NMVOC	SO_2	N_2O
	ktonnes	kg/kg	kg/kg	kg/kg	kg/kg	kg/kg	kg/kg	kg/kg
2010	173	2.09	0.0116	0.0020	0.0059	0.0025	0.00002	0.00034
2009	216	2.05	0.0098	0.0012	0.0066	0.0032	0.00001	0.00008
2008	132	1.96	0.0071	0.0013	0.0064	0.0036	0.00002	0.00008
2007	159	1.85	0.0065	0.0012	0.0066	0.0033	0.00001	0.00008
2006	132	2.14	0.0089	0.0012	0.0067	0.0027	0.00001	0.00008
2005	150	1.96	0.0069	0.0012	0.0065	0.0027	0.00002	0.00008
2004	136	1.98	0.0084	0.0012	0.0067	0.0032	0.00002	0.00008
2003	83	2.27	0.0074	0.0012	0.0065	0.0030	0.00003	0.00008
2002	130	2.27	0.0059	0.0011	0.0066	0.0036	0.00002	0.00008
2001	124	2.62	0.0068	0.0012	0.0040	0.0046	0.00022	0.00005
2000	239	2.16	0.0064	0.0009	0.0047	0.0026	0.00019	0.00006
1999	71	2.62	0.0122	0.0016	0.0087	0.0047	0.00028	0.00009
1998	84	2.68	0.0177	0.0014	0.0070	0.0021	0.00014	0.00008
1997	84	2.68	0.0177	0.0015	0.0073	0.0021	0.00013	0.00008
1996	101	2.27	0.0097	0.0013	0.0069	0.0090	0.00013	0.00007
1995	95	2.39	0.0100	0.0013	0.0073	0.0095	0.00014	0.00008

1994	130	1.47	0.0067	0.0008	0.0056	0.0079	0.00004	0.00005
1993	98	1.85	0.0090	0.0011	0.0071	0.0103	0.00005	0.00006
1992	98	1.72	0.0098	0.0011	0.0068	0.0101	0.00005	0.00005
1991	100	1.56	0.0095	0.0010	0.0064	0.0097	0.00005	0.00005
1990	111	1.43	0.0091	0.0009	0.0058	0.0085	0.00004	0.00005

A3.3.8.2.2 Oil & Gas Production: Fuel Combustion

This refers to the use of unrefined natural gas and gas oil on offshore platforms and onshore terminals as a fuel in heaters, boilers, turbines and reciprocating engines. Gas and gas oil combustion emission data for CO_2, SO_2, NO_x, CO, NMVOC, and CH_4 are taken from the EEMS dataset (DECC, 2011). Data from 1995-2010 are based on detailed operator returns, whilst 1990-1994 data are calculated from extrapolation of total emissions data and the use of 1995 data splits between sources. N_2O emissions are based on operator information from 1999-2010, and on emission factors and production throughput data for 1990-1998.

The activity data and implied emission factors for natural gas use are given below in **Table A 3.3.54** and **Table A 3.3.55**. The implied emission factors for 1990-2010 are reported as tonne pollutant per Mtherm gas used and are calculated from the emissions data reported within the EEMS dataset, and the activity data reported as “Producer’s Own Use” within the Digest of UK Energy Statistics.

Table A 3.3.54 Oil Production Own Gas Use: Activity Data & Implied Emission Factors

Year	Activity	CO_2	CH_4	NO_x	CO	NMVOC	SO_2	N_2O
	Mth	kt/Mth	t/Mth	t/Mth	t/Mth	t/Mth	t/Mth	t/Mth
2010	1508	6.26	1.94	20.28	6.50	0.09	0.96	0.41
2009	1514	6.29	2.36	19.65	6.97	0.15	0.36	0.46
2008	1511	6.60	2.28	20.16	7.14	0.13	0.40	0.45
2007	1614	6.42	2.42	19.24	6.97	0.14	0.17	0.45
2006	1828	5.80	1.91	18.59	6.33	0.11	0.26	0.46
2005	1788	6.24	2.00	20.09	6.77	0.17	0.18	0.49
2004	1890	6.23	2.41	19.37	6.69	0.21	0.20	0.48
2003	1887	6.44	2.36	19.41	6.83	0.15	0.27	0.52
2002	1941	6.46	2.37	19.83	6.61	0.15	0.26	0.51
2001	1842	6.36	2.63	15.93	6.98	0.20	1.66	0.51
2000	1625	7.23	3.03	18.40	7.88	0.22	1.97	0.59
1999	1614	7.36	2.90	17.35	7.69	0.21	2.53	0.54
1998	1669	7.14	3.49	19.03	7.82	0.30	0.41	0.55
1997	1485	8.02	3.49	19.03	7.82	0.30	0.33	0.55
1996	1424	8.02	3.49	19.03	7.82	0.30	0.33	0.55
1995	1255	8.02	3.49	19.03	7.82	0.30	0.33	0.55
1994	1230	8.02	3.49	19.03	7.82	0.30	0.33	0.55
1993	1036	8.02	3.49	19.03	7.82	0.30	0.33	0.55
1992	981	8.02	3.49	19.03	7.82	0.30	0.33	0.55
1991	922	8.02	3.49	19.03	7.82	0.30	0.33	0.55
1990	887	8.02	3.49	19.03	7.82	0.30	0.33	0.55

Table A 3.3.55 Gas Production Own Gas Use: Activity Data & Implied Emission Factors

Year	Activity	CO_2	CH_4	NO_x	CO	NMVOC	SO_2	N_2O
	Mth	kt/Mth	t/Mth	t/Mth	t/Mth	t/Mth	t/Mth	t/Mth
2010	578	6.22	5.53	15.64	6.93	0.44	0.08	0.44
2009	572	6.18	4.44	14.45	7.07	0.46	0.08	0.48
2008	581	6.41	3.84	13.76	8.01	0.35	0.07	0.48
2007	577	6.36	3.51	18.53	7.08	0.37	0.08	0.48
2006	535	5.71	3.88	16.92	6.45	0.42	0.01	0.49
2005	716	6.18	5.28	22.37	7.48	0.64	0.06	0.51
2004	763	6.16	4.74	21.21	7.18	0.55	0.05	0.51
2003	735	6.30	4.21	19.06	7.31	0.46	0.06	0.51
2002	767	6.59	4.88	22.60	7.47	0.55	0.04	0.76
2001	835	6.45	3.47	14.84	6.80	0.34	0.03	0.52
2000	612	7.34	3.29	18.47	7.59	0.27	0.05	0.60
1999	592	7.42	5.11	23.60	8.19	0.56	0.09	0.59
1998	566	7.18	3.49	19.03	7.82	0.30	0.11	0.55
1997	504	8.07	3.49	19.03	7.82	0.30	0.33	0.55
1996	483	8.07	3.49	19.03	7.82	0.30	0.33	0.55
1995	426	8.07	3.49	19.03	7.82	0.30	0.33	0.55
1994	417	8.07	3.49	19.03	7.82	0.30	0.33	0.55
1993	351	8.07	3.49	19.03	7.82	0.30	0.33	0.55
1992	333	8.07	3.49	19.03	7.82	0.30	0.33	0.55
1991	313	8.07	3.49	19.03	7.82	0.30	0.33	0.55
1990	301	8.07	3.49	19.03	7.82	0.30	0.33	0.55

These emissions apply to the mixture of methane, ethane, propane and butane used. In the NAEI database they are reported in the categories:

- Oil & Gas Production, fuel combustion: natural gas;
- Gas separation plant: LPG; and
- Gas separation plant: OPG.

Emissions are reported under 1A1cii Other Energy Industries.

The activity data and implied emission factors for gas oil use are given below in **Table A 3.3.56 and Table A 3.3.57**. The implied emission factors for 1990-2010 are reported as kilotonne pollutant per megatonne gas oil used and are calculated from the emissions data reported within the EEMS dataset, and the activity data reported as “Producer’s Own Use” within the Digest of UK Energy Statistics.

Table A 3.3.56 Oil Production, Gas Oil: Activity Data & Implied Emission Factors

Year	Activity	CO_2	CH_4	NO_x	CO	NMVOC	SO_2	N_2O
	Mt	Mt/Mt	kt/Mt	kt/Mt	kt/Mt	kt/Mt	kt/Mt	kt/Mt
2010	0.460	3.19	0.130	32.1	6.48	0.952	2.38	0.172
2009	0.437	3.19	0.158	31.0	6.44	0.886	2.87	0.209
2008	0.453	3.19	0.157	31.2	6.71	0.927	2.68	0.190
2007	0.386	3.19	0.928	30.7	6.07	0.895	2.80	0.193
2006	0.415	3.19	0.146	27.7	5.06	0.767	3.42	0.214
2005	0.459	3.19	0.087	31.7	6.53	0.940	4.03	0.216
2004	0.411	3.19	0.080	29.9	5.69	0.835	4.28	0.217

2003	0.440	3.19	0.096	30.1	5.89	0.852	3.11	0.217
2002	0.467	3.19	0.087	33.1	6.48	0.926	2.99	0.214
2001	0.493	3.19	0.116	31.5	7.10	1.041	2.95	0.217
2000	0.466	3.19	0.105	34.4	7.85	1.378	3.10	0.219
1999	0.480	3.19	0.098	34.2	7.60	1.039	3.37	0.353
1998	0.506	3.19	0.098	34.2	7.60	1.039	3.37	0.353
1997	0.489	3.19	0.098	34.2	7.60	1.039	3.37	0.353
1996	0.495	3.19	0.098	34.2	7.60	1.039	3.37	0.353
1995	0.495	3.19	0.098	34.2	7.60	1.039	3.37	0.353
1994	0.482	3.19	0.098	34.2	7.60	1.039	3.37	0.353
1993	0.382	3.19	0.098	34.2	7.60	1.039	3.37	0.353
1992	0.359	3.19	0.098	34.2	7.60	1.039	3.37	0.353
1991	0.348	3.19	0.098	34.2	7.60	1.039	3.37	0.353
1990	0.349	3.19	0.098	34.2	7.60	1.039	3.37	0.353

Table A 3.3.57 Gas Production, Gas Oil: Activity Data & Implied Emission Factors

Year	Activity	CO_2	CH_4	NO_x	CO	NMVOC	SO_2	N_2O
	Mt	Mt/Mt	kt/Mt	kt/Mt	kt/Mt	kt/Mt	kt/Mt	kt/Mt
2010	0.0294	3.19	0.283	45.4	12.03	1.78	3.10	0.176
2009	0.0128	3.19	0.142	38.7	7.40	1.22	2.81	0.193
2008	0.0191	3.19	0.121	39.1	8.98	1.35	3.08	0.169
2007	0.0183	3.19	0.097	38.4	8.86	1.20	3.45	0.196
2006	0.0147	3.19	0.107	28.9	8.86	1.18	3.54	0.217
2005	0.0166	3.19	0.120	41.1	11.33	1.39	3.70	0.221
2004	0.0156	3.19	0.150	48.2	14.88	1.67	3.78	0.227
2003	0.0201	3.19	0.154	49.5	13.22	1.70	3.46	0.215
2002	0.0215	3.19	0.139	46.3	11.54	1.52	4.66	0.384
2001	0.0178	3.19	0.126	42.5	10.18	1.37	2.13	0.218
2000	0.0139	3.19	0.144	48.0	11.99	1.59	3.15	0.220
1999	0.0171	3.19	0.148	49.1	12.33	1.57	3.55	0.220
1998	0.0192	3.19	0.148	49.1	12.33	1.57	3.55	0.220
1997	0.0183	3.19	0.148	49.1	12.33	1.57	3.55	0.220
1996	0.0179	3.19	0.148	49.1	12.33	1.57	3.55	0.220
1995	0.0151	3.19	0.148	49.1	12.33	1.57	3.55	0.220
1994	0.0137	3.19	0.148	49.1	12.33	1.57	3.55	0.220
1993	0.0129	3.19	0.148	49.1	12.33	1.57	3.55	0.220
1992	0.0109	3.19	0.148	49.1	12.33	1.57	3.55	0.220
1991	0.0108	3.19	0.148	49.1	12.33	1.57	3.55	0.220
1990	0.0097	3.19	0.148	49.1	12.33	1.57	3.55	0.220

Emissions are reported under 1A1cii Other Energy Industries.

A3.3.8.2.3 Oil & Gas Production: Well Testing

This activity involves the combustion of crude oil and crude gas during well testing, and is an activity that is not recorded within the Digest of UK Energy Statistics. Combustion emission data for CO_2, SO_2, NO_x, CO, NMVOC, and CH_4 are taken from the EEMS dataset (DECC, 2011). Activity data (tonnes fuel burnt) are also now available from the EEMS dataset for 1998 onwards, whilst the activity data for 1990-1997 has been estimated, based on the assumption that the Carbon emission factor remains constant back to 1990. This revised approach is more transparent for the assessment of implied emission factors for 1998 onwards, as the previous approach compared emissions against "numbers of wells explored" which is a poor parameter to use to represent gas and oil consumption during well testing.

This new approach does create new “estimated” activity data for 1990-1997, but the emissions data are unchanged (as there is no new data on emissions during 1990-1997) and overall the method change is considered an improvement. This new approach has also helped to identify possible inconsistencies in emissions data within the earlier years of the time-series, most notably for emissions of SO_2 during 1990-1997 and for N_2O during 1990-1994.

Emissions data from 1995-2010 are based on operator returns, whilst 1990-1994 data are calculated from extrapolation of total emissions data and the use of 1997 data splits between sources. N_2O emissions are based on operator information from 1999-2010, and on emission factors and production throughput data for 1990-1998.

The activity data and implied emission factors are given below in **Table A 3.3.58 and Table A 3.3.59**.

Oil production and gas production well testing emissions are reported under 1B2a.

Table A 3.3.58 Oil Production Well Testing: Activity Data and Implied Emission Factors

Year	Activity	CO_2	CH_4	NO_x	CO	NMVOC	SO_2	N_2O
	ktonnes	kt/kt	t/kt	t/kt	t/kt	t/kt	t/kt	t/kt
2010	10.3	3.20	25.0	3.70	18.00	25.00	0.013	0.081
2009	33.2	3.20	25.0	3.70	18.00	25.00	0.013	0.081
2008	9.5	3.20	25.0	3.70	18.00	25.0	0.013	0.080
2007	11.7	3.03	30.7	5.67	11.03	10.64	0.013	0.074
2006	13.3	3.03	18.1	4.61	11.03	34.0	0.012	0.071
2005	20.5	3.20	25.0	3.70	18.0	25.0	0.013	0.081
2004	13.2	3.20	25.0	3.70	18.0	25.0	0.013	0.081
2003	15.4	3.20	25.0	3.70	18.0	25.0	0.013	0.081
2002	29.2	3.20	25.0	3.70	18.0	25.0	0.013	0.081
2001	21.4	3.20	25.0	3.70	18.0	25.0	0.013	0.081
2000	27.5	3.20	25.0	3.70	18.0	25.0	0.013	0.081
1999	37.5	3.20	25.1	3.68	17.9	24.9	0.013	0.081
1998	111.5	3.19	24.2	3.63	17.7	22.9	0.013	0.081
1997	107.8	3.19	34.8	2.59	13.3	15.0	29.9	0.081
1996	107.2	3.19	36.9	2.74	14.1	15.8	31.6	0.085
1995	102.5	3.19	34.8	2.59	13.3	14.9	29.8	0.081
1994	282.5	3.19	11.2	17.9	10.4	6.09	14.2	0.029
1993	265.6	3.19	11.9	19.1	10.6	6.37	14.7	0.029
1992	248.7	3.19	14.0	20.4	10.9	6.68	15.2	0.029
1991	231.8	3.19	14.9	22.0	67.7	7.04	15.9	0.029
1990	234.4	3.19	15.7	22.0	11.2	6.73	15.9	0.029

Table A 3.3.59 Gas Production Well Testing: Activity Data and Implied Emission Factors

Year	Activity	CO_2	CH_4	NO_x	CO	NMVOC	SO_2	N_2O
	ktonnes	kt/kt	t/kt	t/kt	t/kt	t/kt	t/kt	t/kt
2010	17.9	2.80	45.0	1.20	6.70	5.00	0.012	0.081
2009	22.9	2.80	45.0	1.20	6.70	5.00	0.013	0.080
2008	11.3	2.80	45.0	1.20	6.70	5.00	0.011	0.080
2007	14.0	2.65	55.2	1.84	4.10	2.13	0.012	0.075
2006	15.9	2.65	32.5	1.50	4.10	6.8	0.011	0.072
2005	19.7	2.80	45.0	1.20	6.7	5.0	0.013	0.081
2004	30.1	2.83	43.7	1.36	7.4	6.3	0.013	0.081
2003	29.7	2.83	43.6	1.38	7.5	6.4	0.013	0.081
2002	19.1	2.81	44.5	1.26	7.0	5.5	0.013	0.081
2001	14.0	2.88	41.2	1.67	8.8	8.8	0.013	0.081
2000	17.2	2.91	39.3	1.92	9.9	10.7	0.013	0.081
1999	32.9	2.80	45.0	1.20	6.7	5.0	0.013	0.081
1998	107.2	2.69	45.0	1.50	8.7	5.0	0.013	0.081
1997	103.7	2.69	34.8	2.59	13.3	15.0	29.9	0.081
1996	103.1	2.69	36.9	2.74	14.1	15.8	31.6	0.085
1995	98.6	2.69	34.8	2.59	13.3	14.9	29.8	0.081
1994	271.7	2.69	11.2	17.9	10.4	6.09	14.2	0.029
1993	255.5	2.69	11.9	19.1	10.6	6.37	14.7	0.029
1992	239.2	2.69	14.0	20.4	10.9	6.68	15.2	0.029

Year	Activity	CO_2	CH_4	NO_x	CO	NMVOC	SO_2	N_2O
	ktonnes	kt/kt	t/kt	t/kt	t/kt	t/kt	t/kt	t/kt
1991	223.0	2.69	14.9	22.0	67.7	7.04	15.9	0.029
1990	225.5	2.69	15.7	22.0	11.2	6.73	15.9	0.029

A3.3.8.2.4 Other Emissions from Offshore Platforms and Onshore Terminals

These include emissions from offshore platforms and onshore terminals, including the following sources:

- Gas Venting (CO_2 CH_4, NMVOC estimates only);
- Fugitive emissions (CO_2 CH_4, NMVOC estimates only);
- Direct process emissions, such as acid gas stripping plant at terminals (CO_2, NO_X, SO_2, CO, CH_4, NMVOC);
- Storage vessel emissions from the storage of crude oil at terminals (CH_4, NMVOC estimates only).

Emissions data are taken from the EEMS dataset (DECC, 2011) and previous industry studies by Oil & Gas UK (1998). Data from 1995-2010 are based on detailed operator returns, whilst 1990-1994 data are calculated from extrapolation of total emissions data and the use of 1997 data splits between sources.

Note that there are no “activity data” for these activities available from DECC or UK Oil & Gas, and hence the method used in the compilation of the UK GHGI is merely to compile the sum of the operator emissions reported via the EEMS system, and report the emissions against an activity data of “1”.

Gaps in reported fugitive & storage tank emissions by certain operators and sites are evident in recent years, and where possible, data have been extrapolated from previous years to provide estimates to fill these gaps. There have also been some significant changes in activities at some sites that have led to notable emission reductions in recent years, including reduction of direct process emissions of SO_2 at the Elgin PUQ platform, due to a change to venting acid gases rather than flaring them.

These other emissions from platforms and terminals are reported in the following IPCC and NAEI categories:

1B2a Oil production: process emissions (includes fugitive emissions)
Oil production: oil terminal storage
Gas production: process emissions (includes fugitive emissions)

1B2c Oil production: gas venting
Gas production: gas venting

Table A 3.3.60 Aggregate Emission Factors used for Emissions from Platforms and Terminals

	Period	Units	CH_4	NMVOC
Gas Platforms	1970-92	kt/installation	0.589	0.0754
Oil Platforms	1970-92	kt/installation	0.327	0.393
Oil/Gas Platforms	1970-92	kt/installation	0.763	0.686
Gas Terminals	1970-92	kt/installation	3.0	0.425
Oil Terminals	1970-92	kt/installation	0.076	0.315

A3.3.8.2.5 Oil Loading Emissions

This sector includes emissions of CH_4 and NMVOCs from tanker loading and unloading based on data from the EEMS dataset (DECC, 2011). Data from 1995-2010 are based on detailed operator returns, whilst 1990-1994 data are calculated from extrapolation of total emissions data and the use of 1997 data splits between sources. In recent years, the methane and NMVOC data from operators appear to be incomplete in the EEMS dataset, most notably from ship loading emissions at BP sites (onshore terminals and offshore platforms). Hence estimates have been made for emissions from these sources, extrapolating emission estimates from earlier years. These emission totals for methane and NMVOCs are therefore subject to considerable uncertainty.

Activity data (tonnes oil loaded / unloaded) are available from the EEMS dataset for 1998 onwards, whilst the activity data for 1990-1997 has been estimated, based on the assumption that the methane emission factor remains constant back to 1990. This approach enables a transparent assessment of implied emission factors for 1998 onwards. Activity data for 1990-1997 are not available and are therefore estimated, but the emissions data are unchanged (as there is no new data on emissions during 1990-1997).

Emissions data from 1995-2010 are based on operator returns, whilst 1990-1994 data are calculated from extrapolation of total emissions data and the use of 1997 data splits between sources. The activity data and implied emission factors are given in **Table A 3.3.61**.

Table A 3.3.61 Crude Oil Loading, Onshore and Offshore: Activity Data and Implied Emission Factors

Year	ONSHORE LOADING			OFFSHORE LOADING		
	Activity	CH_4	NMVOC	Activity	CH_4	NMVOC
	kt	t/kt	t/kt	kt	t/kt	t/kt
2010	33,101	0.016	0.69	10,040	0.076	1.12
2009	32,161	0.017	0.75	11,938	0.080	1.41
2008	36,795	0.015	0.96	14,011	0.095	1.45
2007	60,291	0.012	0.67	20,401	0.106	1.60
2006	59,676	0.011	0.67	24,699	0.072	1.25
2005	66,447	0.012	0.70	21,721	0.097	1.30
2004	64,387	0.012	0.68	32,784	0.084	1.12
2003	74,824	0.013	0.79	36,547	0.080	1.38
2002	82,464	0.012	0.86	41,171	0.115	1.64
2001	86,663	0.012	0.85	42,277	0.113	1.54
2000	93,192	0.012	0.87	30,644	0.118	1.67
1999	102,395	0.011	0.83	35,484	0.074	1.34
1998	104,354	0.013	0.94	30,639	0.043	1.44
1997	104,776	0.013	0.94	24,013	0.043	2.39

Year	ONSHORE LOADING			OFFSHORE LOADING		
	Activity	CH_4	NMVOC	Activity	CH_4	NMVOC
	kt	t/kt	t/kt	kt	t/kt	t/kt
1996	114,031	0.013	0.94	19,640	0.043	2.40
1995	125,628	0.013	0.94	17,163	0.043	2.40
1994	177,194	0.013	0.94	15,676	0.043	2.76
1993	176,810	0.013	0.94	15,642	0.043	2.72
1992	193,646	0.013	0.94	17,132	0.043	2.44
1991	193,224	0.013	0.94	17,094	0.043	2.40
1990	204,684	0.013	0.94	18,108	0.043	2.19

A3.3.8.2.6 Leakage from the Gas Transmission System

The NAEI category Gas Leakage covers emissions of CH_4 and NMVOC from the UK gas transmission and distribution system. This is accounted for within the IPCC category 1B2b Natural Gas. Data on natural gas leakage are provided by UK Transco, four companies (formed in 2005) that operate the low-pressure gas distribution networks within Great Britain, and also from Phoenix Gas in Northern Ireland. The leakage estimates are determined in four parts:

- Losses from High Pressure Mains (Transco);
- Losses from Low Pressure Distribution Network (UKD, Scotia Gas, Northern Gas Networks, Wales & West, Phoenix Gas);
- Other losses, from Above Ground Installations (AGIs) and other sources (Transco);
- Leakage at point of use (Commercial and domestic sectors).

The emissions from these leakage sources are reported within the CRF as follows:

- 1B2biv: Gas Distribution (includes transmission and distribution leakage emissions, as well as those from other sources such as AGIs)
- 1B2bv: Other leakage (point of use leakage emissions)

Further consultation with the gas network operators in 2012 will seek to determine whether gas transmission leakage emissions can be published discretely within 1B2biii across the full time series, in future inventories. For now they are included within the 1B2biv estimates.

Gas Network Leakage Model

Estimates are derived from specific leakage rates measured on the various types of gas mains and installations, together with data on the infrastructure of the UK supply system (such as length and type of pipelines and other units). Historic data for the leakage from the low-pressure distribution network and other losses (Above Ground Installations etc.) is based on studies from British Gas in the early 1990s (British Gas, 1993; Williams, 1993). Emission estimates for 1997 to 2010 are derived from an industry leakage model; the data are provided independently by the gas network operators to mitigate commercial confidentiality concerns. Emission estimates from 1990-96 are based on an older British Gas model that provided historical data for 1991-94 but projected estimates for 1995-96.

Natural Gas Compositional Data

The methane, CO_2 and NMVOC content of natural gas is shown in **Table A 3.3.62**. The methane and NMVOC data were provided by contacts within British Gas Research for 1990-1996 and by UK Transco from 1997 to 2005 (Personal Communication: Dave Lander, 2008), and from the gas network operators from 2006 onwards (UKD, Scotia Gas, Northern Gas

Networks, Wales & West). NMVOC content for 2001-2003 has been estimated by interpolation due to a lack of data; CO_2 compositional data from 2004 onwards are derived from annual compositional analysis by gas network operators, whilst the 1990-2003 data have been extrapolated back from the 2004 figure. No gas composition data have been provided by Phoenix Gas and hence the UK average gas composition is assumed for Northern Ireland.

The gas compositional analysis methodology was revised and updated during 2010 following consultation with the gas network operators, to correct a methodological error that was identified by the Inventory Agency. The gas compositional data provided by the network operators in 2011 exhibited a very large range in the number of data points between networks, i.e. the number of gas compositional analyses per network varied greatly in the data submission for inventory compilation ranging from a few thousand data points for some networks to several million data points for others. The consultation identified that each of the gas network operators obtain their compositional analysis from a central system of data logging from the automated sampling and analysis network that was operated previously under the Transco ownership, prior to the network being opened up to greater market competition. The variability of data analysis count point provided by each network operator enabled the Inventory Agency to determine that in some cases a limited (i.e. not fully representative) dataset of gas compositions had previously been provided for some local distribution zones, indicating that the derived UK average composition was based on an incomplete dataset and was therefore not fully representative of UK gas content. Supplementary data was therefore obtained from the central database of gas compositional analysis, and the UK average composition re-calculated using this more comprehensive, representative data. The calculation of the reported UK average gas composition is derived from the sum-product of the annual Local Distribution Zone (LDZ) compositional data and the estimated gas consumption through each of the LDZs, to provide an average gas composition for Great Britain which is then applied across the UK.

Table A 3.3.62 Methane, Carbon Dioxide and NMVOC Composition of Natural Gas

Year	CH_4 weight %	CO_2 weight %	NMVOC weight %
1990-96	84.3[1]	3.92[6]	8.9[1]
1997-99	77.1[2]	3.92[6]	14.7[2]
2000	77.6[2]	3.92[6]	14.7[2]
2001	76.3[2]	3.92[6]	14.8[3]
2002	77.3[2]	3.92[6]	15.0[3]
2003	77.4[2]	3.92[6]	15.2[3]
2004	77.6[5]	3.92[5]	15.3[5]
2005	78.1[5]	3.60[5]	15.2[5]
2006	78.6[5]	3.70[5]	14.9[5]
2007	78.3[5]	3.74[5]	14.8[5]
2008	79.0[5]	3.62[5]	14.4[5]
2009	79.2[5]	3.45[5]	14.7[5]
2010	79.9[5]	3.01[5]	14.4[5]

1 British Gas (1994)
2 UK Transco (2005)
3 AEA Energy & Environment estimate (2005), based on data provided for other years
4 National Grid UK (2006)
5 Gas compositional analysis provided by gas network operators: UKD, Scotia Gas, Northern Gas Networks, Wales and West (2011)
6 Extrapolated back from the 2004 analysis by network operators

Northern Ireland Gas Network
The gas infrastructure in Northern Ireland is much newer than in the rest of the UK, as the gas pipeline (from Scotland) was only commissioned in 1999. Since then, the gas network has continued to develop across Northern Ireland. Annual estimates of gas leakage from 2005 onwards have been provided by the main gas operator (Phoenix Gas, 2011), and the data for 1999 to 2004 have been extrapolated back from the 2005 figure.

Gas Leakage at the Point of Use
During 2010, consultation with the gas network operators confirmed that the scope of the network leakage model used by each operator did not include estimates of gas leakage downstream from the gas meter, i.e. at the point of use. Therefore, new estimates have been derived for gas leakage at the point of use during this inventory cycle, using data on the numbers of gas appliances in the UK in the commercial and domestic sectors. These new estimates have been included within the gas network leakage data in 1B2bii, and represent around 0.5% of the total gas leakage emissions from the transmission and distribution system in the UK in 2009.

The estimation of gas leaks at point of use has considered various sources of potential gas leaks which are discussed below:

Gas Fires/Gas Ovens/Gas Ranges/Hobs
After discussion with combustion experts in AEA, we have assumed that any gas released prior to the ignition of the gas fires is not lost to atmosphere as it is burnt when ignition occurs, even if ignition is slightly delayed after the release of gas in the appliance. It is therefore assumed that the releases of methane would be “Not Occurring” from this source.

Industrial/Commercial Heating Boilers
After discussions with combustion experts in the Combined Heat and Power team at AEA it is assumed that due to operational and safety reasons there is a very limited likelihood of methane releases from large industrial boilers. It is considered that larger boilers will be likely to be on almost permanently once ignited (particularly if they for steam-raising) with much less or no cycling from on to off states. In addition to this, releases of un-burnt natural gas are strictly controlled in industrial locations for safety reasons. It is therefore assumed that the releases of methane would be “Not Occurring” from this source.

Domestic Heating and Water Heating Boilers
The emissions of methane from the domestic heating and water heating boilers have been estimated. The approach for both heating and water heating are similar but there are differing assumptions relating to the boiler yearly operation and cycling frequency. The approach used assumes an average boiler size in the UK of around 30kW, a burn chamber size, natural gas flow rate taken from a typical combination boiler, an air flow rate based on 25% excess oxygen in the combustion chamber when compared to stoichiometric ratio, an equation for a mixed reactor ($1-e^{x}$) that when integrated will provide an estimate of the concentration of un-burnt air/fuel mixture released. Using this model the emissions of the un-burnt mixture can be estimated for both the boiler when cycling during heating and water heating operation. The assumptions for the two operations are detailed below.

Domestic Heating
It is assumed that on average in the UK domestic properties have heating systems operating for half of the year and on average the heating is on for 5 hours per day. It is also assumed that during each hour that the boiler providing heating cycles on and off 4 times.

Domestic Water Heating
It is assumed that all UK domestic properties have hot water heating systems also have gas heated hot water. We have assumed operation every day of the year and on average heating is on for 4 hours per day. It is also assumed that during each hour that the boiler is providing hot water heating the boiler cycles on and off 5 times. This assumption is very uncertain as it is thought to depend on the boiler type, boiler condition and hot water usage in the property, and is thought to derive a conservative estimate.

The number of boilers from 1990 to 2010 is thought to have increased due to the increasing use of gas central heating for space heating, and the increase in the number of houses. It is possible that pre-ignition gas loss in boilers installed in houses in 1990 might have been greater than in the current boilers installed, as technology has improved. However, the stock of domestic boilers (ca. 22 million in 2008) is likely to be much greater than that in 1990. So we could assume that the greater pre-ignition losses of the older boilers would be offset to some extent by the greater number of boilers with relatively lower pre ignition losses.

We do not have reliable data for i) the stock of boilers in use over the time series; ii) the leakage from the boilers, and how this leakage changes with boiler technology. Therefore the estimates given below for 2008 are assumed to be applicable across the entire time series, from 1990-2010.

Methane Emission Estimates from Natural Gas Leakage at Point of Use
Based on the model and assumptions outlined above the estimated emissions of methane from this source are:

Table A 3.3.63 Emissions from natural gas at point of use

Source	Methane Emission (m^3)	Release of Methane (ktonnes)	GWP (CO_2 Equiv.) (ktonnes)
Domestic Heating	440,246	0.299	6.287
Domestic Water Heating	880,492	0.599	12.573
Total	**1,320,739**	**0.898**	**18.860**

These emission estimates are very uncertain due to the lack of detailed activity data, lack of industry-specific leakage information and therefore the range of assumptions that have been made within the method; an estimated uncertainty of >50% has therefore been assigned to this source within the UK inventory uncertainty analysis.

A3.3.8.2.7 Petrol Distribution

Petrol distribution begins at refineries where petrol may be loaded into rail or road vehicles. Petrol is distributed to approximately 60 petrol terminals where it is stored prior to loading into road tankers for distribution to petrol stations. At petrol stations it is stored and then dispensed into the fuel tanks of road vehicles. Emissions of NMVOC occur from each storage stage and from each transfer stage.
The NAEI reports emissions from the storage, distribution and sale of petrol in the following categories each of which is further divided into emissions of leaded and unleaded petrol:

- Refineries (Road/Rail Loading). Emissions during loading of petrol on to road and rail tankers at refineries;
- Petrol Terminals (Storage). Emissions from storage tanks at petrol distribution terminals;
- Petrol Terminals (Tanker Loading). Emissions during loading of petrol on to road and rail tankers at petrol terminals;

- Petrol Stations (Petrol Delivery). Emissions during loading of petrol from road tankers into storage tanks at petrol stations;
- Petrol Stations (Storage Tanks). Emissions from storage tanks at petrol stations;
- Petrol Stations (Vehicle Refuelling). Emissions due to displacement of vapour during the refuelling of motor vehicle at petrol stations; and
- Petrol Stations (Spillages). Emissions due to spillages during refuelling of motor vehicles at petrol stations.

Emissions also occur from storage tanks at refineries. This source is included together with emissions from the storage of crude oil and other volatile materials in the NAEI source category, refineries (tankage).

The emission estimates from road and rail tanker loading at refineries are supplied by UKPIA (2011). The remaining estimates are based on methodologies published by the Institute of Petroleum (2000) or, in the case of petrol terminal storage, based on methods given by CONCAWE (1986). The calculations require information on petrol density, given in DECC (2011), and petrol Reid Vapour Pressure (RVP), data for which have been obtained from a series of surveys carried out by Associated Octel between 1970 and 1994.

More recent, detailed RVP data are not available, but UKPIA have suggested values for 1999 onwards. Central England Temperature (CET) data (Met Office, 2011) are used for ambient UK temperatures. The methodology also includes assumptions regarding the level of vapour recovery in place at terminals and petrol stations. These assumptions draw upon annual account surveys carried out by the Petroleum Review (2000 onwards) that include questions on petrol station controls, and the timescales recommended in Secretary of State's Guidance for petrol terminals (PG 1/13 (97)). The activity data are the sales of leaded and unleaded petrol from DECC (2011).

A3.3.8.2.8 Refineries and Petroleum Processes

The IPCC category 1B2aiv Refining and Storage includes estimates of NMVOC emissions from oil refineries. Emissions of carbon, CH_4, CO, N_2O, NO_x, SO_2, and VOC occur at refineries due to venting of process plant for reasons of safety, from flaring of waste products, leakages from process plant, evaporation of organic contaminants in refinery wastewater, regeneration of catalysts by burning off carbon fouling, and storage of crude oil, intermediates, and products at refineries.

In the NAEI these are split into:

- Refineries (drainage);
- Refineries (tankage); and
- Refineries (process).

All are based on UKPIA (2011) estimates for 1994-2010. The UKPIA data refer to the following UK refinery installations:

- Texaco, Milford Haven;
- Elf, Milford Haven;
- BP, Coryton;
- Shell, Shell Haven (closed during 1999);
- Conoco, South Killingholme;
- Lindsey, Killingholme;

- Shell, Stanlow;
- PIP, North Tees;
- Esso, Fawley;
- BP, Grangemouth; and
- Gulf, Milford Haven (closed during 1997).

UKPIA also supply estimates for loading of petrol into road and rail tankers at refineries – see **Section A3.3.8.2.7**

Prior to 1994, process emissions are estimated by extrapolation from the 1994 figure on the basis of refinery throughput, whereas emissions from tankage, flares and drainage systems are assumed to be constant.

Also included under 1B2aiv Refining and Storage are NMVOC emissions from the NAEI category petroleum processes. This reports NMVOC emissions from specialist refineries (Llandarcy, Eastham, Dundee, & Harwich), onshore oil production facilities, and miscellaneous petroleum processes not covered elsewhere in the inventory, the most significant of which are Kimmeridge and Horndean well sites.

Emissions are taken from the Pollution Inventory (Environment Agency, 2011). No emissions data have been found for the Dundee refinery.

A3.3.8.2.9 Gasification Processes

The NAEI also reports NMVOC emissions from onshore gas production facilities, refining and odourisation of natural gas, natural gas storage facilities, and processes involving reforming of natural gas and other feedstock to produce carbon monoxide and hydrogen gases. Emissions are taken from the Pollution Inventory (Environment Agency, 2011) and Scottish Pollutant Release Inventory (SEPA, 2011). For the years prior to 1994, they are extrapolated based on gas throughput. Care is taken to avoid double counting with the upstream oil and gas exploration and production emissions outlined earlier in this annex.

A3.3.9 Stored Carbon

As part of our review of the base year GHG inventory estimates, the UK reviewed the treatment of stored carbon in the UK GHG inventory and the fate of carbon from the non-energy use (NEU) of fuels and other fossil carbon products.

This appraisal included a review of the National Inventory Reports (NIRs) of other countries. The US NIR contained a detailed methodology of the approach used in the US inventory to estimate emissions of stored carbon, and the US NIR presents ‘storage factors’ for a range of products. Some of these factors have been used in the new UK method.

The UK Inventory Agency has conducted a series of calculations to estimate the fate of carbon contained in those petroleum products shown in the NEU line of the UK commodity balance tables. The analysis indicates that most of the carbon is stored, although a significant quantity does appear to be emitted. Some of the emitted carbon had been included in previous versions of the GHG inventory, e.g. carbon from chemical waste incinerators; most had not. A summary of the estimates of emitted/stored carbon was produced and these have been presented in a separate technical report[7]. The study also provides subjective, qualitative commentary regarding the quality of the estimates.

Following the review of stored carbon, the procedure adopted is to assume that emissions from the non-energy use of fuels are zero (i.e. the carbon is assumed to be sequestered as products), except for cases where emissions could be identified and included in the inventory:

- Catalytic crackers – regeneration of catalysts;
- Ammonia production;
- Aluminium production – consumption of anodes;
- Combustion of waste lubricants and waste solvents;
- Burning of lubricants during use in engines;
- Use of waste products from chemical production as fuels;
- Emissions of carbon due to use and/or disposal of chemical products;
- Incineration of fossil carbon in products disposed of as waste.

Methodology for some of these sources has been described in detail elsewhere and so is not repeated here.

Carbon deposits build up with time on catalysts used in refinery processes such as catalytic cracking. These deposits need to be burnt off to ensure continued effectiveness of the catalyst and emissions from this process are treated as use of a fuel (since heat from the process is used) and reported under IA1a. Details are given in **Chapter 3** of the report.

Natural gas is used as a feedstock in the manufacture of ammonia and emissions from this process are reported under 2B1. Coal tar pitch and petroleum coke are used in the manufacture of carbon anodes used by the aluminium industry and CO_2 is emitted during use of the anodes. Details of methodology for both sources are given in **Chapter 4**.

AEA estimates of the quantities of lubricants burnt are based on data from Recycling Advisory Unit, 1999; BLF/UKPIA/CORA, 1994; Oakdene Hollins Ltd, 2001 & ERM, 2008, as well as recent research which has obtained information regarding the recent market for waste oils (Oil Recycling Association, 2010). Separate estimates are produced for the following sources:

- Power stations;
- Cement kilns; and
- Other industry.

The figures for other industry currently assume that waste oils are used by two sectors: roadstone coating plant and garages. In reality, other sectors may use waste oils as fuels or as a reductant, but further investigation is needed before estimates can be made. The figures for power station use of waste lubricants reflect the fact that the Waste Incineration Directive (WID) had a profound impact on the market for waste oil, used as a fuel. It is assumed that no waste oil was burnt in power stations for the years 2006-2008. In 2009 a Quality Protocol[8] was introduced that allowed compliant fuel produced from waste oils to be

[7] Passant, Watterson and Jackson. (2007) *Review of the Treatment of Stored Carbon and the Non-Energy Uses of Fuel in the UK Greenhouse Gas Inventory*. AEA Energy and Environment, The Gemini Building, Fermi Avenue, Harwell, Didcot, Oxfordshire, OX11 0QR, UK. Report to Defra CESA for contract RMP/2106.

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

burned as non-waste. Information from the waste oil industry suggests that alternative markets opened up for waste oil during this period including use of waste oils in blast furnaces but we have not been able to confirm that this occurred at UK blast furnaces. Waste oils might have also been stockpiled or exported, or used in other processes. Further investigation is needed to ascertain the fate of this oil. Emissions from use of waste oils as fuels are reported under 1A1a and 1A2f.

In addition, an estimate is made of lubricants burnt in vehicle engines. Carbon emissions from these sources are calculated using a carbon factor derived from analysis of eight samples of waste oil (Passant, 2004). In 2005, the combustion of lubricating oils within engines was reviewed. Analysis by UK experts in transport emissions and oil combustion have lead to a revision to the assumptions regarding re-use or combustion of lubricating oils from vehicle and industrial machinery.

The fate of the unrecovered oil has now been allocated across several IPCC source sectors including road, rail, marine, off-road and air transport. Emissions from these sources are reported under 1A3b, 1A3d & 1A4c. Some of the unrecovered oil is now allocated to non-oxidising fates such as coating on products, leaks and disposal to landfill.

Emissions can occur from products from the chemical industry. Sources of emissions include burning of waste products and final products (e.g. flaring and use of wastes as fuels, or burning of candles, firelighters and other products etc.) or degradation of products after disposal resulting in CO_2 emissions (including breakdown of consumer products such as detergents etc.).

After considering the magnitude of the sources in relation to the national totals, the uncertainty associated with emissions, and the likely reporting requirements in the 2006 IPCC Guidelines, emissions of carbon from the following sources were included in the 2004 GHG inventory (2006 NIR) and subsequent NIRs:

- Petroleum waxes;
- Carbon emitted during energy recovery - chemical industry;
- Carbon in products - soaps, shampoos, detergents etc; and
- Carbon in products – pesticides.

A full time series of emissions is included in the inventory, and details of the methodology for these sectors are given in Passant, Watterson & Jackson, 2007. Emissions are reported under 2B5.

Fossil carbon destroyed in MSW incinerators and clinical waste incinerators is included in the GHG inventory, as is carbon emitted by chemical waste incinerators. These emissions are reported under 1A1a & 6C, and methodology is detailed in Chapters 3 and 8 of the report.

The analysis also included an assessment of the fate of carbon from the use of coal tars and benzoles. Benzoles and coal tars are shown as an energy use in the DECC DUKES and up until the 2002 version of the GHG inventory, the carbon was included in the coke ovens carbon balance as an emission of carbon from the coke ovens.

When the carbon balance methodology was improved for the 2003 GHG inventory, the UK inventory treated the carbon in these benzoles and coal tars as a non-emissive output from the coke ovens. However, we were not sure what the ultimate fate of the carbon was but were unable to research this in time for the 2003 GHG inventory. It was therefore treated as an emission from the waste disposal sector - thus ensuring that total UK carbon emissions were not altered until we had sufficient new information to judge what the fate of the carbon was.

Information from Corus UK Ltd (the sole UK operator of coke ovens) indicates that the benzoles & coal tars are recovered and sold on for other industrial uses, the emissions from which are already covered elsewhere within the inventory. Hence the carbon content from these coke oven by-products is now considered as stored and the carbon emissions included in previous inventories has been removed from the new version of the GHG inventory.

A3.3.10 Additional information – petroleum coke

DUKES contains only limited information on the use of petroleum coke as a fuel, although it does give data on UK production, imports and exports of petroleum coke, allowing total UK consumption to be derived. However, these data will cover two distinct types of petroleum coke – fuel grade (green) coke and anode grade coke, with the former being used as a fuel, and the latter being used in various processes. As a first order estimate of UK consumption of petroleum coke as a fuel, it could be assumed that all production and exports are anode grade coke (the UK does not produce fuel grade coke) and that all imports are fuel grade coke.

The inventory contains estimates of petroleum coke consumption by various sectors. It is burnt in cement kilns and in a handful of power stations. A few other large industrial sites 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. Fuel grade petroleum coke is also used as a domestic fuel (both smokeless and non-smokeless types). We have used data supplied by the UK fuel supply industry to estimate petroleum coke consumption for domestic fuels over the period 1990 – 2010. These estimates are broadly consistent with estimates published in DUKES for a few years in the late 1990s.

Subtracting these consumption figures from the UK import figures still leaves very significant residual levels of consumption for most years, and it is possible that further uses of petroleum coke as a fuel exist. The consumption estimates for industrial plant are likely to be highly accurate for those sites and for the sectors involved, but other sectors may also include sites that use petroleum coke. The estimates for domestic use as a fuel are more uncertain, being based on expert judgement, but it this uncertainty is not thought large enough to be consistent with the residual consumption figures.

Carbon factors for petroleum coke have been derived from industry-specific data in the case of power stations, cement kilns and other industrial sites, while the factor for domestic consumption is based on analysis of three samples of petroleum coke sold as domestic fuels.

A3.4 INDUSTRIAL PROCESSES (CRF SECTOR 2)

A3.4.1 Mineral Processes (2A)

A3.4.1.1 Cement Production (2A1)

Emission factors and activity data for the production of cement are commercially sensitive and therefore confidential.

A3.4.1.2 Lime Production (2A2)

Emission factors for the production of lime, as discussed in **Chapter 4**, **Section 4.3.**

Table A 3.4.1 Emission Factors for Lime Kilns based on Fuel Consumption, 2010

Fuel	C [a]	CH_4	N_2O	Units
Coal	635[b]	0.011[c]	0.214[e]	Kt / Mt fuel
Natural Gas	1.47[b]	0.00053[f]	1.06E-05[f]	Kt / Mtherm
Coke	852[d]	0.011[c]	0.230[e]	Kt / Mt fuel

a Emission factor as mass carbon per unit fuel consumed
b Derived using the method given in Baggott *et al* (2004)
c Brain, SA et al. British Coal Corp, CRE (1994)
d AEA estimate based on carbon balance
e Fynes *et al* (1994)
f IPCC(1997) IPCC Revised 1996 Guidelines

Table A 3.4.2 Emission Factors for Lime Kilns, 2010: Indirect GHGs

Fuel	CO	NO_x	NMVOC	Units
Coal	8.25	45.3	0.05	Kt / Mt fuel
Natural Gas	0.00106	0.00529	2.35E-3	Kt / Mtherm
Coke	11.51	0.261	0.05	Kt / Mt fuel

A3.4.2 Chemical Industry (2B)

A3.4.2.1 Nitric Acid Production (2B2)

Table A 3.4.3 Summary of Nitric Acid Production in the UK, 1990-2009

Year	No of sites	Production (Mt 100% Nitric Acid)	Aggregate EF (kt N_2O / Mt Acid)	Aggregate EF (kt NO_X / Mt Acid)
1990	8	2.41	5.23	3.36
1994	6	2.49	3.89	1.93
1995	6	2.40	3.82	0.808
1996	6	2.44	3.83	0.743
1997	6	2.35	3.78	0.902
1998	6	2.61	3.99	0.732
1999	6	2.44	6.29	0.913
2000	6	2.03	6.94	0.992
2001	5	1.65	6.62	0.662
2002	4	1.64	4.20	0.392
2003	4	1.71	4.38	0.431
2004	4	1.71	5.00	0.438
2005	4	1.71	3.80	0.379
2006	4	1.47	3.87	0.424
2007	4	1.61	3.54	0.380
2008	4	1.29	3.65	0.234
2009	4	0.93	3.83	0.270
2010	4	1.21	3.51	0.221

A3.4.2.2 Adipic Acid Production (2B3)

There was only one company manufacturing adipic acid in the UK, but this closed in early 2009. Production data are not provided in the NIR because of commercial confidentiality concerns.

Emissions have been estimated based on information from the process operator (Invista, 2010). These emission estimates are based on the use of plant-specific emission factors for unabated flue gases, which were determined through a series of measurements on the plant, combined with plant production data and data on the proportion of flue gases that are unabated.

In 1998 an N_2O abatement system was fitted to the plant. The abatement system is a thermal oxidation unit and is reported by the operators to be 99.99% efficient at N_2O destruction. The abatement unit is not available 100% of the time, and typically achieves 90-95% availability during AA production. The abatement plant availability has a very significant impact upon the annual emissions of N_2O, and leads to somewhat variable trends in IEFs over the time-series.

A small nitric acid (NA) plant is associated with the adipic acid plant. This NA plant also emits nitrous oxide but has no abatement fitted. Operator emission estimates from the NA plant are based on emission factors; there is no online measurement of N_2O in the stack from the NA plant. From 1994 onwards this emission is reported as nitric acid production but prior to 1994 it is included under adipic acid production. This will cause a variation in reported effective emission factor for these years. This allocation reflects the availability of data.

The level of uncertainty associated with reported emissions of N_2O is not known, but the data are considered to be reliable as they are subject to QA/QC checks by the operator, by the Environment Agency (before being reported in the Pollution Inventory) and by the regulators of the UK Emission Trading Scheme (DEFRA NCCP).

A3.4.3 Metal Production (2C)

A3.4.3.1 Iron and Steel (2C1)

The following emissions are reported under 2C1 Iron and Steel Production:

- Blast furnaces: process emissions of CO, NO_X, and SO_2;
- Flaring of blast furnace gas/basic oxygen furnace gas;
- Electric arc furnace emissions;
- Basic oxygen furnaces: process emissions of CO and NO_X.;
- Rolling mill process emissions of VOC; and
- Slag processing: process emissions of SO_2.

Emissions arising from the combustion of blast furnace gas and other fuels used for heating the blast furnace are reported under 1A2a Iron and Steel. Emissions of CO, NO_X, and SO_2 from integrated steelworks, and the flaring of blast furnace gas and basic oxygen furnace gas are reported under 2C1 Iron & Steel Production. CO_2 emissions from limestone and dolomite use in iron and steel production are reported under 2A3 Limestone and Dolomite use.

A3.4.3.1.1 Carbon Dioxide Emissions

Carbon emissions from flaring of blast furnace gas (BFG) and basic oxygen furnace gas (BOFG) are calculated using emission factors which are calculated as part of the carbon balance used to estimate emissions from CRF category 1A2a. The figure for 2009 was 80.4 ktonnes C/PJ. Emissions from electric arc furnaces are 2.2 kt C/Mt steel in 1990, falling to 2 kt C/Mt steel in 2000 and constant thereafter (Corus, 2005).

A3.4.3.1.2 Other Pollutants

Emissions from blast furnaces of other pollutants are partly based on the methodology described in IPCC (1997) for blast furnace charging and pig iron tapping and partly on emissions data reported by the process operators. The emission factors are expressed in terms of the emission per Mt of pig iron produced and are given in **Table A 3.4.4**. Data on iron production are reported in ISSB (2011).

Table A 3.4.4 Emission Factors for Blast Furnaces (BF), Electric Arc Furnaces (EAF) and Basic Oxygen Furnaces (BOF), 2010

	C [a]	CH_4	N_2O	NO_x	SO_2	NMVOC	CO	Units
Blast furnaces	IE	NE	NE	NE	0.0634[b]	0.12[c]	1.33[b]	kt/Mt pig iron
Electric arc furnaces	2[d]	0.01[e]	0.005[e]	0.222[b]	0.116[b]	0.09[e]	0.906[b]	kt/Mt Steel
Basic oxygen furnaces	IE	NE	NE	0.0121[f]	IE	NE	3.78[b]	kt/Mt Steel
Losses of BFG/BOFG	8.58[g]	0.012[e]	2.11E-4[e]	8.33E-3[e]	NE	5.91E-4[e]	4.17E-3[e]	kt/Mtherm gas
Slag processing	NE	NE	NE	NE	1.104E-5[b]	NE	NE	kt/Mt Pig iron

a Emission factor as kt carbon/unit activity
b Emission factor for 2010 based on data from Corus (2011) and data for non-Corus plant from EA (2011)
c IPCC (1997)
d Corus (2005)
e EMEP/CORINAIR(1999)
f EIPPCB(2000), Corus (2001, 2000)
g AEA estimate based on carbon balance
NE Not estimated
IE Emission included elsewhere.

Emissions from electric arc furnaces are calculated mainly using default emission factors taken from EMEP/CORINAIR (1999). The CO_2 emission arises from the consumption of a graphite anode and the emission factor has been suggested by Corus (2005). Emissions of CO from basic oxygen furnaces are based on data supplied by Corus (2007) while the NO_x emission is based on an EIPPCB default.

Emissions of NMVOC are estimated from the hot rolling and cold rolling of steel using emission factors of 1 g/tonne product and 25g/tonne product respectively (EMEP/CORINAIR, 1996). Activity data were taken from ISSB (2011).

There is insufficient activity or emission factor data to make an estimate for emissions from ferroalloys. Emissions of CO_2 will be included in 1A2a, since the fuels used as reducing agents are included in the energy statistics.

A3.4.3.2 Aluminium Production (2C3)

Details of the method used to estimate emissions of F-gases from this source are given in AEA (2008). Emission factors for aluminium production, as discussed in **Chapter 4**, **Section 4.16**, are shown in **Table A 3.4.5**.

Table A 3.4.5 Emission Factors for Aluminium Production, 2010

	C [a]	SO_2 [b]	NO_x [b]	CO [b]	Units
Prebake	420	12.90	1.39	107	Kt / Mt Al
Anode Baking	IE	1.40	0.574	3.58	Kt / Mt anode

a Emission factor as kt carbon per unit activity, Walker, 1997.
b Environment Agency Pollution Inventory (2011) and SEPA (2011)
IE Emission included elsewhere.

A3.4.3.3 SF_6 used in Aluminium and Magnesium Foundries (2C4)

The method used to estimate emissions of SF_6 from this source is described **Chapter 4**, **Section 4.17** of the NIR.

Note that actual emissions of SF_6 for this sector are reported for practical reasons in the CRF under 2C5 'Other metal production'. This is because the CRF Reporter does not allow reporting of HFC emissions under the 2C4 sector category. Reporting under 2C5 allows separate reporting of SF_6 as tonnes of SF_6, and HFCs, as CO_2 equivalent.

A3.4.3.4 Food and Drink (2D2)

NMVOC emission factors for food and drink, as discussed in **Chapter 4**, **Section 4.20**.

Table A 3.4.6 NMVOC Emission Factors for Food and Drink Processing, 2009

Food/Drink	Process	Emission Factor	Units
Beer	Barley Malting Wort Boiling Fermentation	0.6[c] 0.0048[c] 0.02[c]	g/L beer
Cider	Fermentation	0.02[c]	g/L cider
Wine	Fermentation	0.2[c]	kg/m^3
Spirits	Fermentation Distillation Casking Spent grain drying Barley Malting Maturation	1.58[d] 0.79[g] 0.40[h] 1.31[i] 4.8[c] 15.78[d]	g/ L alcohol g/ L alcohol g/ L whiskey kg/ t grain kg/ t grain g/ L alcohol
Bread Baking		1[a]	kg/tonne
Meat, Fish & Poultry		0.3[f]	kg/tonne
Sugar		0.020[b]	kg/tonne
Margarine and solid cooking fat		10[f]	kg/tonne

Food/Drink	Process	Emission Factor	Units
Cakes, biscuits, breakfast cereal, animal feed		1[f]	kg/tonne
Malt production (exports)		4.8[c]	kg/ t grain
Coffee Roasting		0.55[f]	kg/tonne

a Federation of Bakers (2000)
b Environment Agency (2007)
c Gibson *et al* (1995)
d Passant *et al* (1993)
e Assumes 0.1% loss of alcohol based on advice from distiller
f EMEP/CORINAIR, 2006
g Unpublished figure provided by industry
h Based on loss rate allowed by HMCE during casking operations
i US EPA, 2007

A3.4.4 Production of Halocarbons and SF_6 (2E)

Details of the method used to estimate emissions of F-gases from this source are given in **Chapter 4, Section 4.21** of the NIR.

A3.4.5 Consumption of Halocarbons and SF_6 (2F)

A3.4.5.1 Refrigeration and Air Conditioning Equipment (2F1)

Details of the method used to estimate emissions of F-gases from this source are given in **Chapter 4**, **Section 4.22** of the NIR.

A3.4.5.2 Foam Blowing (2F2)

Details of the method used to estimate emissions of F-gases from this source are given in **Chapter 4**, **Section 4.23** of the NIR.

Table A 3.4.7 Species according to application for foam blowing

Application	HFC-245fa	HFC-365mfc	HFC-227ea	HFC-134a	HFC-152a
PU Boardstock	25%	67.5%	7.5%		
PU Cont. Panel		90%	10%		
PU Disc. Panel		90%	10%		
PU Spray	100%				
PU P-i-P		90%	10%		
PU Block - Slab		90%	10%		
PU Block - Pipe		90%	10%		
XPS				65%	35%
PF Boardstock		90%	10%		
PF Disc. Panel		90%	10%		
PF Block - Slab		90%	10%		
PF Block - Pipe		90%	10%		
PU - Appliance	50%	45%	5%		
PU - Reefer	50%	45%	5%		

A3.4.5.3 Fire Extinguishers (2F3)

Details of the method used to estimate emissions of F-gases from this source are given in **Chapter 4**, **Section 4.24** of the NIR.

Table A 3.4.8 Key assumptions used to estimate HFC emissions from fire extinguishers

	Parameter	2010
Activity data	HFC species and ratio HFC 227ea : HFC 23	97.5 : 2.5
	Size of bank (t)	2509
	Used for manufacture	89
	Equipment lifetime (yrs)	n/a
Emission factors	% released through fire	1.5
	% released through servicing	1.0
	% released during recovery	0.1
	PM %	0
	PL %	2.5
	D %	0.1

A3.4.5.4 Aerosols/ Metered Dose Inhalers (2F4)

Details of the method used to estimate emissions of F-gases from these sources are given in **Chapter 4**, **Section 4.25** of the NIR.

Aerosols

Table A 3.4.9 Key assumptions used to estimate HFC134a emissions from aerosols

	Parameter	2010
Activity data	Used for UK manufacture (tonnes)	582.1
	Exported (tonnes)	36.6
	Imported (tonnes)	303.0
	Product lifetime (yrs)	1
Emission factors	PM %	1
	PL %	97
	D%	2

Table A 3.4.10 Key assumptions used to estimate HFC152a emissions from aerosols

	Parameter	2010
Activity data	Used for UK Manufacture (tonnes)	46.6
	Exported (tonnes)	25.0
	Imported (tonnes)	0.0
	Product lifetime (yrs)	1
Emission factors	PM %	1
	PL %	97
	D %	2

Metered Dose Inhalers (MDIs)

Table A 3.4.11 Key assumptions used to estimate HFC134a emissions MDIs

	Parameter	2010
Activity data	HFC species and ratio HFC 134a : HFC 227ea	80 : 20
	% exported	86
	Total HFC used for manufacture (tonnes)	2484.3
	Size of bank (t)	763.3
	Product lifetime (yrs)	1
Emission factors	PM %	2
	PL %	96
	D %	2

Table A 3.4.12 Key assumptions used to estimate HFC227ea emissions MDIs

	Parameter	2010
Activity data	HFC species and ratio HFC 134a : HFC 227ea	80 : 20
	% exported	86
	Total HFC used for manufacture (tonnes)	621.1
	Size of bank (t)	190.8
	Product lifetime (yrs)	1
Emission factors	PM %	2
	PL %	96
	D %	2

A3.4.5.5 Solvents (2F5)

Details of the method used to estimate emissions of F-gases from these sources are given in **Chapter 4**, **Section 4.26** of the NIR.

Table A 3.4.13 Key assumptions used to estimate emissions from the use of solvents

	Parameter	2010
Activity data	EU Estimate (tonnes of HFC released)	600
	UK Estimate (tonnes of HFC released)	82.5
	Product lifetime (yrs)	n/a
Emission factors	PM %	n/a
	PL %	n/a
	D %	n/a

A3.4.5.6 Semiconductor Manufacture (2F6)

Details of the method used to estimate emissions of F-gases from these sources are given in **Chapter 4**, **Section 4.27** of the NIR.

Table A 3.4.14 Key assumptions used to estimate emissions from semiconductor manufacture

	1990-1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2009	2010	2015	2020-2025
Annual growth in UK semiconductor production	15%	15%	15%	15%	16%	-39%	0%	0%	0%	5%	10%	10%	7%	5%
Annual rate of change of usage per unit consumption														
CF_4	3%	2%	1%	0%	-1%	-1%	-2%	-2%	-2%	-8%	-8%	-8%	-1%	-1%
C_2F_6	3%	2%	1%	0%	-1%	-1%	-2%	-2%	-2%	-8%	-8%	-8%	-1%	-1%
C_3F_8	0%	0%	0%	0%	1%	1%	1%	1%	1%	1%	1%	1%	-1%	-1%
C_4F_8	0%	0%	0%	0%	1%	1%	1%	1%	1%	1%	1%	1%	-1%	-1%
CHF_3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
SF_6	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
NF_3	0%	0%	0%	0%	0%	2%	3%	5%	5%	5%	5%	5%	0%	0%
Consumption, kg*														
CF_4		3640	4269	4959	5752	3,474	3404	3336	3270	3158	3313	3352	4859	
C_2F_6		14882	17456	20275	23519	14,203	13919	13641	13368	12914	13545	13707	19867	
C_3F_8		582	669	770	893	550	556	561	567	601	925	1027	1489	
C_4F_8		37	43	49	57	35	35	36	36	38	59	65	95	
CHF_3		2166	2491	2865	3324	2,027	2027	2027	2027	2129	3117	3428	5225	
SF_6		1379	1586	1824	2116	1,291	1291	1291	1291	1355	1984	2183	3327	
NF_3		2459	2828	3252	3772	2,301	2301	2301	2301	2416	3313	3891	5931	
Fraction fed to abatement														
CF_4	0%	0%	0%	0%	0%	0%	0%	0%	10%	15%	35%	40%	50%	50%
C_2F_6	0%	0%	0%	0%	0%	0%	0%	0%	10%	15%	35%	40%	50%	50%
C_3F_8	0%	0%	0%	0%	0%	0%	0%	0%	10%	15%	35%	40%	50%	50%
C_4F_8	0%	0%	0%	0%	0%	0%	0%	0%	10%	15%	35%	40%	50%	50%
CHF_3	0%	0%	0%	0%	0%	0%	0%	0%	10%	15%	35%	40%	50%	50%
SF_6	0%	0%	0%	0%	0%	0%	0%	0%	10%	15%	35%	40%	50%	50%
NF_3	90%	90%	90%	90%	90%	90%	90%	90%	95%	100%	100%	100%	100%	100%

*Derived from 2001 data, working backwards or forwards from 2001 consumption using annual growth rate and rate of change of consumption per unit production for appropriate year.

A3.4.5.7 Electrical Equipment (2F7)

Details of the method used to estimate emissions of F-gases from these sources are given in **Chapter 4**, **Section 4.28** of the NIR.

Table A 3.4.15 Key assumptions used to estimate emissions from electrical equipment

	Parameter	1990	1995	2000	2005	2010	2015	2020
Activity data	Total SF_6 used for manufacture (tonnes)	140	115	70	63	63	63	61
	Net proportion exported (%)	40%	40%	40%	40%	40%	40%	40%
	Decommissioned (tonnes)	20	20	40	32	32	32	32
	Bank size in 1990 (tonnes)	232	-	-	-	-	-	-
Emission factors See note below	PM	0.08	0.08	0.08	0.072	0.064	0.064	0.064
	PL	0.0436	0.0436	0.038	0.032	0.031	0.029	0.028
	D	0.20	0.20	0.05	0.04	0.04	0.04	0.04

Note: PM, PL and D are expressed as factors and not percentages in the table above

A3.4.5.8 One Component Foams (2F9A)

Details of the method used to estimate emissions of F-gases from these sources are given in **Chapter 4**, **Section 4.29** of the NIR.

Table A 3.4.16 Key assumptions used to estimate emissions of HFC152a from the use OCF

	Parameter	2010
Activity data	EU Estimate (tonnes of HFC released)	1364
	UK Estimate (tonnes of HFC released)	75.3
	Product lifetime (yrs)	n/a
Emission factors	PM %	n/a
	PL %	n/a
	D %	n/a

A3.4.5.9 Semiconductors, Electrical and Production of Trainers (2F9B)

Details of the method used to estimate emissions of F-gases from these sources are given in **Chapter 4**, **Section 4.30** of the NIR.

A3.5 SOLVENT AND OTHER PRODUCT USE (CRF SECTOR 3)

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

A3.6 AGRICULTURE (CRF SECTOR 4)

A3.6.1 Enteric Fermentation (4A)

Methane is produced in herbivores as a by-product of enteric fermentation, a digestive process by which carbohydrates are broken down by microorganisms. Emissions are calculated from animal population data (**Table A 3.6.1**) collected in the June Agricultural Survey and published in Defra (2011a) and the appropriate emission factors. Data for earlier years are often revised so information was taken from the Defra agricultural statistics database. Table A 3.6.2 shows the trends in livestock numbers (main categories) from 1990-2010. Generally there has been a significant decrease in livestock numbers over this period (35, 12, 41 and 30% decline in numbers for dairy cows, other cattle, total pigs and total sheep, respectively) although total poultry numbers have increased by 28%.

Table A3.6.3 shows the emission factors used.

Apart from cattle, lambs and deer, the methane emission factors are IPCC Tier 1 defaults (IPCC, 1997) and do not change from year to year. The dairy cattle (for dairy cows only) emission factors are estimated following the IPCC Tier 2 procedure (IPCC, 2000) and vary from year to year. For dairy cows, the calculations are based on the population of the 'dairy breeding herd' which is defined as dairy cows over two years of age with offspring.

The base data and emission factors for dairy cows for 1990-2010 are given in **Table A 3.6.3**, **Table A 3.6.4** and **Table A 3.6.5**.

The main parameters involved in the calculation of the emissions factors for beef are shown in **Table A 3.6.6**. The emission factors for other cattle were also calculated using the IPCC Tier 2 procedure (**Table A 3.6.6**), but do not vary from year to year.

The data used to calculate emissions are summarised below.

Cattle weights

Dairy cow slaughter weights are provided by Sarah Thompson, Defra. The increase in slaughter weights from 2004 (238kg) to 2005 (343kg) was a result of the lifting of the Over Thirty Month rule[9], which was a measure to control the exposure of humans to the disease BSE; see **Table A3.6.4**. A footnote to this table also includes the description of the method used to estimate live weight from slaughter weights.

Animal numbers and categories

The national cattle numbers are the sum of the regional cattle data (from the four constituent countries of the UK).

Animal numbers used to estimate the CH_4 emissions are consistent with the numbers used to estimate N_2O emissions.

A number of additional cattle categories have been introduced to allow for more accurate source apportionment of emissions to the 'Dairy' and 'Beef' sectors. Cattle now comprise the following eight groups: dairy cows, beef cows, dairy heifers, beef heifers, dairy replacements > 1 year, beef all other > 1 year, dairy calves < 1 year, beef calves < 1 year.

[9] To be able to slaughter cattle aged over 30 months (OTM), abattoirs must be OTM approved by the Meat Hygiene Service (MHS). In the UK, it is an offence to slaughter OTM cattle in a non-OTM approved abattoir. It is also an offence to slaughter cattle which were born or reared in the UK before 1 August 1996 for human consumption in any abattoir.

Feed digestibility
A country-specific value (75%) for the digestibility of feed (DE), expressed as a percentage of the gross energy, for dairy cows is used. This value is considerably higher than the IPCC (1997) default value for Western Europe of 60%, but is based on typical diets for cows over the lactating and non-lactating period, combining forage and concentrates, with energy values for the various feeds according to MAFF (1990) (Bruce Cottrill, ADAS, pers. comm.).

The diet characteristics are derived in two components, that fed as concentrates (for which robust industry data in terms of amounts fed exist) and that fed as forage (estimated from the dietary requirement and the knowledge of concentrate use). For the typical dairy cow, the forage component represents 62% of annual dietary dry matter intake. The forage component is assumed to consist of fresh grass (grazed), grass silage and maize silage, in the ratio 4:4:1, with a weighted average DE value of approximately 72%. The constituents of the concentrate feed are assumed to be barley grain, sugar beet pulp (molassed), wheat feed, wheat grain, rapeseed meal, soya bean meal and sunflower meal, with a weighted average DE value of approximately 82%. The overall weighted average DE value for the diet is therefore estimated as 75%.

Beef cows
In the inventory a Tier 2 methodology is used for the calculation of the emissions from beef cows, and other cattle but a time series of cattle weights were not available and so a constant live weight (500 kg) has been assumed.

Sheep

The UK sheep production sector has a complex structure, with many different breeds of sheep and a range of hill, upland and lowland rearing and finishing systems. The UK is currently undertaking a programme of work to improve methodology for calculating emissions from this sector, which will include derivation of monthly sheep and lamb population models and country-specific emission factors. The current approach is to assume the IPCC Tier 1 default emission factor for enteric fermentation (8 kg CH_4/head/year) for all mature sheep (> 1 year old). Lambs have a lower average live weight than mature sheep and the majority have a lifespan of less than 12 months, and should therefore be associated with a lower emission factor than mature sheep. The UK therefore uses a country-specific emission factor for enteric fermentation for lambs derived from the annual emission factor for lambs as 40% of that for mature sheep, 3.2 kg CH_4/head/year (Sneath et al., 1997), multiplied by the average lifespan of lambs in the UK of 0.5 years i.e. giving an emission factor of 1.6 kg CH_4/head/year.

The assumption of a 6 month lifespan for lambs is expert opinion, based on an analysis of available data sources regarding lambs going to slaughter and an expert knowledge of practices within the sector (English Beef and Lamb Executive; K Phillips, ADAS Livestock Specialist; Sneath et al., 1997). Lambs may be finished as early as 8-10 weeks or as late as 12 months. The profile of lambs for slaughter going through auction markets (Defra statistics), which accounts for approximately 50% of lambs going to slaughter, suggest an average lamb age of just over 6 months (7 – 9 months), whereas anecdotal evidence suggests an average age of the remaining 50% of lambs, going directly from farm to slaughter, of less than 6 months. A 6 month lifespan is also supported by industry data (English Beef and Lamb Executive) on mean birth weights and target slaughter weights (approximately 5 and 40 kg, respectively) and target mean daily growth rates of 250 g day^{-1} pre-weaning (12 – 16 weeks) and 150 g day^{-1} post-weaning (although there is considerable variation in practice around these target values). A new survey has just been commissioned to provide more robust data from which to derive the average lamb lifespan, and these data will be incorporated into the inventory when available.

The sheep emission factors in **Table A 3.6.3** are reported on the basis that the animals are alive the whole year.

Table A 3.6.1 Livestock Population Data for 2010 by Animal Type

Animal type	Number
Cattle:	
Dairy cows	1,846,634
Beef cows	1,656,702
Dairy heifers	407,708
Beef heifers	377,530
Dairy replacements >1 year	500,809
Beef all others >1 year	2,458,422
Dairy calves <1 year	519,447
Beef calves <1 year	2,341,838
Pigs:	
Sows	360,268
Gilts	141,152
Boars	16,809
Fattening & other pigs 80 - >110 kg	673,425
Fattening & other pigs 50-80 kg	968,938
Other pigs 20-50 kg	1,133,631
Pigs < 20 kg	1,174,174
Sheep:	
Breeding sheep	15,103,916
Other sheep	551,094
Lambs < 1 year	15,431,477
Goats	92,941
Deer	30,956
Horses	311,413
Poultry:	
Growing pullets	8,724,012
Laying fowls	28,751,081
Breeding flock	9,606,990
Table chicken	105,309,326
Turkeys	3,902,122
Total other poultry	7,548,275

Table A 3.6.2 Trends in Livestock Numbers ('000s) 1990-2010

Year	Dairy cows	Other cattle	Pigs	Sheep	Poultry
1990	2,848	9,344	7,548	44,469	127,952
1991	2,771	9,232	7,695	44,166	140,947
1992	2,683	9,242	7,707	44,540	137,613
1993	2,668	9,183	7,853	44,436	144,171
1994	2,716	9,238	7,892	43,813	140,447
1995	2,603	9,254	7,627	43,304	142,267
1996	2,587	9,452	7,590	42,086	148,936
1997	2,478	9,154	8,072	42,823	179,460
1998	2,439	9,080	8,146	44,471	165,087
1999	2,440	8,983	7,284	44,656	165,157
2000	2,336	8,799	6,482	42,264	169,773
2001	2,251	8,351	5,845	36,716	179,880
2002	2,227	8,118	5,588	35,834	168,996
2003	2,191	8,317	5,046	35,812	178,818
2004	2,129	8,459	5,159	35,817	181,759
2005	2,060	8,380	4,862	35,416	173,909
2006	2,054	8,269	4,933	34,722	173,081
2007	1,954	8,350	4,834	33,946	167,667
2008	1,909	8,198	4,714	33,131	166,200
2009	1,857	8,169	4,724	32,038	159,288
2010	1,847	8,262	4,468	31,086	163,842

Data derived as sum of totals for each Devolved Administration (i.e. England, Wales, Scotland and Northern Ireland), obtained from Devolved Administration statistical publications (June survey results)

Table A 3.6.3 Methane Emission Factors for Livestock Emissions for 2010

Animal type	Enteric methane[a] kg CH_4/head/year	Methane from manures[ab] kg CH_4/head/year
Cattle:[d]		
Dairy cows[fg]	111.5[b]	33.8[b]
Beef cows[f]	50.5[b]	2.6
Dairy heifers	48	7.7
Beef heifers	48	3.3
Dairy replacements >1 year	48	7.7
Beef all others >1 year	48	3.3
Dairy calves<1 year	32.8	0.7
Beef calves <1 year	32.8	0.5
Pigs:		
Sows	1.5	4.0
Gilts	1.5	4.0
Boars	1.5	4.0
Fattening & other pigs 80 - >110 kg	1.5	5.6
Fattening & other pigs 50-80 kg	1.5	5.6
Other pigs 20-50 kg	1.5	5.6
Pigs <20 kg	1.5	5.9
Sheep:		
Breeding sheep	8	0.19
Other sheep	8[e]	0.19[e]
Lambs < 1 year	3.2[ce]	0.19[ce]
Goats	5	0.12
Horses	18	1.4
Deer:		
Stags & hinds	10.4[c]	0.26[c]
Calves	5.2[c]	0.13[c]
Poultry:		
Growing pullets	NE	0.063
Laying fowls	NE	0.064
Breeding flock	NE	0.063
Table chicken	NE	0.082
Turkeys	NE	0.063
Total other poultry	NE	0.063

[a]IPCC (1997); cattle categories changed in 2010 inventory; all manure EF's are tier 2 (with the exception of deer)
[b]Emission factor for the year 2010 (with the exception of deer)
[c]Sneath et al. (1997)
[d]Cattle categories changed in 2010 inventory
[e]Factor quoted assumes animal lives for a year; emission calculation assumes animal lives for 6 months
[f]% time spent grazing revised from 43% to 45% for dairy cows and 54% to 65% for beef cows (linked to AWMS data)
[g]IPCC 2000 methodology

Table A 3.6.4 Dairy Cows Methane Emission Factors[a]

Year	Average weight of cow (kg)[b]	Average milk yield per dairy cow (litres per annum)[d]	Average fat content (%)	Enteric emission factor (kg CH_4/head/y)[c]	Manure emission factor (kg CH_4/head/y)
1990	572	5151	4.01	89.0	21.7
1991	571	5133	4.04	89.0	22.1
1992	585	5237	4.06	90.8	22.1
1993	585	5259	4.07	91.0	22.2
1994	580	5300	4.05	91.0	22.2
1995	583	5398	4.05	92.0	22.4
1996	599	5545	4.08	94.3	23.0
1997	491	5790	4.07	89.8	21.9
1998	492	5775	4.07	89.7	21.9
1999	506	5964	4.03	91.9	22.4
2000	483	5979	4.03	90.6	22.1
2001	488	6346	4.01	93.8	23.4
2002	478	6493	3.97	94.2	24.1
2003	467	6621	3.96	94.5	24.7
2004	495	6763	4.00	97.7	26.2
2005	714	6986	4.02	112.7	30.8
2006	641	6977	4.04	108.6	30.4
2007	652	6913	4.06	108.9	31.1
2008	644	6943	4.06	108.7	31.7
2009	643	7068	3.99	109.1	32.4
2010	653	7315	3.95	111.5	33.8

[a]In 2010, 46% of animals graze on good quality pasture, rest confined
Gestation period 281 days
Digestible energy 74% (Bruce Cottrill, ADAS, pers. comm.)
Methane conversion rate 6%
Ash content of manure 8%
[b]Weights revised from the 2008 inventory onwards, values from carcase weight data from slaughter survey corrected by 1/0.48
[c]IPCC 2000 methodology
[d]Milk yield from AUK, Defra

Table A 3.6.5 Parameters used in the calculations of gross energy for dairy cows Tier 2 emission factors

Year	NE_m (Net energy for maintenance), MJ/d (eq. 4.1)	NE_{feed} (Energy to obtain food), MJ/d (eq 4.2a)	NE_l (Net energy for lactation), MJ/d (eq. 4.5a)	$NE_{pregnancy}$ (Net energy for pregnancy) MJ/d (eq. 4.8)	NE_{ma}/DE (Ratio available energy for maintenance in a diet to digestible energy consumed) (eq. 4.9)	NE_{ga}/DE (Ratio available energy for growth in a diet to digestible energy consumed) (eq. 4.10)	GE (Gross energy intake), MJ/d (eq. 4.11)
1990	39.17	3.00	43.38	3.92	0.54	0.35	226.11
1991	39.13	3.00	43.40	3.91	0.54	0.35	226.06
1992	39.84	3.06	44.39	3.98	0.54	0.35	230.67
1993	39.86	3.06	44.64	3.99	0.54	0.35	231.35
1994	39.61	3.04	44.87	3.96	0.54	0.35	231.21
1995	39.76	3.05	45.70	3.98	0.54	0.35	233.74
1996	40.54	3.11	47.12	4.05	0.54	0.35	239.65
1997	34.97	2.68	49.14	3.50	0.54	0.35	228.19
1998	35.01	2.69	49.02	3.50	0.54	0.35	228.01
1999	35.76	2.74	50.36	3.58	0.54	0.35	233.61
2000	34.53	2.65	50.49	3.45	0.54	0.35	230.28
2001	34.76	2.67	53.41	3.48	0.54	0.35	238.36
2002	34.26	2.63	54.40	3.43	0.54	0.35	239.37
2003	33.63	2.58	55.40	3.36	0.54	0.35	240.03
2004	35.17	2.70	56.88	3.52	0.54	0.35	248.34
2005	46.25	3.55	58.91	4.63	0.54	0.35	286.45
2006	42.69	3.27	58.99	4.27	0.54	0.35	276.03
2007	43.23	3.32	58.60	4.32	0.54	0.35	276.65
2008	42.84	3.29	58.85	4.28	0.54	0.35	276.14
2009	42.77	3.28	59.37	4.28	0.54	0.35	277.25
2010	43.29	3.32	61.13	4.33	0.54	0.35	283.21

Feed digestibility was 74 % according to Bruce Cottrill, ADAS, *pers. comm.*

Table A 3.6.6 Parameters used in the calculation of the Methane Emission Factorsa for beef cows and other cattle

	Equation[d]	Beef cows	Others>1	Others<1
Average weight of animal (kg)		500	400-500	180
Time spent grazing (%)		65	43-50[g]	46
NE_m (Net energy for maintenance), MJ/d	2000GPG Eq4.1	35.4	33.2	15.8
NE_a (Net energy for activity), MJ/d[e]	2000GPG Eq4.2a	3.94	0.00	0.00
NE_l (Net energy for lactation), MJ/d	2000GPG Eq4.5a	0.0	0.0	0.0
$NE_{pregnancy}$ (Net energy for pregnancy), MJ/d	2000GPG Eq4.8	3.54	2.70	0.00

	Equation[d]	Beef cows	Others>1	Others<1
NE_{ma}/DE (Ratio available energy for maintenance in a diet to digestible energy consumed)	2000GPG Eq4.9	0.51	0.51	0.51
NE_{ga}/DE (Ratio available energy for growth in a diet to digestible energy consumed)	2000GPG Eq4.10	0.31	0.31	0.31
GE (gross energy intake), MJ/d[b]	2000GPG Eq4.11	128.4	123.3	83.4[e]
Daily weight gain (kg day^{-1})		0	0.3	0.6
Enteric Emission Factor (kg CH_4/head/y)[f]		50.5[c]	48.0	32.8
Manure Emission Factor (kg CH_4/head/y)		2.6[a]	6.0	2.96

[a]Digestible energy 65%, Ash content of manure 3.04%, Methane producing capacity of manure 0.17 m3/kg VS
[b]Calculated following IPCC guidelines
[c]IPCC (1997) default (48 kg/head/y) replaced in 2008 inventory onwards by value calculated using Tier 2 methodology with constant animal weight values
[d]From IPCC 2000 GPG
[e]Based on 17% of NEm, grazing factor of 0.35 introduced to account for proportion of time spent grazing/housed
[f]Methane conversion rate is 6%
[g]Time spent grazing is 43% and 50% for dairy and beef cattle respectively

A3.6.2 Manure Management (4B)

A3.6.2.1 Methane emissions from animal manures

Methane is produced from the decomposition of manure under anaerobic conditions. When manure is stored or treated as a liquid in a lagoon, pond or tank it tends to decompose anaerobically and produce a significant quantity of methane. When manure is handled as a solid or when it is deposited on pastures, it tends to decompose aerobically and little or no methane is produced. Hence the system of manure management used affects emission rates. Emissions of methane from animal manures are calculated from animal population data (Defra, 2011a) in the same way as the enteric emissions. The emission factors are listed in **Table A 3.6.3**. **Table A 3.6.7** shows the methane conversion factors assumed for the different systems.

The emission factors for manure management are calculated following IPCC Tier 2 methodology but using default IPCC values for the volatile solids (VS) and methane producing potential (B_o) parameters for each livestock type (except for dairy and beef cows, where a Tier 2 calculation is used to determine VS, and deer where no IPCC data are available). The emission factors were calculated for each livestock type based on the VS, Bo, AWMS breakdown and methane conversion factors according to manure management type (IPCC 2000, Equation 4.17):

$$EF_i = VS_i \times 365 \times B_{oi} \times 0.67 \times \sum MCF_j \times MS_{ijk}$$

where

EF_i	=	annual emission factor for animal type *i* (kg CH_4 / head)
VS_i	=	daily volatile solids excretion by animal type *i* (kg / head)
B_{oi}	=	maximum CH4 producing capacity for manure from animal type *i* (m^3 CH_4 / kg VS)
MCF_j	=	CH_4 conversion factors for each manure management system *j*
MS_{ij}	=	proportion of manure from animal type i handled using manure system *j*
0.67	=	methane density conversion factor (kg / m^3)
365	=	days per year

Emission factors and base data for beef cows and other cattle are given in **Tables A 3.6.3.** and **A 3.6.6**. Recent revisions to the activity data concerning manure management practices in the UK ammonia emissions inventory, and the greater level of detail contained within that inventory, were incorporated in the revised spreadsheet model of the GHG inventory. These data derive from a number of sources, including published ad-hoc surveys (e.g. Smith *et al.*, 2000c, 2001a, 2001b; Sheppard 1998, 2002; Webb et al., 2001) and, more recently, relevant data from the Farm Practices Survey for England. We now include a time series for AWMS.

For dairy cows, the calculations are based on the population of the 'dairy breeding herd' which is defined as dairy cows over two years of age with offspring.

Table A 3.6.7 Methane conversion factors for Manure Management Systems in the UK

Manure Handling System	Methane Conversion Factor %[a]
Liquid	39
Daily spread	0.1
Solid storage and drylot	1
Pasture range and paddock	1
Poultry manure - with bedding	1.5
Poultry manure - without bedding	1.5

[a] IPCC (2000)

A3.6.2.2 Nitrous Oxide emissions from Animal Waste Management Systems

Animals are assumed not to give rise to nitrous oxide emissions directly, but emissions from their manures during storage are calculated for a number of animal waste management systems (AWMS) defined by IPCC. Emissions from the following AWMS are reported under the Manure Management IPCC category:

- Flushing anaerobic lagoons. These are assumed not to be in use in the UK.
- Liquid systems (i.e. slurry)
- Solid storage and dry lot (including farm-yard manure)
- Other systems (poultry manure without bedding and poultry manure with bedding (poultry litter); IPCC 2000 Good Practice Guidance)

According to IPCC (1997) guidelines, the following AWMS are reported in the Agricultural Soils category:

- All applied animal manures and slurries
- Pasture range and paddock

Emissions from the combustion of poultry litter for electricity generation are reported under power stations. Emissions occurring during storage of poultry litter that will later be used for energy generation are now included in the agricultural inventory.

The IPCC (1997) method for calculating emissions of N_2O from animal waste management systems can be expressed as:

$$N_2O_{(AWMS)} = 44/28 \cdot \sum N_{(T)} \cdot Nex_{(T)} \cdot AWMS_{(W)} \cdot EF_3$$

where

$N_2O_{(AWMS)}$	=	N_2O emissions from animal waste management systems (kg N_2O/yr)
$N_{(T)}$	=	Number of animals of type T
$Nex_{(T)}$	=	N excretion of animals of type T (kg N/animal/yr)
$AWMS_{(W)}$	=	Fraction of Nex that is managed in one of the different waste management systems of type W
EF_3	=	N_2O emission factor for an AWMS (kg N_2O-N/kg of Nex in AWMS)

The summation takes place over all animal types and the AWMS of interest. Animal population data are taken from Agricultural Statistics (Defra, 2011a). **Table A 3.6.8** shows emission factors for nitrogen excretion per head for domestic livestock in the UK (Nex) from Cottrill and Smith (ADAS).

The conversion of excreted N into N_2O emissions is determined by the type of manure management system used. The distribution of waste management systems for each animal type ($AWMS_{(T)}$) is given in **Table A 3.6.9**. Emissions from poultry are calculated following IPCC 2000 GPG where manure is allocated to poultry with or without bedding, but reported as AWMS 'Other'.

Table A 3.6.8 Nitrogen Excretion Factors, kg N hd^{-1} year^{-1} for livestock in the UK (1990-2010)[a]

Animal type	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cattle:													
Dairy cows	97	100	106	110	112	113	115	117	117	117	117	118	121
Beef cows	79	79	79	79	79	79	79	79	79	79	79	79	79
Dairy heifers	67	67	67	67	67	67	67	67	67	67	67	67	67
Beef heifers	56	56	56	56	56	56	56	56	56	56	56	56	56
Dairy replacements >1 year	53	53	53	53	53	53	53	53	53	53	53	53	53
Beef all others >1 year	53	53	53	53	53	53	53	53	53	53	53	53	53
Dairy calves<1 year	38	38	38	38	38	38	38	38	38	38	38	38	38
Beef calves <1 year	38	38	38	38	38	38	38	38	38	38	38	38	38
Pigs:													
Sows	23.6	22.5	21.4	21.2	20.9	20.7	20.5	20.1	19.7	19.3	18.9	18.5	18.1
Gilts	15.5	15.5	15.5	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	25.8	25.5	25.3	25.0	24.5	23.9	23.4	22.9	22.3	21.8
Fattening & other pigs 80 - >110 kg	20.2	19.3	18.4	18.2	18.0	17.8	17.6	17.2	16.9	16.5	16.1	15.8	15.4
Fattening & other pigs 50-80 kg	17.5	16.7	15.9	15.7	15.5	15.4	15.2	14.9	14.6	14.3	13.9	13.6	13.3
Other pigs 20-50 kg	11.7	11.2	10.6	10.5	10.4	10.3	10.2	10.0	9.8	9.6	9.3	9.1	8.9
Pigs <20 kg	4.6	4.4	4.2	4.1	4.1	4.0	4.0	3.9	3.8	3.7	3.6	3.5	3.4
Sheep:													
Breeding sheep	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2
Other sheep	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2
Lambs < 1 year	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Goats	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6

Animal type	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Deer:													
Stags	13	13	13	13	13	13	13	13	13	13	13	13	13
Hinds & Calves	13	13	13	13	13	13	13	13	13	13	13	13	13
Horses	50	50	50	50	50	50	50	50	50	50	50	50	50
Poultry:													
Growing pullets	0.42	0.39	0.36	0.36	0.35	0.35	0.34	0.34	0.34	0.34	0.33	0.33	0.33
Laying fowls	0.89	0.85	0.81	0.80	0.80	0.79	0.78	0.77	0.75	0.74	0.72	0.71	0.70
Breeding flock	1.16	1.13	1.10	1.10	1.09	1.09	1.08	1.07	1.06	1.05	1.04	1.03	1.02
Table chicken	0.64	0.59	0.55	0.54	0.53	0.52	0.51	0.49	0.47	0.46	0.44	0.42	0.40
Turkeys	1.50	1.59	1.68	1.70	1.71	1.73	1.75	1.76	1.77	1.79	1.80	1.81	1.82
Total other poultry	1.30	1.41	1.52	1.54	1.56	1.58	1.60	1.62	1.64	1.66	1.67	1.69	1.71

[a]Cottrill and Smith, ADAS

Table A 3.6.9 Distribution of Animal Waste Management Systems used for Different Animal types, 2010[a]

Animal Type	Liquid System	Daily Spread	Solid Storage and Dry Lot[b]	Pasture Range and Paddock	Poultry without bedding	Poultry with bedding	Inciner-ation
Cattle:							
Dairy cows	38.3	13.0	3.6	45.1	NA	NA	NA
Beef cows	4.7	14.2	15.7	65.4	NA	NA	NA
Dairy heifers	9.1	9.0	12.9	69.0	NA	NA	NA
Beef heifers	4.7	14.2	15.7	65.4	NA	NA	NA
Dairy replacements >1 year	9.1	9.0	12.9	69.0	NA	NA	NA
Beef all others >1 year	4.7	14.2	15.7	65.4	NA	NA	NA
Dairy calves<1 year	0.0	14.0	31.2	54.8	NA	NA	NA
Beef calves <1 year	0.0	14.0	31.2	54.8	NA	NA	NA
Pigs:							
Sows	16.8	17.1	24.2	42.0	NA	NA	NA
Gilts	16.8	17.1	24.2	42.0	NA	NA	NA
Boars	16.8	17.1	24.2	42.0	NA	NA	NA
Fattening & other pigs 80 - >110 kg	24.8	29.0	44.2	2.0	NA	NA	NA
Fattening & other pigs 50-80 kg	24.8	29.0	44.2	2.0	NA	NA	NA
Other pigs 20-50 kg	24.8	29.0	44.2	2.0	NA	NA	NA
Pigs <20 kg	26.3	23.1	29.7	21.0	NA	NA	NA
Sheep:							
Breeding sheep	0.0	0.0	4.2	95.8	NA	NA	NA
Other sheep	0.0	0.0	4.2	95.8	NA	NA	NA
Lambs < 1 year	0.0	0.0	4.2	95.8	NA	NA	NA
Goats	0.0	0.0	8.2	91.8	NA	NA	NA
Deer:							
Stags[c]	0.0	0.0	0.0	100.0	NA	NA	NA
Hinds & Calves[c]	0.0	0.0	24.9	75.1	NA	NA	NA
Horses	0.0	0.0	0.0	100.0	NA	NA	NA
Poultry:							
Growing pullets	NA	49.4	NA	1.2	0.0	49.4	0.0
Laying fowls	NA	45.6	NA	8.8	45.6	0.0	0.0
Breeding flock	NA	49.9	NA	0.2	0.0	49.9	0.0
Table chicken	NA	31.7	NA	0.9	0.0	31.7	35.7
Turkeys	NA	48.2	NA	3.6	0.0	48.2	0.0
Total other poultry	NA	49.0	NA	2.0	0.0	49.0	0.0

[a]Misselbrook et al., 2011
[b]Farmyard manure
[c]Sneath et al. (1997)

Table A 3.6.10 gives the N_2O emission factor for each animal waste management system ($EF3_{(AWMS)}$). These are expressed as the emission of N_2O-N per mass of excreted N processed by the waste management system.

Table A 3.6.10 Nitrous Oxide Emission Factors for Animal Waste Handling Systems[a]

Waste Handling System	Emission Factor (EF_3), kg N_2O per kg N excreted
Liquid System	0.001
Daily Spread[b]	0
Solid Storage and Dry Lot	0.02
Pasture, Range and Paddock[b]	0.02
Poultry manure - with bedding[c]	0.02
Poultry manure - without bedding[c]	0.005

a IPCC (1997)
b Reported under Agricultural Soils
c IPCC 2000 GPG

A3.6.3 Agricultural Soils (4D)

A3.6.3.1 Source category description

Direct emissions of nitrous oxide from agricultural soils are estimated using the IPCC recommended methodology (IPCC, 1997) but incorporating some UK specific parameters. The IPCC method involves estimating contributions from:

(i) The use of inorganic fertilizer
(ii) Biological fixation of nitrogen by crops
(iii) Crop residues returned to soils
(iv) Cultivation of histosols (organic soils)
(v) Manure deposited by grazing animals in the field
(vi) Application of livestock manures to land
(vii) Application of sewage sludge to land
(viii) Emissions from improved grassland

In addition to these, the following indirect emission sources are estimated:

(ix) Emission of N_2O from atmospheric deposition of agricultural NO_x and NH_3
(x) Emission of N_2O from leaching and run-off of agricultural nitrate

Descriptions of the methods used are described in **Section 6.5.2**.

A3.6.3.2 Inorganic Fertiliser

Emissions from the application of inorganic fertilizer are calculated using the IPCC (1997) methodology and IPCC default emission factors. They are given by:

$$N_2O_{(SN)} = 44/28 \cdot N_{(FERT)} \cdot (1-Frac_{(GASF)}) \cdot EF_1$$

where

$N_2O_{(SN)}$ = Emission of N_2O from synthetic fertiliser application (kg N_2O/yr)
$N_{(FERT)}$ = Total use of synthetic fertiliser (kg N/yr)

$Frac_{(GASF)}$	=	Fraction of synthetic fertiliser emitted as NO_x + NH_3
	=	0.1 kg NH_3-N+NO_x -N / kg synthetic N applied
EF_1	=	Emission Factor for direct soil emissions
	=	0.0125 kg N_2O-N/kg N input

Annual consumption of synthetic fertilizer is estimated based on crop areas (Defra, 2011a) and fertilizer application rates (BSFP, 2011) as shown in **Table A 3.6.11**. **Figure A3.6.1** shows data compiled by the Office of National Statistics (ONS, 2010) and BSFP (used in the inventory) at UK level. The ONS data are derived from a combination of sources, including import/export statistics, BSFP and industry production data. The graph below shows on average the BSFP data is 8.8% larger.

Table A 3.6.11 Areas of UK Crops and quantities of fertiliser applied for 2010

Crop Type	Crop area, ha	Fertiliser, ktN
Winter wheat	1,938,578	374.7
Spring barley	538,631	52.8
Winter barley	382,531	54.7
Oats	124,460	11.6
Rye, triticale & mixed corn	25,944	1.9
Maize	163,928	7.1
Maincrop potatoes	138,312	18.6
Sugar beet	118,493	11.0
Oilseed rape	641,562	126.0
Peas (green)	29,480	0.1
Peas (dry)	41,543	0.1
Broad beans	1,011	0.0
Beans (human consumption)	5	0.0
Beans (animal consumption)	168,510	0.0
Rootcrops for stockfeed	34,517	2.7
Leafy forage crops	4,841	0.3
Other forage crops	23,043	0.6
Vegetable (brassicae)	3,079	0.3
Vegetables (other)	87,431	10.1
Soft fruit	10,184	0.2
Top fruit	24,139	1.6
Hops	0	0.0
Linseed	43,858	2.5
Other tillage	51,995	1.7
Grass under 5 years	1,231,527	125.4
Permanent grass	5,925,810	316.8

Figure A 3.6.1 Comparison of fertiliser data sources BSFP and ONS 1990-2010

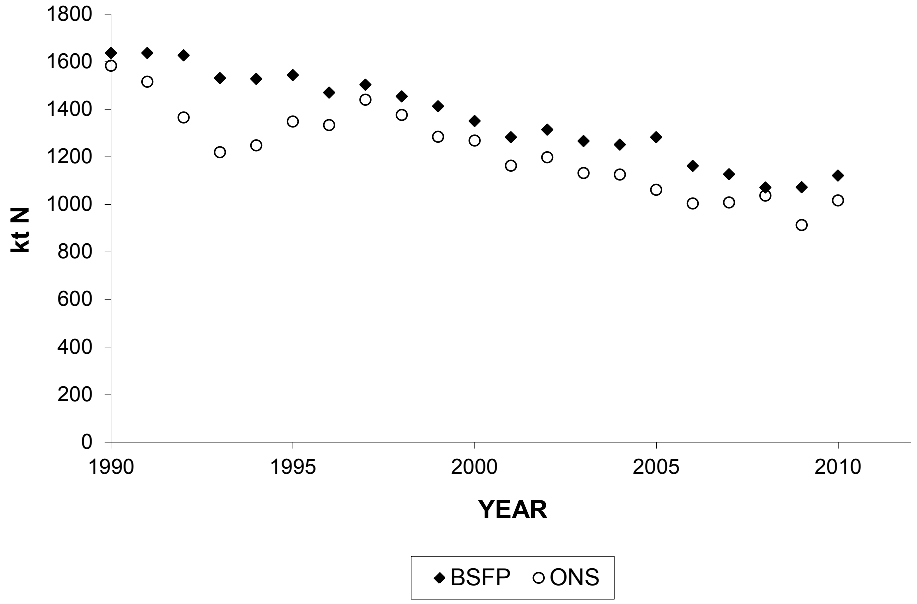


Table A 3.6.12 shows the trend in areas and fertiliser N application rates for the major crop categories over the period 1990-2010.

A3.6.3.3 Biological Fixation of Nitrogen by crops

Emissions of nitrous oxide from the biological fixation of nitrogen by crops are calculated using the IPCC (2000) Tier 1a methodology and IPCC default emission factors. They are given by:

$$N_2O_{(BF)} = 44/28 \cdot 2 \cdot Crop_{(BF)} \cdot Frac_{DM} \cdot Frac_{(NCRBF)} \cdot EF_1$$

where

$N_2O_{(BF)}$	=	Emission of N_2O from biological fixation (kg N_2O/yr)
$Crop_{(BF)}$	=	Production of legumes (kg/yr)
$Frac_{DM}$	=	Dry matter fraction of crop
$Frac_{(NCRBF)}$	=	Fraction of nitrogen in N fixing crop
	=	0.03 kg N/kg dry mass
EF_1	=	Emission Factor for direct soil emissions
	=	0.0125 kg N_2O-N/kg N input

The factor of 2 converts the edible portion of the crop reported in agricultural statistics to the total biomass. The fraction of dry mass for the crops considered is given in **Table A 3.6.13**.

Table A 3.6.12 Trends in area grown ('000 ha) and N fertiliser applied (kg/ha) for the major UK crops, 1990-2010

Year	Winter wheat		Spring barley		Winter barley		Maincrop potatoes		Oilseed rape		Grass leys (<5yrs)		Permanent grassland	
	'000 ha	kg/ha N	'000 ha	kg/ha N	'000 ha	kg/ha N	'000 ha	kg/ha N	'000 ha	kg/ha N	'000 ha	kg/ha N	'000 ha	kg/ha N
1990	2,014	183.0	635	91.5	882	140.0	177	184.8	390	225.5	1,721	160.8	5,344	106.0
1991	1,980	188.0	552	94.9	841	142.1	177	180.5	440	206.4	1,698	166.3	5,390	104.8
1992	2,066	188.1	515	94.9	784	142.2	181	180.4	421	206.3	1,680	166.2	5,327	104.8
1993	1,759	188.1	518	95.0	650	142.1	171	180.6	377	206.2	1,684	165.9	5,310	104.8
1994	1,811	188.1	483	95.0	628	142.1	165	180.5	404	206.1	1,577	164.9	5,379	104.8
1995	1,859	193.0	504	98.5	689	144.5	172	176.0	354	187.4	1,521	169.9	5,402	103.7
1996	1,977	187.3	518	95.1	749	139.9	177	182.9	357	189.8	1,513	161.0	5,370	101.9
1997	2,034	187.4	518	95.1	839	140.2	166	182.9	445	189.9	1,516	161.3	5,304	101.9
1998	2,045	181.8	484	92.1	769	135.8	164	189.8	506	192.4	1,417	151.8	5,392	100.2
1999	1,847	185.0	631	99.5	548	142.5	178	152.5	417	196.5	1,341	178.7	5,476	95.9
2000	2,086	188.3	539	107.3	589	146.6	166	154.6	332	190.0	1,340	144.1	5,391	88.2
2001	1,635	185.3	783	110.6	462	143.9	165	152.8	404	196.3	1,320	137.9	5,612	86.5
2002	1,996	193.0	555	109.1	546	153.9	158	164.1	357	202.0	1,357	139.4	5,546	79.0
2003	1,836	197.2	621	107.0	455	148.7	145	145.4	460	194.7	1,315	130.8	5,711	75.4
2004	1,990	196.7	587	104.0	420	146.2	148	164.9	498	197.3	1,361	117.9	5,648	71.3
2005	1,870	195.1	553	101.5	384	142.5	137	160.7	588	200.2	1,308	114.3	5,739	81.0
2006	1,836	191.6	494	100.6	388	136.8	140	140.9	568	191.3	1,252	105.4	5,995	65.9
2007	1,830	189.8	515	98.0	383	135.7	140	127.6	674	189.6	1,291	99.0	5,992	58.2
2008	2,080	177.9	616	94.3	416	135.0	144	154.1	598	189.7	1,256	97.3	6,063	46.9
2009	1,814	187.3	749	100.1	411	139.6	147	161.8	581	182.3	1,262	90.8	6,081	50.9
2010	1,939	193.3	539	98.1	383	143.0	138	134.8	642	196.5	1,232	101.8	5,926	53.5

Table A 3.6.13 Dry Mass Content and Residue Fraction of UK Crops for 2010

Crop Type	Fraction dry mass[b]	Residue/Crop
Broad Beans, Green Peas	0.08	1.1
Field Bean[d], Peas (harvest dry)	0.86	1.1
Rye, Mixed corn, Triticale	0.855[a]	1.6
Wheat, Oats	0.855[a]	1.3
Barley	0.855[a]	1.2
Oilseed Rape, Linseed	0.91a	1.2
Maize	0.50	1
Hops[c]	0.20	1.2
Potatoes	0.20	0.4
Roots, Onions	0.07	1.2
Brassicas	0.06	1.2
Sugar beet	0.1	0.2
Other	0.05	1.2
Phaseolus beans	0	1.2

[a]Defra (2002)
[b]Burton (1982), Nix (1997) or Defra estimates
[c]Hops dry mass from Brewers Licensed Retail Association (1998)
[d]Field beans dry mass from PGRE (1998)

The data for the ratio residue/crop are default values found under Agricultural Soils or derived from Table 4.17 in Field Burning of Agricultural Residues (IPCC, 1997). Crop production data are taken from Defra (2011a, 2011b).

A3.6.3.4 Crop Residues

Emissions of nitrous oxide from crop residues returned to soil are calculated using IPCC (2000) Tier 1b methodology, for non-N fixing and N-fixing crops, and IPCC default emission factors. They are given by:

$$N_2O_{(CR)} = \sum_i [(Crop_{Oi} \,.\, Res_{oi}/Crop_{oi} \,.\, FracDM_i \,.\, Frac_{(NCRO)} \,.\, (1-Frac_{Bi}) + \sum_j (Crop_{BFj} \,.\, Res_{BFj}/Crop_{BFj} \,.\, FracDM_j \,.\, Frac_{(NCRBF)} \,.\, (1-Frac_{Bj})] \,.\, EF_1 \,.\, 44/28$$

where

$N_2O_{(CR)}$	=	Emission of N_2O from crop residues (kg N_2O/yr)
$Crop_{Oi}$	=	Production of non-N fixing crop i (kg/yr)
$Frac_{(NCRO)}$	=	Fraction of nitrogen in non-N fixing crops
	=	0.015 kg N/kg dry mass
$FracDM_{i,j}$	=	Dry matter fraction of crop i, j.
$Res_{oi,BFj}/Crop_{oi,BFj}$	=	Residue to crop product mass ratio
$Frac_{Bi,j}$	=	Fraction of crop residue that is burnt rather than left on field
EF_1	=	Emission Factor for direct soil emissions
	=	0.0125 kg N_2O-N/kg N input
$Crop_{(BFj)}$	=	Production of legume crop j (kg/year)
$Frac_{(NCRBF)}$	=	Fraction of nitrogen in N fixing crop
	=	0.03 kg N/kg dry mass

Production data of crops are taken from Defra (2011a, 2011b) and are shown in **Table A 3.6.14**. The dry mass fraction of crops and residue fraction are given in **Table A 3.6.13**. Field burning has largely ceased in the UK since 1993. For years prior to

1993, field-burning data were taken from the annual MAFF Straw Disposal Survey (MAFF, 1995).

Table A 3.6.14 Production of UK Crops for 2010

Crop Type	Crop production, kt
Broad Beans	3.5
Field Beans	591.2
Peas green for market	0.0
Peas green for processing	186.4
All peas harvested dry	86.5
Rye, mixed corn, triticale	131.0
Wheat	14,878
Oats	685.3
Barley	5,251
OSR	2,232
Linseed	72.1
Maize	0
Sugar beet	8,330
Hops	0
Potatoes	6,115
Total roots & onions	1,544
Total brassicas	580.9
Total others	53.0
Phaseolus beans	15.6

A3.6.3.5 Histosols

Emissions from histosols were estimated using the IPCC (2000) default factor of 8 kg N_2O-N/ha/yr. The area of cultivated histosols is assumed to be equal to that of eutric organic soils in the UK and is based on a FAO soil map figure supplied by SSLRC (now NSRI).

A3.6.3.6 Grazing Animals

Emissions from manure deposited by grazing animals are reported under agricultural soils as required by IPCC. The proportion of N excretion estimated to be deposited at pasture, range and paddock (country-specific values from survey data) is multiplied by the default emission factor (IPCC, 2007).

A3.6.3.7 Organic Fertilizers

Emissions from animal manures and slurries used as organic fertilizers are reported under agricultural soils by IPCC. The calculation involves estimating the amount of nitrogen applied to the land and applying IPCC emission factors.

The methodology assumes that 20% of the total manure N applied to soil volatilises as NO_x and NH_3 and therefore does not contribute to N_2O emissions from AWMS. This is because in the absence of a more detailed split of NH_3 losses at the different stages of the manure handling process it has been assumed that NH_3 loss occurs prior to major N_2O losses.

For daily spreading of manure and application of previously stored manures to land, the emission is given by:

$N_2O_{(W)}$	=	$44/28 \cdot \sum_T (N_T \cdot Nex_{(T)} \cdot (1-Frac_{(GASM)}) \cdot AWMS_{(W)}) \cdot EF_1$

where

$N_2O_{(W)}$	=	N_2O emissions from daily spreading of wastes and organic fertiliser application (kg N_2O/yr)
N_T	=	Number of animals of type T
$Nex_{(T)}$	=	N excretion of animals of type T (kg N/animal/yr)
$Frac_{(GASM)}$	=	Fraction of livestock nitrogen excretion that volatilises as NH_3 and NO_x
	=	0.2 kg N/kg N
$AWMS_{(W)}$	=	Fraction of Nex that is managed in one of the different waste management systems of type W
EF_1	=	Emission Factor for direct soil emissions
	=	0.0125 kg N_2O-N/kg N input

The summation is for all animal types and manure that is daily spread or previously stored in categories defined as a) liquid, b) solid storage and dry lot and c) other (poultry manure without bedding or poultry manure with bedding (litter)).

A3.6.3.8 Application of sewage sludge to land

Emissions from sewage sludge used as fertilizer are reported under agricultural soils by IPCC. The calculation involves estimating the amount of nitrogen contained per dry matter unit of sludge and applying IPCC emission factors (see **Table A 3.6.15)**. The methodology assumes that 20% of the total sewage N applied to soil volatilises as NO_x and NH_3. The emissions are calculated as follows:

For the application of sewage sludge to land, the emissions were calculated as follows:

$N_2O_{(SEWSLUDGE)}$	=	$44/28 \cdot N_{SEWSLUDGE} \cdot (1-Frac_{(GASM)}) \cdot EF_1$

where

$N_2O_{(SEWSLUDGE)}$	=	N_2O emission from sewage sludge application
$N_{SEWSLUDGE}$	=	Total N from sewage sludge,
$Frac_{(GASM)}$	=	Fraction of sewage sludge emitted as $NO_x + NH_3$
	=	0.2 kg NH_3-N+NO_x -N/kg sewage sludge applied
EF1	=	Emission Factor for direct soil emissions
	=	0.0125 kg N_2O-N/kg N input

Table A 3.6.15 Nitrous oxide emissions from sewage sludge (kt N_2O/yr)

Year	Application of sewage sludge to land (t DM/yr)	Direct N_2O	Indirect N_2O from atmospheric deposition	Indirect N_2O from leaching and runoff
1990	499,000	0.282	0.056	0.212
1995	548,000	0.310	0.062	0.233
2000	582,261	0.329	0.066	0.247
2001	837,476	0.474	0.095	0.355
2002	843,020	0.477	0.095	0.358
2003	1,180,700	0.668	0.134	0.501
2004	1,231,800	0.697	0.139	0.523
2005	1,260,420	0.713	0.143	0.535

2006	1,313,488	0.743	0.149	0.557
2007	1,295,260	0.733	0.147	0.550
2008	1,404,160	0.794	0.159	0.596
2009	1,311,280	0.742	0.148	0.556
2010	1,411,541	0.799	0.160	0.599

A3.6.3.9 Improved grassland

Emissions from improved grassland are calculated using a nitrogen fixation rate of 4 kg N/ha/year (Lord, 1997) using the areas for grass under 5 years and permanent grassland. The fixation rate is based on expert opinion, taking into account the estimated proportion of clover in leys and permanent grassland.

A3.6.3.10 Atmospheric deposition of NO_x and NH_3

Indirect emissions of N_2O from the atmospheric deposition of ammonia and NO_x are estimated according to the IPCC (1997). The sources of ammonia and NO_x considered are synthetic fertiliser application and animal manures applied as fertiliser.

The contribution from synthetic fertilisers is given by:

$$N_2O_{(DSN)} = 44/28 \, . \, N_{(FERT)} \, . \, Frac_{(GASF)} \, . \, EF_4$$

where

$N_2O_{(DSN)}$	=	Atmospheric deposition emission of N_2O arising from synthetic fertiliser application (kg N_2O/yr)
$N_{(FERT)}$	=	Total mass of nitrogen applied as synthetic fertiliser (kg N/yr)
$Frac_{(GASF)}$	=	Fraction of total synthetic fertiliser nitrogen that is emitted as NO_x + NH_3
	=	0.1 kg N/kg N
EF_4	=	N deposition emission factor
	=	0.01 kg N_2O-N/kg NH_3-N and NO_x-N emitted

The indirect contribution from waste management systems is given by:

$$N_2O_{(DWS)} = 44/28. \, (N_{(EX)} - N_{(F)}) \, . \, Frac_{(GASM)} \, . \, EF_4$$

where

$N_2O_{(DWS)}$	=	Atmospheric deposition emission of N_2O arising from animal wastes (kg N_2O/yr)
$N_{(EX)}$	=	Total N excreted by animals (kg N/yr)
$Frac_{(GASM)}$	=	Fraction of livestock nitrogen excretion that volatilises as NH_3 and NO_x
	=	0.2 kg N/kg N
$N_{(F)}$	=	Total N content of wastes used as fuel (kg N/yr)

The indirect contribution from atmospheric deposition from sewage sludge applied to land is given by:

$N_2O_{(SEWSLUDGE)}$	=	44/28. $N_{(SEWSLUDGE)}$. $Frac_{(GASM)}$. EF_4

where

$N_2O_{(SEWSLUDGE)}$	=	Atmospheric deposition emission of N_2O arising from sewage sludge (kg N_2O/yr)
$N_{(SEWSLUDGE)}$	=	Total N from sewage sludge
$Frac_{(GASM)}$	=	Fraction of sewage sludge that volatilises as NH_3 and NO_x
	=	0.2 kg N/kg N

A3.6.3.11 Leaching and runoff

Indirect emissions of N_2O from leaching and runoff are estimated according the IPCC. The sources of nitrogen considered, are synthetic fertiliser application and animal manures applied as fertiliser.

The contribution from synthetic fertilisers is given by:

$N_2O_{(LSN)}$	=	44/28 . $N_{(FERT)}$. $Frac_{(LEACH)}$. EF_5

where

$N_2O_{(LSN)}$	=	Leaching and runoff emission of N_2O arising from synthetic fertiliser application (kg N_2O/yr)
$N_{(FERT)}$	=	Total mass of nitrogen applied as synthetic fertiliser (kg N/yr)
$Frac_{(LEACH)}$	=	Fraction of nitrogen input to soils lost through leaching and runoff
	=	0.3 kg N/kg fertiliser or manure N
EF_5	=	Nitrogen leaching/runoff factor
	=	0.025 kg N_2O-N /kg N leaching/runoff

The indirect contribution from waste management systems is given by:

$N_2O_{(LWS)}$	=	44/28. ($N_{(EX)}$ -$N_{(F)}$) . $Frac_{(LEACH)}$. EF_5

where

$N_2O_{(LWS)}$	=	Leaching and runoff emission of N_2O from animal wastes (kg N_2O/yr)
$N_{(EX)}$	=	Total N excreted by animals (kg N/yr
$N_{(F)}$	=	Total N content of wastes used as fuel (kg N/yr)
$N_{(AWMS)}$	=	Total N content of N_2O emissions from waste management systems including daily spread and pasture range and paddock (kg N_2O-N/yr)
$Frac_{(LEACH)}$	=	Fraction of nitrogen input to soils that is lost through leaching and runoff
	=	0.3 kg N/kg fertiliser or manure N
EF_5	=	Nitrogen leaching/runoff factor
	=	0.025 kg N_2O-N/kg N leaching/runoff

The indirect contribution from leaching from sewage sludge applied to land is given by:

$N_2O_{(SEWSLUDGE)}$	=	44/28. $N_{(SEWSLUDGE)}$. $Frac_{(LEACH)}$. EF_5

where

$N_2O_{(SEWSLUDGE)}$	=	Leaching and runoff emission of N_2O from sewage sludge (kg N_2O/yr)

$N_{(SEWSLUDGE)}$	=	Total N from sewage sludge (kg N/yr)
$Frac_{(LEACH)}$	=	Fraction of nitrogen input to soils that is lost through leaching and runoff
EF_5	=	Nitrogen leaching/runoff factor
	=	0.025 kg N_2O-N/kg N leaching/runoff

A3.6.4 Field Burning of Agricultural Residues (4F)

The National Atmospheric Emissions Inventory reports emissions from field burning under the category agricultural incineration. The estimates are derived from emission factors calculated according to IPCC (1997) and from USEPA (1997) shown in **Table A3.6.16**.

Table A 3.6.16 Emission Factors for Field Burning (kg/t)

	CH_4	CO	NO_x	N_2O	NMVOC
Barley	3.05[a]	63.9[a]	2.18[a]	0.060[a]	7.5[b]
Other	3.24[a]	67.9[a]	2.32[a]	0.064[a]	9.0[b]

[a]IPCC (1997)
[b]USEPA (1997)

The estimates of the masses of residue burnt of barley, oats, wheat and linseed are based on crop production data (Defra, 2011b) and data on the fraction of crop residues burnt (MAFF, 1995; ADAS, 1995b). Field burning ceased in 1993 in England and Wales. Burning in Scotland and Northern Ireland is considered negligible, as is grouse moor burning, so no estimates are reported from 1993 onwards. The carbon dioxide emissions are not estimated because under the IPCC Guidelines they are considered to be part of the annual carbon cycle. Field burning calculations have been included for years 1990-1993

A3.7 LAND USE, LAND USE CHANGE AND FORESTRY (CRF SECTOR 5)

The following section describes in detail the methodology used in the Land-Use Change and Forestry Sector. Further information regarding this Sector can be found in **Chapter 7**.

A3.7.1 Carbon stock changes due to afforestation and forest management (5A)

Carbon uptake by the forests planted since 1921 is calculated by a carbon accounting model (Dewar and Cannell 1992; Cannell and Dewar 1995; Milne *et al*. 1998) as the net change in pools of carbon in standing trees, litter, soil in conifer and broadleaf forests and in products. Restocking is assumed in all forests. The method is Tier 3, as defined in the Good Practice Guidance for LULUCF (IPCC 2003). Two types of input data and two parameter sets are required for the model (Cannell and Dewar 1995). The input data are: (a) areas of new forest planted in each year in the past, and (b) the stemwood growth rate and harvesting pattern. Parameter values are required to estimate (i) stemwood, foliage, branch and root masses from the stemwood volume and (ii) the decomposition rates of litter, soil carbon and wood products.

The estimates described here use the combined area of new private and state planting from 1921 to 2010 for England, Scotland, Wales and Northern Ireland sub-divided into conifers and broadleaves. The model is also used for forest in the Isle of Man (a Crown Dependency of the UK). Restocking is dealt with in the model through the second and subsequent rotations, which occur after clearfelling at the time of Maximum Area Increment (MAI). The key assumption is that the forests are harvested according to standard management tables. However, a comparison of forest census data over time has indicated that there are variations in the felling/replanting date during the 20th century, i.e. non-standard management. These variations in management have been incorporated into the forest model, and the methodology will be kept under review in future reporting.

The carbon flow model uses Forestry Commission Yield Tables (Edwards and Christie 1981) to describe forest growth after thinning commences and an expo-linear curve for growth before first thinning. It is assumed that all new conifer plantations have the same growth characteristics as Sitka spruce (Picea sitchensis (Bong.) Carr.) under an intermediate thinning management regime. Sitka spruce is the commonest species in UK forests being about 50% by area of conifer forests. Milne *et al*. (1998) have shown that mean Yield Class for Sitka spruce varied across Great Britain from 10-16 m^3 ha^{-1} a^{-1}, but with no obvious geographical pattern, and that this variation had an effect of less than 10% on estimated carbon uptake for the country as a whole. The Inventory data have therefore been estimated by assuming all conifers in Great Britain followed the growth pattern of Yield Class 12 m^3 ha^{-1} a^{-1}. In Northern Ireland Yield Class 14 m^3 ha^{-1} a^{-1} was used, based on the original assumptions by Cannell and Dewar (1995). Milne *et al*. (1998) showed that different assumptions for broadleaf species had little effect on carbon uptake. It is assumed that broadleaf forests have the characteristics of beech (Fagus sylvatica L.) of Yield Class 6 m^3 ha^{-1} a^{-1}. The most recent inventory of British woodlands (Forestry Commission 2002) that gives a species breakdown shows that beech occupies about 8% of broadleaf forest area (all ages) and no single species occupies greater than 25%. Beech was selected to represent all broadleaves as it has characteristics intermediate between fast growing species e.g. birch, and very slow growing species e.g. oak. However, using oak or birch Yield Class data instead of beech data has been shown to have an effect of less than 10% on the overall removal of carbon to UK forests (Milne *et al*. 1998). The use of beech as the representative species will be kept under review.

Irrespective of species assumptions, the variation in removals from 1990 to the present is determined by the afforestation rate in earlier decades and the effect this has on the age structure in the present forest estate, and hence the average growth rate. At the current rate of forest expansion removals of atmospheric carbon increased until 2004 and have now started to decrease, reflecting the reduction in afforestation rate after the 1970s. This afforestation is all on ground that has not been wooded for many decades. Table A 3.7.1 shows the afforestation rate since 1921 and a revised estimate of the present age structure of these forests.

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 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). As a result, the afforestation series for conifers in England and Wales were sub-divided into the standard 59 year rotation (1921-2004), a 49 year rotation (1921-1950) and a 39 year rotation (1931-1940, England only). 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).

In addition to these planted forests, there are about 1,195,000 ha of woodland planted prior to 1921 or not of commercial importance (in 1990). These forests are assumed to fall in Category 5.A.1 (Forest Land remaining Forest Land). It is evident from the comparison of historical forest censuses that some of this forest area is actively managed, but overall this category is assumed to be in carbon balance, either equilibrium or steady-cyclic. See the Forest land section in Chapter 7 for a discussion of this assumption.

Table A 3.7.1 Afforestation rate and age distribution of conifers and broadleaves in the United Kingdom since 1921

Period	Planting rate (kha a^{-1})			Age distribution	
	Conifers on all soil types	Conifers on organic soil	Broadleaves	Conifers	Broadleaves
1921-1930	5.43	0.54	2.44	1.2%	7.2%
1931-1940	7.46	0.73	2.13	2.2%	7.8%
1941-1950	7.43	0.82	2.22	5.3%	10.9%
1951-1960	21.66	3.06	3.09	13.9%	10.6%
1961-1970	30.08	5.28	2.55	19.8%	7.7%
1971-1980	31.38	7.61	1.14	19.5%	5.4%
1981-1990	22.31	6.05	2.19	16.8%	4.6%
1991	13.46	3.41	6.71	1.4%	1.0%
1992	11.56	2.97	6.48	1.4%	1.0%
1993	10.06	2.43	8.87	1.3%	1.2%
1994	7.39	1.74	11.16	1.1%	1.4%
1995	9.44	2.37	10.47	1.2%	1.2%
1996	7.42	1.79	8.93	1.1%	1.0%
1997	7.72	1.87	9.46	1.1%	1.1%
1998	6.98	1.62	9.67	1.1%	1.1%
1999	6.63	1.44	10.12	1.1%	1.1%
2000	6.53	1.37	10.91	1.1%	1.2%
2001	4.90	1.01	13.46	1.0%	1.4%
2002	3.89	0.76	10.03	0.9%	1.1%
2003	3.75	0.72	9.36	0.9%	1.0%
2004	2.92	0.59	8.88	0.9%	1.0%
2005	2.10	0.40	9.25	0.9%	1.1%
2006	1.14	0.21	7.12	0.8%	0.9%
2007	2.14	0.39	8.14	1.0%	1.0%
2008	0.86	0.14	6.11	0.9%	0.9%
2009	1.22	0.20	4.80	0.8%	0.8%
2010	0.54	0.08	4.60	0.7%	0.7%

Afforestation rates and ages of GB forests planted later than 1989 are from planting records. The age distribution for GB forests planted before 1990 is from the National Inventory of Woodland and Trees carried out between 1995 and 1999. The age distribution for pre-1990 Northern Ireland forests is estimated from planting records. Conifer planting on organic soil is a subset of total conifer planting. All broadleaf planting is assumed to be on non-organic soil.

Increases in stemwood volume were based on standard Yield Tables, as in Dewar and Cannell (1992) and Cannell and Dewar (1995). These Tables do not provide information for years prior to first thinning so a curve was developed to bridge the gap (Hargreaves *et al.* 2003). The pattern fitted to the stemwood volume between planting and first thinning from the Yield Tables follows a smooth curve from planting to first thinning. The formulation begins with an exponential pattern but progresses to a linear trend that merges with the pattern in forest management tables after first thinning.

The mass of carbon in a forest was calculated from volume by multiplying by species-specific wood density, stem:branch and stem:root mass ratios and the fraction of carbon in wood (0.5 assumed). The values used for these parameters for conifers and broadleaves are given in **Table A 3.7.1.**

The parameters controlling the transfer of carbon into the litter pools and its subsequent decay are given in **Table A 3.7.2**. Litter transfer rate from foliage and fine roots increased to a maximum at canopy closure. A fraction of the litter was assumed to decay each year, half of which was added to the soil organic matter pool, which then decayed at a slower rate. Tree species and Yield Class were assumed to control the decay of litter and soil matter. Additional litter was generated at times of thinning and felling. These carbon transfer parameters have been used to split the living biomass output from C-Flow between gains and losses.

Table A 3.7.2 Main parameters for forest carbon flow model used to estimate carbon uptake by planting of forests of Sitka spruce (P. sitchensis and beech (F. sylvatica) in the United Kingdom (Dewar & Cannell 1992)

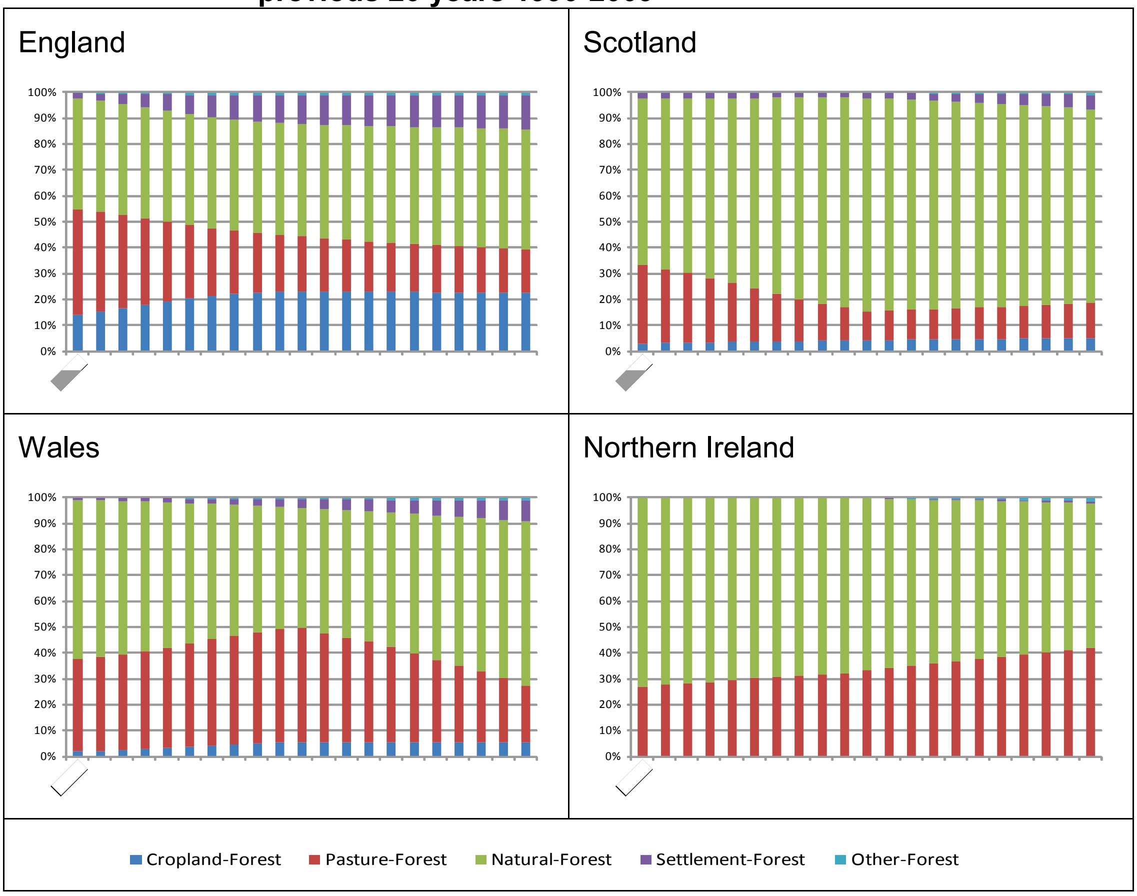
	P. sitchensis	***P. sitchensis***	***F. sylvatica***
	YC12	**YC14**	**YC6**
Rotation (years)	59	57	92
Initial spacing (m)	2	2	1.2
Year of first thinning	25	23	30
Stemwood density (t m^{-3})	0.36	0.35	0.55
Maximum carbon in foliage (t ha^{-1})	5.4	6.3	1.8
Maximum carbon in fine roots (t ha^{-1})	2.7	2.7	2.7
Fraction of wood in branches	0.09	0.09	0.18
Fraction of wood in woody roots	0.19	0.19	0.16
Maximum foliage litterfall (t ha^{-1} a^{-1})	1.1	1.3	2
Maximum fine root litter loss (t ha^{-1} a^{-1})	2.7	2.7	2.7
Dead foliage decay rate (a^{-1})	1	1	3
Dead wood decay rate (a^{-1})	0.06	0.06	0.04
Dead fine root decay rate (a^{-1})	1.5	1.5	1.5
Soil organic carbon decay rate (a^{-1})	0.03	0.03	0.03
Fraction of litter lost to soil organic matter	0.5	0.5	0.5
Lifetime of wood products	57	59	92

Estimates of carbon losses from the afforested soils are based on measurements taken at deep peat moorland locations, covering afforestation of peat from 1 to 9 years previously and at a 26 year old conifer forest (Hargreaves *et al*. 2003). These measurements suggest that long term losses from afforested peatlands are not as great as had been previously thought, settling to about 0.3 tC ha^{-1} a^{-1} thirty years after afforestation. In addition, a short burst of regrowth of moorland plant species occurs before forest canopy closure.

Carbon incorporated into the soil under all new forests is included, and losses from pre-existing soil layers are described by the general pattern measured for afforestation of deep peat with conifers. The relative amounts of afforestation on deep peat and other soils in the decades since 1920 are considered. For planting on organo-mineral and mineral soils, it is assumed that the pattern of emissions after planting will follow that measured for peat, but the emissions from the pre-existing soil layers will broadly be in proportion to the soil carbon density of the top 30 cm relative to that same depth of deep peat. A simplified approach was taken to deciding on the proportionality factors, and it is assumed that emissions from pre-existing soil layers will be equal to those from the field measurements for all planting in Scotland and Northern Ireland and for conifer planting on peat in England and Wales. Losses from broadleaf planting in England and Wales are assumed to proceed at half the rate of those in the field measurements. These assumptions are based on consideration of mean soil carbon densities for non-forest in the fully revised UK soil carbon database. The temporary re-growth of ground vegetation before forest canopy closure is, however, assumed to occur for all planting at the same rate as for afforested peat moorland. This assumption agrees with qualitative field observations at plantings on agricultural land in England.

The C-Flow model was originally spreadsheet-based but has been translated into Matlab (Mathworks 2010) scripts. This allows greater flexibility for further model development, integration with other parts of the LULUCF inventory and partitioning of results according to the required output (UNFCCC inventory, KP-LULUCF inventory, national/regional). The C-Flow model outputs were restructured in 2010 to use 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. 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 inventory year (**Figure A 3.7.1**).

Figure A 3.7.1 Proportional land use contribution to forest conversion in the previous 20 years 1990-2009



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

It is assumed in the C-Flow model that harvested material from thinning and felling is made into wood products. This is described further in Section A3.7.10. The net change in the carbon in this pool of wood products is reported in Category 5G.

Nitrogen fertilization of forest land is assumed to occur only when absolutely necessary, i.e. new planting on ‘poor’ soils (slag heaps, 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 C-Flow model for 5.A.2. Land converted to Forest land.

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 c. 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 emission factor for N_2O of applied nitrogen fertiliser is the default value of 1% used in the IPCC 2006 Guidelines. Emissions of N_2O from N fertilisation of forests have fallen since 1990 due to reduced rates of new forest planting.

A3.7.2 Land Use Change and Soils (5B, 5C, 5E)

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

A3.7.2.1 Land Use Change Matrices

For Great Britain (England, Scotland and Wales), matrices from the Monitoring Landscape Change (MLC) data from 1947 & 1980 (MLC 1986) and the Countryside Surveys (CS) of 1984, 1990, 1998 (Haines-Young *et al*. 2000) and 2007 (Smart *et al*. 2010) 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 is land use areas from The Agricultural Census and The Forest Service (Cruickshank and Tomlinson 2000). Matrices of land use change were estimated for 1970-79 and 1980-89 using area data. The relationship between the matrix of land use transitions and initial area from recent countryside surveys is assumed to be the same as the relationship between the matrix and area data for each of the earlier periods – 1970-79 and 1980-89. The matrices developed in this approach were used to extrapolate areas of land use transition back to 1950 to match the start year in the rest of the UK.

The Good Practice Guidance for Land Use, Land Use Change and Forestry (IPCC 2003) recommends use of six types of land for descriptive purposes: Forest, Grassland, Cropland, Settlements, Wetlands and Other Land. Only areas undergoing active commercial peat extraction and areas of inland water are reported under Wetlands in the current inventory, so the remaining land in the UK has been placed into the five other types. The more detailed habitats for the two surveys in Great Britain were combined as shown in Table A 3.7.3 for the Monitoring Landscape Change dataset and Table A 3.7.4 for the Countryside Survey dataset.

Table A 3.7.3 Grouping of MLC land cover types for soil carbon change modelling

CROPLAND	GRASSLAND	FORESTLAND	SETTLEMENTS (URBAN)	OTHER
Crops	Upland heath	Broadleaved wood	Built up	Bare rock
Market	Upland smooth	Conifer wood	Urban open	Sand/shingle

CROPLAND	GRASSLAND	FORESTLAND	SETTLEMENTS (URBAN)	OTHER
garden	grass			
	Upland coarse grass	Mixed wood	Transport	Inland water
	Blanket bog	Orchards	Mineral workings	Coastal water
	Bracken		Derelict	
	Lowland rough grass			
	Lowland heather			
	Gorse			
	Neglected grassland			
	Marsh			
	Improved grassland			
	Rough pasture			
	Peat bog			
	Fresh Marsh			
	Salt Marsh			

Table A 3.7.4 Grouping of Countryside Survey Broad Habitat types 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 2007 are shown in Table A 3.7.5 and Table A 3.7.6. The land use change data over the different periods were used to estimate annual changes by assuming that these were uniform across the measurement period. Examples of these annual changes (for the period 1998 to 2007) are given in Table A 3.7.7 to Table A 3.7.10.

Table A 3.7.5 Sources of land use change data in Great Britain for different periods in estimation of changes in soil carbon

Year or Period	Method	Change matrix data
1950-1979	Measured LUC matrix	MLC 1947->MLC1980
1980 - 1984	Interpolated	CS1984->CS1990
1984 - 1989	Measured LUC matrix	CS1984->CS1990
1990 - 1998	Measured LUC matrix	CS1990->CS1998
1999-2007	Measured LUC matrix	CS1998->CS2007
2008-2010	*Extrapolated*	CS1998->CS2007

Table A 3.7.6 Sources of land use change data in Northern Ireland for different periods in estimation of changes in soil carbon.

NICS = Northern Ireland Countryside Survey

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
2008-2010	*Extrapolated*	NICS1998->NICS2007

Table A 3.7.7 Annual changes (000 ha) in land use in England in matrix form for 2000 to 2009.

Based on land use change between 1998 and 2007 from Countryside Surveys (Smart *et al*. 2010). Data have been rounded to 100 ha and adjusted for deforestation (see section A.3.7.4)

From / To	Forestland	Grassland	Cropland	Settlements
Forestland		5.83	2.01	1.07
Grassland	0.57		72.66	4.79
Cropland	0.03	35.44		0.11
Settlements	0.17	5.30	4.57	

Table A 3.7.8 Annual changes (000 ha) in land use in Scotland in matrix form for 2000 to 2009.

Based on land use change between 1998 and 2007 from Countryside Surveys (Smart *et al*. 2010). Data have been rounded to 100 ha and adjusted for deforestation (see section A.3.7.4)

From / To	Forestland	Grassland	Cropland	Settlements
Forestland		4.02	0.30	0.60
Grassland	0.26		18.84	2.12
Cropland	0.00	9.52		0.01
Settlements	0.03	1.58	0.59	

Table A 3.7.9 Annual changes (000 ha) in land use in Wales in matrix form for 2000 to 2009.

Based on land use change between 1998 and 2007 from Countryside Surveys (Smart *et al*. 2010). Data have been rounded to 100 ha and adjusted for deforestation (see section A.3.7.4)

To \ From	Forestland	Grassland	Cropland	Settlements
Forestland		1.48	0.07	0.16
Grassland	0.04		3.53	0.54
Cropland	0.00	3.99		0.03
Settlements	0.03	1.24	0.03	

Table A 3.7.10 Annual changes (000 ha) in land use in Northern Ireland in matrix form for 2000 to 2009.

Based on land use change between 1998 and 2007 from Northern Ireland Countryside Surveys (Cooper, McCann and Rogers 2009). Data have been rounded to 100 ha and adjusted for deforestation (see section A.3.7.4)

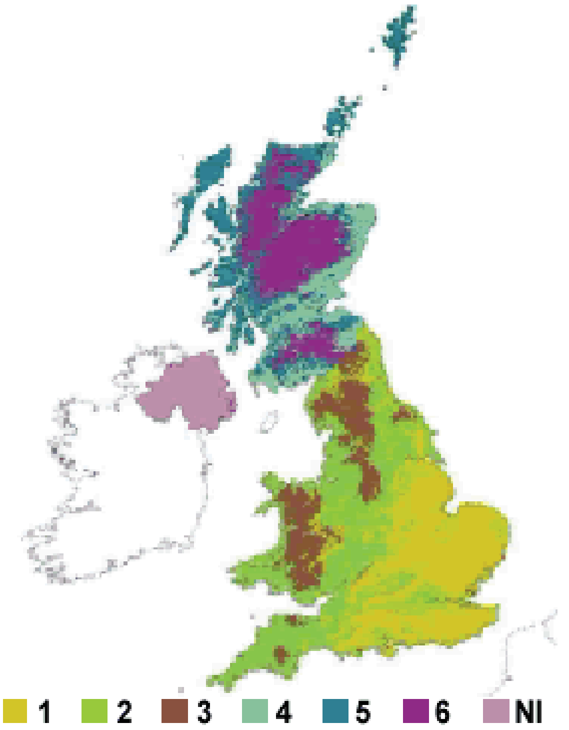
To \ From	Forestland	Grassland	Cropland	Settlements
Forestland		2.20	0.01	0.05
Grassland	0.05		4.01	0.25
Cropland	0.0	3.15		0.00
Settlements	0.04	2.07	0.06	

Data from the Countryside Survey 2007 (Smart *et al*. 2010) were used for the first time for the 2011 inventory submission. The transitions between habitat types were calculated with Geographical Information System software (arcGIS) using the following method.

We identified 544 Countryside Survey squares of Great Britain that coincided between the 1998 and 2007 surveys. Survey square locations are confidential. For each coincident square, we calculated the area that changed from one habitat type in 1998 to another in 2007. There are 47 broad habitats described by the Countryside Survey. Individual surveyed squares contain a subset of these habitats and changes between habitats are called transitions. Each coincident survey square also has a 'land class' assigned to it that doesn't change between survey years. There are currently 45 land classes in the Land Classification of Great Britain. Land classes represent the stratification of environments across the UK. A simplified picture of the stratification is shown in **Figure A 3.7.2**.

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

Figure A 3.7.2 Stratification of environments across the UK with areas 1 to 6 based on the underlying Land Classification (45 classes).



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

A3.7.2.2 Soils modelling

A database of soil carbon density for the UK (Milne & Brown 1997, Cruickshank *et al*. 1998, Bradley *et al*. 2005) is used in conjunction with the land use change matrices. There are three soil survey groups covering the UK and the field data, soil classifications and laboratory methods have been harmonized to reduce uncertainty in the final joint database. The depth of soil considered was also restricted to 1 m at maximum as part of this process. Table A 3.7.11 shows total stock of soil carbon (1990) for different land types in the four devolved areas of the UK.

Table A 3.7.11 Soil carbon stock (TgC = MtC) for depths to 1 m in different land types in the UK

Region / Type	England	Scotland	Wales	N. Ireland	**UK**
Forestland	108	295	45	20	467
Grassland	995	2,349	283	242	3,870
Cropland	583	114	8	33	738
Settlements	54	10	3	1	69
Other	0	0	0	0	-
TOTAL	**1,740**	**2,768**	**340**	**296**	**5,144**

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

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

where

C_t is carbon density at time t
C_0 is carbon density initial land use
C_f is carbon density after change to new land use
k is time constant of change

By differentiating we obtain the equation for flux f_t (emission or removal) per unit area:

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

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

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

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

In the model, we calculate the change in equilibrium carbon density from the initial to the final land use during a transition. These are calculated for each land use category as averages for Scotland, England, Wales and Northern Ireland. These averages are weighted by the area of Land Use Change occurring in four broad soil groups (organic, organo-mineral, mineral, unclassified) in order to account for the actual carbon density where change has occurred.

Hence mean soil carbon density change is calculated as:

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

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

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

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

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

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

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

The land use data (1990 to 1998) is used in the weighting (this will be updated). The averages calculated are presented in **Table A 3.7.12-15.**

Table A 3.7.12 Weighted average change in equilibrium soil carbon density (t ha^{-1}) to 1 m deep for changes between different land types in England

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

Table A 3.7.13 Weighted average change in equilibrium soil carbon density (t ha^{-1}) to 1 m deep for changes between different land types in Scotland

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

Table A 3.7.14 Weighted average change in equilibrium soil carbon density (t ha^{-1}) to 1 m deep for changes between different land types in Wales

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

Table A 3.7.15 Weighted average change in equilibrium soil carbon density (t ha^{-1}) to 1 m deep for changes between different land types in Northern Ireland

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

The rate of loss or gain of carbon is dependent on the type of land use transition (Table A 3.7.16). 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 expert judgement. These are shown in Table A 3.7.17.

Table A 3.7.16 Rates of change of soil carbon for land use change transitions.

("Fast" & "Slow" refer to 99% of change occurring in times shown in Table A3.7.17)

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

Table A 3.7.17 Range of times for soil carbon to reach 99% of a new value after a change in land use in England (E), Scotland (S) and Wales (W)

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

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

A Monte Carlo approach is used to vary the rate of change, the area activity data and the values for soil carbon equilibrium (under initial and final land use) for all countries in the UK. The model of change was run 1000 times using parameters selected from within the ranges described above. The mean carbon flux for each region resulting from this imposed random variation is reported as the estimate for the Inventory. An adjustment was made to these calculations for each country to remove increases in soil carbon due to afforestation, as the C-Flow 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.

For the 2010 inventory, the soil carbon model was run at 20x20km scale i.e. the carbon stock change in soils is calculated for a 20 x 20 km grid covering the UK. Previously, modelling has been carried out at national scales using land use change matrices, spatially disaggregated to England Scotland Wales and Northern Ireland. We are moving towards modelling at finer spatial scales and then summing to obtain carbon fluxes at Devolved Authority scales for the National Inventory.

Reporting in categories 5.B Cropland, 5.C Grassland and 5.E Settlements has been restructured in this inventory submission to use the 20-year transition period for land use conversion before reporting in the Land remaining Land sub-categories.

A3.7.3 Changes in stocks of carbon in non-forest biomass due to land use change (5B2, 5C2, 5E2)

Changes in stocks of carbon in biomass due to land use change are based on the same area matrices used for estimating changes in carbon stocks in soils (see previous section). The biomass carbon density for each land type is assigned by expert judgement based on the work of Milne and Brown (1997) and these are shown in Table A 3.7.18. Five basic land uses were assigned initial biomass carbon densities, and then the relative occurrences of these land uses in the four countries of the UK were used to calculate mean densities for each of the IPCC types, Cropland, Grassland and Settlements. Biomass carbon stock changes due to conversions to and from Forest Land are dealt with elsewhere.

The mean biomass carbon densities for each land type were further weighted by the relative proportions of change occurring between land types (Table A 3.7.19 - 22), in the same way as the calculations for changes in soil carbon densities. Changes between these equilibrium biomass carbon densities were assumed to happen in a single year.

Table A 3.7.18 Equilibrium biomass carbon density (kg m^{-2}) for different land types

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

Table A 3.7.19 Weighted average change in equilibrium biomass carbon density (kg m^{-2}) for changes between different land types in England

(Transitions to and from Forestland are considered elsewhere)

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

Table A 3.7.20 Weighted average change in equilibrium biomass carbon density (kg m^{-2}) for changes between different land types in Scotland.

(Transitions to and from Forestland are considered elsewhere)

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

Table A 3.7.21 Weighted average change in equilibrium biomass carbon density (kg m^{-2}) for changes between different land types in Wales.

(Transitions to and from Forestland are considered elsewhere)

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

Table A 3.7.22 Weighted average change in equilibrium biomass carbon density (kg m^{-2}) for changes between different land types in Northern Ireland.

(Transitions to and from Forestland are considered elsewhere)

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

A3.7.4 Carbon stock changes and biomass burning emissions due to Deforestation (5B, 5C, 5E, 5G)

Deforestation is an activity that cuts across LULUCF categories, affecting net emissions and removals in all the land use categories except 5D Wetlands. The process of land use change affects carbon stock changes in biomass and soil, and the woody material left after felling either moves into the harvested wood products pool or is assumed to be burnt on-site, resulting in immediate biomass burning emissions.

Levy and Milne (2004) discuss methods for estimating deforestation since 1990 using a number of data sources. This approach of combining Forestry Commission felling licence data for rural areas with Ordnance Survey data for non-rural areas has been expanded to include new sources of information and to improve coverage of all countries in the UK. Deforestation before 1990 (which contributes to soil carbon stock changes from historical land use change) is estimated from the land use change matrices described in **A3.7.2**.

A3.7.4.1 Activity datasets

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 Woodland Grant Scheme. Under the Forestry Act 1967, there is a presumption that the felled areas will be restocked, usually by replanting but sometimes by natural regeneration. Thus, in the 1990s, around 14,000 ha a^{-1} were felled and restocked. However, some licences are granted without the requirement to restock, where there is good reason – so-called unconditional felling licences. A felling licence is not required only under certain conditions (http://www.forestry.gov.uk/forestry/INFD-6DFKW6), e.g. if felling is allowed as part of planning permission (for building work) or for service maintenance (for gas, water, electricity). Most unconditional felling licence applications are for small areas (6.8 ±19.2 ha), but their summation gives some indication of areas deforested. In previous years these areas have not been published, but figures from the Forestry Commission were collated for England.

Spatial datasets are now available (http://www.forestry.gov.uk/datadownload) for England (1999-present), Scotland (1998-present) and Wales (1996-present).

Felling for urban development (with no requirement to restock) can be allowed under planning permission but only local planning authorities hold documentation for this, and the need for collation makes estimating the national total difficult. However, in England, the Ordnance Survey (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)

(http://www.communities.gov.uk/planningandbuilding/planningbuilding/planningstatistics/landusechange/). DCLG provide an extract of this dataset, listing annual land use change from forestry and woodland 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, 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 A3.7.2**) 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 woodland conversion compared with the extent estimated by the Forestry Commission. This is due to differences in woodland definitions, amongst other causes.

A3.7.4.2 Compilation of activity datasets

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 is available) and to estimate the conversion to different land use categories[10]. The DCLG data is used to estimate the area of Forest Land converted to Settlement (5.E.2.1). The unconditional felling licence data is used to estimate the area of Forest Land converted to Cropland (5.B.2.1) and of Forest Land converted to Grassland (5.C.2.1). The split between the Cropland and Grassland categories is based on the proportional split between forest to grassland conversion and forest to cropland conversion in the most recent Countryside Surveys. 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 than genuine land use change.

The CS data is used to estimate the relative split of woodland conversion between grassland, cropland and settlements (Table A.3.7. 23), using other known data (e.g. felling licences) to 'discount' the CS areas where datasets overlap in time (Table A.3.7. 24). There is no non-CS data for Northern Ireland so the discount rates for England or Wales are used, depending on availability. The 1990-98 discount rates are also applied to the pre-1990 CS land use change estimates. These changes in the method compared to previously have led to average increase of 0.27 kha a^{-1} (1990-2010) in the estimated area of deforestation in the UK, with a

[10] Discussion with Northern Ireland experts confirmed that there are no direct and comprehensive datasets on woodland loss available. 127 ha of deforestation between 2000 and 2006 is recorded in Environmental Impact Assessments but these do not cover all developments. A new Forestry Act has now introduced felling licences, so it may be possible to obtain direct data in the future.

cumulative area of 26.3 kha in 2009 compared to an estimate of 20.9 kha in the 2009 inventory.

The annual area of forest converted to other land uses is removed from the area of 5A1 Forest Land remaining Forest Land to maintain consistency in the land area matrix.

Table A.3.7. 23: Countryside Survey data for woodland conversion

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

Table A.3.7. 24: "Discounted" woodland conversion rates

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

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

A3.7.4.3 Estimation of emissions

Soil carbon stock changes are estimated using the dynamic soil carbon model described in **section A.3.7.2**. When deforestation it is assumed that 60% of the standing biomass is removed as timber products and the remainder is burnt. A standing biomass of 240 tonnes ha^{-1} (broadleaved timber) is assumed. Biomass losses are reported in the relevant carbon stock change tables (assuming a carbon fraction of 0.5). The carbon removed as timber is reported as harvested wood products (HWP) in 5G, using a lookup table of HWP carbon flux in the years following felling (described in **section A.3.7.10**).

Direct and indirect greenhouse gas emissions from associated biomass burning is estimated using the Tier 1 methodology described in the IPCC 1996 guidelines (IPCC 1997 a, b, c). Only immediate losses are considered because sites are normally completely cleared for development, leaving no debris to decay.

A3.7.5 Biomass Burning – Forest Wildfires (5A)

A3.7.5.1 Activity dataset

Estimates of the area burnt in wildfires 1990-2004 are published in different locations (FAO/ECE 2002; Forestry Commission 2004; FAO 2005) but all originate from either the Forestry Commission (Great Britain) or the Forest Service (Northern Ireland). No data on areas burnt in wildfires in Great Britain has been collected or published since 2004, but areas of wildfires are reported annually for Northern Ireland. Activity data for 2005-2010 is extrapolated using a Burg regression equation based on the trend and variability of the 1990-2004 dataset (**Table A 3.7.25**). These areas refer only to fire damage in state forests; no information is collected on fire damage in privately owned forests. The area of private-owned forest that was burnt each year was assumed to be in proportion to the percentage of the state forest that was burnt each year. An estimated 955 ha of forest was burnt on average every year (the sum of state-owned and privately-owned forests) between 1990 and 2010.

Table A 3.7.25 Area burnt in wildfires in state (Forestry Commission) forests 1990-2010 (* indicates an estimated area)

Year	Area burnt, ha			
	Great Britain	Northern Ireland	UK	% UK forest area burnt
1990	185	127	312	0.0325%
1991	376*	88*	464	0.0486%
1992	92*	22*	114	0.0120%
1993	157*	37*	194	0.0206%
1994	123*	24	147	0.0158%
1995	1023*	16	1039	0.1127%
1996	466	94	560	0.0613%
1997	585	135	720	0.0796%
1998	310	22	332	0.0371%
1999	45	9	54	0.0061%
2000	165	6	171	0.0193%
2001	181	85	266	0.0309%
2002	141	85	226	0.0264%
2003	147	1	148	0.0175%
2004	146	91	237	0.0281%
2005	5*	75*	80*	0.0096%
2006	429*	3*	432*	0.0519%
2007	454*	55	508*	0.0614%

Year	Area burnt, ha			
	Great Britain	Northern Ireland	UK	% UK forest area burnt
2008	427*	35	462*	0.0562%
2009	270*	18	288*	0.0354%
2010	237*	0	237*	0.0271%

A3.7.5.2 Estimation of emissions

The method for estimating emissions of CO_2 and non-CO_2 gases from wildfires within managed forests is that described in the GPG LULUCF (**Section 3.2.1.4**). Emissions from all forest wildfires are reported under 5A1 Forest Land remaining Forest Land, and IE reported under 5A2.

There is no information on the type (conifer or broadleaf) or age of forest that is burnt in wildfires in the UK. Therefore, the amount of biomass burnt is estimated from the mean forest biomass density in each country of the UK, as estimated by the C-Flow model. These densities vary with time due to the different afforestation histories in each country (**Table A 3.7.26**).

Table A 3.7.26 Biomass densities, tonnes DM ha^{-1}, used to estimate mass of available fuel for wildfires

Year	Forest biomass density, tonnes DM ha^{-1}				
	England	Scotland	Wales	Northern Ireland	UK
1990	92.4	59.5	84.8	88.2	71.4
1995	97.9	69.6	96.1	98.1	80.4
2000	102.5	79.5	102.5	107.2	88.6
2005	110.6	93.7	120.5	117.7	101.5
2010	115.4	105.2	130.3	122.5	110.9

A combustion efficiency of 0.5 is used with a carbon fraction of dry matter of 0.5 to estimate the total amount of carbon released, and hence emissions of CO_2 and non-CO_2 gases (using the IPCC emission ratios).

A3.7.6 Liming of Agricultural Soils (5B1, 5C1)

A3.7.6.1 Activity data

The amount of lime, dolomite and chalk produced for agricultural use annually in Great Britain is reported in the Annual Minerals Raised Inquiry (ONS 2010) (available from 1994). All such minerals are assumed to be used within Great Britain in the year of production. Only dolomite is subjected to calcination. However, some of this calcinated dolomite is not suitable for steel making and is returned for addition to agricultural dolomite – this fraction is reported annually by the Office of National Statistics (ONS 2010) as ‘material for calcination’ under agricultural end use. Calcinated dolomite, having already had its CO_2 removed, will therefore not cause the emissions of CO_2 and hence is not included here. Lime (calcinated limestone) is also used for carbonation in the refining of sugar but this is not specifically dealt with in the LULUCF sector. The amount of lime purchased annually for agricultural use in Northern Ireland is reported in the Northern Ireland Statistical review (Department of Agriculture and Rural Development 2011). It is assumed that this is all limestone, as there are limestone deposits but no dolomite deposits in Northern Ireland.

In the UK lime is applied to both grassland and cropland. Totals areas of grassland and cropland are obtained from the annual agricultural census data (Defra 2010). The annual percentages of arable and grassland areas receiving lime in Great Britain for 1994-2010 were obtained from the Fertiliser Statistics Report (Agricultural Industries Confederation 2006), and the British Survey of Fertiliser Practice (BSFP 2011). Percentages for 1990-1993 were assumed to be equal to those for 1994.

A3.7.6.2 Estimation of emissions

The method for estimating CO_2 emissions due to the application of lime and related compounds is that described in the IPCC 1996 Guidelines. The percentages of grassland and cropland where agricultural lime is applied are used to split CO_2 emissions between the Cropland and Grassland categories. For limestone and chalk, an emission factor of 120 tC/kt applied is used, and for dolomite application, 130 tC/kt. These factors are based on the stoichiometry of the reaction and assume pure limestone/chalk and dolomite.

A3.7.7 Lowland Drainage (5B1)

Lowland wetlands in England were drained many years ago for agricultural purposes and continue to emit carbon from the soil. Bradley (1997) described the methods used to estimate these emissions. The baseline (1990) for the area of drained lowland wetland for the UK was taken as 150,000 ha. This represents all of the East Anglian Fen and Skirtland and limited areas in the rest of England. This total consists of 24,000 ha of land with thick peat (more than 1 m deep) and the rest with thinner peat. Different loss rates were assumed for these two thicknesses as shown in Table A.3.7. 27. The large difference between the implied emission factors is due to the observation that peats described as 'thick' lose volume (thickness) more rapidly than peats described as 'thin'. The 'thick' peats are deeper than 1m, have 21% carbon by mass and in general have different texture and less humose topsoil than the 'thin' peats, which have depths up to 1m (many areas ~0.45 m deep) and carbon content of 12% by mass.

Table A.3.7. 27: Area and carbon loss rates of UK fen wetland in 1990

	Area	Organic carbon content	Bulk density kg m^{-3}	Volume loss rate $m^3\ m^{-2}\ a^{-1}$	Carbon mass loss GgC a^{-1}	Implied emission factor gC $m^{-2}\ a^{-1}$
'Thick' peat	$24x10^7$ m^2 (24,000 ha)	21%	480	0.0127	307	1280
'Thin' peat	$126x10^7$ m^2 (126,000 ha)	12%	480	0.0019	138	109
Total	**$150x10^7$ m^2 (150 kha)**				**445**	**297**

The emissions trend since 1990 was estimated assuming that no more fenland has been drained since then but that existing drained areas have continued to lose carbon.

The annual loss for a specific location decreases in proportion to the amount of carbon remaining. Furthermore, as the peat loses carbon it becomes more mineral in structure. The Century model of plant and soil carbon was used to average the carbon losses from these fenland soils over time (Bradley 1997): further data on how these soil structure changes proceed with time is provided in Burton (1995). A current project is looking at extending this methodology to other parts of the UK if suitable activity data is available.

A3.7.8 Changes in Stocks of Carbon in Non-Forest Biomass due to Yield Improvements (5B1)

There is an annual increase in the biomass of cropland vegetation in the UK that is due to yield improvements (from improved species strains or management, rather than fertilization or nitrogen deposition). Under category 5.B.1 an annual value is reported for changes in carbon stock, on the assumption that the annual average standing biomass of cereals has increased linearly with increase in yield between 1980 and 2000 (Sylvester-Bradley *et al*. 2002).

A3.7.9 On-site and off-site emissions from peat extraction (5D)

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 5D.

A3.7.9.1 Activity datasets

Separate activity datasets have been compiled for Northern Ireland and for Great Britain (England, Scotland and Wales). Information for Northern Ireland is taken from papers by Cruikshank and Tomlinson (1997) and Tomlinson (2010). These provide estimates of the extent of peat extraction in 1990-1991 and 2007-2008 by different methods (mechanical extraction, sod-cutting and hand-cutting) and by different end uses (fuel or horticultural peat) (**Table A.3.7.** 28). Estimates for 1992-2006 were interpolated and the estimate for 2010 was assumed to be the same as that for 2008.

Table A.3.7. 28: Activity data for peat extraction sites in Northern Ireland

End use	Method	Area in 1990-1991, ha	Area in 2007-2008, ha
Fuel	Mechanical	3855	329
Fuel	Hand-cutting	107	16
Horticultural	57% vacuum harvesting, 22% mechanical extraction, 18% sod cutting, 3% turfs	576	
Horticultural	95% vacuum harvesting, 5% mechanical extraction		689

For Great Britain areas undergoing peat extraction in 1991 were calculated using the GB area of peat with planning permission (7598 ha) and splitting it between the three countries in proportion to their production volume in 1991 (for both horticultural and fuel peat). Areas of extraction in 2002, 2005 and 2010 (Table A.3.7. 29) were estimated using the Directory of Mines and Quarries point locations with Google Earth imagery (see **Chapter 7**, **Section 7.5.2**). Extraction sites were defined as producing peat for horticultural or for energy use in the latest Directory of Mines and Quarries (Cameron *et al.* 2010). A time series was constructed using linear interpolation. Areas of extraction declined between 1991 and 2009 by 22% in England and 13% on horticultural sites and 52% on fuel sites in Scotland. There is no reported peat production in Wales but five sites are recorded in the Directory of Mines and Quarries (the only site that is visible in the Google Earth imagery is very close to the English border and it is possible that any production from this site is reported in the England production totals). The area of these sites was used for the whole of the time period.

Table A.3.7. 29: Activity data for peat extraction sites in England, Scotland and Wales

Country	Area in 1991, ha	Area in 2002, ha	Area in 2005, ha	Area in 2010, ha
England	5854	4755	4634	4614
Scotland	1734	1471	1469	1296
Horticultural	*1174*	*1285*	*1246*	*1074*
Fuel	*560*	*186*	*223*	*223*
Wales	482	482	482	482

Annual production in Great Britain is inferred from extractor sales by volume as published in the "Annual Minerals Raised Inquiry" report (ONS 2010). This gives a breakdown for horticultural and other uses of peat (assumed to be fuel) for English regions and for Scotland (no peat extraction is reported in Wales) (**Table A 3.7.30**). Annual production is highly variable because extraction methods depend on suitable summer weather for drying peat.

Table A 3.7.30 Annual peat production, m^3 for England and Scotland (from Annual Minerals Raised Inquiry/Mineral Extraction in Great Britain reports)

Year	England		Scotland	
	Horticultural	Fuel	Horticultural	Fuel
1990	1,116,940	2,727	293,170	93,163
1991	1,202,000	2,000	241,000	115,000
1992	1,079,000	4,000	332,000	91,000
1993	1,069,820	2,180	306,511	73,489
1994	1,375,000	1,000	498,000	108,000
1995	1,578,000	2,000	657,000	44,000
1996	1,313,000	2,000	517,000	53,000
1997	1,227,000	2,000	332,000	59,000
1998	936,000	0	107,000	32,000
1999	1,224,000	0	392,000	37,000
2000	1,258,000	1,000	336,000	31,000
2001	1,459,000	1,000	325,000	30,000
2002	856,000	1,000	107,000	10,000
2003	1,227,000	1,000	741,000	38,000
2004	902,000	1,000	338,000	21,000
2005	927,000	1,000	556,000	21,000
2006	856,000	1,000	712,000	24,000
2007	654,000	0	221,000	10,000
2008	455,000	0	243,000	16,630
2009	476,000	0	390,000	21,000
2010*	476,000	0	390,000	21,000

* The latest statistics were not published in time for inclusion in this submission, so the volumes for 2010 were carried forward from 2009

A3.7.9.2 Estimation of emissions

Default on-site emission factors for Tier 1 reporting are published in the IPCC guidance (2006). Peat extracted for horticultural use is inferred to be from oligotrophic (nutrient-poor) bogs, with a default EF of 0.2 tonnes C/ha/yr (uncertainty 0 – 0.63). Peat for fuel is inferred to be from mineratrophic (nutrient-rich) fens or bogs, with an EF of 1.1 tonnes C/ha/yr (uncertainty 0.06 to 7.0). The default EF for N_2O from drained wetlands (nutrient-rich) is 1.8 kg N_2O-N/ha/yr.

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 by Dinsmore (in review). This is higher than the previously used factor of 0.0557 (Cruikshank and Tomlinson 1997) but slightly lower than the default emission factor of 0.07 tonnes C m^{-3} air-dry peat for nutrient-poor peats.

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

Emissions from vacuum harvesting production =
area * annual depth of extraction * carbon fraction by volume
where
Annual depth of extraction by vacuum harvesting, m/ha = 0.1
Carbon fraction of air-dry peat by volume, tonnes C/m3 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%

A3.7.10 Harvested Wood Products (5G)

The activity data used for calculating this activity is the annual forest planting rates. C-Flow assumes an intermediate thinning management regime with clear-felling and replanting at the time of Maximum Area Increment (57 or 59 years for conifers and 92 years for broadleaves). Hence, for a given forest stand, carbon enters the HWP pool when thinning is undertaken (depending on the species first thinning occurs c. 20 years after planting) and when harvesting takes place. Timber produced as a result of Forest conversion to Cropland, Grassland or Settlement is also added to the HWP pool.

A living biomass carbon stock loss of 5% is assumed to occur immediately at harvest (this carbon is transferred to the litter or soil pools). The remaining 95% is transferred to the HWP pool. The residence times of wood products in the HWP pool depend on the type and origin of the products and are based on exponential decay constants. Residence times are estimated as the time taken for 95% of the carbon stock to be lost (from a quantity of HWP entering the HWP pool at the start).

Harvested wood products from thinnings are assumed to have a lifetime (residence time) of 5 years, which equates to a half-life of 0.9 years. Wood products from harvesting operations are assumed to have a residence time equal to the rotation length of the tree species. For conifers this equates to a half life of 14 years (59 years to 95% carbon loss) and for broadleaves a half life of 21 years (92 years to 95% carbon loss). This approach captures differences in wood product use: fast growing softwoods tend to be used for shorter lived products than slower growing hardwoods.

These residence time values fall mid range between those tabled in the LULUCF GPG (IPCC 2003) for paper and sawn products: limited data were available for the decay of HWP in the UK when the C-Flow model was originally developed. A criticism of the current approach is that the mix of wood products in the UK may be changing and this could affect the 'true' mean value of product lifetime. At present there is very limited accurate data on either decay rates or volume statistics for different products in the UK, although this is kept under review.

The C-Flow method does not precisely fit with any of the approaches to HWP accounting described in the IPCC Guidelines (2006) but is closest to the Production Approach (see Thomson and Milne 2005). The UK method is a top-down approach that assumes that the decay of all conifer products and all broadleaf products can be approximated by separate single decay constants. While this produces results with high uncertainty it is arguably as fit-for-purpose as bottom-up approaches where each product is given an (uncertain) decay and combined with (uncertain) decay of other products using harvest statistics which are in themselves uncertain.

According to this method the total HWP pool from UK forests is presently increasing, driven by historical expansion of the forest area and the resulting history of production harvesting (and thinning). The stock of carbon in HWP (from UK forests planted since 1921) has been increasing since 1990 but this positive stock change rate recently reversed, reflecting a severe dip in new planting during the 1940s. The net carbon stock change in the HWP pool has returned to a positive value (i.e. an increasing sink) in 2006, and is forecast to increase sharply as a result of the harvesting of the extensive conifer forests planted between 1950 and the late 1980s.

A3.7.11 Emissions of N_2O due to disturbance associated with land use conversion to Cropland

N_2O emissions due to disturbance associated with land use conversion to cropland are reported in Table 5(III). 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 5B2 Land converted to Cropland. 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 15cm of soil. However, the soil carbon stock changes reported in the inventory are from the top 1m 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.

A3.7.12 Methods for the Overseas Territories and Crown Dependencies

The UK includes direct GHG emissions in its GHG Inventory from those UK Crown Dependencies (CDs) and Overseas Territories (OTs) which have joined, or are likely to join, the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol. Currently, these are: Guernsey, Jersey, the Isle of Man, the Falkland Islands, the Cayman Islands, Bermuda, Montserrat and Gibraltar. The OTs and CDs were contacted for any updates in datasets in 2011 to refresh the LULUCF estimates for this submission. This work builds on an MSc project to calculate LULUCF net emissions/removals for the OTs and CDs undertaken during 2007 (Ruddock 2007).

The availability of data for the different OTs and CDs is very variable, so that emission estimates can only be made for the Isle of Man, Guernsey, Jersey and the Falkland Islands. These four comprise over 95% of the area in all the OTs and CDs. Gibraltar wished to produce their own inventory: their LULUCF net emissions/removals are likely to be extremely small, given the size of the country (6 km^2), and will have little impact on overall numbers. A lack of suitable data for the Caribbean territories (discussed in the 1990-2006 NIR) makes it impossible to create inventories for them at the present time.

Information on the area of each IPCC land category, dominant management practices, land use change, soil types and climate types were compiled for each OT/CD from statistics and personal communications from their government departments and global land/soil cover databases. This allowed Tier 1 level inventories to be constructed for the four OT/CDs already mentioned, and a Tier 3 approach for Forest Land on the Isle of Man (using the C-Flow model also used for the UK). The estimates have high uncertainty and may not capture all relevant activities.

Net emissions/removals from the OTs/CDs are now reported under the relevant sub-categories of Sector 5.

A3.7.13 Uncertainty analysis of the LULUCF sector

A3.7.13.1 Introduction

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. Previous work focused on sensitivity analysis of the CFLOW model, which is central to the forestry sector of the inventory. Here, we extended this work to encompass the whole of the existing inventory methodology, applying uncertainty quantification more widely and rigorously to all model parameters and empirical conversion factors, and to quantify the impact of those uncertainties on the inventory.

A3.7.13.2 Methods

We used a standard Monte Carlo approach to error propagation (Robert and Casella 1999). The basic procedure was to estimate uncertainty in the inventory model inputs and parameters, express these in the form of probability density functions (PDFs) and repeat the calculations iteratively, with samples randomly taken from these PDFs. This propagates the uncertainty into the distribution of the output of interest (generally, a flux of CO_2, CH_4 or N_2O). When including all sources of error simultaneously, the total uncertainty in the inventory can be estimated. Alternatively, by including only one source of error at a time, the contribution of individual sources of error to the total can be quantified.

For simplicity, we used a slightly restricted version of the inventory calculations, and uncertainties in peat extraction activities and the decay of harvested wood products were not included. We performed the calculations for England for the time period 1920-2008, but used only land use change data from the CEH Countryside Survey 2007, and projected this back to 1920 (i.e. we assumed the modern rates of land use change remained the same over time). The absolute values for fluxes are therefore not directly comparable with the reported inventory values, but the relative importance of the different uncertainty terms will remain roughly similar in the full inventory.

We also quantified uncertainty arising from model choice (or model structure), by substituting alternative sub-models for some of the key processes. In modelling forest growth, we compared the effect of using C-FLOW versus the FC Woodland Carbon tables and the BASFOR model. The rate of change in forest soil carbon following afforestation was modelled using either C-FLOW or the single exponential model used elsewhere in the inventory. In modelling soil carbon following other land use changes, we compared the single exponential model against the Roth-C model.

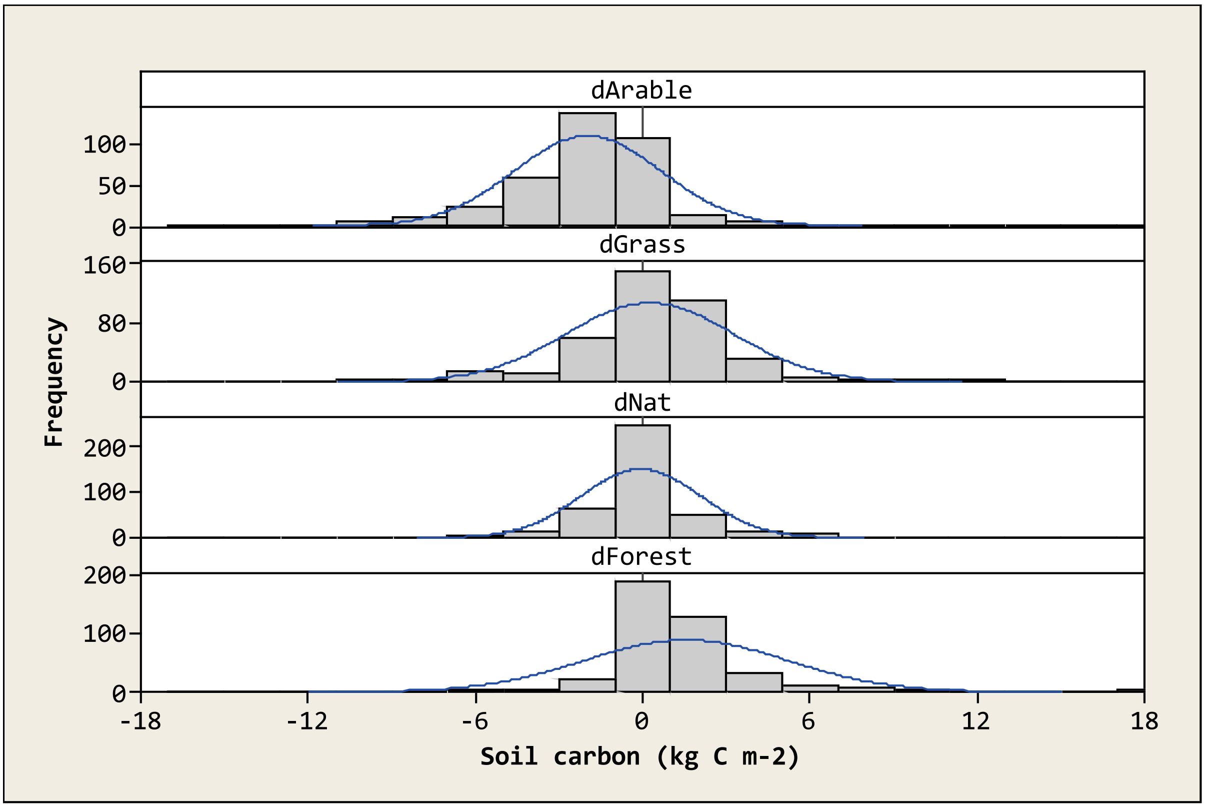
We illustrate the method by which we quantified uncertainty in some of the key model parameters and inputs below. The equation describing soil carbon at time, *t*, following a land use change, assumes an exponential pattern, such that:

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

and requires three parameters to be quantified:
C_0, the carbon density of the initial land use
C_f, the carbon density of the new land use at equilibrium, and
k, the time constant of change.

The first two parameters are estimated from data in the UK soil carbon database (Bradley *et al.* 2005, Milne *et al.* 2004 and later revisions), and their uncertainty can be estimated by the variability in the raw data. The database consists of soil cores from 439 soil series across England and Wales. In each soil series, a number of soil cores were taken to represent different land uses within that soil series. The effect of land use was measured as the difference in soil carbon with land use within each soil series, and its uncertainty quantified by the standard error in the distribution of all across all soil series (**Figure A 3.7.3**). This was used to generate pdfs for the carbon density of each of the land uses, by randomly drawing 1000 samples from Normal distributions with parameters based on these data. There are relatively few data available on the rate of change in soil carbon following land use change, and uncertainty in the *k* parameter is not yet included.

Figure A 3.7.3 Soil carbon by land use type in 439 soil series, relative to soil series mean.



Using an ANOVA-like mixed model analysis gives the variance attributable to land use, after accounting for the variation due to soil series. We used these variances as the parameters of Normal distributions, from which we sampled 1000 soil carbon parameter sets. These parameter sets were then used in the Monte Carlo simulations of the inventory model.

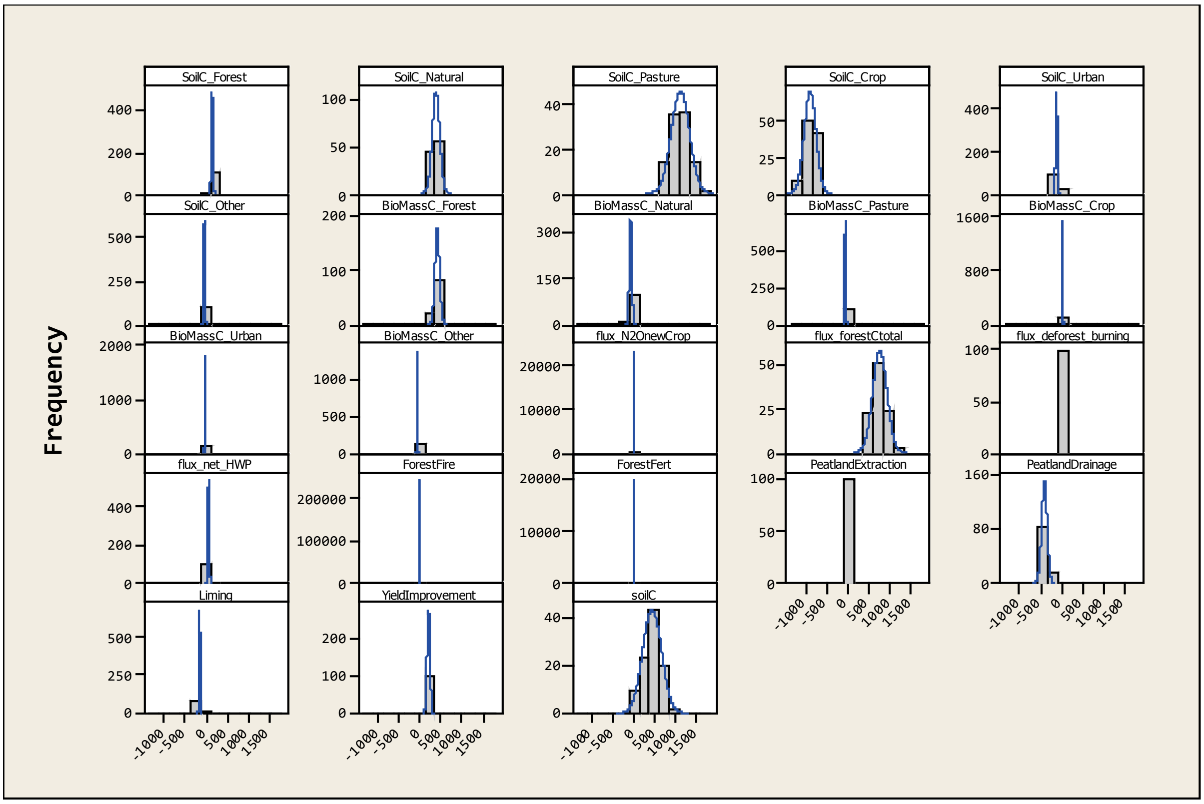
Afforestation (i.e. land use changing from any other class to forestry) is treated separately in the inventory methodology, based on the CFLOW model and including the change in biomass as well as soil carbon. So as to incorporate this within the same framework for uncertainty calculations, we generated simple look-up tables from CFLOW output, and used these in place of the exponential equation above for afforestation. Whilst uncertainty in the more complex CLFLOW model is difficult to quantify rigorously, we do have estimates on the uncertainty in mean yield class and for the effect of afforestation on soil carbon from previous work. These can be used to generate a representative uncertainty in the CFLOW model, which is then reproduced in the look-up table summarising the output.

The main input to the inventory model is the areal extent of each land use which has changed to another use over time. For the period since 1990, these data are based on the CEH Countryside Survey of several hundred 1 km^2 survey squares, spread throughout GB in a stratified sampling design, together with Forestry Commission planting statistics. The analysis of these data, and the derivation of land use change matrices based upon these, is a complex analysis, and not amenable to a simple statistical treatment. However, uncertainty in the land use change data have been estimated by the Countryside Survey team and a range of 30 % is given for each of the terms in the matrix. This estimate is used to generate pdfs for the estimates of land use change used here.

A3.7.13.3 Results

The results of the simulations including both input and parameter uncertainty are shown in **Figure A 3.7.4**. This shows the frequency distribution of all the inventory model outputs. The width of the distribution indicates the contribution of that output to the total uncertainty in the emissions from LULUCF. The standard deviation of these distributions is the conventional metric used to quantify uncertainty. The eight largest terms, when broken down into uncertainty components arising from parameters, inputs and model choice, are shown in **Figure A 3.7.5**. This shows that the area undergoing land use change is the single biggest uncertainty in the inventory, followed by uncertainty in the forest model parameters and the choice of model for the change in soil carbon following land use change. The next five terms are all of a similar magnitude.

Figure A 3.7.4 Frequency distribution of modelled estimates of the flux arising from land use, land use change and forestry in England for the time period 2000-2008



The distributions were obtained from Monte Carlo simulations, using 1000 iterations with parameters and inputs sampled from Normal distributions as described in the text. The output variables are: (top row) changes in soil carbon due to land use changes to forestry, semi-natural land, pasture, cropland, urban, (second row) other land uses, changes in carbon in above-ground biomass due to land use changes to forestry, semi-natural land, pasture, cropland, (third row) urban, other land uses, emissions of N_2O from new croplands, change in total carbon due to land use change to forestry, losses of carbon from deforestation, (fourth row) decay of harvested wood products, and forest fires, emissions of N_2O from fertilised forests, carbon losses from peat extraction, peatland drainage, and (fifth row) lime application, change in crop biomass carbon related to yield improvement, and the total net change in soil carbon.

Figure A 3.7.5 The largest uncertainties in the LULUCF inventory, in terms of standard deviation in the output distributions

A3.7.13.4 Discussion

These results indicate that the land use change data are the biggest source of uncertainty in the inventory, and that there is greatest potential to reduce total uncertainty by focussing effort here. This is perhaps unsurprising, as the Countryside Survey samples a relatively small fraction of the GB land area (~0.2 %), so considerable uncertainty arises in the extrapolation to national scale. One way forward may be to use more sophisticated data assimilation approaches to combine land use data from different sources to produce coherent matrices of land use change (Milne 2009). This could combine Countryside Survey, Forestry Commission, CORINNE, OS and other data sources (e.g. IACS) into a consistent framework.

Parameterisation of the forest model is the second largest source of uncertainty. This suggests that further forest growth data may be needed to constrain these parameters. 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.

A3.8 WASTE (CRF SECTOR 6)

A3.8.1 Solid Waste Disposal on Land (6A)

A summary of total waste sent to landfill is set out **in Table A 3.8.2**. 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. The model treats the old closed sites as unmanaged dumpsites and uses a Methane Correction Factor (MCF) of 0.6

for this type of site, in accordance with the default value given in the Revised 1996 IPCC Guidelines. The modern engineered landfills use 1.0 as the value for their MCF. Only these latter sites have gas management systems, which are described in **Section A3.8.2**. The old closed sites have no gas control. Note that the distribution of waste between these types of site is the same as used for compiling the previous NIR.

Review of activity data and emission factors
The review of MELMod undertaken for the 2009 NIR submission in 2011 (Eunomia, 2011) undertook a detailed revision of activity data (ie quantities of waste landfilled) and emission factors (based on the decomposition behaviour of materials in the landfilled waste. Eunomia's report was peer-reviewed at an expert workshop in 2010, and revisions to MELmod approved by the peer-review group were incorporated into the revised model.

Eunomia based their review of activity data on official waste arisings and composition statistics (for MSW) published by the UK central government and devolved administrations since 2002. Using official information for the levels of recycling, composting and energy recovery, the composition and quantity of residual MSW sent to landfill was estimated for each year back to 1995. The UK now has good estimates of the composition and amounts of MSW and so the quality of the new activity data is judged to be of good quality.

The position with commercial and industrial (C&I) waste is less straight forward. Most C&I waste is managed by the private sector and there is much less publically available information on composition and quantities available than for MSW. The model used to compile the NIR up to 2008 assumed that the quantities and composition of C&I waste landfilled remained constant from 2002. However, in recent years the amount of materials recycled from commercial waste sources has increased, particularly of biodegradable materials such as paper and card, as a result of financial pressure against landfilling from the landfill tax. Similar arguments apply to other components modelled in the C&I waste category, such as general industrial waste and construction and demolition waste. Consequently there are good *a priori* reasons to believe that the amount of C&I waste landfilled has reduced significantly since the late 1990s, and that its composition will have changed too.

In the revisions undertaken for the 2009 NIR, the amounts of C&I waste landfilled were updated with new information based on government receipts of landfill tax revenue[11]. This is one of the most reliable data sets for the quantity of waste landfilled. Receipts are broken down between the two tax bands, a higher rate for "active" (ie biodegradable waste) and a lower rate (for inert material). Data are also provided for exempt material, which consists of largely inert materials used for engineering purposes on landfills, such as surfaces for site roads. The tonnages of material landfilled was calculated from the revenue raised each year since 1997/98 and the prevailing rates of active and lower rates of landfill tax, which is charged on a per tonne of waste landfilled basis. A similar approach was used as for MSW, in which the materials in residual C&I waste sent to landfill were estimated from the composition of C&I waste arisings, less material recycled, from a number of published

[11] Data provide by Her Majesty's Revenue and Customs (HMRC), the UK tax authority.

sources[12]. However, data availability for C&I waste composition is not as good as for MSW and fewer composition surveys have been published. Despite these uncertainties, the quality of activity data for C&I waste is believe to be considerably higher than the previous dataset.

The results do indeed indicate that the amounts of C&I waste landfilled annually have fallen significantly since 1997/98. For example, the revised data used for the 2009 NIR indicates that the C&I waste landfilled in 2008 was about 18 million tonnes less than that indicated in the previous dataset.

The material composition of waste sent to landfill was also revised, removing a number of material categories such as plastics, metal and ash which are not biodegradable, and replacing these with an "other" category for all non-biodegradable wastes. The new categories for MSW are:

- Paper; Card; Textiles (and footware); Miscellaneous combustibles; Food; Garden; Soild and organic waste; Wood; Sanitary / disposable nappies; Furniture; Matresses and "Other" (ie inert materials).

For C&I waste, the new categories are:

- Paper and card; Food; Food effluent / biodegradable sludge; Miscellaneous combustibles; Furniture; Garden; Textiles / carpet and underlay; Wood; Sanitary and "other" (i.e. inert).

The distribution of materials between these categories was estimated from published waste data. The updated waste datasets were spliced into the existing model waste data using linear interpolation back to year 1975. This splicing was done to avoid any artificial step change in going from the old dataset to the new one, which would have produced a corresponding step change in emissions. A linear interpolation was adopted as this requires the least in terms of assumptions as to how waste amounts and composition may have changed between 1975 and 1995 and is justified by the absence of any better data. It should also be recognised that the magnitude of any errors that are introduced in emissions estimates over the reporting period (from 1990 onwards) decrease progressively as time goes on, because of the exponential nature of the decay process.

Having recalculated the quantities and material-level composition of waste sent to landfill since 1995, the revision undertook a review of waste composition to establish the biodegradable content. Moisture content of the materials as received at the landfills is an important factor. Numerous published and unpublished sources were consulted by Eunomia,

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[12] The sources consulted included: Capita Symonda with Alfatek Redox (2010) Construction, Demolition and Excavation Waste Arisings, Use and Disposal for England 2008. CON900-001, Final Report to WRAP; SEPA (2008) Construction and Demolition Wastes in Scotland (2006) http://www.sepa.org.uk/waste/waste_data/commercial__industrial_waste/construction__demolition.aspx ; *Environment Agency (2008) Wales Construction And Demolition Waste Arising Survey 2005-06, http://www.environment-agency.gov.uk/research/library/publications/33979.aspx; Capita Symonds (2006) Survey of Arisings and Use of Construction, Demolition and Excavation Waste as Aggregate in Northern Ireland in 2004/05 and 2005/06, Final Report to the Northern Ireland Environment and Heritage Service, June 2006. Environment Agency (2008) Wales Construction And Demolition Waste Arising Survey 2005-06, http://www.environment-agency.gov.uk/research/library/publications/33979.aspx;* ADAS (2009) *National Study into Commercial and Industrial Waste Arisings*, Final report for EERA; Urban Mines (2009) *Welsh C&I Survey 2007/08*, Report to WAG; SEPA (2007) *Scotland Business Waste Survey 2006*; MEL and EnviroCentre (2002) *Industrial and Commercial Waste Production in Northern Ireland*, Final Report to the Northern Ireland Environment and Heritage Service.

which revealed a wide range of typical moisture contents. The values used for the model were based on these reviewed values, selected according to their relevance to UK conditions.

Eunomia also revised the biochemical materials which give rise to methane to include fats, sugars, proteins, lignin, in addition to the cellulose and hemicelluloses which were the only biodegradable materials considered in the previous model. The composition of materials in the revised model was based on extensive review of the published literature. The biodegradability of these materials was revised, based on the lignin content, and on published laboratory and landfill decomposition studies. The results indicate that the maximum degradation rates used in the new model are in line with the landfill reactor experiments[13]. It is noted that decomposition rates vary considerably between different sorts of similar materials. For example studies have shown that newsprint, office paper and card degrade to markedly different extents under landfill conditions, despite similarities in composition. Choosing a representative rate is therefore extremely difficult. The peer review group believed that the approach adopted by Eunomia's review led to an improvement in activity and emission factor used in the UK model, and so the UK has therefore based its 2011 and 2012 NIR submissions on these revised data. The level of uncertainty in the value of many of the parameters, however, remains high.

Additional checks on the revised model undertaken since the submission of the 2011 NIR resulted in the revision of some of the values assigned to DDOC in the model. The revised values are presented in **Table A3.8.1**.

Waste components are allocated to three "pools" of degradable carbon, which are assumed to degrade at different characteristic decay rates. They are: 0.046 $year^{-1}$ (for slowly degrading organics - SDO), 0.076 $year^{-1}$ (moderately degrading organics - MDO) and 0.116 $year^{-1}$ (rapidly degrading organics - RDO), and are within the range of 0.030 to 0.200 $year^{-1}$ quoted in the 2006 IPPC Guidelines (IPCC, 2006). Fats, sugars and proteins are assigned to the rapidly degrading pool (RDO), lignin to the slowly degrading pool (SDO) and cellulose, hemicelluloses and remaining compounds are allocated to the moderately degrading pool (MDO).

The quantities of LA-controlled and C&I waste sent to landfill are shown in **Table A 3.8.2**, as is the amount of methane generated annually since 1990. Also shown in the table are the amounts of methane recovered, used for power generation, flared, oxidised and emitted to the atmosphere.

[13] Eleazer W E, Odle W S, Wang Y S and Barlaz M A (1997) Biodegradability of Municipal Solid Waste Components in Laboratory Scale Landfills, *Environmental Science and Technology,* 31, pp911-917.

Table A 3.8.1 Revised DDOC values of waste components (Local Authority –controlled waste) and since 1997 (Commercial & Industrial waste)

Local Authority controlled waste		C&I	
Material	**Revised DDOC values**	**Material**	**Revised DDOC values**
Paper	16.11%	Commercial	n/a
Card	15.17%	Paper and Card	16.11%
Nappies	4.30%	General industrial waste	n/a
Textiles (and footwear)	6.67%	Food and Abattoir	8.55%
Misc. Combustible	11.00%	Food effluent	6.76%
Wood	12.53%	C&D	n/a
Food	9.51%	Misc processes	n/a
Garden	8.72%	Other waste	n/a
Soil and other organic	0.27%	Misc Comb	11.00%
Furniture	5.21%	Furniture	5.21%
Mattresses	6.67%	Garden	8.72%
Material 1 (not used)	0.00%	Sewage sludge	n/a
Material 2 (not used)	0.00%	Textiles / Carpet and Underlay	6.67%
Non-inert Fines (as before)	6.35%	Wood	12.53%
Other (as 100% inert, as before)	0.00%	Sanitary	4.30%
		Shaded cells indicate materials that have been re-categorised since 1975.	

Notes:

a. Furniture in LA-managed waste is assumed to be 62% wood and 5% textile on fresh mass basis.
b. Mattresses are assumed to be 50% textiles on fresh mass basis. Excluding non-biodegradable component).
c. “Other” is assumed to be 100% inert – i.e. non-biodegradable.
d. Furniture in C&I waste is assumed to be 50% wood on fresh mass basis.

A3.8.2 Methane recovery from modern landfills

As outlined in Chapter 8, landfill operators are required under their permit conditions to control the release of landfill gas. For large landfills containing biodegradable wastes, this requires the use of impermeable liners and cover material, and the use of gas extraction systems. These typically consist of a system of gas wells (perforated pipes sunk into the waste) connected to a network of gas collection pipes. Suction is applied to the gas wells resulting in a slight negative pressure sufficient to draw out the landfill gas but not enough to draw excessive air into the waste. (Air ingress can result in aerobic decomposition of the waste, which produces considerable heat, and may lead to the waste catching fire, as well as shutting off methane formation). The landfill gas is fed into flares which oxidise the methane to carbon dioxide. The carbon dioxide so produced is not taken into further consideration for inventory purposes as it is considered to be entirely biogenic in origin. Many landfills that produce large quantities of methane recover the gas for power generation on a commercial basis.

A key factor in determining methane emissions is information on the amount of methane collected, either for utilisation or flaring. Data on utilisation is available and of good quality, but data on flaring is generally scarce and of poor quality. The current inventory is based on the estimates of gas collection efficiency developed by Golders (2005)[14] and described in further detail in their report and in subsequent inventory reports. The adopted recovery rates for modern landfills are estimated to have increased from 15% of the methane generated in 1990 to about 75% by 2005 and are assumed to have remained constant thereafter, with no gas collection for old pre-1980 closed sites

The continued use of the 75% time integrated collection efficiency for modern landfills was agreed with peer reviewers of the latest review of the assessment model input data undertaken by Eunomia. Further work has been commissioned to gain greater confidence in the amount of methane flared and this information will be taken into account when available for future inventory reports, as discussed further, below. Current estimates for methane recovered are given in **Table A.3.8.2**.

Regulatory guidance[15] for landfill operators bases permit conditions on a target to collect at least 85% of the methane formed in landfills receiving biodegradable waste. Non-achievement of this target, which applies to landfill cells and areas served by gas collection systems, may result in further permit conditions being imposed to improve collection rates. Waste industry measurements typically show collection efficiencies in excess of 90% for operational landfills, however there is high uncertainty in this figure, as noted in the main report. Final capping of the landfill cell or area and gas collections with flaring and or gas utilisation must generally be implemented within 6 months of completion of the cell or area. Large-scale passive venting of landfill gas is no longer accepted under permitting conditions and impermeable barriers are required as best practice to prevent the migration of landfill gas off-site.

A3.8.2.1 Gas Utilisation

Power generation is currently the dominant use for landfill gas in the UK and good data are available on this from official sources. Power generation from landfill gas has benefitted

[14] Golder Associates (2005), UK Landfill Methane Emissions: Evaluation and Appraisal of Waste Policies and Projections to 2050. Report version A.2, November 2005. Report for the UK Department of Environment, Food and Rural Affairs. Authors: Arnold, S. and Yang. Z. Report number 05529424.500

[15] See "Guidance on the management of landfill gas" The Environment Agency and Scottish Environment Protection Agency 2004.

considerably from government support schemes to encourage to uptake of renewable forms of energy and landfill gas to electricity has been one of the most successful technologies to have benefitted. The first of these schemes, the Non-Fossil Fuel Obligation (NFFO), began in 1990 in England and Wales, with variants in Scotland and Northern Ireland. Although schemes supported under NFFO continue to operate, the system was replaced in 2002 by the Renewables Obligation, which is the main support scheme for renewables in the UK. The essence of these support mechanisms is to provide an obligation on electricity suppliers to meet an increasing proportion of their needs from renewable sources, and in addition to provide market security for electricity from renewable sources, in order to stimulate investment in these technologies. Details of the schemes are available from Ofgem.[16]. To receive support under these schemes, electricity suppliers must inform the authorities of the amount of electricity from renewable sources they have supplied, and consequently there is a high level of confidence in the quality of the official figures. From knowing the typical conversion efficiency of landfill gas electricity generation and the calorific value of methane it is simple to calculate the quantity of methane used for power generation.

The most widely deployed technology for power generation from landfill gas is the use of reciprocating internal combustion engines as the prime mover, powering a conventional alternator to generate the electricity. These are mainly based on the spark-ignition principle, using multi-cylinder engines based on designs developed for heavy duty road transport. Compression-ignition engines using diesel oil as a pilot fuel have also been used in the UK, as have other prime movers such as gas and steam turbines.

Other uses for landfill gas have been demonstrated, both in the UK and elsewhere, such as its use as a direct fuel in industrial processes such as brick and paper making, but these applications depend on having a fuel user close to the landfill. In addition, support for power generation applications has made this option more commercially attractive than direct use, and a number of direct use schemes in operation in the 1980s subsequently converted to power-only with the introduction of the support schemes for electricity. In 1990, about 42% of the energy recovered from landfill gas was used in the form of heat, but by 1994 this had fallen to under 10% and in 2009 less than 1% of landfill gas energy was recovered as heat, the rest as electricity Digest of UK Energy Statistics (DUKES, 2010)[17].

There is increasing interest in removing contaminants from landfill gas and using the methane as a fuel for vehicles or for direct injection into the gas distribution system. Examples of both these applications are seen in other European countries. However, it is understood that there is currently only one example in the UK (the use of liquefied methane from landfill gas to fuel refuse collection vehicles). The scheme, which started in 2008, is claimed use the equivalent of about 5 Gg of landfill methane per year[18], although this does not appear to be included in the current (2011) issue of DUKES.

Current data on the amount of methane used for power generation, calculated from the electricity generated from landfill gas as reported in the Digest of UK Energy Statistics (DUKES, 2011), is given in **Table A.3.8.2**.

[16] Ofgem (Office for Gas and Electricity Markets) . http://www.ofgem.gov.uk/Sustainability/Environment/Pages/Environment.aspx
[17] Data from "Copy of dukes7_4.xls" Annual tables: 'Digest of UK energy statistics' (DUKES) pub by DECC http://www.decc.gov.uk/en/content/cms/statistics/source/renewables/renewables.aspx
[18] SITA 2008 Powered by waste – creating fuel from landfill gas. http://www.sita.co.uk/downloads/Gasrec-web.pdf

A3.8.2.2 Flaring

Until recently, information on the volume of landfill gas treated by flaring was not collected by the environmental regulators and was therefore not publically available. Instead, estimates of methane capture were based on energy recovery statistics and information on flare capacity, rather than on actual volumes of gas treated in this way. Information on flaring capacity was obtained through consultation with flare manufacturers. LQM (2003) collected information from all but one of the UK flare companies contacted. The data collected was divided into flares supplied for routine flaring and flares supplied as back-up to generation sets. The data produced demonstrates total flare capacity as opposed to the actual volumes of gas being flared in each year. There are difficulties in ascertaining the actual volumes of LFG burnt, as detailed records, if they exist at all, are held by individual site operators. The methodology was used to derive the estimated gas collection efficiency for modern landfill (75%) noted above.

The efficiency of flares in destroying methane has improved substantially since 1990. Modern shrouded flares now required by the regulators typically remove at least 98% of incoming methane, compared with the now obsolete candle flares common in the 1980's that released about 10-15% of un-burnt methane in the combustion off-gas[19].

Further work is on-going to improve estimates of landfill gas flare utilisation as they currently contain a high level of uncertainty. The estimates shown in **Table A.3.8.2** are based on the estimate of methane collected, less the amount used for power generation. The amount flared also includes a minor proportion used for non-electricity generation proposes such as direct use and as a vehicle fuel, mentioned above.

Much better quality data on the amounts of landfill gas flared is now becoming available from the UK's environmental regulators. Operators of landfills that are permitted under the Landfill Directive now have to report the volumes of landfill gas flared, as well as that used in engines and for other purposes. Whilst this new data is still undergoing quality checks, initial assessment suggest that the level of flaring is not inconsistent with the overall gas collection efficiency currently adopted. For this reason, we have retained the collection efficiency of 75% referred to above for this NIR. However, we expect to include new estimates of flaring based on reported flaring volumes in next year's NIR and to update the collection efficiency accordingly.

A3.8.2.3 Methane oxidation

The amount of methane oxidised by microorganisms in the surface layers of the landfill varies greatly with season, local conditions and weather. In the absence of more reliable data representative of UK conditions, we have used the IPCC default value of 10% of uncollected methane assumed to be oxidised prior to release. The data for methane oxidation of residual (i.e. uncollected) methane shown in Table **A.3.8.2** are based on this approach.

A3.8.2.4 Methane emission

The right-most column of **Table A.3.8.2** shows the current NIR estimate of methane emitted from UK landfills, according to the approach outlined in **Chapter 8**, taking account of recovery and oxidation.

[19] "Guidance of landfill gas flaring" The Environment Agency and Scottish Environment Protection Agency 2002.

Table A 3.8.2 Amount of waste landfilled and methane generated, captured, utilised, flared, oxidised and emitted.

Year	Waste Landfilled (Mt)			Methane generated	Methane captured		Methane used for power generation		Methane flared		Residual methane oxidised		Methane emitted	
	MSW	C&I	MSW+C&I	kt	kt	%	kt	%	kt	%	kt	%	kt	%
1990	18.19	74.64	92.83	2,539	267	11%	33	1%	234	9%	227	8.9%	2,044	81%
1991	18.84	73.97	92.80	2,586	361	14%	50	2%	311	12%	223	8.6%	2,003	77%
1992	19.47	73.30	92.77	2,631	474	18%	90	3%	383	15%	216	8.2%	1,941	74%
1993	20.09	72.62	92.72	2,673	583	22%	107	4%	476	18%	209	7.8%	1,881	70%
1994	20.71	71.95	92.66	2,713	677	25%	124	5%	553	20%	204	7.5%	1,832	68%
1995	26.46	71.28	97.74	2,769	789	29%	135	5%	655	24%	198	7.1%	1,781	64%
1996	25.75	70.61	96.36	2,813	892	32%	170	6%	722	26%	192	6.8%	1,729	61%
1997	26.98	69.82	96.80	2,855	1,071	38%	220	8%	851	30%	178	6.2%	1,605	56%
1998	26.67	67.44	94.11	2,888	1,215	42%	284	10%	931	32%	167	5.8%	1,506	52%
1999	27.56	66.36	93.92	2,918	1,386	48%	409	14%	978	34%	153	5.2%	1,378	47%
2000	27.57	65.37	92.94	2,946	1,509	51%	525	18%	983	33%	144	4.9%	1,293	44%
2001	28.06	61.74	89.81	2,972	1,717	58%	602	20%	1,115	38%	126	4.2%	1,130	38%
2002	27.63	64.17	91.79	2,991	1,846	62%	643	21%	1,203	40%	114	3.8%	1,030	34%
2003	26.24	65.56	91.80	2,992	1,993	67%	786	26%	1,206	40%	100	3.3%	900	30%
2004	25.05	63.10	88.15	2,979	2,056	69%	961	32%	1,095	37%	92	3.1%	831	28%
2005	22.66	60.13	82.79	2,947	2,050	70%	1,030	35%	1,021	35%	90	3.0%	807	27%
2006	21.33	55.67	77.01	2,900	2,020	70%	1,062	37%	958	33%	88	3.0%	792	27%
2007	19.72	51.53	71.25	2,843	1,984	70%	1,122	39%	861	30%	86	3.0%	774	27%
2008	17.63	47.56	65.19	2,774	1,938	70%	1,142	41%	796	29%	84	3.0%	752	27%
2009	15.96	43.69	59.65	2,693	1,884	70%	1,189	44%	696	26%	81	3.0%	727	27%
2010	13.30	39.73	53.03	2,598	1,821	70%	1,209	47%	612	24%	78	3.0%	699	27%

Notes

a. Methane generated is based on the corrected MELMod 2011 v1-1 UK model.
b. Methane captured is based on the gas collection efficiency averaged over modern and closed landfills as described in the 2008 NIR.
c. Methane used for power generation is calculated from official figures on landfill gas electricity generation (Digest of UK Energy Statistics (DUKES, 2011)), in MWh/year, assuming a net calorific value for methane of 50 GJ/tonnes and a conversion efficiency between methane use and electricity export of 30%, which includes parasitic losses and on-site use of electricity, eg for gas blowers, leachate treatment and site offices.
d. Methane flared is estimated the difference between methane captured and methane used for power generation. It includes minor uses such as direct use and vehicle fuel.
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). Oxidation factor=0.1.

A3.8.3 Wastewater Handling (6B)

A3.8.3.1 Municipal Waste Water Treatment and Sewage Sludge Disposal: Methane

The inventory compilation method for methane estimates from water treatment and sewage sludge treatment and disposal is based on activity data from the water industry annual reporting system to UK industry regulators (for 2000 onwards) and an historic time series of sludge treatment data published by Defra (Defra EPSIM data, 2004). The UK Water Industry Research organisation has developed a spreadsheet emissions estimator tool, drawing upon available emission factors for sub-processes within the industry, and each UK water company uses this tool to estimate its annual emissions. From these reported emissions and activity data, implied emission factors for specific emission sub-sources can be derived.

Emissions data have been made available for the year 2009 by 5 out of 12 of the UK water companies, and the Implied Emission Factors derived from the 2009 data from these companies have been applied to the activity data across all years and across all activity in the UK. The use of such a limited dataset is not ideal, and the uncertainties in the emission estimates, especially for earlier years in the time series, are regarded as high. Further work is needed to investigate a more representative time-series of emission factors for future inventory work, through further consultation with the industry.

Most UK wastewater treatment works comprise the following components as a minimum:

- Initial screening / grit removal;
- Primary settlement tanks, using simple sedimentation; and
- Secondary treatment (usually a biological process such as activated sludge systems & sedimentation or percolating filters).

Many also have a tertiary treatment unit to complete waste-water filtration, remove target nutrients (such as nitrogen or phosphorus) or specific industrial pollutants, to “polish” the water as required prior to outputting treated water to watercourses.

In each of the treatment phases, sewage sludge is produced and may be treated in a variety of ways, each with different methane emission characteristics, and these options are accounted for within the UKWIR spreadsheet tool.

Each of the UK’s 12 water and sewerage companies provides annual activity data on water treatment, sewage sludge arisings and the ultimate fate of sewage sludge, within reporting returns to UK industry regulators. The activity data reported by each company in recent years includes data that are used within the UKWIR spreadsheet tool to estimate company GHG emissions, including:

- Total volume of sludge disposed (kt dry solids)
- Trade effluent load (BOD/yr)
- Total annual load (BOD/yr)
- Population Equivalent Served (‘000)

In addition, there is a detailed split of sewage sludge disposal routes for each company, including data (kt dry solids per year) for the following activities:

- Incineration
- Composted

- Landfill
- Land reclamation
- Farmland
- Disposal at sea (up to the year 2000, when this activity was banned)
- Other

However, the full detail of these final disposal options is not available for all companies for all years. From 1997 to 2008, each of the 10 water companies in England and Wales reported sludge disposal activity within annual submissions (called “June Returns”) to the industry regulator, OFWAT, broken down across 8 sludge disposal routes: incineration, composting, landfill, land reclamation, farmland untreated, farmland conventional, farmland advanced and other. Since 2009 the data published for each water company within the OFWAT June Returns tables is limited to the total activity for all sludge treated and disposed, with no detailed breakdown of ultimate disposal fate published; for each water company in England and Wales, therefore, the 2008 breakdown across the 8 disposal routes has been used to estimate the detailed activity in 2009 and 2010. In Scotland the same level of detailed activity data have been available since 2002 and continue to be published to 2010, from the Water Commissioner for Scotland. In Northern Ireland, fully disaggregated data are only available from the water regulator, UREGNI, since 2007; the Defra EPSIM statistics are used to provide activity data for the early part of the time series to 2003, whilst the Northern Ireland activity data published by the regulator for 2007 are extrapolated back to 2004.

For the earlier part of the time series, a similar breakdown of data is available from UK Government statistics published in 2004. Data from 1990 to 2000 is available for England and Wales (combined), Scotland and Northern Ireland, giving kt dry solids disposal.

The UKWIR spreadsheet tool includes emission factors for sub-processes in the water treatment industry and for final sewage sludge disposal options, but the full detail of the working of the UKWIR tool has not been provided to the Inventory Agency.

Five of the UK water companies have shared their 2009 GHG emissions data for use in the UK GHGI compilation, providing emission estimates for the following sources of methane and nitrous oxide:

- Water treatment
- Digestion processes
- Composting processes
- Disposal of sludge to farmland

Within the UK GHGI, emissions from sewage sludge incineration and disposal to landfill are accounted for within the sector 6C and 6A1 respectively, and hence are disregarded here, to avoid a double-count.

From the reported methane emissions (by sub-source) from the 5 companies and the activity data reported for 2009, emission factors for each sub-source have been calculated. For the 5 companies that reported emissions data, the company-specific emission factors are applied to the activity data for those companies across the time series in order to estimate methane emissions; for the remaining UK activity, methane emission estimates are calculated using the average emission factor from the 5 companies, together with the activity data from across the time series. These (UK industry average) emission factors are shown in **Table A 3.8.2** below.

Note that no GHG emissions were reported by any of the water companies for the disposal of sludge to land reclamation or “other” disposal routes, which in 2009 accounted for around 7% of total sewage sludge disposal activity. In the UK inventory method, therefore, we have assumed that zero additional GHG emissions arise from these two disposal routes. We propose to check this assumption with UK water companies through on-going consultation regarding the UK inventory method and source data for the sector.

Note also that nitrous oxide emissions are calculated using a separate method (see **Section A3.8.3.2**. below), and only the methane emissions data have been used from the water company data at a sub-source-specific level.

Table A 3.8.2 Methane Emission Factors for Sludge Treatment (kg CH_4/kt dry solids) from Reported 2009 Emissions and Activities

Sludge Treatment Route	Methane Emission factor (kg CH_4/kt dry solids)
Treatment	2,731
Digestion	139
Compost	2,553
Agriculture	1,427

From the sub-source-specific activity data and emission estimates, an overall industry methane emission factor has been derived, using the total mass of sewage sludge dry solids arisings as the activity data. These data are summarised in the table below for the 1990-2010 time series. The step-change in activity data in 2000 to 2001 reflects the changes in the UK water industry practices to increase the level of sewage sludge treatment and disposal by non-sea-disposal methods, in reaction to the implementation of the Urban Waste Water Treatment Directive, which banned sewage disposal direct to sea.

Table A 3.8.3 Time-Series of Total Volume Sludge Disposed and Industry (kt of dry solids) and Methane Emission Factors for Emissions from Wastewater Handling (kt CH_4 / kt of dry solids)

Year	Total Volume Sludge Disposed (kt of dry solids)	Industry Emission Factors (kt CH_4 / kt of dry solids)
1990	1,076	0.012
1991	1,072	0.012
1992	1,019	0.013
1993	1,014	0.013
1994	1,039	0.013
1995	1,124	0.012
1996	1,079	0.012
1997	1,038	0.013
1998	1,057	0.013
1999	1,126	0.012
2000	1,108	0.013
2001	1,541	0.010
2002	1,599	0.010
2003	1,653	0.010
2004	1,759	0.009
2005	1,770	0.009
2006	1,792	0.009

Year	Total Volume Sludge Disposed (kt of dry solids)	Industry Emission Factors (kt CH_4 / kt of dry solids)
2007	1,817	0.009
2008	1,815	0.009
2009	1,706	0.009
2010	1,690	0.010

In the review of the 2011 UK GHG inventory submission, the UNFCCC ERT questioned the accuracy of the source estimates due to uncertainty regarding the applicability of factors derived from one year and from only a sub-set of the UK water industry and then applied to water industry operations throughout the time series. Whilst the estimates are somewhat uncertain and further work is needed to consult across the industry to seek out additional data and to improve the method, we remain confident that the method is an improvement compared to the previous approach which used data from a 1996 study, based on information from the early 1990s and then extrapolated the emission estimates forward based on population trends.

- The emission factors derived from 2009 data are based on data from 5 UK water companies that in 2009 managed the disposal of 53% of the total volume of sewage sludge arisings.
- The emission factor for **treatment** emissions is derived from data from 4 of the 5 companies. In 2009, the treatment emissions are estimated to account for 29% of the total methane emissions from the sector and the four company-specific factors show close agreement, ranging from 2532-2834 kg CH_4/ktonne, with a standard deviation that is 5% of the mean figure.
- The emission factor for **digestion** is derived from data from all 5 companies that reported. In 2009, the digestion emissions are estimated to account for 59% of the total methane emissions from the sector and the five company-specific factors show reasonable consistency, ranging from 104-157 kg CH_4/ktonne, with a standard deviation that is 17% of the mean.
- The emission factor for **composting** is derived from data from a single water company that reported data for 2009. In 2009, the composting emissions are estimated to account for less than 1% of the total methane emissions from the sector.
- The emission factor for **disposal of sludge to agriculture** is derived from data from all 5 companies that reported. In 2009, the disposal to agriculture emissions are estimated to account for 12% of the total methane emissions from the sector but the five company-specific factors show wide variability, ranging from 175-2350 kg CH4/ktonne, with a standard deviation that is 68% of the mean. In part this reflects the different types of disposal to agriculture that are conducted by water companies, as in some cases the sludge is pre-treated or dried prior to application to land and the resultant emissions vary as a result of this treatment. However, this high variability in reported data also indicates high uncertainty for this source, and therefore further consultation with the water industry is on-going to seek out a more comprehensive dataset for this source.

The inventory estimates for methane are uncertain due to the limited dataset available to the inventory agency, but the method does utilise emission factors derived from country-specific research and that reflect company-specific waste water treatment and disposal systems, albeit from around half of the UK water industry. The bullet-points above indicate that for the treatment and digestion emission sources together (which comprise around 88% of total estimated methane emissions in 2009), the level of uncertainty in the average UK emission factors is relatively low. We note, however, that the uncertainty in the emission estimates for other sources, notably disposal to agriculture, are higher and these data are subject to on-going industry consultation in order to seek out a more comprehensive dataset.

The previous inventory method used an industry study from 1996 which had assessed the water industry's structure and treatment options from the early 1990s. Emission estimates for later years were extrapolated using population statistics as the basis for the UK estimates, scaling against the methane emission estimates derived from the 1996 study. This approach did not provide a transparent or representative emission estimate, and nor did the previous method enable the inventory time series to reflect the changes in the UK water industry that were prompted by the banning of sludge disposal to sea under the Urban Waste Water Treatment Directive of 1999.

We are confident that despite the limited dataset available, the current inventory method does provide a more representative and accurate time series of methane emissions from the waste water sector. The current method does enable the inventory time series to reflect the step-change in sludge treatment and disposal that are evident from the activity data time series presented in table A3.8.3 above. Furthermore, whilst uncertainty in emission factors may persist, the factors applied in the current method are based on research and investment by the UK water industry in recent years in order to derive more detailed (source-specific) and more accurate emission factors, as the expectations of GHG reporting by the water industry have increased.

In summary, compared to the previous method, the current method brings benefits of:

- Improved time-series consistency, due to the use of national statistics on source-specific waste water treatment and disposal activity rather than just population trends;
- Improved transparency, as the data are based on more detailed source-specific estimates that are derived from company-reported data by emission source and then applied to published activity data;

Improved accuracy of estimates, due to the use of UK-specific research by the water industry to derive emission factors for specific sources of GHGs;

A3.8.3.2 Municipal Waste Water Treatment and Sewage Sludge Disposal: Nitrous Oxide

Nitrous oxide emissions from the treatment of human sewage are based on the IPCC (1997) default methodology. The most recent average protein consumption per person is based on the Expenditure and Food Survey (Defra, 2010); see **Table A 3.8.4**. For the purposes of the 2010 estimates within the inventory, the Expenditure and Food Survey 2011 was not available in time, and therefore the data for 2009 has been used as a best estimate.

In previous years, the protein consumptions used to estimate emissions were "household intakes". However, Defra now produce a time series of the estimates of the small amount of additional protein from consuming meals eaten outside the home; this intake is called "eating out intakes". This time series is only available from 2000 onwards. For values between 1990 and 2000 an average of the data available is applied. The sum of the "household intakes" and "eating out intakes" then provides the total protein consumption per year per person.

The nitrous oxide emissions are calculated multiplying the total protein consumption per year per person by the fraction of nitrogen in protein (0.16 kg N/kg protein based on the IPCC rev

1996 Guidelines) by the emission factor (0.01 kg sewage-N produced based on the IPCC rev 1996 Guidelines).

However, in the 1990-2010 inventory cycle we have revised the methodology for nitrous oxide to remove a double-count that had been introduced in error in the previous inventory cycle; the emission estimates for the agriculture sector in the 1990-2009 GHGI cycle were updated to include an estimate of nitrous oxide emissions from sewage sludge applied to agricultural soils, and this introduced a double-count to the method used in the IPCC sector 6B. Therefore, in the 1990-2010 cycle, the estimates of nitrous oxide from sewage sludge applied to agricultural land have been retained in the agriculture sector and subtracted from the estimates based on the IPCC default methodology for IPCC sector 6B.

Table A 3.8.4 Time-series of per capita protein consumptions (kg/person/yr). Household intakes

Year	Protein consumption (kg/person/yr)
1990	27.9
1991	27.6
1992	28.4
1993	28.2
1994	28.3
1995	28.6
1996	29.4
1997	29.3
1998	29.1
1999	28.7
2000	29.9
2001	30.0
2002	30.0
2003	29.7
2004	29.5
2005	29.8
2006	29.7
2007	29.3
2008	28.5
2009	28.7
2010	28.7

A3.8.3.3 Industrial Wastewater Treatment Plants

There is no separate estimate made of emissions from industrial wastewater treatment plants operated by companies prior to discharge to the public sewage system or rivers. Emissions of GHGs from this source are assumed to be Included Elsewhere within the inventory.

Where an IPPC-regulated industrial process includes an on-site water treatment works, any significant emission sources (point-source or fugitive) are required to be reported within their annual submission to UK environmental regulatory agencies, including emissions from their water treatment plant. Therefore, any GHG emissions from industrial wastewater treatment should be included within operator returns to the pollution inventories of the EA, SEPA and NIEA, and therefore accounted for within the Industrial Process sector of the GHG Inventory. In practice it is not straightforward to ascertain the extent to which emissions from waste water treatment are consistently included in operator estimates across different industry sectors, as the IPPC data are not presented “by source”, but rather “by installation”. Within sector-specific guidance to plant operators on pollution inventory data preparation, emissions of methane from wastewater treatment are not highlighted as a common source to be considered, whilst in guidance for several industrial sectors, wastewater treatment is singled out as a potentially significant source of ammonia and nitrous oxide emissions.

A3.8.3.4 Source-specific methodology improvements

Methane emission estimates have been revised due to the use of revised activity data on waste water treatment and sewage sludge treatment and disposal, from the Northern Ireland utility regulator, UREGNI. There has been no revision to the overall estimation methodology, however.

Emissions of nitrous oxide have been revised downwards across the time series to remove the double-count with the agricultural soils source, as outlined above. In 2009, this revision reduced 6B nitrous oxide emissions by 0.74 Gg N_2O.

A3.8.4 Source-Specific Planned Improvements

Industry consultation has been initiated during 2012 to:

i) Investigate the data available from the UKWIR spreadsheet tool, to review whether the emission factors applied to the June Returns activity data are representative of the industry activity and emissions;
ii) Seek data inputs from more of the UK water companies, building on the example of those that reported emissions data to date;
iii) Seek industry advice on how to improve the emission estimates from earlier in the time series, reviewing the current approach of back-extrapolation of emission factors from more recent research which introduces additional uncertainty;
iv) Investigate further the on-going industry research into nitrous oxide emissions from water treatment processes, to determine whether a more UK-specific methodology can be developed which provides a comprehensive coverage of emissions.

No new data has been provided to date, but all UK water companies have been contacted to request additional data to improve the current approach and ensure that the estimates presented in the UK GHGI are representative of the industry across the UK. The investment of time and resources into taking these improvement actions forward will be determined by the NISC, taken in context of the available inventory research budget and the level of priority assigned to these estimates, accounting for their significance in the UK GHGI emission totals.

A3.8.5 Waste Incineration (6C)

This source category covers the incineration of wastes, excluding waste-to-energy facilities. For the UK, this means that all MSW incineration is excluded, and is reported under CRF source category 1A instead. Emission factors for the municipal solid waste incinerated, and the treatment of biogenic emissions from MSW incineration, can be found the section Energy Industries, in this Annex.

A3.9 EMISSIONS FROM THE UK'S CROWN DEPENDENCIES AND OVERSEAS TERRITORIES

Definitions of the UK's national territory can, at times, be less than straightforward. This Appendix explains the inclusion of emissions originating from UK Crown Dependencies (CDs) and Overseas Territories (OTs) in the UK national emissions inventory.

Emissions from OTs were first included in the UK Greenhouse Gas Inventory in the 1990-2004 inventory, published in 2006. However combustion emissions from fuel use in CDs have always been included in the UK inventory, although not specifically itemised. This is because CD fuel use is included in the UK energy statistics, produced by DECC. Emissions from non-combustion sources were introduced into the inventory at the same time as the estimates for the OTs.

A number of minor revisions and improvements have been made to calculation methodologies for the 1990-2010 emissions inventory. Prior to this, improvements were made for the 1990-2007 greenhouse gas inventory, and were reported in the 2009 NIR.

Table A 3.9.1 Summary of category allocations in the CRF tables and the NIR

Source	Category in CRF	Category in NIR	Notes
Power stations (OTs and CDs)	1A1a: Public Electricity and Heat Production (Other Fuels)	1A1a	The activity data and emissions data in the CRF includes the components from the OTs and CDs for the relevant fuels. In earlier versions of the inventory the OT emissions were included as a separate estimate, CD emissions being already captured within the UK total (although not necessarily allocated to the most representative CRF).
Domestic Aviation (CDs only)	1A3a: Aviation	1A3a	Flights between the UK and the OTs and CDs are classified as domestic.
Industrial Combustion (OTs and CDs)	1A2f: Other - OT Industrial Combustion	1A2f	The activity data and emissions data in the CRF includes the components from the OTs and CDs for the relevant fuels. In earlier versions of the inventory the OT emissions were included as a separate estimate, CD emissions being already captured within the UK total.
Road Transport (OTs and CDs)	1A3b: Road Transport (Other Fuels)	1A3b	The activity data and emissions data in the CRF includes the components from the OTs and CDs for the relevant fuels. In earlier versions of the inventory the OT emissions were included as a separate estimate. CD emissions for CO_2 were assumed to be already captured within the UK total, however for other GHGs, the emissions are calculated based on vkm and therefore these emissions were estimated and added as an additional component.
Memo items: Aviation (OTs only)	1Ca	1C1a	All aviation emissions from the OTs and CDs are now calculated as part of the UK's aviation emissions model. As such, emissions and activity data from this source are now included within the relevant category in the CRF
Residential and Commercial Combustion (OTs and CDs)	1A4a and 1A4b	1A4a and 1A4b	The activity data and emissions data in the CRF includes the components from the OTs and CDs for the relevant fuels. In earlier versions of the inventory the OT emissions were included as a separate estimate, the CD emissions being already captured within the UK total.
OT and CD F gases	2F9: Other - OT and CD F Gas Emissions	2F	This has been included in the CRF as a separate category for all F Gas emissions from the OTs and CDs.
OT and CD Enteric Fermentation	4A10: Other - OTs and CDs All Livestock	Relevant animal categories within 4A	A separate category for all livestock in the OTs and CDs is used.

Source	Category in CRF	Category in NIR	Notes
OT and CD Manure Management	4G: Other - OT and CD Emissions from Manure Management	Relevant categories within 4B	It was not possible to introduce a new category in which to put emissions of N_2O from manure from the OTs and CDs into Sector 4B. A separate category was therefore included in Sector 4G - Other.
OT and CD LULUCF Emissions	Relevant categories within sector 5	5	Net LULUCF emissions from the OTs and CDs are reported in sector 5.
OT and CD Landfill	6A3: Other - OT and CD Landfill Emissions	6A	This has been included in the CRF as a separate category under 6A.
OT and CD Sewage Treatment	6B3: Other - OT and CD Sewage Treatment (all)	6B	This has been included in the CRF as a separate category under 6B.
OT and CD Waste Incineration	6C: Waste Incineration	6C	This has been included in the CRF with the UK MSW incineration, since the same emission factors are applied.

GHG emissions are included from those UK CDs and OTs which have joined the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol[20]. The relevant CDs and OTs are:

Crown Dependencies

- Guernsey
- Jersey
- The Isle of Man

Overseas Territories

- The Falkland Islands
- The Cayman Islands
- Bermuda
- Montserrat
- Gibraltar

Separate CRF tables have also been submitted to the EU to include only the parts of the UK that are also members of the EU. These are the UK itself, and Gibraltar.

Country specific data have been sought to estimate emissions as accurately as possible for all of these locations. In general the data were requested by questionnaire asking for information on fuel use, the vehicle fleet, shipping movements, aircraft, livestock numbers and waste treatment. In some cases (such as for the Channel Islands) much of the data were readily available from government statistical departments. For all of the CDs, activity data used to estimate emissions from fuel combustion sources were already included in the UK activity data because the geographical coverage of the Digest of UK Energy Statistics includes the CDs. However, separate estimates of CD fuel combustion are also now made. In these cases it was possible to make emission estimates using broadly the same methodology as used for the UK inventory.

There were some difficulties obtaining information for some sectors in some of the OTs to estimate emissions using the same methods applied to the existing UK GHG inventory. Modifications were therefore made to the existing methods and surrogate data were used as necessary; this is discussed in the sections below. For sectors in some of the OTs (e.g. Waste Treatment in Montserrat), no data were available and it was not possible to make any estimates of emissions.

20 Emissions from Sovereign Bases (SBs) should also be considered. However, the UK SBs are military bases in Cyprus, and emissions are assumed to be included elsewhere. Emissions from on-base activities are included within the military section of the UK greenhouse gas inventory, whereas any off-base activities will be included within the inventory submitted for Cyprus.

A summary of the emissions of the direct GHGs from the UK's Crown Dependencies and Overseas Territories are given in **Table A 3.9.3** and **Table A 3.9.7**.

A3.9.1 Crown Dependencies: the Channel Islands and the Isle of Man

The methods used to estimate emissions from the Channel Islands and the Isle of Man are summarised in **Table A 3.9.2**. These data are supplied by energy statisticians and other government officials and are thought to be of good quality. Emissions are summarised in

Table A 3.9.3 and relevant background data are presented in **Table A 3.9.4** and **Table A 3.9.5**

Although the fuel used in the Crown Dependencies is included in the total energy statistics for the UK, as published in DUKES, the estimates made of the fuel use in the individual CDs has been used to modify the UK fuel balance, to allow separate reporting of emissions from the CDs. The total fuel used in the UK plus the Crown Dependencies matches the totals published in DUKES.

A3.9.1.1 Jersey

The largest sources of CO_2 emissions for Jersey in 2010 are the commercial and domestic sectors and road transport. Emissions from power generation make up only 9% of total CO_2 emissions, because much of Jersey's electricity is imported from France.

Agricultural activity is the main source of methane emissions, accounting for over 80% of total methane emissions in 2010. Waste is incinerated, and the methodology for calculating emissions from this source is fully consistent with that used for the UK.
There are no active landfill sites in Jersey. Emissions from closed landfill sites have not yet been considered in the emissions calculations.

N_2O emissions arise mainly from the use of off-road machinery, particularly associated with agricultural activities. Emissions of N_2O from manure management only account for approximately a tenth of the total N_2O emission.

F-gas emissions are based on UK emissions as no country specific data are available. The methodology uses proxy statistics such as population or GDP to rescale UK emission estimates. This is considered a reasonable approach as the activities in Jersey are similar to those in the UK. There are no emissions from industrial sources in Jersey, and so the F-gas emissions show a similar trend to the UK emissions from non-industrial sources.

Estimates of emissions from fuel combustion are based on real data supplied for fuel use and vehicle movements, and the uncertainty associated with these emission estimates are considered to be low, and probably similar in magnitude to the uncertainties associated with UK emission estimates from these sources. However, data for 2010 was not available at the time of inventory compilation, and it was necessary to extrapolate the existing time series.

Emissions from livestock were based on an incomplete time series, and rely on extrapolated figures for livestock numbers for the first half of the time series. Emissions from sewage treatment are based on UK per capita emission factors, which may not be an accurate representation of the technology in use for Jersey.

Net emissions of GHGs from LULUCF were updated for the 1990 to 2010 inventory, using updated activity data from Jersey, and ensuring the default land use transition period was applied consistently. The LULUCF sector in Jersey is a small sink, due to conversion to Grassland.

A3.9.1.2 The Isle of Man

The main sources of carbon emissions in the Isle of Man are road transport and power generation, which together contribute over half of the total CO_2 emissions. Residential and commercial combustion are also significant sources, accounting for a further third of total emissions. Some minor industrial sources of combustion emissions also exist - the sewage treatment plant and quarries.

CH_4 emissions are dominated by the agriculture sector, enteric fermentation in non-dairy cattle and sheep being the largest components. The only other significant source of CH_4 is the waste sector, with emissions from landfill up to 2003. Following this an incinerator was has been used for disposal of MSW. Emissions from closed landfill sites are not yet included in the emission estimates.

N_2O emissions arise mainly from agricultural practices, and manure management in particular. Cattle and sheep are the largest sources. No estimate has yet been made of N_2O from agricultural soils.

The emissions for fuel combustion and transportation sources for are based on real data and emission factors sourced from the existing GHG inventory. Emission estimates are therefore considered to have a relatively low level of uncertainty. Emissions from landfill, sewage treatment, and F-gas use rely on UK emissions data scaled by surrogate datasets. This makes an inherent assumption that the sources have similar characteristics and usage patterns to the UK – which is considered to be a sound assumption.

Net emissions of GHGs from LULUCF were updated for the 1990 to 2010 inventory, using updated activity data from the Isle of Man, and ensuring the default land use transition period was applied consistently. The LULUCF sector in the Isle of Man was a net source of CO_2 in 1990 but an increasing net sink since 1996, due to land conversion to forest land and grassland.

A3.9.1.3 Guernsey

The largest sources of CO_2 in 2010 were power stations and road transport. The time series of emissions from power stations reflects the changing proportion of electricity imported from France.

The largest methane source is from waste disposed to landfill. Major improvements were made to these estimates for the 1990-2008 greenhouse gas inventory. Emissions from agriculture are also a relatively large source, and are dominated by emissions from dairy cattle.

The estimates of emissions from fuel consumption for Guernsey are based on a number of assumptions. Fuel consumption figures for power generation were calculated based on electricity consumption figures, total fuel imports, and fuel consumption data for a few years taken from the power station statistical report. Domestic and commercial combustion figures also needed to be separated from the total imports, and split into different fuel types based on data given by the Guernsey government. Shipping and agriculture figures are based on incomplete time series and the missing data have been interpolated or extrapolated as necessary, and are therefore subject to greater uncertainty. The improvements to emissions from landfill, and also aviation have helped to decrease the uncertainties associated with these sources.

Net emissions of GHGs from LULUCF were updated for the 1990 to 2010 inventory, using updated activity data from Guernsey, and ensuring the default land use transition period was applied consistently. The LULUCF sector in Guernsey is a small source, due to conversion to Cropland.

Table A 3.9.2 Isle of Man, Guernsey and Jersey – Summary of Methodologies

Sector	Source name	Activity data	Emission factors	Notes
1	Energy - power stations and small combustion sources	Fuel use data supplied.	1990-2010 GHGi emission factors used for all sources.	In some cases time series were incomplete, and hence some data are arrived at by extrapolation/interpolation. Fuel imports for Guernsey were not always broken down into different fuel classes - this information was derived from data in a previous report (2002). These emissions are included within the UK emissions totals in the CRF.
	Energy - road transport	Time series of vehicle numbers and fuel consumption supplied, UK age profiles used, and vehicle km data derived from the fuel consumption using UK figures.	Factors for vehicle types based on UK figures.	Breakdown of vehicle types not always detailed, some fuel use is based on extrapolated figures. Assumes the same vehicle age profile as the UK. These emissions are included within the UK emissions totals in the CRF.
	Energy - other mobile sources	Aviation based on CAA and DfT data. Shipping movements supplied, and some data about off road machinery.	Aircraft emissions taken from the UK aviation model, shipping from 2003/2002 NAEI.	Incomplete datasets were supplied in many cases - the time series were completed based on interpolation/extrapolation or surrogate datasets such as passenger numbers. These emissions are included within the UK emissions totals in the CRF.
2	Industrial processes	Population, GDP.	Some sources assumed zero. Per capita emission factors based on UK emissions, where appropriate.	For F-gases, based on the assumption that activities such as MDI use and refrigeration per head of population will be similar to the UK, whilst industrial sources are not present. Other industrial process emissions are assumed to be zero unless known otherwise. These emissions are included within 2F9 – other in the CRF.
3	Solvent use	Population, GDP, vehicle and housing numbers.	Per capita (or similar) emission factors based on UK emissions.	Assumes that solvent use for activities such as car repair, newspaper printing, and domestic painting will follow similar patterns to the UK, whilst the more industrial uses will be zero. These emissions are included within the UK emissions totals in the CRF – within 3D5 other non-specified.
4	Agriculture	Livestock statistics supplied.	N_2O from manure management is based on a time series of UK emissions. CH_4 emission factors are IPCC emissions per head defaults.	N_2O emissions assume similar farm management practices as for the UK. These EFs are under review. Some of the farming statistics time series were incomplete - other years were based on interpolated/extrapolated values. Currently no emissions are made for agricultural soils, this has been added to the improvement programme. Emissions from enteric fermentation are included within 4A 'other'

Sector	Source name	Activity data	Emission factors	Notes
				in the CRF. For manure management in the CRF, CH_4 is included within 4B 'other' although N_2O is included within 4G 'other' as there is no way of including this within 4B.
5	Land use change and forestry	Land use and forest planting data.	Emissions and removals have been calculated using a Tier 1 method in most cases, with a Tier 3 method for forestry in the Isle of Man also being used.	Similar climate and land management parameters are assumed as for the UK. Land areas have been interpolated between land area surveys in some cases. More detailed activity data allowed a Tier 3 method to be applied for forestry in the Isle of Man. In the CRF, emissions are included and defined within the sub-sections of sector 5.
6	Waste – MSW	Landfill estimates based on population or waste amounts. Emissions from closed landfills have not been included yet. Incineration estimates based on limited data on the amount of waste incinerated.	Time series of UK per capita emission factors used for land fill sites, improved emission model for Guernsey.	Amounts of waste incinerated are based on limited data and interpolated values. The landfill emissions model that has been implemented for Guernsey has improved estimates for this source. More information on the methods are included in the main chapters of the NIR (Section 7.1). Emissions from landfill are included within 6A 'other' in the CRF, while emissions from waste incineration are included within UK emissions totals in 6C.
	Waste - Sewage treatment	Population.	Time series of UK per capita emission factors.	Assumes the same sewage treatment techniques as for the UK. In practice, treatment not thought to be as comprehensive as UK, but no details available. Emissions are included in 6B3 'other' in the CRF.

Table A 3.9.3 Isle of Man, Guernsey and Jersey – Emissions of Direct GHGs (Mt CO_2 equivalent)

Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1. Energy	1.44	1.50	1.54	1.52	1.55	1.60	1.72	1.79	1.86	1.74	1.62	1.38	1.38	1.25	1.27	1.33	1.34	1.43	1.34	1.37	1.34
2. Industrial Processes	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.05	0.05	0.06	0.06
3. Solvent and Other Products Use																					
4. Agriculture	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.14	0.14	0.10	0.10	0.10	0.12	0.13	0.13	0.12	0.12
5. Land Use, Land Use Change and Forestry	-0.02	- 0.02	- 0.02	- 0.03	- 0.04	- 0.04	- 0.06	- 0.06	- 0.06	- 0.06	- 0.07	- 0.07	- 0.07	- 0.08	- 0.07	- 0.07	- 0.10	- 0.09	- 0.08	- 0.10	- 0.09
6. Waste	0.14	0.14	0.14	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.09	0.09	0.07	0.07	0.04	0.06	0.06	0.05	0.05	0.05	0.04
7. Other																					
Total	**1.69**	**1.76**	**1.81**	**1.75**	**1.78**	**1.84**	**1.94**	**2.02**	**2.10**	**1.98**	**1.82**	**1.57**	**1.55**	**1.38**	**1.38**	**1.46**	**1.47**	**1.57**	**1.49**	**1.49**	**1.46**

Table A 3.9.4 Isle of Man, Guernsey and Jersey – Fuel use data

Fuel Name	Fuel Units	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Aviation spirit	Mt	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Aviation turbine fuel	Mt	0.07	0.06	0.06	0.07	0.06	0.06	0.06	0.07	0.07	0.07	0.08	0.08	0.08	0.09	0.09	0.09	0.08	0.09	0.08	0.08	0.08
Burning oil	Mt	0.23	0.25	0.23	0.23	0.25	0.26	0.30	0.35	0.35	0.31	0.36	0.31	0.35	0.36	0.33	0.34	0.33	0.34	0.32	0.36	0.38
Coal	Mt	0.11	0.11	0.09	0.10	0.10	0.10	0.10	0.08	0.07	0.05	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
DERV	Mt	0.08	0.09	0.08	0.09	0.09	0.10	0.12	0.13	0.13	0.13	0.14	0.13	0.13	0.13	0.12	0.12	0.12	0.14	0.13	0.13	0.13
Fuel oil	Mt	0.50	0.54	0.62	0.58	0.60	0.62	0.63	0.59	0.63	0.63	0.48	0.27	0.22	0.09	0.12	0.10	0.15	0.19	0.15	0.15	0.10
Gas oil	Mt	0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.16	0.20	0.14	0.13	0.13	0.18	0.15	0.13	0.14	0.11	0.13	0.12	0.11	0.11
LPG	Mth	0.05	0.06	0.05	0.05	0.05	0.05	0.06	0.13	0.13	0.13	0.13	0.12	0.12	0.11	0.08	0.08	0.07	0.07	0.07	0.07	0.07
MSW	Mt	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Natural gas	Mth	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04	0.10	0.17	0.16	0.19	0.20	0.20	0.22
Petrol	Mt	**0.24**	**0.24**	**0.24**	**0.24**	**0.24**	**0.24**	**0.28**	**0.26**	**0.26**	**0.25**	**0.23**	**0.25**	**0.23**	**0.23**	**0.23**	**0.23**	**0.23**	**0.22**	**0.21**	**0.21**	**0.20**

Table A 3.9.5 Isle of Man, Guernsey and Jersey – Animal numbers

Animal Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Dairy Cattle	15888	15888	15888	15682	15477	15729	14990	15330	15890	15950	16186
Non-dairy Cattle	28663	30164	31665	27134	27710	28333	28346	27049	28639	29292	29176
Sheep	151764	150972	150180	154483	161798	160228	157432	162159	174345	178705	176259
Goats	91	91	91	91	91	91	74	74	74	74	95
Horses	1928	1928	1928	1928	1928	1928	1928	1928	1928	1928	1928
Swine	4854	5774	6694	5419	5037	5411	5130	6714	7071	6449	4609
Poultry	84048	77855	71662	76675	73469	46481	60080	58356	54552	51071	46448

Animal Type	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Dairy Cattle	15416	14525	15426	14590	14335	14138	13140	12593	11658	11455
Non-dairy Cattle	28562	28438	13873	14828	15562	24089	32449	32615	30147	28180
Sheep	168867	171264	91952	85521	90536	137438	146560	149642	145962	138251
Goats	103	65	63	41	57	79	69.5	76	71.5	65
Horses	1928	1928	1928	1928	1965	2358	2097	2243	2301	2379
Swine	3413	3578	1337	1391	1148	1310	1457.3	1238.5	4615.8	4086
Poultry	42295	46091	50217	48087	58160	58229	53424	52642	40792	38400

A3.9.2 Overseas Territories: Bermuda, Falklands Islands, Montserrat, the Cayman Islands and Gibraltar

Table A 3.9.6 summarises the methods used to estimate emissions from the Falklands Islands, Montserrat, the Cayman Islands and Bermuda. Emissions from some sources are not estimated due to lack of data. Emissions are summarised in **Table A 3.9.7**, and relevant background data in **Table A 3.9.8** and **Table A 3.9.9**. The government of Bermuda prepared its own GHG inventory estimates and methodological report for 1990 to 2000, and has provided more data for the estimates of emissions for subsequent years in the time series. So **Table A 3.9.6** only refers to the methodologies used for the latter part of the time series for Bermuda, and the full time series for the Falkland Islands, Montserrat and the Cayman Islands.

A3.9.2.1 Falklands Islands

The largest source of CO_2 is domestic heating. There are no industrial combustion sources. Estimates have been made for aviation and off-road machinery, but no data were available to allow emission estimates to be made for shipping.

Methane emissions are almost entirely from agriculture. There are a little under half a million sheep on the islands, which account for 90% of the agricultural CH4 emissions. Agriculture is also the dominant source of N_2O. Methane emissions from waste disposal are small, as waste is burnt. Sewage is disposed of to sea.

Net emissions of GHGs from LULUCF were updated for the 1990 to 2010 inventory, using updated activity data from the Falkland Islands, and ensuring the default land use transition period was applied consistently. The Falkland Islands are a small source due to land conversion on organic soils. Overall there is very little land use change on the islands (93% of their area is natural Grassland).

The estimates of emissions from power generation are based on a very nearly complete time series of annual fuel consumption. These emission estimates are therefore considered to be relatively low in uncertainty.

Domestic fuel consumption statistics, however, were only provided for most of the second half of the time series. Extrapolation based on population was used to create a complete activity dataset for the entire time series. Vehicle numbers were provided from 2005 onwards. Data for earlier years were derived by using population statistics as a surrogate. The extent of extrapolation required is expected to result in higher uncertainties in the trend, although the calculation of emissions for later years in the time series are expected to be of satisfactory quality.

A3.9.2.2 Montserrat

Only limited activity data were supplied for Montserrat, typically covering the second half of the complete 1990-2010 time series. It was not possible to make estimates of GHG emissions from a limited number of source sectors. In addition half of the island has been uninhabitable during parts of the time series, due to recent volcanic activity. Nevertheless a reliable time series of the island’s population was supplied, and it was possible to use this to extend some of the time series of available emission estimates.

Estimates have been made for power generation, residential combustion, aviation, road transport, F-gases and agriculture. No information was supplied about shipping. There was also no information supplied about the disposal of waste or treatment of sewage. Since emissions from different waste disposal and sewage treatment techniques vary greatly, it was not considered appropriate to make an emissions estimate based on surrogate statistics. It has also not been possible to calculate emissions and removals from LULUCF activities for Montserrat.

Of the sectors calculated, road transport is the most important for CO_2 emissions. Only fuel consumption figures were supplied for this sector and emissions of non-CO_2 greenhouse gases are therefore quite uncertain. It is assumed that emissions from some off road transport and machinery will be included in the road transport estimates because the data are likely to capture fuel used by mobile machinery. Power generation is the other major source for CO_2. Emissions of CH_4 and N_2O are dominated by the agricultural sector, with emissions arising primarily from cattle.

A3.9.2.3 Cayman Islands

Continued improvements have been made to the data availability from the Cayman Islands, through closer collaboration with data providers. Fuel import data has been received, and fuel use for the power station, together with livestock statistics, shipping movements, aircraft activities, and even off-road mobile machinery.

The largest CO_2 emission source is power generation. Agriculture is not a large source of emissions, and therefore methane and N_2O emissions are small. No data were available to estimate LULUCF emissions from the Cayman Islands.

In some cases assumptions have had to be made to fill gaps in the data, or where the data were inconsistent. For example, the total fuel imports data was inclusive of the power station fuel use, however in some years the reported consumption at the power station was greater than the total fuel imports.

A3.9.2.4 Bermuda

The Bermuda Department for Environmental Protection has produced its own greenhouse gas inventory, compiled according to the IPCC guidelines. Calculated emissions and the methodology used for Bermuda are detailed in Bermuda's Greenhouse Gas Inventory – Technical Report 1990-2000 (the Department of Environmental Protection, Government of Bermuda). An estimate of emissions from waste incineration (excluded from Bermuda's report) has also been made based on UK emission factors, and statistics contained in Bermuda's report on the amount of waste generated per person per day.

Data have now been supplied to improve estimated emission for 2001 to 2010. These data were supplied in the Compendium of Environmental Statistics, and have allowed improvements to emissions from this part of the time series.

The major sources for carbon are road transport and power generation. Emissions of other GHGs are small by comparison. Emissions from landfill were the main source of CH_4 methane in 1990, but waste is now disposed of by incineration. N_2O emissions arise mainly from sewage treatment.

Table A 3.9.6 Cayman Islands, Falklands Islands, Bermuda and Montserrat – Methodology (for estimates of carbon, CH_4 and N_2O)

Sector	Source name	Activity data	Emission factors	Notes
1	Energy - power stations and small combustion sources	Fuel use data supplied.	1990-2010 Emission factors from the UK GHGI.	Fuel data in most cases was only supplied for the latter part of the time series. Extrapolated figures based on population trends have been used to calculate fuel consumption for earlier years, introducing uncertainty in the trend. These emissions are included within the UK emissions totals in the CRF.
	Energy - road transport	Vehicle numbers and fuel use supplied for the Falkland Islands, similarly for Bermuda but limited fuel use time series data, vehicle numbers and vehicle kilometres and fuel use for the Cayman Islands, fuel use for Montserrat.	Factors for vehicle types based on UK figures.	Where vehicle numbers have only been supplied for one year, the time series is generated by using population data. The age profiles are based on UK figures - which may not always be appropriate. Emissions for Montserrat are subject to a greater degree of uncertainty as there is no information about vehicle types or numbers. These emissions are included within the UK emissions totals in the CRF.
	Energy - other mobile sources	Aviation based on CAA and DfT data. Shipping movements supplied for the Cayman Islands	EMEP/CORINAIR factors.	The aircraft movement data can be limited in terms of time series completeness. Shipping data for the Cayman Islands is of good quality. These emissions are included within the UK emissions totals in the CRF.
2	Industrial processes	Population, GDP, number of refrigerators and air conditioning units.	Some sources assumed zero. Per capita emission factors based on UK emissions.	Assumes activities such as aerosol use and refrigeration per capita will be similar to the UK. In practice, this is unlikely, but there is no other data available. The Cayman Island estimates have been scaled using the number of refrigeration and air conditioning units compared with the UK. These emissions are included within 2F9 – other in the CRF.
3	Solvent use	Population, GDP, vehicle and housing numbers.	Per capita (or similar) emission factors based on UK emissions.	Assumes that solvent use for activities such as car repair, newspaper printing, and domestic painting will follow similar patterns to the UK, whilst the more industrial uses will be zero. These emissions are included within the UK emissions totals in the CRF – within 3D5 other non-specified.
4	Agriculture	Livestock statistics supplied.	N_2O from manure management is based on a time series of UK emissions. CH_4 emission factors are IPCC emissions per head defaults.	N_2O emissions assume similar farm management practices as for the UK. These EFs are under review. Some of the farming statistics time series were incomplete - other years were based on interpolated/extrapolated values. Currently no emissions are made for agricultural soils, this has been added to the improvement programme. Emissions from enteric fermentation are included within 4A 'other' in the

Sector	Source name	Activity data	Emission factors	Notes
				CRF. For manure management in the CRF, CH_4 is included within 4B 'other' although N_2O is included within 4G 'other' as there is no way of including this within 4B.
5	Land use change and forestry	Land use data	Tier 1 data.	Data were only available to estimate emissions from the Falklands. More information on the methods are included in the main chapters of the NIR (Section 7.1). In the CRF, emissions are included and defined within the sub-sections of sector 5.
6	Waste - MSW	Tonnes of waste incinerated (Falkland Islands), NE for Montserrat, tonnage of waste incinerated and to landfill (Cayman Islands), waste generation estimates (Bermuda)	US EPA factors for the open burning of municipal refuse, NAEI factors for clinical waste incineration and MSW incineration.	Information on the details relating to waste incineration or landfill is limited or not available. Emissions from landfill are included within 6A 'other' in the CRF, while emissions from waste incineration are included within UK emissions totals in 6C.
	Waste - Sewage treatment	NO (Falkland Islands), population data (Cayman Islands), Wastewater production (Bermuda) and NE (Montserrat)		Sewage from the Falkland Islands is disposed of to sea. Emissions for the Cayman Islands are based on population; wastewater generated is available for Bermuda. No information was available on and Montserrat, so it is reported as NE, but may be NO. Emissions are included in 6B3 'other' in the CRF.

Table A 3.9.7 Cayman Islands, Falklands Islands, Bermuda and Montserrat – Emissions of Direct GHGs (Mt CO_2 equivalent)

Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1. Energy	1.19	1.16	1.15	1.18	1.19	1.20	1.19	1.20	1.31	1.31	1.33	1.44	1.46	1.46	1.52	1.55	1.67	1.80	1.69	1.73	1.75
2. Industrial Processes	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.02
3. Solvent and Other Products Use																					
4. Agriculture	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.21	0.21	0.21	0.21	0.21	0.20	0.20	0.19	0.19	0.18	0.18
5. Land Use, Land Use Change and Forestry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01
6. Waste	0.09	0.08	0.07	0.06	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.06	0.07	0.07	0.08	0.08	0.07	0.08
7. Other																					
Total	**1.51**	**1.47**	**1.45**	**1.46**	**1.47**	**1.48**	**1.48**	**1.49**	**1.61**	**1.60**	**1.63**	**1.73**	**1.75**	**1.76**	**1.82**	**1.85**	**1.97**	**2.10**	**1.99**	**2.01**	**2.03**

Table A 3.9.8 Cayman Islands, Falklands Islands, Bermuda and Montserrat – Fuel use data

Fuel Name	Fuel Units	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Aviation spirit	Mt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aviation turbine fuel	Mt	0.09	0.06	0.05	0.06	0.05	0.04	0.05	0.04	0.06	0.04	0.05	0.05	0.06	0.06	0.06	0.07	0.10	0.09	0.09	0.09	0.09
Burning oil	Mt	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Clinical waste	Mt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DERV	Mt	0.17	0.16	0.16	0.15	0.15	0.14	0.13	0.13	0.17	0.16	0.15	0.21	0.21	0.18	0.24	0.32	0.34	0.41	0.34	0.38	0.37
Fuel oil	Mt	0.29	0.29	0.29	0.30	0.31	0.32	0.32	0.34	0.36	0.38	0.51	0.53	0.55	0.57	0.55	0.56	0.62	0.65	0.66	0.69	0.71
Gas oil	Mt	0.28	0.28	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.19	0.20	0.20	0.21	0.21	0.22	0.22	0.22	0.22	0.22	0.22
LPG	Mth	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
MSW	Mt	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Natural gas	Mth	0.12	0.13	0.13	0.14	0.14	0.15	0.16	0.16	0.17	0.17	0.17	0.18	0.18	0.18	0.18	0.17	0.18	0.20	0.17	0.14	0.14
Petrol	Mt	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.24	0.24	0.23	0.25	0.23	0.23	0.26	0.19	0.18	0.21	0.18	0.19	0.20

Table A 3.9.9 Cayman Islands, Falklands Islands, Bermuda and Montserrat – Animal numbers

Animal Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Dairy Cattle	400	400	400	400	400	400	400	400	400	400	1354
Non-dairy Cattle	1553	1553	1438	228	1764	1751.6	1777.5	1844.4	1914.9	1952.7	6009.3
Sheep	739999	729449	712755	721352	727002	717571	685756	707519	707696	708082	642825
Goats	405	405	569	556	730	839.82	926.02	1042.7	1172.5	1289	1359.9
Horses	2217	2165	2111	1987	2009	2069	1974	1890	1888	1945	1624
Swine	766	786	806	826	846	866	866	866	866	866	1047
Poultry	12400	12400	15000	15000	10500	10636	10846	11037	11210	11368	14907
Deer	0	0	0	0	0	0	0	0	0	0	0

Animal Type	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Dairy Cattle	1687	1272	1118	1145	1299	1254	1170	1202	868	868
Non-dairy Cattle	5646	6028	6529.9	7196.4	6988	7433	7290	6934	6601	6163
Sheep	612925	583457	586567	580864	533551	530109	510085	504720	478625	452530
Goats	1263.6	1176	1096.3	1660.9	2710	2290	2792	2943	2603	2218
Horses	1639	1540	1533	1417	1474	1394	1300	1317	1269	1221
Swine	1002	1024	1045	1021	979	918	962	949	955	955
Poultry	14183	13919	14053	13999	14525	16363	15160	14714	14814	14814
Deer	0	0	0	0	0	124	155	169	184	199

A3.9.2.5 Gibraltar Emissions

A greenhouse gas inventory for Gibraltar has been created which contains annual emission estimates from 1990 to 2010 inclusive and emissions for the Base Year. The year 1995 has been chosen as the Base Year for the fluorinated gases, in agreement with the year the UK has chosen, and in accordance with Article 3(8) of the Kyoto Protocol. Gibraltar made the decision to join the UK's instrument of ratification of the Kyoto Protocol in 2006.

Gibraltar already reports emissions under other international agreements. During the compilation of the Gibraltar GHG inventory, steps have been taken to ensure the existing Gibraltar inventories and the GHG inventory share common activity data where appropriate.

Data specific to Gibraltar have been collected to estimate emissions as accurately as possible. In general the data were requested by questionnaire asking for information on fuel use, the vehicle fleet, shipping movements, livestock numbers and waste treatment. Communications between the Gibraltar Environmental Agency and other companies is extremely good, allowing the acquisition of reliable data relating to the larger emission sources. The Gibraltar Environmental Agency was able to provide information from the government of Gibraltar statistics office, which holds much information relating to several source sectors. However, there are laws in Gibraltar restricting the data available from the Government statistics department. In general these were introduced to protect commercially sensitive information, which is more likely to occur in smaller administrations. For example it is not possible to obtain information on petrol sales from the eight petrol stations on Gibraltar without special dispensation. However, it is possible to obtain information on services that have no direct competitors (and hence the information is not regarded as being commercially sensitive).

There were some difficulties obtaining information for some sectors to estimate emissions using the same methods applied to the existing UK GHG inventory. Modifications were therefore made to the existing methods and surrogate data were used as necessary; this is discussed in the sections below. Where possible, emissions were estimated using same methods used in the UK inventory.

Emission factors for most sources are taken from the NAEI, to be consistent with the UK GHG inventory. Emissions from aircraft are now calculated within the UK aviation model using CAA and DfT data. See Annex section A3.3.5 for more information.

Whilst the data availability was regarded as good for an administrative area the size of Gibraltar, there were a number of sources for which detailed activity data was not available. In these cases expert judgement was required to enable an emission estimate to be obtained. **Table A 3.9.6** summarises the methodologies used to produce emission estimates for Gibraltar.

Emissions from LULUCF have not been estimated from Gibraltar but are believed to be very small.

Emissions from military activities in Gibraltar have been excluded from the totals. This is because the fuel used for these activities is likely to be sourced from the UK, and therefore to include emissions in the Gibraltar inventory would result in a double-count. Aviation between Gibraltar and the UK are classified as domestic.

A summary of the emissions of the direct GHGs from Gibraltar is given in **Table A 3.9.11**, and relevant background data are presented in **Table A 3.9.12**.

Table A 3.9.10 Summary of methodologies used to estimate emissions from Gibraltar

Sector	Source name	Activity data	Emission factors	Notes
1	Energy - power stations, domestic, and small combustion sources	Fuel use data supplied for the three power stations. No activity data available for commercial and institutional combustion and so estimates made. Domestic combustion has been removed from the inventory following consultation with the Gibraltar Environment Agency. Fuel use available for industrial combustion.	Emission factors from the 1990 – 2010 GHGI	In some cases time series were incomplete - other years were based on extrapolated (on population)/interpolated values. These emissions are included within the UK emissions totals in the CRF.
	Energy - road transport	Time series of vehicle numbers and typical annual vehicle km per car, age profile calculated using UK figures.	Factors for vehicle types based on UK figures.	Breakdown of vehicle types not always detailed, some fuel use is based on extrapolated figures. Assumes the same vehicle age profile as the UK. These emissions are included within the UK emissions totals in the CRF.
	Energy - other mobile sources	Shipping movements supplied. Aviation based on CAA and DfT data.	Aircraft factors taken from EMEP/CORINAIR, shipping from 2003/2002 NAEI.	Incomplete datasets were supplied in many cases - the time series were completed based on passenger number data or interpolated values. These emissions are included within the UK emissions totals in the CRF.
2	Industrial processes	No industrial processes identified with GHG emissions. Emissions of F-gases from air conditioning units are included in this sector.	Per capita (or similar) emission factors based on UK emissions.	Estimates of HFCs from air conditioning were based on percentages of homes, cars etc using the equipment, provided by the Environmental Agency. These emissions are included within 2F9 – other in the CRF.
4	Agriculture	No commercial agricultural activity. No emissions from this sector.		
5	Land use change and forestry			Emissions Not Estimated, as insufficient data are available. These emissions are likely to be negligible.

Sector	Source name	Activity data	Emission factors	Notes
6	Waste - MSW	Incineration estimates based on limited data on the amount of waste incinerated up to 2001. Since 2001, waste has been transported to Spain to be land filled.	NAEI factors for clinical waste MSW incineration.	Estimates of waste incinerated between 1990 and 1993 are based on extrapolated values. Data for the remainder of the time series were provided. Emissions from this source are assumed zero after the closure of the incinerator in 2000. Emissions from landfill are included within 6A ‘other’ in the CRF, while emissions from waste incineration are included within UK emissions totals in 6C.
	Waste - Sewage treatment	No emissions from this sector; all sewage is piped directly out to sea, with no processing.		

Table A 3.9.11 Emissions of Direct GHGs (Mt CO_2 equivalent) from Gibraltar

Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1. Energy	0.17	0.18	0.18	0.16	0.17	0.17	0.16	0.16	0.17	0.17	0.18	0.18	0.19	0.19	0.20	0.20	0.19	0.19	0.20	0.21	0.21
2. Industrial Processes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
3. Solvent and Other Products Use																					
4. Agriculture																					
5. Land Use, Land Use Change and Forestry																					
6. Waste	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7. Other																					
Total	**0.17**	**0.18**	**0.19**	**0.17**	**0.18**	**0.18**	**0.17**	**0.17**	**0.18**	**0.18**	**0.19**	**0.19**	**0.19**	**0.19**	**0.20**	**0.21**	**0.20**	**0.20**	**0.21**	**0.22**	**0.21**

Table A 3.9.12 Gibraltar – Fuel use data

Fuel Name	Fuel Units	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Aviation spirit	Mt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aviation turbine fuel	Mt	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.03	0.03	0.02
DERV	Mt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Fuel oil	Mt	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03
Gas oil	Mt	0.06	0.07	0.08	0.06	0.08	0.08	0.07	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.10	0.11	0.10	0.11	0.12	0.13	0.13
MSW	Mt	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural gas	Mth	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Petrol	Mt	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

A4 ANNEX 4: Comparison of CO_2 Reference and Sectoral Approaches

This annex presents information about the Reference Approach calculations, and its comparison with the Sectoral Approach.

A4.1 ESTIMATION OF CO_2 FROM THE REFERENCE APPROACH

The UK greenhouse gas inventory is compiled using a detailed Sectoral Approach methodology, to produce detailed sector-specific inventories of the 10 pollutants in accordance with the IPCC reporting format. These UK GHGI emission estimates are based on bottom-up activity data, such as national energy statistics on fuel combustion within different economic sectors and other statistical datasets to generate estimates of non-combustion emissions from other known sources.

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

The Reference Approach inventory method utilises different sections of the UK national energy statistics, combining aggregated data on fuel inputs and outputs from the overall UK economy, using top-level data on oils, gas and solid fuels to assess the UK carbon balance for combustion sources. This more simplistic, non-source-specific methodology provides a very useful quality check against the more rigorous Sectoral Approach. The Reference Approach typically produces UK CO_2 emission estimates that are between 1.6% lower to 1.7% higher than the more detailed Sectoral Approach, due to differences in assumptions of non-energy use and statistical differences between production-side and demand-side fuel estimates within national energy statistics.

In recent inventory review feedback from the UNFCCC Expert Review teams, a number of data inconsistencies in the CRF data entries for the Reference Approach estimates were identified. The source of these errors were traced during the Centralised Review, as the CRF data were not consistent with the inventory agency's spreadsheet data; evidently a data transcription error had occurred that had not been traced in the CRF output prior to its submission by the UK. In response to the UNFCCC ERT feedback, the UK inventory agency has made specific corrections to the CRF data compared to previous submissions and has also implemented new quality checking routines to improve the UK CRF submissions.

The inventory agency has introduced two new specific quality checking routines:

- ✓ Data outputs within CRF tables 1A(b), 1A(c), and 1A(d) for 1990 and the latest year are checked against the inventory agency's spreadsheet calculations (which are governed by pre-existing quality checking functions); and
- ✓ CRF outputs from the latest submission are checked for 1990 and the latest year – 1, against the CRF outputs from the previous submission for those years. Data points

are checked to identify revisions from tables: 1s1, 1s2, 1A(a)s1, 1A(a)s2, 1A(a)s3, 1A(a)s4, 1A(b), 1A(c), 1A(d). 1B1, and 1B2. These comparisons assist in the identification of outliers and inconsistencies that may arise from data transcription errors.

In addition to these new checking routines, a number of improvements to the Reference Approach calculations were implemented during the latest inventory cycle, to improve the accuracy, completeness and transparency of the data and to respond to the UNFCCC ERT recommendations:

- Annual estimates of carbon stored within coal oils and tars, derived from coking coal, have been revised. The estimates of carbon stored are based on an estimate of coking coal activity. Previously the activity data for coking coal was then used in conjunction with calorific values and carbon content estimates for coal oils and tars. This has been corrected to use the calorific values and carbon factors for coking coal, leading to small revisions in the overall estimates of carbon stored. In addition to this revision in the data, the allocation of this carbon stored has been corrected within the Reference Approach tables. Previously these estimates were misallocated to “Liquid fossil fuels” in CRF table 1A(c); this allocation has been corrected to “solid fossil fuels”, as the carbon is derived from coking coal;

- CRF entries to table 1A(c) across all years have been revised to correct data for Apparent Energy Consumption (PJ) and Apparent Energy Consumption Excluding Non-Energy Use and Feedstocks (PJ). In the previous CRF submission, there were instances of mis-reporting whereby the figure excluding NEU and feedstocks was reported as the higher figure.

- The UNFCCC ERT noted in the review of the previous UK GHGI submission that the handling of colliery methane oxidation factors was inconsistent between years in the CRF tables. In updating the UK submission, the colliery methane data is combined with the other sources of natural gas and reported in one line of the CRF tables. Separate reporting of colliery methane in the previous submission was in error (a double count)

- The UK CRF submission Table 1A(d) has been modified to include lines of data for feedstock estimates for petroleum coke and other oils (including industrial spirit, white spirit and petroleum waxes) and therefore ensure consistency with the data presented in CRF table 1A(b). This correction is in response to the ERT feedback on the previous submission which identified that not all fuels that had reported use in feedstock use were included within the data presented in Table 1A(d).

- A correction has been made to marine bunkers data fuel oil in the Reference Approach CRF tables. In the previous inventory cycle, a data processing error led to incorrect data reported for years 1990-1997, following a revision to the UK GHGI method for derivation of fuel use and emissions in domestic and international shipping. This error has been corrected, to present a new time series of fuel oil estimates for this source.

- Estimates of carbon stored from gas use in ammonia production in the Sectoral approach have been revised, and these revisions to the time series for this source have led to small revisions in the comparison between the Reference and Sectoral Approach, as the UK estimates in the Reference Approach exclude specific consideration of this source.

- A correction to reported data on sub-bituminous coal in the Reference Approach across the full time series has been implemented in this inventory cycle. Data on sub-bituminous coal in the 1990-2009 reference approach for Stock Change were included in error, and introduced a double-count to data reported in Stock Change data for other solid fuels. These data have now been removed from the Reference Approach calculations.

- Data on marine bunker use of gas oil have been revised downwards across the time series, compared to the 1990-2009 version, due to small revisions to gas oil allocations from recent research into shipping, inland waterways and fishing vessels.
- Data on international aviation bunker fuels have been revised upwards across the time series to include the data on Aviation Spirit use by international flights. Previously only data on Aviation Turbine Fuel was included in the Reference Approach analysis; this leads to a very small increase in bunker emissions across the time series.

A4.2 DISCREPANCIES BETWEEN THE IPCC REFERENCE AND SECTORAL APPROACH

The UK GHGI contains a number of emission sources that are not accounted for within the IPCC Reference Approach, and therefore provides a higher estimate of CO_2 emissions. The sources not included in the Reference Approach are:

- Land use, land use change and forestry;
- Offshore flaring and well testing;
- Waste incineration; and
- Non-fuel industrial processes.

In principle, the IPCC Reference Approach total can be compared with the IPCC Table 1A Total, plus the emissions arising from fuel consumption in 1B1 Solid Fuel Transformation and Table 2 Industrial Processes (Iron and Steel and Ammonia Production). The IPCC Reference annual totals typically range between 1% lower to 2 % higher than the comparable bottom-up emission totals of the Sectoral Approach.

The IPCC Reference Approach is based on statistics of production, imports, exports, stock changes and non-energy use of fuels whilst the Sectoral Approach uses fuel consumption data by source sector. The two sets of statistics can be related using mass balances (see the publication 'Digest of UK Energy Statistics' DECC, 2011), but these show that some fuel is unaccounted for. This unaccounted fuel is reported in DUKES as statistical differences, which consist of measurement errors and losses. The system of energy statistics operated by DECC aims to keep UK statistical differences (without normalisation) at less than 0.5% of energy supply, for total supply and also for each fuel.
Nevertheless a proportion of the difference between the Reference Approach and the Sectoral Approach totals will be accounted for by statistical differences, particularly for liquid fuels.
Note that:

1. The Sectoral Approach only includes emissions from the non-energy use of fuel where they can be specifically identified and estimated, for example within industrial processes including ammonia production, fertiliser production and iron and steel production. The IPCC Reference Approach implicitly treats the non-energy use of fuel as if it were combustion. A correction is then applied by deducting an estimate of carbon stored from non-energy fuel use. The carbon stored is estimated from an approximate procedure that

does not identify specific processes. The result is that the IPCC Reference Approach is based on a higher estimate of non-energy use emissions.

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

A4.3 TIME SERIES OF DIFFERENCES IN THE IPCC REFERENCE AND SECTORAL INVENTORIES

Table A 4.3.1 shows the percentage differences in CO2 emissions from fuel combustion sources between the IPCC Reference Approach and the UK GHGI (Sectoral Approach), for each year since 1990. Note that this comparison takes account of the fuel consumption emissions that occur in the 2C Metal Production and 2B1 Ammonia Production sectors.

Note that in most years, the percentage difference is a small positive number, indicating that the Reference Approach estimates are slightly higher than the Sectoral Approach.

Table A 4.3.1 Modified comparison of the IPCC Reference Approach and the Sectoral Approach (% total CO2)

Year	1990	1991	1992	1993	1994	1995
Percentage difference	-1.6	-0.2	0.7	0.2	0.3	1.7

Year	1996	1997	1998	1999	2000	2001
Percentage difference	-0.1	-0.6	0.2	1.0	1.5	0.4

Year	2002	2003	2004	2005	2006	2007
Percentage difference	-0.2	-0.6	-0.6	0.5	0.7	-0.4

Year	2008	2009	2010
Percentage difference	-0.3	0.1	0.1

A5 ANNEX 5: Assessment of Completeness

A5.1 ASSESSMENT OF COMPLETENESS

Table A 5.1.1 shows sources of GHGs that are not estimated in the UK GHG inventory, and the reasons for those sources being omitted. This table is taken from the CRF; "Table9(a)".

Table A 5.1.1 GHGs and sources not considered in the UK GHG inventory

GHG	CRF sector	Source/sink category	Reason
CO_2	1. Energy	1C2 Multilateral Operations	Data unavailable – this is a memo item so does not affect the national total.
CO_2	2. Industrial Processes	2A4 – soda ash production	Emissions from fuels used in soda ash production are reported elsewhere (within 1A2f). Carbon evolved from the initial calcination stage of the process is assumed to be entirely converted into soda ash and therefore not emitted
CO_2	2. Industrial Processes	2A5/6 Asphalt Roofing/Paving	No methodology available but considered negligible (and therefore not a key category).
CO_2	2. Industrial Processes	2C2 Ferroalloys Production	Source considered negligible in the UK (and therefore not a key category).
CO_2	2. Industrial Processes	2D2 Food and Drink	No appropriate data available
CO_2	3. Solvent and Other Product Use		Carbon equivalent of solvent use not included in total.
CO_2	5. Land-Use Change and Forestry	5C1 Grassland remaining Grassland - Carbon stock change in living biomass	Emissions believed small (and therefore not a key category).
CO_2	5. Land-Use Change and Forestry	5B2/5C1/5C2/5D/5F Biomass burning by Wildfires	There is no activity data available for wildfires on non forest land in the UK
CO_2	6. Waste	6A1 Managed Waste disposal on land	Emissions from CO_2 in this category are assumed to be biogenic in origin and therefore not counted towards the total.
CO_2	6. Waste	6C2 Additional fires (vehicles)	No suitable emission factor available
CO_2	KP LULUCF	KP A.1.2 Units of land harvested since the beginning of the commitment period	Assumed not to occur in this commitment period as forest management cycles operate on long time scales
CO_2	KP LULUCF	5(KP-II)4 Carbon emissions from lime application-Afforestation/Reforestation	No lime is applied to forests in the UK
CO_2	KP LULUCF	5(KP-II)4 Carbon emissions from lime application-Forest Management	No lime is applied to forests in the UK
CO_2	KP LULUCF	5(KP-II)5 GHG emissions	Controlled burning for forest

GHG	CRF sector	Source/sink category	Reason
		from biomass burning-Afforestation/Reforestation/Forest Management-Controlled burning	management purposes does not occur in the UK
CO_2	KP LULUCF	5(KP-II)5 GHG emissions from biomass burning-Deforestation- Wildfires	There is no activity data available for wildfires on non-forest land in the UK
N_2O	2. Industrial Processes	2A7 Glass Production	Data not available
N_2O	2. Industrial Processes	2A7 Fletton Brick Production	No suitable method for estimating emissions of N_2O from this source, but emission are thought to be negligible (and therefore not a key category).
N_2O	2. Industrial Processes	2A7 Asphalt	Data unavailable. Believed to be very small and very uncertain
N_2O	2. Industrial Processes	2B1 Ammonia Production	Emissions from this source are considered negligible (and therefore not a key category).
N_2O	3. Solvent and Other Product Use	3D Other –Anaesthesia	Activity not readily available – believed small (and therefore not a key category).
N_2O	5. Land-Use Change and Forestry	5B2/5C1/5C2/5E Biomass burning by Wildfires	There is no activity data for wildfires from non forest land in the UK
N_2O	5. Land-Use Change and Forestry	5G Harvested wood products	No guidance available for calculating non CO_2 emissions from harvested wood products.
N_2O	6. Waste	6B2 Domestic and Commercial	No data are available to estimate emissions from this source. Emissions are believed to be small (and therefore not a key category).
N_2O	6. Waste	6C2 Chemical	High temperature combustion processes, methane and N2O emissions insignificant (and therefore not a key category).
N_2O	6. Waste	6C2 Accidental fires (vehicles)	No suitable emission factor available
N_2O	KP LULUCF	KP A.1.2 Units of land harvested since the beginning of the commitment period	Assumed not to occur in this commitment period as forest management cycles operate on long time scales
N_2O	KP LULUCF	5(KP-II)1 Direct N_2O emissions from N fertilisation- Forest Management	Nitrogen fertilizer is only applied to newly planted forests in the UK (not established forests)
N_2O	KP LULUCF	5(KP-II)2 N_2O emissions from drainage of soils-Forest Management	Reporting not mandatory. No activity data on extent of drainage
N_2O	KP LULUCF	5(KP-II)5 GHG emissions from biomass burning-Afforestation/Reforestation/Forest Management-Controlled burning	Controlled burning for forest management purposes does not occur in the UK
N_2O	KP LULUCF	5(KP-II)5 GHG emissions from biomass burning-	There is no activity data available for wildfires on non-forest land in the

GHG	CRF sector	Source/sink category	Reason
		Deforestation- Wildfires	UK
CH_4	1. Energy	1C2 Multilateral Operations	Data unavailable
CH_4	2. Industrial Processes	2B1 Ammonia Production	Manufacturers do not report emission - believed negligible (and therefore not a key category).
CH_4	2. Industrial Processes	2C1 Iron and Steel	EAF emission and flaring only estimated - methodology not available for other sources
CH_4	2. Industrial Processes	2C2 Ferroalloys	Methodology not available but considered negligible (and therefore not a key category).
CH_4	2. Industrial Processes	2C3 Aluminium	Methodology not available but considered negligible (and therefore not a key category).
CH_4	4. Agriculture	4D3 Indirect emissions	There are no known sources of methane from this
CH_4	4. Agriculture	4D4 Improved grassland	There are no known sources of methane from this
CH_4	5. Land-Use Change and Forestry	5A1 Forest Land remaining Forest Land	Reporting of these estimates is not mandatory
CH_4	5. Land-Use Change and Forestry	5B2/5C1/5C2/5D1/5D2/5F – Wildfires	There is no activity data for wildfires from non forest land in the UK
CH_4	5. Land-Use Change and Forestry	5G Harvested wood products	No guidance available on calculating non-CO2 emissions from HWP
CH_4	KP LULUCF	KP A.1.2 Units of land harvested since the beginning of the commitment period	Assumed not to occur in this commitment period as forest management cycles operate on long time scales
CH_4	KP LULUCF	5(KP-II)5 GHG emissions from biomass burning-Afforestation/Reforestation/ Forest Management-Controlled burning	Controlled burning for forest management purposes does not occur in the UK
CH_4	KP LULUCF	5(KP-II)5 GHG emissions from biomass burning-Deforestation- Wildfires	There is no activity data available for wildfires on non-forest land in the UK
SF_6	2.Industrial Processes	2C5. Non-ferrous metals	Separate estimate not currently made for this source
SF_6	2.Industrial Processes	2F9 Gibraltar F gas emissions	Data not available

A6 ANNEX 6: 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.

A6.1 ANNUAL INVENTORY SUBMISSION

No additional information.

A6.2 SUPPLEMENTARY INFORMATION UNDER ARTICLE 7, PARAGRAGH 1

A6.2.1 KP-LULUCF (accounting table, CRF and/or NIR tables)

No additional information.

A6.2.2 Standard electronic format (SEF) tables

The tables presented below are the tables for 2011. The data are given in standard electronic format (SEF). Further reference can be made to document SEF_GB_2012_1_11-20-42 9-1-2012.xls as part of the SIAR submission, Chapter 12.

Table A 6.2.1 Total quantities of Kyoto Protocol units by account type at beginning of reported year

Table 1. Total quantities of Kyoto Protocol units by account type at beginning of reported year

Account type	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Party holding accounts	2925376964	229773	NO	4840567	NO	NO
Entity holding accounts	385416709	3738543	NO	25403088	NO	NO
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation accounts	NO	NO	NO	NO		
Other cancellation accounts	13433	NO	NO	1122715	NO	NO
Retirement account	260854974	48338	NO	4605119	NO	NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
lCER replacement account for expiry	NO	NO	NO	NO		
lCER replacement account for reversal of storage	NO	NO	NO	NO		NO
lCER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	3571662080	4016654	NO	35971489	NO	NO

Table A 6.2.2 Annual internal transactions

Table 2 (a). Annual internal transactions

Transaction type	Additions						Subtractions					
	Unit type						Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Article 6 issuance and conversion												
Party-verified projects		NO					NO		NO			
Independently verifed projects		NO					NO		NO			
Article 3.3 and 3.4 issuance or cancellation												
3.3 Afforestation and reforestation			NO				NO	NO	NO	NO		
3.3 Deforestation			NO				NO	NO	NO	NO		
3.4 Forest management			NO				NO	NO	NO	NO		
3.4 Cropland management			NO				NO	NO	NO	NO		
3.4 Grazing land management			NO				NO	NO	NO	NO		
3.4 Revegetation			NO				NO	NO	NO	NO		
Article 12 afforestation and reforestation												
Replacement of expired tCERs							NO	NO	NO	NO	NO	
Replacement of expired lCERs							NO	NO	NO	NO		
Replacement for reversal of storage							NO	NO	NO	NO		NO
Replacement for non-submission of certification report							NO	NO	NO	NO		NO
Other cancellation							22796	NO	NO	414931	NO	NO
Sub-total		NO	NO				22796	NO	NO	414931	NO	NO

Transaction type	Retirement					
	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Retirement	456829826	1846470	NO	11034440	NO	NO

Table A 6.2.3 Annual external transactions

	Additions						Subtractions					
	Unit type						Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Transfers and acquisitions												
CDM	NO	NO	NO	85548680	NO	NO	NO	NO	NO	NO	NO	NO
AU	NO	NO	NO	75846	NO	NO	NO	NO	NO	71000	NO	NO
AT	2403497	14773	NO	95000	NO	NO	887865	514773	NO	1133356	NO	NO
BE	15981251	1320864	NO	2476402	NO	NO	8131453	7268593	NO	2807043	NO	NO
BG	3754674	24504	NO	NO	NO	NO	409101	242080	NO	640905	NO	NO
CZ	7683641	171184	NO	1470726	NO	NO	2505818	1804487	NO	2306010	NO	NO
DK	2933331	NO	NO	75000	NO	NO	1606329	6000	NO	961902	NO	NO
EE	19682	10000	NO	NO	NO	NO	3613933	NO	NO	NO	NO	NO
FI	5738949	NO	NO	540746	NO	NO	7141078	683000	NO	2717118	NO	NO
FR	140351230	8674194	NO	40706553	NO	NO	55855606	7390781	NO	83577146	NO	NO
DE	112919155	4959784	NO	34770278	NO	NO	119438269	22874613	NO	64969820	NO	NO
GR	14709370	NO	NO	NO	NO	NO	287000	NO	NO	3283612	NO	NO
HU	3256429	62634	3900000	60000	NO	NO	3104469	300244	NO	441564	NO	NO
IE	15232152	435000	NO	3740189	NO	NO	2167581	234338	NO	9931683	NO	NO
IT	33787220	686000	NO	30061044	NO	NO	19751581	2372000	NO	13307225	NO	NO
JP	NO	130473	NO	29828157	NO	NO	1000	1100000	NO	4748645	NO	NO
LV	324715	NO	NO	NO	NO	NO	10002	8292	NO	10669	NO	NO
LI	891509	80366	NO	241000	NO	NO	351000	1	NO	3381000	NO	NO
LT	22232930	NO	NO	NO	NO	NO	1524000	130234	NO	83808	NO	NO
LU	226987	NO	NO	NO	NO	NO	94521	NO	NO	27618	NO	NO
NL	39193629	6567423	NO	30666057	NO	NO	52838359	4564436	NO	36952712	NO	NO
NZ	1000	450377	NO	1726593	NO	NO	18530	576000	3900000	2958042	NO	NO
NO	7554637	NO	NO	300915	NO	NO	10145742	271994	NO	3059123	NO	NO
PL	13017553	571905	NO	84090	NO	NO	4717635	1616753	NO	5554310	NO	NO
PT	4570612	NO	NO	NO	NO	NO	876000	192915	NO	1104953	NO	NO
RO	20638348	51813	NO	416586	NO	NO	5691549	5016398	NO	3366698	NO	NO
RU	NO	27080	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
SK	6746510	NO	NO	NO	NO	NO	711533	24000	NO	1861300	NO	NO
SI	364409	111974	NO	205306	NO	NO	116015	646602	NO	202797	NO	NO
ES	21580669	5879	NO	5424285	NO	NO	4344567	5152776	NO	14830180	NO	NO
SE	3559451	33416	NO	4173904	NO	NO	2296832	50000	NO	1311483	NO	NO
CH	13860283	38270707	NO	40338876	NO	NO	1473055	731127	NO	8491137	NO	NO
UA	3168835	6426968	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
EU	90000	NO	NO	NO	NO	NO	377706	NO	NO	653402	NO	NO
Sub-total	516792658	69087318	3900000	313026233	NO	NO	310488129	63772437	3900000	274746261	NO	NO

Additional information

Independently verified ERUs								NO				

Table A 6.2.4 Expiry, cancellation and replacement

Table 3. Expiry, cancellation and replacement

Transaction or event type	Expiry, cancellation and requirement to replace – Unit type: tCERs	lCERs	Replacement – Unit type: AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Temporary CERs (tCERS)								
Expired in retirement and replacement accounts	NO							
Replacement of expired tCERs			NO	NO	NO	NO	NO	
Expired in holding accounts	NO							
Cancellation of tCERs expired in holding accounts	NO							
Long-term CERs (lCERs)								
Expired in retirement and replacement accounts		NO						
Replacement of expired lCERs			NO	NO	NO	NO		
Expired in holding accounts		NO						
Cancellation of lCERs expired in holding accounts		NO						
Subject to replacement for reversal of storage		NO						
Replacement for reversal of storage			NO	NO	NO	NO		NO
Subject to replacement for non-submission of certification report		NO						
Replacement for non-submission of certification report			NO	NO	NO	NO		NO
Total			NO	NO	NO	NO	NO	NO

Table A 6.2.5 Total quantities of Kyoto Protocol units by account type at end of reported year

Table 4. Total quantities of Kyoto Protocol units by account type at end of reported year

Account type	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Party holding accounts	2444524126	NO	NO	NO	NO	NO
Entity holding accounts	615721454	7436727	NO	57074256	NO	NO
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation accounts	NO	NO	NO	NO		
Other cancellation accounts	36229	NO	NO	1537646	NO	NO
Retirement account	717684800	1894808	NO	15639559	NO	NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
lCER replacement account for expiry	NO	NO	NO	NO		
lCER replacement account for reversal of storage	NO	NO	NO	NO		NO
lCER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	3777966609	9331535	NO	74251461	NO	NO

Table A 6.2.6 Summary information on additions and subtractions

Table 5 (a). Summary information on additions and subtractions

	Additions						Subtractions					
	Unit type						Unit type					
Starting values	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**ICERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**ICERs**
Issuance pursuant to Article 3.7 and 3.8	3412080630											
Non-compliance cancellation							NO	NO	NO	NO		
Carry-over	NO	NO		NO								
Sub-total	3412080630	NO		NO			NO	NO	NO	NO		
Annual transactions												
Year 0 (2007)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 1 (2008)	195468637	NO	NO	128774640	NO	NO	154160541	NO	NO	104017060	NO	NO
Year 2 (2009)	625404135	1356648	NO	128934348	NO	NO	622175066	594176	NO	129597000	NO	NO
Year 3 (2010)	579540623	16586606	NO	153759889	NO	NO	464509771	13332424	NO	143006043	NO	NO
Year 4 (2011)	516792658	69087318	3900000	313026233	NO	NO	310510925	63772437	3900000	275161192	NO	NO
Year 5 (2012)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 6 (2013)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 7 (2014)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 8 (2015)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sub-total	1917206053	87030572	3900000	724495110	NO	NO	1551356303	77699037	3900000	651781295	NO	NO
Total	5329286683	87030572	3900000	724495110	NO	NO	1551356303	77699037	3900000	651781295	NO	NO

Table A 6.2.7 Summary information on replacement

Table 5 (b). Summary information on replacement

	Requirement for replacement		Replacement					
	Unit type		Unit type					
	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Previous CPs			NO	NO	NO	NO	NO	NO
Year 1 (2008)		NO	NO	NO	NO	NO	NO	NO
Year 2 (2009)		NO	NO	NO	NO	NO	NO	NO
Year 3 (2010)		NO	NO	NO	NO	NO	NO	NO
Year 4 (2011)		NO	NO	NO	NO	NO	NO	NO
Year 5 (2012)	NO	NO	NO	NO	NO	NO	NO	NO
Year 6 (2013)	NO	NO	NO	NO	NO	NO	NO	NO
Year 7 (2014)	NO	NO	NO	NO	NO	NO	NO	NO
Year 8 (2015)	NO	NO	NO	NO	NO	NO	NO	NO
Total	NO	NO	NO	NO	NO	NO	NO	NO

Table A 6.2.8 Summary information on retirement

Table 5 (c). Summary information on retirement

	Retirement					
	Unit type					
Year	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Year 1 (2008)	NO	NO	NO	NO	NO	NO
Year 2 (2009)	260854974	48338	NO	4605119	NO	NO
Year 3 (2010)	NO	NO	NO	NO	NO	NO
Year 4 (2011)	456829826	1846470	NO	11034440	NO	NO
Year 5 (2012)	NO	NO	NO	NO	NO	NO
Year 6 (2013)	NO	NO	NO	NO	NO	NO
Year 7 (2014)	NO	NO	NO	NO	NO	NO
Year 8 (2015)	NO	NO	NO	NO	NO	NO
Total	717684800	1894808	NO	15639559	NO	NO

A6.2.3 National system, including changes
Refer to **Chapter 12**.

A6.2.4 National registry
No additional information.

A6.2.4.1 Changes to national registry
Refer to the following documents as part of the SIAR submission, Chapter 14:

A6.2.4.2 Reports:
No additional information.

A6.2.4.3 Publicly available information
No additional information.

A6.2.5 Adverse impacts under Article 3, paragraph 14 of the Kyoto Protocol
No additional information.

A7 ANNEX 7: Uncertainties

Uncertainty estimates are calculated using two methods: Approach 1 (error propagation) and Approach 2 (Monte Carlo simulation). Our use of the terminology Approach 1 and Approach 2 follows that defined in the IPCC's General Guidance and Reporting (IPCC, 2006).

The uncertainty assessment in this NIR continues a number of improvements that were introduced in the 2007 submission, including presenting estimates of uncertainties according to IPCC sector in addition to presenting estimates by direct greenhouse gas. Estimated uncertainty presented in National Communication categories (which are consistent with the UK's Carbon Budgets sectors) are not reported here, since the categories and geographical coverage are not consistent with the requirements of the UK's commitments under the UNFCCC and Kyoto Protocol.

The Monte Carlo method was reviewed and revised in the 2007 NIR, taking into account guidance from the 2006 Guidelines (IPCC, 2006), a summary of recommendations from the EUMM Workshop on Uncertainties held in Finland in 2005, and from an internal review of the uncertainty work. In the 2008 NIR, there was also a major review of the correlations used in the Monte Carlo simulation, which included discussions with the LULUCF sector experts. The overall method is described below. The work to improve the accuracy of the uncertainty analysis continues.

A further review of the uncertainty parameters used within the industrial processes sector has also been carried out; the recommendations from this review were included in the 2011 submission. The review followed recommendations from the ERT.

A7.1 ESTIMATION OF UNCERTAINTY BY SIMULATION (APPROACH 2)

A7.1.1 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. The parameters of the PDFs were set by analysing the available data on emission factors and activity data or 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 20,000 times and the emission calculations performed to produce a converged output distribution;
- It was assumed that the distribution of errors in the parameter values was normal. The quoted range of possible error of uncertainty is taken as 2s, where s is the standard deviation. If the expected value of a parameter is E and the standard deviation is s, then the uncertainty is quoted as 2s/E expressed as a percentage.

  For a normal distribution the probability of the parameter being less than E-2s is 0.025 and the probability of the emission being less than E+2s is 0.975.
- The uncertainties used for the fuel activity data were estimated from the statistical difference between the total supply and demand for each fuel. Data on the statistical difference between supply and demand for individual sectors are not available. This means that the quoted uncertainties in **Table A 7.2.1** refer to the total fuel consumption rather than the consumption by a particular sector, e.g. coal consumed in the residential sector. Hence, to avoid underestimating uncertainties, it was necessary to correlate the uncertainties used for the same fuel in different sectors; and
- The uncertainty in the trend between 1990 and the latest reported year, according to gas, was also estimated.

A7.1.1.1 Uncertainty Distributions

Distributions

With the exception of one distribution, all of the distributions of emissions from sources in the inventory are now modelled used normal or log normal distributions.

Custom distributions

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. For this study 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.

A7.1.1.2 Correlations

The Monte Carlo model contains a number of correlations. Omitting these correlations would lead to the uncertainties being underestimated. These correlations were not included in the very early versions of the Monte Carlo model used in the UK NIR, and were introduced over the years to improve the accuracy of the predicted uncertainties. The trend uncertainty in the Monte Carlo model is particularly sensitive to some correlations, for example, the correlation across years in emissions of N_2O from agricultural soils. Other correlations have a less marked influence.

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.

A7.1.1.2.1 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.

The model has been designed to aggregate activities and emission factors where possible, and the correlations included are listed at the start of the sections presenting uncertainties according to gas.

The trend estimated by the Monte Carlo model is particularly sensitive to N_2O emissions from agricultural soils (lognormal, with the 97.5 percentile being 100 times the 2.5 percentile). Correlations are also included for N_2O emissions from sewage sludge, calculated from a lognormal distribution. The LULUCF correlations are discussed below. Other correlations are listed at the start of the sections presenting uncertainties according to gas.

A7.1.1.2.2 Between Sources in the same year

Where we have estimated the uncertainty on the activity data based on statistical difference produced by DECC and reported in DUKES, it has been necessary to correlate the fuel use for all sources using the same fuel.

A7.1.2 Review of Recent Improvements to the Monte Carlo Model

Abbott *et al* (2007) completed an internal review was of the Monte Carlo uncertainty analysis used for the UK NIR. This review was commissioned following suggestions from a UNFCCC Expert Review Team about improvements that the UK could make to the transparency of the uncertainty analysis. The review evaluated the Monte Carlo model, and the documentation of the model, as presented in the 2005 NIR. The review was informed by the UNFCCC comments from the Third Centralised Review, from recommendations made at the EU workshop on uncertainties in Greenhouse Gas Inventories[21], and by the IPCC 2006 Guidelines. A range of changes were made to the model to simplify its structure and review and improve the correlations used.

A7.1.2.1 Method Changes

A number of changes have been introduced to the Monte Carlo model, and these are listed below.

A7.1.2.1.1 Change of Simulation Method

Following recommendations in the 2006 IPCC Guidelines, the model now uses a true Monte Carlo sampling method as opposed to the Latin Hypercube method used previously. The revision makes very little difference to the uncertainties estimated by the model.

A7.1.2.1.2 Treatment of Zero Emissions

The original Monte Carlo model contained a number of sources where the emissions were zero, but uncertainties were still allocated to the activity data and emission factors. These zero emissions existed for several reasons:

- Emissions occurred in 1990 but were absent in later years;
  - The activity had been banned (for example, burning of agricultural straw residues);

[21] EU workshop on uncertainties in Greenhouse Gas Inventories Work 5-6 September, Helsinki, Finland. Ministry of the Environment, Finland. Arranged by the VTT Technical Research Centre of Finland (Jaakko Ojala, Sanna Luhtala and Suvi Monni).

- Emissions had been transferred to another sector (for example MSW emissions from waste to IPCC category 6C to 1A1a.); and

- Because data had been included in the analysis for completeness where either the emission factor or the activity data were zero thus leading to a zero emission.

The estimated uncertainties were unaffected when the 'zero emissions' were removed from the model.

A7.1.2.1.3 Aggregation

For the new Monte Carlo model, the detailed data from the GHG inventory was aggregated where appropriate in order to minimise the number of sources used in the calculation. Emissions were aggregated where possible for fuels (any emission arising from combustion), by activity data type e.g. coal, petrol, natural gas, and by emission factor. In doing so, the data are also being correlated as any uncertainty in the emission factor is then applied once, to all appropriate emissions, and the same is true of the activity data. Minimising the number of calculations performed in the Monte Carlo simulation ensures that the overall uncertainty is more accurately estimated by the model.

A7.1.2.2 F-gas uncertainties

Estimated emissions and projections of F-gases have recently been reviewed and updated (AEA, 2008). This work also included an update to the uncertainty analysis, which has been taken into account in the overall uncertainty analysis for the greenhouse gas inventory.

A7.1.2.3 Uncertainty Parameter Reviews

As part of the ongoing inventory improvement process many of the uncertainty distributions for our emission factors and activity data have been reviewed, with expert elicitation sought where appropriate.

A7.1.3 Review of changes made to the Monte Carlo model since the last NIR

A number of changes were made to the model for the 2011 submission. No further changes have been made this year. . The changes made to the model for the 2011 submission are set out below.

The uncertainty parameters used for certain categories in the Industrial Processes sector have been reviewed and updated, based on expert judgement from the UK sector experts responsible for compilation of the emission statistics for the relevant sources. Chemical waste incineration, domestic petroleum coke consumption and the carbon emission factors for OPG have also been reviewed and updated. The changes are summarised as follows:

- Limestone use for sintering – the activity data uncertainty has been revised from 1% to 5%, since the sector experts considered 1% to be an under estimate
- Limestone use for glass and lime production – the activity data uncertainty has been revised from 1% to 10% in the base year and 15% in the latest inventory year. This is because the statistics, particularly for glass production, are based on limited information and are in some cases extrapolated to complete the time series. The latest year estimates for lime production are based on activity statistics from the previous year since the latest year estimates are not published in time for compilation of the inventory and therefore the uncertainty is higher. This follows the recommendation from the ERT.

- Dolomite use for sintering and in basic oxygen furnaces - the activity data uncertainty has been revised from 1% to 5%, since the sector experts considered 1% to be an under estimate
- Dolomite use for glass production – the activity data uncertainty has been revised from 1% to 20%. This is because the data used for the estimation of emissions from glass production is incomplete and the time series is extrapolated
- Soda ash use for glass production – the activity data uncertainty has been revised from 15% to 25% since the data used are incomplete and some extrapolation is needed to complete the time series
- Adipic acid production – the activity data uncertainty has been revised from 0.5% to 2% to account for the potential for misreports in the data supplied to the inventory agency. The emission factor uncertainty has been revised from 15% to 100% in the base year, to reflect the uncertainty in the applicability of emission factors to the activity data in the early part of the time series (for which direct monitoring data are not available) and considering the variability in plant emissions from monitored and reported data in later years. The emission factor uncertainty in the latest inventory year has been revised from 15% to 50%, to account for the uncertainty associated with the calculation of emission statistics from continuous emissions monitoring data (e.g. uncertainty in the effluent mass flow rate calculations, scaling up to annual estimates, and uncertainty in the nitrous oxide sampling and analytical methods).
- Nitric acid production – the emission factor uncertainty has been revised from 230% to 100% in the base year, and 50% in the latest inventory year. The review of this parameter was prompted by comments from the ERT. The original estimate of 230% was considered to be too high. The uncertainty in the latest inventory year is much lower than in the base year since the latest year data are based on continuous emissions monitoring data whilst the base year estimates are calculated using emission factors applied according to plant design information. The activity data uncertainty has also been revised from 10% to 2% in the latest inventory year only, since we the inventory agency obtains annual operator production data for this source in the latest year that was not available in the base year.
- Clinker production – the emission factor uncertainty has been revised from 2.2% to 5%. This reflects the differences between the emission factor used in earlier versions of the GHGI with the emission factor derived from operator reported data.
- Chemical waste incineration – the activity data and emission factor uncertainties have been revised from 7% and 15% to 50% and 100%, respectively. The emissions from this source are calculated based on estimated capacity and incomplete emissions data from the Pollution Inventory.
- Domestic petroleum coke combustion – the activity data uncertainty has been revised from 50% in the base year and 25% in the latest year to 20% in both years. This reflects the improvements to the data quality based on research that has been carried out to obtain new data for this source.
- OPG combustion – the carbon emission factor uncertainty has been revised from 3% to 15% in the base year and 5% in the latest inventory year. This reflects the variability of this fuel, as evidenced by the EU ETS data that is now available.
- Non-energy use of products – the emission factor uncertainty for these sources has been revised from 20% to 100%, since 20% was considered to be an under estimate

In addition to these updates, an error in the model has also been identified and corrected. This affected the trend uncertainty for landfill methane emissions. The model was treating the emission as 100% correlated between the base year and the latest inventory year. This led to an under estimate in the trend uncertainty for methane emissions. This has now been corrected.

A7.1.4 Quality Control Checks on the Monte Carlo Model Output

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

a) *Checks against totals of the national emissions*
To ensure the emissions in the Monte Carlo model closely agree with the reported totals in the NIR, the emissions in the model were checked against the national totals both before the simulation was run. The central estimates from the model are expected to be similar to the emissions totals, but are not expected to match exactly.
b) *Inter-comparison between the output of the error propagation and Monte Carlo models*
We have introduced a new formal check to compare the output of the error propagation and Monte Carlo model. The results of this comparison are discussed in **Section A7.4**.

c) *Calculation of uncertainty on the total*
The uncertainty on the 1990 and the 2009 emissions was calculated using two different methods;

i) Using $\frac{2s.d}{\mu}$

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

The first method uses the standard deviation calculated by @Risk and the mean to give an overall uncertainty, while the second method averages out the implied standard deviation(s) given by the percentiles quoted. When a distribution is completely normally distributed, the two methods will give the same results as the calculated standard deviation will be equal to the implied standard deviation. When a distribution is skewed however, the first method will give a much higher overall uncertainty than the second due to the inequality in the distribution. The overall uncertainty quoted in **Table A 7.3.1** is calculated using the first method in order that uncertainties should not be underestimated in sectors showing a skewed distribution such as agricultural soils and N_2O as a whole.

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. 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.

A7.2 UNCERTAINTIES ACCORDING TO GAS

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

A7.2.1 Carbon Dioxide Emission Uncertainties

A7.2.1.1 General Considerations

The uncertainties in the activity data for major fuels were estimated from the statistical differences data in the UK energy statistics. This is explained further in **Section A7.6.1**.

These are effectively the residuals when a mass balance is performed on the production, imports, exports and consumption of fuels. For solid and liquid fuels both positive and negative results are obtained indicating that these are uncertainties rather than losses. For gaseous fuels these figures include losses and tended to be negative. The uncertainties in activity data for minor fuels (colliery methane, orimulsion, SSF, petroleum coke) and non-fuels (limestone, dolomite and clinker) were estimated based on judgement comparing their relative uncertainty with that of the known fuels. The high uncertainty in the aviation fuel consumption reflects the uncertainty in the split between domestic and international aviation fuel consumption. DECC indicate the total consumption of aviation fuel is accurately known. This uncertainty was reviewed in 2005. Additional uncertainty for this source is also introduced by the use of a model to estimate emissions.

The uncertainties in carbon emission factors (CEFs) for natural gas, coal used in power stations, and selected liquid fuels were derived from the Carbon Factor Review (see **Section A 7.6.1** for further details). The uncertainties in other factors are based on expert judgement.

In the case of non-fuel sources, the uncertainty depended on the purity of limestone or the lime content of clinker so the uncertainties estimated were speculative.

The uncertainties in certain sources were estimated directly. Offshore flaring uncertainties were estimated by comparing the UKOOA flaring time series data with the flaring volumes reported by DTI (2001). The uncertainty in the activity data was found to be around 16%. This uncertainty will be an over estimate since it was assumed that the flaring volume data reported by DTI should be in a fixed proportion to the mass data reported by UKOOA. The uncertainty in the carbon emission factor was estimated by the variation in the time series to be around 6%. Again this will be an over estimate since it was assumed that the carbon emission factor is constant. Uncertainties for fuel gas combustion were estimated in a similar way. Uncertainties in the land use change sources were ascribed to each sector by Milne (pers. comm., 2006), and reviewed and updated in 2008 (Thomson, pers. comm. 2008). The uncertainty for Fletton bricks and peat combustion is based on expert assessment of the data used to make the estimate. The uncertainty used for cement production is based on the estimates reported in IPCC (2000), and the activity data uncertainty has been reviewed and updated for this inventory submission. Clinical waste incineration was assumed to have the same uncertainty as MSW incineration.

Emissions and activity data for petroleum coke are taken from a number of sources. In 2010, data for power stations, refineries and cement are taken from EU ETS returns. The total petroleum coke use in the inventory deviates from the energy statistics total, and as such it is not possible to correlate the uncertainties based on the statistical difference in the energy statistics for 2010. For refineries, the emissions data is taken from the EU ETS return and the activity data is calculated based on an estimate of the emission factor. Petroleum coke use for residential combustion is now based on new data supplied by one of the UK's suppliers of petroleum coke as fuel. The uncertainty parameters for this source have therefore been revised accordingly, since this source is considered to be less uncertain than the previously used data source.

A7.2.1.2 Uncertainty Parameters

Two tables are provided in this section – a table of uncertainties in the activity data and emission factors for the major fuels used to estimate emissions of carbon dioxide, and a table of the same parameters for "non-fuels". These non-fuels relate to emissions from a range of sources, including the following:

- The release of carbon from the breakdown of pesticides and detergents; and
- Use of natural gas for the production of ammonia.

In some cases the individual uncertainties for the activity data and the emission factor are unknown, but the uncertainty on the total emission is known. In these cases, the uncertainties are listed in the column marked “uncertainty in emission”.

Table A 7.2.1 Uncertainties in the activity data and emission factors for fuels used in the carbon dioxide inventory

		1990			2010		
Fuel		Activity uncertainty (%)	Emission factor uncertainty (%)	Uncertainty in emission (%)	Activity uncertainty (%)	Emission factor uncertainty (%)	Uncertainty in emission (%)
Anthracite		1.5	6	‡	0.3	6	‡
Aviation spirit		20	3.3	‡	20	3.3	‡
Aviation turbine fuel		20	3.3	‡	20	3.3	‡
Blast furnace gas		1.5	6	‡	0.3	6	‡
Burning oil		6	2	‡	0.9	2	‡
Chemical waste		50	100	‡	50	100	‡
Clinical waste		7	20	‡	7	20	‡
Clinker production		1	5	‡	1	5	‡
Coal		1.5	1	‡	0.3	1	‡
Coke		3	3	‡	0.1	3	‡
Coke oven gas		1.5	6	‡	0.3	6	‡
Colliery methane		5	5	‡	5	5	‡
DERV		1.8	2.1	‡	0.4	2.1	‡
Dolomite – glass		20	5	‡	20	5	‡
Dolomite – sinter, BOF		5	5	‡	5	5	‡
Exploration drilling		1	28	‡	1	28	‡
Fuel oil		5.5	1.7	‡	1.9	1.7	‡
Fletton bricks		20	70	‡	20	70	‡
Gas oil		1.8	1.4	‡	0.4	1.4	‡
Limestone – glass and lime		10	5	‡	15	5	‡
Limestone - sinter		5	5	‡	5	5	‡
LPG		25.7	3	‡	0.9	3	‡
Lubricants		20	5	‡	20	5	‡
MSW		7	20	‡	7	20	‡
Naphtha		7.3	3	‡	not used	not used	‡
Natural gas		2.8	1.5	‡	0	1.5	‡
OPG		1.4	15	‡	0.6	5	‡
Orimulsion		1	2	‡	not used	not used	‡
Peat		25	25	‡	25	25	‡
Petrol		1	4.8	‡	0.7	4.8	‡
Petroleum coke	1A1a	not used	not used	‡	0.75	3	‡
	1A1b	7.8	3	‡	‡	‡	5
	1A2f	25	3	‡	0.75	3	‡
	1A4b	20	3	‡	20	3	‡
Petroleum waxes		50	100	‡	50	100	‡
Refinery miscellaneous		11.9	3	‡	not used	not used	‡
Soda ash		25	2	‡	25	2	‡
Scrap tyres		15	10	‡	15	10	‡
SSF		3.3	3	‡	0.9	3	‡

	1990			2010		
Fuel	Activity uncertainty (%)	Emission factor uncertainty (%)	Uncertainty in emission (%)	Activity uncertainty (%)	Emission factor uncertainty (%)	Uncertainty in emission (%)
Waste	not used	not used		1	50	‡
Waste oils	20	5	‡	20	5	‡
Waste solvent	1	50	‡	1	10	‡

Notes
1. Uncertainties expressed as 2s/E
2. ‡ input parameters were uncertainties of activity data and emission factors

Not used = Fuel not used

Table A 7.2.2 Uncertainties in the activity data and emission factors for "non-fuels" used in the carbon dioxide inventory

		1990			2010		
Sector	Sources	Activity uncertainty (%)	Emission factor uncertainty (%)	Uncertainty in emission (%)	Activity uncertainty (%)	Emission factor uncertainty (%)	Uncertainty in emission (%)
1B2a	Offshore oil and gas - processes	-	-	28	-	-	28
1B2c_Flaring	Offshore oil and gas - flaring	16	6	‡	16	6	‡
1B2c_Venting	Offshore oil and gas - venting	16	6	‡	16	6	‡
5A	5A2 Forest Land - biomass burning; 5A2 Land converted to forest land	-	-	25	-	-	25
2B1	Ammonia production - feedstock use of gas	2.8	1.5		0	1.5	
5B	5B1 Cropland – Liming; 5B1 Cropland remaining cropland; 5B2 Land converted to cropland	-	-	45	-	-	50
5C	5C Grassland - biomass burning; 5C1 Grassland – liming; 5C1 Grassland remaining grassland; 5C2 Land converted to grassland	-	-	70	-	-	55
5E	5E Settlements - biomass burning; 5E2 Land converted to settlements	-	-	35	-	-	50
5G	5G Harvested Wood Products; 5G LULUCF emissions from OTs and CDs	-	-	30	-	-	30
	Carbon in detergents	-	-	100	-	-	100
	Carbon in pesticides	-	-	100	-	-	100
	Gypsum produced	none produced	none produced	-	1	5	‡
	Primary aluminium production	1	5	‡	1	5	‡
	Steel production (electric arc and oxygen converters)	1	20	‡	1	20	‡

Notes

1. Uncertainties expressed as 2s/E

‡ input parameters were uncertainties of activity data and emission factors

A7.2.1.3 Uncertainty in the Emissions

The overall uncertainty was estimated as around **2% in 2010**.

The central estimate of total CO_2 emissions in 2010 was estimated as 497,859 Gg. The Monte Carlo analysis suggested that 95% of the values were between 490,224 Gg and 505,468 Gg.

A7.2.1.4 Uncertainty in the Trend

The uncertainty in the trend between 1990 and the latest year was estimated. In running this simulation it was necessary to make assumptions about the degree of correlation between sources in 1990 and 2010. If source emission factors are correlated this will have the effect of reducing the trend uncertainty. 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 (i.e. 5A with 5A etc);
- Offshore emissions are not correlated since they are based on separate studies using emission factors appropriate for the time;
- Emission factors covered by the Carbon Factors Review (Baggott *et al*, 2004) are not correlated; and
- Process emissions from blast furnaces, coke ovens and ammonia plant were not correlated.

This analysis indicates that there is a 95% probability that CO_2 emissions in 2010 were between **14% and 18%** below the level in 1990.

A7.2.2 Methane Emission Uncertainties

A7.2.2.1 General Considerations

In the methane inventory, combustion sources are a minor source of emissions. The uncertainties on the quantities of fuel burnt are known, although the effect of the large uncertainty associated with the emission factors will dominate the overall uncertainty on the emissions. The uncertainties are listed in **Table A 7.2.3**. The uncertainty on the activities for the fuels burnt are not pollutant specific, and are reported in **Table A 7.2.1**.

A7.2.2.2 Uncertainty Parameters

Table A 7.2.3 Estimated uncertainties in the activity data and emission factors used in the methane inventory

		1990			2010		
Source	Reference	Activity %	Emission Factor %	Source Uncertainty %	Activity %	Emission Factor %	Source Uncertainty %
Coal			50	‡		50	‡
Coke			50	‡		50	‡
Petroleum coke			50	‡		50	‡
SSF			50	‡		50	‡
Burning oil			50	‡		50	‡
Fuel oil			50	‡		50	‡
Gas oil			50	‡		50	‡
DERV			50	‡		50	‡
Petrol			50	‡		50	‡
Orimulsion			50	‡		50	‡
Aviation turbine fuel			50	‡		50	‡
Natural gas			50	‡		50	‡
Colliery methane			50	‡		50	‡
LPG			50	‡		50	‡
OPG			50	‡		50	‡
MSW			50	‡		50	‡
Sour gas			50	‡		50	‡
Naphtha			50	‡		50	‡
Refinery miscellaneous			50	‡		50	‡
Blast furnace gas			50	‡		50	‡
Coke oven gas			50	‡		50	‡
Town gas			50	‡		50	‡
Lubricants			50	‡		50	‡
Waste oils			50	‡		50	‡
Scrap tyres			50	‡		50	‡
Aviation spirit			50	‡		50	‡

		1990			2010		
Source	Reference	Activity %	Emission Factor %	Source Uncertainty %	Activity %	Emission Factor %	Source Uncertainty %
Anthracite			50	‡		50	‡
Burning oil (premium)			50	‡		50	‡
Vaporising oil			50	‡		50	‡
Clinical waste			50	‡		50	‡
Poultry litter			50	‡		50	‡
Landfill gas			50	‡		50	‡
Sewage gas			50	‡		50	‡
Wood			50	‡		50	‡
Straw			50	‡		50	‡
Sewage sludge combustion			50	‡		50	‡
Field burning	*	25	50	‡	25	50	‡
Landfill	Brown *et al* 1999	-	-	~48[1]	-	-	~48[1]
Livestock: enteric	Williams, 1993	-	-	20	-	-	20
Livestock: wastes	Williams, 1993	-	-	30.5	-	-	30.5
Coal Mining	Bennett *et al*, 1995	-	-	13.3	-	-	13.3
Offshore	*	16	20	‡	16	20	‡
Gas Leakage	Williams, 1993	-	-	17-75[2]	-	-	17-75[2]
Chemical industry	*	20	20	‡	20	20	‡
Fletton bricks	*	20	100	‡	20	100	‡
Sewage sludge	Hobson *et al*, 1996	-	-	50	-	-	50

Notes
1 Skewed distribution
2 Various uncertainties for different types of main and service
* See text
‡ Input parameters were uncertainties of activity data and emission factors
Fuel combustion uncertainties expressed as 2s/E
Uncertainties in the activity data for fuels burnt are reported in **Table A7.2.1**.

The non fuel combustion sources are mainly derived from the source documents for the estimates or from the Watt Committee Report (Williams, 1993). The uncertainty in offshore emissions was revised for the 2000 inventory using improved estimates of the activity data. The methane factors were assumed to have an uncertainty of 20% since the flaring factors are based on test measurements.

The sources quoted in **Table A 7.2.3** are assumed to have normal distributions of uncertainties with the exception of landfills. Brown *et al.* (1999) estimated the uncertainty distribution for landfill emissions using Monte Carlo analysis and found it to be skewed. For normal distributions there is always a probability of negative values of the emission factors arising. For narrow distributions this probability is negligible; however with wide distributions the probability may be significant. In the original work (Eggleston *et al,* 1998) this problem was avoided by using truncated distributions. However, it was found that this refinement made very little difference to the final estimates. In these estimates a lognormal distribution was used rather than truncated normal distributions.

A7.2.2.3 Uncertainty in the Emissions

The overall uncertainty was estimated as around **20% in 2010**.

The central estimate of total CH_4 emissions in the latest year was estimated as 41,495 Gg CO_2 equivalent. The Monte Carlo analysis suggested that 95% of the values were between 35,538 and 48,997 Gg CO_2 equivalent.

A7.2.2.4 Uncertainty in the Trend

The uncertainty in the trend between 1990 and the latest year was estimated. In running this simulation it was necessary to make assumptions about the degree of correlation between sources in 1990 and 2010. If source emission factors are correlated this will have the effect of reducing uncertainty in the emissions trend. The assumptions were:

- Activity data are uncorrelated between years, but activity data for major fuels were correlated in the same year in a similar manner to that described above for carbon;
- 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. Emissions have reduced by 71% hence the degree of correlation was 29%;
- Offshore emissions are not correlated across years since they are based on separate studies using emission factors that reflected the processes in use at the time;
- Gas leakage emissions were partially correlated across years. As a simple estimate it was assumed that the degree of correlation should reflect the reduction in emissions. Emissions have reduced by 47% hence the degree of correlation was 53%; and
- Emissions from deep mines were not correlated across years as they were based on different studies, and a different selection of mines. Open cast and coal storage and transport were correlated since they are based on default emission factors.

This analysis indicates that there is 95% probability that methane emissions in 2010 were between **45% and 67%** below the level in 1990.

A7.2.3 Nitrous Oxide Emission Uncertainties

A7.2.3.1 General Considerations

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 parameter uncertainties are shown in **Table A 7.2.4**. The uncertainty for the fuels burnt are not pollutant specific and are reported in **Table A 7.2.1**. The uncertainty assumed for agricultural soils uses a lognormal distribution since the range of possible values is so high. Here it is assumed that the 97.5 percentile is greater by a factor of 100 than the 2.5 percentile based on advice from the Farming and Food Science Team of DEFRA (pers. comm.).

A7.2.3.2 Uncertainty Parameters

Listed in table overleaf.

Table A 7.2.4 Estimated uncertainties in the activity data and emission factors used in the N_2O inventory

	1990			2010		
Source	Activity %	Emission Factor %	Source Uncertainty %	Activity %	Emission Factor %	Source Uncertainty %
Coke		195	‡		195	‡
Petroleum coke		118	‡		118	‡
SSF		118	‡		118	‡
Burning oil		118	‡		118	‡
Fuel oil		140	‡		140	‡
Gas oil		140	‡		140	‡
DERV		140	‡		140	‡
Petrol		170	‡		170	‡
Orimulsion		170	‡		170	‡
Aviation turbine fuel		140	‡		140	‡
Natural gas		170	‡		170	‡
Colliery methane		110	‡		110	‡
LPG		110	‡		110	‡
OPG		110	‡		110	‡
MSW		110	‡		110	‡
Sour gas		230	‡		230	‡
Naphtha		110	‡		110	‡
Refinery miscellaneous		140	‡		140	‡
Blast furnace gas		140	‡		140	‡
Coke oven gas		118	‡		118	‡
Town gas		118	‡		118	‡
Lubricants		118	‡		118	‡
Waste oils		140	‡		140	‡
Scrap tyres		140	‡		140	‡
Aviation spirit		140	‡		140	‡
Anthracite		170	‡		170	‡
Burning oil (premium)		387	‡		387	‡
Vaporising oil		140	‡		140	‡
Limestone		140	‡		140	‡
Clinical waste		230	‡		230	‡
Poultry litter		230	‡		230	‡
Landfill gas		230	‡		230	‡
Sewage gas		110	‡		110	‡
Wood		110	‡		110	‡
Straw		230	‡		230	‡
Sewage sludge combustion		230	‡		230	‡
Agricultural soils			Log-normal[2]			Log-normal[2]
Wastewater treatment			Log-normal[2]			Log-normal[2]
Adipic Acid	2	100		n/a	n/a	
Nitric Acid	10	100		2	50	

Notes
1 Expressed as 2s/E
2 With 97.5 percentile 100 times the 2.5 percentile and the mean of the distribution factor equal to 1. The logarithm for the variable is normally distributed with standard deviation, σ, equal to ln (100)/(2 x 1.96) and mean equal to $(-\sigma^2)/2$.
3 Uncertainties in the activity data for fuels burnt are reported in **Table A 7.2.1**.
‡ Input parameters were uncertainties of activity data and emission factors

A7.2.3.3 Uncertainty in the Emissions

The central estimate of total N_2O emissions in 2010 was estimated as 36,074 Gg CO_2 equivalent. The Monte Carlo analysis suggested that 95% of the values were between 9,079 and 108,435 Gg CO_2 equivalent.

A7.2.3.4 Uncertainty in the Trend

The uncertainty in the trend between 1990 and the latest year was also estimated. In running this simulation it was necessary to make assumptions about the degree of correlation between sources in 1990 and 2010. If sources are correlated this will have the effect of reducing the emissions. The assumptions were as follows:

- Activity data are uncorrelated between years, but similar fuels are correlated in the same year;
- Emissions from agricultural soils were correlated;
- The emission factor used for sewage treatment was assumed to be correlated, though the protein consumption data used as activity data were assumed not to be correlated;
- Nitric acid production emission factors were assumed not to be correlated, since the mix of operating plant is very different in 2010 compared with 1990 – only 4 of the original 8 sites are still operating in the latest inventory year, 2 of which now have differing levels of abatement fitted; and

This analysis indicates that there is a 95% probability that N_2O emissions in the latest year were between **29% and 76%** below the level in 1990.

A7.2.4 Halocarbons and SF_6

A7.2.4.1 Uncertainty Parameters

The uncertainties in the emissions of HFCs, PFCs and SF_6 are based on the recent study to update emissions and projections of F-gases (AEA, 2008), for all sources except for refrigeration and air conditioning. For these sources, the uncertainty parameters were taken from ICF, 2011.

A7.2.4.2 Uncertainty in the Emissions

The uncertainties were estimated as

1990 (1995)
- 15% (14%) for HFCs,
- 5% (7%) for PFCs
- 17% (17%) for SF_6

2010
- 6% for HFCs

- 22% for PFCs
- 15% for SF_6

A7.2.4.3 Uncertainty in the Trend

This analysis indicates that there is a 95% probability that emissions in 2010 differed from those in 1990 by the following percentages

- +10% to +45% for HFCs
- -87% to -81% for PFCs
- -45% to -18% for SF_6

A7.3 UNCERTAINTIES IN GWP WEIGHTED EMISSIONS

A7.3.1 Uncertainty in the emissions

The uncertainty in the combined GWP weighted emission of all the greenhouse gases was estimated as **15%** in 1990 and **16%** in 2010.

A7.3.2 Uncertainty in the Trend

This analysis indicates that there is a 95% probability that the total GWP GHG emissions in the latest year were between 21% and 26% below the level in 1990.

The uncertainty estimates for all gases are summarised in **Table A 7.3.1**. The source which makes the major contribution to the overall uncertainty is 4D Agricultural Soils. This source shows little change over the years, but other sources have fallen since 1990.

Table A 7.3.1 Summary of Monte Carlo Uncertainty Estimates 1990 - 2010

IPCC Source Category	Gas	1990 Emissions	2010 Emissions	Uncertainty in 1990 emissions as % of emissions in category		Uncertainty introduced on national total in 1990	Uncertainty in 2010 emissions as % of emissions in category		Uncertainty introduced on national total in 2010	% change in emissions between 2010 and 1990	Range of likely % change between 2010 and 1990	
				2.5 percentile	97.5 percentile		2.5 percentile	97.5 percentile			2.5 percentile	97.5 percentile
		Gg CO_2e	Gg CO_2e	Gg CO_2e	Gg CO_2e	%	Gg CO_2e	Gg CO_2e	%	%	%	%
TOTAL	CO_2 (net)	591832	497859	582333	601316	2%	490224	505468	2%	-16%	-18%	-14%
	CH_4	97588	41495	81027	118974	24%	35538	48997	20%	-57%	-67%	-45%
	N_2O	67523	36074	30398	153861		9079	108435		-54%	-76%	-29%
	HFC	11390	14311	9987	12796	15%	13553	15072	6%	26%	10%	45%
	PFC	1401	220	1346	1457	5%	181	259	22%	-84%	-87%	-81%
	SF_6	1030	690	885	1174	17%	602	778	15%	-32%	-45%	-18%
	All	770764	590650	724976	860844	15%	559297	663319	16%	-23%	-26%	-21%

Notes
Uncertainty calculated as 2s/E where s is the standard deviation and E is the mean, calculated in the simulation.
The uncertainty for N_2O is not quoted because the distribution is highly skewed and the uncertainty exceeds 100%.
Emissions of CO_2 are net emissions (i.e. sum of emissions and removals).

Important - 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 reported to the UNFCCC.

A7.4 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 mathematical 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 the Monte Carlo software a country chooses to use, 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 simulation.

If all the distributions in the Monte Carlo model were normal, and there were no correlations between sources, the estimated errors on the trend from the Monte Carlo model should be identical to those estimated by the error propagation approach. In reality there will be correlations between sources, and some distributions are not normal and are heavily skewed.

Table A 7.4.1 shows differences in the trend uncertainty between the error propagation and Monte Carlo approaches. These differences probably arise from the improvements that were made to the Monte Carlo approach that have not yet been implemented into the error propagation approach, due to the timing of the updates. Other reasons why the two models do not give identical answers are 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 within years, and automatically assumes a correlation between the emission factor uncertainty in 1990 and the latest year.

The central estimates of emissions generated by the Monte Carlo model in 1990, and those in the latest inventory year, are very close. Mathematically we would not expect the central estimates from the two methods to be identical.

Table A 7.4.1 Comparison of the central estimates and trends in emissions from the error propagation (Approach 1) and Monte Carlo (Approach 2) uncertainty analyses

Method of uncertainty estimation	Central estimate ($Gg\ CO_2$ equivalent) [b]		Uncertainty on trend, 95% CI (1990 to 2010)
	1990	2010	
Error propagation	771,152	590,177	4.5
Monte Carlo	770,764	590,650	5.8 [a]

Notes

CI Confidence Interval

[a] 2.5^{th} percentile, -26%, 97.5^{th} percentile, -21%. Difference between these values is the 95% Confidence Interval which assuming a normal distribution is equal to ±2 standard deviations on the central estimate.

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

A7.5 SECTORAL UNCERTAINTIES

A7.5.1 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 7.5.1**. We recommend that the estimates in the table are taken only as indicative. The estimates are presented in IPCC categories, which is consistent with the reporting format used within this submission to the UNFCCC.

A7.5.2 Review of Changes made to the Monte Carlo Model since the last NIR

No changes that are specific to the sectoral uncertainty analysis have been made. The changes made to the uncertainty parameters used to estimate the uncertainties by gas are all reflected within the sectoral analysis.

Table A 7.5.1 Sectoral Uncertainty Estimates

IPCC Source Category	Gas	1990 Emissions	2010 Emissions	Uncertainty in 2010 emissions as % of emissions in category		Uncertainty Introduced on national total in 2010	% change in emissions between 1990 and 2010	Range of likely % change between 1990 and 2010	
				2.5 percentile	97.5 percentile			2.5 percentile	97.5 percentile
1A1a	GWP weighted total	205,905	158,411	157,140	159,783	1%	-23%	-24%	-22%
1A1b	GWP weighted total	17,682	16,510	16,094	16,933	3%	-7%	-12%	-1%
1A1c	GWP weighted total	15,234	18,497	18,312	18,698	1%	21%	19%	24%
1A2a	GWP weighted total	24,030	13,928	13,424	14,438	4%	-42%	-45%	-39%
1A2f	GWP weighted total	53,311	37,081	36,589	37,730	2%	-30%	-32%	-29%
1A3a	GWP weighted total	1,601	2,010	1,687	2,335	20%	27%	0%	57%
1A3b	GWP weighted total	110,663	112,645	110,466	114,828	2%	2%	-2%	5%
1A3c	GWP weighted total	1,554	2,227	2,098	2,428	10%	44%	29%	60%
1A3d	GWP weighted total	2,249	2,364	2,340	2,389	1%	5%	2%	8%
1A3e	GWP weighted total	254	479	448	527	11%	89%	67%	112%
1A4a	GWP weighted total	25,064	18,550	18,334	18,766	1%	-26%	-28%	-24%
1A4b	GWP weighted total	79,672	85,769	84,856	86,675	1%	8%	5%	10%
1A4c	GWP weighted total	5,782	4,618	4,351	5,025	9%	-20%	-28%	-11%
1A5b	GWP weighted total	5,340	2,965	2,620	3,317	14%	-44%	-53%	-34%
1B1a	GWP weighted total	18,255	1,790	1,653	1,927	9%	-90%	-91%	-89%
1B1b	GWP weighted total	877	231	225	237	3%	-74%	-74%	-73%
1B2a	GWP weighted total	1,270	407	343	473	19%	-68%	-74%	-60%
1B2b	GWP weighted total	9,507	4,409	4,364	4,456	1%	-54%	-55%	-53%
1B2c_Flaring	GWP weighted total	4,480	4,213	3,724	4,715	14%	-5%	-21%	12%
1B2c_Venting	GWP weighted total	886	593	472	721	26%	-32%	-50%	-10%
2A1	GWP weighted total	7,294	3,792	3,630	3,953	5%	-48%	-51%	-45%
2A2	GWP weighted total	1,207	234	224	243	5%	-81%	-82%	-79%
2A3	GWP weighted total	1,125	921	897	944	3%	-18%	-21%	-15%
2A7	GWP weighted total	562	537	488	594	12%	-4%	-21%	14%

IPCC Source Category	Gas	1990 Emissions	2010 Emissions	Uncertainty in 2010 emissions as % of emissions in category		Uncertainty Introduced on national total in 2010	% change in emissions between 1990 and 2010	Range of likely % change between 1990 and 2010	
				2.5 percentile	97.5 percentile			2.5 percentile	97.5 percentile
2B1	GWP weighted total	1,431	978	966	990	2%	-32%	-34%	-30%
2B2	GWP weighted total	3,903	1,316	777	1,860	50%	-62%	-84%	-30%
2B3	GWP weighted total	20,665	0	0	0	n/a	-100%	-100%	-100%
2B5	GWP weighted total	1,734	2,044	1,136	3,345	68%	28%	-44%	140%
2C1	GWP weighted total	1,887	1,479	1,408	1,551	6%	-22%	-27%	-16%
2C3	GWP weighted total	1,783	400	377	422	7%	-78%	-79%	-76%
2E1	GWP weighted total	11,378	81	68	95	20%	-99%	-99%	-99%
2E2	GWP weighted total	11	39	34	43	15%	257%	198%	324%
2F1	GWP weighted total	0	10,919	10,279	11,557	7%	5457299%	4005517%	7543931%
2F2	GWP weighted total	0	299	225	373	30%	0%	n/a	n/a
2F3	GWP weighted total	0	203	170	237	20%	0%	n/a	n/a
2F4	GWP weighted total	12	2,688	2,282	3,101	19%	22849%	18195%	28147%
2F5	GWP weighted total	0	107	85	129	25%	0%	n/a	n/a
2F9	GWP weighted total	662	628	536	719	18%	-4%	-23%	17%
4A1	GWP weighted total	13,801	11,902	9,952	13,844	20%	-13%	-32%	9%
4A10	GWP weighted total	9	6	5	7	20%	-34%	-48%	-17%
4A3	GWP weighted total	4,545	3,201	2,674	3,727	20%	-29%	-44%	-11%
4A4	GWP weighted total	11	11	9	12	20%	-3%	-24%	21%
4A6	GWP weighted total	78	119	100	139	20%	54%	20%	93%
4A8	GWP weighted total	238	141	118	164	20%	-40%	-53%	-25%
4B1	GWP weighted total	1,779	1,798	1,353	2,245	30%	4%	-29%	45%
4B3	GWP weighted total	134	94	70	117	31%	-28%	-51%	1%
4B4	GWP weighted total	0	0	0	0	30%	2%	-31%	43%
4B6	GWP weighted total	6	9	7	12	30%	56%	5%	119%
4B8	GWP weighted total	1,499	518	390	648	30%	-65%	-76%	-50%

IPCC Source Category	Gas	1990 Emissions	2010 Emissions	Uncertainty in 2010 emissions as % of emissions in category		Uncertainty Introduced on national total in 2010	% change in emissions between 1990 and 2010	Range of likely % change between 1990 and 2010	
				2.5 percentile	97.5 percentile			2.5 percentile	97.5 percentile
4B9	GWP weighted total	169	260	194	326	31%	58%	6%	123%
4B10	GWP weighted total	0	0	0	0	31%	-33%	-55%	-6%
Agriculture - N2O	GWP weighted total	34,491	28,614	2,029	100,990	334%	-18%	-19%	-16%
5A	GWP weighted total	-12,142	-10,559	-12,725	-8,433	-25%	-12%	-35%	17%
5B	GWP weighted total	16,521	12,754	7,734	17,752	48%	-18%	-57%	34%
5C	GWP weighted total	-6,269	-8,527	-12,029	-5,797	-45%	46%	-22%	143%
5D	GWP weighted total	486	264	154	372	50%	-41%	-71%	1%
5E	GWP weighted total	7,014	6,211	3,652	8,769	50%	-8%	-51%	44%
5G	GWP weighted total	-1,729	-3,989	-4,963	-3,017	-30%	136%	61%	231%
6A1	GWP weighted total	43,086	14,823	9,279	22,047	54%	-63%	-81%	-36%
6B2	GWP weighted total	1,447	1,473	409	4,247	245%	8%	-16%	43%
6C	GWP weighted total	1,410	345	235	500	48%	-75%	-84%	-63%
Grand Total	GWP weighted total	770,673	590,669	559,382	662,922	16%	-23%	-26%	-21%

Important - 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 reported to the UNFCCC.

A7.6 ESTIMATION OF UNCERTAINTIES USING AN ERROR PROPAGATION APPROACH (APPROACH 1)

The IPCC Good Practice Guidance (IPCC, 2000) and 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 **Tables A7.5.2-5**. In the error propagation approach the emission sources are aggregated up to a level broadly similar to the IPCC Summary Table 7A. Uncertainties are then estimated for these categories. 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 far less detailed. However, the values used were chosen to agree approximately with those used in the Monte Carlo Simulation. The error propagation approach is only able to model normal distributions. This presented a problem in how to estimate a normal distribution approximation of the lognormal distribution used for agricultural soils and wastewater treatment. The approach adopted was to use a normal distribution with the same mean as the lognormal distribution.

There were a number of major improvements to the key source analysis in the 2006 NIR. In part, these improvements have been made following comments made in the Fourth Centralised Review and have been made to improve the transparency of the uncertainty analysis. The improvements are summarised below.

A7.6.1 Review of Recent Improvements to the Error Propagation Model

- An ERT commented that the key source analysis was not consistent with the IPCC GPG. The comment was in reference to the guidance where it says "*The (key source) analysis should be performed at the level of IPCC source categories*". Our analysis included disaggregation of 1B1 and 1B2 in the case of CH_4, rather than treating each of these as a single source category. This has been revised by summing these categories; and

- The uncertainties associated with some of the fuel consumptions in the 2005 NIR were derived from an analysis of the statistical differences between supply and demand for one year, presented in the 1996 UK energy statistics. This analysis was updated for the 2008 NIR, and we have now revised the uncertainty associated the consumptions of the fuels listed below this bullet point. The uncertainties were calculated from the differences between supply and demand[22] for fuel categories presented in the 1996 DTI DUKES. We have now chosen to use a 5-year rolling average since this is a time period short enough to allow a satisfactory estimate of the change in the variability in the supply and demand, but avoids the sometimes large year-to-year variability that can be a feature of the UK energy statistics.

  This large year-to-year variability is in part controlled by the historical revisions to the energy statistics that the DECC perform each year, and in some years, by revisions to historic estimates of supply and demand which will then alter the uncertainty calculated from previous data.

[22] We have assumed that the distribution of errors in the parameter values was normal. The quoted range of possible error of uncertainty is taken as 2s, where s is the standard deviation. If the expected value of a parameter is E and the standard deviation is s, then the uncertainty is quoted as 2s/E expressed as a percentage. For a normal distribution the probability of the parameter being less than E-2s is 0.025 and the probability of the emission being less than E+2s is 0.975.

The uncertainty between supply and demand has been estimated for the following fuels:

- Coal
- Coke
- Petroleum coke
- Solid smokeless fuel
- Burning oil
- Fuel oil
- Gas oil
- Petrol
- Natural gas
- LPG
- OPG
- Naphtha
- Miscellaneous
- Blast furnace gas
- Coke oven gas

- In a few cases in this uncertainty analysis, types of fuels are grouped into one class: for example, oil in IPCC sector 1A used in stationary combustion; this oil is a combination of burning oil (minimal quantities used), fuel oil, and gas oil. In this case, and in other instances like it, we have used expert judgement to assign an uncertainty to a fuel class from the estimated uncertainties associated with individual fuels of that class. The uncertainties in the consumption of Aviation Turbine Fuel and Aviation Spirit has been reviewed and this is discussed below;

- We have reviewed the uncertainties associated with the emissions of HFC, PFC and SF_6 from industrial processes. The uncertainties associated with the total F-gas emissions has been assigned to the EF in the error propagation analysis since uncertainties are not known individually for the ADs and EFs as the emissions are produced from a model. The uncertainties used are weighted values, and reflect the individual uncertainties and the magnitude of emissions in each of the respective sectors;

- The LULUCF sectoral experts, CEH, have revised the uncertainties associated with emissions associated with Land Use Change and Forestry. The uncertainties associated with the emissions in each LULUCF category have been assigned to the EF in the error propagation analysis, since uncertainties are not known individually for the ADs and EFs as emissions are produced from a complicated model;

- We have reviewed the uncertainties associated with the consumptions of Aviation Turbine Fuel and Aviation Spirit

  For this review we contacted DECC for their view about the 95% CI that could be applied to the demand of Aviation Spirit and Aviation Turbine Fuel in the UK energy statistics. We then considered the additional uncertainty that would be introduced by the Tier 3 aviation model, which is used to estimate emissions. The overall uncertainty in the AD has been assigned by expert judgement considering the uncertainty in the DECC fuel consumption data and the additional uncertainty introduced by the model;

- We have reviewed the uncertainties associated with carbon emission factors (CEFs) for natural gas, coal used in power stations, and selected liquid fuels. The CEF uncertainty for natural gas was taken from analytical data of determinations of the carbon contents presented in a TRANSCO report - this report was produced for the Carbon Factor Review. The CEF uncertainty for the coal used in power stations has been derived from expert judgement following a consultation with representatives from the UK electricity supply industry, and takes into account analytical data of determinations of the carbon contents of power station coal. Analytical data of determinations of the carbon contents of liquid fuels from UKPIA have been used to determine the CEF uncertainties associated with the following fuels: motor spirit, kerosene, diesel, gas oil, and fuel oil. Analytical data were available for naphtha and aviation spirit, but these were not used to modify the existing uncertainties, as the sample sizes were too small. The existing CEF uncertainties were retained for these fuels; and

- Uncertainties for the ADs and EFs for peat combustion have been assigned using expert judgement.

A7.6.2 Review of Changes Made to the Error Propagation Model since the last NIR

There have been no substantial changes to error propagation model since the last NIR.

A7.6.3 Uncertainty in the Emissions

The error propagation analysis, **including** LULUCF emissions, suggests an uncertainty of 19% in the combined GWP total emission in the latest reported year.

The error propagation analysis, **excluding** LULUCF emissions, suggests an uncertainty of 19% in the combined GWP total emission in the latest reported year.

A7.6.4 Uncertainty in the Trend

The analysis, **including** LULUCF emissions, estimates an uncertainty of 2.3% in the trend between the base year and the latest reported year.

The analysis, **excluding** LULUCF emissions, estimates an uncertainty of 2.2% in the trend between the base year and the latest reported year.

A7.6.5 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 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 set out in Section 7.2 of the IPCC Good Practice Guidance (2000) (*Determining national key source categories*) to determine the key source categories. The results of this key source analysis can be found in **Annex 1**.

A7.6.6 Tables of uncertainty estimates from the error propagation approach

See overleaf.

Table A 7.6.1 Summary of error propagation uncertainty estimates including LULUCF, base year to the latest reported year

	Source Category (Analysis with LULUCF)	Gas	BaseYear Emissions 1990 & 1995	Year Y emissions 2010	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty range as % of national total in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced trend in total emissions by source category
			Gg CO2 equiv	Gg CO2 equiv	%	%	%	%	%	%	%	%	%
	A	B	C	D	E	F	G	H	I	J	K	L	M
1A	Coal	CO2	247785	114863	0.4	1	1.077	0.209618	-0.095237	0.148333	-0.095237	0.083910	0.126929
1A(stationary)	Oil	CO2	92868	53506	15	2	15.133	1.371947	-0.022279	0.069097	-0.044557	1.465761	1.466438
1A	Natural Gas	CO2	108956	197885	0.2	1.5	1.513	0.507397	0.148100	0.255545	0.222150	0.072279	0.233613
1A	Other (waste)	CO2	212	1661	7	20	21.190	0.059621	0.001935	0.002144	0.038707	0.021229	0.044146
1A	Lubricant	CO2	387	225	30	2	30.067	0.011477	-0.000090	0.000291	-0.000180	0.012343	0.012344
1A	Combined Fuel	CO2	802	868	15	15	21.213	0.031194	0.000332	0.001121	0.004978	0.023774	0.024290
1A3a	Aviation Fuel	CO2	1581	1991	20	3.3	20.270	0.068371	0.001015	0.002571	0.003350	0.072709	0.072787
1A3b	Auto Fuel	CO2	108565	111579	2.8	3.5	4.482	0.847404	0.037188	0.144091	0.130157	0.570572	0.585230
1A3c	Coal	CO2	0	50	0.4	6	6.013	0.000506	0.000064	0.000064	0.000384	0.000036	0.000386
1A3d	Marine Fuel	CO2	2123	2265	1.7	1.4	2.202	0.008450	0.000835	0.002924	0.001168	0.007031	0.007127
1A3	Other Diesel	CO2	1614	2371	1.7	1.4	2.202	0.008847	0.001473	0.003062	0.002063	0.007361	0.007645
1A4	Peat	CO2	476	47	30	10	31.623	0.002542	-0.000407	0.000061	-0.004068	0.002599	0.004828
1A4	Combined Fuel	CO2	0	0	15	15	21.213	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1B	Solid Fuel Transformation	CO2	856	220	0.4	6	6.013	0.002238	-0.000559	0.000284	-0.003356	0.000160	0.003359
1B	Oil & Natural Gas	CO2	5778	4388	16	6	17.088	0.127063	-0.000020	0.005667	-0.000117	0.128233	0.128233
2A1	Cement Production	CO2	7295	3792	1	2.2	2.417	0.015527	-0.002283	0.004897	-0.005023	0.006925	0.008555
2A2	Lime Production	CO2	1206	234	1	5	5.099	0.002019	-0.000886	0.000302	-0.004428	0.000427	0.004448
2A3	Limestone & Dolomite use	CO2	1125	921	1	5	5.099	0.007955	0.000082	0.001189	0.000408	0.001682	0.001730
2A4	Soda Ash Use	CO2	0	0	15	2	15.133	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2A7	Fletton Bricks	CO2	539	531	20	70	72.801	0.065459	0.000154	0.000685	0.010806	0.019383	0.022191
2B	Ammonia Production	CO2	1431	978	10	1.5	10.112	0.016764	-0.000145	0.001264	-0.000218	0.017869	0.017870
2B5	NEU	CO2	1563	1970	50	20	53.852	0.179740	0.001006	0.002544	0.020110	0.179873	0.180994
2C1	Iron&Steel Production	CO2	2309	1747	1.2	6	6.119	0.018116	-0.000016	0.002256	-0.000098	0.003829	0.003831
5A	5A LUCF	CO2	-12155	-10569	1	25	25.020	-0.448054	-0.001685	-0.013648	-0.042134	-0.019302	0.046345
5B	5B LUCF	CO2	15732	12116	1	50	50.010	1.026653	0.000162	0.015646	0.008110	0.022127	0.023566
5C	5C LUCF	CO2	-6261	-8541	1	70	70.007	-1.013138	-0.004868	-0.011030	-0.340745	-0.015598	0.341101
5D	5D LUCF	CO2	482	263	1	50	50.010	0.022287	-0.000134	0.000340	-0.006723	0.000480	0.006741
5E	5E LUCF	CO2	7012	6216	1	50	50.010	0.526746	0.001126	0.008028	0.056310	0.011353	0.057443
5G	5G LUCF	CO2	-1727	-3985	1	30	30.017	-0.202682	-0.003446	-0.005146	-0.103387	-0.007278	0.103643
6C	Waste Incineration	CO2	1228	292	7	20	21.190	0.010484	-0.000831	0.000377	-0.016621	0.003733	0.017035
		CO2 Total	591,781.12	497,883.30									
1A	All Fuel	CH4	2077.990017	1069.028944	0.4	50	50.002	0.090571	-0.000665	0.001381	-0.033233	0.000781	0.033242
1A3a	Aviation Fuel	CH4	3.29913401	1.113138293	20	50	53.852	0.000102	-0.000002	0.000001	-0.000090	0.000041	0.000099
1A3b	Auto Fuel	CH4	634.8335315	71.41371836	2.8	50	50.078	0.006060	-0.000533	0.000092	-0.026629	0.000365	0.026632
1A3c	Coal	CH4	0	0.98700087	0.4	50	50.002	0.000084	0.000001	0.000001	0.000064	0.000001	0.000064
1A3d	Marine Fuel	CH4	1.851174337	3.912920378	1.7	50	50.029	0.000332	0.000003	0.000005	0.000162	0.000012	0.000162
1A3	Other Diesel	CH4	3.107635705	3.775673402	1.7	50	50.029	0.000320	0.000002	0.000005	0.000091	0.000012	0.000092
1B1	Coal Mining	CH4	18277.663	1796.797	0.4	13	13.006	0.039597	-0.015665	0.002320	-0.203647	0.001313	0.203651
	Solid Fuel Transformation	CH4	4.043	2.672	0.4	50	50.002	0.000226	-0.000001	0.000003	-0.000026	0.000002	0.000026
1B2	Natural Gas Transmission	CH4	8505.883	4187.694	1	15	15.033	0.106671	-0.002963	0.005408	-0.044451	0.007648	0.045104
	Offshore Oil& Gas	CH4	1817.038	1003.600	16	20	25.612	0.043554	-0.000492	0.001296	-0.009846	0.029326	0.030935
2A7	Fletton Bricks	CH4	23.602	5.633	20	100	101.980	0.000973	-0.000016	0.000007	-0.001596	0.000206	0.001609
2B	Chemical Industry	CH4	169.425	73.497	20	20	28.284	0.003522	-0.000072	0.000095	-0.001437	0.002685	0.003045
2C	Iron & Steel Production	CH4	16.357	11.813	0.4	50	50.002	0.001001	-0.000001	0.000015	-0.000042	0.000009	0.000043
4A	Enteric Fermentation	CH4	18694.633	15385.930	0.1	20	20.000	0.521407	0.001469	0.019869	0.029383	0.002810	0.029517
4B	Manure Management	CH4	3585.618	2679.297	0.1	30	30.000	0.136195	-0.000069	0.003460	-0.002071	0.000489	0.002128
4F	Field Burning	CH4	265.508	0.000	25	50	55.902	0.000000	-0.000261	0.000000	-0.013066	0.000000	0.013066
5A	5A LUCF	CH4	4.298	8.174	1	20	20.025	0.000277	0.000006	0.000011	0.000126	0.000015	0.000127
5B	5B LUCF	CH4	0.136	0.395	1	50	50.010	0.000033	0.000000	0.000001	0.000019	0.000001	0.000019
5C2	5C2 LUCF	CH4	3.903	11.741	1	20	20.025	0.000398	0.000011	0.000015	0.000226	0.000021	0.000227
5E2	5E2 LUCF	CH4	9.963	8.297	1	20	20.025	0.000282	0.000001	0.000011	0.000018	0.000015	0.000024
6A	Solid Waste Disposal	CH4	43143.467	14767.000	15	46	48.384	1.210628	-0.023380	0.019070	-1.075469	0.404532	1.149034
6B	Wastewater Handling	CH4	287.213	347.895	1	50	50.010	0.029480	0.000167	0.000449	0.008329	0.000635	0.008353
6C	Waste Incineration	CH4	134.433	6.246	7	50	50.488	0.000534	-0.000124	0.000008	-0.006212	0.000080	0.006213
		CH4 total	97,664.27	41,446.91									

Table A 7.6.2 Summary of error propagation uncertainty estimates including LULUCF, base year to the latest reported year (continued)

	Source Category	Gas	BaseYear Emissions 1990 & 1995	Year Y emissions 2010	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty range as % of national total in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced trend in total emissions by source category
			Gg CO2 equiv	Gg CO2 equiv	%	%	%	%	%	%	%	%	%
	A	B	C	D	E	F	G	H	I	J	K	L	M
1A1&1A2&1A4&1A5	Other Combustion	N2O	4829.072	3122.224	0.4	195	195.000	1.031614	-0.000721	0.004032	-0.140563	0.002281	0.140582
1A3a	Aviation Fuel	N2O	15.559	19.596	20	170	171.172	0.005683	0.000010	0.000025	0.001699	0.000716	0.001843
1A3b	Auto Fuel	N2O	1179.781	847.950	2.8	170	170.023	0.244284	-0.000066	0.001095	-0.011243	0.004336	0.012050
1A3c	Coal	N2O	0.000	0.117	0.4	118	118.001	0.000023	0.000000	0.000000	0.000018	0.000000	0.000018
1A3d	Marine Fuel	N2O	16.562	17.640	1.7	170	170.008	0.005082	0.000006	0.000023	0.001102	0.000055	0.001103
1A3	Other Diesel	N2O	191.401	282.121	1.7	140	140.010	0.066929	0.000176	0.000364	0.024632	0.000876	0.024648
1B1	Coke Oven Gas	N2O	2.085	1.378	0.4	118	118.001	0.000276	0.000000	0.000002	-0.000032	0.000001	0.000032
1B2	Oil & Natural Gas	N2O	42.396	46.175	16	110	111.158	0.008697	0.000018	0.000060	0.001969	0.001349	0.002387
2B	Adipic Acid Production	N2O	20737.345	0.000	0.5	15	15.008	0.000000	-0.020405	0.000000	-0.306069	0.000000	0.306069
2B	Nitric Acid Production	N2O	3903.850	1316.570	10	230	230.217	0.513570	-0.002142	0.001700	-0.492646	0.024044	0.493233
2C	Iron & Steel	N2O	11.107	6.717	0.4	118	118.001	0.001343	-0.000002	0.000009	-0.000266	0.000005	0.000266
4B	Manure Management	N2O	2053.051	1750.562	1	414	414.001	1.227995	0.000240	0.002261	0.099354	0.003197	0.099406
4D	Agricultural Soils	N2O	32825.071	26385.594	1	424	424.001	18.956212	0.001766	0.034074	0.748814	0.048188	0.750363
4F	Field Burning	N2O	77.604	0.000	25	230	231.355	0.000000	-0.000076	0.000000	-0.017567	0.000000	0.017567
4G	OvTerr Agriculture N2O (all)	N2O	0.000	0.000	10	50	50.990	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5A	5A LUCF	N2O	5.569	1.922	1	20	20.025	0.000065	-0.000003	0.000002	-0.000060	0.000004	0.000060
5B	5B LUCF	N2O	781.557	622.477	1	50	50.010	0.052747	0.000035	0.000804	0.001732	0.001137	0.002071
5C2	5C2 LUCF	N2O	0.396	1.192	1	20	20.025	0.000040	0.000001	0.000002	0.000023	0.000002	0.000023
5D2	5D2 LUCF	N2O	3.982	0.498	1	20	20.025	0.000017	-0.000003	0.000001	-0.000066	0.000001	0.000066
5E2	5E2 LUCF	N2O	1.011	0.842	1	20	20.025	0.000029	0.000000	0.000001	0.000002	0.000002	0.000002
5G	5G LUCF	N2O	0.000	0.000	1	50	50.010	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6B	Wastewater Handling	N2O	1164.855	1151.566	10	401	401.125	0.782683	0.000341	0.001487	0.136594	0.021031	0.138203
6C	Waste Incineration	N2O	47.902	47.248	7	230	230.106	0.018422	0.000014	0.000061	0.003190	0.000604	0.003247
		N2O Total	67,890.16	35,622.39									
2	Industrial Processes	HFC	15328	14314	1	19	19.026	0.461461	0.003398	0.018485	0.064571	0.026142	0.069662
2	Industrial Processes	PFC	462	220	1	10	10.050	0.003754	-0.000170	0.000285	-0.001698	0.000403	0.001745
2	Industrial Processes	SF6	1239	690	1	20	20.025	0.023412	-0.000329	0.000891	-0.006574	0.001260	0.006694
		Halocarbon & SF6 Total	17,028.77	15,224.53									
	TOTALS	GWP	774,364.31	590,177.13									
	Total Uncertainties%							19.2					2.25

Table A 7.6.3 Summary of error propagation uncertainty estimates excluding LULUCF, base year to the latest reported year

	Source Category (Analysis without LULUCF)	Gas	BaseYear Emissions 1990 & 1995 Gg CO2 equiv	Year Y emissions 2010 Gg CO2 equiv	Activity data uncertainty %	Emission factor uncertainty %	Combined uncertainty %	Combined uncertainty range as % of national total in year t %	Type A sensitivity %	Type B sensitivity %	Uncertainty in trend in national emissions introduced by emission factor uncertainty %	Uncertainty in trend in national emissions introduced by activity data uncertainty %	Uncertainty introduced trend in total emissions by source category %
	A	B	C	D	E	F	G	H	I	J	K	L	M
1A	Coal	CO2	247785	114863	0.4	1	1.077	0.208261	-0.098551	0.149082	-0.098551	0.084334	0.129709
1A(stationary)	Oil	CO2	92868	53506	15	2	15.133	1.363069	-0.023455	0.069446	-0.046911	1.473167	1.473913
1A	Natural Gas	CO2	108956	197885	0.2	1.5	1.513	0.504113	0.147599	0.256836	0.221398	0.072644	0.233011
1A	Other (waste)	CO2	212	1661	7	20	21.190	0.059235	0.001943	0.002155	0.038854	0.021336	0.044327
1A	Lubricant	CO2	387	225	30	2	30.067	0.011402	-0.000095	0.000292	-0.000190	0.012405	0.012406
1A	Combined Fuel	CO2	802	868	15	15	21.213	0.030992	0.000324	0.001126	0.004865	0.023895	0.024385
1A3a	Aviation Fuel	CO2	1581	1991	20	3.3	20.270	0.067928	0.001002	0.002584	0.003307	0.073077	0.073152
1A3b	Auto Fuel	CO2	108565	111579	2.8	3.5	4.482	0.841920	0.036132	0.144819	0.126460	0.573455	0.587234
1A3c	Coal	CO2	0	50	0.4	6	6.013	0.000502	0.000064	0.000064	0.000386	0.000036	0.000388
1A3d	Marine Fuel	CO2	2123	2265	1.7	1.4	2.202	0.008396	0.000814	0.002939	0.001140	0.007066	0.007158
1A3	Other Diesel	CO2	1614	2371	1.7	1.4	2.202	0.008790	0.001462	0.003077	0.002047	0.007398	0.007676
1A4	Peat	CO2	476	47	30	10	31.623	0.002525	-0.000414	0.000062	-0.004143	0.002612	0.004898
1A4	Combined Fuel	CO2	0	0	15	15	21.213	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1B	Solid Fuel Transformation	CO2	856	220	0.4	6	6.013	0.002223	-0.000572	0.000285	-0.003431	0.000161	0.003435
1B	Oil & Natural Gas	CO2	5778	4388	16	6	17.088	0.126240	-0.000086	0.005696	-0.000515	0.128881	0.128882
2A1	Cement Production	CO2	7295	3792	1	2.2	2.417	0.015427	-0.002378	0.004922	-0.005232	0.006960	0.008707
2A2	Lime Production	CO2	1206	234	1	5	5.099	0.002006	-0.000904	0.000303	-0.004519	0.000429	0.004540
2A3	Limestone & Dolomite use	CO2	1125	921	1	5	5.099	0.007904	0.000069	0.001195	0.000345	0.001690	0.001725
2A4	Soda Ash Use	CO2	0	0	15	2	15.133	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2A7	Fletton Bricks	CO2	539	531	20	70	72.801	0.065035	0.000149	0.000689	0.010428	0.019481	0.022096
2B	Ammonia Production	CO2	1431	978	10	1.5	10.112	0.016656	-0.000162	0.001270	-0.000243	0.017959	0.017961
2B5	NEU	CO2	1563	1970	50	20	53.852	0.178577	0.000993	0.002557	0.019853	0.180782	0.181869
2C1	Iron&Steel Production	CO2	2309	1747	1.2	6	6.119	0.017999	-0.000043	0.002268	-0.000258	0.003849	0.003857
5A	5A LUCF	CO2	0	0	1	25	25.020	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5B	5B LUCF	CO2	0	0	1	50	50.010	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5C	5C LUCF	CO2	0	0	1	70	70.007	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5D	5D LUCF	CO2	0	0	1	50	50.010	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5E	5E LUCF	CO2	0	0	1	50	50.010	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5G	5G LUCF	CO2	0	0	1	30	30.017	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6C	Waste Incineration	CO2	1228	292	7	20	21.190	0.010416	-0.000849	0.000379	-0.016986	0.003752	0.017396
		CO2 Total	588,698.99	502,383.21									
1A	All Fuel	CH4	2077.990017	1069.028944	0.4	50	50.002	0.089985	-0.000692	0.001387	-0.034593	0.000785	0.034602
1A3a	Aviation Fuel	CH4	3.29913401	1.113138293	20	50	53.852	0.000101	-0.000002	0.000001	-0.000093	0.000041	0.000101
1A3b	Auto Fuel	CH4	634.8335315	71.41371836	2.8	50	50.078	0.006020	-0.000543	0.000093	-0.027128	0.000367	0.027131
1A3c	Coal	CH4	0	0.98700087	0.4	50	50.002	0.000083	0.000001	0.000001	0.000064	0.000001	0.000064
1A3d	Marine Fuel	CH4	1.851174337	3.912920378	1.7	50	50.029	0.000330	0.000003	0.000005	0.000161	0.000012	0.000162
1A3	Other Diesel	CH4	3.107635705	3.775673402	1.7	50	50.029	0.000318	0.000002	0.000005	0.000090	0.000012	0.000090
1B1	Coal Mining	CH4	18277.663	1796.797	0.4	13	13.006	0.039341	-0.015954	0.002332	-0.207402	0.001319	0.207406
	Solid Fuel Transformation	CH4	4.043	2.672	0.4	50	50.002	0.000225	-0.000001	0.000003	-0.000029	0.000002	0.000029
1B2	Natural Gas Transmission	CH4	8505.883	4187.694	1	15	15.033	0.105981	-0.003076	0.005435	-0.046140	0.007687	0.046775
	Offshore Oil& Gas	CH4	1817.038	1003.600	16	20	25.612	0.043272	-0.000516	0.001303	-0.010313	0.029474	0.031226
2A7	Fletton Bricks	CH4	23.602	5.633	20	100	101.980	0.000967	-0.000016	0.000007	-0.001631	0.000207	0.001644
2B	Chemical Industry	CH4	169.425	73.497	20	20	28.284	0.003500	-0.000074	0.000095	-0.001483	0.002698	0.003079
2C	Iron & Steel Production	CH4	16.357	11.813	0.4	50	50.002	0.000994	-0.000001	0.000015	-0.000052	0.000009	0.000052
4A	Enteric Fermentation	CH4	18694.633	15385.930	0.1	20	20.000	0.518033	0.001262	0.019970	0.025242	0.002824	0.025400
4B	Manure Management	CH4	3585.618	2679.297	0.1	30	30.000	0.135314	-0.000111	0.003477	-0.003316	0.000492	0.003352
4F	Field Burning	CH4	265.508	0.000	25	50	55.902	0.000000	-0.000266	0.000000	-0.013284	0.000000	0.013284
5A	5A LUCF	CH4	0.000	0.000	1	20	20.025	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5B	5B LUCF	CH4	0.000	0.000	1	50	50.010	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5C2	5C2 LUCF	CH4	0.000	0.000	1	20	20.025	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5E2	5E2 LUCF	CH4	0.000	0.000	1	20	20.025	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6A	Solid Waste Disposal	CH4	43143.467	14767.000	15	46	48.384	1.202793	-0.023993	0.019166	-1.103659	0.406576	1.176166
6B	Wastewater Handling	CH4	287.213	347.895	1	50	50.010	0.029289	0.000164	0.000452	0.008206	0.000639	0.008231
6C	Waste Incineration	CH4	134.433	6.246	7	50	50.488	0.000531	-0.000126	0.000008	-0.006321	0.000080	0.006321
		CH4 total	97,645.97	41,418.31									

Table A 7.6.4 Summary of error propagation uncertainty estimates excluding LULUCF, base year to the latest reported year (continued)

	Source Category	Gas	BaseYear Emissions 1990 & 1995	Year Y emissions 2010	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty range as % of national total in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced trend in total emissions by source category
			Gg CO2 equiv	Gg CO2 equiv	%	%	%	%	%	%	%	%	%
	A	B	C	D	E	F	G	H	I	J	K	L	M
1A1&1A2&1A4&1A5	Other Combustion	N2O	4829.072	3122.224	0.4	195	195.000	1.024938	-0.000780	0.004052	-0.152077	0.002292	0.152095
1A3a	Aviation Fuel	N2O	15.559	19.596	20	170	171.172	0.005647	0.000010	0.000025	0.001677	0.000719	0.001825
1A3b	Auto Fuel	N2O	1179.781	847.950	2.8	170	170.023	0.242703	-0.000080	0.001101	-0.013601	0.004358	0.014282
1A3c	Coal	N2O	0.000	0.117	0.4	118	118.001	0.000023	0.000000	0.000000	0.000018	0.000000	0.000018
1A3d	Marine Fuel	N2O	16.562	17.640	1.7	170	170.008	0.005049	0.000006	0.000023	0.001075	0.000055	0.001076
1A3	Other Diesel	N2O	191.401	282.121	1.7	140	140.010	0.066496	0.000175	0.000366	0.024449	0.000880	0.024465
1B1	Coke Oven Gas	N2O	2.085	1.378	0.4	118	118.001	0.000274	0.000000	0.000002	-0.000035	0.000001	0.000035
1B2	Oil & Natural Gas	N2O	42.396	46.175	16	110	111.158	0.008641	0.000018	0.000060	0.001926	0.001356	0.002355
2B	Adipic Acid Production	N2O	20737.345	0.000	0.5	15	15.008	0.000000	-0.020746	0.000000	-0.311184	0.000000	0.311184
2B	Nitric Acid Production	N2O	3903.850	1316.570	10	230	230.217	0.510246	-0.002198	0.001709	-0.505437	0.024166	0.506015
2C	Iron & Steel	N2O	11.107	6.717	0.4	118	118.001	0.001334	-0.000002	0.000009	-0.000283	0.000005	0.000283
4B	Manure Management	N2O	2053.051	1750.562	1	414	414.001	1.220048	0.000218	0.002272	0.090104	0.003213	0.090161
4D	Agricultural Soils	N2O	32825.071	26385.594	1	424	424.001	18.833532	0.001399	0.034246	0.592969	0.048431	0.594944
4F	Field Burning	N2O	77.604	0.000	25	230	231.355	0.000000	-0.000078	0.000000	-0.017861	0.000000	0.017861
4G	OvTerr Agriculture N2O (all)	N2O	0.000	0.000	10	50	50.990	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5A	5A LUCF	N2O	0.000	0.000	1	20	20.025	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5B	5B LUCF	N2O	0.000	0.000	1	50	50.010	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5C2	5C2 LUCF	N2O	0.000	0.000	1	20	20.025	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5D2	5D2 LUCF	N2O	0.000	0.000	1	20	20.025	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5E2	5E2 LUCF	N2O	0.000	0.000	1	20	20.025	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5G	5G LUCF	N2O	0.000	0.000	1	50	50.010	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6B	Wastewater Handling	N2O	1164.855	1151.566	10	401	401.125	0.777617	0.000329	0.001495	0.131924	0.021137	0.133607
6C	Waste Incineration	N2O	47.902	47.248	7	230	230.106	0.018303	0.000013	0.000061	0.003080	0.000607	0.003139
		N2O Total	67,097.64	34,995.46									
2	Industrial Processes	HFC	15328	14314	1	19	19.026	0.458475	0.003240	0.018578	0.061557	0.026274	0.066929
2	Industrial Processes	PFC	462	220	1	10	10.050	0.003730	-0.000176	0.000286	-0.001760	0.000405	0.001806
2	Industrial Processes	SF6	1239	690	1	20	20.025	0.023260	-0.000345	0.000896	-0.006892	0.001266	0.007007
		Halocarbon & SF6 Total	17,028.77	15,224.53									
	TOTALS	GWP	770,471.37	594,021.50									
	Total Uncertainties%							19.1					2.20

A8 ANNEX 8: IPCC Sectoral Tables of GHG Emissions

The tables in this Annex present summary data for UK greenhouse gas emissions for the years 1990-2010, inclusive. The data are given in IPCC reporting format. These data are updated annually to reflect revisions in the methodology and the availability of new information. These adjustments are applied retrospectively to earlier years, which accounts for any differences in data published in previous reports, to ensure a consistent time series.

These tables are taken directly from the CRF.

A8.1 SUMMARY TABLES

Tables A 8.1.1 to **A 8.1.21** present UK GHG emissions as summary reports for national greenhouse gas inventories (IPCC Table 7A).

Table A 8.1.1 Summary Report For National Greenhouse Gas Inventories (IPCC TABLE 7A) – 1990

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 emissions/removals	CH_4	N_2O	HFCs[1]		PFCs[1]		SF_6		NO_x	CO	NMVOC	SO_2
				P	A	P	A	P	A				
	(Gg)			CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals	**591,781.12**	**4,650.68**	**219.00**	**11.88**	**11,385.62**	**73.47**	**1,401.60**	**0.10**	**0.04**	**2,895.81**	**9,118.15**	**2,766.03**	**3,722.67**
1. Energy	**572,001.76**	**1,491.70**	**20.25**							**2,867.44**	**8,547.83**	**1,713.94**	**3,660.41**
A. Fuel Combustion — Reference Approach [2]	560,456.40												
Sectoral Approach [2]	565,367.50	129.58	20.10							2,853.52	8,487.99	1,149.56	3,631.95
1. Energy Industries	236,521.10	10.34	6.67							866.23	136.24	8.74	2,890.56
2. Manufacturing Industries and Construction	101,302.70	15.58	5.62							411.09	740.79	30.05	443.32
3. Transport	114,252.58	30.62	4.53							1,325.40	6,443.95	1,018.78	90.93
4. Other Sectors	108,006.30	72.89	3.13							211.85	1,153.65	89.77	200.97
5. Other	5,284.82	0.15	0.16							38.96	13.37	2.21	6.17
B. Fugitive Emissions from Fuels	6,634.26	1,362.13	0.14							13.92	59.84	564.38	28.46
1. Solid Fuels	856.42	870.56	0.01							0.58	38.35	0.34	20.68
2. Oil and Natural Gas	5,777.84	491.57	0.14							13.34	21.49	564.04	7.78
2. Industrial Processes	**15,469.73**	**9.97**	**79.52**	**11.88**	**11,385.62**	**73.47**	**1,401.60**	**0.10**	**0.04**	**13.33**	**281.56**	**265.34**	**54.80**
A. Mineral Products	10,166.37	1.12	NE							NE,NO	5.31	13.08	4.27
B. Chemical Industry	2,994.08	8.07	79.49	NO	NO	NO	NO	NO	NO	8.49	82.06	172.96	41.60
C. Metal Production	2,309.27	0.78	0.04				1,332.75		0.02	4.85	194.20	2.05	8.94
D. Other Production [3]	NE									NE	NE	77.25	NE
E. Production of Halocarbons and SF_6					11,373.73		10.90		NA,NO				
F. Consumption of Halocarbons and SF_6				11.88	11.89	73.47	57.95	0.10	0.03				
G. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NE**		**NE,NO**						**0.00**	**NO**	**NO**	**670.25**	**NO**
4. Agriculture		**1,073.61**	**112.76**							**9.07**	**266.04**	**26.06**	**NO**
A. Enteric Fermentation		890.22											
B. Manure Management		170.74	6.32									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils [4]		NE	105.89									NO	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		12.64	0.25							9.07	266.04	26.06	
G. Other		NA	0.30							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**3,082.13**	**0.87**	**2.56**							**0.22**	**7.63**	**NA,NO**	**NA**
A. Forest Land	-12,192.20	0.20	0.02							0.05	1.79		
B. Cropland	15,736.25	0.01	2.52							0.00	0.06		
C. Grassland	-6,272.17	0.19	0.00							0.05	1.63		
D. Wetlands	481.73	NE,NO	0.01							NO	NO		
E. Settlements	7,039.21	0.47	0.00							0.12	4.15		
F. Other Land	NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-1,710.68	NE	NE							NE	NE	NA	NA
6. Waste	**1,227.50**	**2,074.53**	**3.91**							**5.75**	**15.08**	**90.44**	**7.46**
A. Solid Waste Disposal on Land	NA,NE,NO	2,054.45								NA,NE	NA,NE	85.96	
B. Waste-water Handling		13.68	3.76							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	1,227.50	6.40	0.15							5.75	15.08	4.48	7.46
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)*** [7]	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items: [8]													
International Bunkers	**24,550.33**	**0.44**	**0.72**							**270.11**	**33.72**	**12.02**	**102.02**
Aviation	15,674.67	0.30	0.50							75.25	13.10	5.54	3.00
Marine	8,875.66	0.14	0.22							194.86	20.62	6.47	99.02
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**526.03**												

Table A 8.1.2 Summary Report For National Greenhouse Gas Inventories (IPCC TABLE 7A) – 1991

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 emissions/removals	CH_4	N_2O	HFCs[1]		PFCs[1]		SF_6		NO_x	CO	NMVOC	SO_2
				P	A	P	A	P	A				
	(Gg)			CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals	**598,959.45**	**4,611.05**	**219.52**	**106.85**	**11,862.01**	**82.77**	**1,170.87**	**0.10**	**0.05**	**2,786.80**	**9,322.84**	**2,706.93**	**3,561.69**
1. Energy	**581,324.86**	**1,508.86**	**20.15**							**2,761.24**	**8,799.48**	**1,707.75**	**3,501.30**
A. Fuel Combustion — Reference Approach [2]	577,113.68												
Sectoral Approach [2]	575,091.99	132.32	20.01							2,747.64	8,716.88	1,153.60	3,476.11
1. Energy Industries	234,346.17	10.31	6.66							767.98	135.01	8.60	2,693.93
2. Manufacturing Industries and Construction	103,583.55	15.41	5.50							405.76	694.10	28.47	484.12
3. Transport	113,462.26	30.26	4.52							1,314.75	6,609.98	1,022.11	84.26
4. Other Sectors	119,407.60	76.22	3.21							221.82	1,267.03	92.55	207.57
5. Other	4,292.42	0.12	0.13							37.32	10.77	1.88	6.23
B. Fugitive Emissions from Fuels	6,232.88	1,376.54	0.14							13.60	82.60	554.15	25.18
1. Solid Fuels	519.42	895.05	0.00							0.41	35.63	0.31	17.49
2. Oil and Natural Gas	5,713.46	481.49	0.14							13.19	46.97	553.84	7.69
2. Industrial Processes	**13,358.70**	**9.48**	**80.02**	**106.85**	**11,862.01**	**82.77**	**1,170.87**	**0.10**	**0.05**	**11.84**	**271.90**	**254.51**	**53.06**
A. Mineral Products	8,644.97	0.91	NE							NE,NO	4.30	12.62	3.46
B. Chemical Industry	3,030.02	8.03	79.99	NO	NO	NO	NO	NO	NO	7.68	80.20	162.82	40.97
C. Metal Production	1,683.72	0.53	0.03				1,095.57		0.02	4.16	187.39	1.92	8.63
D. Other Production [3]	NE									NE	NE	77.14	NE
E. Production of Halocarbons and SF_6					11,841.76		10.91		NA,NO				
F. Consumption of Halocarbons and SF_6				106.85	20.25	82.77	64.39	0.10	0.03				
G. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NE**	**0.00**	**NE,NO**						**0.00**	**NO**	**NO**	**633.44**	**NO**
4. Agriculture		**1,059.20**	**112.91**							**7.76**	**227.78**	**22.52**	**NO**
A. Enteric Fermentation		877.74											
B. Manure Management		170.92	6.51									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils [4]		NE	105.89									NO	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		10.54	0.21							7.76	227.78	22.52	
G. Other		NA	0.30							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**3,054.44**	**0.98**	**2.56**							**0.24**	**8.59**	**NA,NO**	**NA**
A. Forest Land	-12,663.68	0.35	0.02							0.09	3.02		
B. Cropland	15,938.79	0.01	2.52							0.00	0.06		
C. Grassland	-6,234.06	0.19	0.00							0.05	1.63		
D. Wetlands	489.31	NE,NO	0.01							NO	NO		
E. Settlements	6,970.70	0.44	0.00							0.11	3.88		
F. Other Land	NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-1,446.62	NE	NE							NE	NE	NA	NA
6. Waste	**1,221.44**	**2,032.54**	**3.88**							**5.72**	**15.09**	**88.71**	**7.33**
A. Solid Waste Disposal on Land	NA,NE,NO	2,012.53								NA,NE	NA,NE	84.21	
B. Waste-water Handling		13.67	3.73							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	1,221.44	6.35	0.15							5.72	15.09	4.50	7.33
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)*** [7]	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items: [8]													
International Bunkers	**24,291.90**	**0.39**	**0.71**							**267.00**	**32.91**	**11.19**	**94.89**
Aviation	15,427.15	0.25	0.49							73.15	12.32	4.78	3.93
Marine	8,864.75	0.14	0.22							193.86	20.59	6.41	90.96
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**569.17**												

Table A 8.1.3 Summary Report For National Greenhouse Gas Inventories (IPCC TABLE 7A) – 1992

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 emissions/removals	CH_4	N_2O	HFCs (1)		PFCs (1)		SF_6		NO_x	CO	NMVOC	SO_2
				P	A	P	A	P	A				
	(Gg)			CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals	**582,043.11**	**4,525.75**	**204.00**	**299.07**	**12,346.95**	**93.79**	**573.36**	**0.10**	**0.05**	**2,720.66**	**8,905.31**	**2,629.46**	**3,481.53**
1. Energy	**565,657.52**	**1,489.07**	**19.80**							**2,698.36**	**8,456.59**	**1,672.98**	**3,424.68**
A. Fuel Combustion — Reference Approach (2)	566,053.60												
Sectoral Approach (2)	559,070.27	124.45	19.65							2,684.85	8,401.95	1,114.60	3,400.73
1. Energy Industries	223,259.96	10.30	6.38							755.05	132.67	8.24	2,582.45
2. Manufacturing Industries and Construction	100,457.17	14.71	5.53							396.90	704.21	28.19	522.95
3. Transport	114,851.53	29.12	4.54							1,283.10	6,415.83	988.67	86.52
4. Other Sectors	116,414.82	70.22	3.08							214.99	1,138.97	87.72	203.00
5. Other	4,086.79	0.11	0.12							34.81	10.26	1.78	5.82
B. Fugitive Emissions from Fuels	6,587.25	1,364.61	0.15							13.51	54.65	558.39	23.95
1. Solid Fuels	450.00	887.57	0.00							0.35	32.44	0.28	16.04
2. Oil and Natural Gas	6,137.25	477.04	0.15							13.16	22.20	558.11	7.91
2. Industrial Processes	**12,669.53**	**9.92**	**65.07**	**299.07**	**12,346.95**	**93.79**	**573.36**	**0.10**	**0.05**	**10.97**	**262.36**	**252.92**	**49.65**
A. Mineral Products	8,131.19	0.82	NE							NE,NO	3.85	12.54	3.10
B. Chemical Industry	3,087.88	8.64	65.04	NO	NO	NO	NO	NO	NO	6.87	79.50	161.21	38.40
C. Metal Production	1,450.46	0.46	0.03				490.38		0.02	4.10	179.00	1.89	8.15
D. Other Production (3)	NE									NE	NE	77.28	NE
E. Production of Halocarbons and SF_6					12,310.08		10.96		NA,NO				
F. Consumption of Halocarbons and SF_6				299.07	36.87	93.79	72.02	0.10	0.03				
G. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NE**		**NE,NO**						**0.00**	**NO**	**NO**	**600.70**	**NO**
4. Agriculture		**1,055.65**	**112.57**							**5.63**	**165.25**	**16.72**	**NO**
A. Enteric Fermentation		877.47											
B. Manure Management		170.43	6.51									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils (4)		NE	105.60									NO	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		7.75	0.15							5.63	165.25	16.72	
G. Other		NA	0.30							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**2,535.82**	**0.69**	**2.56**							**0.17**	**6.06**	**NA,NO**	**NA**
A. Forest Land	-13,342.56	0.09	0.02							0.02	0.77		
B. Cropland	16,020.59	0.01	2.52							0.00	0.06		
C. Grassland	-6,383.56	0.19	0.00							0.05	1.63		
D. Wetlands	483.23	NE,NO	0.01							NO	NO		
E. Settlements	6,894.18	0.41	0.00							0.10	3.61		
F. Other Land	NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-1,136.06	NE	NE							NE	NE	NA	NA
6. Waste	**1,180.24**	**1,970.42**	**4.01**							**5.52**	**15.05**	**86.14**	**7.20**
A. Solid Waste Disposal on Land	NA,NE,NO	1,950.80								NA,NE	NA,NE	81.63	
B. Waste-water Handling		13.53	3.86							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	1,180.24	6.09	0.15							5.52	15.05	4.51	7.20
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)*** **(7)**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items: (8)													
International Bunkers	**26,069.93**	**0.38**	**0.77**							**277.83**	**34.17**	**11.26**	**94.09**
Aviation	17,040.75	0.24	0.54							79.88	13.18	4.72	5.42
Marine	9,029.18	0.14	0.23							197.95	21.00	6.54	88.66
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**647.41**												

Table A 8.1.4 Summary Report For National Greenhouse Gas Inventories (IPCC TABLE 7A) – 1993

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 emissions/removals	CH_4	N_2O	HFCs [1]		PFCs [1]		SF_6		NO_x	CO	NMVOC	SO_2
				P	A	P	A	P	A				
	(Gg)			CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals	**566,966.47**	**4,378.49**	**188.82**	**1,258.74**	**13,020.44**	**106.82**	**489.60**	**0.10**	**0.05**	**2,551.42**	**8,562.94**	**2,505.33**	**3,140.41**
1. Energy	**551,785.11**	**1,411.42**	**19.17**							**2,535.80**	**8,269.75**	**1,590.02**	**3,087.49**
A. Fuel Combustion — Reference Approach [2]	548,559.39												
Sectoral Approach [2]	544,880.06	122.05	19.01							2,522.27	8,216.23	1,052.37	3,063.93
1. Energy Industries	207,109.96	10.44	5.64							665.86	123.50	8.18	2,257.67
2. Manufacturing Industries and Construction	97,630.29	14.68	5.30							389.73	701.61	28.51	496.44
3. Transport	116,041.62	27.40	4.80							1,219.42	6,128.14	926.90	82.97
4. Other Sectors	119,957.26	69.42	3.14							214.94	1,252.54	87.01	221.96
5. Other	4,140.93	0.12	0.12							32.31	10.44	1.76	4.89
B. Fugitive Emissions from Fuels	6,905.05	1,289.37	0.16							13.53	53.52	537.65	23.56
1. Solid Fuels	344.83	826.27	0.00							0.39	30.37	0.27	15.43
2. Oil and Natural Gas	6,560.22	463.09	0.16							13.14	23.15	537.38	8.13
2. Industrial Processes	**12,665.43**	**8.71**	**52.44**	**1,258.74**	**13,020.44**	**106.82**	**489.60**	**0.10**	**0.05**	**10.26**	**268.09**	**247.18**	**47.45**
A. Mineral Products	8,169.47	0.69	NE							NE,NO	3.24	12.09	2.61
B. Chemical Industry	3,130.99	7.59	52.42	NO	NO	NO	NO	NO	NO	6.06	81.69	155.47	36.65
C. Metal Production	1,364.97	0.44	0.03				381.33		0.02	4.20	183.16	1.89	8.19
D. Other Production [3]	NE									NE	NE	77.72	NE
E. Production of Halocarbons and SF_6					12,779.93		27.23		NA,NO				
F. Consumption of Halocarbons and SF_6				1,258.74	240.51	106.82	81.04	0.10	0.03				
G. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NE**		**NE,NO**						**0.00**	**NO**	**NO**	**584.04**	**NO**
4. Agriculture		**1,049.60**	**110.67**							**0.12**	**3.53**	**0.47**	**NO**
A. Enteric Fermentation		876.20											
B. Manure Management		173.34	6.53									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils [4]		NE	103.84									NO	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		0.06	0.00							0.12	3.53	0.47	
G. Other		NA	0.30							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**1,419.07**	**0.75**	**2.55**							**0.19**	**6.53**	**NA,NO**	**NA**
A. Forest Land	-13,695.49	0.15	0.01							0.04	1.35		
B. Cropland	15,581.74	0.01	2.53							0.00	0.06		
C. Grassland	-6,748.46	0.19	0.00							0.05	1.63		
D. Wetlands	476.50	NE,NO	0.01							NO	NO		
E. Settlements	6,850.86	0.40	0.00							0.10	3.50		
F. Other Land	NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-1,046.07	NE	NE							NE	NE	NA	NA
6. Waste	**1,096.86**	**1,908.01**	**3.98**							**5.06**	**15.04**	**83.63**	**5.47**
A. Solid Waste Disposal on Land	NA,NE,NO	1,889.09								NA,NE	NA,NE	79.08	
B. Waste-water Handling		13.51	3.83							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	1,096.86	5.41	0.15							5.06	15.04	4.55	5.47
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)*** [7]	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items: [8]													
International Bunkers	**27,136.71**	**0.37**	**0.80**							**281.84**	**34.77**	**11.34**	**93.15**
Aviation	18,224.79	0.23	0.58							85.33	14.05	4.82	4.64
Marine	8,911.92	0.14	0.22							196.51	20.73	6.52	88.51
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**688.73**												

Table A 8.1.5 Summary Report For National Greenhouse Gas Inventories (IPCC TABLE 7A) – 1994

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 emissions/removals	CH_4	N_2O	HFCs[1]		PFCs[1]		SF_6		NO_x	CO	NMVOC	SO_2
				P	A	P	A	P	A				
	(Gg)			CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals	**561,193.66**	**4,035.32**	**190.09**	**3,829.36**	**13,937.57**	**122.25**	**485.90**	**0.09**	**0.05**	**2,442.24**	**8,098.49**	**2,415.85**	**2,679.12**
1. Energy	**545,072.76**	**1,115.08**	**19.57**							**2,428.35**	**7,803.42**	**1,514.60**	**2,624.19**
A. Fuel Combustion — Reference Approach [2]	542,699.44												
Sectoral Approach [2]	537,949.61	107.94	19.41							2,414.81	7,748.57	972.84	2,601.53
1. Energy Industries	205,107.28	11.71	5.61							621.58	134.92	9.15	1,904.65
2. Manufacturing Industries and Construction	97,108.27	15.38	5.35							398.98	751.05	30.21	407.98
3. Transport	116,543.76	25.47	5.34							1,157.55	5,738.69	856.78	87.96
4. Other Sectors	115,230.49	55.27	2.99							206.45	1,113.91	75.03	196.26
5. Other	3,959.80	0.11	0.12							30.27	10.00	1.67	4.68
B. Fugitive Emissions from Fuels	7,123.15	1,007.14	0.17							13.54	54.85	541.75	22.66
1. Solid Fuels	163.25	548.08	0.00							0.44	30.84	0.27	14.31
2. Oil and Natural Gas	6,959.90	459.06	0.16							13.10	24.01	541.49	8.35
2. Industrial Processes	**13,931.74**	**10.28**	**53.05**	**3,829.36**	**13,937.57**	**122.25**	**485.90**	**0.09**	**0.05**	**9.58**	**274.41**	**240.47**	**50.51**
A. Mineral Products	9,123.70	0.77	NE							NE,NO	3.65	12.61	5.45
B. Chemical Industry	3,168.69	8.95	53.02	NO	NO	NO	NO	NO	NO	5.26	86.33	147.15	36.96
C. Metal Production	1,639.35	0.56	0.03				345.16		0.02	4.32	184.43	1.95	8.09
D. Other Production [3]	NE									NE	NE	78.75	NE
E. Production of Halocarbons and SF_6					13,264.93		49.01		NA,NO				
F. Consumption of Halocarbons and SF_6				3,829.36	672.64	122.25	91.73	0.09	0.03				
G. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NE**		**NE,NO**						**0.00**	**NO**	**NO**	**579.26**	**NO**
4. Agriculture		**1,051.93**	**110.94**							**NA,NO**	**NA,NO**	**NA,NO**	**NO**
A. Enteric Fermentation		882.11											
B. Manure Management		169.81	6.58									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils [4]		NE	104.06									NO	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other		NA	0.30							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**1,246.68**	**0.72**	**2.55**							**0.18**	**6.28**	**NA,NO**	**NA**
A. Forest Land	-14,174.52	0.12	0.01							0.03	1.07		
B. Cropland	15,668.06	0.01	2.53							0.00	0.06		
C. Grassland	-6,817.73	0.19	0.00							0.05	1.63		
D. Wetlands	594.63	NE,NO	0.01							NO	NO		
E. Settlements	6,807.47	0.40	0.00							0.10	3.53		
F. Other Land	NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-831.24	NE	NE							NE	NE	NA	NA
6. Waste	**942.48**	**1,857.33**	**3.97**							**4.13**	**14.38**	**81.53**	**4.43**
A. Solid Waste Disposal on Land	NA,NE,NO	1,839.75								NA,NE	NA,NE	77.02	
B. Waste-water Handling		13.59	3.85							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	942.48	3.98	0.12							4.13	14.38	4.51	4.43
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)*** [7]	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items: [8]													
International Bunkers	**27,063.19**	**0.33**	**0.81**							**265.89**	**32.64**	**10.52**	**81.04**
Aviation	18,994.27	0.21	0.60							89.03	13.88	4.69	6.04
Marine	8,068.92	0.13	0.20							176.85	18.76	5.83	75.00
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**1,018.45**												

Table A 8.1.6 Summary Report For National Greenhouse Gas Inventories (IPCC TABLE 7A) – 1995

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		Net CO_2 emissions/removals	CH_4	N_2O	HFCs (1)		PFCs (1)		SF_6		NO_x	CO	NMVOC	SO_2
					P	A	P	A	P	A				
		(Gg)			CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals		**553,470.81**	**4,008.01**	**185.30**	**6,927.69**	**15,327.65**	**140.50**	**461.81**	**0.10**	**0.05**	**2,324.34**	**7,587.01**	**2,230.54**	**2,371.25**
1. Energy		**536,563.44**	**1,156.85**	**20.02**							**2,313.20**	**7,277.33**	**1,364.05**	**2,309.34**
A. Fuel Combustion	Reference Approach (2)	540,328.88												
	Sectoral Approach (2)	527,907.99	93.73	19.82							2,298.85	7,222.27	901.69	2,291.94
1. Energy Industries		203,388.44	12.13	5.56							589.28	134.70	9.54	1,730.88
2. Manufacturing Industries and Construction		93,757.37	15.66	5.22							383.03	757.57	30.68	324.01
3. Transport		115,719.31	23.56	6.15							1,099.30	5,449.18	796.03	76.32
4. Other Sectors		111,156.70	42.27	2.77							196.83	871.01	63.80	156.31
5. Other		3,886.18	0.11	0.12							30.41	9.80	1.65	4.40
B. Fugitive Emissions from Fuels		8,655.45	1,063.12	0.20							14.35	55.06	462.37	17.40
1. Solid Fuels		225.84	600.03	0.00							0.47	30.89	0.26	10.79
2. Oil and Natural Gas		8,429.61	463.09	0.20							13.88	24.17	462.10	6.61
2. Industrial Processes		**14,358.89**	**8.31**	**47.99**	**6,927.69**	**15,327.65**	**140.50**	**461.81**	**0.10**	**0.05**	**6.94**	**282.32**	**248.08**	**57.56**
A. Mineral Products		9,245.87	0.77	NE							NE,NO	3.64	11.93	9.67
B. Chemical Industry		3,174.78	6.84	47.95	NO	NO	NO	NO	NO	NO	2.40	88.52	155.42	39.80
C. Metal Production		1,938.24	0.70	0.03				286.29		0.02	4.54	190.16	2.02	8.09
D. Other Production (3)		NE									NE	NE	78.72	NE
E. Production of Halocarbons and SF_6						13,980.68		70.79		NA,NO				
F. Consumption of Halocarbons and SF_6					6,927.69	1,346.98	140.50	104.74	0.10	0.03				
G. Other		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use		**NE**	**0.00**	**NE,NO**						**0.00**	**NO**	**NO**	**539.02**	**NO**
4. Agriculture			**1,035.02**	**110.73**							**NA,NO**	**NA,NO**	**NA,NO**	**NO**
A. Enteric Fermentation			873.79											
B. Manure Management			161.23	6.72									NO	
C. Rice Cultivation			NA,NO										NA,NO	
D. Agricultural Soils (4)			NE	103.71									NO	
E. Prescribed Burning of Savannas			NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues			NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other			NA	0.31							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry		**1,640.15**	**1.52**	**2.56**							**0.38**	**13.30**	**NA,NO**	**NA**
A. Forest Land		-13,732.72	0.96	0.02							0.24	8.41		
B. Cropland		15,839.29	0.01	2.53							0.00	0.06		
C. Grassland		-6,812.81	0.19	0.00							0.05	1.63		
D. Wetlands		681.10	NE,NO	0.01							NO	NO		
E. Settlements		6,742.87	0.37	0.00							0.09	3.20		
F. Other Land		NE,NO	NE,NO	NE,NO							NO	NO		
G. Other		-1,077.58	NE	NE							NE	NE	NA	NA
6. Waste		**908.33**	**1,806.31**	**4.00**							**3.82**	**14.07**	**79.38**	**4.36**
A. Solid Waste Disposal on Land		NA,NE,NO	1,788.65								NA,NE	NA,NE	74.89	
B. Waste-water Handling			13.84	3.88							NA,NE	NA,NE	NA,NE	
C. Waste Incineration		908.33	3.81	0.12							3.82	14.07	4.50	4.36
D. Other		NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)*** (7)		**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items: (8)														
International Bunkers		**28,508.36**	**0.33**	**0.85**							**279.81**	**33.63**	**11.03**	**91.29**
Aviation		20,192.48	0.20	0.64							94.58	14.29	4.83	5.14
Marine		8,315.89	0.13	0.21							185.24	19.34	6.20	86.15
Multilateral Operations		**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass		**1,107.12**												

Table A 8.1.7 Summary Report For National Greenhouse Gas Inventories (IPCC TABLE 7A) – 1996

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 emissions/removals	CH_4	N_2O	HFCs[1]		PFCs[1]		SF_6		NO_x	CO	NMVOC	SO_2
				P	A	P	A	P	A				
	(Gg)			CO_2 equivalent (Gg)					(Gg)				
Total National Emissions and Removals	**575,182.41**	**3,909.62**	**185.09**	**10,683.20**	**16,563.90**	**162.12**	**479.65**	**0.06**	**0.05**	**2,218.46**	**7,633.73**	**2,149.53**	**2,026.73**
1. Energy	**557,979.72**	**1,102.60**	**19.24**							**2,207.50**	**7,327.52**	**1,302.85**	**1,967.21**
A. Fuel Combustion — Reference Approach[2]	551,566.44												
Sectoral Approach[2]	548,700.08	96.37	19.04							2,196.10	7,273.49	867.18	1,948.60
1. Energy Industries	205,410.83	12.66	5.36							546.06	135.30	10.18	1,459.83
2. Manufacturing Industries and Construction	94,800.68	16.16	5.10							356.34	776.87	30.86	260.27
3. Transport	120,244.93	21.96	5.62							1,056.66	5,459.84	758.66	62.89
4. Other Sectors	124,438.65	45.49	2.84							206.64	891.89	65.85	161.24
5. Other	3,804.99	0.11	0.11							30.41	9.59	1.62	4.37
B. Fugitive Emissions from Fuels	9,279.65	1,006.23	0.20							11.40	54.03	435.68	18.61
1. Solid Fuels	366.77	556.28	0.00							0.45	30.87	0.26	11.49
2. Oil and Natural Gas	8,912.88	449.95	0.20							10.95	23.16	435.41	7.12
2. Industrial Processes	**14,913.35**	**9.51**	**47.69**	**10,683.20**	**16,563.90**	**162.12**	**479.65**	**0.06**	**0.05**	**6.67**	**282.02**	**241.76**	**56.63**
A. Mineral Products	9,504.60	0.72	NE							NE,NO	3.40	10.69	10.16
B. Chemical Industry	3,183.31	8.00	47.65	NO	NO	NO	NO	NO	NO	2.25	85.58	148.05	38.16
C. Metal Production	2,225.44	0.79	0.03				282.17		0.02	4.42	193.03	2.07	8.30
D. Other Production[3]	NE									NE	NE	80.95	NE
E. Production of Halocarbons and SF_6					14,320.56		77.13		NA,NO				
F. Consumption of Halocarbons and SF_6				10,683.20	2,243.34	162.12	120.35	0.06	0.04				
G. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NE**	**0.00**	**NE,NO**						**0.00**	**NO**	**NO**	**527.73**	**NO**
4. Agriculture		**1,042.15**	**111.46**							**NA,NO**	**NA,NO**	**NA,NO**	**NO**
A. Enteric Fermentation		884.00											
B. Manure Management		158.15	6.92									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils[4]		NE	104.24									NO	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other		NA	0.30							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**1,366.02**	**1.09**	**2.56**							**0.27**	**9.54**	**NA,NO**	**NA**
A. Forest Land	-13,601.29	0.50	0.01							0.12	4.38		
B. Cropland	15,905.04	0.01	2.53							0.00	0.06		
C. Grassland	-7,040.48	0.19	0.00							0.05	1.63		
D. Wetlands	587.27	NE,NO	0.01							NO	NO		
E. Settlements	6,722.47	0.40	0.00							0.10	3.48		
F. Other Land	NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-1,206.98	NE	NE							NE	NE	NA	NA
6. Waste	**923.31**	**1,754.28**	**4.14**							**4.02**	**14.66**	**77.19**	**2.89**
A. Solid Waste Disposal on Land	NA,NE,NO	1,736.37								NA,NE	NA,NE	72.69	
B. Waste-water Handling		13.75	4.00							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	923.31	4.15	0.13							4.02	14.66	4.50	2.89
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other *(please specify)*[7]	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items:[8]													
International Bunkers	**30,629.63**	**0.35**	**0.91**							**305.86**	**36.44**	**11.87**	**96.86**
Aviation	21,366.64	0.20	0.68							100.44	14.89	5.02	5.44
Marine	9,262.99	0.15	0.23							205.42	21.54	6.84	91.42
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**1,172.33**												

Table A 8.1.8 Summary Report For National Greenhouse Gas Inventories (IPCC TABLE 7A) – 1997

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 emissions/removals	CH_4	N_2O	HFCs (1)		PFCs (1)		SF_6		NO_x	CO	NMVOC	SO_2
				P	A	P	A	P	A				
	(Gg)			CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals	**550,985.17**	**3,693.52**	**186.39**	**15,342.59**	**18,991.10**	**187.70**	**397.58**	**0.05**	**0.05**	**2,046.37**	**7,122.78**	**2,058.94**	**1,665.10**
1. Energy	**534,592.68**	**1,049.25**	**18.52**							**2,037.18**	**6,808.15**	**1,249.97**	**1,604.24**
A. Fuel Combustion — Reference Approach (2)	526,891.33												
Sectoral Approach (2)	527,141.51	91.47	18.34							2,032.40	6,758.93	792.97	1,585.40
1. Energy Industries	192,866.91	12.48	4.90							466.20	75.55	8.14	1,158.00
2. Manufacturing Industries and Construction	93,582.78	16.73	4.96							346.26	765.66	31.04	224.56
3. Transport	121,749.10	20.15	5.59							995.22	5,085.91	689.08	52.52
4. Other Sectors	115,312.00	42.01	2.79							193.49	822.70	63.14	145.68
5. Other	3,630.71	0.10	0.11							31.24	9.11	1.58	4.65
B. Fugitive Emissions from Fuels	7,451.17	957.77	0.18							4.78	49.22	457.00	18.84
1. Solid Fuels	459.63	532.92	0.00							0.38	30.87	0.26	11.40
2. Oil and Natural Gas	6,991.54	424.86	0.18							4.40	18.36	456.74	7.44
2. Industrial Processes	**14,756.32**	**8.02**	**48.29**	**15,342.59**	**18,991.10**	**187.70**	**397.58**	**0.05**	**0.05**	**7.17**	**289.36**	**223.75**	**59.71**
A. Mineral Products	10,072.53	0.71	NE							NE,NO	3.35	10.13	13.41
B. Chemical Industry	2,721.88	6.62	48.26	NO	NO	NO	NO	NO	NO	2.60	86.64	132.12	35.62
C. Metal Production	1,961.90	0.69	0.03				220.26		0.02	4.57	199.37	2.12	10.68
D. Other Production (3)	NE									NE	NE	79.38	NE
E. Production of Halocarbons and SF_6					15,622.21		38.32		NA,NO				
F. Consumption of Halocarbons and SF_6				15,342.59	3,368.89	187.70	139.00	0.05	0.03				
G. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NE**	**0.00**	**NE,NO**						**0.00**	**NO**	**NO**	**513.25**	**NO**
4. Agriculture		**1,007.40**	**113.05**							**NA,NO**	**NA,NO**	**NA,NO**	**NO**
A. Enteric Fermentation		854.33											
B. Manure Management		153.06	7.17									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils (4)		NE	105.57									NO	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other		NA	0.31							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**1,098.74**	**1.34**	**2.56**							**0.33**	**11.71**	**NA,NO**	**NA**
A. Forest Land	-13,352.09	0.66	0.01							0.16	5.75		
B. Cropland	15,669.08	0.01	2.53							0.00	0.06		
C. Grassland	-7,040.89	0.24	0.00							0.06	2.09		
D. Wetlands	524.91	NE,NO	0.01							NO	NO		
E. Settlements	6,708.79	0.44	0.00							0.11	3.82		
F. Other Land	NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-1,411.07	NE	NE							NE	NE	NA	NA
6. Waste	**537.43**	**1,627.52**	**3.97**							**1.69**	**13.56**	**71.96**	**1.15**
A. Solid Waste Disposal on Land	NA,NE,NO	1,612.83								NA,NE	NA,NE	67.50	
B. Waste-water Handling		14.37	3.90							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	537.43	0.33	0.07							1.69	13.56	4.46	1.15
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)*** **(7)**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items: (8)													
International Bunkers	**32,759.55**	**0.36**	**0.97**							**331.73**	**38.77**	**12.82**	**114.21**
Aviation	22,710.33	0.20	0.72							106.64	15.45	5.25	7.22
Marine	10,049.22	0.16	0.25							225.10	23.33	7.58	106.99
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**1,249.57**												

Table A 8.1.9 Summary Report For National Greenhouse Gas Inventories (IPCC TABLE 7A) – 1998

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 emissions/removals	CH_4	N_2O	HFCs [1]		PFCs [1]		SF_6		NO_x	CO	NMVOC	SO_2
				P	A	P	A	P	A				
	(Gg)			CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals	**554,201.15**	**3,497.94**	**185.85**	**20,847.75**	**16,894.46**	**193.40**	**387.25**	**0.05**	**0.05**	**1,984.38**	**6,816.51**	**1,910.64**	**1,646.46**
1. Energy	**538,198.62**	**961.55**	**18.58**							**1,976.27**	**6,527.25**	**1,147.86**	**1,586.15**
A. Fuel Combustion – Reference Approach [2]	535,177.05												
Sectoral Approach [2]	531,118.95	91.97	18.40							1,972.04	6,478.82	734.45	1,575.34
1. Energy Industries	197,672.45	13.78	5.15							469.50	93.55	6.20	1,202.72
2. Manufacturing Industries and Construction	92,084.64	16.19	4.84							346.60	731.86	31.02	200.53
3. Transport	121,436.25	18.48	5.62							944.43	4,872.10	632.22	47.98
4. Other Sectors	116,731.61	43.42	2.69							187.72	773.24	63.66	120.75
5. Other	3,194.00	0.09	0.10							23.79	8.07	1.34	3.36
B. Fugitive Emissions from Fuels	7,079.67	869.58	0.18							4.22	48.42	413.42	10.82
1. Solid Fuels	158.41	454.04	0.00							0.38	30.75	0.26	9.45
2. Oil and Natural Gas	6,921.26	415.54	0.18							3.84	17.68	413.16	1.37
2. Industrial Processes	**15,032.72**	**6.14**	**49.19**	**20,847.75**	**16,894.46**	**193.40**	**387.25**	**0.05**	**0.05**	**6.15**	**265.65**	**198.31**	**59.05**
A. Mineral Products	10,287.49	0.71	NE							NE,NO	3.35	9.93	13.08
B. Chemical Industry	2,958.40	4.80	49.16	NO	NO	NO	NO	NO	NO	2.49	69.05	107.07	36.53
C. Metal Production	1,786.83	0.63	0.03				208.07		0.02	3.66	193.25	2.02	9.44
D. Other Production [3]	NE									NE	NE	79.28	NE
E. Production of Halocarbons and SF_6					12,117.13		42.50		NA,NO				
F. Consumption of Halocarbons and SF_6				20,847.75	4,777.33	193.40	136.68	0.05	0.03				
G. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NE**		**NE,NO**						**0.00**	**NO**	**NO**	**496.61**	**NO**
4. Agriculture		**1,001.22**	**111.41**							**NA,NO**	**NA,NO**	**NA,NO**	**NO**
A. Enteric Fermentation		854.67											
B. Manure Management		146.56	7.10									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils [4]		NE	104.01									NO	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other		NA	0.30							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**427.73**	**0.96**	**2.56**							**0.24**	**8.40**	**NA,NO**	**NA**
A. Forest Land	-13,308.97	0.36	0.01							0.09	3.19		
B. Cropland	15,566.93	0.01	2.53							0.00	0.06		
C. Grassland	-7,425.33	0.16	0.00							0.04	1.38		
D. Wetlands	404.95	NE,NO	0.01							NO	NO		
E. Settlements	6,670.21	0.43	0.00							0.11	3.78		
F. Other Land	NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-1,480.06	NE	NE							NE	NE	NA	NA
6. Waste	**542.08**	**1,528.06**	**4.11**							**1.72**	**15.21**	**67.86**	**1.26**
A. Solid Waste Disposal on Land	NA,NE,NO	1,513.42								NA,NE	NA,NE	63.32	
B. Waste-water Handling		14.27	3.95							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	542.08	0.37	0.16							1.72	15.21	4.54	1.26
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other *(please specify)* [7]	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items: [8]													
International Bunkers	**35,786.04**	**0.37**	**1.07**							**350.83**	**41.24**	**13.36**	**107.49**
Aviation	25,262.58	0.20	0.80							118.10	16.85	5.63	8.03
Marine	10,523.45	0.16	0.26							232.72	24.39	7.73	99.46
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**1,266.22**												

Table A 8.1.10 Summary Report For National Greenhouse Gas Inventories (IPCC TABLE 7A) – 1999

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		Net CO_2 emissions/removals	CH_4	N_2O	HFCs [1]		PFCs [1]		SF_6		NO_x	CO	NMVOC	SO_2
					P	A	P	A	P	A				
		(Gg)			CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals		**544,851.62**	**3,270.16**	**151.39**	**26,426.98**	**10,248.26**	**224.58**	**366.38**	**0.05**	**0.06**	**1,866.98**	**6,449.58**	**1,728.21**	**1,259.77**
1. Energy		**529,230.04**	**865.03**	**17.99**							**1,858.80**	**6,142.08**	**1,032.56**	**1,209.69**
A. Fuel Combustion	Reference Approach [2]	531,267.40												
	Sectoral Approach [2]	523,192.49	92.77	17.82							1,854.21	6,104.10	667.38	1,199.93
1. Energy Industries		188,021.70	13.84	4.67							425.51	85.62	5.55	889.91
2. Manufacturing Industries and Construction		92,651.32	15.84	4.83							333.78	714.36	30.64	157.11
3. Transport		122,519.04	16.88	5.57							887.43	4,513.29	564.27	38.76
4. Other Sectors		116,850.81	46.13	2.66							182.25	782.90	65.57	110.85
5. Other		3,149.63	0.09	0.09							25.24	7.93	1.34	3.30
B. Fugitive Emissions from Fuels		6,037.55	772.26	0.17							4.59	37.98	365.18	9.76
1. Solid Fuels		112.08	375.71	0.00							0.32	23.95	0.26	8.03
2. Oil and Natural Gas		5,925.47	396.56	0.17							4.27	14.03	364.92	1.73
2. Industrial Processes		**14,875.29**	**5.35**	**17.31**	**26,426.98**	**10,248.26**	**224.58**	**366.38**	**0.05**	**0.06**	**6.30**	**282.72**	**167.53**	**48.59**
A. Mineral Products		9,819.39	0.59	NE							NE,NO	1.56	8.57	8.95
B. Chemical Industry		2,966.95	4.03	17.28	NO	NO	NO	NO	NO	NO	2.69	65.90	76.36	31.30
C. Metal Production		2,088.95	0.73	0.03				187.75		0.03	3.61	215.26	1.93	8.34
D. Other Production [3]		NE									NE	NE	80.67	NE
E. Production of Halocarbons and SF_6						4,881.55		19.50		NA,NO				
F. Consumption of Halocarbons and SF_6					26,426.98	5,366.71	224.58	159.13	0.05	0.03				
G. Other		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use		**NE**		**NE,NO**						**0.00**	**NO**	**NO**	**465.63**	**NO**
4. Agriculture			**997.93**	**109.46**							**NA,NO**	**NA,NO**	**NA,NO**	**NO**
A. Enteric Fermentation			856.55											
B. Manure Management			141.38	6.79									NO	
C. Rice Cultivation			NA,NO										NA,NO	
D. Agricultural Soils [4]			NE	102.36									NO	
E. Prescribed Burning of Savannas			NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues			NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other			NA	0.30							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry		**246.30**	**1.08**	**2.56**							**0.27**	**9.42**	**NA,NO**	**NA**
A. Forest Land		-13,471.75	0.06	0.01							0.01	0.50		
B. Cropland		15,492.80	0.02	2.54							0.00	0.15		
C. Grassland		-7,428.93	0.45	0.00							0.11	3.92		
D. Wetlands		540.91	NE,NO	0.01							NO	NO		
E. Settlements		6,711.38	0.56	0.00							0.14	4.86		
F. Other Land		NE,NO	NE,NO	NE,NO							NO	NO		
G. Other		-1,598.11	NE	NE							NE	NE	NA	NA
6. Waste		**499.98**	**1,400.78**	**4.07**							**1.62**	**15.35**	**62.49**	**1.49**
A. Solid Waste Disposal on Land		NA,NE,NO	1,385.93								NA,NE	NA,NE	57.96	
B. Waste-water Handling			14.46	3.91							NA,NE	NA,NE	NA,NE	
C. Waste Incineration		499.98	0.38	0.16							1.62	15.35	4.53	1.49
D. Other		NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)*** [7]		**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items: [8]														
International Bunkers		**35,167.77**	**0.30**	**1.06**							**295.33**	**35.50**	**11.30**	**71.24**
Aviation		27,442.77	0.18	0.87							126.64	17.62	5.76	6.11
Marine		7,725.00	0.12	0.19							168.69	17.88	5.54	65.13
Multilateral Operations		**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass		**1,426.35**												

Table A 8.1.11 Summary Report For National Greenhouse Gas Inventories (IPCC TABLE 7A) – 2000

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 emissions/removals	CH_4	N_2O	HFCs (1)		PFCs (1)		SF_6		NO_x	CO	NMVOC	SO_2
				P	A	P	A	P	A				
	(Gg)			CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals	**552,063.05**	**3,057.39**	**148.56**	**34,898.86**	**9,321.55**	**260.51**	**464.94**	**0.08**	**0.08**	**1,796.33**	**5,671.71**	**1,588.69**	**1,239.49**
1. Energy	**537,543.59**	**781.41**	**18.01**							**1,788.42**	**5,361.33**	**928.89**	**1,197.28**
A. Fuel Combustion — Reference Approach (2)	543,043.28												
Sectoral Approach (2)	531,808.21	78.84	17.86							1,785.22	5,323.90	576.52	1,188.42
1. Energy Industries	198,297.05	12.96	5.06							452.84	97.07	7.48	919.38
2. Manufacturing Industries and Construction	92,514.31	15.31	4.74							316.34	604.72	30.34	145.39
3. Transport	121,812.62	14.74	5.47							820.78	3,941.78	481.89	29.21
4. Other Sectors	116,267.92	35.76	2.50							171.16	673.01	55.55	91.40
5. Other	2,916.31	0.08	0.09							24.10	7.33	1.26	3.04
B. Fugitive Emissions from Fuels	5,735.38	702.57	0.15							3.20	37.43	352.37	8.86
1. Solid Fuels	102.36	323.22	0.00							0.31	24.43	0.20	7.31
2. Oil and Natural Gas	5,633.01	379.35	0.15							2.89	13.00	352.17	1.55
2. Industrial Processes	**14,436.22**	**5.04**	**17.90**	**34,898.86**	**9,321.55**	**260.51**	**464.94**	**0.08**	**0.08**	**5.91**	**283.64**	**163.33**	**40.99**
A. Mineral Products	9,301.90	0.59	NE							NE,NO	2.75	9.79	10.51
B. Chemical Industry	3,149.55	3.78	17.87	NO	NO	NO	NO	NO	NO	2.43	83.10	72.84	22.94
C. Metal Production	1,984.76	0.68	0.03				257.46		0.05	3.48	197.78	1.77	7.53
D. Other Production (3)	NE									NE	NE	78.93	NE
E. Production of Halocarbons and SF_6					2,619.64		23.08		NA,NO				
F. Consumption of Halocarbons and SF_6				34,898.86	6,701.91	260.51	184.40	0.08	0.03				
G. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NE**		**NE,NO**						**0.00**	**NO**	**NO**	**437.55**	**NO**
4. Agriculture		**955.79**	**105.88**							**NA,NO**	**NA,NO**	**NA,NO**	**NO**
A. Enteric Fermentation		822.74											
B. Manure Management		133.04	6.75									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils (4)		NE	98.83									NO	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other		NA	0.30							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**-425.00**	**1.31**	**2.50**							**0.32**	**11.44**	**NA,NO**	**NA**
A. Forest Land	-13,727.68	0.20	0.01							0.05	1.76		
B. Cropland	15,095.67	0.02	2.48							0.00	0.18		
C. Grassland	-7,696.22	0.52	0.00							0.13	4.56		
D. Wetlands	537.01	NE,NO	0.01							NO	NO		
E. Settlements	6,668.85	0.57	0.00							0.14	4.95		
F. Other Land	NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-1,302.62	NE	NE							NE	NE	NA	NA
6. Waste	**508.24**	**1,313.84**	**4.27**							**1.67**	**15.30**	**58.91**	**1.22**
A. Solid Waste Disposal on Land	NA,NE,NO	1,299.00								NA,NE	NA,NE	54.38	
B. Waste-water Handling		14.44	4.11							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	508.24	0.40	0.16							1.67	15.30	4.54	1.22
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)*** **(7)**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items: (8)													
International Bunkers	**37,244.51**	**0.26**	**1.14**							**287.74**	**34.71**	**10.90**	**57.65**
Aviation	30,256.24	0.15	0.96							138.17	18.54	6.00	6.92
Marine	6,988.27	0.11	0.17							149.57	16.17	4.89	50.72
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**1,509.26**												

Table A 8.1.12 Summary Report For National Greenhouse Gas Inventories (IPCC TABLE 7A) – 2001

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 emissions/removals	CH_4	N_2O	HFCs (1)		PFCs (1)		SF_6		NO_x	CO	NMVOC	SO_2
				P	A	P	A	P	A				
	(Gg)			CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals	**563,789.86**	**2,806.30**	**140.37**	**42,187.15**	**10,239.42**	**157.40**	**384.71**	**0.07**	**0.06**	**1,766.65**	**5,323.98**	**1,483.22**	**1,139.60**
1. Energy	**551,038.10**	**742.19**	**18.02**							**1,759.34**	**5,000.01**	**858.53**	**1,103.57**
A. Fuel Combustion – Reference Approach (2)	549,847.24												
Sectoral Approach (2)	545,107.23	73.52	17.87							1,755.97	4,973.31	502.72	1,093.79
1. Energy Industries	208,826.68	13.89	5.33							474.81	96.47	6.19	831.05
2. Manufacturing Industries and Construction	92,025.55	14.15	4.74							303.28	637.08	30.31	147.43
3. Transport	122,007.96	12.88	5.24							787.65	3,569.85	413.06	26.01
4. Other Sectors	119,325.13	32.52	2.47							167.58	662.55	51.91	86.31
5. Other	2,921.90	0.08	0.09							22.65	7.37	1.24	2.99
B. Fugitive Emissions from Fuels	5,930.88	668.67	0.15							3.38	26.70	355.82	9.78
1. Solid Fuels	101.68	286.83	0.00							0.25	13.69	0.17	8.16
2. Oil and Natural Gas	5,829.20	381.84	0.15							3.13	13.02	355.64	1.62
2. Industrial Processes	**13,127.09**	**4.69**	**15.54**	**42,187.15**	**10,239.42**	**157.40**	**384.71**	**0.07**	**0.06**	**4.64**	**273.21**	**150.40**	**33.69**
A. Mineral Products	8,458.92	0.58	NE							NE,NO	2.54	9.22	9.07
B. Chemical Industry	3,154.42	3.68	15.52	NO	NO	NO	NO	NO	NO	1.62	82.14	59.42	16.83
C. Metal Production	1,513.75	0.42	0.02				217.59		0.03	3.02	188.53	1.58	7.79
D. Other Production (3)	NE									NE	NE	80.18	NE
E. Production of Halocarbons and SF_6					2,387.42		54.05		NA,NO				
F. Consumption of Halocarbons and SF_6				42,187.15	7,852.00	157.40	113.07	0.07	0.03				
G. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NE**		**NE,NO**						**0.00**	**NO**	**NO**	**422.31**	**NO**
4. Agriculture		**906.38**	**100.20**							**NA,NO**	**NA,NO**	**NA,NO**	**NO**
A. Enteric Fermentation		777.05											
B. Manure Management		129.34	6.56									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils (4)		NE	93.31									NO	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other		NA	0.33							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**-905.34**	**1.62**	**2.44**							**0.40**	**14.13**	**NA,NO**	**NA**
A. Forest Land	-14,232.69	0.28	0.01							0.07	2.44		
B. Cropland	14,736.22	0.03	2.42							0.01	0.23		
C. Grassland	-7,752.55	0.73	0.00							0.18	6.35		
D. Wetlands	582.90	NE,NO	0.01							NO	NO		
E. Settlements	6,636.88	0.58	0.00							0.15	5.11		
F. Other Land	NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-876.09	NE	NE							NE	NE	NA	NA
6. Waste	**530.01**	**1,151.43**	**4.16**							**2.27**	**36.63**	**51.98**	**2.35**
A. Solid Waste Disposal on Land	NA,NE,NO	1,135.16								NA,NE	NA,NE	47.50	
B. Waste-water Handling		15.93	4.00							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	530.01	0.34	0.16							2.27	36.63	4.48	2.35
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)*** **(7)**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items: (8)													
International Bunkers	**36,668.55**	**0.23**	**1.12**							**285.32**	**34.08**	**10.58**	**55.34**
Aviation	29,470.18	0.12	0.94							133.78	17.42	5.64	7.49
Marine	7,198.37	0.11	0.18							151.54	16.67	4.94	47.84
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**1,692.79**												

Table A 8.1.13 Summary Report For National Greenhouse Gas Inventories (IPCC TABLE 7A) – 2002

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 emissions/removals	CH_4	N_2O	HFCs[1]		PFCs[1]		SF_6		NO_x	CO	NMVOC	SO_2
				P	A	P	A	P	A				
	(Gg)			CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals	**546,618.39**	**2,666.39**	**134.57**	**51,227.48**	**10,701.18**	**154.38**	**318.66**	**0.07**	**0.06**	**1,683.14**	**4,695.45**	**1,390.60**	**1,020.09**
1. Energy	**535,037.44**	**718.58**	**17.72**							**1,678.55**	**4,441.78**	**781.33**	**987.79**
A. Fuel Combustion — Reference Approach [2]	530,546.78												
Sectoral Approach [2]	529,380.09	66.10	17.58							1,674.82	4,422.19	436.27	980.76
1. Energy Industries	206,136.22	14.45	5.39							475.68	94.08	8.26	758.01
2. Manufacturing Industries and Construction	83,712.49	12.95	4.67							280.15	576.75	29.52	125.60
3. Transport	124,552.57	11.55	5.08							745.18	3,190.10	350.37	26.85
4. Other Sectors	111,922.17	27.05	2.35							152.23	553.52	46.85	67.41
5. Other	3,056.63	0.09	0.09							21.57	7.74	1.27	2.89
B. Fugitive Emissions from Fuels	5,657.36	652.48	0.15							3.73	19.59	345.06	7.03
1. Solid Fuels	107.95	282.01	0.00							0.26	7.11	0.13	5.82
2. Oil and Natural Gas	5,549.40	370.47	0.14							3.46	12.48	344.93	1.21
2. Industrial Processes	**12,763.87**	**4.79**	**8.98**	**51,227.48**	**10,701.18**	**154.38**	**318.66**	**0.07**	**0.06**	**2.43**	**223.02**	**147.76**	**31.35**
A. Mineral Products	8,304.19	0.59	NE							NE,NO	2.53	9.60	12.00
B. Chemical Industry	3,288.84	3.92	8.96	NO	NO	NO	NO	NO	NO	1.09	39.60	56.98	13.09
C. Metal Production	1,170.83	0.29	0.02				150.49		0.04	1.34	180.89	1.36	6.26
D. Other Production [3]	NE									NE	NE	79.81	NE
E. Production of Halocarbons and SF_6					2,034.23		57.35		NA,NO				
F. Consumption of Halocarbons and SF_6				51,227.48	8,666.95	154.38	110.82	0.07	0.03				
G. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NE**		**NE,NO**						**0.00**	**NO**	**NO**	**413.73**	**NO**
4. Agriculture		**889.48**	**101.29**							**NA,NO**	**NA,NO**	**NA,NO**	**NO**
A. Enteric Fermentation		762.21											
B. Manure Management		127.27	6.23									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils [4]		NE	94.74									NO	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other		NA	0.32							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**-1,711.70**	**1.75**	**2.39**							**0.43**	**15.28**	**NA,NO**	**NA**
A. Forest Land	-14,917.87	0.24	0.01							0.06	2.07		
B. Cropland	14,466.13	0.03	2.36							0.01	0.25		
C. Grassland	-7,785.27	0.94	0.01							0.23	8.24		
D. Wetlands	391.14	NE,NO	0.00							NO	NO		
E. Settlements	6,569.45	0.54	0.00							0.13	4.73		
F. Other Land	NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-435.27	NE	NE							NE	NE	NA	NA
6. Waste	**528.78**	**1,051.79**	**4.19**							**1.72**	**15.37**	**47.77**	**0.95**
A. Solid Waste Disposal on Land	NA,NE,NO	1,035.25								NA,NE	NA,NE	43.33	
B. Waste-water Handling		16.20	4.02							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	528.78	0.33	0.16							1.72	15.37	4.44	0.95
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)*** [7]	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items: [8]													
International Bunkers	**34,575.82**	**0.20**	**1.06**							**248.60**	**30.18**	**9.51**	**46.84**
Aviation	28,931.57	0.11	0.92							130.19	17.13	5.58	6.07
Marine	5,644.25	0.09	0.14							118.42	13.06	3.93	40.77
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**1,759.87**												

Table A 8.1.14 Summary Report For National Greenhouse Gas Inventories (IPCC TABLE 7A) – 2003

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 emissions/removals	CH_4	N_2O	HFCs[1] P	HFCs[1] A	PFCs[1] P	PFCs[1] A	SF_6 P	SF_6 A	NO_x	CO	NMVOC	SO_2
	(Gg)			CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals	**556,305.21**	**2,390.55**	**132.80**	**58,829.40**	**11,891.07**	**157.57**	**275.06**	**0.06**	**0.06**	**1,649.90**	**4,208.50**	**1,260.92**	**996.88**
1. Energy	**544,372.36**	**571.12**	**17.27**							**1,645.24**	**4,030.13**	**653.65**	**962.22**
A. Fuel Combustion — Reference Approach [2]	538,306.62												
Sectoral Approach [2]	538,998.09	63.27	17.15							1,642.31	4,008.68	375.66	953.71
1. Energy Industries	213,538.83	13.65	5.40							497.67	98.75	6.31	749.71
2. Manufacturing Industries and Construction	84,710.22	13.79	4.50							272.18	555.15	28.44	113.81
3. Transport	124,334.90	10.35	4.86							704.61	2,855.69	294.80	26.74
4. Other Sectors	113,251.97	25.40	2.29							144.53	491.11	44.78	60.16
5. Other	3,162.18	0.09	0.09							23.32	7.99	1.33	3.29
B. Fugitive Emissions from Fuels	5,374.27	507.84	0.13							2.93	21.45	277.99	8.52
1. Solid Fuels	111.87	232.23	0.00							0.28	10.74	0.12	7.29
2. Oil and Natural Gas	5,262.40	275.61	0.12							2.65	10.70	277.87	1.23
2. Industrial Processes	**13,498.97**	**5.78**	**9.41**	**58,829.40**	**11,891.07**	**157.57**	**275.06**	**0.06**	**0.06**	**2.57**	**149.03**	**156.81**	**33.74**
A. Mineral Products	8,493.73	0.62	NE							NE,NO	2.67	9.24	16.37
B. Chemical Industry	3,159.14	4.57	9.38	NO	NO	NO	NO	NO	NO	1.13	37.41	65.88	9.88
C. Metal Production	1,846.10	0.59	0.02				110.91		0.03	1.44	108.95	1.57	7.49
D. Other Production [3]	NE									NE	NE	80.13	NE
E. Production of Halocarbons and SF_6					1,981.33		55.71		NA,NO				
F. Consumption of Halocarbons and SF_6				58,829.40	9,909.74	157.57	108.44	0.06	0.03				
G. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NE**		**NE,NO**						**0.00**	**NO**	**NO**	**408.18**	**NO**
4. Agriculture		**890.62**	**99.82**							**NA,NO**	**NA,NO**	**NA,NO**	**NO**
A. Enteric Fermentation		764.09											
B. Manure Management		126.52	6.29									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils [4]		NE	93.25									NO	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other		NA	0.28							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**-2,044.21**	**1.60**	**2.33**							**0.40**	**14.02**	**NA,NO**	**NA**
A. Forest Land	-15,503.55	0.20	0.01							0.05	1.75		
B. Cropland	14,251.99	0.01	2.31							0.00	0.11		
C. Grassland	-7,870.97	0.84	0.01							0.21	7.34		
D. Wetlands	628.74	NE,NO	0.00							NO	NO		
E. Settlements	6,537.51	0.55	0.00							0.14	4.82		
F. Other Land	NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-87.93	NE	NE							NE	NE	NA	NA
6. Waste	**478.08**	**921.43**	**3.97**							**1.69**	**15.32**	**42.28**	**0.92**
A. Solid Waste Disposal on Land	NA,NE,NO	904.49								NA,NE	NA,NE	37.84	
B. Waste-water Handling		16.61	3.81							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	478.08	0.33	0.16							1.69	15.32	4.44	0.92
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)*** **[7]**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items: [8]													
International Bunkers	**36,315.08**	**0.21**	**1.11**							**272.69**	**32.71**	**10.30**	**56.67**
Aviation	29,620.08	0.11	0.94							133.01	17.24	5.63	7.15
Marine	6,695.01	0.10	0.17							139.68	15.48	4.67	49.52
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**1,990.14**												

Table A 8.1.15 Summary Report For National Greenhouse Gas Inventories (IPCC TABLE 7A) – 2004

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		Net CO_2 emissions/removals	CH_4	N_2O	HFCs (1)		PFCs (1)		SF_6		NO_x	CO	NMVOC	SO_2
					P	A	P	A	P	A				
		(Gg)			CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals		**556,855.77**	**2,318.84**	**135.01**	**64,321.62**	**11,165.15**	**157.74**	**339.95**	**0.05**	**0.05**	**1,597.80**	**3,915.88**	**1,164.61**	**835.43**
1. Energy		**545,715.00**	**557.41**	**16.88**							**1,592.87**	**3,744.83**	**580.99**	**801.87**
A. Fuel Combustion	Reference Approach (2)	540,135.97												
	Sectoral Approach (2)	540,434.72	61.43	16.74							1,589.95	3,727.32	328.66	791.74
1. Energy Industries		213,133.70	14.21	5.22							481.04	99.65	6.55	590.28
2. Manufacturing Industries and Construction		83,424.33	13.46	4.52							267.61	589.03	28.86	116.24
3. Transport		125,797.04	9.31	4.74							681.08	2,571.54	249.67	26.74
4. Other Sectors		115,026.91	24.35	2.18							135.77	459.42	42.27	54.84
5. Other		3,052.75	0.08	0.09							24.45	7.67	1.31	3.63
B. Fugitive Emissions from Fuels		5,280.28	495.98	0.13							2.92	17.52	252.33	10.14
1. Solid Fuels		168.08	208.55	0.01							0.36	6.61	0.10	8.79
2. Oil and Natural Gas		5,112.20	287.44	0.13							2.56	10.90	252.24	1.35
2. Industrial Processes		**13,792.11**	**5.36**	**12.11**	**64,321.62**	**11,165.15**	**157.74**	**339.95**	**0.05**	**0.05**	**2.90**	**141.24**	**135.92**	**32.70**
A. Mineral Products		8,645.87	0.61	NE							NE,NO	2.61	9.36	16.55
B. Chemical Industry		3,092.73	4.09	12.08	NO	NO	NO	NO	NO	NO	1.25	28.78	44.94	8.77
C. Metal Production		2,053.51	0.66	0.03				153.04		0.02	1.65	109.85	1.62	7.38
D. Other Production (3)		NO									NE	NE	79.99	NE
E. Production of Halocarbons and SF_6						444.68		90.23		NA,NO				
F. Consumption of Halocarbons and SF_6					64,321.62	10,719.29	157.74	96.68	0.05	0.03				
G. Other		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use		**NE**		**NE,NO**						**0.00**	**NO**	**NO**	**408.37**	**NO**
4. Agriculture			**903.33**	**99.82**							**NA,NO**	**NA,NO**	**IE,NA,NE,NO**	**NO**
A. Enteric Fermentation			773.00											
B. Manure Management			130.33	6.28									NO	
C. Rice Cultivation			NA,NO										NA,NO	
D. Agricultural Soils (4)			IE,NA,NE	93.25									IE,NA,NE	
E. Prescribed Burning of Savannas			NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues			NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other			NA	0.28							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry		**-3,101.53**	**1.68**	**2.29**							**0.42**	**14.68**	**NA,NO**	**NA**
A. Forest Land		-16,120.80	0.26	0.01							0.07	2.32		
B. Cropland		13,916.27	0.02	2.26							0.00	0.15		
C. Grassland		-8,052.06	0.86	0.01							0.21	7.52		
D. Wetlands		458.99	NE,NO	0.00							NO	NO		
E. Settlements		6,491.80	0.54	0.00							0.13	4.70		
F. Other Land		NE,NO	NE,NO	NE,NO							NO	NO		
G. Other		204.27	NE	NE							NE	NE	NA	NA
6. Waste		**450.19**	**851.07**	**3.92**							**1.61**	**15.13**	**39.33**	**0.86**
A. Solid Waste Disposal on Land		NA,NE,NO	833.78								NA,NE	NA,NE	34.92	
B. Waste-water Handling			16.98	3.76							NA,NE	NA,NE	NA,NE	
C. Waste Incineration		450.19	0.32	0.16							1.61	15.13	4.40	0.86
D. Other		NA	NA	NA							NA	NA	NA	NA
7. Other *(please specify)* (7)		**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items: (8)														
International Bunkers		**40,032.19**	**0.22**	**1.22**							**305.27**	**35.82**	**11.48**	**76.82**
Aviation		32,479.06	0.10	1.03							145.35	18.38	5.97	8.46
Marine		7,553.13	0.12	0.19							159.92	17.44	5.50	68.36
Multilateral Operations		**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass		**2,261.81**												

Table A 8.1.16 Summary Report For National Greenhouse Gas Inventories (IPCC TABLE 7A) – 2005

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 emissions/removals	CH_4	N_2O	HFCs[1]		PFCs[1]		SF_6		NO_x	CO	NMVOC	SO_2
				P	A	P	A	P	A				
	(Gg)			CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals	**553,074.95**	**2,250.52**	**132.08**	**70,719.81**	**12,062.05**	**146.95**	**258.81**	**0.05**	**0.05**	**1,584.85**	**3,516.02**	**1,089.34**	**710.11**
1. Energy	**542,206.87**	**489.97**	**17.09**							**1,580.67**	**3,349.23**	**518.86**	**676.44**
A. Fuel Combustion — Reference Approach [2]	542,484.58												
Sectoral Approach [2]	536,335.81	57.82	16.94							1,577.52	3,330.69	287.91	666.92
1. Energy Industries	212,299.41	13.73	5.40							499.21	105.62	6.10	470.53
2. Manufacturing Industries and Construction	83,867.59	13.19	4.73							270.29	566.14	29.78	118.69
3. Transport	126,684.58	8.47	4.58							657.23	2,260.88	211.36	27.03
4. Other Sectors	110,713.52	22.36	2.15							128.88	391.09	39.49	47.39
5. Other	2,770.72	0.08	0.08							21.91	6.97	1.19	3.29
B. Fugitive Emissions from Fuels	5,871.06	432.15	0.15							3.14	18.53	230.95	9.52
1. Solid Fuels	111.98	156.34	0.00							0.24	6.14	0.11	8.25
2. Oil and Natural Gas	5,759.08	275.81	0.15							2.90	12.40	230.84	1.26
2. Industrial Processes	**14,131.14**	**4.88**	**9.53**	**70,719.81**	**12,062.05**	**146.95**	**258.81**	**0.05**	**0.05**	**2.58**	**143.01**	**129.58**	**32.85**
A. Mineral Products	8,539.80	0.51	NE							NE,NO	4.28	9.61	17.24
B. Chemical Industry	3,135.57	3.53	9.50	NO	NO	NO	NO	NO	NO	1.01	25.41	40.08	7.22
C. Metal Production	2,455.77	0.84	0.03				60.02		0.01	1.57	113.31	1.59	8.39
D. Other Production [3]	NO									NE	NE	78.30	NE
E. Production of Halocarbons and SF_6					442.32		110.28		NA,NO				
F. Consumption of Halocarbons and SF_6				70,719.81	11,617.82	146.95	88.52	0.05	0.04				
G. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NE**	**0.00**	**NE,NO**						**0.00**	**NO**	**NO**	**402.58**	**NO**
4. Agriculture		**925.85**	**99.23**							**NA,NO**	**NA,NO**	**IE,NA,NE,NO**	**NO**
A. Enteric Fermentation		789.50											
B. Manure Management		136.35	6.00									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils [4]		IE,NA,NE	92.95									IE,NA,NE	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other		NA	0.27							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**-3,657.76**	**1.00**	**2.23**							**0.25**	**8.77**	**NA,NO**	**NA**
A. Forest Land	-15,596.98	0.06	0.01							0.01	0.50		
B. Cropland	13,579.66	0.01	2.22							0.00	0.12		
C. Grassland	-8,473.01	0.42	0.00							0.10	3.68		
D. Wetlands	517.42	NE,NO	0.00							NO	NO		
E. Settlements	6,441.07	0.51	0.00							0.13	4.47		
F. Other Land	NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-125.93	NE	NE							NE	NE	NA	NA
6. Waste	**394.70**	**828.81**	**3.99**							**1.36**	**15.03**	**38.32**	**0.82**
A. Solid Waste Disposal on Land	NA,NE,NO	811.34								NA,NE	NA,NE	33.94	
B. Waste-water Handling		17.15	3.83							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	394.70	0.32	0.16							1.36	15.03	4.38	0.82
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)*** [7]	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items: [8]													
International Bunkers	**43,184.13**	**0.23**	**1.32**							**327.95**	**38.15**	**12.42**	**89.30**
Aviation	35,148.38	0.11	1.12							156.93	19.61	6.41	9.16
Marine	8,035.75	0.13	0.20							171.02	18.54	6.00	80.14
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**2,572.47**												

Table A 8.1.17 Summary Report For National Greenhouse Gas Inventories (IPCC TABLE 7A) – 2006

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 emissions/removals	CH_4	N_2O	HFCs[1]		PFCs[1]		SF_6		NO_x	CO	NMVOC	SO_2
				P	A	P	A	P	A				
	(Gg)			CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals	**551,429.07**	**2,189.83**	**125.43**	**76,977.81**	**12,736.76**	**146.10**	**303.14**	**0.04**	**0.04**	**1,529.91**	**3,290.44**	**1,040.14**	**669.49**
1. Energy	**541,379.29**	**457.81**	**16.69**							**1,525.89**	**3,082.48**	**476.29**	**636.52**
A. Fuel Combustion — Reference Approach[2]	542,682.18												
Sectoral Approach[2]	536,346.45	55.96	16.57							1,523.12	3,061.85	256.26	627.80
1. Energy Industries	218,973.29	11.92	5.59							501.81	105.07	6.83	447.27
2. Manufacturing Industries and Construction	81,681.95	13.31	4.41							247.54	567.07	27.28	106.65
3. Transport	126,940.47	7.74	4.46							634.99	2,002.33	182.72	25.94
4. Other Sectors	105,691.76	22.90	2.02							116.57	379.65	38.15	44.47
5. Other	3,058.99	0.09	0.09							22.21	7.72	1.28	3.47
B. Fugitive Emissions from Fuels	5,032.84	401.86	0.13							2.78	20.63	220.02	8.72
1. Solid Fuels	138.77	142.10	0.00							0.26	10.01	0.13	7.76
2. Oil and Natural Gas	4,894.07	259.76	0.12							2.51	10.62	219.89	0.95
2. Industrial Processes	**13,540.92**	**4.70**	**7.66**	**76,977.81**	**12,736.76**	**146.10**	**303.14**	**0.04**	**0.04**	**2.26**	**178.31**	**122.80**	**32.20**
A. Mineral Products	8,596.64	0.83	NE							NE,NO	4.67	9.58	18.39
B. Chemical Industry	2,819.31	3.21	7.63	NO	NO	NO	NO	NO	NO	0.95	26.41	33.79	5.77
C. Metal Production	2,124.96	0.66	0.02				128.38		0.01	1.31	147.24	1.64	8.04
D. Other Production[3]	NO									NE	NE	77.79	NE
E. Production of Halocarbons and SF_6					387.47		90.23		NA,NO				
F. Consumption of Halocarbons and SF_6				76,977.81	12,347.11	146.10	84.53	0.04	0.03				
G. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NE**		**NE,NO**						**0.00**	**NO**	**NO**	**403.27**	**NO**
4. Agriculture		**911.71**	**94.93**							**NA,NO**	**NA,NO**	**IE,NA,NE,NO**	**NO**
A. Enteric Fermentation		775.31											
B. Manure Management		136.41	5.91									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils[4]		IE,NA,NE	88.73									IE,NA,NE	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other		NA	0.29							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**-3,811.37**	**1.69**	**2.19**							**0.42**	**14.75**	**NA,NO**	**NA**
A. Forest Land	-14,960.55	0.65	0.01							0.16	5.67		
B. Cropland	13,388.98	0.02	2.17							0.00	0.15		
C. Grassland	-8,538.54	0.57	0.00							0.14	5.03		
D. Wetlands	538.65	NE,NO	0.00							NO	NO		
E. Settlements	6,368.19	0.45	0.00							0.11	3.90		
F. Other Land	NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-608.10	NE	NE							NE	NE	NA	NA
6. Waste	**320.23**	**813.92**	**3.96**							**1.34**	**14.90**	**37.77**	**0.77**
A. Solid Waste Disposal on Land	NA,NE,NO	796.29								NA,NE	NA,NE	33.30	
B. Waste-water Handling		17.31	3.80							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	320.23	0.31	0.16							1.34	14.90	4.47	0.77
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)***[7]	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items:[8]													
International Bunkers	**46,012.24**	**0.27**	**1.39**							**378.51**	**43.80**	**14.25**	**112.98**
Aviation	35,595.86	0.11	1.13							159.09	19.76	6.53	10.97
Marine	10,416.37	0.16	0.26							219.42	24.04	7.71	102.01
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**2,521.24**												

Table A 8.1.18 Summary Report For National Greenhouse Gas Inventories (IPCC TABLE 7A) – 2007

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 emissions/removals	CH_4	N_2O	HFCs [1]		PFCs [1]		SF_6		NO_x	CO	NMVOC	SO_2
				P	A	P	A	P	A				
	(Gg)			CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals	**543,897.41**	**2,115.24**	**123.02**	**83,779.09**	**13,040.30**	**148.36**	**218.28**	**0.04**	**0.03**	**1,466.08**	**2,990.72**	**1,003.13**	**590.31**
1. Energy	**533,050.93**	**420.59**	**16.36**							**1,461.88**	**2,781.89**	**446.74**	**559.86**
A. Fuel Combustion — Reference Approach [2]	529,402.12												
Sectoral Approach [2]	527,797.77	56.97	16.23							1,459.27	2,760.11	226.70	548.36
1. Energy Industries	214,701.68	12.63	5.18							469.89	105.08	4.70	376.01
2. Manufacturing Industries and Construction	80,651.51	13.11	4.61							246.86	553.87	28.46	101.06
3. Transport	128,030.34	6.94	4.38							608.74	1,703.74	154.25	19.45
4. Other Sectors	100,700.51	24.18	1.95							107.00	387.99	37.55	43.78
5. Other	3,713.74	0.11	0.11							26.78	9.42	1.74	8.07
B. Fugitive Emissions from Fuels	5,253.16	363.62	0.13							2.61	21.79	220.04	11.50
1. Solid Fuels	197.58	93.04	0.00							0.25	10.52	0.13	11.13
2. Oil and Natural Gas	5,055.59	270.58	0.13							2.35	11.26	219.91	0.37
2. Industrial Processes	**14,689.46**	**5.38**	**8.91**	**83,779.09**	**13,040.30**	**148.36**	**218.28**	**0.04**	**0.03**	**2.49**	**178.73**	**122.89**	**29.67**
A. Mineral Products	8,831.02	0.88	NE							NE,NO	3.44	9.96	15.86
B. Chemical Industry	3,201.13	3.63	8.88	NO	NO	NO	NO	NO	NO	1.07	29.33	32.33	5.87
C. Metal Production	2,657.31	0.87	0.03				83.43		0.01	1.42	145.96	1.70	7.95
D. Other Production [3]	NO									NE	NE	78.89	NE
E. Production of Halocarbons and SF_6					175.60		54.56		NA,NO				
F. Consumption of Halocarbons and SF_6				83,779.09	12,862.36	148.36	80.28	0.04	0.03				
G. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NE**		**NE,NO**						**0.00**	**NO**	**NO**	**396.62**	**NO**
4. Agriculture		**892.10**	**91.65**							**NA,NO**	**NA,NO**	**IE,NA,NE,NO**	**NO**
A. Enteric Fermentation		760.27											
B. Manure Management		131.83	5.75									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils [4]		IE,NA,NE	85.60									IE,NA,NE	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other		NA	0.29							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**-4,186.53**	**1.75**	**2.15**							**0.44**	**15.35**	**NA,NO**	**NA**
A. Forest Land	-14,052.75	0.74	0.01							0.18	6.48		
B. Cropland	13,229.53	0.02	2.13							0.00	0.17		
C. Grassland	-8,697.96	0.57	0.00							0.14	4.95		
D. Wetlands	376.98	NE,NO	0.00							NO	NO		
E. Settlements	6,326.05	0.43	0.00							0.11	3.75		
F. Other Land	NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-1,368.38	NE	NE							NE	NE	NA	NA
6. Waste	**343.55**	**795.42**	**3.95**							**1.29**	**14.74**	**36.88**	**0.77**
A. Solid Waste Disposal on Land	NA,NE,NO	778.04								NA,NE	NA,NE	32.54	
B. Waste-water Handling		17.07	3.79							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	343.55	0.31	0.16							1.29	14.74	4.34	0.77
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)*** [7]	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items: [8]													
International Bunkers	**45,382.64**	**0.26**	**1.37**							**390.17**	**42.45**	**15.42**	**147.22**
Aviation	35,442.92	0.10	1.13							158.10	19.55	6.50	9.79
Marine	9,939.72	0.15	0.25							232.07	22.90	8.91	137.44
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**2,673.79**												

Table A 8.1.19 Summary Report For National Greenhouse Gas Inventories (IPCC TABLE 7A) – 2008

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 emissions/removals	CH_4	N_2O	HFCs[1]		PFCs[1]		SF_6		NO_x	CO	NMVOC	SO_2
				P	A	P	A	P	A				
	(Gg)			CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals	**531,050.85**	**2,056.75**	**119.90**	**89,713.56**	**13,620.81**	**150.70**	**205.83**	**0.03**	**0.03**	**1,321.23**	**2,827.72**	**922.93**	**495.31**
1. Energy	**521,576.96**	**405.38**	**15.28**							**1,317.14**	**2,632.43**	**396.13**	**473.38**
A. Fuel Combustion — Reference Approach [2]	519,178.54												
Sectoral Approach [2]	517,038.79	57.39	15.17							1,314.80	2,614.44	209.25	461.44
1. Energy Industries	208,903.61	12.27	4.86							385.39	106.18	5.09	296.97
2. Manufacturing Industries and Construction	78,396.41	12.44	4.33							227.34	544.41	26.81	93.83
3. Transport	123,519.13	6.10	3.91							573.46	1,536.66	137.12	17.14
4. Other Sectors	102,627.98	26.49	1.96							102.43	418.08	38.53	45.54
5. Other	3,591.67	0.10	0.11							26.17	9.11	1.70	7.95
B. Fugitive Emissions from Fuels	4,538.17	347.99	0.11							2.34	17.99	186.88	11.94
1. Solid Fuels	236.18	97.05	0.00							0.24	8.41	0.13	10.24
2. Oil and Natural Gas	4,301.99	250.94	0.10							2.10	9.59	186.75	1.70
2. Industrial Processes	**13,752.08**	**4.28**	**7.81**	**89,713.56**	**13,620.81**	**150.70**	**205.83**	**0.03**	**0.03**	**2.44**	**164.28**	**116.69**	**21.20**
A. Mineral Products	7,677.73	0.43	NE							NE,NO	2.29	8.63	9.11
B. Chemical Industry	3,010.94	2.88	7.78	NO	NO	NO	NO	NO	NO	0.73	24.32	25.85	4.26
C. Metal Production	3,063.41	0.97	0.03				117.94		0.00	1.71	137.67	1.61	7.83
D. Other Production [3]	NO									NE	NE	80.61	NE
E. Production of Halocarbons and SF_6					125.86		11.67		NA,NO				
F. Consumption of Halocarbons and SF_6				89,713.56	13,468.72	150.70	76.21	0.03	0.03				
G. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NE**		**NE,NO**						**0.00**	**NO**	**NO**	**374.19**	**NO**
4. Agriculture		**871.58**	**90.93**							**NA,NO**	**NA,NO**	**IE,NA,NE,NO**	**NO**
A. Enteric Fermentation		743.01											
B. Manure Management		128.57	5.59									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils [4]		IE,NA,NE	85.04									IE,NA,NE	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other		NA	0.29							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**-4,576.17**	**1.91**	**2.11**							**0.47**	**16.70**	**NA,NO**	**NA**
A. Forest Land	-13,511.53	0.70	0.01							0.17	6.15		
B. Cropland	12,908.11	0.03	2.09							0.01	0.24		
C. Grassland	-8,684.01	0.80	0.01							0.20	6.98		
D. Wetlands	335.35	NE,NO	0.00							NO	NO		
E. Settlements	6,271.15	0.38	0.00							0.09	3.32		
F. Other Land	NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-1,895.24	NE	NE							NE	NE	NA	NA
6. Waste	**297.98**	**773.60**	**3.77**							**1.18**	**14.32**	**35.92**	**0.72**
A. Solid Waste Disposal on Land	NA,NE,NO	756.17								NA,NE	NA,NE	31.63	
B. Waste-water Handling		17.14	3.63							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	297.98	0.29	0.14							1.18	14.32	4.30	0.72
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other *(please specify)* [7]	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items: [8]													
International Bunkers	**45,663.49**	**0.27**	**1.37**							**415.28**	**44.61**	**16.35**	**171.90**
Aviation	34,499.17	0.10	1.10							153.50	18.91	6.30	10.37
Marine	11,164.33	0.17	0.28							261.78	25.70	10.04	161.53
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**3,004.91**												

Table A 8.1.20 Summary Report For National Greenhouse Gas Inventories (IPCC TABLE 7A) – 2009

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 emissions/removals	CH_4	N_2O	HFCs (1)		PFCs (1)		SF_6		NO_x	CO	NMVOC	SO_2
				P	A	P	A	P	A				
	(Gg)			CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals	**479,853.10**	**2,006.26**	**113.43**	**92,763.77**	**13,965.23**	**153.13**	**144.50**	**0.03**	**0.03**	**1,147.52**	**2,318.10**	**823.31**	**400.77**
1. Energy	**475,001.41**	**396.77**	**13.90**							**1,144.36**	**2,176.32**	**329.16**	**387.38**
A. Fuel Combustion — Reference Approach (2)	472,421.55												
Sectoral Approach (2)	470,223.90	52.69	13.78							1,142.02	2,157.30	161.14	378.30
1. Energy Industries	185,749.99	12.53	4.40							354.52	95.89	4.83	229.48
2. Manufacturing Industries and Construction	67,688.63	10.32	3.56							183.00	475.21	22.03	83.92
3. Transport	118,667.33	4.53	3.74							486.61	1,160.85	96.54	15.76
4. Other Sectors	95,069.33	25.22	1.99							93.24	417.66	36.23	41.44
5. Other	3,048.62	0.09	0.09							24.65	7.69	1.50	7.70
B. Fugitive Emissions from Fuels	4,777.51	344.08	0.12							2.34	19.02	168.02	9.08
1. Solid Fuels	149.12	93.29	0.00							0.13	7.92	0.11	8.64
2. Oil and Natural Gas	4,628.39	250.78	0.12							2.21	11.10	167.91	0.44
2. Industrial Processes	**9,435.89**	**4.21**	**3.82**	**92,763.77**	**13,965.23**	**153.13**	**144.50**	**0.03**	**0.03**	**1.73**	**117.35**	**109.97**	**12.66**
A. Mineral Products	5,417.66	0.26	NE							NE,NO	1.68	6.88	6.39
B. Chemical Industry	2,763.85	3.63	3.80	NO	NO	NO	NO	NO	NO	0.67	13.16	20.58	1.69
C. Metal Production	1,254.39	0.31	0.02				60.59		0.00	1.06	102.51	1.18	4.58
D. Other Production (3)	NO									NE	NE	81.32	NE
E. Production of Halocarbons and SF_6					93.71		11.46		NA,NO				
F. Consumption of Halocarbons and SF_6				92,763.77	13,858.21	153.13	72.46	0.03	0.02				
G. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NE**		**NE,NO**						**0.00**	**NO**	**NO**	**349.29**	**NO**
4. Agriculture		**856.19**	**89.77**							**NA,NO**	**NA,NO**	**IE,NA,NE,NO**	**NO**
A. Enteric Fermentation		730.06											
B. Manure Management		126.13	5.44									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils (4)		IE,NA,NE	84.05									IE,NA,NE	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other		NA	0.28							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**-4,871.70**	**1.14**	**2.06**							**0.28**	**10.02**	**NA,NO**	**NA**
A. Forest Land	-12,730.38	0.45	0.01							0.11	3.96		
B. Cropland	12,745.37	0.01	2.05							0.00	0.05		
C. Grassland	-9,047.09	0.29	0.00							0.07	2.57		
D. Wetlands	263.04	NE,NO	0.00							NO	NO		
E. Settlements	6,250.51	0.39	0.00							0.10	3.44		
F. Other Land	NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-2,353.16	NE	NE							NE	NE	NA	NA
6. Waste	**287.50**	**747.95**	**3.88**							**1.15**	**14.41**	**34.89**	**0.73**
A. Solid Waste Disposal on Land	NA,NE,NO	731.16								NA,NE	NA,NE	30.59	
B. Waste-water Handling		16.50	3.74							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	287.50	0.29	0.15							1.15	14.41	4.30	0.73
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other *(please specify)* (7)	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items: (8)													
International Bunkers	**43,318.48**	**0.26**	**1.30**							**389.84**	**41.85**	**15.37**	**156.77**
Aviation	32,961.65	0.10	1.05							147.65	18.00	6.06	8.59
Marine	10,356.84	0.16	0.26							242.20	23.85	9.30	148.19
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**3,067.94**												

Table A 8.1.21 Summary Report For National Greenhouse Gas Inventories (IPCC TABLE 7A) – 2010

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 emissions/removals	CH_4	N_2O	HFCs[1]		PFCs[1]		SF_6		NO_x	CO	NMVOC	SO_2
				P	A	P	A	P	A				
	(Gg)			CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals	**497,883.30**	**1,973.66**	**114.92**	**97,486.57**	**14,314.07**	**155.66**	**220.47**	**0.03**	**0.03**	**1,109.93**	**2,127.69**	**789.59**	**409.29**
1. Energy	**491,918.47**	**387.67**	**13.99**							**1,106.38**	**2,020.35**	**298.08**	**396.03**
A. Fuel Combustion — Reference Approach [2]	490,597.58												
Sectoral Approach [2]	487,310.39	54.77	13.84							1,103.79	2,001.83	148.73	383.23
1. Energy Industries	191,776.41	12.89	4.43							340.52	97.26	4.91	240.25
2. Manufacturing Industries and Construction	66,398.79	10.11	3.52							183.35	462.97	22.87	79.31
3. Transport	118,471.52	3.87	3.77							459.23	986.13	82.33	14.93
4. Other Sectors	107,725.69	27.83	2.04							96.07	448.07	37.15	42.55
5. Other	2,937.98	0.08	0.09							24.62	7.40	1.47	6.18
B. Fugitive Emissions from Fuels	4,608.07	332.89	0.15							2.60	18.52	149.35	12.80
1. Solid Fuels	219.64	85.69	0.00							0.30	8.86	0.13	12.40
2. Oil and Natural Gas	4,388.43	247.20	0.15							2.30	9.65	149.22	0.40
2. Industrial Processes	**10,172.73**	**4.33**	**4.27**	**97,486.57**	**14,314.07**	**155.66**	**220.47**	**0.03**	**0.03**	**2.00**	**80.88**	**110.28**	**12.52**
A. Mineral Products	5,477.14	0.27	NE							NE,NO	1.64	6.45	6.91
B. Chemical Industry	2,948.26	3.50	4.25	NO	NO	NO	NO	NO	NO	0.68	18.38	19.79	1.25
C. Metal Production	1,747.34	0.56	0.02				113.16		0.01	1.32	60.87	1.17	4.36
D. Other Production [3]	NO									NE	NE	82.86	NE
E. Production of Halocarbons and SF_6					81.61		38.74		NA,NO				
F. Consumption of Halocarbons and SF_6				97,486.57	14,218.86	155.66	68.57	0.03	0.02				
G. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NE**	**0.00**	**NE,NO**						**0.00**	**NO**	**NO**	**347.51**	**NO**
4. Agriculture		**860.25**	**90.76**							**NA,NO**	**NA,NO**	**IE,NA,NE,NO**	**NO**
A. Enteric Fermentation		732.66											
B. Manure Management		127.59	5.38									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils [4]		IE,NA,NE	85.11									IE,NA,NE	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other		NA	0.27							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**-4,499.91**	**1.36**	**2.03**							**0.34**	**11.92**	**NA,NO**	**NA**
A. Forest Land	-10,610.02	0.39	0.01							0.10	3.41		
B. Cropland	12,145.10	0.02	2.01							0.00	0.16		
C. Grassland	-8,653.91	0.56	0.00							0.14	4.89		
D. Wetlands	263.02	NE,NO	0.00							NO	NO		
E. Settlements	6,250.41	0.40	0.00							0.10	3.46		
F. Other Land	NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-3,894.51	NE	NE							NE	NE	NA	NA
6. Waste	**292.01**	**720.05**	**3.87**							**1.20**	**14.54**	**33.72**	**0.75**
A. Solid Waste Disposal on Land	NA,NE,NO	703.19								NA,NE	NA,NE	29.42	
B. Waste-water Handling		16.57	3.71							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	292.01	0.30	0.15							1.20	14.54	4.31	0.75
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)*** [7]	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items: [8]													
International Bunkers	**40,546.61**	**0.23**	**1.23**							**351.62**	**37.83**	**13.91**	**130.94**
Aviation	31,522.26	0.09	1.00							141.09	17.05	5.80	8.41
Marine	9,024.35	0.14	0.22							210.53	20.78	8.11	122.52
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**3,325.68**												

A9 ANNEX 9: Additional Information Quantitative Discussion of 2010 Inventory

This Annex discusses the emission estimates made in the 1990-2010 Greenhouse Gas Inventory. Each IPCC sector is described in detail with significant points noted for each pollutant where appropriate. The tables show rounded percentages only. All calculations are based on IPCC categorisation.

A9.1 ENERGY SECTOR (1)

Figure A 9.1.1 and **Figure A 9.1.2** show both emissions of direct and indirect Greenhouse Gases for the Energy sector (category 1) in the UK for the years 1990-2010. Emissions from direct greenhouse gases in this sector have declined 17% since 1990. However an increase in emissions of around 3.4% is also seen between 2009 and 2010. This is driven mostly by increases in the domestic combustion (1A4b) category.

Table A 9.1.1 to **Table A 9.1.4** summarise the changes observed through the time series for each pollutant, as well as the contribution the emissions make to both sector 1 and the overall emissions in the UK during 2010.

A9.1.1 Carbon Dioxide

Analysing emissions by pollutant shows that 99% of total net CO_2 emissions in 2010 came from the Energy sector (**Table A 9.1.4**), making this sector by far the most important source of CO_2 emissions in the UK. Overall, CO_2 emissions from sector 1 have decreased by 14% since 1990 (**Table A 9.1.1**) and have also shown an increase of 3.6% between 2009 and 2010 (**Table A 9.1.2**).

Energy industries (category 1A1) were responsible for 39% of the sector's CO_2 emissions in 2010 (**Table A 9.1.3**). There has been an overall decline in emissions from this sector of 19% since 1990 (**Table A 9.1.1**). After the privatisation of the power industry in 1990, there was a strong move away from coal and oil generation towards use of gas. Many coal and oil-fired stations closed, and about 20 combined cycle gas turbine (CCGT) stations were built. As a result, coal consumption in power stations roughly halved between 1990 and 1999, while oil consumption declined over the same period to approximately 20% of 1990 levels. Gas consumption increased by a factor of 50, and went from just 1% of fossil fuel input in energy terms in 1990 to 50% in 1999. Use of nuclear power also increased, by about 35%.

Since 1999 the use of coal, oil and gas has changed less dramatically, with a general trend of increasing use of both coal and gas, mainly due to a decline in use of nuclear power. During 2009, this general trend was reversed, with sharp decreases in coal and gas use, and increases in nuclear generation. These changes reflected decreased electricity consumption and greater availability of nuclear plant in 2009, following maintenance work and outages. Coal and gas use increased again in 2010, coupled with a decrease in electricity from nuclear, contributing to an increase in emissions from power generation between 2009 and 2010.

Overall, between 1990 and 2010, there has been a 22% increase in the amount of electricity generated but a 23% decrease in CO_2 emissions from Power stations (1A1a). This can be attributed to several reasons. Firstly, the shift towards use of CCGT stations rather than conventional steam stations burning coal or oil – CCGT stations operate at a higher thermal efficiency, for example in 2010 they operated at 48% efficiency, whilst coal-fired stations operated at 36% efficiency.[1] Secondly, the calorific value of natural gas per unit mass carbon is higher than that of coal and oil. Thirdly, a slight increase in electricity generated from non-fossil fuel energy sources, due to increased use of wastes and renewable energy sources.

Emissions of from category 1A2 – Manufacturing Industries and Construction contributed 13% (**Table A 9.1.4**) to overall net CO_2 emissions in the UK in 2010. Since 1990, these emissions have declined by 34%, (**Table A 9.1.1**) mostly as a result of a decline in the emissions from the Iron and steel industry. This sector has seen a significant decrease in coke, coal and fuel oil usage, with an increase occurring in the emissions from combustion of natural gas.

Emissions of CO_2 from 1A3 (Transport) have increased by 4% since 1990 (**Table A 9.1.1**). In 2010, this sector contributed 24% (**Table A 9.1.4**) to overall CO_2 emissions within the UK. Emissions from transport are dominated by road transport (1A3b), which in 2010 contributed 94% to the total emissions from transport. Since 1990, emissions from road transport have increased by 3% - from 2007 CO_2 emissions from road transport have started to decline and up to 2009 had decreased by 4% each year. This may be as a result of recent economic downturn. Emissions from domestic aviation have increased by 26% since 1990, but have shown a decrease of 26% since 2005 despite an increase in the total number of km flown. This is because of a move to use more fuel efficient aeroplanes in 2006.

Emissions of CO_2 from 1A4 (Other) in 2010 were at a similar level to 1990 (**Table A 9.1.1**). During this period, residential emissions have increased by 9% and emissions from the commercial/institutional subsector have decreased by 26%. Fuel consumption data since 1990 indicates a general trend in fuel switching in these sectors, away from more carbon-intensive fuels such as coal, coke, fuel oil and gas oil, towards burning oil and natural gas. This shift has partly been driven by fuel prices but also through the growth of the UK gas supply network (most notably in Northern Ireland). After a decrease between 2008 and 2009, residential emissions increased again by 16% between 2009 and 2010 which is mainly to do with an increase in gas consumption, thought to be due to a combination of colder shoulder heating season and improvement in the economic climate. There has been an increase of 4% in the commercial/institutional subsector between 2009 and 2010 which has also been mainly due to an increase in gas consumption.

Emissions of CO_2 from 1A5 (Fuel Combustion; Other), 1B1 (Fugitive Emissions from Fuels; Solid fuels) and 1B2 (Fugitive Emissions from Fuels; Oil and Natural Gas) all show decreases between 1990-2010, although they only contribute a small percentage towards emissions from the energy sector.

A9.1.2 Methane

In 2010, 20% (see **Table A 9.1.4**) of total methane emissions came from the energy sector, the majority (64%, **Table A 9.1.3**) from fugitive emissions from oil and natural gas (1B2). Emissions from this category have decreased by 50% since 1990 (**Table A 9.1.1**). Sources

[1] Plant loads, demand and efficiency, Table 5.10, DECC (2010)

include leakage from the gas transmission and distribution system and offshore emissions. Estimates of leakage from the gas distribution system are based on leakage measurements made by National Grid UK together with data on their gas main replacement programme, and have declined since 1990 as old mains are replaced. The major sources of emissions from the offshore oil and gas industry are venting, fugitive emissions and loading and flaring from offshore platforms.

A9.1.3 Nitrous Oxide

The energy sector accounted for 12% of total N_2O emissions in the UK during 2010. Of this, 32%, **Table A 9.1.3** arose from energy industries (1A1). Within this category, emissions from public electricity production have shown a 45% decrease, whilst emissions from petroleum refining have increased by 21%. Emissions from 1A1c (Manufacture of Solid Fuels and Other Energy Industries) have increased by 10% between 1990 and 2010. N_2O emissions from the energy sector have decreased overall by 31% since 1990. Over this period the use of coal has decreased and the use of natural gas increased.

The other major contribution towards N_2O emissions within the energy sector is the transport sector (1A3) (27%, **Table A 9.1.3**). Between 1990 and 1999, emissions increased by 32% due to the increasing numbers of petrol driven cars fitted with early generation three-way catalysts. These are used to reduce emissions of nitrogen oxides, carbon monoxide and non-methane volatile organic compounds however; nitrous oxide is produced as a by-product. Since then, emission factors have been declining with successive Euro standards, presumably due to better catalyst formulations as well as reductions in fuel sulphur content. The overall change in the N_2O emissions from the transport sector between 1990 and 2010 is a 17% decrease (**Table A 9.1.1**) and a 1% increase was observed between 2009 and 2010.

A9.1.4 Nitrogen Oxides

In 2010, over 99% of NO_x emissions in the UK came from the energy sector. Since 1990 emissions from this sector have decreased by 61% (**Table A 9.1.1**), mostly as a result of abatement measures on power stations, three-way catalysts fitted to cars and stricter emission regulations on trucks. The main source of NO_x emissions is transport: in 2010, emissions from transport contributed 42% (**Table A 9.1.4**) to the total emissions of NO_x in the UK, with 34% arising from road transport (1A3b). From 1970, emissions from transport increased (especially during the 1980s) and reached a peak in 1989 before falling by 70% (**Table A 9.1.1**) since 1990. This reduction in emissions is due to the requirement since the early 1990s for new petrol cars to be fitted with three way catalysts and the further tightening up of emission standards on these and all types of new diesel vehicles over the last decade.

Emissions from the energy industries (1A1) contributed 31% (**Table A 9.1.4**) to total NO_x emissions in the UK during 2010. Between 1990 and 2010, emissions from this sector decreased by 61% (**Table A 9.1.1**). The main reason for this was a decrease in emissions from public electricity and heat production (1A1a) of 68%. Since 1998 the electricity generators adopted a programme of progressively fitting low NO_x burners to their 500 MWe coal fired units. Since 1990, further changes in the electricity supply industry such as the increased use of nuclear generation and the introduction of CCGT plant have resulted in additional reduction in NO_x emissions.

Emissions from Manufacturing, Industry and Construction (1A2) have fallen by 55% (**Table A 9.1.1**) since 1990. In 2010, emissions from this sector contributed 17%

(**Table A 9.1.4**) to overall emissions of NO_x. Over this period, the industrial sector has seen a move away from the use of coal, coke and fuel oil towards natural gas and gas oil usage.

A9.1.5 Carbon Monoxide

Emissions of carbon monoxide from the energy sector contributed 95% (**Table A 9.1.4**) to overall UK CO emissions in 2010. Of this, 49% of emissions (**Table A 9.1.3**) occur from the transport sector. Since 1990, emissions from 1A3 have declined by 85% (**Table A 9.1.1**), which is mainly because of the increased use of three way catalysts, although a proportion is a consequence of fuel switching in moving from petrol to diesel cars.

Emissions from sector 1A2 contributed 22% (**Table A 9.1.4**) to overall emissions of CO in 2010. Emissions from within this category mostly come from the Iron and Steel industry and from petrol use in off-road vehicles within the Manufacturing, industry and combustion sector.

A9.1.6 Non Methane Volatile Organic Compounds

In 2010, 38% (**Table A 9.1.4**) of non-methane volatile organic compound emissions came from the energy sector. Of these, the largest contribution arises from the fugitive emissions of oil and natural gas (1B2), which contributed 19% (**Table A 9.1.4**) towards the overall UK emissions of NMVOCs in 2010. This includes emissions from gas leakage, which comprise around 12% of the total for the energy sector. Remaining emissions arise from oil transportation, refining, storage and offshore.

Emissions from transport (1A3) contribute 10% (**Table A 9.1.4**) to overall emissions of NMVOC in the UK in 2010. Since 1990, emissions from this sector have decreased by 92% (**Table A 9.1.1**) due to the increased use of three way catalysts on petrol cars.

A9.1.7 Sulphur Dioxide

97% (**Table A 9.1.4)** of emissions of sulphur dioxide came from the energy sector in 2010. 61% (**Table A 9.1.3**) of these emissions arose from the energy industries sector (1A1). A majority of these emissions are from the public electricity and heat production category (1A1a). Since 1990, emissions from power stations have declined by 94%. This decline has been due to the increase in the proportion of electricity generated CCGT stations and other gas fired plant. CCGTs run on natural gas and are more efficient (see **Section A9.1.1**) than conventional coal and oil stations and have negligible SO_2 emissions.

Emissions from Manufacturing, Industry and Construction were responsible for 19% (**Table A 9.1.4**) of UK emissions of SO_2 in 2010. Since 1990, emissions from this sector have declined by 82% (**Table A 9.1.1**). This decline is due to the reduction in the use of coal and oil in favour of natural gas, and also some improvement in energy efficiency.

Figure A 9.1.1 UK emissions of direct greenhouse gases from IPCC sector 1, 1990-2010

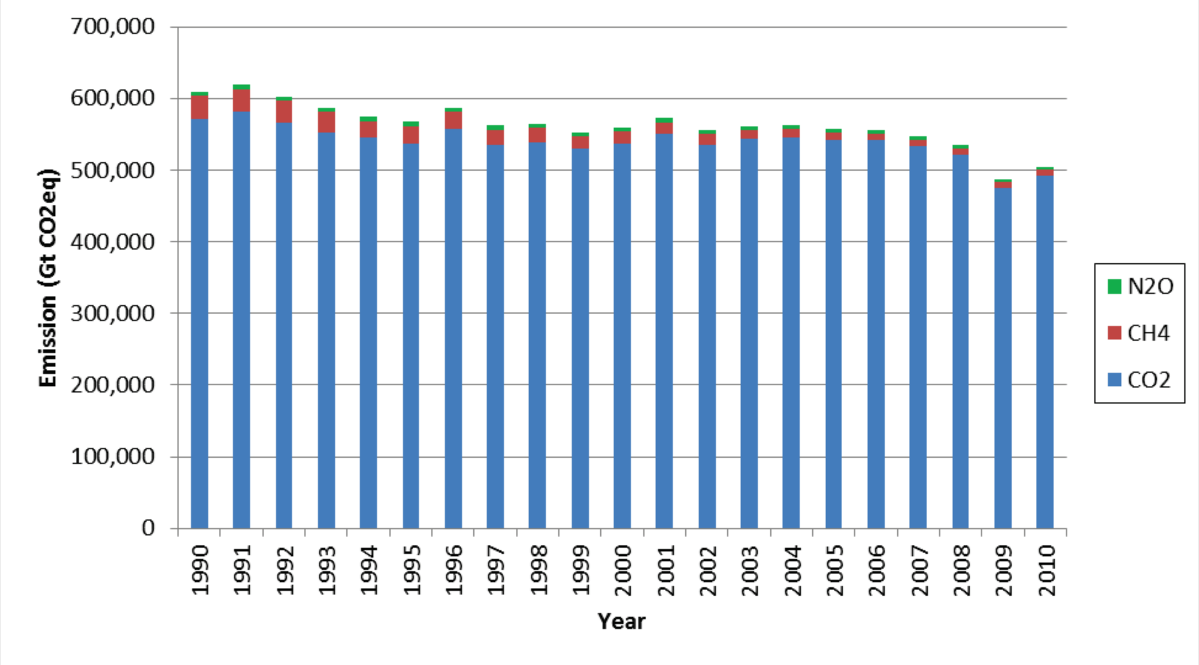


Figure A 9.1.2 UK emissions of Indirect Greenhouse Gases from IPCC sector 1, 1990-2010

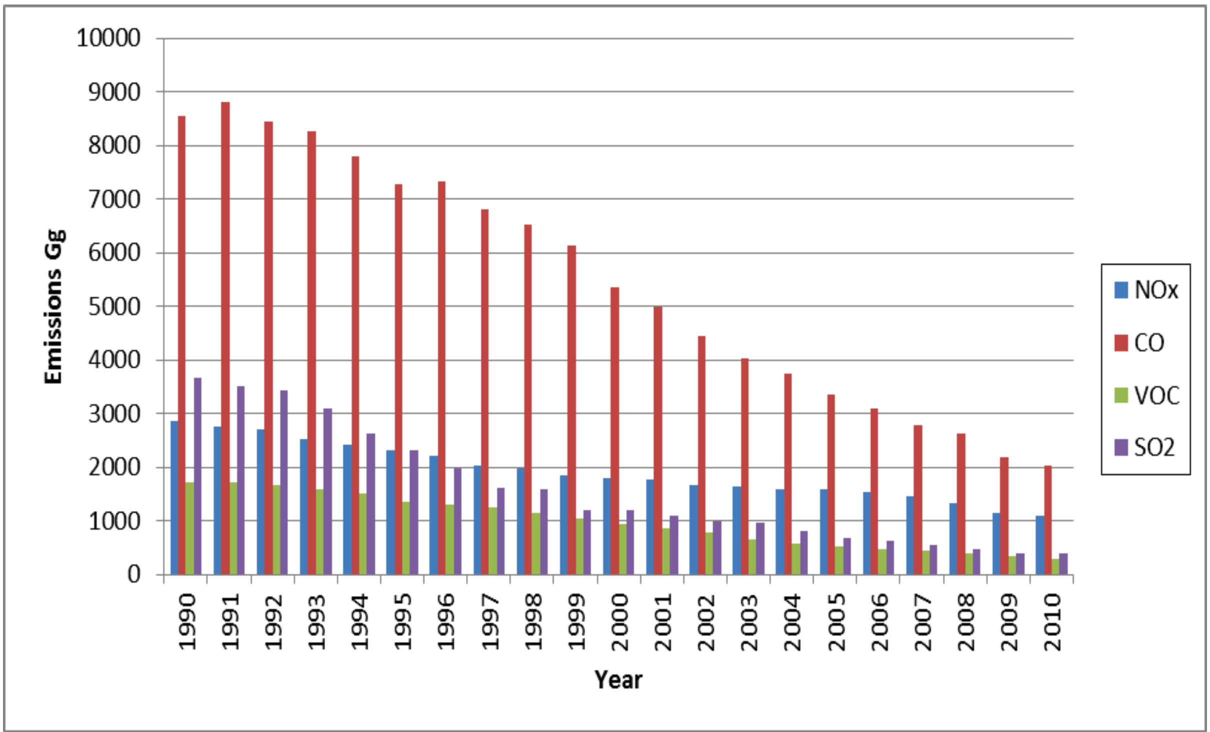


Table A 9.1.1 % Changes from 1990 to 2010 in Sector 1

	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
1A1	-19%	25%	-34%	-61%	-29%	-44%	-92%
1A2	-34%	-35%	-37%	-55%	-38%	-24%	-82%
1A3	4%	-87%	-17%	-65%	-85%	-92%	-84%
1A4	0%	-62%	-35%	-55%	-61%	-59%	-79%
1A5	-44%	-46%	-45%	-37%	-45%	-33%	0%
1B1	-74%	-90%	-34%	-48%	-77%	-63%	-40%
1B2	-24%	-50%	9%	-83%	-55%	-74%	-95%
Overall	**-14%**	**-74%**	**-31%**	**-61%**	**-76%**	**-83%**	**-89%**

Table A 9.1.2 % Changes from 2009 to 2010 in Sector 1

	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
1A1	3%	3%	1%	-4%	1%	2%	5%
1A2	-2%	-2%	-1%	0%	-3%	4%	-5%
1A3	0%	-15%	1%	-6%	-15%	-15%	-5%
1A4	13%	10%	3%	3%	7%	3%	3%
1A5	-4%	-5%	-4%	0%	-4%	-2%	-20%
1B1	47%	-8%	727%	135%	12%	12%	44%
1B2	-5%	-1%	26%	4%	-13%	-11%	-11%
Overall	**4%**	**-2%**	**1%**	**-3%**	**-7%**	**-9%**	**2%**

Table A 9.1.3 % Contribution to Sector 1

	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
1A1	39%	3%	32%	31%	5%	2%	61%
1A2	13%	3%	25%	17%	23%	8%	20%
1A3	24%	1%	27%	42%	49%	28%	4%
1A4	22%	7%	15%	9%	22%	12%	11%
1A5	1%	0%	1%	2%	0%	0%	2%
1B1	0%	22%	0%	0%	0%	0%	3%
1B2	1%	64%	1%	0%	0%	50%	0%

Table A 9.1.4 % Contribution to Overall Pollutant Emissions

	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
1A1	39%	1%	4%	31%	5%	1%	59%
1A2	13%	1%	3%	17%	22%	3%	19%
1A3	24%	0%	3%	41%	46%	10%	4%
1A4	22%	1%	2%	9%	21%	5%	10%
1A5	1%	0%	0%	2%	0%	0%	2%
1B1	0%	4%	0%	0%	0%	0%	3%
1B2	1%	13%	0%	0%	0%	19%	0%
Overall	**99%**	**20%**	**12%**	**100%**	**95%**	**38%**	**97%**

A9.2 INDUSTRIAL PROCESSES SECTOR (2)

Figure A 9.2.1 and **Figure A 9.2.2** show both emissions of direct and indirect Greenhouse Gases for the UK industrial processes sector in 1990-2010. Emissions from direct Greenhouse gases within this sector have decreased by 50% since 1990. **Table A 9.2.1** to **Table A 9.2.4** summarise the changes observed through the time series for each pollutant as well as the contribution the emissions make to Sector 2 and total UK emissions during 2010.

A9.2.1 Carbon Dioxide

The industrial processes sector is not a major source of emissions in the UK for carbon dioxide. In 2010, just 2% (**Table A 9.2.4**) of UK emissions originated from this sector.

A9.2.2 Methane

Emissions of methane from the industrial processes sector are very small and have a negligible effect on overall methane emissions in the UK.

A9.2.3 Nitrous Oxide

In 2010, 4% (**Table A 9.2.4**) of N_2O emissions in the UK came from the industrial processes sector. Between 1990 and 2010, emissions from this sector declined by an estimated 95% (**Table A 9.2.1**) due to reductions in emissions from adipic acid manufacture (a feedstock for nylon) and nitric acid production. N_2O emissions from nitric acid manufacture show a fall in 1995 due to the installation of an abatement system at one of the plants. Emissions from adipic acid manufacture were reduced significantly from 1998 onwards due to the retrofitting of an emissions abatement system to the only adipic acid plant in the UK, which subsequently closed in April 2009.

A9.2.4 Hydrofluorocarbons

Table A 9.2.4 shows that the industrial processes sector was responsible for 100% of emissions of HFCs in the UK in 2010. Since 1990, emissions of HFCs have increased by 26% (**Table A 9.2.1**). The largest contribution to this sector in 2010 arises from category 2F1 – refrigeration and air conditioning equipment. In 2010, these contributed 76% (**Table A 9.2.4**) to the overall emissions of HFCs. Emissions from this category arise due to leakage from refrigeration and air conditioning equipment during its manufacture and lifetime. Emissions from aerosols contribute the next largest percentage (19%, **Table A 9.2.4**) to overall HFC emissions. In this category, it is assumed that all the fluid is emitted in the year of manufacture. This category contains mainly industrial aerosols and also metered dose inhalers (MDI).

The remaining emissions arise mainly from foam blowing (2%, **Table A 9.2.4**), fugitive emissions from HFC production (1%, **Table A 9.2.4**) and fire extinguishers (1%, **Table A 9.2.4**). A small emission also arises from the use of HFCs as a cover gas in magnesium foundries.

A9.2.5 Perfluorocarbons

All emissions (**Table A 9.2.4**) of PFCs come from the industrial processes sector. Since 1990, emissions from this sector have declined by 84% (**Table A 9.2.1**). The main source of PFC emissions is aluminium production (51%,**Table A 9.2.4**). During the process of aluminium smelting, PFC is formed as a by-product. The emissions are caused by the anode effect, which occurs when alumina concentrations become too low in the smelter. This can cause very high electrical current and decomposition of the salt – fluorine bath. The fluorine released then reacts with the carbon anode to create CF_4 and C_2F_6. Since 1990, emissions arising from aluminium production have shown a 92% decrease (**Table A 9.2.1**) due to significant improvements in process control and an increase in the rate of aluminium recycling.

The next largest source is 2F9, which includes a range of sources including the semiconductor and electronics industries. In 2010, this sector contributed 31% (**Table A 9.2.4**) to overall PFC emissions in the UK .The remaining contribution arises from fugitive emissions from PFC manufacture. In 2010, these sources contributed 18% (**Table A 9.2.4**) to overall PFC totals in the UK.

A9.2.6 Sulphur Hexaflouride

All emissions of SF_6 arise in the industrial processes sector (**Table A 9.2.4**). The use of SF_6 in magnesium foundries contributed 19% (**Table A 9.2.4**) towards total emissions in 2010. Emissions from 2F9 – Other contributed 81% (**Table A 9.2.4**) towards emissions, which includes emissions from electrical insulation. Emissions arise during the manufacture and filling of circuit breakers and from leakage and maintenance during the equipment lifetime. It also includes emissions from applications in the electronics industry and sports shoes. Since 1990, emissions from SF_6 have decreased by 33% (**Table A 9.2.1**).

A9.2.7 Nitrogen Oxides

Although emissions of NO_x from this sector do occur, overall they have little impact on emissions of NO_x in the UK (see **Table A 9.2.4**).

A9.2.8 Carbon Monoxide

During 2010, emissions from the industrial sector contributed 4% (**Table A 9.2.4**) to overall CO emissions in the UK. Contributions within this sector arise mainly from the chemical industry, iron and steel production, and aluminium production. For details see **Table A 9.2.3**. Since 1990, emissions from this sector have decreased by 71% (**Table A 9.2.1**).

A9.2.9 Non Methane Volatile Organic Compounds

In 2010, emissions from the industrial processes sector contributed 14% (**Table A 9.2.4**) to overall UK emissions of NMVOCs. The majority of emissions within this category come from the food and drink sector. Emissions also arise from the chemical industry.

A9.2.10 Sulphur Dioxide

In 2010, SO_2 emissions from the industrial processes sector contributed just 3% (**Table A 9.2.4**) to overall emissions in the UK. Emissions arise from a variety of sources including the chemical industry, metal production and mineral products (Fletton brick production). Since 1990, SO_2 emissions from this sector have declined 77% (**Table A 9.2.1**).

Figure A 9.2.1 Emissions of direct greenhouse gases from IPCC sector 2, 1990-2010

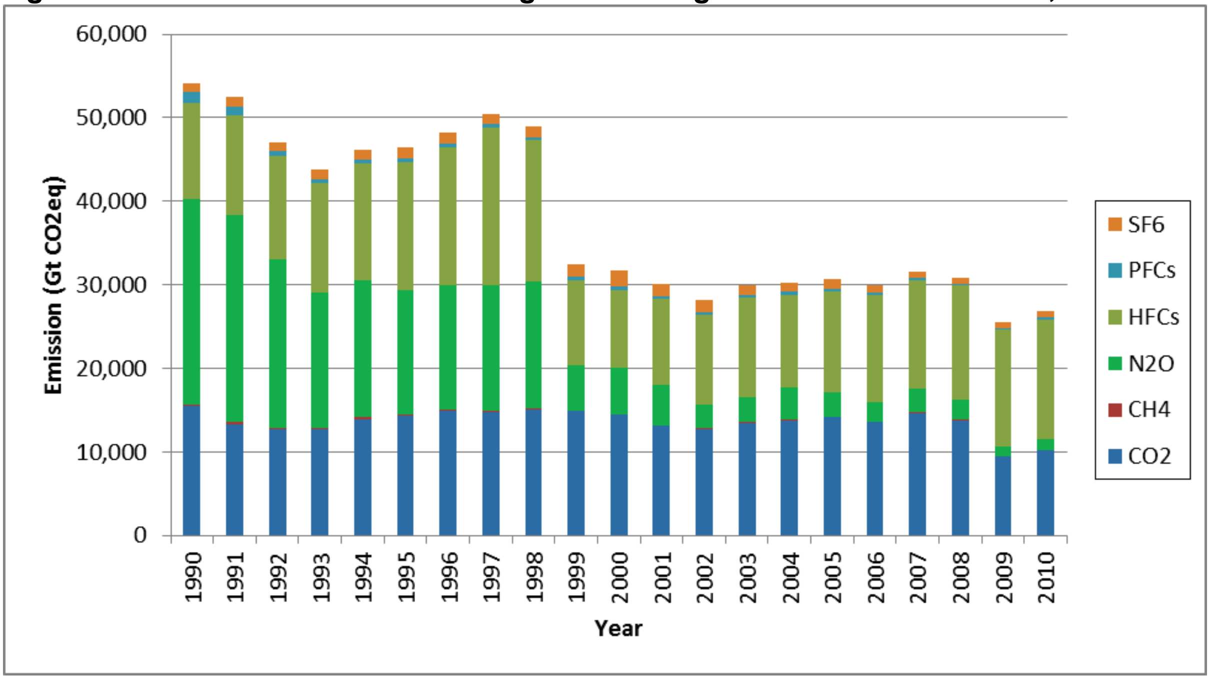


Figure A 9.2.2 Emissions of indirect greenhouse gases from IPCC sector 2, 1990-2010

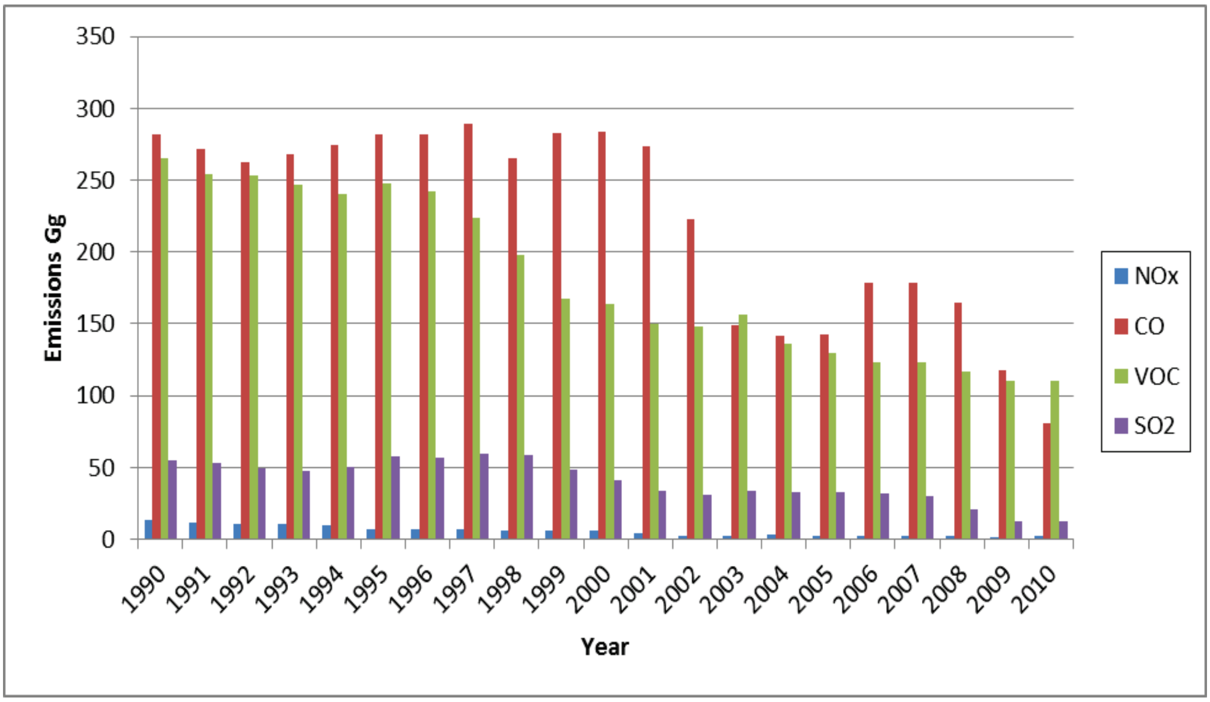


Table A 9.2.1 % Changes from 1990 to 2010 in Sector 2

	CO_2	CH_4	N_2O	HFC	PFC	SF_6	NOx	CO	NMVOC	SO_2
2A1	-48%									
2A2	-81%									
2A3	-18%									
2A6									-45%	
2A7	-2%	-76%						-69%	-68%	62%
2B1	-32%									
2B2			-66%				-97%			
2B3			-100%							
2B5	26%	-57%					7%	-78%	-89%	-97%
2C1	-21%	-28%	-40%				-75%	-68%	-43%	-76%
2C3	-36%				-92%		-64%	-7%		-38%
2C4						-69%				
2C5								-98%		-40%
2D1									-96%	
2D2									13%	
2E1				-99%						
2E2					255%					
2F1				15392781%	-81%					
2F2										
2F3										
2F4				22658%						
2F5										
2F9					19%	-7%				
Overall	**-34%**	**-57%**	**-95%**	**26%**	**-84%**	**-33%**	**-85%**	**-71%**	**-58%**	**-77%**

Table A 9.2.2 % Changes from 2009 to 2010 in Sector 2

	CO_2	CH_4	N_2O	HFC	PFC	SF_6	NOx	CO	NMVOC	SO_2
2A1	2%									
2A2	0%									
2A3	-4%									
2A6									-1%	
2A7	6%	1%						-2%	-27%	8%
2B1	15%									
2B2			19%				6%			
2B3			-100%							
2B5	3%	-4%					-1%	40%	-4%	-26%
2C1	69%	79%	36%				27%	-47%	-1%	-24%
2C3	-27%				87%		18%	-22%		13%
2C4				2%		67%				
2C5								-34%		-21%
2D1									0%	
2D2									2%	
2E1				-13%						
2E2					238%					
2F1				4%	-3%	0%				
2F2				4%						
2F3				1%	-100%					
2F4				-3%						
2F5				13%						
2F9					-5%	-4%				
Overall	**8%**	**3%**	**12%**	**2%**	**53%**	**4%**	**16%**	**-31%**	**0%**	**-1%**

Table A 9.2.3 % Contribution to Sector 2

	CO_2	CH_4	N_2O	HFC	PFC	SF_6	NOx	CO	NMVOC	SO_2
2A1	37%									
2A2	2%									
2A3	9%									
2A6									5%	
2A7	5%	6%						2%	1%	55%
2B1	10%									
2B2			99%				13%			
2B3			0%							
2B5	19%	81%					21%	23%	18%	10%
2C1	14%	13%	1%				50%	49%	1%	6%
2C3	3%				51%		16%	25%		20%
2C4				0%		19%				
2C5								1%		9%
2D1									0%	
2D2									75%	
2E1				1%						
2E2					18%					
2F1				76%	0%	0%				
2F2				2%						
2F3				1%	0%					
2F4				19%						
2F5				1%	0%					
2F9				0%	31%	81%				

Note the contribution of N_2O to category 2B3 is 0 in 2010 as the adipic acid plant closed.

Table A 9.2.4 % Contribution to Overall Pollutant Emissions

	CO_2	CH_4	N_2O	HFC	PFC	SF_6	NOx	CO	NMVOC	SO_2
2A1	1%									
2A2	0%									
2A3	0%									
2A6									1%	
2A7	0%	0%						0%	0%	2%
2B1	0%									
2B2			4%				0%			
2B3			0%							
2B5	0%	0%					0%	1%	3%	0%
2C1	0%	0%	0%				0%	2%	0%	0%
2C3	0%				51%		0%	1%		1%
2C4				0%		19%				
2C5								0%		0%
2D1									0%	
2D2									10%	
2E1				1%						
2E2					18%					
2F1				76%	0%	0%				
2F2				2%						
2F3				1%	0%					
2F4				19%						
2F5				1%	0%					
2F9				0%	31%	81%				
Overall	**2%**	**0%**	**4%**	**100%**	**100%**	**100%**	**0%**	**4%**	**14%**	**3%**

A9.3 SOLVENTS AND OTHER PRODUCT USE SECTOR (3)

Only emissions of NMVOCs occur from the solvents category. **Figure A 9.3.1** displays total NMVOC emissions for 1990-2010. **Table A 9.3.1 - Table A 9.3.4** summarise the changes observed through the time series as well as the contribution the emissions make to both sector 3 and the overall emissions in the UK during 2010. Emissions from this sector contribute 44% to overall emissions of NMVOC in the UK (**Table A 9.3.4**), and since 1990 emissions have declined by 48% (**Table A 9.3.1**).

The largest source of emissions within the solvents sector is category 3D (solvent and other product use: other), contributing 67% of NMVOC emissions in this sector (**Table A 9.3.3**).

Figure A 9.3.1 Emissions of NMVOC from IPCC Sector 3, 1990-2010

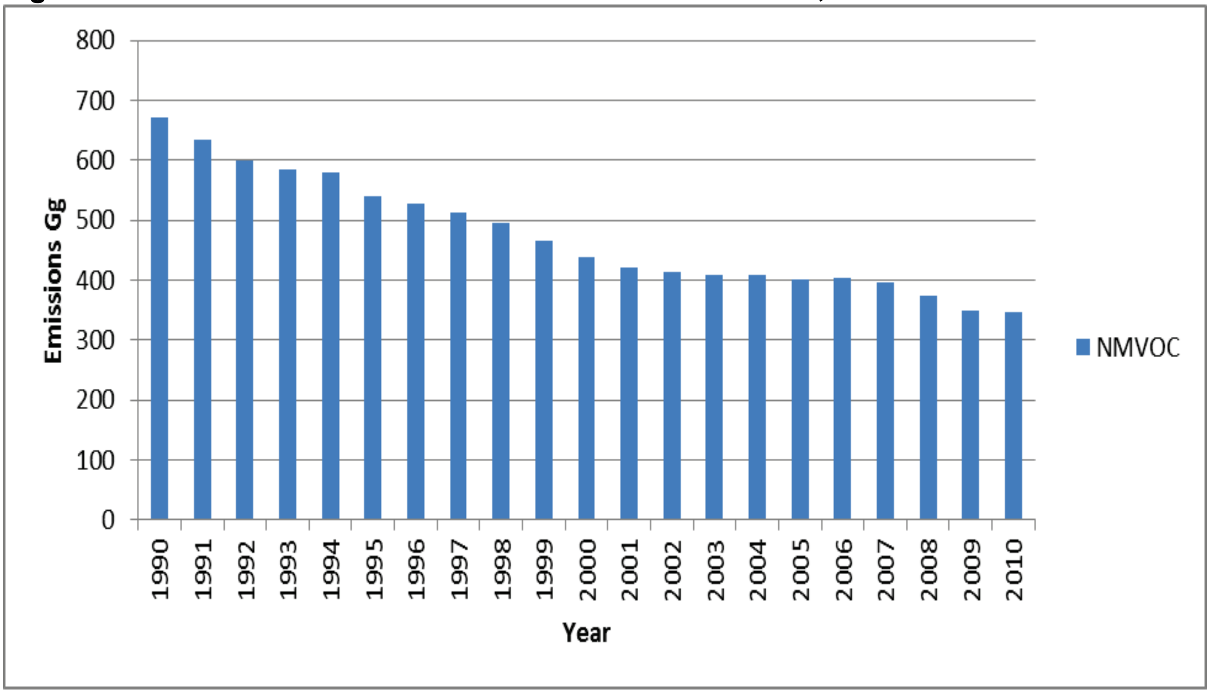


Table A 9.3.1 % Changes 1990-2010 within Sector 3

	NMVOC
3A	-64%
3B	-67%
3C	-75%
3D	-29%
Overall	**-48%**

Table A 9.3.2 % Changes 2009-2010 within Sector 3

	NMVOC
3A	-6%
3B	0%
3C	-1%
3D	1%
Overall	**-1%**

Table A 9.3.3 % Contribution to Sector 3

	NMVOC
3A	22%
3B	8%
3C	3%
3D	67%

Table A 9.3.4 % Contribution to Overall Pollutant Emissions

	NMVOC
3A	10%
3B	4%
3C	1%
3D	29%
Overall	**44%**

A9.4 AGRICULTURE SECTOR (4)

Figure A 9.4.1 and **Figure A 9.4.2** show both emissions of direct and indirect greenhouse gases for the agricultural sector (category 4) in the UK for the years 1990-2010. Emissions of direct greenhouse gases from this sector have decreased by 20% since 1990.

Table A 9.4.1-Table A 9.4.4 summarise the changes observed through the time series for each pollutant emitted from the agricultural sector, as well as the contribution emissions make to both the sector and the overall UK estimates during 2010.

A9.4.1 Methane

Agriculture is the largest source of methane in the UK, and in 2010 emissions from this sector totalled 44% (**Table A 9.4.4**) of the UK total. Since 1990, methane emissions from agriculture have declined by 20% (**Table A 9.4.1**). The largest single source within the agricultural sector is 4A1 – enteric fermentation from cattle. This accounts for 66% of methane emissions from this sector (**Table A 9.4.3**), and 29% of total methane emissions in 2010 (**Table A 9.4.4**). Since 1990, emissions from this sector have declined by 14% (**Table A 9.4.1**) and this is due to a decline in cattle numbers over this period.

A9.4.2 Nitrous Oxide

In 2010, nitrous oxide emissions from agriculture contributed 79% (**Table A 9.4.4**) to the UK total emission. Of this, 94% (**Table A 9.4.3**) came from the agricultural soils sector, 4D. Since 1990, emissions of N_2O from the agricultural sector have declined by 20% (**Table A 9.4.1**), driven by a fall in synthetic fertiliser application and a decline in animal population over this period.

A9.4.3 Nitrogen Oxides

Emissions from the agricultural sector occur for NO_X until 1993 only. During 1993, agricultural stubble burning was stopped and therefore emissions of NO_X became zero after this time.

A9.4.4 Carbon Monoxide

Emissions from the agricultural sector occur for CO until 1993 only. During 1993, agricultural stubble burning was stopped and therefore emissions of CO became zero after this time.

A9.4.5 Non-Methane Volatile Organic Compounds

Emissions from the agricultural sector occur for NMVOC until 1993 only. During 1993, agricultural stubble burning was stopped and therefore emissions of NMVOC became zero after this time.

Figure A 9.4.1 Emissions of direct greenhouse gases from IPCC sector 4, 1990-2010

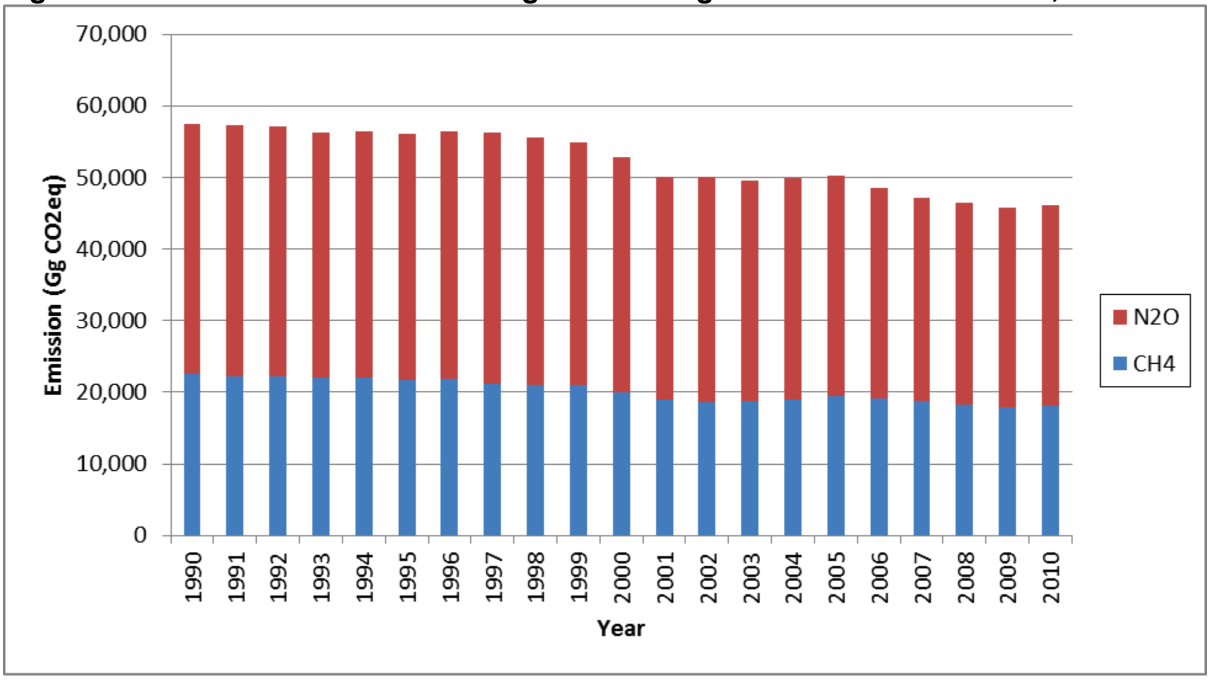


Figure A 9.4.2 Emissions of indirect greenhouse gases from IPCC sector 4, 1990-2010

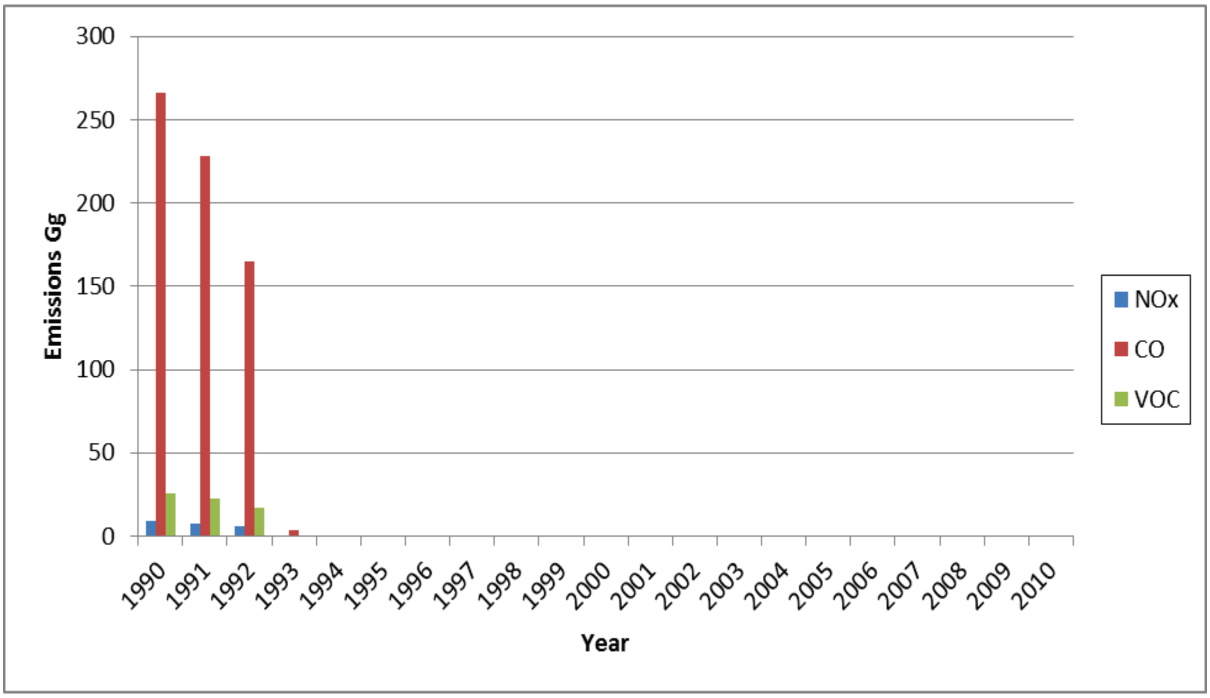


Table A 9.4.1 % Changes 1990-2010 within Sector 4

	CH_4	N_2O	NO_x	CO	NMVOC
4A1	-14%				
4A3	-30%				
4A4	-4%				
4A6	53%				
4A8	-41%				
4A10	-35%				
4B1	1%				
4B3	-30%				
4B4	-1%				
4B6	52%				
4B8	-65%				
4B9	54%				
4B10	-35%				
4B12		-17%			
4B13		-25%			
4B14		24%			
4D		-20%			
4F1	-100%	-100%	-100%	-100%	-100%
4F5	-100%	-100%	-100%	-100%	-100%
Overall	**-20%**	**-20%**	**-100%**	**-100%**	**-100%**

Table A 9.4.2 % Changes 2009-2010 within Sector 4

	CH_4	N_2O	Nox	CO	NMVOC
4A1	1%				
4A3	-2%				
4A4	-8%				
4A6	-17%				
4A8	-5%				
4A10	-11%				
4B1	3%				
4B3	-3%				
4B4	-8%				
4B6	-17%				
4B8	-6%				
4B9	3%				
4B10	-11%				
4B12		3%			
4B13		-1%			
4B14		-2%			
4D		1%			
4F1					
4F5					
Overall	**0%**	**1%**			

Table A 9.4.3 % Contribution to Sector 4

	CH_4	N_2O	NOx	CO	NMVOC
4A1	66%				
4A3	18%				
4A4	0%				
4A6	1%				
4A8	1%				
4A10	0%				
4B1	10%				
4B3	1%				
4B4	0%				
4B6	0%				
4B8	3%				
4B9	1%				
4B10	0%				
4B12		0%			
4B13		4%			
4B14		2%			
4D		94%			
4F1	0%	0%			
4F5	**0%**	**0%**			

Table A 9.4.4 % Contribution to Overall Pollutant Emissions

	CH_4	N_2O	NOx	CO	NMVOC
4A1	29%				
4A3	8%				
4A4	0%				
4A6	0%				
4A8	0%				
4A10	0%				
4B1	4%				
4B3	0%				
4B4	0%				
4B6	0%				
4B8	1%				
4B9	1%				
4B10	0%				
4B12		0%			
4B13		3%			
4B14		2%			
4D		74%			
4F1	0%	0%	0%	0%	0%
4F5	0%	0%	0%	0%	0%
Overall	**44%**	**79%**	**0%**	**0%**	**0%**

A9.5 LAND USE, LAND USE CHANGE AND FORESTRY (5)

Figure A 9.5.1 and **Figure A 9.5.2** show both net emissions of direct Greenhouse gases, and emissions of indirect Greenhouse gases for the land-use, land use change and forestry sector (sector 5) in the UK for the years 1990-2010.

Table A 9.5.1 and **Table A 9.5.2** summarise the changes observed through the time series for each pollutant.

A9.5.1 Carbon Dioxide

Figure A 9.5.1 shows net emissions/removals of carbon dioxide. In 1990, the UK was a net source of CO_2 from LULUCF activities. In 2010, the UK was a net sink, therefore showing a decrease in emissions of 246%.

A9.5.2 Methane

Emissions of methane from Land Use Change and Forestry are emitted from forestry, cropland, grassland and settlements categories (5A, 5B, 5C and 5E). Emissions from this sector have increased by 19% from 2009 (**Table A 9.5.2**), and have increased overall by 56% since 1990 (**Table A 9.5.1**). Methane emissions from this sector contribute only 0.1% to total methane emissions.

A9.5.3 Nitrous Oxide

Emissions of nitrous oxide from this sector have decreased by 21% since 1990 (**Table A 9.5.1**), and shown a decline of 2% since 2009 (**Table A 9.5.2**). Emissions from this sector contribute around 2% to total nitrous oxide emissions.

A9.5.4 Nitrogen Oxides

Emissions of nitrogen oxides from Land Use Change and Forestry are emitted from forestry, cropland, grassland and settlements categories (5A, 5B, 5C and 5E). Emissions from this sector have increased by 19% since 2009 (**Table A 9.5.2**), and have increased overall by 56% since 1990 (**Table A 9.5.1**).

A9.5.5 Carbon Monoxide

Emissions of carbon monoxide from Land Use Change and Forestry are emitted from forestry, cropland, grassland and settlements categories (5A, 5B, 5C and 5E), due to the burning of biomass.

Figure A 9.5.1 Net emissions/removals of direct greenhouse gases from IPCC sector 5, 1990-2010

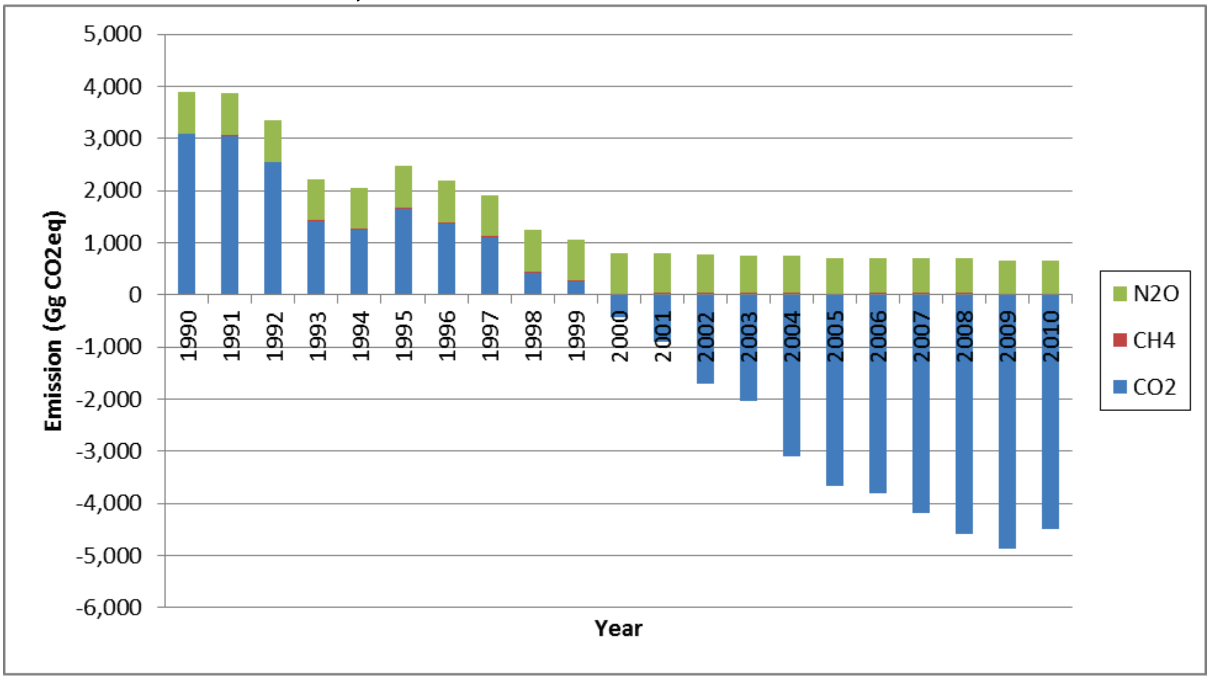


Figure A 9.5.2 Emissions of indirect greenhouse gases from IPCC sector 5, 1990-2010

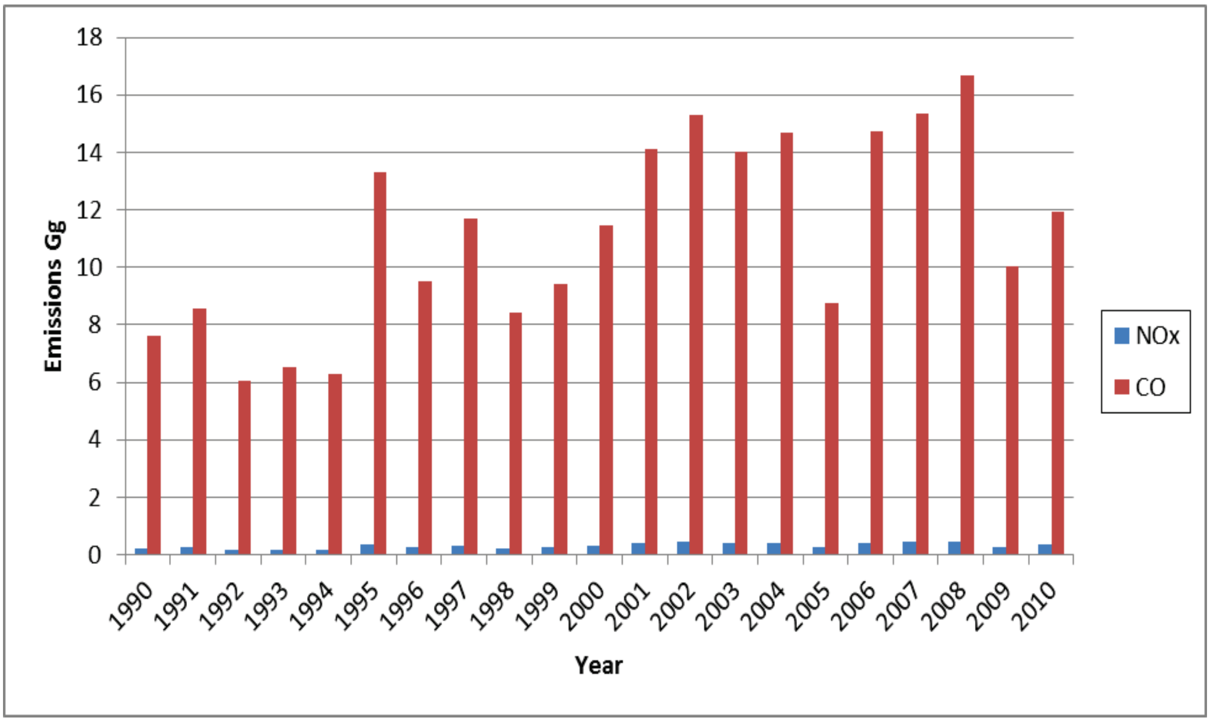


Table A 9.5.1 % Changes 1990-2010 within Sector 5

	CO_2	CH_4	N_2O	NOx	CO
5A	-13%	90%	-65%	90%	90%
5B	-23%	189%	-20%	189%	189%
5C	36%	201%	201%	201%	201%
5D	-45%		-87%		
5E	-11%	-17%	-17%	-17%	-17%
5F					
5G	131%		3101%		
Overall	**-246%**	**56%**	**-21%**	**56%**	**56%**

Table A 9.5.2 % Changes 2009-2010 within Sector 5

	CO_2	CH_4	N_2O	NOx	CO
5A	-17%	-14%	-2%	-14%	-14%
5B	-5%	220%	-2%	220%	220%
5C	-4%	90%	90%	90%	90%
5D	0%		0%		
5E	0%	1%	1%	1%	1%
5F					
5G	63%		2%		
Overall	**-8%**	**19%**	**-2%**	**19%**	**19%**

A9.6 WASTE (6)

Figure A 9.6.1 and **Figure A 9.6.2** show emissions of both direct and indirect greenhouse gases from the waste category (sector 6) in the UK for the years 1990-2010. Emissions from direct greenhouse gases in this sector have declined by 64% since 1990. This is mostly as a result of a decline in methane emissions.

Table A 9.6.1 to **Table A 9.6.4** summarise the changes observed through the time series for each pollutant, as well as the contribution the emissions make to both sector 6 and the overall emissions in the UK during 2010.

A9.6.1 Carbon Dioxide

Emissions of carbon dioxide from the waste sector occur from waste incineration only. These emissions are small in comparison to CO_2 emissions from other sectors and have a negligible effect on overall net CO_2 emissions in the UK (see **Table A 9.6.4**). Since 1990, CO_2 emissions arising from the waste sector have decreased by 76% (**Table A 9.6.1**) although have seen little change since 2009 (**Table A 9.6.2**).

A9.6.2 Methane

Emissions of methane from the waste sector accounted for around 36% (**Table A 9.6.4**) of total CH_4 emissions in the UK during 2010. Emissions from methane occur from landfills, waste water treatment and waste incineration. The largest single source is landfill (6A1), with emissions from wastewater treatment and incineration being small in comparison (see **Table A 9.6.3**). Emissions estimates from landfill are derived from the amount of biodegradable waste disposed of to landfill and are based on a model of the kinetics of anaerobic digestion involving four classifications of landfill site. The model also accounts for the effects of methane recovery, utilisation and flaring. Since 1990, methane emissions from landfill have declined by 66% (**Table A 9.6.1**) due to the implementation of methane recovery systems. This trend is likely to continue as all new landfill sites are required to have these systems and many existing sites may have systems retrofitted.

A9.6.3 Nitrous Oxide

Nearly all nitrous oxide waste emissions in the waste sector occur from the wastewater handling (see **Table A 9.6.3**). Since 1990, N_2O emissions from this sector have increased by 90% **Table** A 9.6.1). Overall, this sector contributes just 3% (**Table A 9.6.4**) to overall nitrous oxide emissions.

A9.6.4 Nitrogen Oxides

Emissions of NO_x from the waste category have a negligible effect on overall UK emissions.

A9.6.5 Carbon Monoxide

Emissions of CO from the waste category have a negligible effect on overall UK emissions, contributing around 1% during 2010 (**Table A 9.6.4**).

A9.6.6 Non-Methane Volatile Organic Compounds

Emissions of NMVOC from the waste category have a very small influence (4%) (**Table A 9.6.4**) on overall UK emissions.

A9.6.7 Sulphur Dioxide

Emissions of SO_2 from the waste category have a negligible effect on overall UK emissions.

Figure A 9.6.1 Emissions of direct greenhouse gases from IPCC sector 6, 1990-2010

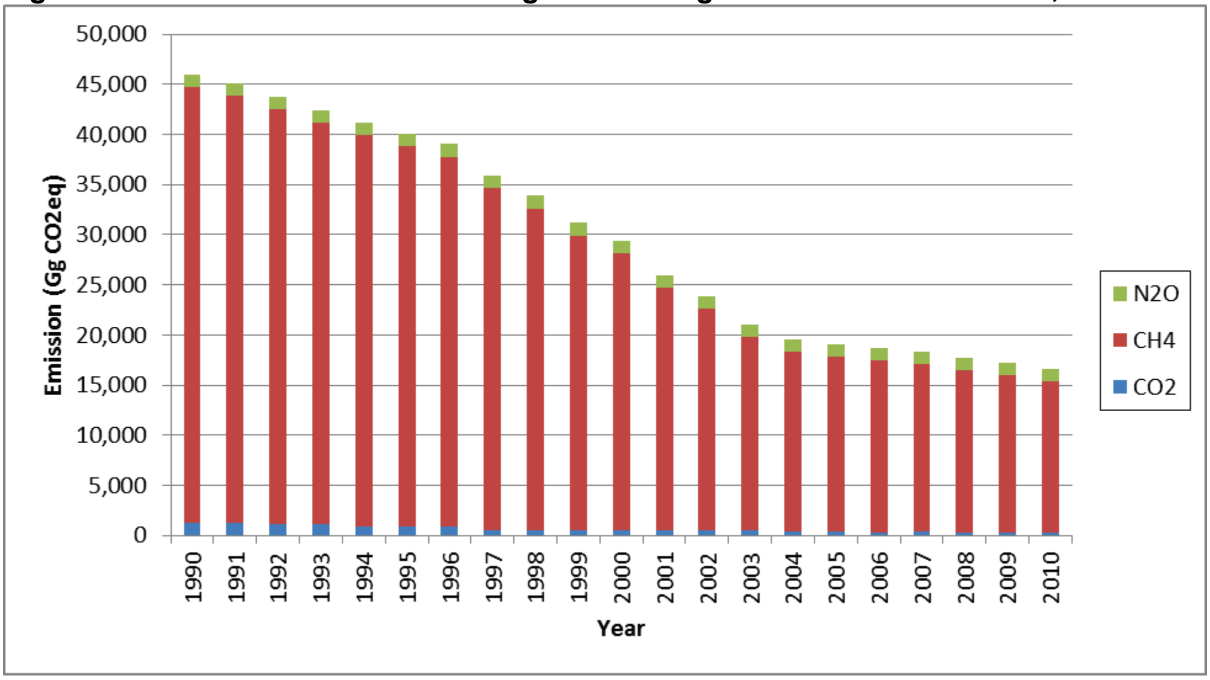


Figure A 9.6.2 Emissions of indirect greenhouse gases from IPCC sector 6, 1990-2010

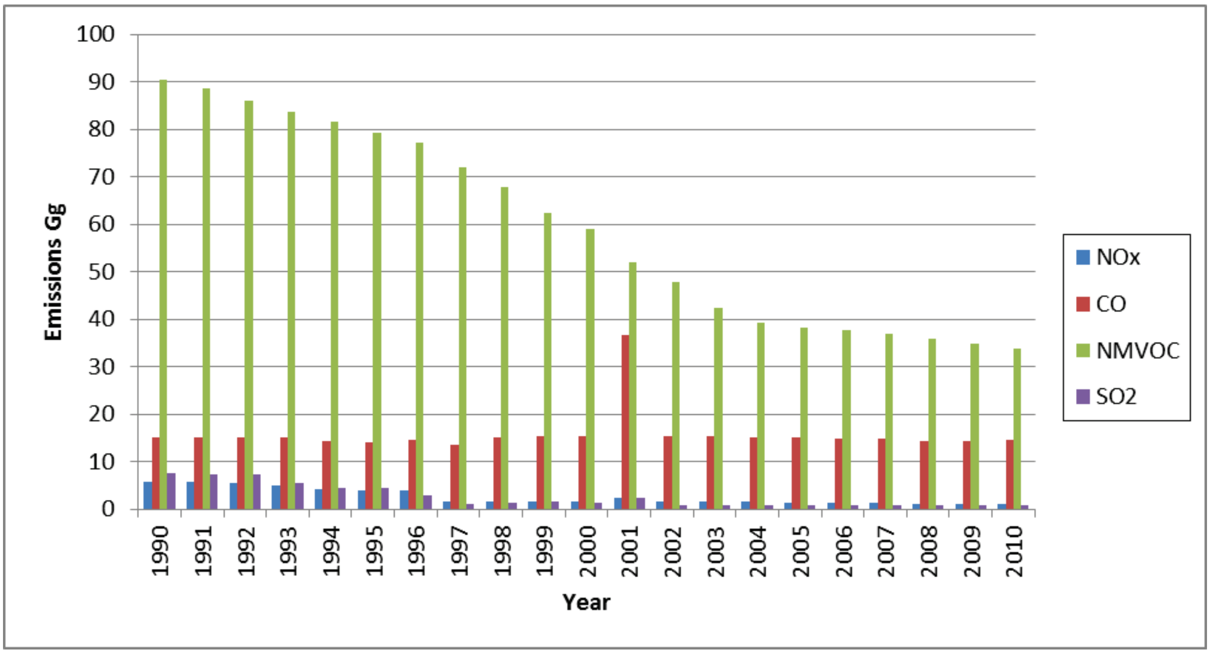


Table A 9.6.1 % Changes 1990-2010 within Sector 6

	CO_2	CH_4	N_2O	NOx	CO	NMVOC	SO_2
6A1		-66%				-66%	
6B2		21%	-1%				
6C	-76%	-95%	-1%	-79%	-4%	-4%	-90%
Overall	**-76%**	**-65%**	**-1%**	**-79%**	**-4%**	**-63%**	**-90%**

Table A 9.6.2 % Changes 2009-2010 within Sector 6

	CO_2	CH_4	N_2O	NOx	CO	NMVOC	SO_2
6A1		-4%				-4%	
6B2		0%	-1%				
6C	2%	2%	4%	5%	1%	0%	2%
Overall	**2%**	**-4%**	**0%**	**5%**	**1%**	**-3%**	**2%**

Table A 9.6.3 % Contribution to Sector 6

	CO_2	CH_4	N_2O	NOx	CO	NMVOC	SO_2
6A1		98%				87%	
6B2		2%	96%				
6C	100%	0%	4%	100%	100%	13%	100%

Table A 9.6.4 % Contribution to Overall Pollutant Emissions

	CO_2	CH_4	N_2O	NOx	CO	NMVOC	SO_2
6A1		36%				4%	
6B2		1%	3%				
6C	0%	0%	0%	0%	1%	1%	0%
Overall	**0%**	**36%**	**3%**	**0%**	**1%**	**4%**	**0%**

A10 ANNEX 10: Verification

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

A10.1 MODELLING APPROACH USED FOR THE VERIFICATION OF THE UK GHGI

In order to provide verification of the UK Greenhouse Gas Inventory (GHGI), DECC (Department of Energy and Climate Change) have established and maintained a high-quality remote observation station at Mace Head on the west coast of Ireland. The station reports high-frequency concentrations of the key greenhouse gases and is under the supervision of Dr. Simon O'Doherty of the University of Bristol (O'Doherty *et al.* 2004).

The Met Office, under contract to DECC, employs the Lagrangian dispersion model NAME (Numerical Atmospheric dispersion Modelling Environment) (Ryall *et al*. 1998) (Jones et al. 2007) driven by three-dimensional modelled meteorology to interpret the observations. NAME determines the history of the air arriving at Mace Head at the time of each observation. By estimating and removing the underlying *baseline* trends (Northern Hemisphere mid-latitude atmospheric concentrations where the short-term impact of regional pollution have been removed from the data) from the observations and by modelling where the air has passed over on route to Mace Head on a regional scale, estimates of UK emissions are made. This NAME-inversion methodology uses an iterative best-fit technique which searches a set of random emission maps to determine the one that most accurately mimics the Mace Head observations [Manning et al 2003, 2011].

In the work presented here both the NAME *baseline* trends and the UK emission estimates are presented. The 'top-down' NAME-inversion estimates of UK emissions are compared to the 'bottom-up' GHGI estimates.

A10.2 METHANE

Figure A.10.2.1 shows the baseline atmospheric concentration of methane from 1990 onwards. The underlying trend is positive but there is strong year to year variability and a strong seasonal cycle.

In **Figure A.10.2.2** the emission estimates made for the UK with the NAME-inversion methodology are compared to the GHGI emission estimates for the period 1990 onwards.

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 diurnal, annual, growth and decay cycles. Such non-uniform emissions will add to the uncertainties in the modelling, although in North West Europe the natural emissions are thought to be small compared to the anthropogenic emissions (<5%, Bergamaschi *et al* 2005). Due to the relatively strong local (within 20km) influence of biogenic emissions at Mace Head, a peat bog area, observations taken when local emissions will be significant (low wind speeds and low boundary layer heights) have been removed from the data set prior to applying the inversion technique.

The GHGI trend is monotonically downwards whereas the median of the NAME estimates show no clear trend (**Figure A 10.2.2**). The agreement between the two estimates is good from 2003 onwards.

Figure A 10.2.1 Monthly and annual Northern Hemisphere trend in methane estimated from Mace Head observations (ppb). The grey area denotes data that are not yet ratified.

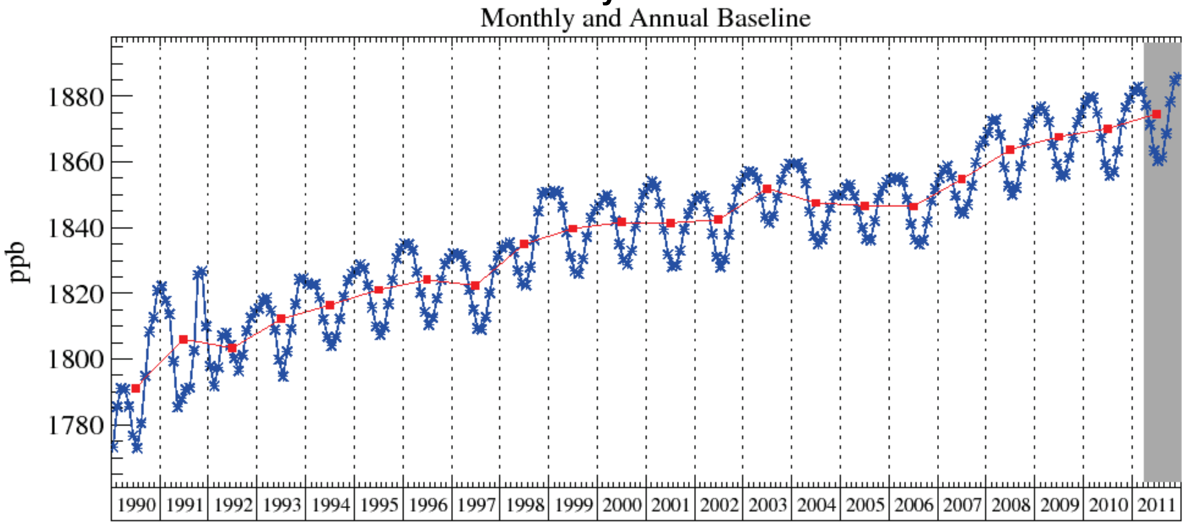
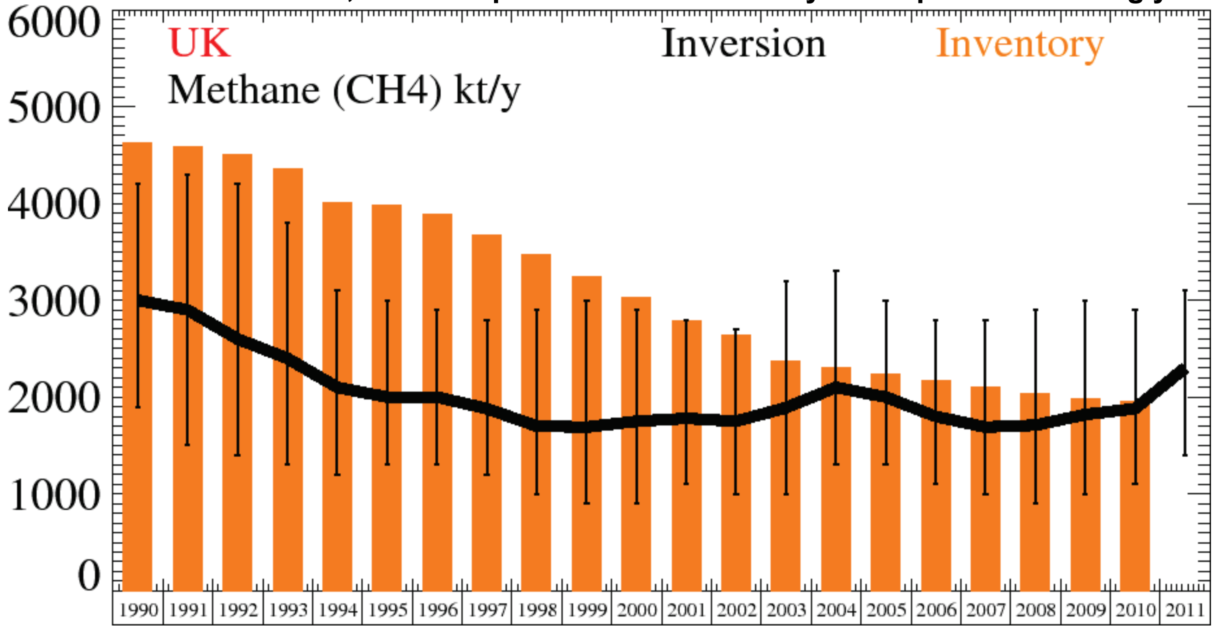


Figure A 10.2.2 Verification of the UK emission inventory estimates for methane in Gg yr^{-1} for 1990-2011. GHGI estimates are shown in orange. NAME-inversion estimates are shown in black. NAME-inversion uncertainties are shown with the black whisker lines showing 5th, median, and 95th percentiles. Note: 1 kt yr^{-1} is equivalent to 1 Gg yr^{-1}.



A10.3 NITROUS OXIDE

Figure A10.3.1 shows the baseline atmospheric concentration of nitrous oxide from 1990 onwards. The annual trend is monotonic and positive at ~0.7 ppb/yr.

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 10.3.2 shows the NAME-inversion and GHGI emission estimates for the UK for nitrous oxide for the period 1990 onwards. The median NAME-inversion estimates are approximately 30-40 kt lower than the GHGI estimates throughout the whole time period. The trends in the time-series are in good agreement. Both show declining UK totals. The GHGI estimates show a sharp decline (40 Gg) between 1998 and 1999 in line with the introduction of the clean technology at an adipic acid plant in Wilton, north east England. It is estimated to have cut its emissions of N_2O by 90%, from 46 thousand tonne yr^{-1} to around 6 thousand tonne yr^{-1} (DEFRA, 2000). The NAME-inversion estimates, with a longer averaging period, show a more gradual decline from 1998 to 2003 but the overall reduction is similar.

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

Figure A 10.3.1 Monthly and annual Northern Hemisphere trend in nitrous oxide estimated from Mace Head observations (ppb). The grey area denotes data that are not yet ratified.

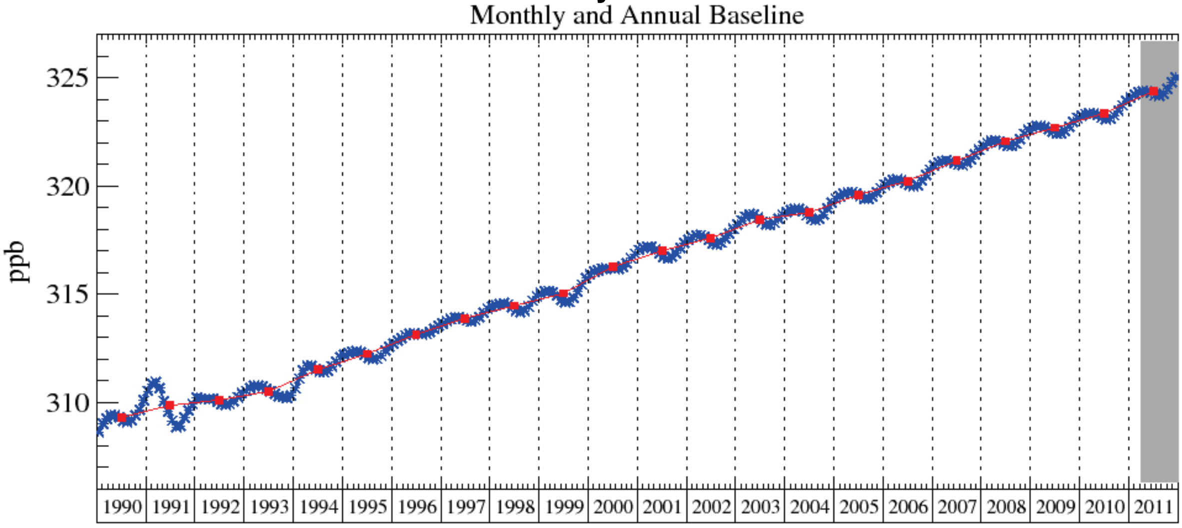
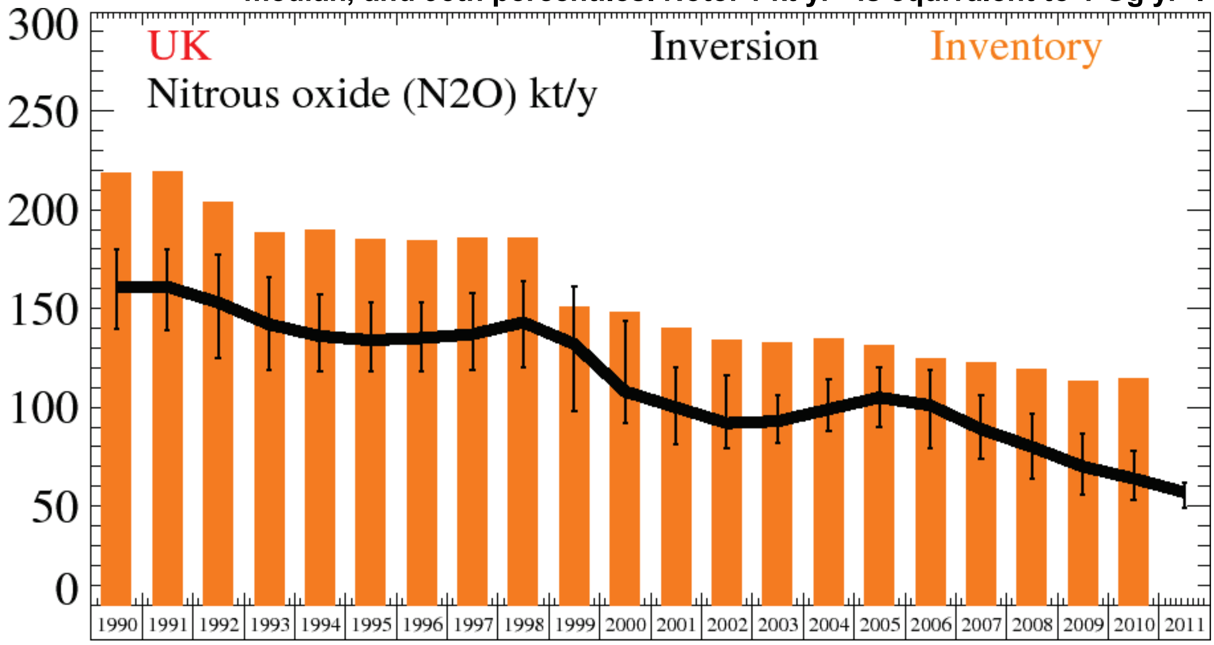


Figure A 10.3.2 Verification of the UK emission inventory estimates for nitrous oxide in Gg yr^{-1} for 1990-2011. GHGI estimates are shown in orange. NAME-inversion estimates are shown in black. NAME-inversion uncertainties are shown with the black whisker lines showing 5th, median, and 95th percentiles. Note: 1 kt yr^{-1} is equivalent to 1 Gg yr^{-1}.



A10.4 HYDROFLUOROCARBONS

A10.4.1 HFC-134a

Figure A 10.4.1 shows the baseline atmospheric concentration of HFC-134a from 1995 onwards. The annual trend is monotonic and positive at 4 ppt/yr.

Figure A 10.4.1 Monthly and annual Northern Hemisphere trend in HFC-134a estimated from Mace Head observations (ppt). The grey area denotes data that are not yet ratified.

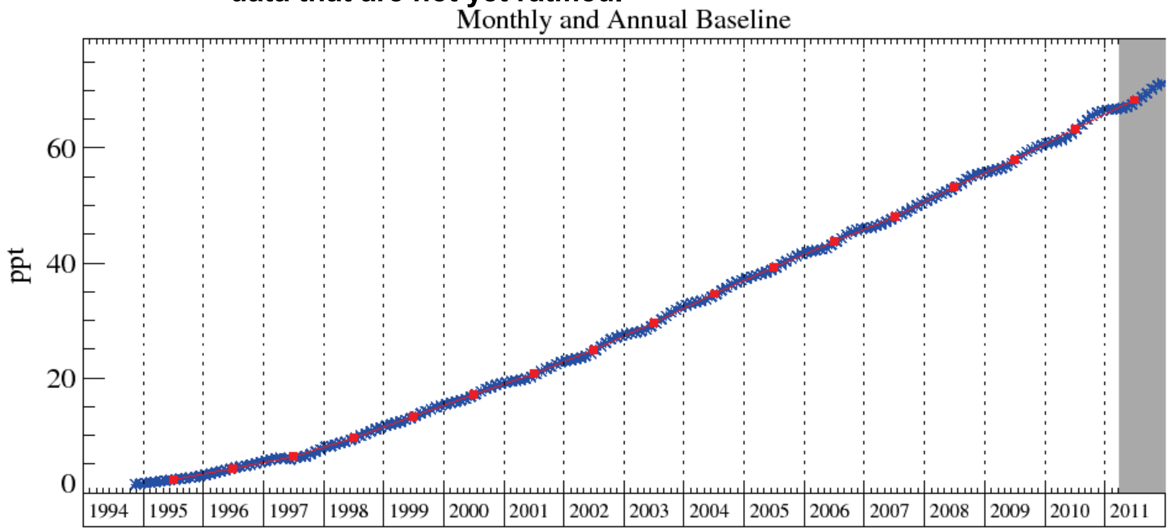
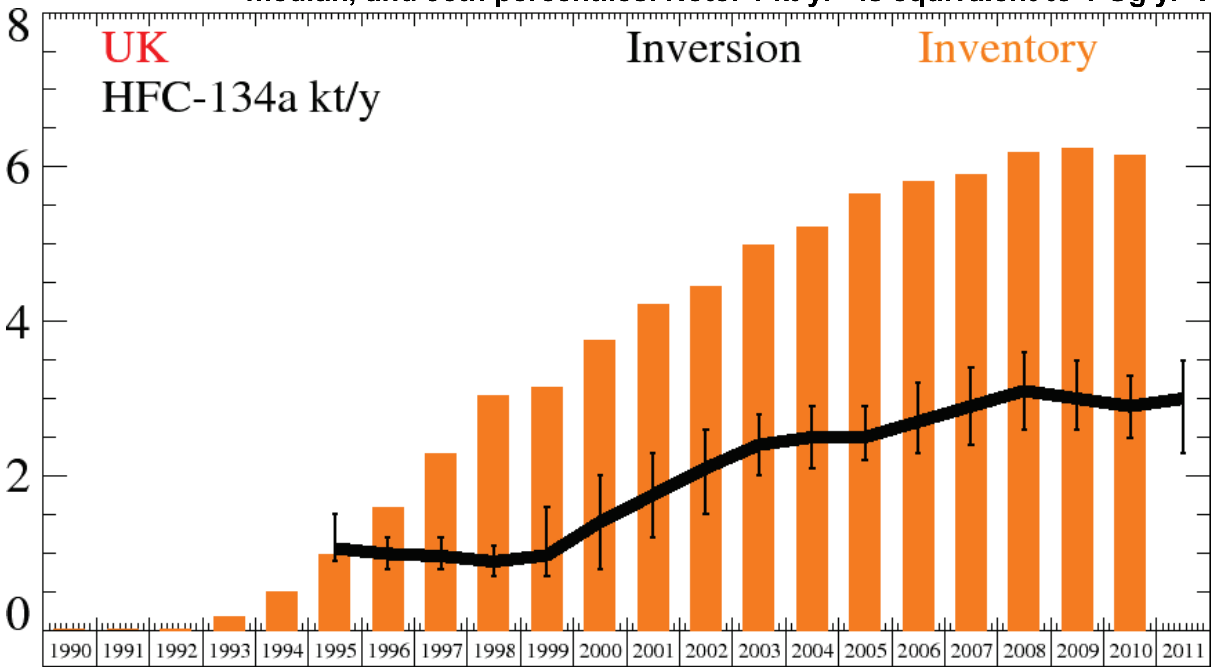


Figure A 10.4.2 shows the NAME-inversion and GHGI emission estimates for the UK for HFC-134a for the period 1990 onwards. The GHGI shows an earlier increase in emission compared to the NAME-inversion estimates. The NAME-inversion estimates begin their rise in 1999-2000 whereas the GHGI estimates began to rise from 1994.

Figure A 10.4.2 Verification of the UK emission inventory estimates for HFC-134a in Gg yr^{-1} for 1990-2011. GHGI estimates are shown in orange. NAME-inversion estimates are shown in black. NAME-inversion uncertainties are shown with the black whisker lines showing 5th, median, and 95th percentiles. Note: 1 kt yr^{-1} is equivalent to 1 Gg yr^{-1}.



A10.4.2 HFC-152a

Figure A 10.4.3 shows the baseline atmospheric concentration of HFC-152a from 1995 onwards. The annual trend shows a strong rise from the mid-1990s until 2008 and then a much reduced annual increase.

Figure A 10.4.3 Monthly and annual Northern Hemisphere trend in HFC-152a estimated from Mace Head observations (ppt). The grey area denotes data that are not yet ratified.

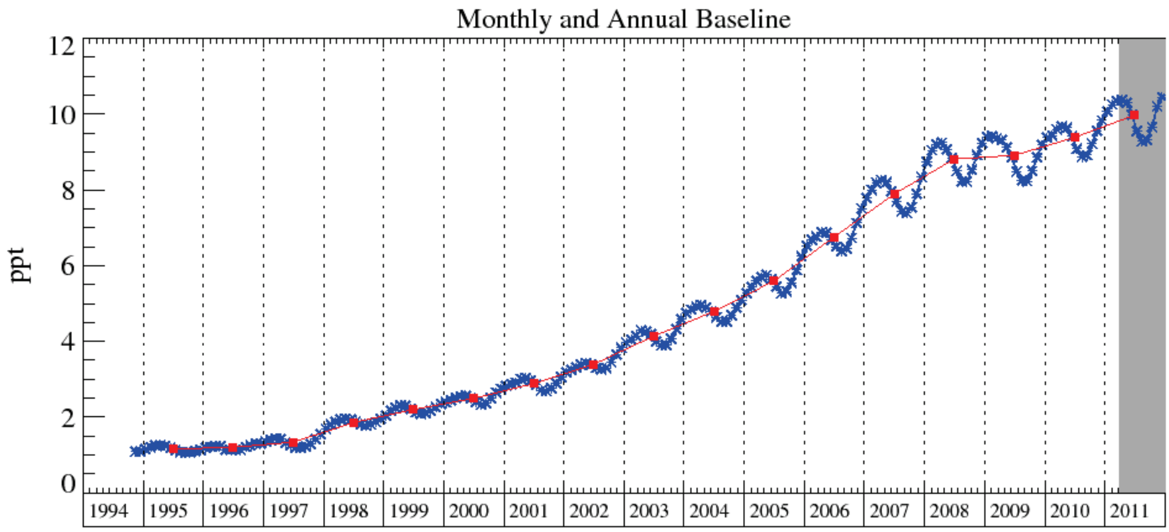
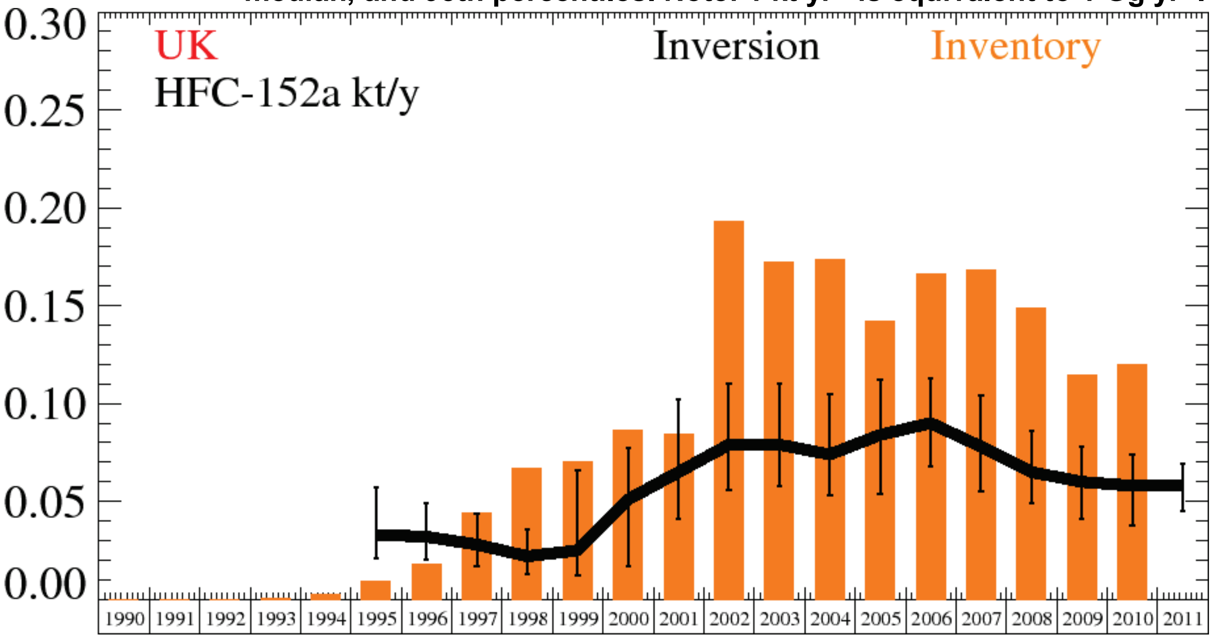


Figure A 10.4.4 shows the NAME-inversion and the GHGI emission estimates for the UK for HFC-152a for the period 1990 onwards. From 2002 the GHGI estimates are twice those estimated through the inversion modelling.

Figure A 10.4.4 Verification of the UK emission inventory estimates for HFC-152a in Gg yr^{-1} for 1990-2011. GHGI estimates are shown in orange. NAME-inversion estimates are shown in black. NAME-inversion uncertainties are shown with the black whisker lines showing 5th, median, and 95th percentiles. Note: 1 kt yr^{-1} is equivalent to 1 Gg yr^{-1}.



A10.4.3 HFC-125

Figure A 10.4.5 shows the baseline atmospheric concentration of HFC-125 from 1998 onwards. The annual trend is monotonic and positive at 0.7 ppt/yr.

NAME-inversion emission estimates for the UK for HFC-125 for the period 1999 onwards are shown in **Figure A 10.4.6**. Both estimates suggest that the emissions of HFC-125 from the UK have increased significantly from the mid-1990s. The agreement between the 2 methods is excellent.

Figure A 10.4.5 Monthly and annual Northern Hemisphere trend in HFC-125 estimated from Mace Head observations (ppt). The grey area denotes data that are not yet ratified.

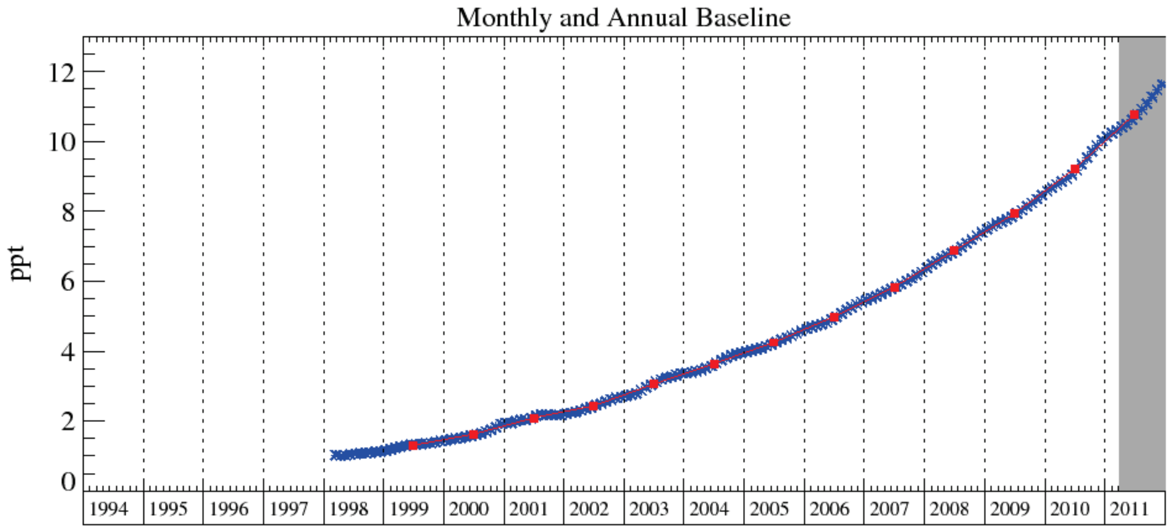
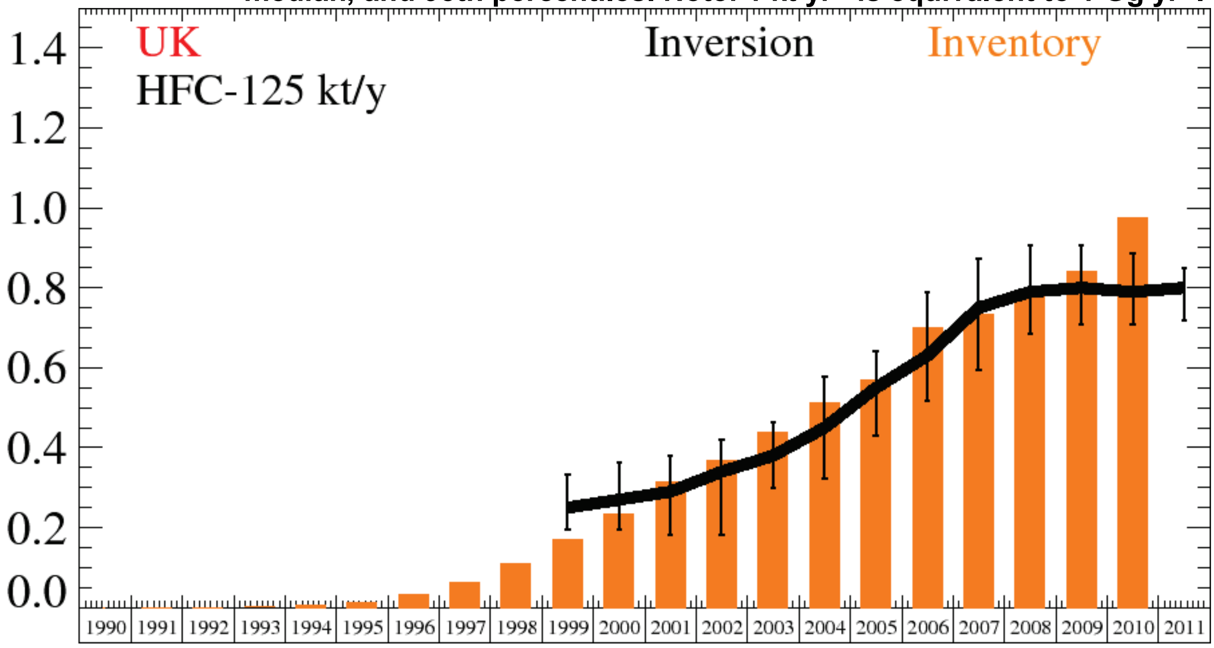


Figure A 10.4.6 Verification of the UK emission inventory estimates for HFC-125 in Gg yr^{-1} for 1990-2010. GHGI estimates are shown in orange. NAME-inversion estimates are shown in black. NAME-inversion uncertainties are shown with the black whisker lines showing 5th, median, and 95th percentiles. Note: 1 kt yr^{-1} is equivalent to 1 Gg yr^{-1}.



A10.4.4 HFC-143a

Figure A 10.4.7 shows the baseline atmospheric concentration of HFC-143a from 2004 onwards. The annual trend is monotonic and positive at more than 1 ppt/yr.

NAME-inversion emission estimates for the UK for HFC-143a for the period 2004 onwards are shown below in **Figure A 10.4.8** and are compared to the GHGI estimates. UK emissions as estimated through the GHGI are increasing year on year from the early 1990s. The NAME-inversion estimates show a rise 2004-2007 and then a decline but the uncertainty ranges are such that a flat emission is also possible.

Figure A 10.4.7 Monthly and annual Northern Hemisphere trend in HFC-143a estimated from Mace Head observations (ppt). The grey area denotes data that are not yet ratified.

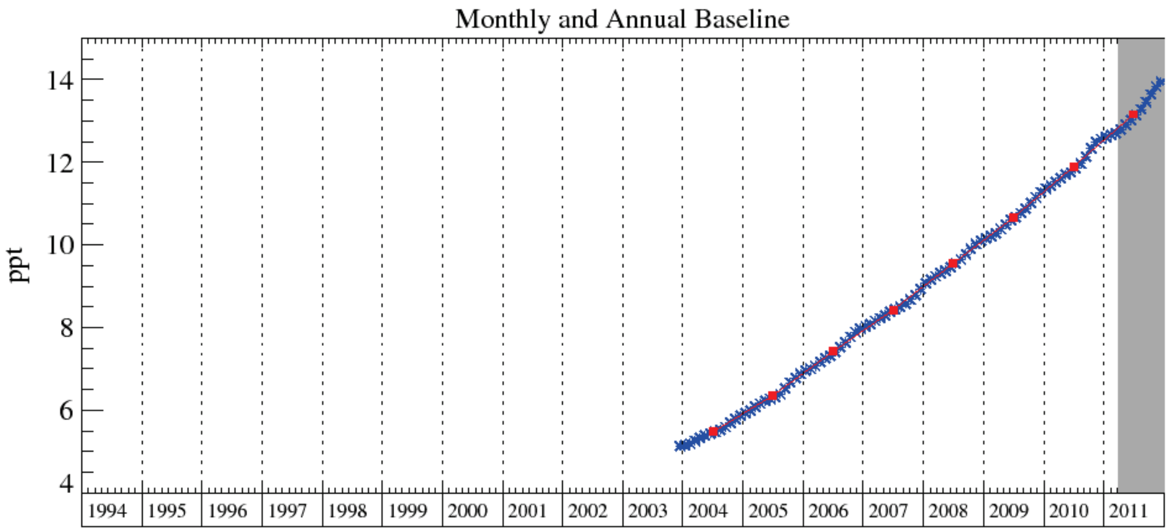
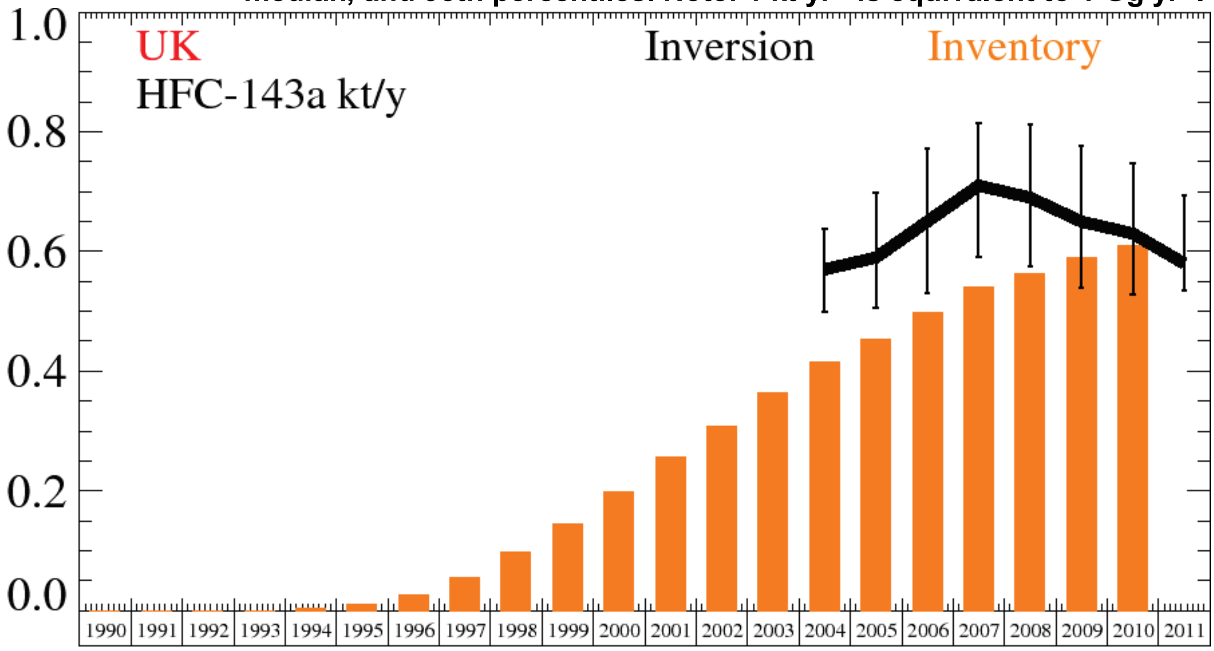


Figure A 10.4.8 Verification of the UK emission inventory estimates for HFC-143a in Gg yr^{-1} for 1990-2010. GHGI estimates are shown in orange. NAME-inversion estimates are shown in black. NAME-inversion uncertainties are shown with the black whisker lines showing 5th, median, and 95th percentiles. Note: 1 kt yr^{-1} is equivalent to 1 Gg yr^{-1}.



A10.4.5 HFC-23

Figure A 10.4.9 shows the baseline atmospheric concentration of HFC-23 from 2008 onwards. The annual trend is monotonic and positive at around 0.5 ppt/yr.

NAME-inversion emission estimates for the UK for HFC-23 for 2008-2010 agree with the recent low emissions estimated by the GHGI (**Figure A 10.4.10**).

Figure A 10.4.9 Monthly and annual Northern Hemisphere trend in HFC-23 estimated from Mace Head observations (ppt). The grey area denotes data that are not yet ratified.

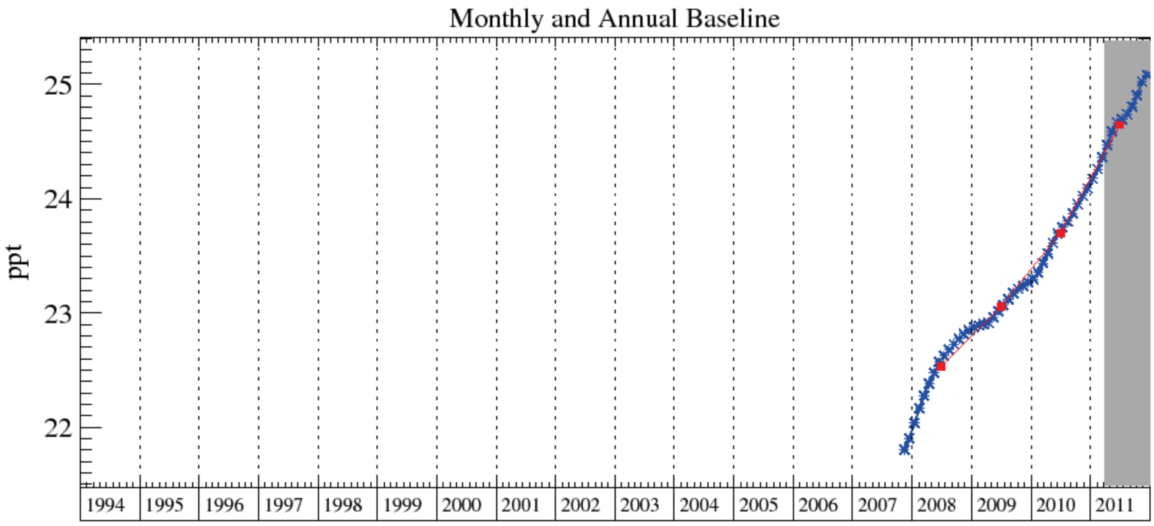
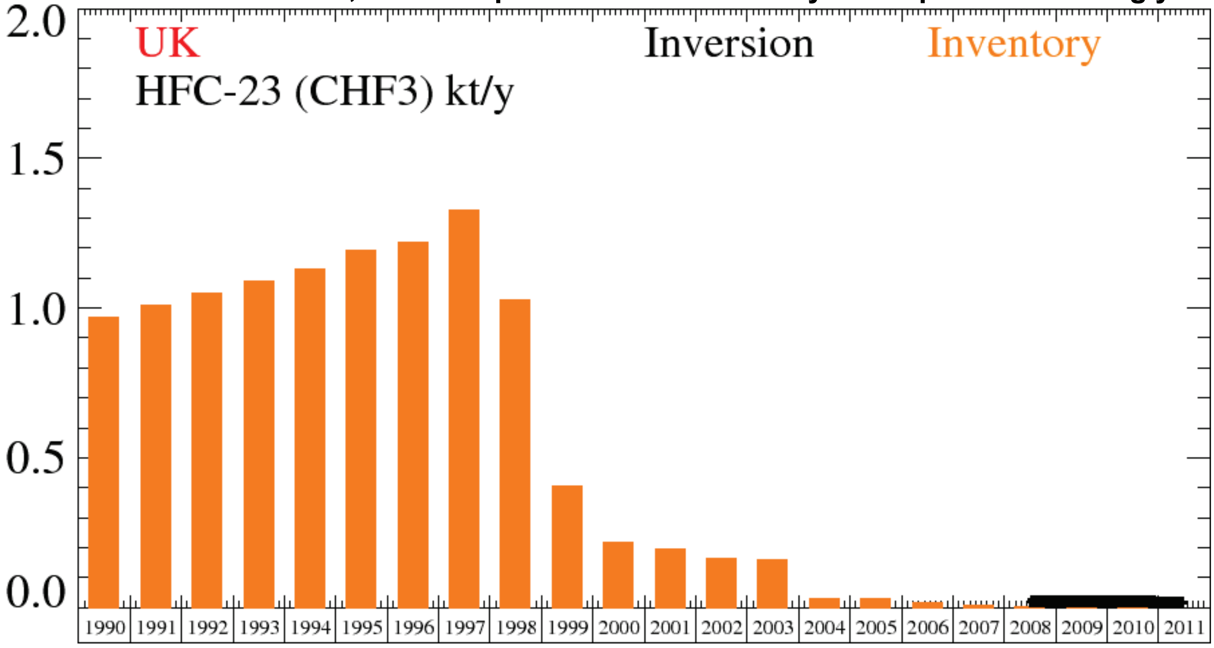


Figure A 10.4.10 Verification of the UK emission inventory estimates for HFC-23 in Gg yr^{-1} for 1990-2010. GHGI estimates are shown in orange. NAME-inversion estimates are shown in black. NAME-inversion uncertainties are shown with the black whisker lines showing 5th, median, and 95th percentiles. Note: 1 kt yr^{-1} is equivalent to 1 Gg yr^{-1}.



A10.4.6 HFC-32

Figure A 10.4.11 shows the baseline atmospheric concentration of HFC-32 from 2004 onwards. The annual trend is monotonic and positive at around 0.7 ppt/yr.

NAME-inversion emission estimates for the UK for HFC-32 for 2004 onwards are shown in **Figure A 10.4.12**. The NAME-inversion emission estimates are lower than the GHGI estimates but the trend agrees 2004-2008. Post-2008 the NAME-inversion estimates flatten whereas the GHGI continues to increase.

Figure A 10.4.11 Monthly and annual Northern Hemisphere trend in HFC-32 estimated from Mace Head observations (ppt). The grey area denotes data that are not yet ratified.

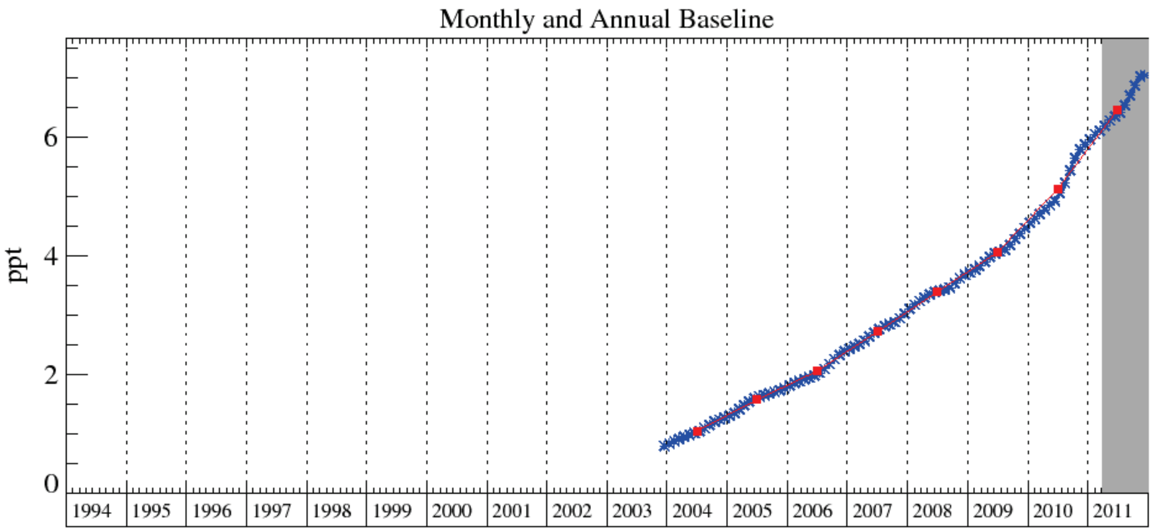
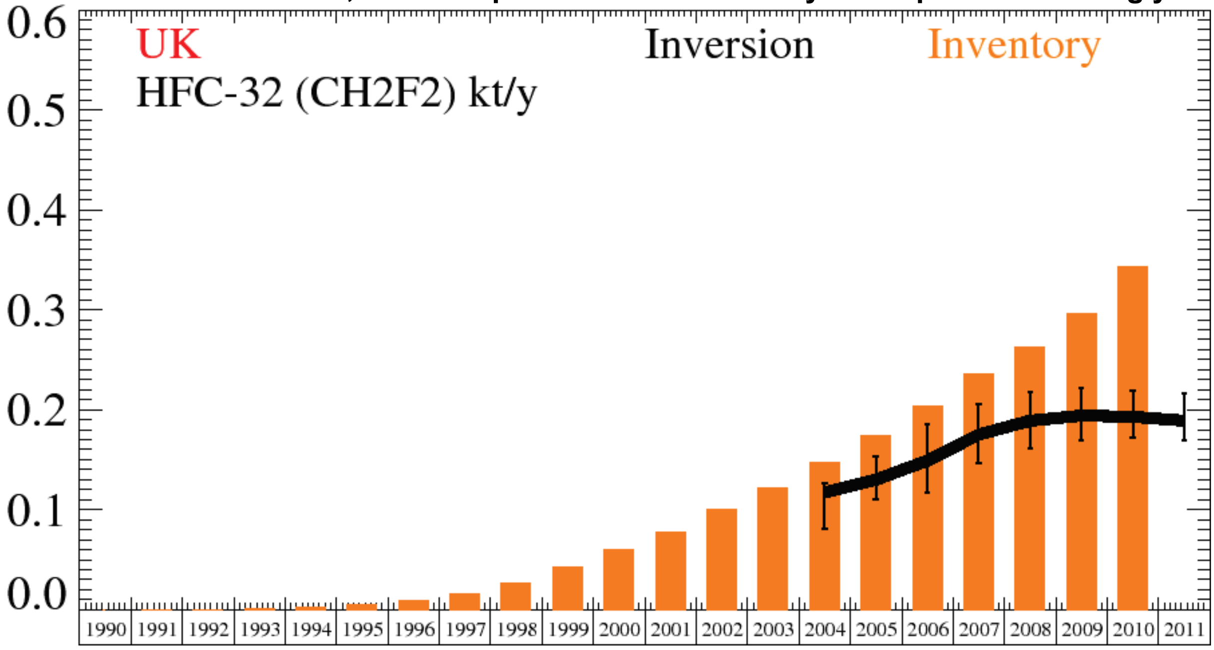


Figure A 10.4.12 Verification of the UK emission inventory estimates for HFC-32 in Gg yr^{-1} for 1990-2010. GHGI estimates are shown in orange. NAME-inversion estimates are shown in black. NAME-inversion uncertainties are shown with the black whisker lines showing 5th, median, and 95th percentiles. Note: 1 kt yr^{-1} is equivalent to 1 Gg yr^{-1}.



A10.5 PERFLUOROCARBONS

A10.5.1 PFC-14

Figure A 10.5.1 shows the baseline atmospheric concentration of PFC-14 from 2004 onwards. The annual trend is monotonic and positive at around 0.7 ppt/yr.

The NAME-inversion and GHGI estimates of UK emissions of PFC-14 are shown in **Figure A 10.5.2**. The NAME estimates are approximately double those reported in the GHGI. However the emissions now are significantly smaller than estimated in the GHGI in the early 1990s.

Figure A 10.5.1 Monthly and annual Northern Hemisphere trend in PFC-14 estimated from Mace Head observations (ppt). The grey area denotes data that are not yet ratified.

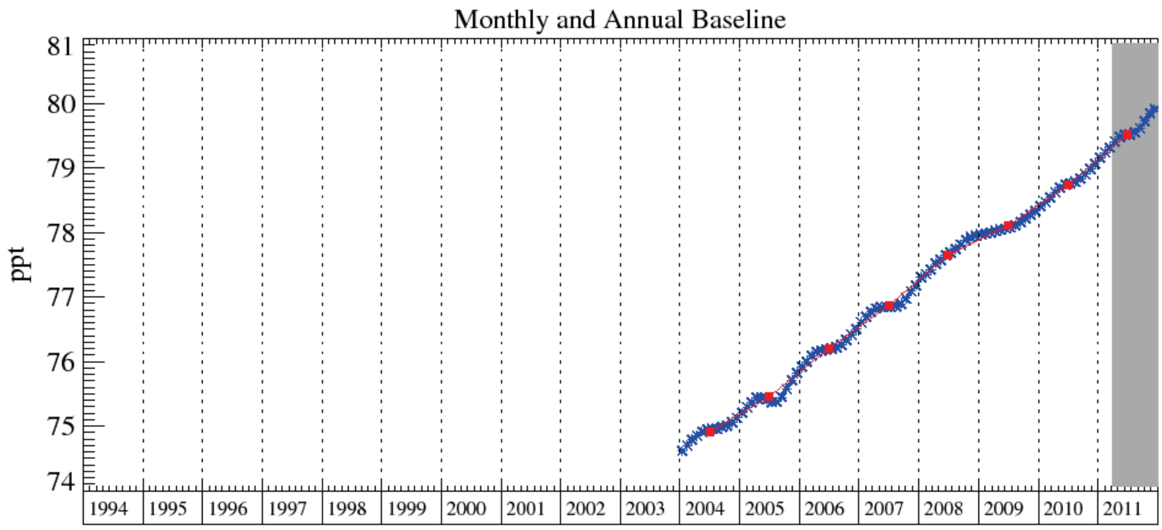
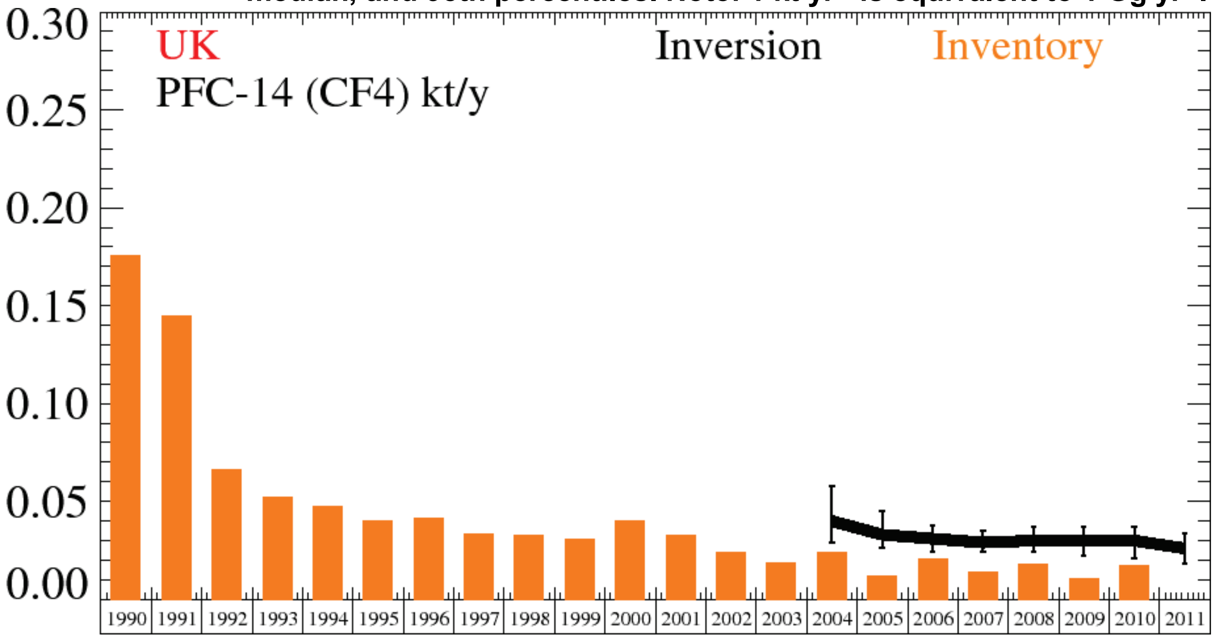


Figure A 10.5.2 Verification of the UK emission inventory estimates for PFC-14 in Gg yr^{-1} for 1990-2010. GHGI estimates are shown in orange. NAME-inversion estimates are shown in black. NAME-inversion uncertainties are shown with the black whisker lines showing 5th, median, and 95th percentiles. Note: 1 kt yr^{-1} is equivalent to 1 Gg yr^{-1}.



A10.5.2 PFC-116

Figure A 10.5.3 shows the baseline atmospheric concentration of PFC-116 from 2004 onwards. The annual trend is monotonic and positive at around 0.1 ppt/yr.

The UK NAME-inversion estimates are broadly consistent with those reported in the GHGI (**Figure A 10.5.4**).

Figure A 10.5.3 Monthly and annual Northern Hemisphere trend in PFC-116 estimated from Mace Head observations (ppt). The grey area denotes data that are not yet ratified.

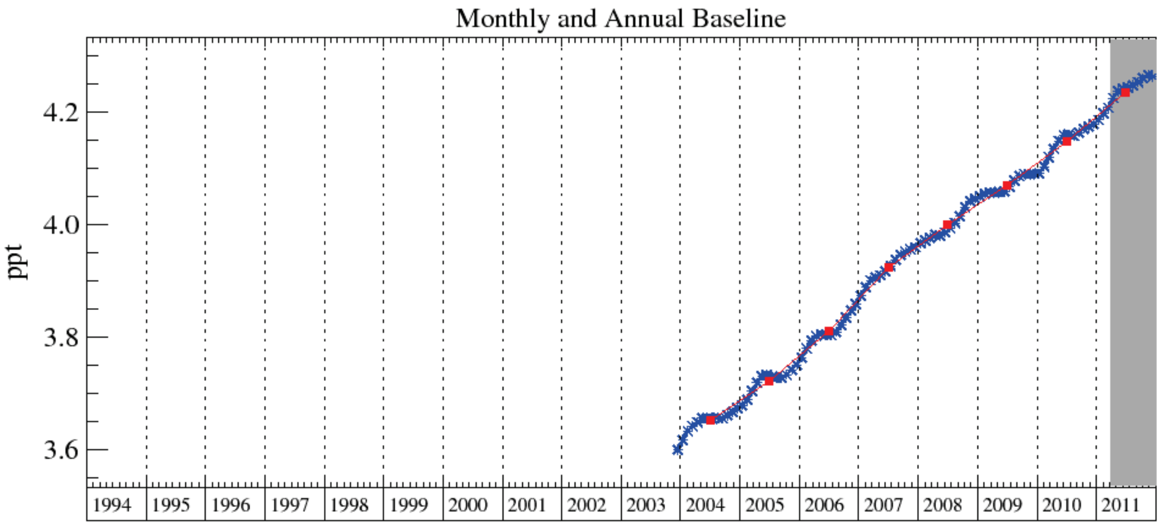
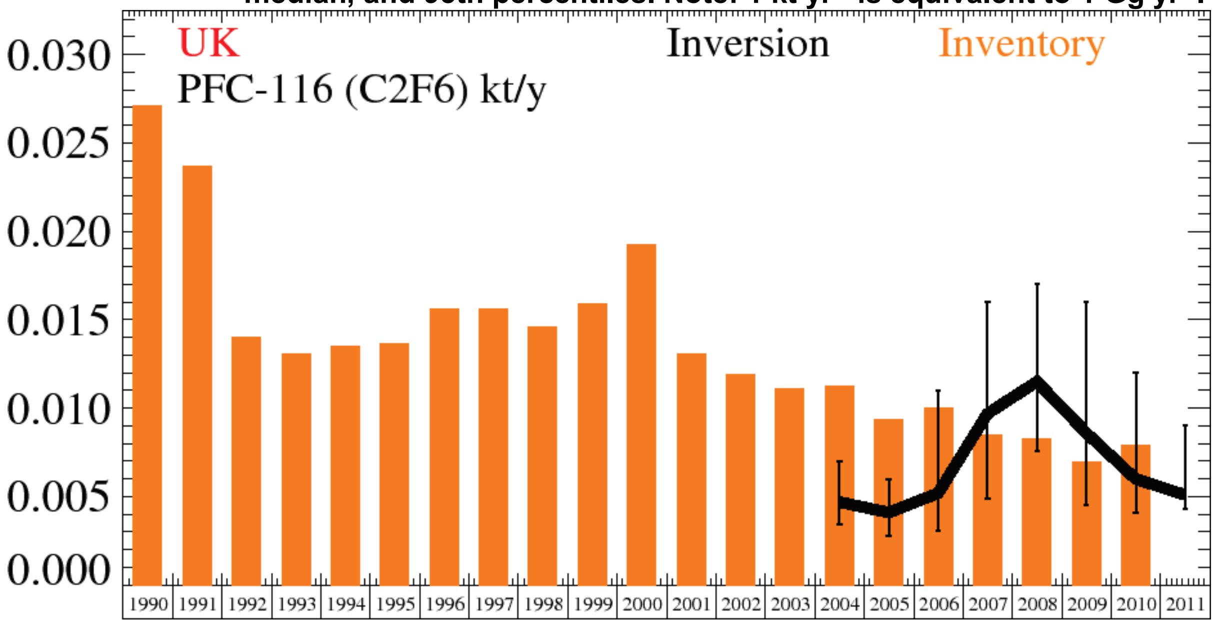


Figure A 10.5.4 Verification of the UK emission inventory estimates for PFC-116 in Gg yr^{-1} for 1990-2010. GHGI estimates are shown in orange. NAME-inversion estimates are shown in black. NAME-inversion uncertainties are shown with the black whisker lines showing 5th, median, and 95th percentiles. Note: 1 kt yr^{-1} is equivalent to 1 Gg yr^{-1}.



A10.5.3 PFC-218

Figure A 10.5.5 shows the baseline atmospheric concentration of PFC-218 from 2004 onwards. The annual trend is monotonic and positive at around 0.02 ppt/yr.

The UK NAME-inversion estimates are significantly higher than those reported in the GHGI (**Figure A 10.5.6**).

Figure A 10.5.5 Monthly and annual Northern Hemisphere trend in PFC-218 estimated from Mace Head observations (ppt). The grey area denotes data that are not yet ratified.

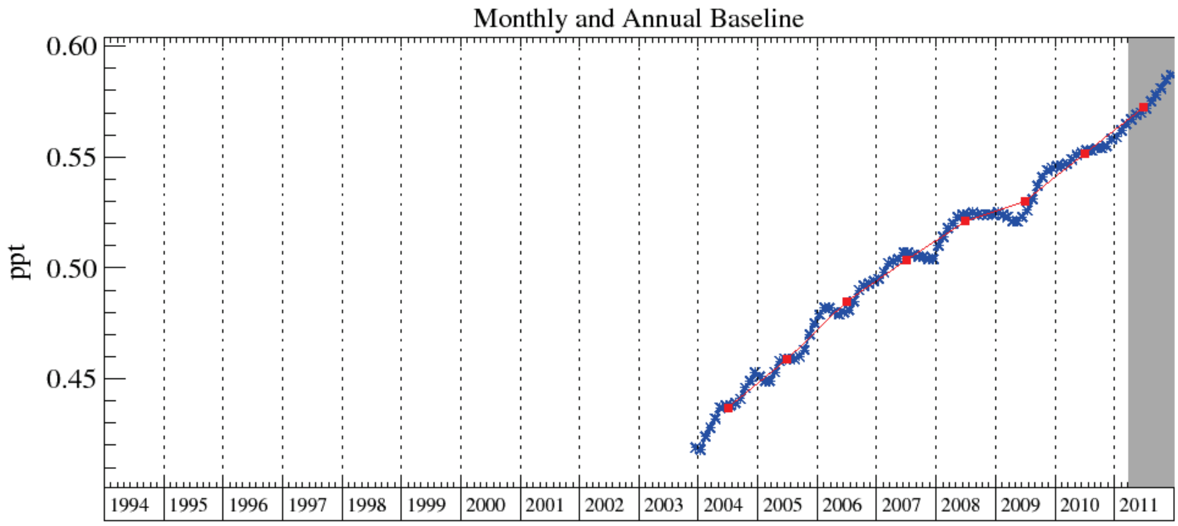
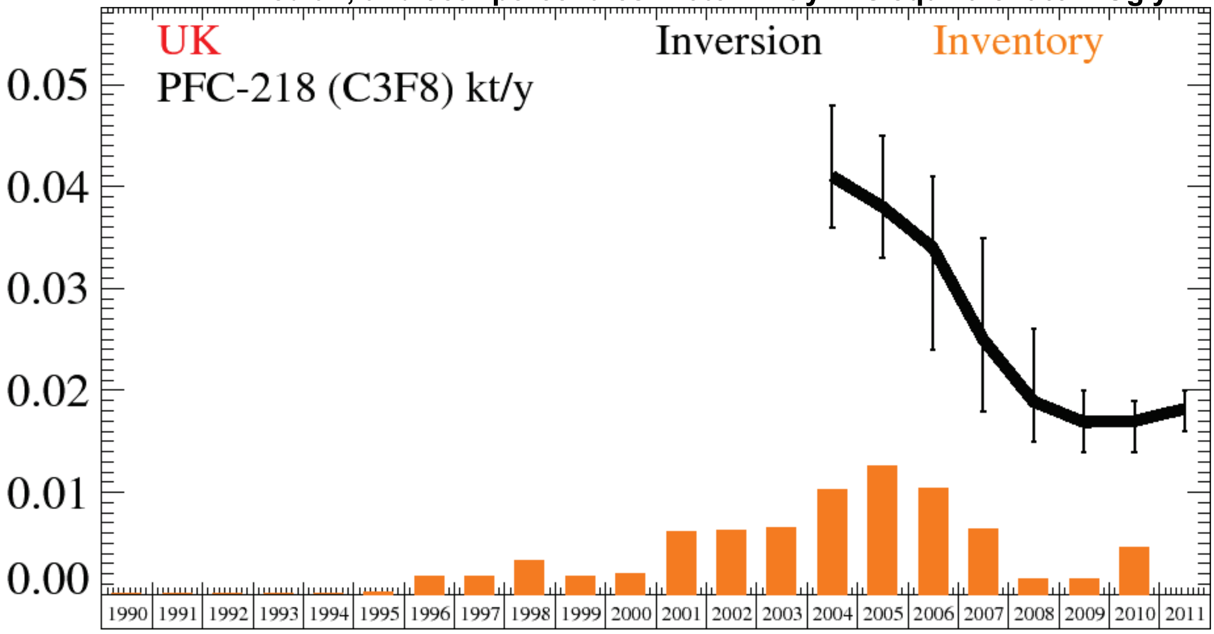


Figure A 10.5.6 Verification of the UK emission inventory estimates for PFC-218 in Gg yr^{-1} for 1990-2010. GHGI estimates are shown in orange. NAME-inversion estimates are shown in black. NAME-inversion uncertainties are shown with the black whisker lines showing 5th, median, and 95th percentiles. Note: 1 kt yr^{-1} is equivalent to 1 Gg yr^{-1}.



A10.6 SULPHUR HEXAFLUORIDE

Figure A 10.6.1 shows the baseline atmospheric concentration of SF_6 from 2004 onwards. The annual trend is monotonic and positive at around 0.3 ppt/yr.

The UK NAME-inversion estimates are broadly consistent with those reported in the GHGI (**Figure A 10.6.2**).

Figure A 10.6.1 Monthly and annual Northern Hemisphere trend in SF_6 estimated from Mace Head observations (ppt). The grey area denotes data that are not yet ratified.

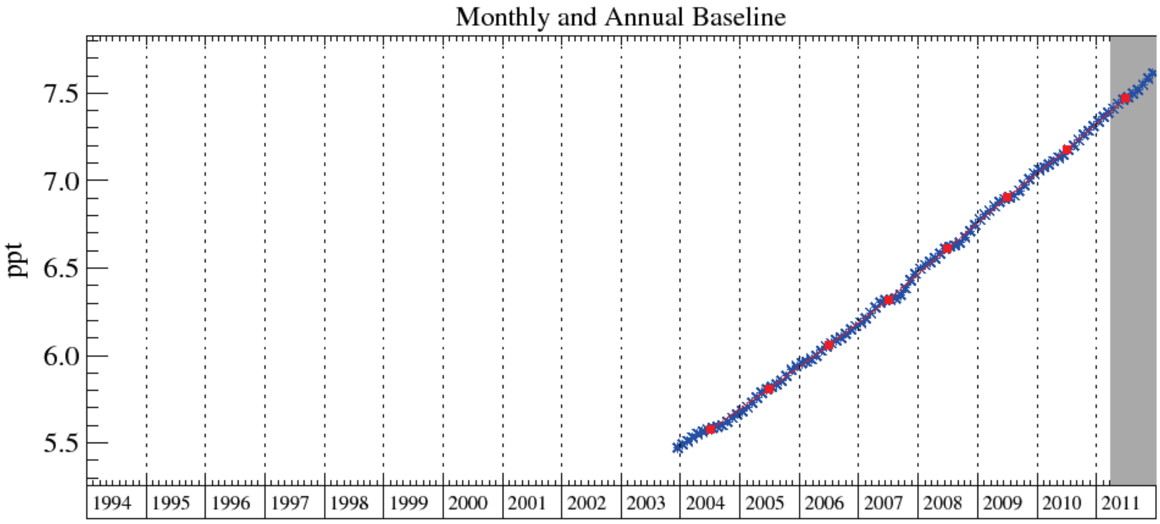
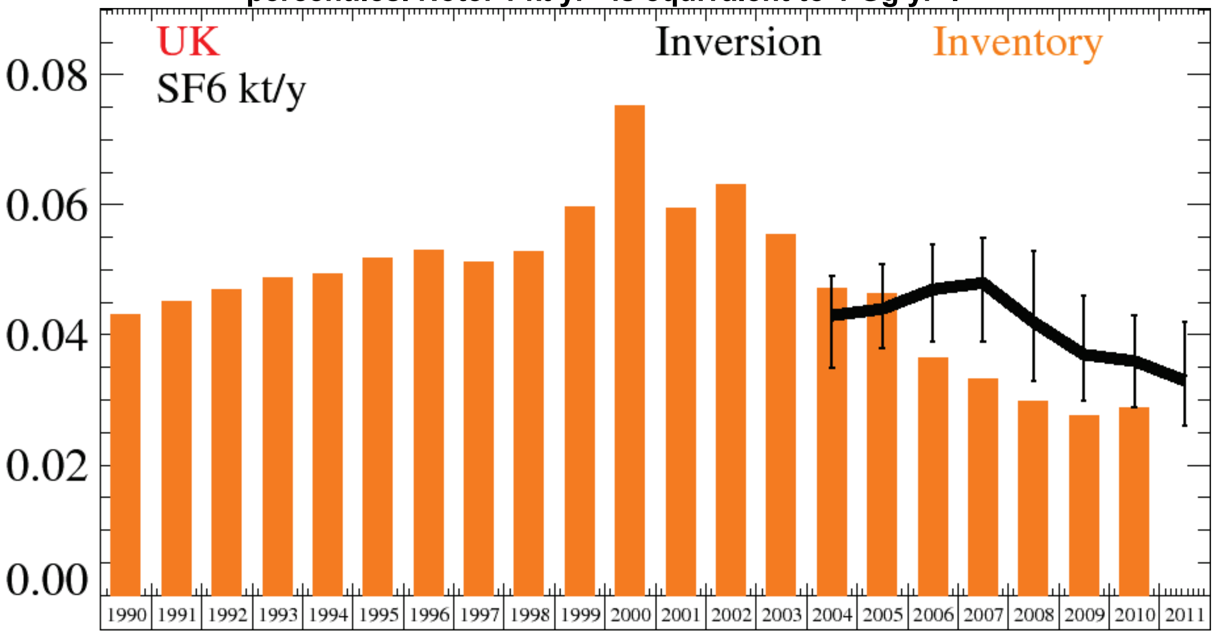


Figure A 10.6.2 Verification of the UK emission inventory estimates for SF_6 in Gg yr^{-1} for 1990-2010. GHGI estimates are shown in orange. NAME-inversion estimates are shown in black. NAME-inversion uncertainties are shown with the black whisker lines showing 5th, median, and 95th percentiles. Note: 1 kt yr^{-1} is equivalent to 1 Gg yr^{-1}.



A11 ANNEX 11: Analysis of EU ETS Data

A11.1 INTRODUCTION

This annex summarises the analysis of the 2010 European Union Emissions Trading System (EUETS) energy and emissions data that is used within the compilation of the UK GHG inventory. The EUETS 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 Energy and Climate Change (DECC).

The EUETS data are used in the UK GHGI compilation as follows:

- EUETS 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 EUETS are allocated to inventory fuels and source codes, outliers are identified and clarifications of data inconsistencies are sought with the regulatory agencies;
- The verified EUETS 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, oil and gas sources and iron and steel works;
- EUETS activity data are closely compared against the UK national energy balance (DUKES) published by DECC, and any inconsistencies are researched, seeking to resolve these through consultation with DECC wherever possible;
- The EUETS dataset for offshore oil and gas installations are checked to assess data consistency in emissions reporting between the EUETS 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 EUETS 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 EUETS 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 key findings from the analysis and use of the EUETS data include:

- In the 2010 EUETS dataset, a very high coverage of Tier 3 emissions data is evident for all fuel use in the power sector, as well as for coal autogeneration, coal use in the lime sector, and refinery fuel oil and OPG use. All of the fuel quality data for these sources and fuels are therefore used within the UK GHGI, as the EUETS fuel quality data is the most representative dataset available to inform UK carbon dioxide emission factors in the inventory;
- EUETS emissions data from refineries are higher than estimates derived from DUKES activity data, with a discrepancy evident in OPG emissions. Comparison against data from the trade association, UKPIA, indicates that the EUETS data are

correct, and revisions to UK GHGI estimates back to 2004 have been implemented for the refinery sector as a result;

- There are a range of other activity data discrepancies 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 EUETS does not map explicitly to energy balance and GHG inventory reporting requirements.

A11.2 BACKGROUND

A11.2.1 EUETS Data and GHG Inventories

The European Union Emissions Trading System (EUETS) data provided to the inventory team by the Environment Agency, 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 that 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 EUETS has operated since 2005, and there are now 6 years' worth of data on fuel use and emissions across major UK industrial plant, for 2005-2010.

The data reported under the EUETS includes quantities of fuels consumed, carbon contents, calorific values and emissions of carbon dioxide, all presented by installation and by emission source. 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 EUMM and UNFCCC, the UK must include a comparison of the EUETS data against the national inventory dataset within the National Inventory Report. Furthermore, the analysis of the inventory against the EUETS dataset is coming under increasing scrutiny due to the development of domestic GHG reduction targets that are based on non-traded[23] emissions data only, and the growing need to understand the UK non-traded sector emissions for future reporting under the Effort Sharing Decision.

The EUETS 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
- Acting as a source of quality assurance to inventory data.

In the 1990-2010 inventory cycle, the inventory agency has updated and extended the EUETS analysis conducted for inventory compilation, using the 2010 EUETS dataset. This

[23] All GHG emissions that are regulated within the EUETS 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 EUETS), and progress towards this target will be monitored through the UK GHG inventory.

report presents a comprehensive review of the six years' of EUETS 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 study has included a review of available EUETS operator forms (ETS7 forms) for around half of the offshore oil and gas installations in EUETS. This has enabled a more detailed review of the offshore sector EUETS data than has previously been possible.

The analysis of the EUETS data for use in the UK GHGI necessitates a high level of 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 known data reporting discrepancies have been identified from previous work. For example, it is important to review emission factors from all major installations in a given sector to ensure that outliers are identified and checked prior to their inclusion in inventory calculations.

Wherever possible, consistent assumptions and allocations are applied across all years of the EUETS, and the information on the EUETS method "Tier" informs use of the data in inventory compilation. Where higher-Tier methods are used, a lower level of uncertainty in the EUETS data is assumed. In most instances where calculations appear inconsistent between emissions data and activity data, it is assumed that the EUETS emissions data are correct, and activity data are amended as appropriate.

A11.2.2 Scope of the UK EUETS and Implications for the GHG Inventory

There are a number of limitations to the EUETS data that affect the data usefulness in GHG inventory compilation, including:

- The EUETS data are only available from 2005 onwards, whilst the UK GHG inventory reports emission trends back to 1990. The additional information that EUETS 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 EUETS 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 EUETS reporting has evolved through the years, from Phase I (2005 to 2007) into Phase II (2008 to 2010 data). The comparability of EUETS data for many sectors is poor between these two phases. For example, many cement kilns did not report to EUETS until Phase II; several sectors including cement were reporting under Climate Change Agreements and were opted-out of EUETS during Phase I. Therefore in several sectors, more complete coverage of EUETS reporting is evident in Phase II and data from 2008 onwards are therefore much more useful for UK GHGI reporting. There are now three years worth of Phase II data and hence the EUETS dataset is now becoming a more robust dataset;

- In the UK during EUETS Phases I and II, the regulators have adopted a "medium" definition of the term "combustion", and there are many sectors where fuel use in specific types of combustion unit have not been included in the EUETS reporting scope. Examples of this include flaring on chemical sites, 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 are typically under-reported within the EUETS, with many sites and sources excluded from the scope of EUETS.

- Further to this point, Phase III of EUETS from 2013 onwards will encompass a wider scope of reporting compared to Phase II (including the reporting of some non-CO_2 emissions), and hence additional data will become available to inform GHGI estimates in future years.

- When using the EUETS data, assumptions and interpretations are required to be made regarding the fuel types used by operators. There is not a specific list of fuels to be selected from in operator returns and so assumptions occasionally need to be made where the fuel type used is not clear.

Note that:

- The direct use of EUETS data (e.g. fuel use data by sector) to inform UK GHGI estimates is limited to where the EUETS is known to cover close to 100% of sector installations. For example, the EUETS is regarded as representative and almost 100% comprehensive in coverage of refineries, power stations, cement kilns, lime kilns and integrated iron and steelworks; for many other industrial sectors (such as chemicals, non ferrous metals, food and drink, engineering) the EUETS is not comprehensive and therefore the data are of limited use, other than to provide a de-minimis fuel use for these sectors;

- EUETS Implied Emissions Factors (IEFs) can be used within the UK GHGI, but only where the evidence indicates that EUETS data are representative of sector as whole and provides more comprehensive and accurate data than alternative sources. The key criteria to consider in the assessment of EUETS IEF usefulness is the percentage of annual fuel use by sector where operator estimates use Tier 3 emission factors.

- Review of the EUETS 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 EUETS through the time series and the level of variability in fuel quality for the different major fuels in the UK.

A11.3 DATA PROCESSING

DECC provided the detailed EUETS regulator data from the Environment Agency, Scottish Environment Protection Agency and Northern Ireland Environment Agency during summer 2011, and the AEA team of industrial emissions analysts have progressed the analysis, combining the datasets to generate a UK-wide EUETS dataset. This work builds on analysis conducted in previous years, as the EUETS has been in place since 2005, but this present analysis has reviewed all 6 annual datasets, 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 EUETS 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. There were a small number of new installations included in the 2010 EUETS data which had to be allocated to DUKES' sectors, and all of the fuel data for 2010 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 AEA team using the reported EUETS 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 EUETS spreadsheet. But 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 ambiguous names for fuels within the EUETS 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.

The quality checking and allocation process is an open-ended task for such a large dataset, and hence the AEA team 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 DECC DUKES team, for their information and input, as ultimately the EUETS analysis by the AEA team 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 EUETS regulator spreadsheets are then compared against the total installation emissions for 2010 on the Community Installation Transaction Log (CITL) which is a central website that holds the verified EUETS 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 CITL dataset, and therefore some "residual" emissions allocations are generated, from the difference between CITL and regulator information. These instances are then 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.

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 EUETS and DUKES;
- Identify any emission sources that are not contained in the GHGI.

A11.4 EUETS DATA COVERAGE

The coverage of the EUETS data has changed over the 6 years for which data are available. Major changes have been outlined in **Section A11.2.2**, 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 of EUETS, beginning in 2008. In addition, smaller combustion installations in the industrial, commercial and public sectors are outside the scope of EUETS, and so for some source sectors in the GHGI, the EUETS data only includes a small proportion of the sector and the EUETS are not useful to directly inform the GHGI.

The following GHGI source sectors are well represented in the EUETS data sets in the UK:

- Power stations, particularly those burning coal, gas, and fuel oil;
- Oil refineries;
- Coke ovens & Integrated steelworks;
- Cement kilns (from Phase II onwards); and
- Lime kilns (from Phase II onwards, and excluding kilns used in the Soda Ash industry).

However, GHGI sectors such as industrial combustion, autogeneration, and public sector combustion are only partially represented in the EUETS data. An analysis of the actual level of coverage of the EUETS data can be seen in **Table A 11.4.1** below. The number of sites in each sector which are included in the ETS dataset for 2005 and 2010 are given, together with AEA's estimate of the total number of installations in that sector throughout the UK in those years.

Table A 11.4.1 Numbers of installations included in the EUETS data

Sector	Number of installations			
	2005		2010	
	EUETS	UK total	EUETS	UK total
Power stations (fossil fuel, > 75MWe)	60	60	63	63
Power stations (fossil fuel, < 75MWe)	23	27	24	29
Power stations (nuclear)	12	12	10	10
Coke ovens	4	4	4	4
Sinter plant	3	3	3	3
Blast furnaces	3	3	3	3
Cement kilns	8	15	12	12
Lime kilns	4	17	13	15
Refineries	12	12	12	12
Combustion – iron & steel industry	11	200[a]	12	200[a]
Combustion – other industry	171	5000[a]	394	5000[a]
Combustion – commercial sector	28	1000[a]	40	1000[a]
Combustion – public sector	169	1000[a]	127	1000[a]

[a] These estimates are 'order of magnitude' figures, to show that the number of installations in the UK is likely to be considerably higher than the number of installations reporting in the EUETS.

Data are included in EUETS 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 five stations are not included in the EUETS data for 2010 (4 in 2005), 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 EUETS). All cement kilns are included in 2010 and all but two lime kilns, which are excluded, these latter being used in the manufacture of soda ash.

For most emission sources the level of detail given in the EUETS 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 EUETS 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 the EUETS data has still been useful as a quality check for the overall use of fuels.

A11.5 EUETS DATA USE IN THE UK GHGI

A11.5.1 Activity Data

A11.5.1.1 Crude Oil Refineries

The comparison of EUETS 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 EUETS analysis indicated that petcoke data in DUKES were too low; the DECC energy statistics team have investigated this matter with the refinery operators and have revised data for a number of sites that had been mis-reporting data through the DORS system used to compile DUKES. In recent years, therefore, the EUETS and DUKES data are closely consistent for petcoke use by refineries.

Data inconsistencies between DUKES and EUETS remain for other fuels, however. In some cases, this will be due to mis-allocation of fuel use data within the EUETS analysis, where fuel names are unclear, e.g. “fuel gas” could be interpreted as refinery use of OPG or the use of natural gas as a support fuel within the refinery fuel gas system.

The fuel oil data in most years is around 10% higher in EUETS than in DUKES. Natural gas is a relatively minor fuel in the sector; whilst the EUETS allocations indicate an over-report in DUKES, there is considerable uncertainty over the allocations of gases in the EUETS dataset, as noted above. The comparison of OPG data (even including the autogenerator allocation in DUKES within the refinery sector) indicates a considerable under-report in DUKES in all years, ranging from 23% to 35% across the time series. The petcoke data from 2007 onwards shows quite close consistency between EUETS and DUKES. The alignment of GHGI emissions data with EUETS sector data is achieved by using OPG activity data to deliver a consistent emissions dataset.

In the 1990-2009 GHGI cycle, the inconsistencies in the refinery sector were highlighted in the analysis of the traded and non-traded inventory data; the traded emissions in 2009 for the sector as a whole were 11% higher than the estimates in the GHGI based on DUKES energy statistics. There is very low uncertainty regarding the scope of the refinery installations or the scope of EUETS; the EUETS data indicate that the GHG inventory includes a large under-report for the refinery sector data.

Note that the GHGI estimates in the 1990-2009 cycle also included 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 DECC 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 the GHGI data against EUETS data, and also considered the total carbon dioxide emissions for the refinery sector provided annually by UKPIA. At the installation level, the UKPIA and EUETS data show very close consistency for recent years. The close consistency of the EUETS and UKPIA data further strengthens the case for using EUETS 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 EUETS, with the difference between the two then allocated to OPG use in the UK GHGI. Revisions have been made for all years back to 2005, using the EUETS data.

Prior to 2005, there are no EUETS data, but the comparison of current GHGI estimates against the UKPIA dataset show very close consistency for 2000 to 2003, but in 2004 the GHGI estimates are lower than the UKPIA data by around 8%. The inventory agency has therefore revised the 2004 OPG data to make up the emissions gap between current GHGI estimates and the UKPIA total.

No revisions are proposed prior to 2004, as the available data are closely consistent.
The time series of emissions data and the amended OPG activity data for the sector are shown below. (The year-specific Tier 3 implied emission factors for OPG are used to derive the additional activity data needed, with the 2004 data calculated using the 2005 EUETS IEF for OPG.)

Table A 11.5.1 Refinery Emissions Data Comparison and Proposed Revision to OPG Activity

Year	EUETS total	UKPIA total	UKPIA / EUETS	GHGI (based on DUKES)	UKPIA / GHGI	Difference in emissions	Revised OPG use in GHGI
	kt C	kt C	%	kt C	%	kt C	Mth
2000	No data	4599	-	4528	102%		-
2001	No data	4535	-	4420	103%		-
2002	No data	4767	-	4917	97%		-
2003	No data	4772	-	4741	101%		-
2004	No data	4999	-	4636	108%	364	1491
					EUETS / GHGI (%)		
2005	5006.7	4974	99.3%	4892	107%	115	1235
2006	4910.2	4677	95.3%	4395	114%	516	1593

2007	4856.8	4828	99.4%	4426	111%	430	1440
2008	4708.7	4660	99.0%	4325	109%	384	1614
2009	4491.6	4423	98.5%	4083	110%	408	1590
2010	4465.8	4811	107.7%	4187	107%	278	1567

There is some level of uncertainty in the allocation of fuels in EUETS 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 DECC DUKES team have reviewed the year to year consistency of OPG use in refineries through the DORS system; there may be further revisions needed, but for the 1990-2010 cycle it is recommended that the EUETS emissions data are used in preference to the published DUKES activity data to determine the inventory estimates for this sector.

A11.5.1.2 Oil & Gas Terminal OPG and LPG Use

The allocation of reported fuel use within EUETS to map to UK energy balance fuel nomenclature is uncertain in some cases. Analysis of the EUETS fuel use data does indicate that there are small amounts of these fuels being used in the upstream oil & gas sector that are not evident within DUKES.

The DECC 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 these sources, for the year 2002.

Therefore, the data from the EUETS from oil and gas processing terminals on LPG and OPG combustion are used directly within the UK GHG inventory for the Phase II years of 2008 to 2010, with estimates for 2003 to 2007 derived by interpolation between the EUETS 2008 data and the DUKES 2002 data.

A11.5.1.3 Natural Gas Use by Downstream Gas Supply Installations

The EUETS 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 EUETS for these sites throughout Phase II has been notably higher than the allocation of gas within DUKES Commodity Balance table 4.2 (Energy Industry Use, Other). This has been evident in the traded / non-traded analysis for the gas supply sector in the UK and DA GHGI.

As this gas use arises from the downstream network, the inventory agency and the DECC DUKES team consider that the DUKES data indicate a small mis-allocation of gas use, rather than a gap in reported gas use. For 2005 to 2010, therefore, the EUETS 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 1A2f); the EUETS data since 2005 shows good consistency with the data from DUKES for earlier years.

Even the increase of gas use to this sector informed by EUETS data is expected to be a small under-report for the sector as a whole, as the EUETS scope only includes around 28 of the larger gas compressor 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.

A11.5.1.4 Other Industry OPG use

There are a number of “other industry” sites where OPG use has been allocated by the AEA team from EUETS 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”, or “RFG/OPG/ROG” within the EUETS forms. The direct reference to refinery gases and the locations of the installations raises questions about how the fuel consumption is tracked and then reported within DUKES.

For a small number of sites, consultation with the DUKES team, regulators and operators has clarified that there is an under-report within DUKES and that the EUETS energy and emissions data are the more accurate dataset and should be used in the UK GHGI. At some sites, energy supplier data returns to DECC have been mis-interpreted with gases allocated to non-energy uses in the UK energy balance, when in fact a higher proportion of petroleum-based gases are used in combustion.

Within the DUKES petroleum commodity balance tables, there is no allocation of OPG or other light hydrocarbons to these industrial combustion processes, but there is an allocation to non-energy use of these gases, as well as some OPG use reported in autogeneration. Based on the EUETS evidence, some proportion of this non-energy use has been re-allocated to account for the GHG emissions from these facilities, to address this gap in the inventory totals.

A11.5.1.5 Other Processes

The EUETS dataset contains some emission sources that are not included in the GHGI. These sources are individually small but the EUETS data have been used to generate new estimates of emissions included within the UK GHGI for the first time in this submission. The sources are:

- Emissions from clays and brick making additives. The GHGI currently includes carbon emissions from carbonaceous material contained in the Lower Oxford Clay used in Fletton bricks, but does not include the less significant emissions from other types of clays used in Non-Fletton bricks and emissions from other additives;
- Emissions from additives used in steelmaking, such as scrap metals and alloys;
- Emissions from additives used in glassmaking, such as barium carbonate and calumite.

Emissions are only available back to 2005, and data for 2005-2007 are more limited in some cases due to the opting out of processes involved in Climate Change Agreements, but annual production estimates are available for all three sectors and have been used to construct a time series of emissions for inclusion in the UK GHGI.

A11.5.2 Implied Emission Factors

A11.5.2.1 Power Stations

Table A 11.5.2 summarises EUETS 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 EUETS emissions based on Tier 3 factors.

Table A 11.5.2 EUETS 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	615.6
2006		100	615.6
2007		100	615.4
2008		100	614.0
2009		100	610.5
2010		100	610.4
2005	Fuel oil / Waste oil[a]	59	860.2
2006		66	873.3
2007		70	871.1
2008		92	869.5
2009		97	872.7
2010		96	873.3
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
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

[a] It is not possible to distinguish between fuel oil and waste oil in the EUETS data, so all emissions have been reported under fuel oil.

The EUETS 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 EUETS data for power stations also cover almost all UK installations in this sector, and certainly cover all of the larger installations.

The EUETS based emission factors presented above for power stations are therefore 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 EUETS. Small quantities of sour gas were burnt at one power station in 2005-2007 and 2009 and EUETS 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 EUETS factors for coal-fired autogenerators are slightly different to the factors for the power stations in that, although the EUETS data are exclusively Tier 3, they only represent about 80% of total fuel used by the sector.

A11.5.2.2 Crude Oil Refineries

The tables below summarise the EUETS 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 EUETS 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 11.5.3 Refinery EUETS Data for Fuel Oil, OPG and Natural Gas (Emission Factors in kt / Mt for Fuel Oil and kt / Mth for OPG and Natural Gas)

Year	Fuel	% Tier 3	Average Carbon Emission Factor (Tier 3 sites only)
2005	Fuel Oil	25	861.0
2006		65	873.9
2007		79	877.4
2008		91	871.6
2009		91	876.2
2010		97	878.2
2005	OPG	60	1.495
2006		58	1.469
2007		69	1.582
2008		82	1.483
2009		81	1.489
2010		82	1.512
2005	Natural Gas	0	n/a
2006		43	1.460
2007		45	1.462
2008		98	1.475
2009		98	1.480
2010[24]		93	1.467

Emission factors for **fuel oil** generated from EUETS 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, but levels of more than 80% for 2008 onwards. There is some uncertainty regarding the allocation of EUETS 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 perhaps reflects the nature of this fuel, and the data for all six years have been used in the inventory.

[24] Notably lower Tier 3 analysis and lower IEF, as one refinery reports at Tier 2 in 2010 that had previously reported at Tier 3.

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. Within the UK GHGI, we propose to use the factors for 2008 to 2010, and for earlier years retain the previous emission factors used for natural gas, which are derived from gas network operator gas analysis.

EUETS emission data for **petroleum coke** are higher in 2005-2008 and lower in 2009 and 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 EUETS. Consultation with DECC energy statisticians has identified that the figures given in DUKES are subject to uncertainty and hence the EUETS data are used directly within the UK GHGI.

A11.5.2.3 Integrated Steelworks & Coke Ovens

Table A 11.5.4 summarises EUETS data for the major fuels burnt at integrated steelworks and coke ovens. The data exclude one independent coke oven which calculates emissions using a detailed mass balance approach which makes it more difficult to assess the data in the same way as the other installations.

Table A 11.5.4 EUETS data for Fuels used at Integrated Steelworks and 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	-
2006		92	6.873
2007		91	6.920
2008		91	6.945
2009		91	7.029
2010		100	6.949
2005	Coke oven gas	0	-
2006		0	-
2007		0	-
2008		57	1.093
2009		100	1.140
2010		100	1.117
2005	Natural gas	0	-
2006		3	1.479
2007		2	1.478
2008		0	-
2009		59	1.425
2010		68	1.441
2005	Fuel oil	0	-
2006		0	-
2007		0	-
2008		84	878.3
2009		89	884.7
2010		83	887.6

With the exception of blast furnace gas, reporting of emission factors at Tier 3 has only predominated in the last few years of the time series. None of the data are currently used in the GHGI. In the case of natural gas, the derived emission factors are quite variable, and the level of Tier 3 reporting is particularly low. The factors for fuel oil for the period 2008-2010 are based on a much higher level of Tier 3 data, and are quite consistent.

Emission factors for blast furnace gas and coke oven gas are currently based on a carbon mass balance approach that utilises DUKES energy data and fixed/estimated carbon factors for selected input fuels such as coal, and selected outputs such as coke oven gas & pig iron, and then calculates the carbon content of coke oven coke, blast furnace gas, and basic oxygen furnace gas.

A11.5.2.4 Cement Kilns

Table A 11.5.5 summarises EUETS data for the major fuels burnt at cement kilns.

Table A 11.5.5 EUETS data for Fuels used at Cement Kilns (kt / Mt)

Year	Fuel	% Tier 3	Average Carbon Emission Factor (Tier 3 sites only)
2005	Coal	8	671.1
2006		100	546.2
2007		100	664.3
2008		100	655.8
2009		100	658.3
2010		100	637.7
2005	Petroleum coke	-	-
2006		100	820.8
2007		100	830.2
2008		100	819.1
2009		100	796.8
2010		100	750.8

The EUETS 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 EUETS data cover only a fraction of the sector, so differences might be expected. The data for 2008-2010 are closer, generally within 1% of each other. 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 EUETS estimates, with the sum of the EUETS data around 1% lower than those reported to the GHGI, as outlined below in **Table A 11.5.6**.

Table A 11.5.6 Comparison of Cement Sector Carbon Dioxide Emissions within the UK GHGI and the EUETS for 2008-2010

	2008	2009	2010
GHGI CO_2 emissions (kt)	5203	3720	3792
Sum of EUETS CO_2 emissions (kt)	5163	3677	3754
EUETS / GHGI	99.2 %	98.8 %	99.0%

A11.5.2.5 Lime Kilns

Table A 11.5.7 summarises data given in the EUETS 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. Coke oven coke is believed to be used in some lime kilns but these currently do not report in EUETS, therefore no data for this fuel can be presented.

Table A 11.5.7 EUETS 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	-	-
2006		-	-
2007		60	698.5
2008		83	686.6
2009		100	664.7
2010		100	635.1
2005	Natural gas	-	-
2006		-	-
2007		33	1.456
2008		7	1.468
2009		64	1.471
2010		63	1.485

The EUETS data for lime kilns are variable across the time series, both in terms of the proportion of emissions based on Tier 3 factors, and in the emission factors themselves. Only in the case of the natural gas factors, is there a high degree of consistency. EUETS based factors are currently used for coal and petroleum coke from 2008 onwards, as the EUETS data do include all lime kilns burning those fuels and almost all of those data are Tier 3 and hence are regarded as highly reliable.

The EUETS data for gas cover all installations burning this fuel, however the proportion of emissions based on Tier 3 factors is quite low, never exceeding two thirds. Therefore the EUETS emission factors are not used in the UK GHGI, and the emission factors for this fuel continue to be based on the methodology given in Baggott *et al,* 2004.

Table A 11.5.8 shows implied emission factors for process-related emissions from lime kilns. 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 11.5.8** therefore does not cover these installations. None of the emission factors in EUETS are Tier 3, so the table shows the overall emission factors for all tiers of data.

Table A 11.5.8 EUETS emission factor data for production of lime (kt / Mt lime produced)

Year	Activity	EUETS
2005	Lime production	200.4
2006		201.2
2007		201.3
2008		200.8
2009		195.6
2010		194.0

These factors compare with a theoretical emission factor of 214 kt / Mt lime, assuming use of pure limestone.

A11.5.2.6 Other Industrial Combustion

Table A 11.5.9 summarises EUETS 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 91% or more of emissions based on Tier 3 factors in each year. However, it must be recalled that numerous smaller industrial consumers will not be represented in EUETS and that the EUETS data are not fully representative of UK fuels as a whole – see **Section A 11.4** for details. This is also true for EUETS data for fuel oil and natural gas but here, in addition, very little of the EUETS 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 11.5.9 EUETS 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	630.9
2006		98	603.0	631.7
2007		99	615.7	645.6
2008		94	598.6	639.7
2009		92	595.4	651.3
2010		93	589.0	657.2
2005	Fuel oil	17	864.7	879.0
2006		27	865.3	879.0
2007		44	872.3	879.0
2008		24	871.4	879.0
2009		40	871.3	879.0
2010		40	873.0	879.0
2005	Natural gas	12	1.593	1.478
2006		33	1.449	1.478
2007		42	1.468	1.477
2008		33	1.505	1.474
2009		46	1.495	1.474
2010		50	1.494	-[a]

[a] – figure not yet available.

Emission factors can also be derived from EUETS 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 EUETS-derived emission factors are confidential and are not tabulated here. The source/activity combinations for which EUETS 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 EUETS-derived emission factors for colliery methane for each year (2005-10) are also applied to all other sources using these fuels.

A12 ANNEX 12: UK Domestic Emissions Reporting Requirements

In addition to the reporting requirements of the UNFCCC, Kyoto Protocol and EUMM, UK Greenhouse Gas Inventory statistics are published annually in the Department of Energy and Climate Change's statistical release. The geographical coverage of these estimates differs from the UNFCCC and EUMM coverage, with the totals only including emissions from the UK and the UK's Crown Dependencies. Summary tables of these data are presented below. The data are presented in the nine categories used for the UK's National Communications to the UNFCCC (NC Categories).

A12.1 NATIONAL STATISTICS

Table A 12.1.1 Summary table of GHG emissions by NC Category (Mt CO_2eq) – National Statistics coverage

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Energy Supply	273.43	271.14	260.06	242.44	234.84	235.85	237.32	221.75	224.36	211.47	220.08
Transport	121.51	119.75	120.96	122.23	122.73	122.05	126.34	127.62	126.73	127.76	126.68
Residential	80.76	89.56	86.91	90.92	86.51	82.26	93.87	87.35	90.06	89.71	90.15
Business	113.25	117.53	113.14	111.38	110.90	108.23	110.77	108.33	108.18	109.93	111.25
Public	13.13	13.98	14.65	13.31	12.96	12.80	13.84	13.49	12.48	12.27	11.55
Industrial Process	54.41	52.52	47.16	43.53	45.42	44.94	45.73	47.00	44.03	26.99	24.58
Agriculture	63.08	62.86	62.73	62.03	62.22	61.77	62.23	61.88	61.05	60.36	58.02
Land Use Change	3.89	3.87	3.34	2.22	2.05	2.46	2.18	1.92	1.24	1.06	0.37
Waste Management	45.90	45.02	43.72	42.33	41.12	40.02	38.98	35.88	33.83	31.11	29.35
Total	**769.36**	**776.22**	**752.67**	**730.41**	**718.75**	**710.38**	**731.26**	**705.22**	**701.95**	**670.66**	**672.02**

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Energy Supply	230.16	226.86	230.96	230.24	228.65	233.85	228.87	221.93	198.72	204.35
Transport	126.69	129.21	128.72	129.89	130.38	130.81	132.44	127.73	122.19	121.89
Residential	92.56	89.10	90.20	91.69	87.82	85.22	81.47	83.38	78.07	89.87
Business	111.86	102.51	105.01	104.15	105.30	102.71	101.69	100.30	89.01	89.02
Public	12.04	10.22	10.23	11.17	11.08	10.07	9.34	9.37	8.27	8.47
Industrial Process	21.86	18.78	19.54	18.88	18.18	16.65	18.02	16.26	10.21	10.88
Agriculture	55.29	55.24	54.77	54.79	55.13	53.15	51.55	50.90	50.19	50.67
Land Use Change	-0.12	-0.94	-1.29	-2.36	-2.95	-3.10	-3.49	-3.89	-4.21	-3.85
Waste Management	25.93	23.85	20.99	19.48	18.96	18.56	18.20	17.63	17.12	16.54
Total	**676.28**	**654.83**	**659.13**	**657.92**	**652.55**	**647.93**	**638.09**	**623.63**	**569.57**	**587.83**

Table A 12.1.2 Summary table of GHG emissions by Gas (Mt CO_2eq) – National Statistics coverage

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO_2	590.32	597.55	580.64	565.54	559.76	552.02	573.75	549.54	552.63	543.30	550.47
CH_4	97.40	96.58	94.81	91.73	84.53	83.96	81.90	77.36	73.25	68.47	64.00
N_2O	67.82	67.98	63.17	58.46	58.86	57.37	57.30	57.71	57.54	46.86	45.98
HFCs	11.39	11.86	12.35	13.02	13.94	15.32	16.56	18.98	16.88	10.23	9.30
PFCs	1.40	1.17	0.57	0.49	0.49	0.46	0.48	0.40	0.39	0.37	0.46
SF_6	1.03	1.08	1.12	1.17	1.18	1.24	1.27	1.23	1.26	1.43	1.80
Total	**769.36**	**776.22**	**752.67**	**730.41**	**718.75**	**710.38**	**731.26**	**705.22**	**701.95**	**670.66**	**672.02**

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CO_2	562.08	544.88	554.56	555.03	551.21	549.44	541.78	529.03	477.79	495.80
CH_4	58.73	55.80	50.01	48.51	47.07	45.79	44.23	43.00	41.95	41.27
N_2O	43.44	41.64	41.09	41.78	40.87	38.81	38.06	37.10	35.09	35.56
HFCs	10.22	10.68	11.87	11.14	12.03	12.71	13.01	13.59	13.93	14.28
PFCs	0.38	0.32	0.28	0.34	0.26	0.30	0.22	0.21	0.14	0.22
SF_6	1.42	1.51	1.32	1.13	1.11	0.87	0.79	0.71	0.66	0.69
Total	**676.28**	**654.83**	**659.13**	**657.92**	**652.55**	**647.93**	**638.09**	**623.63**	**569.57**	**587.83**

A12.2 CARBON BUDGETS

The UK's Climate Change Act includes legally binding targets for the UK to reduce its greenhouse gas emissions by at least 80 per cent by 2050, and by at least 34 per cent by 2020, both below base year levels. It also establishes a system of binding five-year carbon budgets to set the trajectory towards these targets. The geographical coverage of the Act and the carbon budgets is UK only. Summary statistics for the UK only are presented below.

Table A 12.2.1 Summary table of GHG emissions by NC Category (Mt CO_2eq) – UK only

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Energy Supply	272.91	270.58	259.41	241.83	234.22	235.20	236.67	221.15	223.71	210.82	219.59
Transport	121.04	119.28	120.49	121.76	122.26	121.57	125.80	127.08	126.17	127.23	126.12
Residential	80.45	89.25	86.61	90.62	86.21	81.94	93.53	86.92	89.61	89.33	89.76
Business	113.04	117.31	112.94	111.18	110.68	108.01	110.50	108.02	107.86	109.66	110.95
Public	13.13	13.98	14.65	13.31	12.96	12.80	13.84	13.49	12.48	12.27	11.55
Industrial Process	54.41	52.52	47.16	43.53	45.42	44.94	45.73	47.00	44.03	26.99	24.58
Agriculture	62.94	62.72	62.59	61.90	62.08	61.63	62.10	61.74	60.90	60.22	57.87
Land Use Change	3.91	3.89	3.36	2.25	2.09	2.50	2.24	1.98	1.30	1.12	0.44
Waste Management	45.77	44.88	43.58	42.20	40.99	39.88	38.84	35.74	33.70	30.97	29.26
Total	**767.59**	**774.39**	**750.79**	**728.58**	**716.90**	**708.47**	**729.25**	**703.12**	**699.77**	**668.60**	**670.10**

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Energy Supply	229.94	226.65	230.82	230.01	228.39	233.54	228.53	221.58	198.38	204.03
Transport	126.12	128.65	128.15	129.32	129.81	130.26	131.87	127.19	121.67	121.37
Residential	92.19	88.71	89.83	91.37	87.47	84.88	81.12	83.05	77.72	89.51
Business	111.52	102.15	104.70	103.83	104.99	102.43	101.36	100.03	88.70	88.72
Public	12.04	10.22	10.23	11.17	11.08	10.07	9.34	9.37	8.27	8.47
Industrial Process	21.86	18.78	19.54	18.88	18.18	16.65	18.02	16.26	10.21	10.88
Agriculture	55.15	55.10	54.67	54.70	55.03	53.03	51.42	50.77	50.07	50.55
Land Use Change	-0.05	-0.86	-1.21	-2.29	-2.88	-3.01	-3.40	-3.80	-4.12	-3.75
Waste Management	25.84	23.77	20.92	19.44	18.91	18.51	18.14	17.58	17.08	16.49
Total	**674.62**	**653.18**	**657.64**	**656.42**	**650.98**	**646.36**	**636.42**	**622.03**	**567.98**	**586.25**
Total - with allowance for EU ETS								***602.73***	***581.48***	***593.85***

Table A 12.2.2 Summary table of GHG emissions by Gas (Mt CO_2eq) – UK Only

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO_2	588.85	596.02	579.07	564.01	558.21	550.41	572.04	547.76	550.77	541.57	548.83
CH_4	97.15	96.33	94.55	91.48	84.28	83.71	81.65	77.11	73.00	68.21	63.80
N_2O	67.77	67.94	63.12	58.42	58.81	57.32	57.26	57.66	57.49	46.81	45.93
HFCs	11.39	11.86	12.35	13.02	13.93	15.32	16.55	18.97	16.86	10.21	9.28
PFCs	1.40	1.17	0.57	0.49	0.49	0.46	0.48	0.40	0.39	0.37	0.46
SF_6	1.03	1.08	1.12	1.17	1.18	1.24	1.27	1.23	1.26	1.43	1.80
Total - no allowance for EU ETS	**767.59**	**774.39**	**750.79**	**728.58**	**716.90**	**708.47**	**729.25**	**703.12**	**699.77**	**668.60**	**670.10**

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CO_2	560.69	543.49	553.30	553.73	549.85	548.11	540.35	527.67	476.43	494.46
CH_4	58.54	55.62	49.86	48.39	46.94	45.65	44.08	42.85	41.81	41.14
N_2O	43.39	41.59	41.06	41.74	40.83	38.77	38.02	37.05	35.05	35.51
HFCs	10.19	10.64	11.83	11.10	11.99	12.66	12.96	13.54	13.88	14.23
PFCs	0.38	0.32	0.28	0.34	0.26	0.30	0.22	0.21	0.14	0.22
SF_6	1.42	1.51	1.32	1.13	1.11	0.87	0.79	0.71	0.66	0.69
Total - no allowance for EU ETS	**674.62**	**653.18**	**657.64**	**656.42**	**650.98**	**646.36**	**636.42**	**622.03**	**567.98**	**586.25**
Total - with allowance for EU ETS								***602.73***	***581.48***	***593.85***

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A13 ANNEX 13: End User Emissions

A13.1 INTRODUCTION

This Annex explains the concept of a final user or end user, summarises the final user calculation methodology with examples, and contains tables of greenhouse gas emissions according to final user from 1990 to 2010.

The final user sectoral categories used are consistent with those used in the National Communications (NC) to the FCCC. The sectoral categories in the NC are derived from the UNFCCC reporting guidelines on national communications[25].

The purpose of the final 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 final user data to be included in the UK's National Inventory Report. These data have been included to provide DECC with information for their policy support needs.

The tables in this Annex present summary data for UK greenhouse gas emissions for the years 1990-2010, inclusive. These data are updated annually to reflect revisions in the methods used to estimate emissions, and the availability of new information. 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 from the UK Overseas Territories are not included in the calculations; there is not enough information available to reallocate emissions from energy supply. Emissions presented in this chapter show emissions from the UK and Crown Dependencies, consistent with the UK statistical release.

A13.2 DEFINITION OF FINAL USERS

The final user[26] or end user calculations allocate emissions from fuel producers to fuel users. The final 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 final user categories can be illustrated with an example of two final users - the residential sector and road transport:

- Emissions in the **residential** final user category include:

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

[26] A final user is a consumer of fuel for useful energy. A 'fuel producer' is someone who extracts, processes and converts fuels for the end use of final users. Clearly there can be some overlap of these categories but here the fuel uses categories of the UK DECC publication DUKES are used, which enable a distinction to be made.

1. Direct emissions from domestic premises, for example, from burning gas, coal or oil for space heating.

2. Emissions from power stations generating the electricity used by domestic consumers; 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** final user category include:

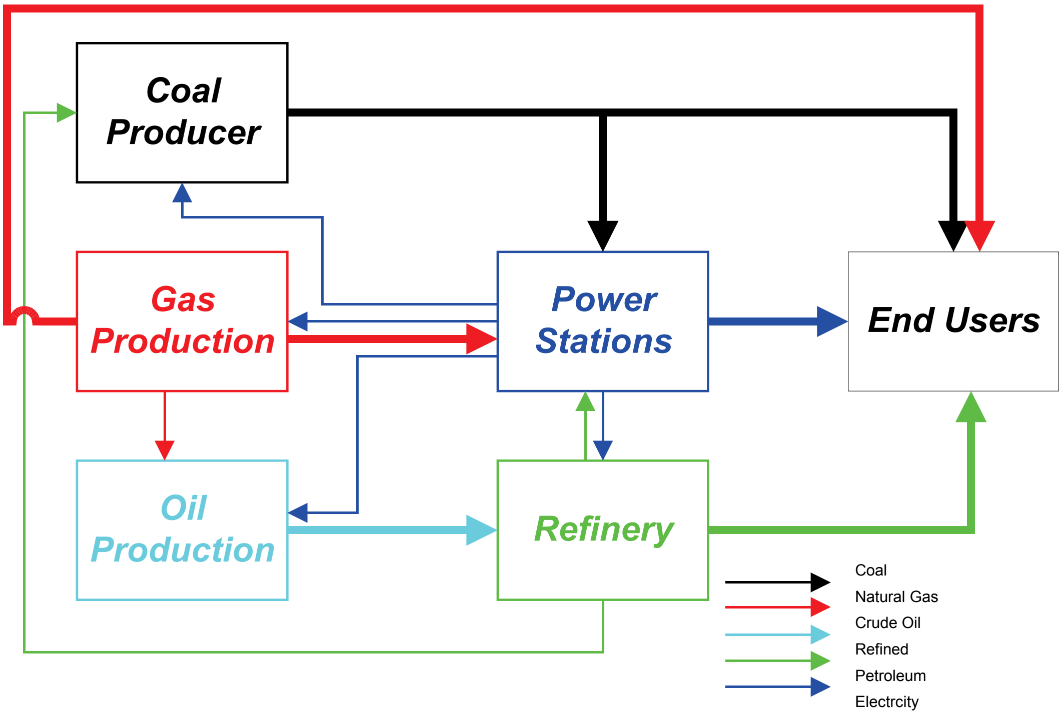
1. Direct emissions from motor vehicle exhausts.
2. Emissions refineries producing motor fuels, including refining, storage, flaring and extraction of oil; and from the distribution and supply of motor fuels.

A13.3 OVERVIEW OF THE FINAL USERS CALCULATIONS

As fuel and electricity producers use energy from other producers, they are allocated emissions from each other and these have to then be reallocated to final users. This circularity results in an iterative approach being used to estimate emissions from categories of final users.

Figure A13.3.1 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 final 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 13.3.1 Simplified fuel flows for a final 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[27] of the fuel they use (these sectors can include other fuel producers).
3. By this stage in the calculation, emissions from final 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 (e.g. 1% or 0.01%)[28] the process continues at Step 2. If this percentage matches or is less than the predetermined value, the calculation is finished.

Convergence of this iterative approach is likely, as the fuel flows to the final users are much greater than fuel flows amongst the fuel producers.

[27] 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.
[28] In the model used to determine emissions from final users, the value of this percentage can be adjusted. The tables presented later in this Appendix were calculated for a convergence at 0.001%.

While a direct solution could possibly be used (for example, after defining a system of linear equations and solving by an inverse matrix or Gaussian elimination) 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.

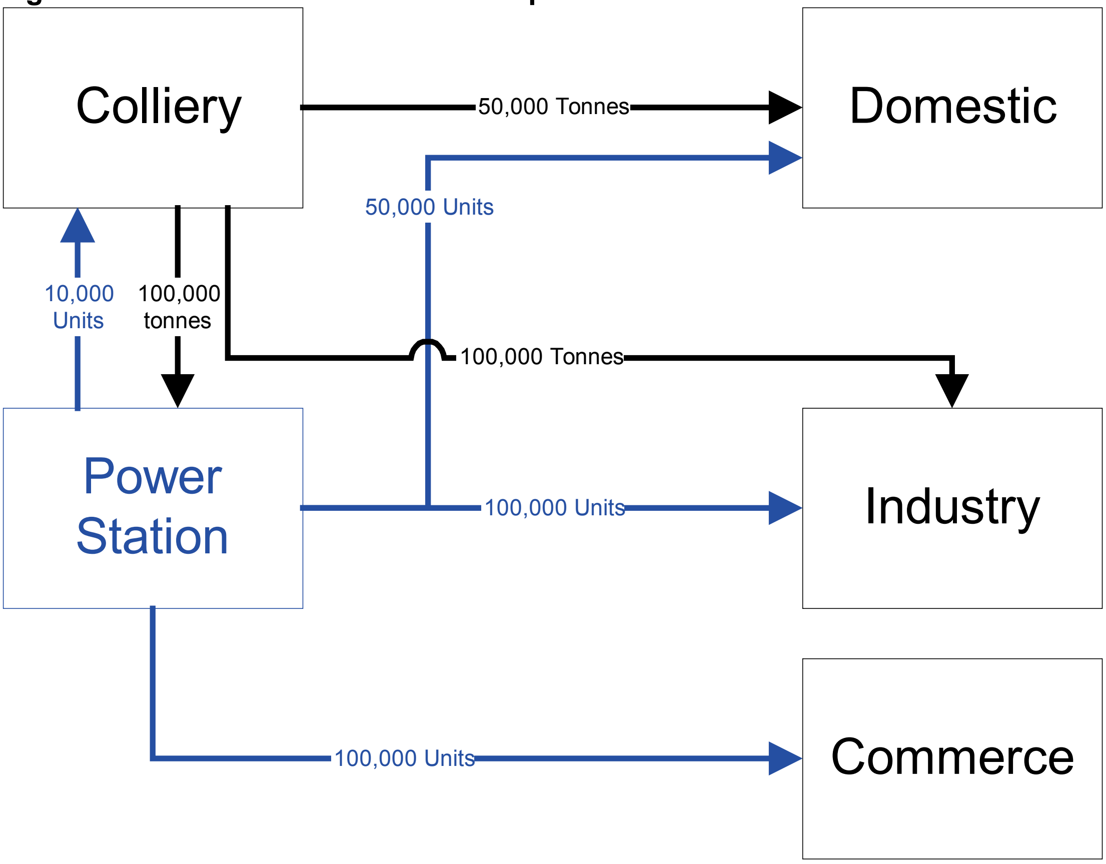
A13.4 EXAMPLE FINAL USER CALCULATION

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

The example in **Figure A13.4.1** has two fuel producers, *power stations* and *collieries*, and three final 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.

Figure A 13.4.1 Fuel use in the example calculation



In **Figure A13.4.1**, 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 final 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 a final user. The colliery is a 'fuel producer' as it is part of the chain that extracts, processes and converts fuels for the final users.

Table A13.4.1 summarises the outputs during this example final user calculation.

Table A 13.4.1 Example of the outputs during a final 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	70000	35000	70000	0	40.02	175070
	Emissions after Iteration step	1	2692	28	48476	96951	26923	1.55	175070
		2	1	1077	49020	98039	26934	0.62	175070
		3	41	1	49227	98454	27348	0.02	175070
		4	0	17	49235	98470	27348	0.01	175070
		5	1	0	49238	98477	27355	0	175070
		6	0	0	49239	98477	27355	0	175070

The initial carbon emissions are 70% of the mass of coal burnt. The emissions from the power stations are distributed to the other sectors by using the factor:

- (Electricity used by that sector)/(total electricity used minus own use by power stations);

Similarly for the colliery emissions the following factor is used; and

- (Energy of coal used by that sector)/(total energy of coal consumed used minus own use by collieries).

At the end of iteration step one, the commerce sector has 26923 tonnes of carbon emissions allocated to it, mainly derived from power stations. Emissions allocated to the residential and industry sectors have also increased over their initial allocations. However collieries and power stations still have some emissions allocated to them (these come from each other) and so the reallocation process is repeated to reduce these allocations to zero – these two sectors are not final 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 (175070 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 final user calculations.

Figure A 13.4.2 Comparison of 'direct' and final user emissions of carbon according the sectors considered in the final user example

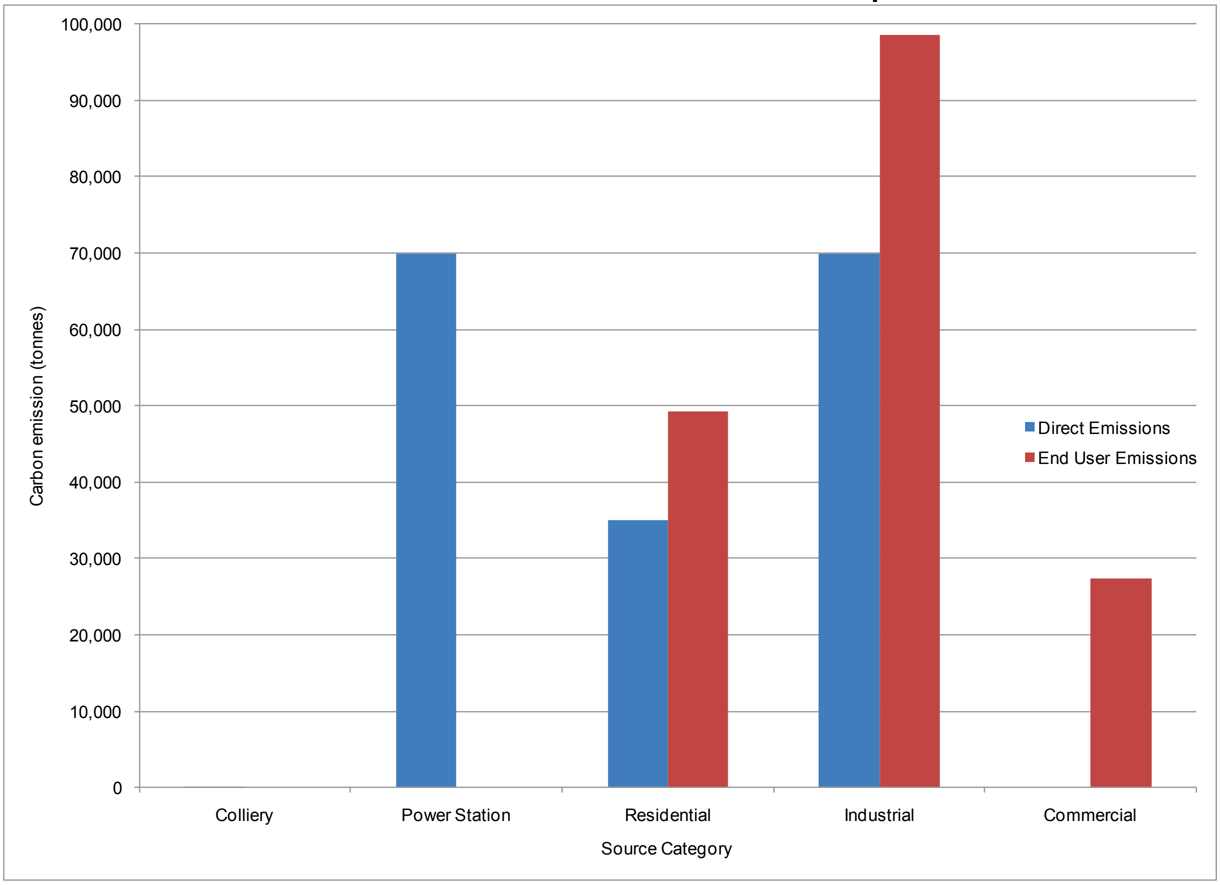


Figure A13.4.2 compares the quantities of direct and final user carbon emitted from each sector at the end of the final user calculation. The direct emissions of carbon are from the combustion of coal in the sectors. The direct and final user emissions are from two distinct calculations and must be considered independently – in other words, the direct and final user emissions in each sector must not be summed. The sum of all the direct emissions and the sum of the final user emissions, are identical.

There are relatively large direct emissions of carbon from power stations, residential and industry sectors. The final user emissions from the power stations and the colliery are zero because these two sectors are not final users. The carbon emissions from these two sectors have been reallocated to the residential, industrial and commercial sectors. This reallocation means the final user emissions for the residential and industrial sectors are greater than their 'direct' emissions.

A13.5 FINAL USER CALCULATION METHODOLOGY FOR THE UK GREENHOUSE GAS INVENTORY

The approach divides fuel user emissions into 7 categories (see column 1 of **Table A13.5.1**). 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 final users according to the energy use of anthracite and coal combined.

Table A 13.5.1 Sources reallocated to final users and the fuels used

Final user group	Emission sources to be reallocated to final 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 & transport	Anthracite
	Collieries	
	Deep-mined coal	
	Open-cast coal	
3. Natural gas	Gas leakage	Natural gas
	Gas production	
	Gas Production - combustion at gas separation plant	
	Gas Production - gas combustion	
	Gas Production - gas flaring	
	Gas Production - Gas terminal storage	
	Gas Production - gas venting	
	Gas Production - Offshore Well Testing	
	Gas Production - Onshore Oil Loading	
	Gas Production - process emissions	
4. Electricity	Nuclear fuel production	Electricity
	Power stations	
	Autogeneration – exported to grid	
	Power stations - FGD	
5. Petroleum	Oil Production - gas combustion	Naphtha
	Oil Production - gas flaring	Burning oil (premium)
	Oil Production - gas venting	Burning oil
	Oil Production - Offshore Oil Loading	Aviation turbine fuel
	Oil Production - Offshore Well Testing	Aviation spirit
	Oil Production - Oil terminal storage	Derv
	Oil Production - Onshore Oil Loading	Fuel oil
	Oil Production - process emissions	Gas oil
	Petrol stations - petrol delivery	OPG
	Petrol stations - vehicle refuelling	Refinery misc.
	Petrol terminals - storage	Petrol
	Petrol terminals - tanker loading	Petroleum coke
	Petroleum processes	Wide-cut gasoline
	Refineries - combustion	Vaporizing oil
	Refineries - drainage	LPG
	Refineries - flares	
	Refineries - general	
	Refineries - process	
	Refineries - road/rail loading	
	Refineries - tankage	
	Sea going vessel loading	

Final user group	Emission sources to be reallocated to final users	Fuels used for redistribution
	Ship purging	
6. Solid Smokeless Fuels	Solid Smokeless fuel production	Solid Smokeless Fuels
7. Town gas	Town gas manufacture	Town gas

Comments on the calculation methodology used to allocate emissions according final users are listed below:

- Emissions are allocated to final users on the basis of the proportion of the total energy produced 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
- Final 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 final user calculation.

Our exact mapping of final user emissions to IPCC categories is shown in the following table. 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 final user tables for the greenhouse gases given in this section. As this table is for final users, no fuel producers are included in the table.

Table A 13.5.2 Final user category, IPCC sectors, and NAEI source names and activity names used in the emission calculation

NC Category	IPCC Category	Source Name	Activity Name
Agriculture	1A4ci_Agriculture/Forestry/Fishing:Stationary	Agriculture - stationary combustion	Coal Fuel oil Natural gas Straw
		Miscellaneous industrial/commercial combustion	Burning oil
	1A4cii_Agriculture/Forestry/Fishing:Off-road	Agricultural engines	Lubricants
		Agriculture - mobile machinery	Gas oil Petrol
	2B5_Chemical_Industry_Other	Agriculture - agrochemicals use	Carbon in pesticides
	4A10_Enteric_Fermentation_Deer	Agriculture livestock - deer enteric	Non-fuel combustion
	4A1a_Enteric_Fermentation_Dairy	Agriculture livestock - dairy cattle enteric	Non-fuel combustion
	4A1b_Enteric_Fermentation_Non-Dairy	Agriculture livestock - other cattle enteric	Non-fuel combustion
	4A3_Enteric_Fermentation_Sheep	Agriculture livestock - sheep enteric	Non-fuel combustion
	4A4_Enteric_Fermentation_Goats	Agriculture livestock - goats enteric	Non-fuel combustion
	4A6_Enteric_Fermentation_Horses	Agriculture livestock - horses enteric	Non-fuel combustion
	4A8_Enteric_Fermentation_Swine	Agriculture livestock - pigs enteric	Non-fuel combustion
	4B10_Manure_Management_Deer	Agriculture livestock - deer wastes	Non-fuel combustion
	4B12_Liquid_Systems	Agriculture livestock - manure liquid systems	Non-fuel combustion
	4B13_Solid_Storage_and_Drylot	Agriculture livestock - manure solid storage and dry lot	Non-fuel combustion
	4B14_Other	Agriculture livestock - manure other	Non-fuel combustion
	4B1a_Manure_Management_Dairy	Agriculture livestock - dairy cattle wastes	Non-fuel combustion
	4B1b_Manure_Management_Non-Dairy	Agriculture livestock - other cattle wastes	Non-fuel combustion
	4B3_Manure_Management_Sheep	Agriculture livestock - sheep goats and deer wastes	Non-fuel combustion
	4B4_Manure_Management_Goats	Agriculture livestock - goats wastes	Non-fuel combustion
	4B6_Manure_Management_Horses	Agriculture livestock - horses wastes	Non-fuel combustion
	4B8_Manure_Management_Swine	Agriculture livestock - pigs wastes	Non-fuel combustion
	4B9_Manure_Management_Poultry	Agriculture livestock - broilers wastes	Non-fuel combustion
		Agriculture livestock - laying hens wastes	Non-fuel combustion

NC Category	IPCC Category	Source Name	Activity Name
		Agriculture livestock - other poultry wastes	Non-fuel combustion
	4D_Agricultural_Soils	Agricultural soils	Non-fuel crops Non-fuel fertilizer
	4F1_Field_Burning_of_Agricultural_Residues	Field burning	Barley residue Oats residue Wheat residue
	4F5_Field_Burning_of_Agricultural_Residues	Field burning	Linseed residue
	non-IPCC	Agriculture - stationary combustion	Electricity
Business	1A2a_Manufacturing_Industry&Construction:I&S	Blast furnaces	Blast furnace gas Coke oven gas LPG Natural gas
		Iron and steel - combustion plant	Blast furnace gas Coal Coke Coke oven gas Fuel oil Gas oil LPG Natural gas
	1A2b_Non-Ferrous_Metals	Non-Ferrous Metal (combustion)	Coal Fuel oil Gas oil Natural gas
	1A2b_Non-Ferrous_Metals	Non-Ferrous Metal (combustion)	Coal Fuel oil Gas oil Natural gas
	1A2c_Chemicals	Chemicals (combustion)	Coal Fuel oil Gas oil

NC Category	IPCC Category	Source Name	Activity Name
			Natural gas
	1A2d_Pulp_Paper_Print	Pulp, Paper and Print (combustion)	Coal Fuel oil Gas oil Natural gas
	1A2e_Food_drink_tobacco	Food & drink, tobacco (combustion)	Coal Fuel oil Gas oil Natural gas
	1A2f_Manufacturing_Industry&Construction:Other	Ammonia production - combustion	Natural gas
		Autogenerators	Coal Natural gas
		Cement production - combustion	Coal Fuel oil Gas oil Natural gas Petroleum coke Scrap tyres Waste Waste oils Waste solvent
		Lime production - non decarbonising	Coal Coke Natural gas
		Other industrial combustion	Burning oil Coal Coke Coke oven gas Colliery methane Fuel oil Gas oil LPG

NC Category	IPCC Category	Source Name	Activity Name
			Lubricants Natural gas OPG Petroleum coke SSF Wood
	1A2fii_Manufacturing_Industry&Construction:Off-road	Industrial engines	Lubricants
		Industrial off-road mobile machinery	Gas oil Petrol
	1A4a_Commercial/Institutional	Miscellaneous industrial/commercial combustion	Coal Fuel oil Gas oil Landfill gas MSW Natural gas
	2B5_Carbon from NEU of products	Other industrial combustion	Energy recovery - chemical industry
	2C1_Iron&Steel	Blast furnaces	Coal
	2F1_Refrigeration_and_Air_Conditioning_Equipment	Commercial Refrigeration	Refrigeration and Air Conditioning - Disposal Refrigeration and Air Conditioning - Lifetime Refrigeration and Air Conditioning - Manufacture
		Domestic Refrigeration	Refrigeration and Air Conditioning - Disposal Refrigeration and Air Conditioning - Lifetime

NC Category	IPCC Category	Source Name	Activity Name
			Refrigeration and Air Conditioning - Manufacture
		Industrial Refrigeration	Refrigeration and Air Conditioning - Disposal
			Refrigeration and Air Conditioning - Lifetime
			Refrigeration and Air Conditioning - Manufacture
		Mobile Air Conditioning	Refrigeration and Air Conditioning - Disposal
			Refrigeration and Air Conditioning - Lifetime
			Refrigeration and Air Conditioning - Manufacture
		OvTerr F-gas emissions (all)- Guernsey, Jersey, IOM	Non-fuel combustion
		Refrigerated Transport	Refrigeration and Air Conditioning - Disposal
			Refrigeration and Air Conditioning - Lifetime
			Refrigeration and Air Conditioning - Manufacture
		Stationary Air Conditioning	Refrigeration and Air Conditioning - Disposal

NC Category	IPCC Category	Source Name	Activity Name
			Refrigeration and Air Conditioning - Lifetime Refrigeration and Air Conditioning - Manufacture
	2F2_Foam_Blowing	Foams	Non-fuel combustion
	2F3_Fire_Extinguishers	Firefighting	Non-fuel combustion
	2F5_Solvents	Precision cleaning - HFC	Non-fuel combustion
	2F9_Other_(one_component_foams)	One Component Foams	Non-fuel combustion
	2F9_Other_(semiconductors_electrical_sporting_goods)	Electrical insulation	Non-fuel combustion
		Electronics - PFC	Non-fuel combustion
		Electronics - SF6	Non-fuel combustion
		Sporting goods	Non-fuel combustion
	non-IPCC	Iron and steel - combustion plant	Electricity
		Miscellaneous industrial/commercial combustion	Electricity
		Other industrial combustion	Electricity
Energy Supply	1A1a_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	Coke production	Natural gas
		Solid smokeless fuel production	Coke
	1A1cii_Other_Energy_Industries	Collieries - combustion	Natural gas
		Gas production	LPG
		Nuclear fuel production	Natural gas
		Gas Production - combustion at gas separation plant	LPG OPG

NC Category	IPCC Category	Source Name	Activity Name
		Oil Production - gas combustion	Natural gas Gas oil
	1B1b_Solid_Fuel_Transformation	Coke production	Coal
		Solid smokeless fuel production	Coal
	non-IPCC	Collieries - combustion	Electricity
		Gas production	Electricity
		Refineries - combustion	Electricity
Exports	1A3di_International_Marine	Shipping - international IPCC definition	Fuel oil Gas oil
	Aviation_Bunkers	Aircraft - international cruise	Aviation spirit Aviation turbine fuel
		Aircraft - international take off and landing	Aviation spirit Aviation turbine fuel
		Aircraft between UK and Gibraltar - TOL	Aviation spirit Aviation turbine fuel
		Aircraft between UK and other OTs (excl Gib.) - TOL	Aviation turbine fuel
		Aircraft between UK and Gibraltar - Cruise	Aviation spirit Aviation turbine fuel
		Aircraft between UK and other Ots (excl Gib.) - Cruise	Aviation turbine fuel
	non-IPCC	Exports	Aviation turbine fuel Burning oil Coke DERV Electricity Fuel oil Petrol SSF
Industrial Process	1A2a_Manufacturing_Industry&Construction:I&S	Sinter production	Coke

NC Category	IPCC Category	Source Name	Activity Name
	2A1_Cement_Production	Cement - decarbonising	Clinker production
	2A2_Lime_Production	Lime production - decarbonising	Limestone
	2A3_Limestone_&_Dolomite_Use	Basic oxygen furnaces	Dolomite
		Glass - general	Dolomite Limestone
		Sinter production	Dolomite Limestone
	2A4_Soda_Ash_Production_&_Use	Glass - general	Soda ash
	2A7_(Fletton_Bricks)	Brick manufacture - Fletton	Fletton bricks
	2B1_Ammonia_Production	Ammonia production - feedstock use of gas	Natural gas
	2B2_Nitric_Acid_Production	Nitric acid production	Acid production
	2B3_Adipic_Acid_Production	Adipic acid production	Adipic acid produced
	2B5_Chemical_Industry_Other	Chemical industry - ethylene	Ethylene
		Chemical industry - general	Process emission
		Chemical industry - methanol	Methanol
	2C1_Iron&Steel	Blast furnaces	Coke Fuel oil
		Electric arc furnaces	Steel production (electric arc)
		Ladle arc furnaces	Steel production (electric arc) Steel production (oxygen converters)
	2C3_Aluminium_Production	Primary aluminium production - general	Primary aluminium production
		Primary aluminium production - PFC emissions	Primary aluminium production
	2C4_Cover_gas_used_in_Al_and_Mg_foundries	Magnesium cover gas	Non-fuel combustion
	2E1_Production_of_Halocarbons_and_Sulphur_Hexafluoride	Halocarbons production - by-product	Non-fuel combustion
	2E2_Production_of_Halocarbons_and_Sulphur_Hexafluoride	Halocarbons production - fugitive	Non-fuel combustion
	non-IPCC	Blast furnaces	Electricity
Land Use	5A_Forest Land (Biomass Burning - wildfires)	Forest Land - Biomass burning	Biomass

NC Category	IPCC Category	Source Name	Activity Name
Change			
	5A1_Forest Land Remaining Forest Land	Forest Land remaining Forest Land	Non-fuel combustion
	5A2_Forest Land (N fertilisation)	Direct N2O emission from N fertilisation of forest land	Non-fuel combustion
	5A2_Land Converted to Forest Land	Land converted to Forest Land	Non-fuel combustion
	5B_Cropland (Biomass Burning - controlled)	Cropland - Biomass Burning	Biomass
	5B_Liming	Cropland - Liming	Dolomite Limestone
	5B1_Cropland Remaining Cropland	Cropland remaining Cropland	Non-fuel combustion
	5B2_Land Converted to Cropland	Land converted to Cropland	Non-fuel combustion
	5B2_N2O emissions from disturbance associated with land-use conversion to cropland	N2O emissions from disturbance associated with land-use conversion to cropland	Non-fuel combustion
	5C_Grassland (Biomass burning - controlled)	Grassland - Biomass Burning	Biomass
	5C_Liming	Grassland - Liming	Dolomite Limestone
	5C2_Land converted to grassland	Land converted to Grassland	Non-fuel combustion
	5D1_Wetlands remaining wetlands	Wetlands remaining Wetland	Non-fuel combustion
	5D2_Non-CO_2 emissions from drainage of soils and wetlands	Non-CO_2 emissions from drainage of soils and wetlands	Non-fuel combustion
	5E_Settlements (Biomass burning - controlled)	Settlements - Biomass Burning	Biomass
	5E2_Land converted to settlements	Land converted to Settlements	Non-fuel combustion
	5G_Other (Harvested wood)	Harvested Wood Products	Non-fuel combustion
	5G_Other (OT and CD)	OvTerr LULUCF - Jersey, Guernsey and IOM	Non-fuel combustion
Public	1A4a_Commercial/Institutional	Public sector combustion	Burning oil Coal Coke Fuel oil Gas oil Natural gas Sewage gas
	non-IPCC	Public sector combustion	Electricity

NC Category	IPCC Category	Source Name	Activity Name
Residential	1A4b_Residential	Domestic combustion	Anthracite Burning oil Coal Coke Fuel oil Gas oil LPG Natural gas Peat Petroleum coke SSF Wood
	1A4bii_Residential:Off-road	House and garden machinery	DERV Petrol
	2B5_Chemical_Industry_Other	Non-aerosol products - household products	Carbon in detergents Petroleum waxes
	2F4_Aerosols	Aerosols - halocarbons	Non-fuel combustion
		Metered dose inhalers	Non-fuel combustion
	6C_Waste_Incineration	Accidental fires - vehicles	Mass burnt
	non-IPCC	Domestic combustion	Electricity
Transport	1A3aii_Civil_Aviation_Domestic	Aircraft - domestic cruise	Aviation spirit Aviation turbine fuel
		Aircraft - domestic take off and landing	Aviation spirit Aviation turbine fuel
		Aircraft between UK and CDs - TOL	Aviation spirit Aviation turbine fuel
		Aircraft between UK and CDs - Cruise	Aviation spirit Aviation turbine fuel
	1A3b_Road_Transportation	Road transport - all vehicles LPG use	LPG
		Road transport - buses and coaches - motorway driving	DERV

NC Category	IPCC Category	Source Name	Activity Name
		Road transport - buses and coaches - rural driving	DERV
		Road transport - buses and coaches - urban driving	DERV
		Road transport - cars - cold start	DERV Petrol
		Road transport - cars - motorway driving	DERV Petrol
		Road transport - cars - rural driving	DERV Petrol
		Road transport - cars - urban driving	DERV Petrol
		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
		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
		Road transport - mopeds (<50cc 2st) - urban driving	Petrol
		Road transport - motorcycle (>50cc 2st) - urban driving	Petrol
		Road transport - motorcycle (>50cc 4st) - motorway driving	Petrol
		Road transport - motorcycle (>50cc 4st) - rural	Petrol

NC Category	IPCC Category	Source Name	Activity Name
		driving	
		Road transport - motorcycle (>50cc 4st) - urban driving	Petrol
		Road vehicle engines	Lubricants
	1A3c_Railways	Railways - freight	Gas oil
		Railways - intercity	Gas oil
		Railways - regional	Gas oil
		Rail - coal	Coal
	1A3dii_National_Navigation	Marine engines	Lubricants
		Shipping - coastal	Fuel oil Gas oil
		Inland goods-carrying vessels	DERV Gas oil Petrol
		Motorboats / workboats (e.g. canal boats, dredgers, service boats, tourist boats, river boats)	DERV Gas oil Petrol
		Personal watercraft e.g. jet ski	DERV Gas oil Petrol
		Sailing boats with auxiliary engines	DERV Gas oil Petrol
	1A3e_Other_Transportation	Aircraft - support vehicles	Gas oil
	1A4a_Commercial/Institutional	Railways - stationary combustion	Burning oil Coal Fuel oil Natural gas
	1A4ciii_Fishing	Fishing vessels	Gas oil
	1A5b_Other:Mobile	Aircraft - military	Aviation turbine fuel
		Shipping - naval	Gas oil
	non-IPCC	Railways - regional	Electricity

NC Category	IPCC Category	Source Name	Activity Name
Waste Management	6A1_Managed_Waste_Disposal_on_Land	Landfill	Non-fuel combustion
	6B2_Wastewater_Handling	Sewage sludge decomposition	Non-fuel domestic
	6C_Waste_Incineration	Incineration	MSW
		Incineration - chemical waste	Chemical waste
		Incineration - clinical waste	Clinical waste
		Incineration - sewage sludge	Sewage sludge combustion

A13.6 DETAILED EMISSIONS ACCORDING TO FINAL USER CATEGORIES

The final user categories in the data tables in this summary are those used in National Communications. The final user reallocation includes all emissions from the UK and Crown Dependencies, this is the coverage used for the UK statistical release[29], where the final users data are presented in more detail.

The base year for hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride is 1995. For carbon dioxide, methane and nitrous oxide, the base year is 1990.

Notes

- LULUCF Land Use Land Use Change and Forestry

[29] http://www.decc.gov.uk/en/content/cms/statistics/climate_stats/gg_emissions/uk_emissions/2010_final/2010_final.aspx

Table A 13.6.1 Final user emissions from all National Communication categories, $MtCO_2$ equivalent

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Agriculture	66.79	66.93	66.67	66.31	65.38	65.48	64.97	65.35	64.76	63.97	63.08	60.75
Business	246.63	245.44	243.70	229.64	220.31	214.58	212.91	214.49	206.41	206.41	203.54	211.41
Energy Supply	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exports	9.54	9.54	10.55	11.37	12.81	13.17	13.91	15.25	16.65	16.24	14.40	13.59
Industrial Process	58.68	57.06	55.21	49.82	46.16	47.66	47.26	48.15	49.47	46.26	29.06	26.45
LULUCF	3.91	3.89	3.87	3.34	2.22	2.05	2.46	2.18	1.92	1.24	1.06	0.37
Public	30.89	30.89	33.89	35.68	29.41	28.82	28.29	29.05	26.64	25.48	24.54	23.69
Residential	170.20	169.81	179.38	173.14	169.89	162.47	156.84	169.26	154.01	159.90	155.13	159.21
Transport	139.90	139.90	137.93	139.65	141.89	143.41	143.73	148.56	149.49	148.62	148.75	147.20
Waste Management	45.77	45.90	45.02	43.72	42.33	41.12	40.02	38.98	35.88	33.83	31.11	29.35
Total greenhouse gas emissions	**772.31**	**769.36**	**776.22**	**752.67**	**730.41**	**718.75**	**710.38**	**731.26**	**705.22**	**701.95**	**670.66**	**672.02**

Final user category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Agriculture	58.30	58.18	57.71	57.67	57.91	55.98	54.32	53.61	52.61	53.23
Business	216.94	201.91	206.00	204.53	206.63	208.30	204.99	203.02	175.16	179.43
Energy Supply	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exports	13.09	14.95	15.68	17.15	17.17	16.56	17.05	15.57	16.00	16.35
Industrial Process	23.35	20.10	20.62	19.84	18.89	17.57	18.84	17.03	11.22	11.74
LULUCF	-0.12	-0.94	-1.29	-2.36	-2.95	-3.10	-3.49	-3.89	-4.21	-3.85
Public	24.52	21.80	22.02	22.62	22.16	20.74	20.16	20.05	17.85	17.84
Residential	166.67	163.71	167.62	169.29	163.71	163.56	156.66	155.09	144.12	157.21
Transport	147.60	151.26	149.79	149.72	150.07	149.76	151.36	145.51	139.70	139.34
Waste Management	25.93	23.85	20.99	19.48	18.96	18.56	18.20	17.63	17.12	16.54
Total greenhouse gas emissions	**676.28**	**654.83**	**659.13**	**657.92**	**652.55**	**647.93**	**638.09**	**623.63**	**569.57**	**587.83**

Table A 13.6.2 Final user CO_2 emissions from all National Communication categories, $MtCO_2$ equivalent

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Agriculture	8.76	8.76	8.75	8.57	8.38	8.40	8.30	8.30	7.97	7.84	7.66	7.34
Business	228.76	228.76	227.30	213.64	204.81	201.48	198.57	200.40	192.07	192.37	189.73	197.11
Energy Supply	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exports	8.86	8.86	9.84	10.63	12.04	12.39	13.08	14.41	15.75	15.37	13.65	12.86
Industrial Process	17.49	17.49	15.30	14.68	14.59	15.72	16.12	16.72	16.62	16.84	16.70	15.88
LULUCF	3.10	3.08	3.05	2.53	1.42	1.24	1.64	1.36	1.10	0.42	0.24	-0.43
Public	28.91	28.91	31.71	33.31	27.54	27.32	26.71	27.56	25.26	24.26	23.46	22.73
Residential	156.67	156.67	165.67	159.71	157.07	152.25	146.66	158.96	144.11	149.68	145.80	150.35
Transport	136.58	136.58	134.70	136.40	138.62	140.02	140.06	145.13	146.15	145.33	145.59	144.14
Waste Management	1.22	1.22	1.22	1.18	1.09	0.94	0.89	0.90	0.52	0.52	0.48	0.49
Total greenhouse gas emissions	**590.34**	**590.32**	**597.55**	**580.64**	**565.54**	**559.76**	**552.02**	**573.75**	**549.54**	**552.63**	**543.30**	**550.47**

Final user category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Agriculture	7.69	7.59	7.58	7.31	7.26	7.00	6.79	6.73	6.39	6.60
Business	202.12	186.52	191.06	189.01	190.88	192.32	188.80	186.43	158.70	162.67
Energy Supply	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exports	12.40	14.21	14.99	16.36	16.48	15.90	16.35	14.98	15.35	15.73
Industrial Process	14.31	13.52	14.25	14.41	14.57	13.95	15.20	13.85	9.41	9.70
LULUCF	-0.91	-1.72	-2.05	-3.11	-3.66	-3.82	-4.19	-4.58	-4.88	-4.51
Public	23.59	20.94	21.34	21.93	21.54	20.18	19.65	19.55	17.38	17.40
Residential	157.72	154.92	159.80	161.53	156.10	156.16	149.80	148.30	137.45	150.53
Transport	144.65	148.38	147.13	147.14	147.67	147.45	149.05	143.49	137.71	137.42
Waste Management	0.51	0.51	0.46	0.43	0.38	0.30	0.33	0.28	0.27	0.27
Total greenhouse gas emissions	**562.08**	**544.88**	**554.56**	**555.03**	**551.21**	**549.44**	**541.78**	**529.03**	**477.79**	**495.80**

Table A 13.6.3 Final user CH_4 emissions from all National Communication categories, $MtCO_2$ equivalent

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Agriculture	22.55	22.66	22.36	22.28	22.14	22.13	21.79	21.93	21.19	21.04	20.95	20.06
Business	13.31	13.31	13.05	12.65	12.10	9.33	10.17	9.45	9.30	8.37	7.50	6.91
Energy Supply	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exports	0.59	0.59	0.60	0.62	0.64	0.64	0.67	0.66	0.71	0.67	0.56	0.55
Industrial Process	1.70	1.70	1.66	1.66	1.63	1.33	1.43	1.46	1.49	1.26	1.14	0.96
LULUCF	0.02	0.02	0.02	0.01	0.02	0.02	0.03	0.02	0.03	0.02	0.02	0.03
Public	1.78	1.78	1.97	2.15	1.71	1.35	1.44	1.36	1.27	1.11	0.99	0.86
Residential	12.18	12.18	12.71	12.49	11.93	9.28	9.04	8.80	7.91	7.46	6.78	6.01
Transport	1.69	1.69	1.62	1.62	1.56	1.49	1.51	1.42	1.33	1.27	1.16	1.08
Waste Management	43.34	43.47	42.60	41.31	40.01	38.95	37.89	36.80	34.13	32.04	29.37	27.54
Total greenhouse gas emissions	**97.16**	**97.40**	**96.58**	**94.81**	**91.73**	**84.53**	**83.96**	**81.90**	**77.36**	**73.25**	**68.47**	**64.00**

Final user category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Agriculture	19.03	18.68	18.68	18.94	19.41	19.11	18.69	18.27	17.96	18.05
Business	6.52	6.27	4.94	4.68	4.15	3.86	3.41	3.39	3.15	3.01
Energy Supply	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exports	0.52	0.55	0.50	0.59	0.48	0.46	0.51	0.42	0.47	0.45
Industrial Process	0.74	0.65	0.57	0.53	0.43	0.39	0.35	0.34	0.33	0.31
LULUCF	0.03	0.04	0.03	0.04	0.02	0.04	0.04	0.04	0.02	0.03
Public	0.83	0.77	0.59	0.60	0.54	0.47	0.43	0.42	0.40	0.38
Residential	5.86	5.78	4.52	4.44	3.96	3.74	3.44	3.35	3.35	3.44
Transport	1.06	1.02	0.87	0.86	0.72	0.68	0.71	0.59	0.61	0.54
Waste Management	24.13	22.04	19.30	17.83	17.35	17.04	16.65	16.19	15.65	15.07
Total greenhouse gas emissions	**58.73**	**55.80**	**50.01**	**48.51**	**47.07**	**45.79**	**44.23**	**43.00**	**41.95**	**41.27**

Table A 13.6.4 Final user N_2O emissions from all National Communication categories, $MtCO_2$ equivalent

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Agriculture	35.48	35.52	35.56	35.45	34.86	34.95	34.88	35.11	35.60	35.09	34.47	33.34
Business	2.70	2.70	2.63	2.55	2.38	2.36	2.31	2.23	2.11	2.08	2.01	2.05
Energy Supply	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exports	0.09	0.09	0.11	0.12	0.13	0.14	0.15	0.17	0.19	0.20	0.18	0.18
Industrial Process	24.73	24.73	24.88	20.24	16.33	16.52	14.95	14.86	15.04	15.32	5.44	5.62
LULUCF	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.77
Public	0.20	0.20	0.21	0.22	0.16	0.15	0.14	0.13	0.12	0.11	0.10	0.10
Residential	0.95	0.95	0.99	0.93	0.86	0.82	0.74	0.73	0.63	0.65	0.60	0.62
Transport	1.63	1.63	1.62	1.63	1.72	1.90	2.17	2.01	2.00	2.02	2.00	1.98
Waste Management	1.21	1.21	1.20	1.24	1.23	1.23	1.24	1.28	1.23	1.27	1.26	1.32
Total greenhouse gas emissions	**67.78**	**67.82**	**67.98**	**63.17**	**58.46**	**58.86**	**57.37**	**57.30**	**57.71**	**57.54**	**46.86**	**45.98**

Final user category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Agriculture	31.57	31.91	31.45	31.41	31.24	29.87	28.84	28.61	28.26	28.58
Business	2.11	2.06	2.00	1.99	2.09	2.04	2.05	1.94	1.61	1.63
Energy Supply	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exports	0.16	0.19	0.19	0.20	0.21	0.20	0.19	0.17	0.18	0.17
Industrial Process	4.88	2.84	2.98	3.82	3.02	2.43	2.82	2.48	1.22	1.36
LULUCF	0.76	0.74	0.72	0.71	0.69	0.68	0.67	0.65	0.64	0.63
Public	0.10	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.07	0.07
Residential	0.67	0.66	0.64	0.63	0.62	0.64	0.60	0.57	0.53	0.55
Transport	1.90	1.86	1.79	1.72	1.68	1.63	1.60	1.43	1.38	1.38
Waste Management	1.29	1.29	1.23	1.21	1.23	1.22	1.22	1.16	1.20	1.20
Total greenhouse gas emissions	**43.44**	**41.64**	**41.09**	**41.78**	**40.87**	**38.81**	**38.06**	**37.10**	**35.09**	**35.56**