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 level.

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). A qualitative assessment was not conducted, but we do not anticipate that additional source categories would have been identified using such an assessment. The emission estimates were taken from the current inventory.

The results of the level assessment with and without LULUCF 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, 1990 and the latest reported year are shown in **Table A 1.1.7** and **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.

The emissions of nitric and adipic acid are both key categories in the UK inventory and the emissions from nitric acid production are associated with a very high uncertainty. 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 dominate the overall uncertainty of N_2O emissions in sector 2B. The uncertainty assigned to the EF of nitric acid production was taken from a study commissioned by UK Defra (Salway *et al*., 1998). The uncertainty in the emission factor from nitric acid production was estimated from a range of values in the available literature - the reference in the report indicates the main source was the 1996 IPCC guidelines. The UK has not reviewed the uncertainties associated with nitric and adipic acid for some time. A review of the uncertainties was planned with the manufacturers during the compilation of the 2009 NIR but this has been deferred until the 2011 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 (-13,627 Gg CO_2e) is a key category although the AR component (forest planted since 1990) is not key on its own (i.e. its category contribution (-2,766 Gg CO_2e) is smaller than the smallest UNFCCC key category (1A Coal)). Removals from this category are also predicted to increase over time as a result of tree planting schemes partially focussed on climate change mitigation.

Article 3.3 Deforestation (CO_2): The associated UNFCCC categories (5C and 5E) are key categories (-8,156 and 6,280 Gg CO_2e respectively). However, the Deforestation category contribution (615 Gg CO_2e) to these UNFCCC categories is smaller than the smallest UNFCCC key category (1A Coal). The data used in the calculation of deforestation emissions are the most uncertain of the data sources in the KP-LULUCF inventory and are a priority for improvement.

Article 3.4 Forest Management (CO_2): The associated UNFCCC category 5A is a key category (-13,627 Gg CO_2e). The Forest Management category contribution (-10,698 Gg CO_2e) is also greater than other categories in the UNFCCC key category.

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

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. 2009	Combined uncertainty range as a % of source category	Level Parameter (used to order sources)	Level / Sum(Level)*100 %	Cumulative %
4D	Agricultural Soils	N2O	32091.46	24905.17	424.00	0.1729738	51.50408	
6A	Solid Waste Disposal	CH4	56216.71	16052.77	48.38	0.0345772	10.29559	61.79967
1A(stationary)	Oil	CO2	92200.71	50820.20	15.13	0.0177368	5.28125	67.08092
4B	Manure Management	N2O	2759.23	2056.29	414.00	0.0145216	4.32390	71.40482
1A1&1A2&1A4&1A5	Other Combustion	N2O	4675.84	3079.56	195.00	0.0115909	3.45128	74.85609
2B	Nitric Acid Production	N2O	3903.85	1106.70	230.22	0.0114250	3.40186	78.25795
5B	5B LULUCF	CO2	15694.70	12692.42	50.01	0.0099778	2.97095	81.22890
6B	Wastewater Handling	N2O	1250.63	1376.64	401.12	0.0063772	1.89886	83.12776
1A3b	Auto Fuel	CO2	109570.50	112986.66	4.48	0.0062432	1.85895	84.98671
5C	5C LULUCF	CO2	-6260.28	-8649.52	70.01	0.0055713	1.65890	86.64561
4A	Enteric Fermentation	CH4	18527.34	15263.07	20.00	0.0047106	1.40260	88.04821
5E	5E LULUCF	CO2	7038.09	6054.37	50.01	0.0044744	1.33228	89.38050
2B	Adipic Acid Production	N2O	20737.34	71.02	15.01	0.0039565	1.17807	90.55857
5A	5A LULUCF	CO2	-12155.07	-12722.83	25.02	0.0038661	1.15114	91.70971
2	Industrial Processes	HFC	15457.72	10927.21	19.03	0.0037387	1.11323	92.82294
1A	Coal	CO2	248165.51	111465.07	1.08	0.0033978	1.01171	93.83465
1B1	Mining & Solid Fuel Transformation	CH4	18289.71	2867.52	59.72	0.0030259	0.90098	94.73562
1A3b	Auto Fuel	N2O	1176.84	978.75	170.02	0.0025436	0.75738	95.49300
1B2	Production, Refining & Distribution of Oil & Natu	CH4	10322.92	5266.15	23.83	0.0022172	0.66017	96.15317
1A	Natural Gas	CO2	108984.72	182791.69	1.51	0.0020966	0.62426	96.77744
4B	Manure Management	CH4	3607.76	2816.72	30.00	0.0013759	0.40968	97.18712
1A	All Fuel	CH4	2078.74	1005.71	50.00	0.0013213	0.39343	97.58055
1B	Oil & Natural Gas	CO2	5777.84	4599.43	17.09	0.0012551	0.37372	97.95427
2B5	NEU	CO2	1562.92	1913.77	53.85	0.0010699	0.31858	98.27285
5G	5G LULUCF	CO2	-1637.10	-2402.42	30.02	0.0006247	0.18600	98.45885
5B	5B LULUCF	N2O	781.77	633.04	50.01	0.0004970	0.14799	98.60684
1A3b	Auto Fuel	CH4	634.36	89.61	50.08	0.0004038	0.12025	98.72708
1A3a	Aviation Fuel	CO2	1509.56	2119.03	20.27	0.0003890	0.11582	98.84291
1A3	Other Diesel	N2O	195.32	277.83	140.01	0.0003476	0.10351	98.94642
6C	Waste Incineration	CO2	1212.41	297.01	21.19	0.0003266	0.09724	99.04366
2	Industrial Processes	SF6	1239.30	661.81	20.02	0.0003155	0.09394	99.13760
5D	5D LULUCF	CO2	422.26	281.99	50.01	0.0002685	0.07993	99.21753
4F	Field Burning	N2O	77.76	0.00	231.35	0.0002287	0.06810	99.28563
2A1	Cement Production	CO2	7295.26	3720.48	2.42	0.0002241	0.06673	99.35236
1A4	Peat	CO2	475.59	47.44	31.62	0.0001912	0.05693	99.40929
4F	Field Burning	CH4	266.04	0.00	55.90	0.0001891	0.05629	99.46558
6B	Wastewater Handling	CH4	287.27	345.31	50.01	0.0001826	0.05438	99.51996
2C1	Iron&Steel Production	CO2	2309.27	1193.28	6.12	0.0001796	0.05348	99.57344
2B	Ammonia Production	CO2	1321.67	801.29	10.11	0.0001699	0.05059	99.62403
2A7	Fletton Bricks	CO2	179.87	73.76	72.80	0.0001665	0.04956	99.67360
1A	Lubricant	CO2	386.90	197.64	30.07	0.0001479	0.04403	99.71763
6C	Waste Incineration	N2O	47.90	43.56	230.11	0.0001401	0.04172	99.75935
6C	Waste Incineration	CH4	134.43	6.14	50.49	0.0000863	0.02569	99.78504
2A3	Limestone & Dolomite use	CO2	1317.50	1194.63	5.10	0.0000854	0.02543	99.81047
2A2	Lime Production	CO2	1191.52	626.63	5.10	0.0000772	0.02300	99.83347
1B	Solid Fuel Transformation	CO2	856.42	150.05	6.01	0.0000655	0.01949	99.85296
2B	Chemical Industry	CH4	169.43	76.27	28.28	0.0000609	0.01814	99.87110
1B2	Oil & Natural Gas	N2O	42.40	36.76	111.16	0.0000599	0.01784	99.88894
2	Industrial Processes	PFC	462.03	147.10	10.05	0.0000590	0.01758	99.90651
1A	Other (waste)	CO2	212.42	1566.25	21.19	0.0000572	0.01704	99.92355
1A3	Other Diesel	CO2	1647.37	2356.15	2.20	0.0000461	0.01373	99.93728
1A3d	Marine Fuel	CO2	1643.03	1447.85	2.20	0.0000460	0.01370	99.95098
1A3a	Aviation Fuel	N2O	14.86	20.86	171.17	0.0000323	0.00963	99.96061
2A4	Soda Ash Use	CO2	167.32	184.95	15.13	0.0000322	0.00958	99.97019
2A7	Fletton Bricks	CH4	23.60	5.52	101.98	0.0000306	0.00911	99.97930
1A3d	Marine Fuel	N2O	12.81	11.23	170.01	0.0000277	0.00824	99.98754
2C	Iron & Steel	N2O	11.11	4.96	118.00	0.0000167	0.00496	99.99251
2C	Iron & Steel Production	CH4	16.36	6.66	50.00	0.0000104	0.00310	99.99560
1B1	Coke Oven Gas	N2O	2.08	0.17	118.00	0.0000031	0.00093	99.99653
5E2	5E2 LULUCF	CH4	9.25	2.89	20.02	0.0000024	0.00070	99.99723
1A3a	Aviation Fuel	CH4	3.30	1.23	53.85	0.0000023	0.00067	99.99791
1A3	Other Diesel	CH4	3.16	4.36	50.03	0.0000020	0.00060	99.99851
5A	5A LULUCF	N2O	5.57	1.95	20.02	0.0000014	0.00042	99.99893
5A	5A LULUCF	CH4	4.30	9.48	20.02	0.0000011	0.00033	99.99925
5D	5D LULUCF	N2O	3.98	0.54	20.02	0.0000010	0.00030	99.99956
5C2	5C2 LULUCF	CH4	2.95	13.82	20.02	0.0000007	0.00022	99.99978
1A3d	Marine Fuel	CH4	0.54	0.48	50.03	0.0000003	0.00010	99.99988
5E2	5E2 LULUCF	N2O	0.94	0.29	20.02	0.0000002	0.00007	99.99995
5B	5B LULUCF	CH4	0.13	0.46	50.01	0.0000001	0.00002	99.99998
5C2	5C2 LULUCF	N2O	0.30	1.40	20.02	0.0000001	0.00002	100.00000
1A	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A4	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	CH4	0.00	0.00	33.54	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	N2O	0.00	0.00	33.54	0.0000000	0.00000	100.00000
4G	OvTerr Agriculture N2O (all)	N2O	0.00	0.00	50.99	0.0000000	0.00000	100.00000
		Sum -- >	786,640.25	565,984.29		0.3358	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. 2009	Combined uncertainty range as a % of source category	Level Parameter (used to order sources)	Level / Sum(Level)*100 %	Cumulative %
4D	Agricultural Soils	N2O	32091.46	24905.17	424.00	0.1738383	55.69772	
6A	Solid Waste Disposal	CH4	56216.71	16052.77	48.38	0.0347500	11.13389	66.83162
1A(stationary)	Oil	CO2	92200.71	50820.20	15.13	0.0178255	5.71127	72.54289
4B	Manure Management	N2O	2759.23	2056.29	414.00	0.0145942	4.67596	77.21885
1A1&1A2&1A4&1A5	Other Combustion	N2O	4675.84	3079.56	195.00	0.0116489	3.73229	80.95114
2B	Nitric Acid Production	N2O	3903.85	1106.70	230.22	0.0114821	3.67885	84.62999
6B	Wastewater Handling	N2O	1250.63	1376.64	401.12	0.0064091	2.05347	86.68346
1A3b	Auto Fuel	CO2	109570.50	112986.66	4.48	0.0062744	2.01032	88.69378
4A	Enteric Fermentation	CH4	18527.34	15263.07	20.00	0.0047341	1.51680	90.21058
2B	Adipic Acid Production	N2O	20737.34	71.02	15.01	0.0039763	1.27399	91.48457
2	Industrial Processes	HFC	15457.72	10927.21	19.03	0.0037574	1.20387	92.68845
1A	Coal	CO2	248165.51	111465.07	1.08	0.0034148	1.09409	93.78253
1B1	Mining & Solid Fuel Transformation	CH4	18289.71	2867.52	60.46	0.0030410	0.97434	94.75687
1A3b	Auto Fuel	N2O	1176.84	978.75	170.02	0.0025563	0.81904	95.57591
1B2	Production, Refining & Distribution of Oil & Natu	CH4	10322.92	5266.15	24.12	0.0022282	0.71393	96.28984
1A	Natural Gas	CO2	108984.72	182791.69	1.51	0.0021070	0.67509	96.96493
4B	Manure Management	CH4	3607.76	2816.72	30.00	0.0013828	0.44304	97.40797
1A	All Fuel	CH4	2078.74	1005.71	50.00	0.0013279	0.42547	97.83344
1B	Oil & Natural Gas	CO2	5777.84	4599.43	17.09	0.0012614	0.40415	98.23758
2B5	NEU	CO2	1562.92	1913.77	53.85	0.0010753	0.34452	98.58211
1A3b	Auto Fuel	CH4	634.36	89.61	50.08	0.0004059	0.13004	98.71214
1A3a	Aviation Fuel	CO2	1509.56	2119.03	20.27	0.0003909	0.12525	98.83740
1A3	Other Diesel	N2O	195.32	277.83	140.01	0.0003494	0.11194	98.94934
6C	Waste Incineration	CO2	1212.41	297.01	21.19	0.0003282	0.10516	99.05450
2	Industrial Processes	SF6	1239.30	661.81	20.02	0.0003171	0.10158	99.15608
4F	Field Burning	N2O	77.76	0.00	231.35	0.0002298	0.07364	99.22973
2A1	Cement Production	CO2	7295.26	3720.48	2.42	0.0002252	0.07217	99.30189
1A4	Peat	CO2	475.59	47.44	31.62	0.0001921	0.06156	99.36345
4F	Field Burning	CH4	266.04	0.00	55.90	0.0001900	0.06088	99.42433
6B	Wastewater Handling	CH4	287.27	345.31	50.01	0.0001835	0.05881	99.48314
2C1	Iron&Steel Production	CO2	2309.27	1193.28	6.12	0.0001805	0.05784	99.54098
2B	Ammonia Production	CO2	1321.67	801.29	10.11	0.0001707	0.05471	99.59568
2A7	Fletton Bricks	CO2	179.87	73.76	72.80	0.0001673	0.05360	99.64928
1A	Lubricant	CO2	386.90	197.64	30.07	0.0001486	0.04762	99.69690
6C	Waste Incineration	N2O	47.90	43.56	230.11	0.0001408	0.04512	99.74202
6C	Waste Incineration	CH4	134.43	6.14	50.49	0.0000867	0.02778	99.76980
2A3	Limestone & Dolomite use	CO2	1317.50	1194.63	5.10	0.0000858	0.02750	99.79730
2A2	Lime Production	CO2	1191.52	626.63	5.10	0.0000776	0.02487	99.82217
1B	Solid Fuel Transformation	CO2	856.42	150.05	6.01	0.0000658	0.02108	99.84325
2B	Chemical Industry	CH4	169.43	76.27	28.28	0.0000612	0.01962	99.86287
1B2	Oil & Natural Gas	N2O	42.40	36.76	111.16	0.0000602	0.01929	99.88216
2	Industrial Processes	PFC	462.03	147.10	10.05	0.0000593	0.01901	99.90116
1A	Other (waste)	CO2	212.42	1566.25	21.19	0.0000575	0.01842	99.91959
1A3	Other Diesel	CO2	1647.37	2356.15	2.20	0.0000464	0.01485	99.93444
1A3d	Marine Fuel	CO2	1643.03	1447.85	2.20	0.0000462	0.01481	99.94925
1A3a	Aviation Fuel	N2O	14.86	20.86	171.17	0.0000325	0.01041	99.95966
2A4	Soda Ash Use	CO2	167.32	184.95	15.13	0.0000323	0.01036	99.97003
2A7	Fletton Bricks	CH4	23.60	5.52	101.98	0.0000308	0.00985	99.97988
1A3d	Marine Fuel	N2O	12.81	11.23	170.01	0.0000278	0.00891	99.98879
2C	Iron & Steel	N2O	11.11	4.96	118.00	0.0000167	0.00536	99.99416
2C	Iron & Steel Production	CH4	16.36	6.66	50.00	0.0000104	0.00335	99.99751
1B1	Coke Oven Gas	N2O	2.08	0.17	118.00	0.0000031	0.00101	99.99851
1A3a	Aviation Fuel	CH4	3.30	1.23	53.85	0.0000023	0.00073	99.99924
1A3	Other Diesel	CH4	3.16	4.36	50.03	0.0000020	0.00065	99.99989
1A3d	Marine Fuel	CH4	0.54	0.48	50.03	0.0000003	0.00011	100.00000
1A	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A4	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	CH4	0.00	0.00	33.54	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	N2O	0.00	0.00	33.54	0.0000000	0.00000	100.00000
4G	OvTerr Agriculture N2O (all)	N2O	0.00	0.00	50.99	0.0000000	0.00000	100.00000
		Sum -->	782,728.46	570,066.41		0.3121	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. 2009	Combined uncertainty range as a % of source category	Level Parameter (used to order sources)	Level / Sum(Level)*100 %	Cumulative %
4D	Agricultural Soils	N2O	32091.46	24905.17	424.00	0.1737118	51.64527	
6A	Solid Waste Disposal	CH4	56216.71	16052.77	48.38	0.0347247	10.32381	61.96908
1A(stationary)	Oil	CO2	92200.71	50820.20	15.13	0.0178125	5.29573	67.26482
4B	Manure Management	N2O	2759.23	2056.29	414.00	0.0145835	4.33575	71.60057
1A1&1A2&1A4&1A5	Other Combustion	N2O	4675.84	3079.56	195.00	0.0116404	3.46074	75.06131
2B	Nitric Acid Production	N2O	3903.85	1106.70	230.22	0.0114737	3.41118	78.47249
5B	5B LULUCF	CO2	15694.70	12692.42	50.01	0.0100203	2.97909	81.45158
6B	Wastewater Handling	N2O	1250.63	1376.64	401.12	0.0064044	1.90406	83.35564
1A3b	Auto Fuel	CO2	109570.50	112986.66	4.48	0.0062698	1.86405	85.21969
5C	5C LULUCF	CO2	-6260.28	-8649.52	70.01	0.0055951	1.66345	86.88314
4A	Enteric Fermentation	CH4	18527.34	15263.07	20.00	0.0047307	1.40644	88.28959
5E	5E LULUCF	CO2	7038.09	6054.37	50.01	0.0044935	1.33594	89.62552
2B	Adipic Acid Production	N2O	20737.34	71.02	15.01	0.0039734	1.18130	90.80682
5A	5A LULUCF	CO2	-12155.07	-12722.83	25.02	0.0038826	1.15430	91.96112
1A	Coal	CO2	248165.51	111465.07	1.08	0.0034123	1.01448	92.97560
1B1	Mining & Solid Fuel Transformation	CH4	18289.71	2867.52	59.98	0.0030388	0.90345	93.87905
2	Industrial Processes	HFC	11385.62	10927.21	19.03	0.0027656	0.82221	94.70127
1A3b	Auto Fuel	N2O	1176.84	978.75	170.02	0.0025545	0.75945	95.46072
1B2	Production, Refining & Distribution of Oil & Natural Gas	CH4	10322.92	5266.15	23.93	0.0022266	0.66198	96.12270
1A	Natural Gas	CO2	108984.72	182791.69	1.51	0.0021055	0.62598	96.74867
4B	Manure Management	CH4	3607.76	2816.72	30.00	0.0013818	0.41080	97.15948
1A	All Fuel	CH4	2078.74	1005.71	50.00	0.0013270	0.39451	97.55399
1B	Oil & Natural Gas	CO2	5777.84	4599.43	17.09	0.0012605	0.37474	97.92873
2B5	NEU	CO2	1562.92	1913.77	53.85	0.0010745	0.31945	98.24819
5G	5G LULUCF	CO2	-1637.10	-2402.42	30.02	0.0006273	0.18651	98.43470
5B	5B LULUCF	N2O	781.77	633.04	50.01	0.0004991	0.14839	98.58309
1A3b	Auto Fuel	CH4	634.36	89.61	50.08	0.0004056	0.12057	98.70367
1A3a	Aviation Fuel	CO2	1509.56	2119.03	20.27	0.0003906	0.11614	98.81981
1A3	Other Diesel	N2O	195.32	277.83	140.01	0.0003491	0.10380	98.92360
6C	Waste Incineration	CO2	1212.41	297.01	21.19	0.0003280	0.09751	99.02111
5D	5D LULUCF	CO2	422.26	281.99	50.01	0.0002696	0.08015	99.10126
2	Industrial Processes	SF6	1029.95	661.81	20.02	0.0002633	0.07828	99.17955
4F	Field Burning	N2O	77.76	0.00	231.35	0.0002297	0.06828	99.24783
2A1	Cement Production	CO2	7295.26	3720.48	2.42	0.0002251	0.06691	99.31475
1A4	Peat	CO2	475.59	47.44	31.62	0.0001920	0.05708	99.37183
4F	Field Burning	CH4	266.04	0.00	55.90	0.0001899	0.05645	99.42828
6B	Wastewater Handling	CH4	287.27	345.31	50.01	0.0001834	0.05453	99.48280
2C1	Iron&Steel Production	CO2	2309.27	1193.28	6.12	0.0001804	0.05363	99.53644
2	Industrial Processes	PFC	1401.60	147.10	10.05	0.0001798	0.05346	99.58990
2B	Ammonia Production	CO2	1321.67	801.29	10.11	0.0001706	0.05073	99.64062
2A7	Fletton Bricks	CO2	179.87	73.76	72.80	0.0001672	0.04970	99.69032
1A	Lubricant	CO2	386.90	197.64	30.07	0.0001485	0.04415	99.73448
6C	Waste Incineration	N2O	47.90	43.56	230.11	0.0001407	0.04184	99.77631
6C	Waste Incineration	CH4	134.43	6.14	50.49	0.0000866	0.02576	99.80208
2A3	Limestone & Dolomite use	CO2	1317.50	1194.63	5.10	0.0000858	0.02550	99.82757
2A2	Lime Production	CO2	1191.52	626.63	5.10	0.0000776	0.02306	99.85063
1B	Solid Fuel Transformation	CO2	856.42	150.05	6.01	0.0000657	0.01955	99.87018
2B	Chemical Industry	CH4	169.43	76.27	28.28	0.0000612	0.01819	99.88837
1B2	Oil & Natural Gas	N2O	42.40	36.76	111.16	0.0000602	0.01789	99.90626
1A	Other (waste)	CO2	212.42	1566.25	21.19	0.0000575	0.01708	99.92334
1A3	Other Diesel	CO2	1647.37	2356.15	2.20	0.0000463	0.01377	99.93711
1A3d	Marine Fuel	CO2	1643.03	1447.85	2.20	0.0000462	0.01373	99.95084
1A3a	Aviation Fuel	N2O	14.86	20.86	171.17	0.0000325	0.00966	99.96050
2A4	Soda Ash Use	CO2	167.32	184.95	15.13	0.0000323	0.00961	99.97011
2A7	Fletton Bricks	CH4	23.60	5.52	101.98	0.0000307	0.00914	99.97925
1A3d	Marine Fuel	N2O	12.81	11.23	170.01	0.0000278	0.00826	99.98751
2C	Iron & Steel	N2O	11.11	4.96	118.00	0.0000167	0.00497	99.99248
2C	Iron & Steel Production	CH4	16.36	6.66	50.00	0.0000104	0.00310	99.99559
1B1	Coke Oven Gas	N2O	2.08	0.17	118.00	0.0000031	0.00093	99.99652
5E2	5E2 LULUCF	CH4	9.25	2.89	20.02	0.0000024	0.00070	99.99723
1A3a	Aviation Fuel	CH4	3.30	1.23	53.85	0.0000023	0.00067	99.99790
1A3	Other Diesel	CH4	3.16	4.36	50.03	0.0000020	0.00060	99.99850
5A	5A LULUCF	N2O	5.57	1.95	20.02	0.0000014	0.00042	99.99892
5A	5A LULUCF	CH4	4.30	9.48	20.02	0.0000011	0.00033	99.99925
5D	5D LULUCF	N2O	3.98	0.54	20.02	0.0000010	0.00030	99.99955
5C2	5C2 LULUCF	CH4	2.95	13.82	20.02	0.0000008	0.00022	99.99978
1A3d	Marine Fuel	CH4	0.54	0.48	50.03	0.0000003	0.00010	99.99988
5E2	5E2 LULUCF	N2O	0.94	0.29	20.02	0.0000002	0.00007	99.99995
5B	5B LULUCF	CH4	0.13	0.46	50.01	0.0000001	0.00003	99.99998
5C2	5C2 LULUCF	N2O	0.30	1.40	20.02	0.0000001	0.00002	100.00000
1A	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A4	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	CH4	0.00	0.00	33.54	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	N2O	0.00	0.00	33.54	0.0000000	0.00000	100.00000
4G	OvTerr Agriculture N2O (all)	N2O	0.00	0.00	50.99	0.0000000	0.00000	100.00000
		Sum -->	783,298.37	565,984.29		0.34	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. 2009	Combined uncertainty range as a % of source category	Level Parameter (used to order sources)	Level / Sum(Level)*100 %	Cumulative %
4D	Agricultural Soils	N2O	32091.46	24905.17	424.001	0.1745837	55.86288	
6A	Solid Waste Disposal	CH4	56216.71	16052.77	48.384	0.0348990	11.16691	67.02979
1A(stationary)	Oil	CO2	92200.71	50820.20	15.133	0.0179019	5.72821	72.75800
4B	Manure Management	N2O	2759.23	2056.29	414.001	0.0146567	4.68983	77.44783
1A1&1A2&1A4&1A5	Other Combustion	N2O	4675.84	3079.56	195.000	0.0116988	3.74336	81.19119
2B	Nitric Acid Production	N2O	3903.85	1106.70	230.217	0.0115313	3.68976	84.88094
6B	Wastewater Handling	N2O	1250.63	1376.64	401.125	0.0064366	2.05956	86.94050
1A3b	Auto Fuel	CO2	109570.50	112986.66	4.482	0.0063013	2.01628	88.95678
4A	Enteric Fermentation	CH4	18527.34	15263.07	20.000	0.0047544	1.52130	90.47808
2B	Adipic Acid Production	N2O	20737.34	71.02	15.008	0.0039933	1.27777	91.75585
1A	Coal	CO2	248165.51	111465.07	1.077	0.0034294	1.09733	92.85318
1B1	Mining & Solid Fuel Transformation	CH4	18289.71	2867.52	60.715	0.0030540	0.97723	93.83041
2	Industrial Processes	HFC	11385.62	10927.21	19.026	0.0027794	0.88936	94.71977
1A3b	Auto Fuel	N2O	1176.84	978.75	170.023	0.0025673	0.82147	95.54124
1B2	Production, Refining & Distribution of Oil & Natural Gas	CH4	10322.92	5266.15	24.224	0.0022378	0.71604	96.25728
1A	Natural Gas	CO2	108984.72	182791.69	1.513	0.0021161	0.67710	96.93438
4B	Manure Management	CH4	3607.76	2816.72	30	0.0013887	0.44435	97.37873
1A	All Fuel	CH4	2078.74	1005.71	50.002	0.0013336	0.42673	97.80546
1B	Oil & Natural Gas	CO2	5777.84	4599.43	17.088	0.0012668	0.40534	98.21080
2B5	NEU	CO2	1562.92	1913.77	53.852	0.0010799	0.34554	98.55635
1A3b	Auto Fuel	CH4	634.36	89.61	50.078	0.0004076	0.13042	98.68677
1A3a	Aviation Fuel	CO2	1509.56	2119.03	20.2704218	0.0003926	0.12563	98.81239
1A3	Other Diesel	N2O	195.32	277.83	140.010	0.0003509	0.11227	98.92467
6C	Waste Incineration	CO2	1212.41	297.01	21.190	0.0003296	0.10547	99.03014
2	Industrial Processes	SF6	1029.95	661.81	20	0.0002646	0.08467	99.11481
4F	Field Burning	N2O	77.76	0.00	231.355	0.0002308	0.07386	99.18867
2A1	Cement Production	CO2	7295.26	3720.48	2.416609195	0.0002262	0.07238	99.26105
1A4	Peat	CO2	475.59	47.44	31.623	0.0001930	0.06174	99.32280
4F	Field Burning	CH4	266.04	0.00	55.902	0.0001908	0.06106	99.38386
6B	Wastewater Handling	CH4	287.27	345.31	50.010	0.0001843	0.05898	99.44284
2C1	Iron&Steel Production	CO2	2309.27	1193.28	6	0.0001813	0.05801	99.50085
2	Industrial Processes	PFC	1401.60	147.10	10.050	0.0001807	0.05783	99.55868
2B	Ammonia Production	CO2	1321.67	801.29	10.112	0.0001715	0.05487	99.61355
2A7	Fletton Bricks	CO2	179.87	73.76	72.801	0.0001680	0.05376	99.66731
1A	Lubricant	CO2	386.90	197.64	30.067	0.0001493	0.04776	99.71506
6C	Waste Incineration	N2O	47.90	43.56	230.106	0.0001414	0.04525	99.76032
6C	Waste Incineration	CH4	134.43	6.14	50	0.0000871	0.02787	99.78818
2A3	Limestone & Dolomite use	CO2	1317.50	1194.63	5.099	0.0000862	0.02758	99.81576
2A2	Lime Production	CO2	1191.52	626.63	5.099	0.0000780	0.02494	99.84071
1B	Solid Fuel Transformation	CO2	856.42	150.05	6.013	0.0000661	0.02114	99.86185
2B	Chemical Industry	CH4	169.43	76.27	28.284	0.0000615	0.01967	99.88152
1B2	Oil & Natural Gas	N2O	42.40	36.76	111.158	0.0000605	0.01935	99.90087
1A	Other (waste)	CO2	212.42	1566.25	21.190	0.0000578	0.01848	99.91935
1A3	Other Diesel	CO2	1647.37	2356.15	2.202	0.0000465	0.01489	99.93424
1A3d	Marine Fuel	CO2	1643.03	1447.85	2.202	0.0000464	0.01486	99.94910
1A3a	Aviation Fuel	N2O	14.86	20.86	171.172	0.0000326	0.01044	99.95954
2A4	Soda Ash Use	CO2	167.32	184.95	15.133	0.0000325	0.01040	99.96994
2A7	Fletton Bricks	CH4	23.60	5.52	101.980	0.0000309	0.00988	99.97982
1A3d	Marine Fuel	N2O	12.81	11.23	170.008	0.0000279	0.00894	99.98876
2C	Iron & Steel	N2O	11.11	4.96	118.001	0.0000168	0.00538	99.99414
2C	Iron & Steel Production	CH4	16.36	6.66	50.002	0.0000105	0.00336	99.99750
1B1	Coke Oven Gas	N2O	2.08	0.17	118.001	0.0000032	0.00101	99.99851
1A3a	Aviation Fuel	CH4	3.30	1.23	53.852	0.0000023	0.00073	99.99924
1A3	Other Diesel	CH4	3.16	4.36	50.029	0.0000020	0.00065	99.99989
1A3d	Marine Fuel	CH4	0.54	0.48	50.029	0.0000003	0.00011	100.00000
1A	Combined Fuel	CO2	0.00	0.00	21.213	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	CO2	0.00	0.00	21.213	0.0000000	0.00000	100.00000
1A4	Combined Fuel	CO2	0.00	0.00	21.213	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	CH4	0.00	0.00	33.541	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	N2O	0.00	0.00	33.54101966	0.0000000	0.00000	100.00000
4G	OvTerr Agriculture N2O (all)	N2O	0.00	0.00	50.990	0.0000000	0.00000	100.00000
		Sum -->	779,386.57	570,066.41		0.31	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	Base year emissions Gg CO2 equiv. 1990 & 1995	Year Y emissions Gg CO2 equiv. 2009	Combined uncertainty range as a % of source category	Level Parameter (used to order sources)	Level / Sum(Level)*100 %	Cumulative %
4D	Agricultural Soils	N2O	32091.46	24905.17	424.00	0.1865745	56.73827	
4B	Manure Management	N2O	2759.23	2056.29	414.00	0.0150412	4.57410	61.31237
6A	Solid Waste Disposal	CH4	56216.71	16052.77	48.38	0.0137229	4.17321	65.48558
1A(stationary)	Oil	CO2	92200.71	50820.20	15.13	0.0135878	4.13213	69.61771
5B	5B LULUCF	CO2	15694.70	12692.42	50.01	0.0112149	3.41052	73.02823
5C	5C LULUCF	CO2	-6260.28	-8649.52	70.01	0.0106987	3.25352	76.28175
1A1&1A2&1A4&1A5	Other Combustion	N2O	4675.84	3079.56	195.00	0.0106101	3.22659	79.50834
6B	Wastewater Handling	N2O	1250.63	1376.64	401.12	0.0097565	2.96700	82.47535
1A3b	Auto Fuel	CO2	109570.50	112986.66	4.48	0.0089477	2.72105	85.19640
5A	5A LULUCF	CO2	-12155.07	-12722.83	25.02	0.0056243	1.71037	86.90677
4A	Enteric Fermentation	CH4	18527.34	15263.07	20.00	0.0053935	1.64020	88.54697
5E	5E LULUCF	CO2	7038.09	6054.37	50.01	0.0053496	1.62684	90.17381
1A	Natural Gas	CO2	108984.72	182791.69	1.51	0.0048873	1.48626	91.66007
2B	Nitric Acid Production	N2O	3903.85	1106.70	230.22	0.0045016	1.36895	93.02901
2	Industrial Processes	HFC	15457.72	10927.21	19.03	0.0036733	1.11708	94.14609
1A3b	Auto Fuel	N2O	1176.84	978.75	170.02	0.0029402	0.89412	95.04021
1A	Coal	CO2	248165.51	111465.07	1.08	0.0021211	0.64504	95.68526
2B5	NEU	CO2	1562.92	1913.77	53.85	0.0018209	0.55374	96.23900
1B2	Production, Refining & Distribution of Oil & Natural Gas	CH4	10322.92	5266.15	16.99	0.0015805	0.48064	96.71964
4B	Manure Management	CH4	3607.76	2816.72	30.00	0.0014930	0.45403	97.17367
1B	Oil & Natural Gas	CO2	5777.84	4599.43	17.09	0.0013886	0.42229	97.59596
5G	5G LULUCF	CO2	-1637.10	-2402.42	30.02	0.0012741	0.38746	97.98343
1A	All Fuel	CH4	2078.74	1005.71	50.00	0.0008885	0.27020	98.25362
1A3a	Aviation Fuel	CO2	1509.56	2119.03	20.27	0.0007589	0.23079	98.48441
1A3	Other Diesel	N2O	195.32	277.83	140.01	0.0006873	0.20901	98.69342
1B1	Mining & Solid Fuel Transformation	CH4	18289.71	2867.52	13.01	0.0006592	0.20045	98.89387
1A	Other (waste)	CO2	212.42	1566.25	21.19	0.0005864	0.17832	99.07220
5B	5B LULUCF	N2O	781.77	633.04	50.01	0.0005594	0.17010	99.24230
6B	Wastewater Handling	CH4	287.27	345.31	50.01	0.0003051	0.09279	99.33508
5D	5D LULUCF	CO2	422.26	281.99	50.01	0.0002492	0.07577	99.41086
2	Industrial Processes	SF6	1239.30	661.81	20.02	0.0002342	0.07121	99.48206
6C	Waste Incineration	N2O	47.90	43.56	230.11	0.0001771	0.05385	99.53592
2A1	Cement Production	CO2	7295.26	3720.48	2.42	0.0001589	0.04831	99.58423
2B	Ammonia Production	CO2	1321.67	801.29	10.11	0.0001432	0.04354	99.62776
2C1	Iron&Steel Production	CO2	2309.27	1193.28	6.12	0.0001290	0.03923	99.66699
6C	Waste Incineration	CO2	1212.41	297.01	21.19	0.0001112	0.03382	99.70081
2A3	Limestone & Dolomite use	CO2	1317.50	1194.63	5.10	0.0001076	0.03273	99.73354
1A	Lubricant	CO2	386.90	197.64	30.07	0.0001050	0.03193	99.76547
2A7	Fletton Bricks	CO2	179.87	73.76	72.80	0.0000949	0.02885	99.79432
1A3	Other Diesel	CO2	1647.37	2356.15	2.20	0.0000917	0.02788	99.82220
1A3b	Auto Fuel	CH4	634.36	89.61	50.08	0.0000793	0.02411	99.84631
1B2	Oil & Natural Gas	N2O	42.40	36.76	111.16	0.0000722	0.02196	99.86827
1A3a	Aviation Fuel	N2O	14.86	20.86	171.17	0.0000631	0.01919	99.88745
2A2	Lime Production	CO2	1191.52	626.63	5.10	0.0000565	0.01717	99.90462
1A3d	Marine Fuel	CO2	1643.03	1447.85	2.20	0.0000563	0.01713	99.92175
2A4	Soda Ash Use	CO2	167.32	184.95	15.13	0.0000495	0.01504	99.93679
2B	Chemical Industry	CH4	169.43	76.27	28.28	0.0000381	0.01159	99.94838
1A3d	Marine Fuel	N2O	12.81	11.23	170.01	0.0000337	0.01026	99.95864
1A4	Peat	CO2	475.59	47.44	31.62	0.0000265	0.00806	99.96670
2	Industrial Processes	PFC	462.03	147.10	10.05	0.0000261	0.00794	99.97465
2B	Adipic Acid Production	N2O	20737.34	71.02	15.01	0.0000188	0.00573	99.98037
1B	Solid Fuel Transformation	CO2	856.42	150.05	6.01	0.0000159	0.00485	99.98522
2C	Iron & Steel	N2O	11.11	4.96	118.00	0.0000103	0.00315	99.98837
2A7	Fletton Bricks	CH4	23.60	5.52	101.98	0.0000099	0.00302	99.99139
2C	Iron & Steel Production	CH4	16.36	6.66	50.00	0.0000059	0.00179	99.99318
6C	Waste Incineration	CH4	134.43	6.14	50.49	0.0000055	0.00167	99.99484
5C2	5C2 LULUCF	CH4	2.95	13.82	20.02	0.0000049	0.00149	99.99633
1A3	Other Diesel	CH4	3.16	4.36	50.03	0.0000039	0.00117	99.99750
5A	5A LULUCF	CH4	4.30	9.48	20.02	0.0000034	0.00102	99.99852
1A3a	Aviation Fuel	CH4	3.30	1.23	53.85	0.0000012	0.00036	99.99888
5E2	5E2 LULUCF	CH4	9.25	2.89	20.02	0.0000010	0.00031	99.99919
5A	5A LULUCF	N2O	5.57	1.95	20.02	0.0000007	0.00021	99.99940
5C2	5C2 LULUCF	N2O	0.30	1.40	20.02	0.0000005	0.00015	99.99955
1A3d	Marine Fuel	CH4	0.54	0.48	50.03	0.0000004	0.00013	99.99968
5B	5B LULUCF	CH4	0.13	0.46	50.01	0.0000004	0.00012	99.99980
1B1	Coke Oven Gas	N2O	2.08	0.17	118.00	0.0000004	0.00011	99.99991
5D	5D LULUCF	N2O	3.98	0.54	20.02	0.0000002	0.00006	99.99997
5E2	5E2 LULUCF	N2O	0.94	0.29	20.02	0.0000001	0.00003	100.00000
1A	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A4	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	CH4	0.00	0.00	33.54	0.0000000	0.00000	100.00000
4F	Field Burning	CH4	266.04	0.00	55.90	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	N2O	0.00	0.00	33.54	0.0000000	0.00000	100.00000
4F	Field Burning	N2O	77.76	0.00	231.35	0.0000000	0.00000	100.00000
4G	OvTerr Agriculture N2O (all)	N2O	0.00	0.00	50.99	0.0000000	0.00000	100.00000
		Sum -- >	786,640.25	565,984.29		0.33	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	Base year emissions Gg CO2 equiv. 1990 & 1995	Year Y emissions Gg CO2 equiv. 2009	Combined uncertainty range as a % of source category	Level Parameter (used to order sources)	Level / Sum(Level)*100 %	Cumulative %
4D	Agricultural Soils	N2O	32091.46	24905.17	424.00	0.1852385	63.49260	
4B	Manure Management	N2O	2759.23	2056.29	414.00	0.0149335	5.11862	68.61123
6A	Solid Waste Disposal	CH4	56216.71	16052.77	48.38	0.0136246	4.67000	73.28123
1A(stationary)	Oil	CO2	92200.71	50820.20	15.13	0.0134905	4.62403	77.90526
1A1&1A2&1A4&1A5	Other Combustion	N2O	4675.84	3079.56	195.00	0.0105341	3.61070	81.51595
6B	Wastewater Handling	N2O	1250.63	1376.64	401.12	0.0096866	3.32021	84.83616
1A3b	Auto Fuel	CO2	109570.50	112986.66	4.48	0.0088837	3.04497	87.88114
4A	Enteric Fermentation	CH4	18527.34	15263.07	20.00	0.0053549	1.83546	89.71659
1A	Natural Gas	CO2	108984.72	182791.69	1.51	0.0048523	1.66319	91.37978
2B	Nitric Acid Production	N2O	3903.85	1106.70	230.22	0.0044693	1.53191	92.91169
2	Industrial Processes	HFC	15457.72	10927.21	19.03	0.0036470	1.25006	94.16175
1A3b	Auto Fuel	N2O	1176.84	978.75	170.02	0.0029191	1.00056	95.16231
1A	Coal	CO2	248165.51	111465.07	1.08	0.0021059	0.72183	95.88414
2B5	NEU	CO2	1562.92	1913.77	53.85	0.0018079	0.61966	96.50380
1B2	Production, Refining & Distribution of Oil & Natural Gas	CH4	10322.92	5266.15	16.99	0.0015692	0.53785	97.04166
4B	Manure Management	CH4	3607.76	2816.72	30.00	0.0014823	0.50808	97.54974
1B	Oil & Natural Gas	CO2	5777.84	4599.43	17.09	0.0013787	0.47257	98.02231
1A	All Fuel	CH4	2078.74	1005.71	50.00	0.0008821	0.30236	98.32467
1A3a	Aviation Fuel	CO2	1509.56	2119.03	20.27	0.0007535	0.25827	98.58293
1A3	Other Diesel	N2O	195.32	277.83	140.01	0.0006824	0.23389	98.81682
1B1	Mining & Solid Fuel Transformation	CH4	18289.71	2867.52	13.01	0.0006544	0.22432	99.04114
1A	Other (waste)	CO2	212.42	1566.25	21.19	0.0005822	0.19955	99.24068
6B	Wastewater Handling	CH4	287.27	345.31	50.01	0.0003029	0.10383	99.34452
2	Industrial Processes	SF6	1239.30	661.81	20.02	0.0002325	0.07968	99.42420
6C	Waste Incineration	N2O	47.90	43.56	230.11	0.0001758	0.06027	99.48447
2A1	Cement Production	CO2	7295.26	3720.48	2.42	0.0001577	0.05406	99.53853
2B	Ammonia Production	CO2	1321.67	801.29	10.11	0.0001421	0.04872	99.58724
2C1	Iron&Steel Production	CO2	2309.27	1193.28	6.12	0.0001281	0.04390	99.63115
6C	Waste Incineration	CO2	1212.41	297.01	21.19	0.0001104	0.03784	99.66899
2A3	Limestone & Dolomite use	CO2	1317.50	1194.63	5.10	0.0001069	0.03663	99.70561
1A	Lubricant	CO2	386.90	197.64	30.07	0.0001042	0.03573	99.74134
2A7	Fletton Bricks	CO2	179.87	73.76	72.80	0.0000942	0.03229	99.77363
1A3	Other Diesel	CO2	1647.37	2356.15	2.20	0.0000910	0.03120	99.80483
1A3b	Auto Fuel	CH4	634.36	89.61	50.08	0.0000787	0.02698	99.83181
1B2	Oil & Natural Gas	N2O	42.40	36.76	111.16	0.0000717	0.02457	99.85638
1A3a	Aviation Fuel	N2O	14.86	20.86	171.17	0.0000626	0.02147	99.87785
2A2	Lime Production	CO2	1191.52	626.63	5.10	0.0000560	0.01921	99.89706
1A3d	Marine Fuel	CO2	1643.03	1447.85	2.20	0.0000559	0.01917	99.91623
2A4	Soda Ash Use	CO2	167.32	184.95	15.13	0.0000491	0.01683	99.93306
2B	Chemical Industry	CH4	169.43	76.27	28.28	0.0000378	0.01297	99.94603
1A3d	Marine Fuel	N2O	12.81	11.23	170.01	0.0000335	0.01148	99.95751
1A4	Peat	CO2	475.59	47.44	31.62	0.0000263	0.00902	99.96653
2	Industrial Processes	PFC	462.03	147.10	10.05	0.0000259	0.00889	99.97542
2B	Adipic Acid Production	N2O	20737.34	71.02	15.01	0.0000187	0.00641	99.98183
1B	Solid Fuel Transformation	CO2	856.42	150.05	6.01	0.0000158	0.00543	99.98726
2C	Iron & Steel	N2O	11.11	4.96	118.00	0.0000103	0.00352	99.99078
2A7	Fletton Bricks	CH4	23.60	5.52	101.98	0.0000099	0.00338	99.99416
2C	Iron & Steel Production	CH4	16.36	6.66	50.00	0.0000058	0.00200	99.99616
6C	Waste Incineration	CH4	134.43	6.14	50.49	0.0000054	0.00187	99.99803
1A3	Other Diesel	CH4	3.16	4.36	50.03	0.0000038	0.00131	99.99934
1A3a	Aviation Fuel	CH4	3.30	1.23	53.85	0.0000012	0.00040	99.99974
1A3d	Marine Fuel	CH4	0.54	0.48	50.03	0.0000004	0.00014	99.99988
1B1	Coke Oven Gas	N2O	2.08	0.17	118.00	0.0000003	0.00012	100.00000
1A	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A4	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	CH4	0.00	0.00	33.54	0.0000000	0.00000	100.00000
4F	Field Burning	CH4	266.04	0.00	55.90	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	N2O	0.00	0.00	33.54	0.0000000	0.00000	100.00000
4F	Field Burning	N2O	77.76	0.00	231.35	0.0000000	0.00000	100.00000
4G	OvTerr Agriculture N2O (all)	N2O	0.00	0.00	50.99	0.0000000	0.00000	100.00000
		Sum -->	782,728.46	570,066.41		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. 2009	Combined uncertainty range as a % of source category	Trend Parameter (used to order sources)	Trend / Sum(Trend)*100 %	Cumulative %
4D	Agricultural Soils	N2O	32091.46	24905.17	424.00	0.0801491	53.86293	
2B	Nitric Acid Production	N2O	3903.85	1106.70	230.22	0.0221528	14.88746	68.75039
6B	Wastewater Handling	N2O	1250.63	1376.64	401.12	0.0188398	12.66100	81.41139
6A	Solid Waste Disposal	CH4	56216.71	16052.77	48.38	0.0140239	9.42453	90.83592
4B	Manure Management	N2O	2759.23	2056.29	414.00	0.0029898	2.00925	92.84517
1A1&1A2&1A4&1A5	Other Combustion	N2O	4675.84	3079.56	195.00	0.0026583	1.78645	94.63162
1A3b	Auto Fuel	N2O	1176.84	978.75	170.02	0.0009371	0.62978	95.26140
1A(stationary)	Oil	CO2	92200.71	50820.20	15.13	0.0008726	0.58644	95.84785
5B	5B LULUCF	CO2	15694.70	12692.42	50.01	0.0008599	0.57789	96.42574
2B	Adipic Acid Production	N2O	20737.34	71.02	15.01	0.0008214	0.55199	96.97773
1A3	Other Diesel	N2O	195.32	277.83	140.01	0.0006609	0.44416	97.42189
5E	5E LULUCF	CO2	7038.09	6054.37	50.01	0.0006083	0.40881	97.83070
2B5	NEU	CO2	1562.92	1913.77	53.85	0.0005621	0.37773	98.20843
1B1	Mining & Solid Fuel Transformation	CH4	18289.71	2867.52	13.01	0.0004290	0.28830	98.49673
1A	All Fuel	CH4	2078.74	1005.71	50.00	0.0003008	0.20215	98.69887
1A3b	Auto Fuel	CH4	634.36	89.61	50.08	0.0002259	0.15181	98.85068
4A	Enteric Fermentation	CH4	18527.34	15263.07	20.00	0.0001898	0.12759	98.97827
1A3b	Auto Fuel	CO2	109570.50	112986.66	4.48	0.0001685	0.11323	99.09149
1A	Other (waste)	CO2	212.42	1566.25	21.19	0.0001558	0.10473	99.19622
1B2	Production, Refining & Distribution of Oil & Natural Gas	CH4	10322.92	5266.15	16.99	0.0001553	0.10438	99.30060
6C	Waste Incineration	N2O	47.90	43.56	230.11	0.0001182	0.07945	99.38005
1A3a	Aviation Fuel	CO2	1509.56	2119.03	20.27	0.0001042	0.07004	99.45009
6B	Wastewater Handling	CH4	287.27	345.31	50.01	0.0000851	0.05722	99.50731
1A3a	Aviation Fuel	N2O	14.86	20.86	171.17	0.0000732	0.04916	99.55647
2A7	Fletton Bricks	CO2	179.87	73.76	72.80	0.0000724	0.04868	99.60515
1A4	Peat	CO2	475.59	47.44	31.62	0.0000724	0.04864	99.65379
6C	Waste Incineration	CO2	1212.41	297.01	21.19	0.0000634	0.04263	99.69642
1A	Natural Gas	CO2	108984.72	182791.69	1.51	0.0000587	0.03945	99.73587
6C	Waste Incineration	CH4	134.43	6.14	50.49	0.0000567	0.03810	99.77397
4B	Manure Management	CH4	3607.76	2816.72	30.00	0.0000488	0.03282	99.80679
5B	5B LULUCF	N2O	781.77	633.04	50.01	0.0000433	0.02912	99.83591
1B	Oil & Natural Gas	CO2	5777.84	4599.43	17.09	0.0000317	0.02131	99.85723
2A7	Fletton Bricks	CH4	23.60	5.52	101.98	0.0000293	0.01967	99.87690
2	Industrial Processes	SF6	1239.30	661.81	20.02	0.0000226	0.01521	99.89211
1A	Coal	CO2	248165.51	111465.07	1.08	0.0000191	0.01284	99.90495
1B2	Oil & Natural Gas	N2O	42.40	36.76	111.16	0.0000190	0.01276	99.91772
1A	Lubricant	CO2	386.90	197.64	30.07	0.0000179	0.01204	99.92976
2	Industrial Processes	HFC	15457.72	10927.21	19.03	0.0000173	0.01162	99.94139
1A3d	Marine Fuel	N2O	12.81	11.23	170.01	0.0000143	0.00962	99.95100
5D	5D LULUCF	CO2	422.26	281.99	50.01	0.0000134	0.00901	99.96001
2C	Iron & Steel	N2O	11.11	4.96	118.00	0.0000104	0.00696	99.96698
2B	Chemical Industry	CH4	169.43	76.27	28.28	0.0000090	0.00602	99.97300
2	Industrial Processes	PFC	462.03	147.10	10.05	0.0000046	0.00309	99.97609
1B1	Coke Oven Gas	N2O	2.08	0.17	118.00	0.0000046	0.00306	99.97915
2C1	Iron&Steel Production	CO2	2309.27	1193.28	6.12	0.0000043	0.00289	99.98204
1B	Solid Fuel Transformation	CO2	856.42	150.05	6.01	0.0000041	0.00278	99.98482
2B	Ammonia Production	CO2	1321.67	801.29	10.11	0.0000038	0.00253	99.98735
2A4	Soda Ash Use	CO2	167.32	184.95	15.13	0.0000036	0.00244	99.98979
2C	Iron & Steel Production	CH4	16.36	6.66	50.00	0.0000031	0.00211	99.99190
2A1	Cement Production	CO2	7295.26	3720.48	2.42	0.0000022	0.00147	99.99337
2A3	Limestone & Dolomite use	CO2	1317.50	1194.63	5.10	0.0000016	0.00106	99.99443
2A2	Lime Production	CO2	1191.52	626.63	5.10	0.0000015	0.00099	99.99542
1A3	Other Diesel	CO2	1647.37	2356.15	2.20	0.0000014	0.00094	99.99635
1A3	Other Diesel	CH4	3.16	4.36	50.03	0.0000013	0.00086	99.99721
5C2	5C2 LULUCF	CH4	2.95	13.82	20.02	0.0000012	0.00077	99.99799
1A3a	Aviation Fuel	CH4	3.30	1.23	53.85	0.0000008	0.00055	99.99853
5A	5A LULUCF	CH4	4.30	9.48	20.02	0.0000006	0.00042	99.99896
5E2	5E2 LULUCF	CH4	9.25	2.89	20.02	0.0000004	0.00025	99.99921
1A3d	Marine Fuel	CO2	1643.03	1447.85	2.20	0.0000003	0.00021	99.99942
5D	5D LULUCF	N2O	3.98	0.54	20.02	0.0000002	0.00015	99.99957
5B	5B LULUCF	CH4	0.13	0.46	50.01	0.0000002	0.00015	99.99972
5A	5A LULUCF	N2O	5.57	1.95	20.02	0.0000002	0.00014	99.99986
5C2	5C2 LULUCF	N2O	0.30	1.40	20.02	0.0000001	0.00008	99.99994
1A3d	Marine Fuel	CH4	0.54	0.48	50.03	0.0000001	0.00004	99.99997
5E2	5E2 LULUCF	N2O	0.94	0.29	20.02	0.0000000	0.00003	100.00000
1A	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A4	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
5A	5A LULUCF	CO2	-12155.07	-12722.83	25.02	0.0000000	0.00000	100.00000
5C	5C LULUCF	CO2	-6260.28	-8649.52	70.01	0.0000000	0.00000	100.00000
5G	5G LULUCF	CO2	-1637.10	-2402.42	30.02	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	CH4	0.00	0.00	33.54	0.0000000	0.00000	100.00000
4F	Field Burning	CH4	266.04	0.00	55.90	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	N2O	0.00	0.00	33.54	0.0000000	0.00000	100.00000
4F	Field Burning	N2O	77.76	0.00	231.35	0.0000000	0.00000	100.00000
4G	OvTerr Agriculture N2O (all)	N2O	0.00	0.00	50.99	0.0000000	0.00000	100.00000
		Sum -->	786,640.25	565,984.29		0.15	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. 2009	Combined uncertainty range as a % of source category	Trend Parameter (used to order sources)	Trend / Sum(Trend)*100 %	Cumulative %
4D	Agricultural Soils	N2O	32091.46	24905.17	424.00	0.0663688	50.33942	
2B	Nitric Acid Production	N2O	3903.85	1106.70	230.22	0.0221672	16.81338	67.15280
6B	Wastewater Handling	N2O	1250.63	1376.64	401.12	0.0180516	13.69175	80.84455
6A	Solid Waste Disposal	CH4	56216.71	16052.77	48.38	0.0140343	10.64473	91.48928
1A1&1A2&1A4&1A5	Other Combustion	N2O	4675.84	3079.56	195.00	0.0029846	2.26379	93.75307
4B	Manure Management	N2O	2759.23	2056.29	414.00	0.0019288	1.46299	95.21606
1A(stationary)	Oil	CO2	92200.71	50820.20	15.13	0.0009007	0.68317	95.89923
1A3b	Auto Fuel	N2O	1176.84	978.75	170.02	0.0008470	0.64241	96.54164
2B	Adipic Acid Production	N2O	20737.34	71.02	15.01	0.0008155	0.61857	97.16021
1A3	Other Diesel	N2O	195.32	277.83	140.01	0.0006401	0.48552	97.64573
2B5	NEU	CO2	1562.92	1913.77	53.85	0.0005417	0.41085	98.05657
1B1	Mining & Solid Fuel Transformation	CH4	18289.71	2867.52	13.01	0.0004274	0.32414	98.38072
1A	All Fuel	CH4	2078.74	1005.71	50.00	0.0003061	0.23214	98.61286
1A3b	Auto Fuel	CH4	634.36	89.61	50.08	0.0002249	0.17061	98.78347
4A	Enteric Fermentation	CH4	18527.34	15263.07	20.00	0.0001705	0.12931	98.91278
1A3b	Auto Fuel	CO2	109570.50	112986.66	4.48	0.0001606	0.12180	99.03457
1B2	Production, Refining & Distribution of Oil & Natural Gas	CH4	10322.92	5266.15	16.99	0.0001590	0.12056	99.15513
1A	Other (waste)	CO2	212.42	1566.25	21.19	0.0001527	0.11578	99.27092
6C	Waste Incineration	N2O	47.90	43.56	230.11	0.0001106	0.08387	99.35479
1A3a	Aviation Fuel	CO2	1509.56	2119.03	20.27	0.0001009	0.07654	99.43132
6B	Wastewater Handling	CH4	287.27	345.31	50.01	0.0000820	0.06218	99.49350
2A7	Fletton Bricks	CO2	179.87	73.76	72.80	0.0000731	0.05542	99.54892
1A4	Peat	CO2	475.59	47.44	31.62	0.0000720	0.05461	99.60353
1A3a	Aviation Fuel	N2O	14.86	20.86	171.17	0.0000708	0.05372	99.65725
6C	Waste Incineration	CO2	1212.41	297.01	21.19	0.0000634	0.04807	99.70532
1A	Natural Gas	CO2	108984.72	182791.69	1.51	0.0000570	0.04326	99.74859
6C	Waste Incineration	CH4	134.43	6.14	50.49	0.0000563	0.04273	99.79132
4B	Manure Management	CH4	3607.76	2816.72	30.00	0.0000410	0.03110	99.82242
2A7	Fletton Bricks	CH4	23.60	5.52	101.98	0.0000292	0.02217	99.84460
2	Industrial Processes	HFC	15457.72	10927.21	19.03	0.0000288	0.02187	99.86647
1B	Oil & Natural Gas	CO2	5777.84	4599.43	17.09	0.0000275	0.02088	99.88735
2	Industrial Processes	SF6	1239.30	661.81	20.02	0.0000233	0.01764	99.90499
1A	Coal	CO2	248165.51	111465.07	1.08	0.0000194	0.01468	99.91967
1A	Lubricant	CO2	386.90	197.64	30.07	0.0000183	0.01390	99.93356
1B2	Oil & Natural Gas	N2O	42.40	36.76	111.16	0.0000175	0.01329	99.94685
1A3d	Marine Fuel	N2O	12.81	11.23	170.01	0.0000133	0.01005	99.95690
2C	Iron & Steel	N2O	11.11	4.96	118.00	0.0000105	0.00796	99.96486
2B	Chemical Industry	CH4	169.43	76.27	28.28	0.0000091	0.00689	99.97175
2	Industrial Processes	PFC	462.03	147.10	10.05	0.0000046	0.00349	99.97524
1B1	Coke Oven Gas	N2O	2.08	0.17	118.00	0.0000045	0.00343	99.97867
2C1	Iron&Steel Production	CO2	2309.27	1193.28	6.12	0.0000044	0.00334	99.98201
1B	Solid Fuel Transformation	CO2	856.42	150.05	6.01	0.0000041	0.00313	99.98514
2B	Ammonia Production	CO2	1321.67	801.29	10.11	0.0000040	0.00301	99.98816
2A4	Soda Ash Use	CO2	167.32	184.95	15.13	0.0000035	0.00264	99.99080
2C	Iron & Steel Production	CH4	16.36	6.66	50.00	0.0000032	0.00240	99.99320
2A1	Cement Production	CO2	7295.26	3720.48	2.42	0.0000022	0.00170	99.99490
2A2	Lime Production	CO2	1191.52	626.63	5.10	0.0000015	0.00115	99.99604
2A3	Limestone & Dolomite use	CO2	1317.50	1194.63	5.10	0.0000015	0.00112	99.99716
1A3	Other Diesel	CO2	1647.37	2356.15	2.20	0.0000014	0.00102	99.99818
1A3	Other Diesel	CH4	3.16	4.36	50.03	0.0000012	0.00094	99.99912
1A3a	Aviation Fuel	CH4	3.30	1.23	53.85	0.0000008	0.00062	99.99974
1A3d	Marine Fuel	CO2	1643.03	1447.85	2.20	0.0000003	0.00022	99.99996
1A3d	Marine Fuel	CH4	0.54	0.48	50.03	0.0000000	0.00004	100.00000
1A	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A4	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	CH4	0.00	0.00	33.54	0.0000000	0.00000	100.00000
4F	Field Burning	CH4	266.04	0.00	55.90	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	N2O	0.00	0.00	33.54	0.0000000	0.00000	100.00000
4F	Field Burning	N2O	77.76	0.00	231.35	0.0000000	0.00000	100.00000
4G	OvTerr Agriculture N2O (all)	N2O	0.00	0.00	50.99	0.0000000	0.00000	100.00000
		Sum -->	782,728.46	570,066.41		0.13	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. 2009	Combined uncertainty range as a % of source category	Trend Parameter (used to order sources)	Trend / Sum(Trend)*100 %	Cumulative %
4D	Agricultural Soils	N2O	32091.46	24905.17	424.00	0.0754781	52.45663	
2B	Nitric Acid Production	N2O	3903.85	1106.70	230.22	0.0222140	15.43855	67.89518
6B	Wastewater Handling	N2O	1250.63	1376.64	401.12	0.0186087	12.93291	80.82809
6A	Solid Waste Disposal	CH4	56216.71	16052.77	48.38	0.0140631	9.77372	90.60181
1A1&1A2&1A4&1A5	Other Combustion	N2O	4675.84	3079.56	195.00	0.0027804	1.93238	92.53419
4B	Manure Management	N2O	2759.23	2056.29	414.00	0.0026221	1.82235	94.35654
1A3b	Auto Fuel	N2O	1176.84	978.75	170.02	0.0009076	0.63078	94.98732
1A(stationary)	Oil	CO2	92200.71	50820.20	15.13	0.0008848	0.61491	95.60223
5B	5B LULUCF	CO2	15694.70	12692.42	50.01	0.0008268	0.57462	96.17685
2B	Adipic Acid Production	N2O	20737.34	71.02	15.01	0.0008214	0.57086	96.74771
1A3	Other Diesel	N2O	195.32	277.83	140.01	0.0006552	0.45538	97.20310
5E	5E LULUCF	CO2	7038.09	6054.37	50.01	0.0005925	0.41180	97.61489
2B5	NEU	CO2	1562.92	1913.77	53.85	0.0005563	0.38661	98.00150
1B1	Mining & Solid Fuel Transformation	CH4	18289.71	2867.52	13.01	0.0004295	0.29850	98.30000
1A	All Fuel	CH4	2078.74	1005.71	50.00	0.0003034	0.21087	98.51088
2	Industrial Processes	HFC	11385.62	10927.21	19.03	0.0002390	0.16612	98.67700
1A3b	Auto Fuel	CH4	634.36	89.61	50.08	0.0002261	0.15716	98.83416
4A	Enteric Fermentation	CH4	18527.34	15263.07	20.00	0.0001835	0.12752	98.96167
1A3b	Auto Fuel	CO2	109570.50	112986.66	4.48	0.0001661	0.11545	99.07712
1B2	Production, Refining & Distribution of Oil & Natural Gas	CH4	10322.92	5266.15	16.99	0.0001570	0.10911	99.18623
1A	Other (waste)	CO2	212.42	1566.25	21.19	0.0001551	0.10780	99.29403
6C	Waste Incineration	N2O	47.90	43.56	230.11	0.0001158	0.08049	99.37452
1A3a	Aviation Fuel	CO2	1509.56	2119.03	20.27	0.0001033	0.07180	99.44632
6B	Wastewater Handling	CH4	287.27	345.31	50.01	0.0000842	0.05854	99.50487
2A7	Fletton Bricks	CO2	179.87	73.76	72.80	0.0000728	0.05062	99.55549
1A3a	Aviation Fuel	N2O	14.86	20.86	171.17	0.0000725	0.05040	99.60589
1A4	Peat	CO2	475.59	47.44	31.62	0.0000724	0.05034	99.65623
6C	Waste Incineration	CO2	1212.41	297.01	21.19	0.0000636	0.04418	99.70041
1A	Natural Gas	CO2	108984.72	182791.69	1.51	0.0000583	0.04049	99.74090
6C	Waste Incineration	CH4	134.43	6.14	50.49	0.0000567	0.03942	99.78032
4B	Manure Management	CH4	3607.76	2816.72	30.00	0.0000462	0.03210	99.81242
5B	5B LULUCF	N2O	781.77	633.04	50.01	0.0000417	0.02897	99.84139
1B	Oil & Natural Gas	CO2	5777.84	4599.43	17.09	0.0000303	0.02107	99.86246
2A7	Fletton Bricks	CH4	23.60	5.52	101.98	0.0000293	0.02039	99.88284
2	Industrial Processes	PFC	1401.60	147.10	10.05	0.0000214	0.01486	99.89770
1A	Coal	CO2	248165.51	111465.07	1.08	0.0000192	0.01338	99.91108
1B2	Oil & Natural Gas	N2O	42.40	36.76	111.16	0.0000185	0.01287	99.92395
1A	Lubricant	CO2	386.90	197.64	30.07	0.0000181	0.01258	99.93653
5D	5D LULUCF	CO2	422.26	281.99	50.01	0.0000141	0.00983	99.94636
1A3d	Marine Fuel	N2O	12.81	11.23	170.01	0.0000140	0.00971	99.95607
2C	Iron & Steel	N2O	11.11	4.96	118.00	0.0000104	0.00725	99.96333
2B	Chemical Industry	CH4	169.43	76.27	28.28	0.0000090	0.00627	99.96960
2	Industrial Processes	SF6	1029.95	661.81	20.02	0.0000081	0.00562	99.97521
1B1	Coke Oven Gas	N2O	2.08	0.17	118.00	0.0000046	0.00316	99.97838
2C1	Iron&Steel Production	CO2	2309.27	1193.28	6.12	0.0000044	0.00302	99.98140
1B	Solid Fuel Transformation	CO2	856.42	150.05	6.01	0.0000041	0.00288	99.98428
2B	Ammonia Production	CO2	1321.67	801.29	10.11	0.0000038	0.00267	99.98695
2A4	Soda Ash Use	CO2	167.32	184.95	15.13	0.0000036	0.00249	99.98945
2C	Iron & Steel Production	CH4	16.36	6.66	50.00	0.0000032	0.00219	99.99164
2A1	Cement Production	CO2	7295.26	3720.48	2.42	0.0000022	0.00154	99.99318
2A3	Limestone & Dolomite use	CO2	1317.50	1194.63	5.10	0.0000015	0.00107	99.99425
2A2	Lime Production	CO2	1191.52	626.63	5.10	0.0000015	0.00104	99.99529
1A3	Other Diesel	CO2	1647.37	2356.15	2.20	0.0000014	0.00096	99.99625
1A3	Other Diesel	CH4	3.16	4.36	50.03	0.0000013	0.00088	99.99713
5C2	5C2 LULUCF	CH4	2.95	13.82	20.02	0.0000011	0.00080	99.99793
1A3a	Aviation Fuel	CH4	3.30	1.23	53.85	0.0000008	0.00057	99.99849
5A	5A LULUCF	CH4	4.30	9.48	20.02	0.0000006	0.00043	99.99893
5E2	5E2 LULUCF	CH4	9.25	2.89	20.02	0.0000004	0.00026	99.99919
1A3d	Marine Fuel	CO2	1643.03	1447.85	2.20	0.0000003	0.00021	99.99940
5D	5D LULUCF	N2O	3.98	0.54	20.02	0.0000002	0.00016	99.99956
5B	5B LULUCF	CH4	0.13	0.46	50.01	0.0000002	0.00016	99.99972
5A	5A LULUCF	N2O	5.57	1.95	20.02	0.0000002	0.00014	99.99986
5C2	5C2 LULUCF	N2O	0.30	1.40	20.02	0.0000001	0.00008	99.99994
1A3d	Marine Fuel	CH4	0.54	0.48	50.03	0.0000001	0.00004	99.99997
5E2	5E2 LULUCF	N2O	0.94	0.29	20.02	0.0000000	0.00003	100.00000
1A	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A4	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
5A	5A LULUCF	CO2	-12155.07	-12722.83	25.02	0.0000000	0.00000	100.00000
5C	5C LULUCF	CO2	-6260.28	-8649.52	70.01	0.0000000	0.00000	100.00000
5G	5G LULUCF	CO2	-1637.10	-2402.42	30.02	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	CH4	0.00	0.00	33.54	0.0000000	0.00000	100.00000
4F	Field Burning	CH4	266.04	0.00	55.90	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	N2O	0.00	0.00	33.54	0.0000000	0.00000	100.00000
4F	Field Burning	N2O	77.76	0.00	231.35	0.0000000	0.00000	100.00000
4G	OvTerr Agriculture N2O (all)	N2O	0.00	0.00	50.99	0.0000000	0.00000	100.00000
		Sum -->	783,298.37	565,984.29		0.14	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. 2009	Combined uncertainty range as a % of source category	Trend Parameter (used to order sources)	Trend / Sum(Trend)*100 %	Cumulative %
4D	Agricultural Soils	N2O	32091.46	24905.17	424.00	0.0617645	48.62391	
2B	Nitric Acid Production	N2O	3903.85	1106.70	230.22	0.0222275	17.49854	66.12246
6B	Wastewater Handling	N2O	1250.63	1376.64	401.12	0.0178238	14.03172	80.15418
6A	Solid Waste Disposal	CH4	56216.71	16052.77	48.38	0.0140729	11.07888	91.23306
1A1&1A2&1A4&1A5	Other Combustion	N2O	4675.84	3079.56	195.00	0.0031051	2.44445	93.67750
4B	Manure Management	N2O	2759.23	2056.29	414.00	0.0015664	1.23315	94.91065
1A(stationary)	Oil	CO2	92200.71	50820.20	15.13	0.0009127	0.71851	95.62916
1A3b	Auto Fuel	N2O	1176.84	978.75	170.02	0.0008179	0.64387	96.27302
2B	Adipic Acid Production	N2O	20737.34	71.02	15.01	0.0008156	0.64204	96.91507
1A3	Other Diesel	N2O	195.32	277.83	140.01	0.0006345	0.49953	97.41459
2B5	NEU	CO2	1562.92	1913.77	53.85	0.0005360	0.42193	97.83653
1B1	Mining & Solid Fuel Transformation	CH4	18289.71	2867.52	13.01	0.0004279	0.33683	98.17336
1A	All Fuel	CH4	2078.74	1005.71	50.00	0.0003086	0.24298	98.41634
2	Industrial Processes	HFC	11385.62	10927.21	19.03	0.0002257	0.17766	98.59400
1A3b	Auto Fuel	CH4	634.36	89.61	50.08	0.0002252	0.17726	98.77127
4A	Enteric Fermentation	CH4	18527.34	15263.07	20.00	0.0001642	0.12927	98.90054
1B2	Production, Refining & Distribution of Oil & Natural Gas	CH4	10322.92	5266.15	16.99	0.0001606	0.12644	99.02697
1A3b	Auto Fuel	CO2	109570.50	112986.66	4.48	0.0001582	0.12458	99.15155
1A	Other (waste)	CO2	212.42	1566.25	21.19	0.0001519	0.11960	99.27115
6C	Waste Incineration	N2O	47.90	43.56	230.11	0.0001082	0.08518	99.35634
1A3a	Aviation Fuel	CO2	1509.56	2119.03	20.27	0.0001000	0.07873	99.43507
6B	Wastewater Handling	CH4	287.27	345.31	50.01	0.0000811	0.06384	99.49891
2A7	Fletton Bricks	CO2	179.87	73.76	72.80	0.0000735	0.05784	99.55675
1A4	Peat	CO2	475.59	47.44	31.62	0.0000721	0.05672	99.61347
1A3a	Aviation Fuel	N2O	14.86	20.86	171.17	0.0000702	0.05526	99.66873
6C	Waste Incineration	CO2	1212.41	297.01	21.19	0.0000635	0.05000	99.71873
1A	Natural Gas	CO2	108984.72	182791.69	1.51	0.0000566	0.04457	99.76330
6C	Waste Incineration	CH4	134.43	6.14	50.49	0.0000564	0.04436	99.80766
4B	Manure Management	CH4	3607.76	2816.72	30.00	0.0000384	0.03023	99.83789
2A7	Fletton Bricks	CH4	23.60	5.52	101.98	0.0000293	0.02306	99.86096
1B	Oil & Natural Gas	CO2	5777.84	4599.43	17.09	0.0000261	0.02058	99.88154
2	Industrial Processes	PFC	1401.60	147.10	10.05	0.0000213	0.01674	99.89828
1A	Coal	CO2	248165.51	111465.07	1.08	0.0000195	0.01534	99.91363
1A	Lubricant	CO2	386.90	197.64	30.07	0.0000185	0.01457	99.92819
1B2	Oil & Natural Gas	N2O	42.40	36.76	111.16	0.0000171	0.01342	99.94162
1A3d	Marine Fuel	N2O	12.81	11.23	170.01	0.0000129	0.01017	99.95179
2C	Iron & Steel	N2O	11.11	4.96	118.00	0.0000106	0.00831	99.96010
2B	Chemical Industry	CH4	169.43	76.27	28.28	0.0000091	0.00720	99.96730
2	Industrial Processes	SF6	1029.95	661.81	20.02	0.0000088	0.00693	99.97423
1B1	Coke Oven Gas	N2O	2.08	0.17	118.00	0.0000045	0.00356	99.97779
2C1	Iron&Steel Production	CO2	2309.27	1193.28	6.12	0.0000045	0.00350	99.98130
1B	Solid Fuel Transformation	CO2	856.42	150.05	6.01	0.0000041	0.00325	99.98455
2B	Ammonia Production	CO2	1321.67	801.29	10.11	0.0000041	0.00319	99.98774
2A4	Soda Ash Use	CO2	167.32	184.95	15.13	0.0000034	0.00271	99.99045
2C	Iron & Steel Production	CH4	16.36	6.66	50.00	0.0000032	0.00250	99.99295
2A1	Cement Production	CO2	7295.26	3720.48	2.42	0.0000023	0.00178	99.99474
2A2	Lime Production	CO2	1191.52	626.63	5.10	0.0000015	0.00120	99.99594
2A3	Limestone & Dolomite use	CO2	1317.50	1194.63	5.10	0.0000014	0.00113	99.99707
1A3	Other Diesel	CO2	1647.37	2356.15	2.20	0.0000013	0.00105	99.99813
1A3	Other Diesel	CH4	3.16	4.36	50.03	0.0000012	0.00097	99.99909
1A3a	Aviation Fuel	CH4	3.30	1.23	53.85	0.0000008	0.00065	99.99974
1A3d	Marine Fuel	CO2	1643.03	1447.85	2.20	0.0000003	0.00023	99.99996
1A3d	Marine Fuel	CH4	0.54	0.48	50.03	0.0000000	0.00004	100.00000
1A	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A4	Combined Fuel	CO2	0.00	0.00	21.21	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	CH4	0.00	0.00	33.54	0.0000000	0.00000	100.00000
4F	Field Burning	CH4	266.04	0.00	55.90	0.0000000	0.00000	100.00000
1A3b	Combined Fuel	N2O	0.00	0.00	33.54	0.0000000	0.00000	100.00000
4F	Field Burning	N2O	77.76	0.00	231.35	0.0000000	0.00000	100.00000
4G	OvTerr Agriculture N2O (all)	N2O	0.00	0.00	50.99	0.0000000	0.00000	100.00000
		Sum -->	779,386.57	570,066.41		0.13	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	YES	Level	
1A(stationary)	Oil	CO2	YES	Level	
1A	Natural Gas	CO2			
1A	Other (waste)	CO2			
1A	Lubricant	CO2			
1A3a	Aviation Fuel	CO2			
1A3b	Auto Fuel	CO2	YES	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	YES	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	YES	Level	
5B	5B LULUCF	CO2	YES	Level	
5C	5C LULUCF	CO2	YES	Level	
5E	5E LULUCF	CO2	YES	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	YES	Level	
1B2	Oil & Natural Gas	CH4			
2A7	Fletton Bricks	CH4			
2B	Chemical Industry	CH4			
2C	Iron & Steel Production	CH4			
4A	Enteric Fermentation	CH4	YES	Level	
4B	Manure Management	CH4			
4F	Field Burning	CH4			
5C2	5C2 LULUCF	CH4			
5E2	5E2 LULUCF	CH4			
6A	Solid Waste Disposal	CH4	YES	Level	high uncertainty
6B	Wastewater Handling	CH4			
6C	Waste Incineration	CH4			
1A1&1A2&1A4&1A	Other Combustion	N2O	YES	Level	
1A3a	Aviation Fuel	N2O			
1A3b	Auto Fuel	N2O	YES	Level	
1A3d	Marine Fuel	N2O			
1A3	Other Diesel	N2O			
1B1	Coke Oven Gas	N2O			
1B2	Oil & Natural Gas	N2O			
2B	Adipic Acid Production	N2O	YES	Level	
2B	Nitric Acid Production	N2O	YES	Level	
2C	Iron & Steel	N2O			
4B	Manure Management	N2O	YES	Level	high uncertainty
4D	Agricultural Soils	N2O	YES	Level	high uncertainty
4F	Field Burning	N2O			
5C2	5C2 LULUCF	N2O			
5E2	5E2 LULUCF	N2O			
6B	Wastewater Handling	N2O	YES	Level	
6C	Waste Incineration	N2O			
2	Industrial Processes	HFC	YES	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	YES	Level	
1A(stationary)	Oil	CO2	YES	Level	
1A	Natural Gas	CO2			
1A	Other (waste)	CO2			
1A	Lubricant	CO2			
1A3a	Aviation Fuel	CO2			
1A3b	Auto Fuel	CO2	YES	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	YES	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			
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	YES	Level	
1B2	Oil & Natural Gas	CH4			
2A7	Fletton Bricks	CH4			
2B	Chemical Industry	CH4			
2C	Iron & Steel Production	CH4			
4A	Enteric Fermentation	CH4	YES	Level	
4B	Manure Management	CH4			
4F	Field Burning	CH4			
6A	Solid Waste Disposal	CH4	YES	Level	high uncertainty
6B	Wastewater Handling	CH4			
6C	Waste Incineration	CH4			
1A1&1A2&1A4&1A	Other Combustion	N2O	YES	Level	
1A3a	Aviation Fuel	N2O			
1A3b	Auto Fuel	N2O	YES	Level	
1A3d	Marine Fuel	N2O			
1A3	Other Diesel	N2O			
1B1	Coke Oven Gas	N2O			
1B2	Oil & Natural Gas	N2O			
2B	Adipic Acid Production	N2O	YES	Level	
2B	Nitric Acid Production	N2O	YES	Level	
2C	Iron & Steel	N2O			
4B	Manure Management	N2O	YES	Level	high uncertainty
4D	Agricultural Soils	N2O	YES	Level	high uncertainty
4F	Field Burning	N2O			
6B	Wastewater Handling	N2O	YES	Level	
6C	Waste Incineration	N2O			
2	Industrial Processes	HFC	YES	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		B	C	D	E
IPCC Source Categories		**Gas**	**Category Key Source Category**	**If Column C is Yes, Criteria for Identification**	**Comments**
1A	Coal	CO2			
1A(stationary)	Oil	CO2	YES	Level	
1A	Natural Gas	CO2	YES	Level	
1A	Other (waste)	CO2			
1A	Lubricant	CO2			
1A3a	Aviation Fuel	CO2			
1A3b	Auto Fuel	CO2	YES	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	YES	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	YES	Level	
5B	5B LULUCF	CO2	YES	Level	
5C	5C LULUCF	CO2	YES	Level	
5E	5E LULUCF	CO2	YES	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	Coal Mining	CH4			
1B2	Oil & Natural Gas	CH4			
2A7	Fletton Bricks	CH4			
2B	Chemical Industry	CH4			
2C	Iron & Steel Production	CH4			
4A	Enteric Fermentation	CH4	YES	Level	
4B	Manure Management	CH4			
4F	Field Burning	CH4			
5C2	5C2 LULUCF	CH4			
5E2	5E2 LULUCF	CH4			
6A	Solid Waste Disposal	CH4	YES	Level, Trend	high uncertainty
6B	Wastewater Handling	CH4			
6C	Waste Incineration	CH4			
1A1&1A2&1A4&1A	Other Combustion	N2O	YES	Level, Trend	
1A3a	Aviation Fuel	N2O			
1A3b	Auto Fuel	N2O	YES	Level, Trend	
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	YES	Level, Trend	
2C	Iron & Steel	N2O			
4B	Manure Management	N2O	YES	Level, Trend	high uncertainty
4D	Agricultural Soils	N2O	YES	Level, Trend	high uncertainty
4F	Field Burning	N2O			
5C2	5C2 LULUCF	N2O			
5E2	5E2 LULUCF	N2O			
6B	Wastewater Handling	N2O	YES	Level, Trend	
6C	Waste Incineration	N2O			
2	Industrial Processes	HFC	YES	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		B	C	D	E
IPCC Source Categories		Gas	Category Key Source Category	If Column C is Yes, Criteria for Identification	Comments
1A	Coal	CO2			
1A(stationary)	Oil	CO2	YES	Level	
1A	Natural Gas	CO2	YES	Level	
1A	Other (waste)	CO2			
1A	Lubricant	CO2			
1A3a	Aviation Fuel	CO2			
1A3b	Auto Fuel	CO2	YES	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	YES	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			
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	Coal Mining	CH4			
1B2	Oil & Natural Gas	CH4			
2A7	Fletton Bricks	CH4			
2B	Chemical Industry	CH4			
2C	Iron & Steel Production	CH4			
4A	Enteric Fermentation	CH4	YES	Level	
4B	Manure Management	CH4			
4F	Field Burning	CH4			
6A	Solid Waste Disposal	CH4	YES	Level, Trend	high uncertainty
6B	Wastewater Handling	CH4			
6C	Waste Incineration	CH4			
1A1&1A2&1A4&1A	Other Combustion	N2O	YES	Level, Trend	
1A3a	Aviation Fuel	N2O			
1A3b	Auto Fuel	N2O	YES	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	YES	Level, Trend	
2C	Iron & Steel	N2O			
4B	Manure Management	N2O	YES	Level, Trend	high uncertainty
4D	Agricultural Soils	N2O	YES	Level, Trend	high uncertainty
4F	Field Burning	N2O			
6B	Wastewater Handling	N2O	YES	Level, Trend	
6C	Waste Incineration	N2O			
2	Industrial Processes	HFC	YES	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-GBE-2011-2009-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 (5A2) is key	The Afforestation and Reforestation category contribution is smaller than the smallest UNFCCC key category but the associated UNFCCC category (5A2 Land converted to 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 (5C and 5E) are key)	The Deforestation category contribution is smaller than the smallest UNFCCC key category but the associated UNFCCC categories (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 (5A2) 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, 2010), 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 13% in 2009 for lubricants burnt in all types of engines - this is made up of 8% burnt in road vehicle engines, 4% burnt in marine engines and the remaining 1% split between agricultural, industrial and aircraft engines.

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

	GHGI	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 1A2c Chemicals 1A2d Pulp, Paper and Print 1A2e Food Processing, Beverages, Tobacco	Included under Other Industry (Combustion)
1A2fi Other	Other Industry (Combustion) Cement (Fuel Combustion) Cement (Non-decarbonising) Lime Production (Combustion) Autogenerators Ammonia (Combustion)
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
2A5 Asphalt Roofing	Not Estimated

IPCC Source Category	NAEI Source Category
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
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

IPCC Source Category	NAEI Source Category
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)
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

IPCC Source Category	NAEI Source Category
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
4B9 Manure Management: Poultry	Broilers Wastes Laying Hens Wastes Other Poultry
4B9a Manure Management: Other: Deer	Deer Wastes
4B10 Anaerobic Lagoons	Not Occurring
4B11 Liquid Systems	Manure Liquid Systems
4B12 Solid Storage and Dry Lot	Manure Solid Storage and Dry Lot
4B13 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

IPCC Source Category	NAEI Source Category
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 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
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 (2010). 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);
- Other Industry (Combustion);
- Autogenerators;
- Gas Production;
- Collieries;
- Production of Nuclear Fuel;
- Coastal Shipping;
- Fishing;
- 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, 2009) 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 (2010) 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 the chemicals, food & drink, non-ferrous metal, glass, ceramics & bricks, textiles & engineering sectors). The 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, 2010).

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. 85% of total GHG emissions are from the energy sector. 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, 2010). 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. EU-ETS factors have continued to be used in the 2010 and 2011 GHGIs. The sectors are listed below, along with the years for which EUETS data is used:

- Power Stations – coal – for 2005-2009
- Power Stations – fuel oil – for 2005-2009

- Power Stations – natural gas – for 2006 - 2009, (interpolated 2005)
- Power Stations – Petroleum Coke - 2005-2009
- Power Stations – sour gas – 2005-2009
- Autogenerators – coal – 2005 - 2009
- Refineries – fuel oil - 2006 - 2009 (interpolated 2005)
- Refineries – Petroleum coke – for 2005-2009
- Refineries – OPG – 2008-2009 (earlier years use the mean of the 2008 and 2009 data, and the emission factor is also applied to other sources using this fuel)
- Lime kilns – coal – for 2008 and 2009
- Other industrial combustion - petroleum coke - for 2008-2009
- Other industrial combustion - waste solvents – for 2005-2009
- Other industrial combustion - colliery methane – for 2005 - 2009 (also applied to other sources using this fuel)

Further information on the use of EU ETS data within the inventory is included in **Annex 11.**

For years and sectors not listed, 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 2009[1]

Fuel	Source	Units	C[aj]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
ATF	Aircraft Military	kg/t	859[a]	0.103[ad]	0.1[g]	8.5[ad]	8.2[ad]	1.1[ad]	0.87[z]
Burning Oil	Domestic	kg/t	859[a]	0.462[g]	0.0277[g]	3.23[l]	1.85[l]	0.047[f]	0.52[z]
Burning Oil	Other Industry	kg/t	859[a]	0.0924[g]	0.0277[g]	3.33[l]	0.19[l]	0.028[e]	0.52[z]
Burning Oil	Public Service, Railways (Stationary)	kg/t	859[a]	0.462[g]	0.0277[g]	2.05[l]	0.16[l]	0.047[f]	0.52[z]
Burning Oil	Miscellaneous	kg/t	859[a]	0.462[g]	0.0277[g]	2.70[l]	0.16[l]	0.047[f]	0.52[z]
Gas Oil	Cement	kg/t	C	C	C	C	C	C	C
Gas Oil	Domestic	kg/t	870[a]	0.455[g]	0.0273[g]	3.19[l]	1.82[l]	0.047[f]	1.68[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, 26.37, 26.37[av]
Gas Oil	Iron&Steel	kg/t	870[a]	0.0910[g]	0.0273[g]	6.78[l]	2.00[l]	0.028[f]	1.68[z]
Gas Oil	Refineries	kg/t	870[a]	0.137[g]	0.0273[g]	4.56[k]	0.24[i]	0.028[f]	1.68[z]
Gas Oil	Other Industry	kg/t	870[a]	0.0910[g]	0.0273[g]	14.76[l]	3.29[l]	0.028[f]	1.68[z]
Gas Oil	Public Service	kg/t	870[a]	0.455[g]	0.0273[g]	2.44[l]	0.38[l]	0.047[f]	1.68[z]
Gas Oil	Miscellaneous	kg/t	870[a]	0.455[g]	0.0273[g]	0.29[l]	0.04[l]	0.047[f]	1.68[z]
Fuel Oil	Agriculture	kg/t	879[a]	0.433[g]	0.0260[g]	7.69[l]	0.31[l]	0.139[f]	16.98[z]
Fuel Oil	Cement	kg/t	C	C	C	C	C	C	C
Fuel Oil	Public Service	kg/t	879[a]	0.433[g]	0.0260[g]	7.48[l]	0.83[l]	0.139[f]	16.98[z]
Fuel Oil	Miscellaneous	kg/t	879[a]	0.433[g]	0.0260[g]	0.74[l]	0.03[l]	0.139[f]	16.98[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]	5.517, 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]	0.139[f]	16.98[z]
Fuel Oil	Iron&Steel	kg/t	879[a]	0.087[g]	0.026[g]	7.19	0.89[l]	0.034[f]	16.98[z]
Fuel Oil	Railways (Stationary)	kg/t	879[a]	0.433[g]	0.026[g]	7.48[l]	0.83[l]	0.139[f]	16.98[z]
Fuel Oil	Other Industry	kg/t	879[a]	0.087[g]	0.026[g]	10.84[l]	1.60[l]	0.034[f]	16.98[z]
Fuel Oil	Refineries (Combustion)	kg/t	876[at]	0.130[g]	0.026[g]	3.52[ag]	0.75[ag]	0.034[f]	29.74[ag]
Lubricants	Other Industry	kg/t	865[x]	0.091[e]	0.027[e]	4.56[k]	0.25[f]	0.133[f]	11.41[x]
Petrol	Refineries	kg/t	855[a]	0.138[an]	0.028[g]	4.62[k]	0.24[e]	0.028[e]	0.01[z]

Fuel	Source	Units	C[aj]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
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	837.2 [ay]	NE	NE	3.95[az]	158 [az]	4.9 [az]	142.4 [az]
Petroleum Coke	Refineries	kg/t	930[at]	0.107[ai]	0.281[w]	6.15ag	2.30[ag]	0.054[ai]	28.44[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]	8.90[f]	3.779[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]	3.779[f]	0
LPG	Gas Production – combustion at gas separation plant	g/GJ Gross	16227[a]	41.182[aw]	4.416[aw]	127.37[aw]	65.54[aw]	4.272[aw]	0.73[aw]
OPG	Gas production	g/GJ Gross	14114[at]	1.000[g]	NE	70.00[k]	2.37[i]	3.779[f]	0
OPG	Refineries (Combustion)	g/GJ Gross	14114[at]	1.000[g]	NE	86.78[ag]	13.68[z]	3.779[f]	0
OPG	Other Industry	g/GJ Gross	14114[at]	5.000[g]	0.100[g]	70.00[k]	2.37[i]	3.779[f]	0
OPG	Gas production – combustion at gas separation plant	g/GJ Gross	14114[a]	41.182[aw]	4.416[aw]	127.37[aw]	65.54[aw]	4.272[aw]	0.73[aw]

Table A 3.3.2 Emission Factors for the Combustion of Solid fuels for 2009[1]

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]	0.147[w]	4.75[l]	8.25[l]	0.05[o]	17.0[aa]
Coal	Collieries	Kg/tonne	678.1[ao]	0.011[o]	0.148[w]	4.75[l]	8.25[l]	0.05[o]	23.0[aa]
Coal	Domestic	Kg/tonne	683.5[ao]	15.7[o]	0.122[w]	2.34[l]	159.96[l]	14.00[o]	23.2[aa]
Coal	Iron and Steel (Combustion)	Kg/tonne	693.8[a]	0.011[o]	0.237[w]	1.23	0.53	0.05[o]	17.0[aa]
Coal	Lime Production (Combustion)	Kg/tonne	664.7[ao]	0.011[o]	0.214[w]	28.26[v]	3.83[v]	0.05[o]	17.0[aa]
Coal	Miscellaneous	Kg/tonne	707.6[ao]	0.011[o]	0.148[w]	4.74[l]	8.09[l]	0.05[o]	17.0[aa]
Coal	Public Service	Kg/tonne	707.6[ao]	0.011[o]	0.148[w]	4.72[l]	7.00[l]	0.05[o]	17.0[aa]
Coal	Other Industry	Kg/tonne	652.5[ao]	0.011[o]	0.214[w]	4.28[l]	1.94[l]	0.05[o]	17.0[aa]
Coal	Railways	Kg/tonne	707.6[ao]	0.011[o]	0.148[w]	4.72[l]	7.00[l]	0.05[o]	17.0[aa]
Coal	Autogenerators	Kg/tonne	600.6[at]	0.020[o]	0.066[w]	5.54[l]	1.63[l]	0.03[o]	17.0[aa]
Coal	Cement production (combustion)	Kg/tonne	C	C	C	C	C	C	C
Anthracite	Domestic	Kg/tonne	818.2[ap]	2[o]	0.142[w]	3.47[k]	208.2[k]	1.7[o]	15.4[aa]
Coke	Agriculture	Kg/tonne	806.0[r]	0.011[p]	0.150[w]	4.52[l]	18.29[l]	0.05[p]	19[ab]
Coke	SSF Production	Kg/tonne	806.0[r]	0.011[p]	0.230[w]	IE	IE	0.05[p]	19[ab]
Coke	Domestic	Kg/tonne	806.0[r]	5.8[o]	0.117[w]	3.04[l]	118.6[l]	4.9[o]	15.4[aa]
Coke	I&Sak (Sinter Plant)	Kg/tonne	806.0[r]	1.61[ae]	0.230[w]	13.69[ae]	352.7[ae]	0.44[ae]	18.8[ae]
Coke	I&Sak (Combustion)	Kg/tonne	806.0[r]	0.011[p]	0.230[w]	0.87[l]	226[l]	0.05[p]	19[ab]
Coke	Other Industry	Kg/tonne	806.0[r]	0.011[p]	0.230[w]	4.52[l]	18.29[l]	0.05[p]	19[ab]
Coke	Railways	Kg/tonne	806.0[r]	0.011[p]	0.150[w]	4.52[l]	18.29[l]	0.05[p]	19[ab]
Coke	Miscellaneous; Public Service	Kg/tonne	806.0[r]	0.011[p]	0.150[w]	4.52[l]	18.29[l]	0.05[p]	19[ab]
Peat	Domestic	Kg/tonne	370.0[g]	4.17[g]	0.056[g]	0.70[g]	69.5[g]	23.63[g]	NE
SSF	Miscellaneous;	Kg/tonne	766.3[n]	0.011[p]	0.151[w]	4.58[k]	48.9[k]	0.05[o]	19[ab]

Fuel	**Source**	**Units**	**C**[aj]	**CH_4**	**N_2O**	**NO_x**	**CO**	**NMVOC**	**SO_2**
	Public Service								
SSF	Domestic	Kg/tonne	774.2[n]	5.8[o]	0.118[w]	3.05[k]	130.4[k]	4.9[p]	16[ab]
SSF	Other Industry	Kg/tonne	766.3[n]	0.011[p]	0.232[w]	4.58[g]	48.9[g]	0.05[g]	19 [ab]
Blast Furnace Gas	Coke Production	g/GJ Gross	80410[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	80410[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	80410[r]	112.01[k]	2.00[k]	37.0[v]	39.5[k]	5.60[k]	0
Coke Oven Gas	Other Sources	g/GJ Gross	11295[r]	57.25[k]	2.00[k]	80.5[k]	40.0[k]	4.35[k]	270.4[v]
Coke Oven Gas	I&Sak Blast Furnaces	g/GJ Gross	11295[r]	57.25[k]	2.00[k]	37.0[v]	40.0[k]	4.35[k]	270.4[v]
Coke Oven Gas	Coke Production	g/GJ Gross	11295[r]	57.25[k]	2.00[k]	365.8[v]	40.0[k]	4.35[k]	270.4[v]

Table A 3.3.3 Emission Factors for the Combustion of Gaseous Fuels 2009[1] (g/GJ gross)

Fuel	Source	C[aj]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Natural Gas	Agriculture	13969[r]	5.0[g]	0.10[g]	39.2[l]	2.13[l]	2.22[f]	0
Natural Gas	Miscellaneous	13969[r]	5.0[g]	0.10[g]	52.9[l]	58.2[l]	2.22[f]	0
Natural Gas	Public Service	13969[r]	5.0[g]	0.10[g]	56.0[l]	13.48[l]	2.22[f]	0
Natural Gas	Coke Production, SSF Prodn[al],	13969[r]	1.0[g]	0.10[g]	175.0[k]	2.37[l]	2.22[f]	0
Natural Gas	Refineries	14026[at]	1.0[g]	0.10[g]	70.0[k]	2.37[l]	2.22[f]	0
Natural Gas	Blast Furnaces	13969[r]	5.0[g]	0.10[g]	37.0[v]	2.37[l]	2.22[f]	0
Natural Gas	Domestic	13969[r]	5.0[g]	0.10[g]	22.5[l]	30.8[l]	2.22[f]	0
Natural Gas	Gas Prodn[al],	13969[r]	1.0[g]	0.10[g]	89.5[l4]	17.4[l]	2.22[f]	0
Natural Gas	Oil Prodn[al]	15887[aw]	22.1[aw]	4.24[aw]	184.4[aw]	65.1[aw]	1.43[aw]	3.28[aw]
Natural Gas	I&S[ak]	13969[r]	5.0[g]	0.10[g]	176.7[l]	172.9[l]	2.22[f]	0
Natural Gas	Railways	13969[r]	5.0[g]	0.10[g]	89.4[l]	33.8[l]	2.22[f]	0
Natural Gas	Other Industry	13969[r]	5.0[g]	0.10[g]	139.9[l]	74.4[l]	2.22[f]	0
Natural Gas	Nuclear Fuel Prodn[al], Collieries	13969[r]	1.0[g]	0.10[g]	139.9[l]	74.4[l]	2.22[f]	0
Natural Gas	Autogenerators	13969[r]	5.0[g]	0.10[g]	61.9[l]	20.6[l]	2.22[f]	0
Natural Gas	Ammonia (Combustion)	13969[r]	5.0[g]	0.10[g]	157.2[d]	NE	2.22[f]	0
Colliery Methane	Other Industry, collieries	17079[a]	5.0[s]	0.10[g]	70.0[k]	2.37[i]	2.22[f]	0
Colliery Methane	Coke Production, Gas Production	17079[a]	1.0[s]	0.10[g]	70.0[k]	2.37[i]	2.22[f]	0

Table A 3.3.4 Emission Factors for the Combustion of other fuels and biomass 2009[1]

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]	0.76[v]	0.09[v]	0.0046[v]	0.074[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	418[g]	4.5[g]	0.06[g]	1.5[k]	75[g]	9[k]	
Wood	Domestic	Kg/tonne	387[g]	4.17[g]	0.06[g]	0.7[k]	69.5[k]	23.6[o]	0.11[aa]
Wood	Other industry	Kg/tonne	381[g]	0.41	0.05	2.06	68.5	0.82	0.13
Sewage Gas	Public Services	g/GJ Gross	27406[g]	5.0[g]	0.10[g]	66.78[f]	7.1[f]	2.42[f]	0
Landfill Gas	Miscellaneous	g/GJ Gross	27406[g]	5.0[g]	0.10[g]	38.96[f]	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: Terra Nitrogen (2009), Invista (2009), BP Chemicals (2009)
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
q	EMEP/CORINAIR (2003)
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, 2008)
w	Fynes *et al* (1994)
x	Passant (2005)
y	UKPIA (1989)
z	Emission factor derived from data supplied by UKPIA (2006, 2007, 2008, 2009)
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 Energy & Environment estimate based on data from Environment Agency (2005) and Corus (2005)
af	UKPIA (2004)
ag	AEA Energy & Environment estimate based on data from Environment Agency (2005), UKPIA, DUKES, and other sources
ah	Royal Commission on Environmental Pollution (1993)
ai	DTI (1994)
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 Energy & Environment estimate based on carbon factors review
ap	EMEP/CORINAIR
aq	AEA Energy & Environment 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 and 2009, DECC Oil and Gas.
ax	UKPIA, pers. Comm., 2000
ay	Loader *et al* (2008)
az	As for domestic wood
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, (2010). 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, 2010) 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 2009 [A time series of carbon emission factors can be found in the background energy tables on the accompanying CD]

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]	4.88[n]	0.63[n]	0.018[n]	3.82[n]
Petroleum Coke	Kt/Mt	614 [a]	0.107[q]	0.087[r]	3.39[n]	9.14[n]	0.023[n]	10.39[n]
Fuel Oil	Kt/Mt	873[s]	0.130[h]	0.026[h]	11.37[n]	1.00[n]	0.038[n]	10.32[n]
Gas Oil	Kt/Mt	870[a]	0.137[h]	0.0273[h]	14.91[n]	1.58[n]	0.353[n]	4.77[n]
Natural gas	Kt/Mth	1.464[s]	0.000106[h]	1.06E-05[h]	0.00402[n]	0.0011[n]	0.000125[n]	6.81E-05[n]
MSW	Kt/Mt	75[d]	0.285[h]	0.038[h]	0.759[o]	0.0923[o]	0.00463[o]	0.0741[o]
Sour gas	Kt/Mth	1.931[c]	0.000106[h]	1.06E-05[h]	0.003[n]	0.0014[o]	9.8E-05[n]	0.0011[n]
Poultry Litter	Kt/Mt	NE	0.283[h]	0.0378[j]	0.950[n]	0.352[o]	0.0588[o]	0.291[n]
Sewage Gas	Kt/Mth	NE	0.000106[h]	1.06E-05[h]	0.00705[k]	0.000749[k]	0.000255[k]	NE
Waste Oils	Kt/Mt	864.8[b]	NE	NE	11.37[n]	0.995[n]	0.0377[n]	10.32[n]
Landfill gas	Kt/Mth	NE	0.000106[h]	1.06E-05[h]	0.00411[k]	0.0129[k]	0.000382[k]	NE
Wood	Kt/Mt		0.179	0.0372	1.623	15.5	0.3748	0.011

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, 2009), SEPA's Scottish Pollutant Release inventory (SEPA, 2009), NI DoE's Inventory of Sources and Releases list (NI DoE, 2009) and direct communications with plant operators (Pers. Comms., 2009)
o Environment Agency (2009)
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 2010). 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, 2010) on the amount of waste used in heat and electricity generation and the emissions from the incinerators (Environment Agency, 2010). 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 (BCA, 2010). 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 (2010) 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, 2010). 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 (2010) 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 are currently allocated to 1A4 but would be more correctly allocated to 1A1a. This will be corrected for the next version of the inventory. 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, 2010), 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, 2009). For other pollutants and fuels, emission factors are all based on either operator reported data (UKPIA, 2009) 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 (2010). 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.

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. For the 2008 inventory these recommendations 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. For the 2008 inventory these recommendations 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 have been 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.

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 3.3.7 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 3.3.7 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.

  Fights between the UK and overseas territories have been reclassified as domestic aviation.

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

  A summary of aircraft movement data is given in **Table A 3.3.8**. Fights between the UK and overseas territories are included in domestic.

- **Inland Deliveries of Aviation Spirit and Aviation Turbine Fuel**
  Total inland deliveries of aviation spirit and aviation turbine fuel to air transport are given in DECC (2010). This is the best approximation of aviation bunker fuel consumption available and is assumed to cover international, domestic and military use.

- **Consumption of Aviation Turbine Fuel by the Military**
  Total consumption by military aviation has been given in ONS (1995) and MOD (2005a) and is 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. Adjustments were made to the data to derive figures on a calendar year basis.

  For the 2008 inventory, figures for 2008/09 were not complete so data for 2007/08 were used. These data have been revised for the 2009 inventory.

Table A 3.3.8 Aircraft Movement Data

	International LTOs (000s)	Domestic LTOs (000s)	International Aircraft, Gm flown	Domestic Aircraft, Gm flown
1990	408.6	347.2	631.3	111.0
1991	396.0	319.5	620.7	104.5
1992	431.5	337.3	703.2	109.0
1993	442.4	344.3	714.6	112.9
1994	460.7	322.0	789.7	108.6
1995	479.7	336.0	828.7	114.7
1996	506.2	346.9	868.7	119.3
1997	536.7	351.4	946.4	124.1
1998	575.2	364.7	1031.5	131.1
1999	609.0	372.4	1098.8	135.1
2000	645.7	383.5	1168.7	140.2
2001	652.6	398.1	1183.5	149.4
2002	649.0	396.6	1175.9	148.4
2003	668.1	405.8	1227.9	151.4
2004	699.2	436.9	1331.9	161.9
2005	737.8	461.1	1423.6	172.7
2006	760.9	461.4	1488.8	173.6
2007	787.0	453.8	1543.7	170.8
2008	774.7	442.3	1530.3	167.2
2009	711.8	399.9	1414.5	151.9

Notes

Gm Giga metres, or 10^9 metres

Estimated emissions from aviation are based on data provided by the CAA / International aircraft, Gm flown, calculated from total flight distances for departures from UK 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.3.3.9 Carbon Dioxide and Sulphur Dioxide Emission Factors for Civil and Military Aviation for 2009 (kg/t)

Fuel	CO_2	SO_2
Aviation Turbine Fuel	859	0.82
Aviation Spirit	853	0.82

Notes

Carbon and sulphur contents of fuels provided by UKPIA (2010)
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 taken 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 3.3.10 Non-CO2 Emission Factors for Civil and Military Aviation

	Fuel	Units	CH_4	N_2O	NO_x	CO	NMVOC
Civil aviation							
Domestic LTO	AS	kt/Mt	1.49	0.10	5.17	956.25	13.56
Domestic Cruise	AS	kt/Mt	-	0.10	6.75	3.62	0.24
Domestic LTO	ATF	kt/Mt	0.15	0.10	10.67	9.30	1.52
Domestic Cruise	ATF	kt/Mt	-	0.10	13.70	2.51	0.55
International LTO	AS	kt/Mt	1.92	0.10	2.97	1157.78	17.54
International Cruise	AS	kt/Mt	-	0.10	6.90	-	-
International LTO	ATF	kt/Mt	0.11	0.10	12.92	8.46	1.15
International Cruise	ATF	kt/Mt	-	0.10	14.16	1.15	0.52
Military aviation	ATF	kt/Mt	0.10	0.10	8.5	8.2	1.10

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 the 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 the carbon contents of the aviation fuels.

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.

Fights between the UK and overseas territories are considered to be international in the CAA aircraft movement data, but have been reclassified as domestic aviation in the 2009 inventory.

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 3.3.10)**. 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, but not fuel uplifted at foreign military airfields or *ad hoc* uplift from civilian airfields.

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 ATF fuel consumptions presented in DECC DUKES include the use of both civil and military ATF, and the military ATF use must be subtracted from the DUKES total to provide an estimate of the civil aviation consumption. This estimate of civil ATF consumption has been used in the fuel reconciliation. Emissions from flights from overseas territories to the UK have been excluded from the fuel reconciliation process as the fuel associated with these flights in 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. 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. These emissions are based on fuel consumption data from DECC (2010). Emission factors are reported in **Table A 3.3.1** to **Table A 3.3.4**.

The UK GHGI reports emissions from diesel trains 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.

For the 2009 inventory, emissions have been reported from consumption of coal used to power steam trains using new information on coal consumption allocated to the rail sector in DUKES. Estimates have been made across the time-series from 1990-2009 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.

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). Fuel consumption was estimated for Intercity and regional rail movements on the basis of reported train kilometres travelled and adjusted to align with the ORR estimates of fuel consumption. As no data from ATOC/ORR were available for 2009, fuel consumption was estimated on the basis of trends in train km from 2008. Fuel consumption for rail freight was also estimated from train km data and adjusted to align with ORR estimates of fuel consumption for the rail freight sector. Again, no data from ATOC/ORR were available for rail freight in 2009, so fuel consumption was estimated on the basis of trends in tonne km from 2008. Alignment with data provided by ORR marked an improvement in the methodology and the change was reflected across the time series.

In 2009, the estimated fuel consumption in regional and Intercity Rail showed a slight increase in comparison to 2008 as a consequence of increased train km travelled. In contrast, fuel oil consumption by Freight Rail in 2009 was estimated to be lower than those recorded in 2008 as a result of a decrease in billion tonne train km travelled.

Carbon dioxide, sulphur dioxide and nitrous oxide emissions are calculated using fuel-based emission factors and fuel consumption factors. Emissions of CO, NMVOC, NO_x, PM and methane are based on the train km estimates and emission factors for different train types. The fuel consumption is distributed according to:

- Train km data taken from the National rail trends yearbook (2010) http://www.rail-reg.gov.uk/upload/pdf/nrt-yearbook-2009-10.pdf;
- 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 3.3.11** are aggregate implied factors for diesel trains in 2009 so that all factors are reported on the common basis of fuel consumption.

Compared with the last version of the inventory, changes to implied emission factors are noted for Freight rail with respect to CH_4, N_2O, NO_x, CO and NMVOC. Similarly, minor changes to the implied emission factors for Regional Passenger Rail with respect to NO_x CO and NMVOC, and for Intercity Passenger Rail with respect to CH_4, NO_x, CO and NMVOC occur. These changes to the implied factors are a net result in changes in estimated km travel and fuel consumed by each category following alignment with ORR estimates of fuel consumption.

The emission factor for SO_2 has increased slightly from 1.63 kt/ Mt fuel in 2008 to 1.68 kt/ Mt fuel in 2009 in line with UKPIA's Table of the S-content in fuels in 2009 (UKPIA, 2010).

Table A 3.3.11 Diesel Railway Emission Factors for 2009 (kt/Mt fuel)

	C[1]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Freight	870	0.26	1.2	120.4	13.4	6.70	1.68
Intercity	870	0.19	1.2	40.6	13.1	4.81	1.68
Regional	870	0.38	1.2	32.9	36.5	6.34	1.68

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 2009 inventory

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

- Updated vehicle km activity data by road types in Great Britain. DfT was able to provide a consistent time series of vehicle km data for 1993 to 2009 by road type and vehicle type for the first time. The overall totals for each vehicle type remain the same but the distribution between road types has been updated, in particular over the period 1993-2001 for LGVs, HGVs and motorcycles and from 1993-2001 and 2007 for buses.
- Revisions to the vehicle km activity data for cars, LGVs and rigid HGVs in Northern Ireland (NI) after clarification on the vehicle classifications used in the traffic census report.
- Assumptions on the split between buses and coaches on urban and rural roads has been updated, based on information provided in DfT's Transport Statistics Great Britain (TSGB) on vehicle km done by local and non-local bus services.
- Assumptions on the split in vehicle km for buses by vehicle weight class have been updated using licensing information and correlations between vehicle weight class and number of seats. This is to improve how the emission factors for different bus vehicle weight classes are utilised.
- The treatment of emissions from buses operating in London has been improved by taking into account the specific composition of the fleet operated by TfL separately from other bus services in London.
- The estimation of emissions from HGVs and buses in London in 2008 and 2009 was improved by taking into account the effects of the London Low Emissions Zone on the composition (by Euro class) of the HGV and bus fleet separately from the fleet in other parts of the UK.
- A more detailed breakdown in the activity by 2-stroke and 4-stroke motorcycles has been used following a detailed review of motorcycle sales, population and lifetime by engine size.
- New figures from DfT on average mpg fuel efficiency of different sizes of HGVs in 2008 were used.
- Updated figures from DfT's Bus Services Operators Grant system were used on the average fuel efficiency of local bus services in 2008.
- Methane and N_2O emissions from LPG vehicles are estimated explicitly for the first time in response to feedback from the UNFCCC Expert Review of the UK inventory in 2010.

- The methodology for calculation of evaporative emissions of NMVOCs from petrol vehicles was updated with that recommended in the EMEP/CORINAIR Emission Inventory Guidebook 2007.

For CO_2, these changes have only affected the distribution of fuel consumption and hence CO_2 emissions between vehicle types, but the total CO_2 emissions from road transport in all years remains unchanged, because these are based on the total fuel consumption figures reported in DUKES. 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). However, 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 2009, 15.76 Mtonnes of petrol and 20.06 Mtonnes of diesel fuel (DERV) were consumed in the UK (a very small proportion of this was used in the Crown Dependencies). For both fuels, this is a decrease in consumption compared with 2008. It was estimated that of this, around 1.7% of petrol was consumed by off-road vehicles and machinery and 0.4% used in the Crown Dependencies, leaving 15.44 Mtonnes of petrol consumed by road vehicles in the UK in 2009. Around 0.05% of road diesel is estimated to be used by off-road vehicles and machinery (the bulk of these use gas oil) and 0.3% used in the Crown Dependencies, leaving 19.99 Mtonnes of diesel consumed by road vehicles in the UK in 2009.

According to figures in DUKES (DECC, 2010), 0.107 Mtonnes of LPG were used for transport in 2009, down from 0.125 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 (2010), 0.25 Mtonnes bioethanol and 0.93 Mtonnes biodiesel were consumed in the UK in 2009. On a volume basis, this represents about 1.5% of all petrol and 4.2% of all diesel sold in the UK, respectively, and on an energy basis it is estimated that consumption of bioethanol and biodiesel displaced around 0.152 Mtonnes of mineral-based petrol (about 1.0% of total petrol that would have been consumed) and 0.808 Mtonnes of mineral-based diesel (about 4.0% 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 3.3.12**. Values for SO_2 vary annually as the sulphur-content of fuels change, and are shown in **Table A 3.3.12** for 2009 fuels based on data from UKPIA (2010).

Table A 3.3.12 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 2009 emission factor calculated from UKPIA (2010) – figures on the weighted average sulphur-content of fuels delivered in the UK in 2009

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/pgr/roads/environment/emissions/ 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://www.dft.gov.uk/pgr/roads/environment/emissions/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 3.3.13** for average speeds on urban, rural and motorway roads. The different emission standards are described in a later section.

Table A 3.3.13 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
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
Petrol LGVs	Pre-Euro 1	68.7	64.1	70.0
	Euro 1	63.6	59.0	64.8

g fuel /km		Urban	Rural	Motorway
	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 fuel efficiency of different sizes of lorries (DfT, 2010a). A time-series of mpg figures from 1989 to 2009 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. New mpg factors for 2008 were used that were not available from DfT for the previous inventory.

Table A 3.3.14 presents the fleet-averaged fuel consumption factors for rigid and articulated HGVs from 1990-2009 for urban, rural and motorway conditions based on the road freight statistics published in DfT (2008a and 2010a).

Table A 3.3.14 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	271	220	228	437	337	344
1991	275	224	231	436	335	343
1992	275	224	232	432	333	341
1993	266	216	223	411	316	323

g fuel/km	Rigid HGVs			Artic HGVs		
	urban	rural	m-way	urban	rural	m-way
1994	258	210	218	404	311	318
1995	262	215	222	394	304	311
1996	257	212	219	387	299	306
1997	255	211	218	386	299	306
1998	244	203	210	369	287	293
1999	249	208	216	369	287	293
2000	247	208	215	368	287	294
2001	257	217	225	373	292	298
2002	250	212	219	371	290	296
2003	259	220	227	376	293	300
2004	250	212	219	363	283	289
2005	245	209	216	358	279	286
2006	252	214	221	361	281	287
2007	260	221	228	367	286	293
2008	271	230	237	382	297	304
2009	271	229	237	383	297	304

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, 2010b). DfT believe this provides a relatively robust estimation of fuel consumption on local bus services and would be based on a larger evidence base than the DfT/TRL speed-related functions which are derived from a relatively small sample of buses and coaches tested. The BSOG data actually imply an increase in the average fuel consumption factor for local buses, i.e. a reduction in fuel efficiency over the period from 1996 to 2005/2006, which has been levelling off, though factors increased again for the 2008/09 year.

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 more 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 2008/09. The financial year figures were used to represent the factors for the earlier calendar year. Hence, the 2008/09 figures were used for the 2008 calendar year and superceded estimates for 2008 made last year when these data were not available. As there are no corresponding BSOG data to use for 2009, 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 2008 and 2009. This produced a fuel efficiency scaling factor that could be applied to the factor for 2008.

Table A 3.3.15 presents the fleet-averaged fuel consumption factor for buses and coaches from 1990-2009 for urban, rural and motorway conditions based on this method.

Table A 3.3.15 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	305	190	216
1991	305	190	216
1992	305	190	216
1993	304	190	216
1994	300	188	214
1995	296	185	212
1996	290	182	209
1997	289	182	210
1998	289	183	212
1999	300	191	222
2000	313	200	234
2001	314	201	236
2002	327	210	247
2003	342	220	259
2004	355	228	269
2005	370	237	280
2006	356	228	269
2007	350	224	264
2008	379	242	286
2009	379	242	286

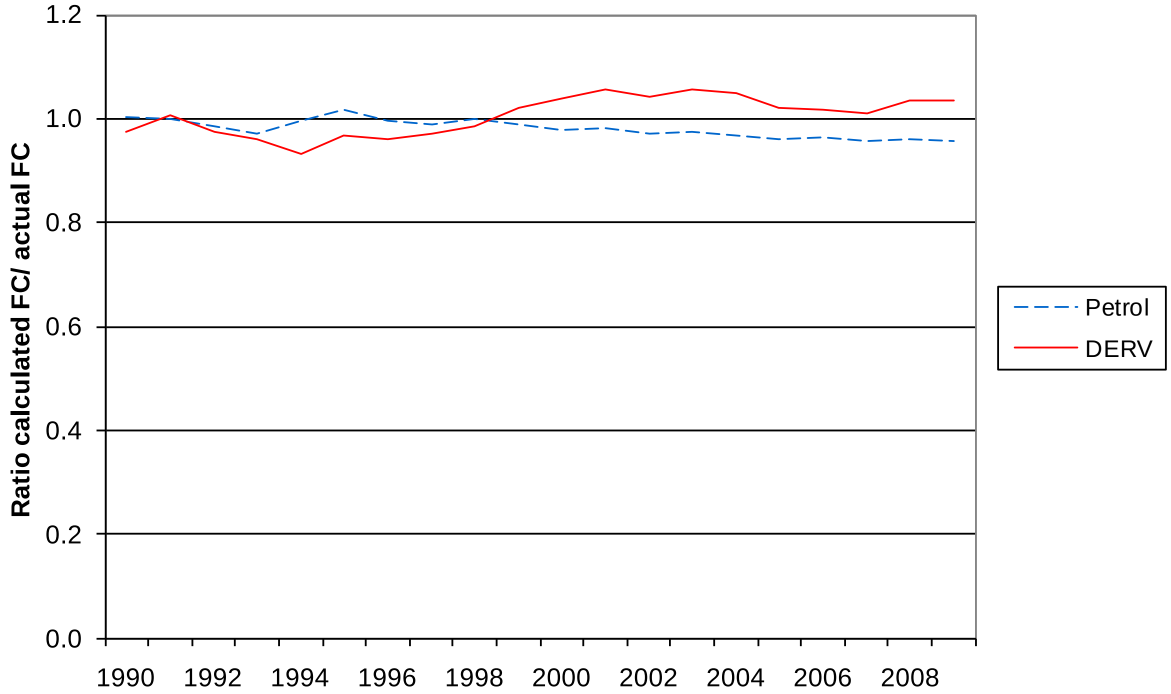
Fuel reconciliation and normalisation

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 off-road machinery and consumption in the Crown Dependencies. 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 calculated fuel consumption to the figures in DUKES based on total fuel sales of petrol and diesel in the UK. 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 7%. In 2009, the bottom-up method underestimates petrol consumption by 4% and over-estimates diesel consumption by 3%. 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 4% to align with fuel sales in 2009. 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 (the difference being 0.67 Mtonnes or 3% in 2009) 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 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 670 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 have been calculated for the first time using traffic-based emission factors as described in following sections. This is in response to the UNFCCC Expert Review of the UK inventory.

Emissions from natural gas consumption
It has been pointed out by the UNFCCC Expert Review of the UK inventory that emissions from vehicles running on natural gas are not estimated. 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://www.dft.gov.uk/pgr/roads/environment/emissions/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, 2010c). This detailed data was in the past only available for the latest inventory year, however, DfT was able to provide a consistent time series of vkm data by vehicle and road types going back to 1993 for the 2009 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, 2002, 2003, 2006, 2007, 2008, 2009a, 2010a). These provided a consistent time-series of vehicle km data for all years up to 2009. 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, 2010b). Revisions were made to the vehicle km activity data for cars, LGVs and rigid HGVs in Northern Ireland after clarification on the vehicle classifications used in the traffic census report. This has led to an increase in NI's car vkm and a reduction in the vkm for LGVs and rigid HGVs compared with the vkm used in the 2008 inventory for 1990-2008.

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 2009 as shown in **Table A 3.3.16**

Table A 3.3.16 UK vehicle km by road vehicles

Billion vkm		1990	1995	2000	2005	2006	2007	2008	2009
Petrol cars	urban	143.3	141.0	140.3	130.0	127.5	125.2	120.8	118.1
	rural	139.0	128.9	127.2	119.0	117.5	113.9	110.0	106.0
	m-way	47.8	45.1	48.4	44.1	43.0	41.5	39.8	38.5
Diesel cars	urban	4.8	14.1	21.5	34.2	37.2	40.3	42.5	45.0
	rural	8.2	23.1	35.5	56.9	62.1	66.4	69.8	72.9
	m-way	4.2	11.7	19.2	29.9	32.4	34.5	36.2	38.0
Petrol LGVs	urban	11.1	7.5	4.2	1.9	1.9	1.8	1.6	1.4
	rural	11.4	8.3	5.0	2.3	2.3	2.2	2.0	1.8
	m-way	3.9	3.2	2.0	0.9	1.0	0.9	0.8	0.7
Diesel LGVs	urban	5.7	10.2	15.6	21.7	22.5	23.4	23.6	23.0
	rural	6.1	11.5	18.9	26.2	27.4	29.6	30.0	29.3
	m-way	2.0	4.4	7.4	10.5	11.2	11.7	11.6	11.5
Rigid HGVs	urban	4.5	3.7	3.9	4.1	4.0	3.8	3.7	3.4
	rural	7.1	6.8	7.2	7.5	7.5	7.6	7.3	6.8
	m-way	3.7	3.7	4.2	4.2	4.2	4.2	4.2	4.0
Artic HGVs	urban	1.1	1.1	1.1	1.0	1.0	1.0	0.9	0.9
	rural	4.3	4.7	5.1	5.3	5.5	5.6	5.6	5.0
	m-way	4.7	6.0	7.4	7.9	8.0	8.3	8.0	7.3
Buses	urban	2.4	2.9	3.0	3.2	3.3	3.4	3.2	3.2
	rural	1.7	1.5	1.7	1.5	1.6	1.7	1.6	1.6
	m-way	0.6	0.5	0.5	0.5	0.6	0.5	0.5	0.4
M/cycle	urban	3.3	1.9	2.3	3.0	2.8	3.2	2.7	2.8
	rural	2.0	1.6	2.0	2.2	2.1	2.1	2.1	2.1
	m-way	0.3	0.3	0.4	0.4	0.4	0.4	0.5	0.4
Total		**423.4**	**443.9**	**484.0**	**518.6**	**527.1**	**533.1**	**528.8**	**524.3**

Vehicle speeds by road type

Vehicle speed data are used to calculate emission factors from the emission factor-speed relationships available for different pollutants. Average speed data for traffic in a number of different areas were taken from the following main sources: Transport Statistics Great Britain (DfT, 2009b) provided averages of speeds in Central, Inner and Outer London surveyed at different times of day during 1990 to 2008. Speeds data from other DfT's publications such as 'Road Statistics 2006: Traffic, Speeds and Congestion' (DfT, 2007a) and 2008 national road traffic and speed forecasts (DfT, 2008b) 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 3.3.17** shows the speeds used in the previous and 2009 inventory for light duty vehicles, HGVs and buses. DfT confirmed these data were still valid for 2009.

Table A 3.3.17 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. DfT Vehicle Licensing Statistics (DfT, 2010d) provide the number of vehicles licensed in GB by fuel type. This information is combined with data on the relative mileage done by petrol and diesel cars (DfT, 2008c, pers comm). This indicates that diesel cars do on average 60% more annual mileage than petrol cars. The information originated from the National Travel Survey (DfT, 2007b). It has been assumed that the additional mileage done by diesel cars is mainly done on motorways and rural roads. On this basis, the petrol car/diesel car mix on urban roads is assumed to be that 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. This leads to the vehicle km data for petrol and diesel cars on different road types shown in **Table A 3.3.16**.

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, 2010d). 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, 2008c).

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.

Only limited information on the sizes of buses and coaches by weight exists and it was assumed based on analysis of local bus operator information 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 have been updated using 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 has been updated, 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.

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 3.3.18** shows the regulations that have come into force up to 2009 for each vehicle type.

Table A 3.3.18 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
	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
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

The average age profile and the fraction of petrol and diesel cars and LGVs in the fleet each year are based on the composition of the UK vehicle fleet using DfT Vehicle Licensing Statistics. The Transport Statistics Bulletin "Vehicle Licensing Statistics: 2009" (DfT, 2010d) either gives historic trends in the composition of the UK fleet by age directly or provides sufficient information for this to be calculated from new vehicle registrations and average vehicle survival rates. Thus, year-of-first registration data for vehicles licensed in each year from 1990 to 2009 have been taken to reflect the age distribution of the fleet in these years. Statistics are also available on the number of new registrations in each year up to 2009, reflecting the number of new vehicles entering into service in previous years.

The two sets of data combined allow an average survival rate to be determined for each type of vehicle. This defines the turnover in the fleet and therefore the composition of the fleet by Euro standard each year. Particularly detailed information is available on the composition of the HGV stock by age and size. The age composition data are combined with data on the change in annual vehicle mileage with age to take account of the fact that newer vehicles on average travel a greater number of kilometres in a year than older vehicles. For cars and LGVs, such mileage by age data are from the National Travel Survey (DETR, 1998a); data for HGVs of different weights are taken from the Continuous Survey of Road Goods Transport (DETR, 1996a). Data from these sources were used to develop a mileage with age profile which is applied to all years.

Separate vehicle licensing statistics for private and light goods vehicles (PLG) in Northern Ireland are available from the Central Statistics and Research Branch of the Department of Regional Development in Northern Ireland (DRDNI, 2010c). These show a higher proportion of diesel cars here than in Great Britain. Unlike other regional licensing statistics, it is more likely that these statistics reflect the actual fuel mix of cars on the road in Northern Ireland and so this information was used in the inventory.

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% in 2000. In 2001, an assumption was made that 15% of all new petrol cars sold in the UK met Euro 4 standards, increasing to 81% in 2004 even though the mandatory date of introduction of this standard is not until 2006 (DfT, 2004). The remaining new petrol car registrations in 2001 - 2005 would meet Euro 3 standards. From 2006, all new cars must fully comply with Euro 4 standards.

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 in 2008 and 2009 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.

The specific features of the fleet of buses operated by 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 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 accept 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, 2007) 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 HGVs, buses and motorcycles make no distinction between different Euro standards and road types. **Table A 3.3.24** 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 3.3.25** 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 estimated explicitly for the first time in the 2009 inventory. These are calculated from vehicle km data and emission factors (expressed as gram 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 3.3.19** shows fleet-averaged emission factors for vehicles using LPG in the UK in 2009 for each main road type.

Table A 3.3.19 Fleet-weighted emission factors for light duty vehicles running on LPG in 2009

g/km	Urban	Rural	Motorway
CH_4	0.0401	0.0221	0.0195
N_2O	0.0114	0.0043	0.0024

The UNFCCC Expert Review Team commented that the UK does not include CH_4 and N_2O emissions from lubricants. 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 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, total hydrocarbons (THC) and CO are represented as equations relating emission factor in g/km to average speed (Boulter et al, 2009). The DfT/TRL (Boulter et al) 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. **Tables A 3.3.26-28** summarise the NO_x, CO and THC emission factors for all vehicle types under typical urban, rural and motorway road conditions in g/km normalised to 50,000km accumulated mileage and current fuels. These are derived from the tables at http://www.dft.gov.uk/pgr/roads/environment/emissions/ for detailed vehicle size classes and averaged according to the proportion of different vehicle sizes in the UK fleet according to vehicle licensing statistics. Factors for NMVOCs are derived by subtracting the calculated g/km factors for methane 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 3.3.17**. 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.

The inventory takes into account the change in emissions with mileage using the TRL functions and change in mileage with age data and 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 (2010) 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 3.3.20**.

Table A 3.3.20 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 3.3.21**.

Table A 3.3.21 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

Comments on current NO_x emission factors

The current inventory for exhaust emissions of NO_x used emission factors published by DfT/TRL in 2009. The factors are based on TRL's analysis of a database of raw emissions test data from various sources measured over various drive cycles which are supposed to mimic real-world behaviour. However, recent evidence is casting some doubt on the accuracy of these emission factors, especially for more modern diesel vehicles (Euro 3+) and even some of the earlier Euro1 and 2 petrol cars. The time-series in NO_x emissions in urban areas implied by the emissions inventory shows a clear downward trend in emissions since 2002 that does not seem to be borne out by roadside measurements of ambient NO_x concentrations which instead show the trend to be fairly flat. There is also some evidence from roadside remote sensing of exhaust plumes from a large number of vehicles that the NO_x emissions are significantly higher than indicated by the current emission factors. The evidence points to some doubt as to whether the technologies intended to bring emissions from Euro 3+ diesel vehicles to within limits over the regulatory test cycle are actually delivering the expected improvements under real-world conditions. Work is currently underway by a Defra-led consortium including the inventory team and other experts to assess this uncertainty in the NO_x emission factors and the implications to current and future emissions and urban NO_2 concentrations. This work is in progress and when concluded, a report will be prepared for peer-review which may recommend changes to the NO_x emission factors.

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, 2007a). 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 3.3.22**. There are no cold start factors for HGVs and buses.

Table A 3.3.22 Cold Start Emission Factors for N_2O (in mg/km)

mg/km	Petrol cars	Petrol LGVs
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

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 only 0.2% 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 has been updated in the 2009 inventory following a review on alternative and more up-to-date methodologies (Stewart et al., 2009) and recommendations of a recent review carried by TRL under contract to DfT (Latham and Boulter 2009). It was concluded that the COPERT 4 simple approach is the preferred approach to use for national scale modelling of evaporative emissions for the UK inventory (EEA 2007). The previous methodology used was largely based on the COPERT II/COPERT III methodology (EEA, 1997, 2000) supplemented by factors with a more UK bias.

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 has 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 as in the previous method, however, it utilises look-up tables to assign emission factors according to summer/winter climate conditions and fuel vapour pressure rather than continuous mathematical equations relating emission factor to these parameters as previously used.

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 (2010), 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 2009 is shown for petrol cars and motorcycles in **Table A 3.3.23**. The units are in grammes per vehicle per day.

Table A 3.3.23 Fleet-average emission factor for evaporative emissions of NMVOCs in 2009

g/vehicle.day	2009
Petrol cars	1.15
Motorcycles	1.70

Adopting the new methodology for petrol cars and motorcycles leads to a higher estimate of evaporative emissions in 2008 of around 13.7 ktonnes compared with 10.4 ktonnes previously estimated or a 32% difference. However, the difference is greater in earlier years indicating that the rate of decline in evaporative emissions is faster than implied by previous estimates. The relative contributions made by the three different processes leading to evaporation of fuel vapour from vehicles are very different to those previously estimated such that the hot soak and running loss mechanisms dominate.

Table A 3.3.24 N_2O Emission Factors for Road Transport (in mg/km)

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
Diesel cars	Pre-Euro 1	0	0	0
	Euro 1	2	4	4
	Euro 2	4	6	6
	Euro 3	9	4	4
	Euro 4	9	4	4
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
	Euro 1	2	4	4
	Euro 2	4	6	6
	Euro 3	9	4	4
	Euro 4	9	4	4
Rigid HGVs	Pre-1988	30	30	30
	88/77/EEC	30	30	30
	Euro I	30	30	30
	Euro II	30	30	30
	Euro III	30	30	30
	Euro IV	30	30	30
Artic HGVs	Pre-1988	30	30	30
	88/77/EEC	30	30	30
	Euro I	30	30	30
	Euro II	30	30	30
	Euro III	30	30	30
	Euro IV	30	30	30
Buses	Pre-1988	30	30	30
	88/77/EEC	30	30	30
	Euro I	30	30	30
	Euro II	30	30	30
	Euro III	30	30	30
	Euro IV	30	30	30
Mopeds, <50cc, 2st	Pre-Euro 1	1		
	Euro 1	1		
	Euro 2	1		
	Euro 3	1		
Motorcycles, >50cc, 2st	Pre-Euro 1	2	2	
	Euro 1	2	2	
	Euro 2	2	2	
	Euro 3	2	2	
Motorcycles, >50cc, 4st	Pre-Euro 1	2	2	2
	Euro 1	2	2	2
	Euro 2	2	2	2
	Euro 3	2	2	2

Table A 3.3.25 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
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
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
	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 3.3.26 NOx Emission Factors for Road Transport (in g/km) normalised to 50,000 km accumulated mileage (where applicable).

g NOx (as NO2 eq)/km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	1.558	1.982	2.600
	Euro 1	0.301	0.319	0.371
	Euro 2	0.143	0.154	0.189
	Euro 3	0.064	0.066	0.079
	Euro 4	0.046	0.043	0.045
Diesel cars	Pre-Euro 1	0.578	0.613	0.805
	Euro 1	0.523	0.550	0.809
	Euro 2	0.617	0.647	0.922
	Euro 3	0.477	0.491	0.660
	Euro 4	0.297	0.328	0.471
Petrol LGVs	Pre-Euro 1	1.496	2.025	2.731
	Euro 1	0.350	0.384	0.462
	Euro 2	0.091	0.089	0.123
	Euro 3	0.050	0.058	0.079
	Euro 4	0.034	0.028	0.025
Diesel LGV	Pre-Euro 1	1.649	1.769	2.353
	Euro 1	1.143	1.339	1.980
	Euro 2	1.247	1.491	2.260
	Euro 3	0.736	0.921	1.478
	Euro 4	0.368	0.461	0.739
Rigid HGVs	Pre-Euro I	8.094	8.229	8.717
	Euro I	5.400	5.540	5.810
	Euro II	5.675	5.738	5.959
	Euro III	4.431	4.390	4.572
	Euro IV	2.729	2.748	2.895
	Euro V	1.608	1.612	1.700
Artic HGVs	Pre-Euro I	14.440	13.426	14.223
	Euro I	10.122	9.430	9.987
	Euro II	10.440	9.714	10.296
	Euro III	8.267	7.654	8.113
	Euro IV	5.101	4.745	5.014
	Euro V	2.989	2.775	2.932
Buses & coaches	Pre-Euro I	11.182	10.106	10.199
	Euro I	7.471	6.658	7.663
	Euro II	7.977	7.047	8.288
	Euro III	6.431	5.366	6.573
	Euro IV	3.935	3.353	4.030
	Euro V	2.361	1.976	2.409
Mopeds, <50cc, 2st	Pre-Euro 1	0.030		
	Euro 1	0.030		
	Euro 2	0.010		
	Euro 3	0.010		
Motorcycles, >50cc, 2st	Pre-Euro 1	0.026	0.039	
	Euro 1	0.041	0.054	
	Euro 2	0.048	0.062	
	Euro 3	0.023	0.036	
Motorcycles, >50cc, 4st	Pre-Euro 1	0.223	0.446	0.569
	Euro 1	0.229	0.443	0.569
	Euro 2	0.127	0.306	0.664
	Euro 3	0.065	0.155	0.337

Table A 3.3.27 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	9.774	6.850	5.531
	Euro 1	2.423	1.637	3.132
	Euro 2	0.534	0.695	1.823
	Euro 3	0.230	0.615	1.583
	Euro 4	0.419	0.705	1.564
Diesel cars	Pre-Euro 1	0.583	0.434	0.361
	Euro 1	0.318	0.223	0.183
	Euro 2	0.193	0.118	0.079
	Euro 3	0.057	0.035	0.024
	Euro 4	0.052	0.030	0.016
Petrol LGVs	Pre-Euro 1	11.689	8.169	6.688
	Euro 1	3.098	3.245	4.807
	Euro 2	0.096	1.154	3.116
	Euro 3	0.406	0.767	2.215
	Euro 4	0.406	0.767	2.215
Diesel LGV	Pre-Euro 1	0.713	0.768	0.953
	Euro 1	0.547	0.456	0.425
	Euro 2	0.592	0.624	0.758
	Euro 3	0.174	0.132	0.120
	Euro 4	0.136	0.103	0.094
Rigid HGVs	Pre-Euro I	2.140	1.957	2.059
	Euro I	1.377	1.296	1.370
	Euro II	1.173	1.122	1.179
	Euro III	1.042	0.963	0.980
	Euro IV	0.567	0.497	0.547
	Euro V	0.078	0.072	0.074
Artic HGVs	Pre-Euro I	2.489	2.258	2.392
	Euro I	2.170	1.981	2.099
	Euro II	1.804	1.692	1.835
	Euro III	1.907	1.738	1.855
	Euro IV	0.340	0.311	0.340
	Euro V	0.134	0.120	0.128
Buses & coaches	Pre-Euro I	2.723	1.893	1.504
	Euro I	1.677	1.106	1.239
	Euro II	1.333	0.867	1.130
	Euro III	1.457	0.922	1.218
	Euro IV	0.127	0.084	0.090
	Euro V	0.129	0.085	0.092
Mopeds, <50cc, 2st	Pre-Euro 1	13.800		
	Euro 1	5.600		
	Euro 2	1.300		
	Euro 3	1.300		
Motorcycles, >50cc, 2st	Pre-Euro 1	16.081	23.667	
	Euro 1	10.608	15.616	
	Euro 2	8.392	12.352	
	Euro 3	4.634	6.818	
Motorcycles, >50cc, 4st	Pre-Euro 1	16.588	22.015	25.843
	Euro 1	10.083	17.564	15.740
	Euro 2	5.270	8.981	9.511
	Euro 3	2.909	4.957	5.252

Table A 3.3.28 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
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
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
	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 and international marine. Coastal shipping is reported within IPCC category 1A3dii National Navigation and to date has included emissions from fishing vessels. 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 has been used to estimate coastal and international marine emissions for the 2009 inventory. The method is centred around a new 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 is the first time such an approach has been feasible for the UK inventory. Previous emission estimates for coastal and international marine have been 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, 2010). This has led to very erratic time series trends in fuel consumption and emissions which bears 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 years, 2007, but Entec used proxy data to backcast movements and fuel consumption to 1990 and forward cast to 2009.

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 new 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.

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
- Entec’s estimates for domestic shipping fuel consumption and emissions backcast to 1990 and forecast to 2009 are used
- 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 (less fuel used for naval shipping) and the fuel consumption estimate for domestic shipping taken from Entec is assigned to international shipping.

Details in the approach are given in the following sections. Further details of the bottom-up methodology for estimating fuel consumption and emissions based on 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, 2008d) 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 3.3.29 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 used in the last year's inventory (2008 GHGI) in units g/kg fuel were unchanged. The factors for CH_4 and N_2O 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 3.3.30 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.

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 Entec used an alternative approach based on proxy data to develop a consistent time series in emissions back to 1990 and forward to 2009 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 ones 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 1990-2009.
- 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 1990-2009
- 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, 2009).

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.

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 1990-2009 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.

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 3.3.31** 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 3.3.31 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

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.

Thus, for fuel consumption across the time series:

International shipping = (DUKES Marine Bunkers + DUKES national navigation –Entec domestic - military)

This implies that the total marine fuel consumption used in the inventory time series is consistent with DUKES, but that a different domestic/international split is used. The proportion of fuel consumption (hence emissions) allocated to domestic shipping is considerably smaller than that implied by the data in DUKES, as can be seen in **Table A 3.3.32**.

Table A 3.3.32 Consumption of marine fuels by domestic and international shipping calculated by the inventory approach on the basis of Entec figures for domestic movements 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	0.392	0.94
	International	1.177	0.63
	Total	1.569	1.569
	% domestic	25%	60%
Fuel oil	Domestic	0.103	0.569
	International	1.936	1.471
	Total	2.040	2.040
	% domestic	5%	28%

Following this 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 thought 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

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 3.3.33 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.

Table A 3.3.33 Fuel consumption for domestic 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	1.704	0.346	1.132
1991	0.169	0.005	1.764	0.342	1.065
1992	0.166	0.006	1.791	0.335	1.095
1993	0.164	0.006	1.708	0.332	1.143
1994	0.174	0.006	1.643	0.352	0.951
1995	0.181	0.006	1.476	0.368	1.196
1996	0.182	0.006	1.700	0.370	1.259
1997	0.178	0.005	1.630	0.361	1.570
1998	0.181	0.005	1.923	0.371	1.417
1999	0.181	0.004	1.580	0.374	0.877
2000	0.169	0.004	1.588	0.347	0.630
2001	0.163	0.004	1.742	0.334	0.541
2002	0.170	0.004	1.332	0.351	0.460
2003	0.166	0.004	1.539	0.342	0.576
2004	0.168	0.005	1.443	0.343	0.935
2005	0.172	0.005	1.361	0.356	1.164
2006	0.163	0.004	1.789	0.337	1.480
2007	0.388	0.004	1.177	0.103	1.936
2008	0.378	0.004	1.056	0.100	2.458
2009	0.359	0.004	1.057	0.094	2.208

Table A 3.3.34 shows the implied emission factors for each pollutant, for both domestic and international vessel movements and fishing in 2009. The units are in g/kg fuel and are implied by the figures in the Entec study.

Table A 3.3.34 2009 Inventory Implied Emission Factors – Greenhouse Gases

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	26.37	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 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, 2010). 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 revisions to the shipping methodology described above have led to changes in the domestic/international split in fuel use allocation for marine fuels from the allocations in the national energy statistics (DUKES) and submissions to IEA/EUROSTAT.

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:

$$E_{vj} = N_j \,.\, H_j \,.\, e_{vj}$$

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 2005-2009.

For industrial and construction machinery, a new set of four drivers was used. Each of the individual machinery types was 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 3.3.35**.

For domestic house and garden machinery, trends in number of households were used (CLG, 2010), for airport machinery, statistics on number of terminal passengers at UK airports were used (CAA, 2010), and for agricultural off road machinery, the trends in gas oil allocated to agriculture in DUKES (DECC, 2010) were 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 3.3.35 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 2010. http://www.statistics.gov.uk/downloads/theme_commerce/CSA-2010/Opening%20page.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 2010.	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	generator sets 100-1000KW
		pumps

Category	Driver source	Machinery types
	from data supplied by DECC for use in energy and emissions projections.	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 2009 are shown in **Table A 3.3.36** by fuel type. The fleet-average (aggregated) emission factors for most machinery types are lower than in the 2008 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.

Table A 3.3.36 Aggregate Emission Factors for Off-Road Source Categories in 2009 (t/kt fuel)

Source	Fuel	C[2]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2[3]
Domestic House&Garden	DERV	863	0.158	1.306	47.96	4.3	2.6	0.015
Domestic House&Garden	Petrol	855	1.050	0.031	3.82	667.9	61.0	0.012
Agricultural Power Units	Gas Oil	870	0.162	1.318	28.98	16.8	5.2	1.68
Agricultural Power Units	Petrol	855	2.175	0.015	1.45	716.3	248.6	0.012
Industrial Off-road	Gas Oil	870	0.152	1.292	38.43	16.7	6.4	1.68
Industrial Off-road	Petrol	855	3.757	0.051	6.24	1035 7	39.3	0.012
Aircraft Support	Gas Oil	870	0.164	1.337	28.19	12.5	5.0	1.68

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

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 (2010). 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 3.3.37**.

Table A 3.3.37 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	8.46b	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 1998-2008 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 3.3.37** 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, 2010).

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

The original study into closed coal mine emissions was conducted during 2005. The estimation method for both historic and projected methane emissions from UK coal mines comprised two separate sets of calculations to estimate emissions from (1) coal mines that had been closed for some years, and (2) methane emissions from mines that had recently closed or were forecast to close over 2005 to 2009. The 2005 study derived emission estimates for the years 1990 to 2050 using a relationship between emissions and the quantity of the underlying methane gas within the abandoned mine workings, including site-specific considerations of the most appropriate decay model for the recently closed mines. Consultation with the author has confirmed the actual mine closure programme in the UK and has thus provided updated estimates for 2005 and 2006. The emission calculations include estimates for the methane utilised or burned at collieries and other mitigating factors such as flooding of closed coal mines which reduces the source of methane gas over time.

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 seams 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 A.3.3.1**.

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 3.3.38**.

Emissions of carbon from solid smokeless fuel production are calculated using a mass balance approach, described previously in **Section A.3.3.1**. 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 3.3.38** 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 3.3.38 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]	2.14[c]	-	1.91[c]	0.0286[e]
Coke	kt/Mt coal consumed	-	-	0.02[b]		-
SSF	kt/Mt SSF made	0.0802[a]	0.0156[c]	0.0235[c]	-	0.0178[a]
SSF	kt/Mt coal consumed	-	-	-	4.39[d]	-

a EIPPCB, (2000)
b USEPA (2004)
c Factor for 2009 based on Environment Agency (2010)
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 DECC Oil & Gas and developed in conjunction with the trade association Oil & Gas UK (formerly UKOOA). The EEMS data provides a detailed inventory of point source emissions estimates, based on operator returns for the years 1995-2009. Additional data on CO_2 emissions from some offshore combustion processes has become available via the National Allocation Plan and annual operator emission estimates for sites participating in the EU Emission Trading Scheme. In recent years these EU ETS data have been used by operators to update their EEMS emission estimates for combustion processes, ensuring consistency between EEMS and EU ETS, and by the Inventory Agency as a useful Quality Check on time-series consistency of carbon emission factors.

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 oil & gas team of regulators, 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 EA holds emissions data from industrial plant from around 1995 onwards. For some terminals, occasional data gaps are evident in the EEMS data, most notably for methane and NMVOC emissions from oil loading activities. In these instances, the emission estimates reported under IPC/IPPC are used to provide an indication of the level of emissions in that year, but the longer time-series of the EEMS data for Scottish sites has led the Inventory Agency to use the EEMS data as the primary data source for these terminals.

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 Oil & Gas team of regulators 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 (Furneaux, 2010):

- Offshore gas flaring, 2008: data revised for four offshore platforms, three due to new operator data, one to correct reported activity data;
- Offshore process emissions, 2008: revised operator data provided for one platform;
- Offshore fugitive and venting emissions, 2008: revised operator data provided for four platforms;
- Offshore gas combustion, 2008: data revised for four platforms by operators, with estimates derived for non-CO_2 GHGs using IEFs from previous year;
- Offshore well testing, 2008: revised data for well testing emissions from oil and gas exploration activities provided by DECC;
- Onshore flaring, 2008: emission estimates from two terminals revised based on new operator data, one via EEMS and the other via IPPC data (due to missing data in EEMS);
- Onshore fugitive emissions, 2008: estimates from eight terminals have been revised, seven of them from new operator data and one based on IPPC-reported data (due to missing data in EEMS);
- Onshore gas consumption, 2008: data revised for two terminals based on new operator data;
- Onshore oil loading and storage tank emissions, 2008: data for one terminal has been updated with new operator data;
- Offshore fugitives and flaring, 2009: emissions from one site amended to resolve incorrect activity data submissions by operator;
- Offshore process emissions, 2009: operator contacted to correct acid gas venting emissions estimates, following analysis of time-series consistency problems.
- Onshore gas consumption, 2009: activity data corrected for one terminal where IEFs were out by orders of magnitude;
- Onshore flaring, 2009: emission estimates corrected for one terminal, to address large inconsistencies between IPPC and EEMS data.

The inventory compilation method was overhauled in the 1990-2007 submission, to take advantage of developments in the EEMS dataset from the DECC Oil & Gas team, 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 Oil & Gas team, and the DECC Energy Statistics team. There are two reporting systems from upstream oil & gas processing in the UK; the EEMS system provides emissions data to the DECC Oil & Gas team, whilst the Petroleum Processing Reporting System (PPRS) is used to report 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 diesel oil consumption by offshore installations is not reported separately in the UK Energy Statistics but is allocated across other sectors within the energy balance tables, including "Other Industries" (DECC, 2011). In order to avoid double counts, the Oil and Gas UK estimates have been corrected to remove diesel oil emissions.

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: Own gas use (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 for the first time 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.

The data gaps and inconsistencies evident within the latest (2009) data submission indicate that there is still some further improvement to the QA/QC of the source data by operators and regulators alike. Furthermore there are inconsistencies evident from oil and gas terminal submissions to different reporting mechanisms. During 2010, the inventory agency conducted research to review the emissions data reported by oil and gas terminal operators, refinery operators and several petrochemical manufacturers, using data from EEMS (for the oil and gas sites), IPPC (for all sites) and EUETS (for all sites). The report can be found at:

http://www.airquality.co.uk/archive/reports/cat07/1005251107_DA_Improvement_Report_Industry_Task_May2010_Issue_1.pdf

In many cases, the research enabled the inventory agency to clarify the difference in reporting scope between the different mechanisms. However, the research also identified several reporting errors, and has led to several revisions of the source data for oil and gas terminals, and also provided feedback to regulators to help identify where QAQC of emissions data has previously been inconsistent.

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, 2010). Data from 1995-2009 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 1999-2009, and on emission factors and production throughput data for 1990-1998.

The activity data and implied emission factors are given below in **Table A 3.3.39a (oil) and b (gas)**. The implied emission factors for 1997-2009 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 3.3.39a 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
2009	1293	2.62	0.0093	0.0013	0.0066	0.0091	0.00016	0.00007
2008	1290	2.59	0.0090	0.0013	0.0062	0.0088	0.00027	0.00007
2007	1502	2.59	0.0098	0.0014	0.0067	0.0081	0.00012	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

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
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 (2010).

Table A 3.3.39b 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
2009	216	2.05	0.0098	0.0012	0.0066	0.0032	0.00001	0.00008
2008	132	1.96	0.0070	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: Own Gas Use

This refers to the use of unrefined natural gas on offshore platforms and onshore terminals as a fuel in heaters, boilers, turbines and reciprocating engines. Gas combustion emission data for CO_2, SO_2, NO_x, CO, NMVOC, and CH_4 are taken from the EEMS dataset (DECC, 2010). Data from 1995-2009 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 1999-2009, and on emission factors and production throughput data for 1990-1998.

The activity data and implied emission factors are given below in **Table A 3.3.40 a (oil) and b (gas)**. The implied emission factors for 1990-2009 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 3.3.40a 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
2009	1501	6.15	2.33	19.46	6.86	0.15	0.35	0.45
2008	1499	6.47	2.25	20.99	7.04	0.13	0.39	0.44
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 3.3.40b 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
2009	585	6.04	4.34	13.44	6.91	0.45	0.08	0.47
2008	592	6.29	3.76	12.85	7.86	0.35	0.07	0.47
2007	577	6.35	3.51	17.88	7.08	0.37	0.08	0.48
2006	535	5.71	3.88	16.13	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, own gas use: natural gas;
- Gas separation plant: LPG; and
- Gas separation plant: OPG.

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 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, 2010). 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 1995-2009 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 1999-2009, and on emission factors and production throughput data for 1990-1998.

The activity data and implied emission factors are given below in **Table A 3.3.41 a (oil) and b (gas)**.

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

Table A 3.3.41a Oil Production Well Testing: Activity Data and Implied Emission Factors

Year	Activity	CO_2	SO_2	NO_x	CO	NMVOC	CH_4	N_2O
	ktonnes	kt/kt	t/kt	t/kt	t/kt	t/kt	t/kt	t/kt
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 3.3.41b Gas Production Well Testing: Activity Data and Implied Emission Factors

Year	Activity	CO_2	SO_2	NO_x	CO	NMVOC	CH_4	N_2O
	ktonnes	kt/kt	t/kt	t/kt	t/kt	t/kt	t/kt	t/kt
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	5.0	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
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, 2010) and previous industry studies by Oil & Gas UK (1998). Data from 1995-2009 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:

reductions in direct process emissions of SO_2 have been achieved 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 3.3.42 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, 2010). Data from 1995-2009 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 1995-2009 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 3.3.43**.

Table A 3.3.43 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
2009	32,161	0.017	0.75	11,938	0.080	1.41
2008	32,644	0.017	1.08	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
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 2011 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 2009 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 3.3.44**. 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 2010 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 3.3.44 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]

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 (2010)
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. In this inventory, we have obtained estimates of the very small amount of annual leakage for the Northern Ireland grid for the first time, from the main gas operator (Phoenix Gas, 2010). Annual estimates from 2005 onwards have been provided, 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.

Time Series of Emissions (1990 to 2009)
The number of boilers from 1990 to 2009 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 1990-2009.

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 3.3.45 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 (2010). 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 (2009), 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, 2010) 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 (2010).

A3.3.8.2.8 Refineries and Petroleum Processes

The IPCC category 1B2aiv Refining and Storage reports 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 (2010) estimates for 1994-2009. 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 (most significant of which are the Tetney Lock and Tranmere oil terminals). Emissions are taken from the Pollution Inventory (Environment Agency, 2010). 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, 2010) and Scottish Pollutant Release Inventory (SEPA, 2010). 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[5]. 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.

[5] 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.

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[6] was introduced that allowed compliant fuel produced from waste oils to be 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,

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

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, 2009

Fuel	C [a]	CH_4	N_2O	Units
Coal	665[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	806[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, 2009: Indirect GHGs

Fuel	CO	NO_x	NMVOC	Units
Coal	3.83	28.3	0.05	Kt / Mt fuel
Natural Gas	0.00615	0.00534	2.34E-3	Kt / Mtherm
Coke	6.08	0.919	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	0.807
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	0.437
2005	4	1.71	3.80	0.373
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	1.05	3.39	0.239

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 3.4.3.4**. Data on iron production are reported in ISSB (2010).

Table A 3.4.4 Emission Factors for Blast Furnaces (BF), Electric Arc Furnaces (EAF) and Basic Oxygen Furnaces (BOF), 2009

	C [a]	CH_4	N_2O	NO_x	SO_2	NMVOC	CO	Units
Blast furnaces	IE	NE	NE	NE	0.0850[b]	0.12[c]	2.08[b]	kt/Mt pig iron
Electric arc furnaces	2[d]	0.01[e]	0.005[e]	0.227[b]	0.152[b]	0.09[e]	0.934[b]	kt/Mt Steel
Basic oxygen furnaces	IE	NE	NE	0.0106[f]	IE	NE	7.17[b]	kt/Mt Steel
Losses of BFG/BOF G	8.48[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	1.04E-5[b]	NE	NE	kt/Mt Pig iron

a Emission factor as kt carbon/unit activity
b Emission factor for 2008 based on data from Corus (2009) and data for non-Corus plant from EA (2009)
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 (2007).

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, 2009

	C [a]	SO_2 [b]	NO_x [b]	CO [b]	Units
Prebake	420	8.73	0.839	108	Kt / Mt Al
Anode Baking	IE	0.244	0.418	4.26	Kt / Mt anode

a Emission factor as kt carbon per unit activity, Walker, 1997.
b Environment Agency Pollution Inventory (2009) and SEPA (2009)
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
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.

The sections below present the detailed assumptions and EFs that are used in the calculations.

A3.4.5.2 Detailed Assumptions for Refrigeration and Air Conditioning Equipment (2F1)

Domestic refrigeration (including refrigerators, chest freezers, upright freezers and fridge-freezers) *(R1)*

Table A 3.4.7 Key assumptions used to estimate emissions from domestic refrigeration

	Parameter	2009
Activity data	Total UK stock refrigerators and freezers	40,915,361
	Derived annual sales UK refrigerators and freezers	2,805,994
	Average fluid fill (kg)	0.13
	% of goods containing HFC	6
	Used for manufacture (t)	8.10
	Equipment lifetime (yrs)	11
	Refrigerants Used	HFC134a
Emission factors	PM %	2
	PL %	11 for new systems (up to 30 for older systems)
	D %	1 (65 to 2000; fallen to 5 by 2005)

Other small hermetic refrigeration units *(R2)*

Table A 3.4.8 Key assumptions used to estimate emissions from small hermetic refrigeration units

	Parameter	2009
Activity data	Used for manufacture (t)	50
	Equipment lifetime (yrs)	5
	Refrigerants Used	HFC134a (20%), R404A (10%), R407C (5%), R410A (65%)
Emission factors	PM %	1
	PL %	1 for new systems (up to 5 for older systems)
	D %	6 (up to 50 historically)

Small commercial distributed systems *(R3)*

Table A 3.4.9 Key assumptions used to estimate emissions from small commercial distributed systems

	Parameter	2009
Activity data	Used for manufacture (t)	120
	Equipment lifetime (yrs)	14
	Refrigerants Used	HFC134a (20%), R404A (79%), R507 (1%)
Emission factors	PM %	2
	PL %	3 for new systems (up to 20 for older systems)
	D %	5 (up to 10 historically)

Supermarket systems *(R4)*

Table A 3.4.10 Key assumptions used to estimate emissions from supermarket systems

	Parameter	2009
Activity data	Used for manufacture (t)	800
	Equipment lifetime (yrs)	11
	Refrigerants used	HFC134a (2%), R404A (95%), R407A (3%)
Emission factors	PM %	2
	PL %	11 for new systems (up to 30 for older systems)
	D %	5 (up to 10 historically)

Industrial refrigeration *(R5)*

Table A 3.4.11 Key assumptions used to estimate emissions from industrial refrigeration

	Parameter	2009
Activity data	Used for manufacture (t)	500
	Equipment lifetime (yrs)	16
	Refrigerants used	HFC134a (10%), R404A (58%), R410A (1%), R507 (30%), R422D (1%)
Emission factors	PM %	1
	PL %	8 for new systems (up to 20 for older systems)
	D %	5 (up to 10 historically)

Building air conditioning systems (direct use of refrigerant) *(R6)*

Table A 3.4.12 Key assumptions used to estimate emissions from building air conditioning systems (direct use of refrigerant)

	Parameter	2009
Activity data	Used for manufacture (t)	576.47
	Equipment lifetime (yrs)	13
	Refrigerants used	HFC134a (5%), R404A (1%), R407C (51%), R410A (43%)
Emission factors	PM %	2
	PL %	8.5 for new systems (up to 20 or older systems)
	D %	5 (up to 10 historically)

Building air-conditioning chillers (indirect use of refrigerant) *(R7)*

Table A 3.4.13 Key assumptions used to estimate emissions from building chillers (indirect use of refrigerant)

	Parameter	2009
Activity data	Used for manufacture (t)	480.88
	Equipment lifetime (yrs)	13
	Refrigerants used	HFC134a (20%), R404A (1%), R407C (40%), R410A (39%)
Emission factors	PM %	1
	PL %	3 for new systems (up to 10 for older systems)
	D %	5 (up to 10 historically)

Refrigerated transport *(R8)*

Table A 3.4.14 Key assumptions used to estimate emissions from refrigerated transport

	Parameter	2009
Activity data	Used for manufacture (t)	16
	Equipment lifetime (yrs)	8
	Refrigerants used	HFC134a (16%), R404A(82%), R410A (2%)
Emission factors	PM %	1
	PL %	32.5% (Midpoint of IPCC default range)
	D %	6 (was 10 in 2000)

***Mobile air conditioning** (R9)*

Table A 3.4.15 Key assumptions used to estimate emissions from mobile air conditioning

	Parameter	2009
Activity data	Vehicle registrations (passenger and commercial	2,605,914
	Vehicles manufactured in the UK	1,649,515
	% of vehicles having HFC MAC systems	90
	Average charge size (kg) at manufacture	0.64
	Used for topping up (t) (Includes imported and UK produced cars)	1287.30
	Size of bank (t)	1494.25
	Equipment lifetime (yrs)	13
	Refrigerants used	HFC134a
Emission factors	PM %	1
	PL %	7.5
	D %	12 (was 20 in 2005)

A3.4.5.3 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 3.4.16 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%		

A3.4.5.4 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 3.4.17 Key assumptions used to estimate HFC emissions from fire extinguishers

	Parameter	2009
Activity data	HFC species and ratio HFC 227ea : HFC 23	97.5 : 2.5
	Size of bank (t)	2484
	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

A3.4.5.5 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 3.4.18 Key assumptions used to estimate HFC134a emissions from aerosols

	Parameter	2009
Activity data	HFC species and ratio HFC 134a : HFC 152a	96 : 4
	Used for UK manufacture (tonnes)	741.2
	Exported (tonnes)	126.5
	Imported (tonnes)	304.0
	Product lifetime (yrs)	1
Emission factors	PM %	1
	PL %	97
	D%	2

Table A 3.4.19 Key assumptions used to estimate HFC152a emissions from aerosols

	Parameter	2009
Activity data	HFC species and ratio HFC 134a : HFC 152a	96 : 4
	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 3.4.20 Key assumptions used to estimate HFC134a emissions MDIs

	Parameter	2009
Activity data	HFC species and ratio HFC 134a : HFC 227ea	80 : 20
	% exported	86
	Total HFC used for manufacture (tonnes)	2487.2
	Size of bank (t)	763.5
	Product lifetime (yrs)	1
Emission factors	PM %	2
	PL %	96
	D %	2

Table A 3.4.21 Key assumptions used to estimate HFC227ea emissions MDIs

	Parameter	2009
Activity data	HFC species and ratio HFC 134a : HFC 227ea	80 : 20
	% exported	86
	Total HFC used for manufacture (tonnes)	621.8
	Size of bank (t)	190.9
	Product lifetime (yrs)	1
Emission factors	PM %	2
	PL %	96
	D %	2

A3.4.5.6 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 3.4.22 Key assumptions used to estimate emissions from the use of solvents

	Parameter	2009
Activity data	EU Estimate (tonnes of HFC released)	531.25
	UK Estimate (tonnes of HFC released)	73.05
	Product lifetime (yrs)	n/a
Emission factors	PM %	n/a
	PL %	n/a
	D %	n/a

A3.4.5.7 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 3.4.23 Key assumptions used to estimate emissions from the use of solvents

	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.

A3.4.5.8 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 3.4.24 Key assumptions used to estimate emissions from electrical equipment

	Parameter	1990	1995	2000	2005	2010	2009	2015	2020
Activity data	Total SF_6 used for manufacture (tonnes)	140	115	70	63	63	63	63	61
	Net proportion exported (%)	40%	40%	40%	40%	40%	40%	40%	40%
	Decommissioned (tonnes)	20	20	40	32	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	0.064
	PL	0.0436	0.0436	0.038	0.032	0.031	0.031	0.029	0.028
	D	0.20	0.20	0.05	0.04	0.04	0.04	0.04	0.04

Note: PM, PL and D are expressed as factors and not percentages in the table above

A3.4.5.9 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 3.4.25 Key assumptions used to estimate emissions of HFC134a from the use OCF

	Parameter	2009
Activity data	EU Estimate (tonnes of HFC released)	1592.4
	UK Estimate (tonnes of HFC released)	87.9
	Product lifetime (yrs)	n/a
Emission factors	PM %	n/a
	PL %	n/a
	D %	n/a

Table A 3.4.26 Key assumptions used to estimate emissions of HFC152a from the use OCF

	Parameter	2009
Activity data	EU Estimate (tonnes of HFC released)	1327.6
	UK Estimate (tonnes of HFC released)	73.3
	Product lifetime (yrs)	n/a
Emission factors	PM %	n/a
	PL %	n/a
	D %	n/a

A3.4.5.10 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 A3.6.1**) collected in the June Agricultural Census and published in Defra (2010a) and the appropriate emission factors. Data for earlier years are often revised so information was taken from the Defra agricultural statistics database.

Table A3.6.2 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 emission factors are estimated following the IPCC Tier 2 procedure (IPCC, 1997) and vary from year to year. For dairy cattle, the calculations are based on the population of the 'dairy breeding herd' rather than 'dairy cattle in milk'. The former definition includes 'cows in calf but not in milk'.

The base data and emission factors for cattle for 1990-2009 are given in **Table A3.6.3** and **Table A3.6.4**.

The main parameters involved in the calculation of the emissions factors for beef are shown in **Table A3.6.5**. The emission factors for other cattle were also calculated using the IPCC Tier 2 procedure (**Table A3.6.4**), but do not vary from year to year.

The data used to calculate emissions are summarised below.

Cattle weights

In the inventory the dairy cattle weights are slaughter weight data 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[7], which is a measure to control the exposure of humans to the disease BSE; see **Table A3.6.3** in **Annex 3** for further details. A footnote to this table also includes the description of the method used to estimate live weight from slaughter weights.

Animal numbers

The national cattle numbers are sum of the regional cattle data (from the four constituent countries of the UK).

[7] 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.

Animal numbers used to estimate the methane emissions are consistent with the numbers used to estimate N_2O emissions.

Milk yield
Calculation of milk yield for leap years is estimated from dividing the total by 365. Values of milk production are corrected by dairy herd to match values from regional totals.

Feed digestibility
The digestibility value (75%) was derived from calculations based on typical diets for cows in dry/milking period mixing forage and concentrates and digestibilities of the gross energy for various feeds according to MAFF (1990).

Beef cattle
In the inventory a Tier 2 methodology is used for the calculation of the emissions from beef, but a time series of cattle weights were not available and so a constant weight is assumed of 500 kg.

Sheep
The emission factor for lambs is assumed to be 40% of that for adult sheep (Sneath *et al.* 1997). In using the animal population data, it is assumed that the reported numbers of animals are alive for that whole year. The exception is the treatment of sheep where it is normal practice to slaughter lambs and other non-breeding sheep after 6 to 9 months. Hence it is assumed that breeding sheep are alive the whole year but that lambs and other non-breeding sheep are only alive 6 months of a given year (based on Smith and Frost, 2000). The sheep emission factors in **Table A 3.6.2** are reported on the basis that the animals are alive the whole year.

Table A 3.6.1 Livestock Population Data for 2009 by Animal Type

Animal Type	Number
Cattle:	
Dairy Breeding Herd	1,856,862
Beef Herd[a]	1,625,556
Beef and others >1 year old[b]	5,334,363
Others < 1 year old	2,834,255
Pigs:	
All breeding pigs	530,520
Other pigs > 50 kg	1,708,937
Other pigs 20-50 kg	1,226,857
Pigs <20 kg	1,257,984
Sheep:	
Breeding sheep	14,911,994
Other sheep	948,634
Lambs < 1 year	16,177,427
Goats	101,260
Horses	376,716
Deer	34,616
Poultry:	
Broilers	102,759,129
Breeders	9,608,870
Layers	26,757,353
Growing Pullets	8,356,031
Ducks, geese and guinea fowl	2,702,762
Turkeys	4,565,910

[a]Beef herd refers to mature beef cows
[b]Beef and others >1 year old include dairy heifers, beef heifers, others>2 and others 1-2 years old.

Table A 3.6.2 Methane Emission Factors for Livestock Emissions for 2009

Animal Type	Enteric methane[a] kg CH_4/head/year	Methane from manures[a] kg CH_4/head/year
Dairy Breeding Herd	109.4[b]	26.9[b]
Beef Herd	49.8[b]	2.74
Other Cattle >1 year, Dairy Heifers	48	6
Other Cattle <1 year	32.8	2.96
Pigs	1.5	7.06[f]
Breeding Sheep	8	0.19
Other Sheep	8[e]	0.19[e]
Lambs < 1 year	3.2[ce]	0.076[ce]
Goats	5	0.12
Horses	18	1.4
Deer: Stags & Hinds	10.4[c]	0.26[c]
Deer: Calves	5.2[c]	0.13[c]
Poultry[d]	NE	0.078

a IPCC (1997)
b Emission factor for year 2009

[c] Sneath *et al.* (1997)
[d] Chickens, turkeys, geese, ducks and guinea fowl
e Factor quoted assumes animal lives for a year; emission calculation assumes animal lives for 6 months
[f] Factor changed according to 2000 GPG (IPCC, 2000)

Table A 3.6.3 Dairy Cattle Methane Emission Factors[a]

	Average Weight of cow (kg) [b]	Average Rate of Milk Production (litre/d)	Average Fat Content (%)	Volatile solids (kg/d)	Enteric Emission Factor (kg CH_4/head/y)	Manure Emission Factor (kg CH_4/head/y)
1990	572	14.3	4.01	2.99	89.4	21.9
1991	571	14.2	4.04	2.99	89.3	21.9
1992	585	14.5	4.06	3.06	91.5	22.4
1993	585	14.7	4.07	3.08	91.9	22.6
1994	580	14.7	4.05	3.06	91.4	22.5
1995	583	15.0	4.05	3.10	92.6	22.7
1996	599	15.1	4.08	3.15	94.0	23.1
1997	491	15.9	4.07	3.01	90.0	22.1
1998	492	16.1	4.07	3.03	90.5	22.2
1999	506	16.4	4.03	3.08	92.0	22.6
2000	483	16.5	4.03	3.05	91.0	22.4
2001	488	16.7	4.01	3.07	91.6	22.5
2002	478	17.9	3.97	3.16	94.4	23.2
2003	467	18.3	3.96	3.18	94.8	23.3
2004	495	18.2	4.00	3.23	96.5	23.7
2005	714	18.8	4.02	3.74	111.6	27.4
2006	641	18.7	4.04	3.59	107.2	26.3
2007	652	19.1	4.06	3.67	109.5	26.9
2008	644	19.3	4.06	3.65	108.9	26.8
2009	643	19.5	3.99	3.67	109.4	26.9

[a] In 2003, 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%
Methane producing capacity of manure 0.24 m^3/kg VS
[b] Weights revised in the 2008 inventory, values from carcase weight data from slaughter survey corrected by 1/0.48

Table A 3.6.4 Parameters used in the calculations of gross energy for dairy Cattle Tier 2 emission factors

Year	NEm (Net energy for maintenance), MJ/d (eq 4.1)	NEfeed (Energy to obtain food), MJ/d (eq. 4.2a)	NEl (Net energy for lactation), MJ/d (eq. 4.5a)	NEpregnancy (Net energy for pregnancy), MJ/d (eq. 4.8)	NEma/DE (Ratio available energy for maintenance in a diet to digestible energy consumed) (eq. 4.9)	NEga/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	2.86	43.83	3.99	0.54	0.35	227.08
1991	39.13	2.86	43.82	3.99	0.54	0.35	226.95
1992	39.84	2.91	44.94	4.07	0.54	0.35	231.90
1993	39.86	2.91	45.54	4.07	0.54	0.35	233.49
1994	39.61	2.90	45.35	4.04	0.54	0.35	232.27
1995	39.76	2.91	46.38	4.06	0.54	0.35	235.31
1996	40.54	2.96	46.83	4.14	0.54	0.35	238.76
1997	34.97	2.56	49.39	3.54	0.54	0.35	228.62
1998	35.01	2.56	49.89	3.55	0.54	0.35	230.02
1999	35.76	2.61	50.46	3.63	0.54	0.35	233.69
2000	34.53	2.52	50.97	3.50	0.54	0.35	231.30
2001	34.76	2.54	51.31	3.52	0.54	0.35	232.85
2002	34.26	2.50	54.72	3.47	0.54	0.35	239.97
2003	33.63	2.46	55.80	3.40	0.54	0.35	240.85
2004	35.17	2.57	55.77	3.57	0.54	0.35	245.32
2005	46.25	3.38	57.78	4.76	0.54	0.35	283.51
2006	42.69	3.12	57.58	4.37	0.54	0.35	272.36
2007	43.23	3.16	59.23	4.43	0.54	0.35	278.13
2008	42.84	3.13	59.17	4.39	0.54	0.35	276.82
2009	42.77	3.13	59.75	4.38	0.54	0.35	278.08

Feed digestibility was 74 % according to Bruce Cottrill, ADAS, *pers. comm.*

Table A 3.6.5 Parameters used in the calculation of the Methane Emission Factors[a] for Beef and Other Cattle

	Beef herd[b]	Others>1[c]	Others<1
Average Weight of Animal (kg)	500	400-500	180
Time Spent Grazing	54%	43-50%[d]	46%
GE (MJ/d)	126.4	123.3	83.4[e]
Daily weight gain (kg day^{-1})	0	0.30[f]	0.60
Enteric Emission Factor (kg CH_4/head/y)	49.8[g]	48	32.8
Manure Emission Factor (kg CH_4/head/y)	2.74[h]	6	2.96

a Digestible Energy 65%, Ash content of manure 8%, Methane producing capacity of manure 0.17 m^3/kg VS
b Beef herd refers to mature cows
c Includes dairy heifers, beef heifers, others>2, others 1-2
d Time spent grazing is 43% and 50% for dairy and beef cattle respectively
e Calculated following IPCC guidelines
f Only for animals less than 2 years old
g IPCC (1997) default (48 kg/head/y) replaced in 2008 inventory by value calculated using Tier 2 methodology with constant animal weight values
h See parameters associated with the calculation of this emission factor in the next table

Table A 3.6.6 Parameters in calculation of Beef herd Emission Factors[a]

Factor	Equation[a]	Value
Average Weight of Animal (kg)		500
NEm (Net energy for maintenance), MJ/d	4.1	35.4
NE_a (Net energy for activity), MJ/d[b]	4.2a	3.27
NE_l (Net energy for lactation), MJ/d	4.5a	0
$NE_{pregnancy}$ (Net energy for pregnancy), MJ/d	4.8	3.54
NE_{ma}/DE (Ratio available energy for maintenance in a diet to digestible energy consumed)	4.9	0.51
NE_{ga}/DE (Ratio available energy for growth in a diet to digestible energy consumed)	4.10	0.31
GE (Gross energy intake), MJ/d	4.11	126.4
EF enteric, kg CH_4/head/y[c]		49.8[d]
EF manure, kg CH_4/head/y		2.74[e]

[a] From IPCC 2000 GPG
[b] Based on 17% of NEm, grazing factor of 0.085 introduced to account for proportion of time spent grazing/housed
[c] IPCC 1996 guidelines
[d] Methane conversion rate is 6%
[e] The value used for others>1 is the default IPCC

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, 2010a) in the same way as the enteric emissions. The emission factors are listed in **Table A3.6.2**. Apart from cattle, lambs and deer, these are all IPCC Tier 1 defaults (IPCC, 1997) and do not change from year to year. The emission factors for lambs are assumed to be 40% of that for adult sheep. Emission factors for dairy cattle were calculated from the IPCC Tier 2 procedure using data shown in **Table A3.6.3** and **Table A3.6.6** (Defra, 2002). There was a revision (in 2002) of the allocation of manure to the different management systems based on new data. This is detailed in **Section 6.3.2.2**. For dairy cattle, the calculations are based on the population of the 'dairy breeding herd' rather than 'dairy cattle in milk' used in earlier inventories. The former definition includes 'cows in calf but not in milk'. The waste factors used for beef and other cattle are now calculated from the IPCC Tier 2 procedure but do not vary from year to year. Emission factors and base data for beef and other cattle are given in **Table A3.6.4**.

Cattle weights

In the inventory the dairy cattle weights are slaughter weight data provided by Sarah Thompson, Defra. There is an increase in slaughter weights from 2004 (238kg) to 2005 (343kg). This increase was a result of the lifting of the Over Thirty Month rule[8], which is a

[8] 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.

measure to control the exposure of humans to the disease BSE; see **Table A3.6.3** in **Annex 3** for further details. A footnote to this table also includes the description of the method used to estimate live weight from slaughter weights.

Table A 3.6.6 Cattle Manure Management Systems in the UK

Manure Handling System	Methane Conversion Factor %[a]	Fraction of manure handled using manure system %	Fraction of manure handled using manure system %
		Dairy	***Beef and Other***
Pasture Range	1	45.5	50.5
Liquid System	39	30.6	6.0
Solid Storage	1	9.8	20.4
Daily Spread	0.1	14.1	23.0

[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
- Solid storage and dry lot (including farm-yard manure)
- Other systems (including poultry litter, stables)

According to IPCC (1997) guidelines, the following AWMS are reported in the Agricultural Soils category:

- All applied animal manures and slurries
- Pasture range and paddock

Emissions from the combustion of poultry litter for electricity generation are reported under power stations.

The IPCC (1997) method for calculating emissions of N_2O from animal waste management systems can be expressed as:

$$N_2O_{(AWMS)} = 44/28 \, . \sum N_{(T)} \, . \, Nex_{(T)} \, . \, AWMS_{(W)} \, . \, EF_3$$

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
EF3 = 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, 2010a). **Table A 3.6.7** shows emission factors for nitrogen excretion per head for domestic livestock in the UK (Nex) from Cottrill and Smith (ADAS).

Table A 3.6.7 Nitrogen Excretion Factors, kg N hd^{-1} year^{-1} for livestock in the UK[a] (1990-2009)[b]

Animal Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Dairy Cows	97	97	98	98	99	100	101	104	104	106	106	110	112	113	114	115.1	116.2	117.3	118.4	119.5
Dairy heifers in calf	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67
Beef cows and heifers	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79
Other Cattle > 2 year	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56
Other Cattle 1-2 year	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56
Other Cattle <1 year	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38
Pigs < 20kg	4.6	4.6	4.5	4.5	4.4	4.4	4.3	4.3	4.3	4.2	4.2	4.1	4.1	4.0	4	3.9	3.8	3.7	3.6	3.5
Other Pigs 20-50 kg	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.7	10.6	10.5	10.4	10.3	10.2	10.0	9.8	9.6	9.3	9.1
Fattening & Other Pigs > 50 kg	18.26	18.09	17.94	17.77	17.64	17.52	17.44	17.22	17.03	16.88	16.73	16.59	16.46	16.36	16.16	15.86	15.50	15.16	14.82	14.51
Breeding Pigs > 50 kg	23.06	22.85	22.63	22.36	22.20	21.99	21.7	21.48	21.34	21.12	20.94	20.87	20.55	20.35	19.57	19.72	19.33	18.55	17.78	18.26
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	10.2	10.2	10.2	10.2	10.2	10.2	10.2
Other Sheep <1 year	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	10.2	10.2	10.2	10.2	10.2	10.2	10.2

Animal Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Lambs	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	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	20.6	20.6	20.6	20.6	20.6	20.6	20.6
Broilers	0.64	0.63	0.62	0.61	0.60	0.59	0.58	0.57	0.56	0.55	0.55	0.54	0.53	0.52	0.51	0.49	0.47	0.46	0.44	0.44
Broiler Breeders	1.16	1.16	1.15	1.15	1.14	1.13	1.13	1.12	1.12	1.11	1.10	1.10	1.09	1.09	1.08	1.07	1.06	1.05	1.04	1.03
Layers	0.86	0.85	0.85	0.84	0.83	0.82	0.82	0.81	0.80	0.80	0.79	0.79	0.78	0.78	0.77	0.76	0.76	0.74	0.73	0.71
Ducks	1.30	1.33	1.35	1.37	1.39	1.41	1.43	1.45	1.47	1.49	1.52	1.54	1.56	1.58	1.60	1.62	1.64	1.66	1.67	1.69
Turkeys	1.5	1.52	1.54	1.55	1.57	1.59	1.61	1.62	1.64	1.66	1.68	1.70	1.71	1.73	1.75	1.76	1.77	1.79	1.80	1.81
Growing Pullets	0.42	0.41	0.41	0.40	0.39	0.39	0.38	0.38	0.37	0.37	0.36	0.36	0.35	0.35	0.34	0.34	0.34	0.34	0.33	0.33
Horses	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Deer: Stags, hinds and calves	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13

[a] Cottrill and Smith, ADAS

The methodology assumes that 20% of the total manure N applied to soil volatilises as NO_x and NH_3 and therefore does not contribute to N_2O emissions from AWMS. This is because in the absence of a more detailed split of NH_3 losses at the different stages of the manure handling process it has been assumed that NH_3 loss occurs prior to major N_2O losses.

The conversion of excreted N into N_2O emissions is determined by the type of manure management system used. The distribution of waste management systems for each animal type ($AWMS_{(T)}$) is given in **Table A3.6.8**. The distributions used were revised for cattle and poultry in the 2000 Inventory. The change related to the way that data on 'no significant storage capacity' of farmyard manure (FYM) were allocated. This could have a large effect on emissions because it amounted to around 50% of manure and the 'Daily spread (DS)' category has an emission factor of zero, compared to 0.02 for the 'Solid storage and dry lot (SSD)' category. However, we are advised (Smith, 2002) that:

In terms of slurry, it seems likely that where a proportion of the estimated slurry production is attributed with "nil" or little storage (<1 month capacity), as above, it can be assumed that such units will rely on a significant amount of daily – weekly spreading activity, according to land availability and trafficability, throughout. With FYM and poultry manure, however, significant storage capacity exists within the house and so, "no storage" generally implies that manure is cleared from the house/straw littered yard and spread direct on land. Storage capacity within the house or yard might comprise between 7 weeks – 12 months (poultry) or several months (cattle) and is unlikely to require "daily" spreading activity.

Therefore, assigning this 'stored in house' manure to 'daily spread' is acceptable only if emissions from the housing phase are thought to be very small. Calculations were performed with the N_2O Inventory of Farmed Livestock to compare housing and storage phases (Sneath *et al.* 1997). For pigs and poultry, the emission factor for housing is the same as or greater than that of storage. It would therefore lead to significant underestimation to use the daily spread emission factor. A proportion of the pig waste (as FYM) is therefore allocated to SSD. Poultry waste is allocated to 'other' except for that dropped outside by free-range poultry (PRP) and that exported for incineration in power stations (fuel).

For dairy and non-dairy cattle, the emission factor for the housing phase is around 10% of the storage phase, so the non-stored FYM has been split between SSD and DS to account for this.

Table A 3.6.8 Distribution of Animal Waste Management Systems used for Different Animal types[c]

Animal Type	Liquid System	Daily Spread	Solid Storage and Dry Lot[a]	Pasture Range and Paddock	Other[b]	Fuel
Dairy Cows	30.6	14.1	9.8	45.5	NA	NA
Other Cattle >1 year	6.0	23.0	20.4	50.5	NA	NA
Other Cattle <1 year		22.9	22.3	54.8	NA	NA
Fattening & Other Pigs > 20 kg,	29.2	5.8	64.0	1.0	NA	NA
Breeding sows	35.5	7.1	28	29.3	NA	NA
Pigs <20 kg	38.3	7.7	46.0	8.0	NA	NA
Sheep	NA	NA	2.0	98.0	NA	NA
Goats	NA	NA	NA	96.0	4.0	NA

Animal Type	Liquid System	Daily Spread	Solid Storage and Dry Lot[a]	Pasture Range and Paddock	Other[b]	Fuel
Broilers & Table Fowl (2003)	NA	NA	NA	1.0	63.0	36.0
Breeders	NA	NA	NA	1.0	99.0	NA
Layers[e]	NA	NA	NA	10.0	90.0	NA
Pullets[e]	NA	NA	NA	10.0	90.0	NA
Ducks, Geese & Guinea Fowl[e]	NA	NA	NA	50.0	50.0	NA
Turkeys[e]	NA	NA	NA	8.0	92.0	NA
Horses	NA	NA	NA	96.0	4.0	NA
Deer: Stags[d]	NA	NA	NA	100	NA	NA
Deer: Hinds & Calves[d]	NA	NA	NA	75.0	25.0	NA

a Farmyard manure
b Poultry litter, Stables from NH_3 inventory (T. Misselbrook)
c ADAS (1995a), Smith (2002)
d Sneath *et al.* (1997)
e Tucker and Canning (1997)

Table A 3.6.9 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.

Emissions from grazing animals (pasture range and paddock) and daily spread are calculated in the same way as the other AWMS. However, emissions from land spreading of manure that has previously been stored in a) liquid systems, b) solid storage and dry lot and c) other systems, are treated differently. These are discussed in **Section A3.6.3**.

Table A 3.6.9 Nitrous Oxide Emission Factors for Animal Waste Handling Systems[a]

Waste Handling System	Emission Factor kg N_2O-N 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
Other (all poultry except layers)	0.02[c]
Other (layers)	0.005

a IPCC (1997)
b Reported under Agricultural Soils
c 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) Ploughing in crop residues
(iv) Cultivation of Histosols (organic soils)
(v) Manures dropped by animals grazing in the field
(vi) Spreading animal manures on 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 of agricultural nitrate and runoff

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:

$$N_2O_{(SN)} = 44/28 \, . \, N_{(FERT)} \, . \, (1\text{-}Frac_{(GASF)}) \, . \, EF_1$$

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

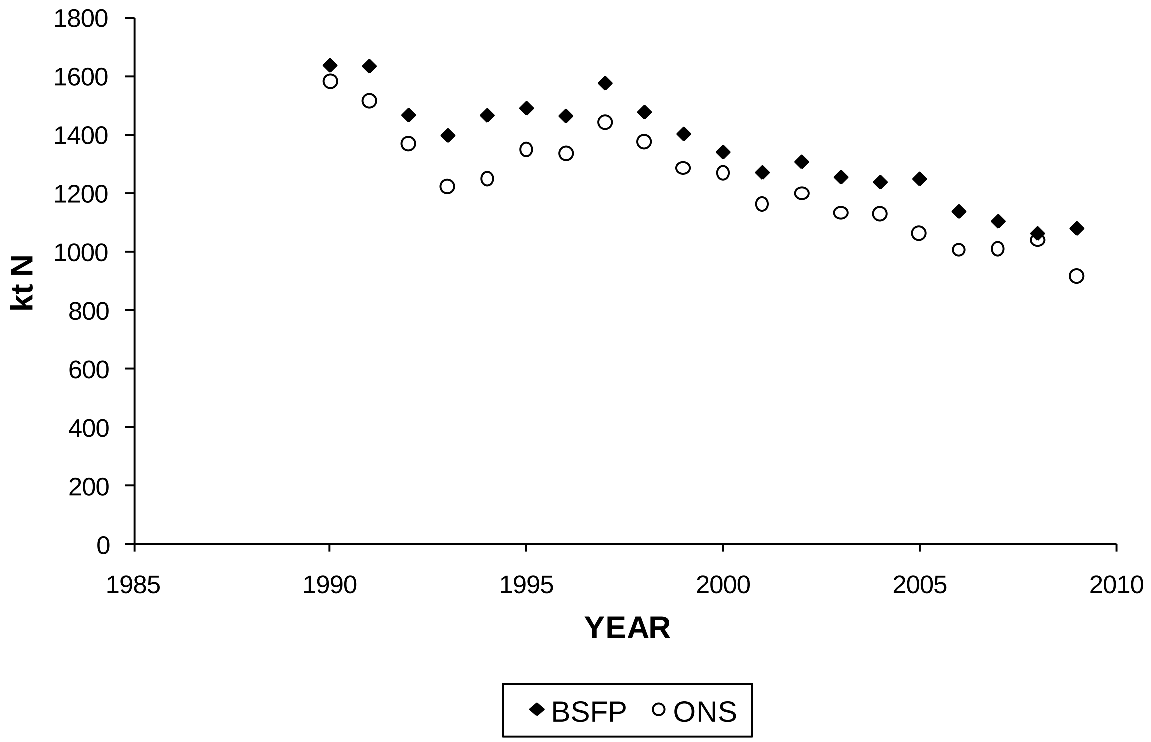
Annual consumption of synthetic fertilizer is estimated based on crop areas (Defra, 2010a) and fertilizer application rates (BSFP, 2010) as shown in **Table A 3.6.10**. **Figure A3.6.1** shows data compiled by the ONS (2010) and BSFP (used in the inventory) at UK level. The ONS data is derived from a combination of sources, including import/export statistics, BSFP and industry production data. The graph below shows the BSFP is 8.8% larger on average.

Table A 3.6.10 Areas of UK Crops and rates of fertiliser applied for 2009

Crop Type	Crop area, ha	Fertiliser rate, ktN
Winter wheat	1,813,750	339.7
Spring barley	749,142	75.0
Winter barley	411,011	57.4
Oats	131,263	11.7
Rye, triticale & mixed corn	26,667	2.7
Maize	165,651	7.4

Crop Type	Crop area, ha	Fertiliser rate, ktN
Maincrop potatoes	147,224	23.8
Sugar beet	116,470	11.0
Oilseed rape	581,457	106.0
Peas (green, human cons)	39,321	0.0
Peas (dry, human cons)	8,620	0.0
Peas, dry, animal cons)	34,480	0.0
Broad beans	899	0.0
Beans (human cons)	7	0.0
Beans (animal cons)	190,083	0.57
Rootcrops for stockfeed	40,064	2.3
Leafy forage crops	5,194	0.2
Other forage crops	27,323	0.0
Vegetables (brassicae)	29,254	4.5
Vegetables (other)	34,227	2.5
Soft fruit	10,074	0.4
Top fruit	24,184	1.6
Hops	0	0.0
Linseed	28,928	0.0
Other tillage	62,911	2.7
Grass under 5 years	1,261,804	114.6
Permanent grass	6,081,174	309.7

Figure A3.6.1. **Comparison of fertiliser data, sources BSFP and ONS**



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 3.6.11**.

Table A 3.6.11 Dry Mass Content and Residue Fraction of UK Crops for 2009

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	0.91[a]	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	0.08	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 (2010a, 2010b).

A3.6.3.4 Crop Residues

Emissions of nitrous oxide from the ploughing in of crop residues are calculated using a combination of the IPCC (2000) Tier 1b and 1a methodology, for non-N fixing and N-fixing crops, respectively, and IPCC default emission factors. They are given by:

$N_2O_{(CR)}$ = $\sum_i$ ($Crop_O$. $Res_{oi}/Crop_{oi}$. $FracDM_i$. $Frac_{(NCRO)}$. (1-$Frac_B$) + $\sum_j$ (2 . $Crop_{(BFj)}$. $FracDM_j$. $Frac_{(NCRBFj)}$) . (1-$Frac_{Rj}$) . (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.
$Frac_R$	=	Fraction of crop that is remove from field as crop
$Frac_B$	=	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 (2010a, 2010b) and are shown in **Table A 3.6.12**. The dry mass fraction of crops and residue fraction are given in **Table A 3.6.11**. 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 3.6.12 Production of UK Crops for 2009

Crop Type	Crop production, kt
Broad beans	11.3
Field Beans	739.9
Peas green for market	5.9
Peas green for processing	166.9
All peas harvested dry	147.7
Rye, mixed corn, triticale	142.4
Wheat	14,379
Oats	756.2
Barley	6,769
OSR	1,952
Linseed	56.1
Maize	0
Sugar beet	8,330
Hops	0
Potatoes	6,275
Total roots & onions	1,254
Total brassicas	546.3
Total others	373.3
Phaseolus beans	15.2

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 by IPCC. The method of calculation is the same as that for AWMS (see **Section A3.6.2.2**), using factors for pasture range and paddock.

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, the emission is given by:

$$N_2O_{(DS)} = 44/28 \;.\; \sum_T (N_T \;.\; Nex_{(T)} \;.\; AWMS_{(DS)}) \;.\; EF_1$$

where

$N_2O_{(DS)}$	=	N_2O emissions from daily spreading of wastes (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), net of N volatilising as NOx and NH_3 (values in **Table A 3.6.7** are without the volatilised fraction removed)
$AWMS_{(DS)}$	=	Fraction of Nex that is daily spread
EF_1	=	Emission Factor for direct soil emissions
	=	0.0125 kg N_2O-N/kg N input

For the application of previously stored manures to land, a correction is applied to account for previous N_2O losses during storage.

$$N_2O_{(FAW)} = 44/28 \;.\; \sum_T (N_T \;.\; Nex_{(T)} \;.\; AWMS_{(W)} - N_{(AWMS)}) \;.\; EF_1$$

where

$N_2O_{(FAW)}$	=	N_2O emission from organic fertiliser application
N_T	=	Number of animals of type T
$Nex_{(T)}$	=	N excretion of animals of type T (kg N/animal/yr) net of N volatilising as NOx and NH_3 (values in **Table A 3.6.7** are without the volatilised fraction removed)
$AWMS_{(W)}$	=	Fraction of Nex that is managed in one of the different waste management systems of type W
$N_{(AWMS)}$	=	N_2O emissions from animal waste management systems as nitrogen (kg N_2O-N/yr)

The summation is for all animal types and manure previously stored in categories defined as a) liquid, b) solid storage and dry lot and c) other.

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. 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:

$$N_2O_{(SEWSLUDGE)} = 44/28 \cdot N_{SEWSLUDGE} \cdot (1-Frac_{(GASF)}) \cdot EF_1$$

where

$N_2O_{(SEWSLUDGE)}$	=	N_2O emission from sewage sludge application
$N_{SEWSLUDGE}$	=	Total N from sewage sludge,
$Frac_{(GASF)}$	=	Fraction of synthetic fertiliser emitted as NO_x + NH_3
	=	0.1 kg NH_3-N+NO_x -N / kg synthetic N applied
EF1	=	Emission Factor for direct soil emissions
	=	0.0125 kg N_2O-N/kg N input

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.

A3.6.3.10 Atmospheric deposition of NOx and NH_3

Indirect emissions of N_2O from the atmospheric deposition of ammonia and NOx are estimated according to the IPCC (1997) methodology but with corrections to avoid double counting N. The sources of ammonia and NOx considered are synthetic fertiliser application and animal manures applied as fertiliser.

The contribution from synthetic fertilisers is given by:

$$N_2O_{(DSN)} = 44/28 \cdot N_{(FERT)} \cdot Frac_{(GASF)} \cdot EF_4$$

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:

$$N_2O_{(DWS)} = 44/28. (N_{(EX)} /(1-Frac_{(GASM)}) - N_{(F)}) \cdot Frac_{(GASM)} \cdot EF_4$$

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), net of N volatilising as NOx and NH_3
$Frac_{(GASM)}$	=	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 equation corrects for the N content of manures used as fuel.

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 methodology but with corrections to avoid double counting N. 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 estimate includes a correction to avoid double counting N_2O emitted from synthetic fertiliser use.

The indirect contribution from waste management systems is given by:

$$N_2O_{(LWS)} = 44/28.\ (N_{(EX)} - N_{(F)} - N_{(AWMS)})\ .\ Frac_{(LEACH)}\ .\ EF_5$$

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), net of N volatilising as NOx and NH_3 (values in **Table A3.6.7** are without the volatilised fraction removed)
$N_{(F)}$	=	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 equation corrects both for the N lost in the direct emission of N_2O from animal wastes and the N content of wastes used as fuel.

The indirect contribution from leaching from sewage sludge applied to land is given by:

$$N_2O_{(SEWAGE)} = 44/28 . N_{(SEWAGE)} . Frac_{(LEACH)} . EF_5$$

where

$N_2O_{(SEWAGE)}$	=	Leaching and runoff emission of N_2O from sewage sludge (kg N_2O/yr)
$N_{(SEWAGE)}$	=	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 A3.6.13**.

Table A 3.6.13 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, 2010b) 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.

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 Land Converted to Forest Land (5A2)

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 2009 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) 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	13.45	1.0%	1.4%
2002	3.89	0.76	9.99	0.9%	1.1%
2003	3.74	0.72	9.22	0.9%	1.0%
2004	2.94	0.59	8.89	0.9%	1.0%
2005	2.10	0.40	9.19	0.9%	1.1%
2006	1.14	0.21	7.03	0.8%	0.9%
2007	2.14	0.39	7.99	1.0%	1.0%
2008	0.86	0.14	6.12	0.9%	0.9%
2009	1.22	0.20	4.72	0.8%	0.8%

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)

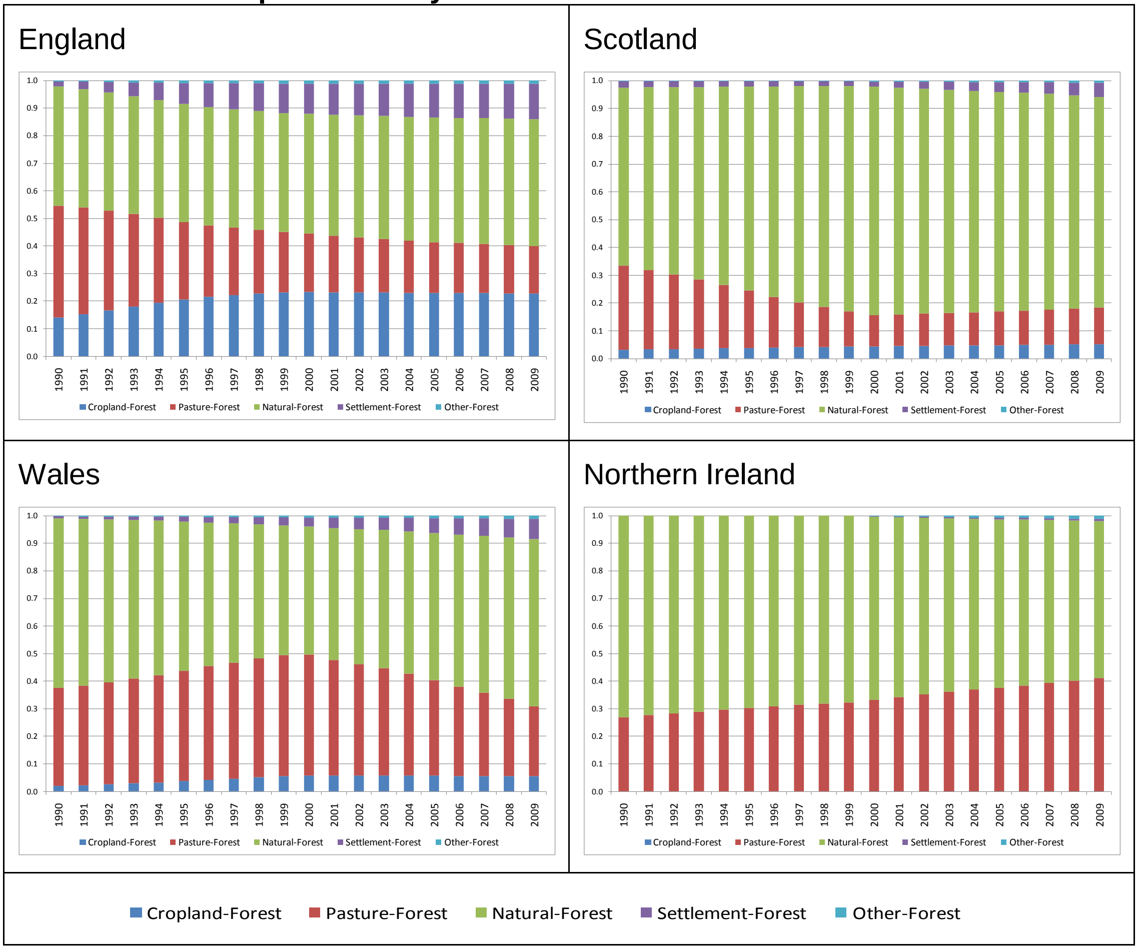
	P. sitchensis	***P. sitchensis***	***F. sylvatica***
	YC12	**YC14**	**YC6**
Rotation (years)	59	57	92
Initial spacing (m)	2	2	1.2
Year of first thinning	25	23	30
Stemwood density (t m^{-3})	0.36	0.35	0.55
Maximum carbon in foliage (t ha^{-1})	5.4	6.3	1.8
Maximum carbon in fine roots (t ha^{-1})	2.7	2.7	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) code. 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 have been 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 (5B2, 5C2, 5E2)

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.

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 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 garden	Upland smooth grass	Conifer wood	Urban open	Sand/shingle
	Upland coarse grass	Mixed wood	Transport	Inland water
	Blanket bog	Orchards	Mineral workings	Coastal water
	Bracken		Derelict	
	Lowland rough grass			
	Lowland heather			
	Gorse			
	Neglected grassland			
	Marsh			
	Improved grassland			
	Rough pasture			
	Peat bog			
	Fresh Marsh			
	Salt Marsh			

Table A 3.7.4 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
2008-2009	*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
2008-2009	*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

From / To	Forestland	Grassland	Cropland	Settlements
Forestland		5.8	2.0	1.1
Grassland	2.9		72.7	4.8
Cropland	0.1	35.4		0.1
Settlements	0.6	5.3	4.6	

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

From / To	Forestland	Grassland	Cropland	Settlements
Forestland		4.0	0.3	0.6
Grassland	10.5		18.8	2.1
Cropland	0.0	9.5		0.0
Settlements	0.1	1.6	0.6	

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

To \ From	Forestland	Grassland	Cropland	Settlements
Forestland		1.5	0.1	0.2
Grassland	0.3		3.5	0.5
Cropland	0.0	4.0		0.0
Settlements	0.1	1.2	0.0	

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.

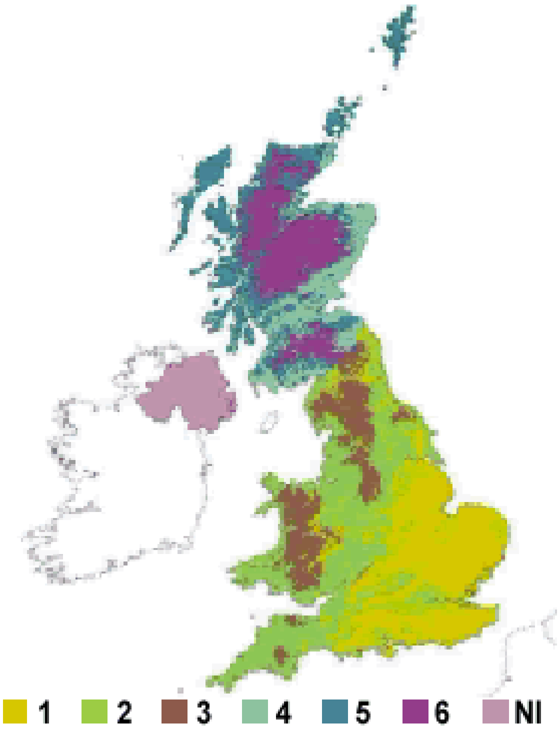
To \ From	Forestland	Grassland	Cropland	Settlements
Forestland		2.2	0.0	0.1
Grassland	0.3		4.0	0.3
Cropland	0.0	3.2		0.0
Settlements	0.1	2.1	0.1	

Data from the Countryside Survey 2007 (Smart *et al*. 2010) were used for the first time for this 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

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

Type \ Region	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 in the next inventory submission). 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

To \ From	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_o) 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 2009 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.

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)

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

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)

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

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)

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

A3.7.4 Carbon stock changes and biomass burning emissions due to Deforestation (5B2, 5C2, 5E2, 5G)

Levy and Milne (2004) discuss methods for estimating deforestation using a number of data sources. Here we use their approach of combining Forestry Commission felling licence data for rural areas with Ordnance Survey data for non-rural areas.

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. 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. Most of these areas are small (1-20 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 have been collated. These provide estimates of rural deforestation rates in England for 1990 to 2002 and for Great Britain (England, Scotland and Wales) in 1999 to 2001. Information on felling licence agreements in England (1999/2000-2008/2009) have recently been published on the UK Government MAGIC data portal http://magic.defra.gov.uk/datadoc/objecttypegb.asp?geoid=272#. The deforestation estimate for 2009 is made by extrapolating forwards from the historical time series. Rural deforestation is assumed to be split between conversion to Grassland (5C2) and conversion to Cropland (5B2). The conversion of forest to cropland had been assumed to be negligible in previous inventory submissions. This assumption was re-examined using the latest Countryside Survey data and a small area of forest-crop conversion in England is now included (the areas of forest-crop conversion in Scotland, Wales and Northern Ireland were so small that they were thought to be due to survey classification error than genuine land use change). The assignment of the rural deforestation area to 5B2 or 5C2 was based on the proportional split between forest:grassland conversion and forest:cropland conversion in the most recent Countryside Surveys.

Felling for urban development (with no requirement to restock) is also permitted 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/). Eleven broad land-use categories are defined, with a number of sub-categories. DCLG provide an extract of this dataset, listing annual land use change from forestry and woodland to developed land uses (1990-2007 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. This non-rural deforestation is assumed to fall into 5E2.1 Forest Land converted to Settlements. The deforestation estimate for 2008 and 2009 is made by extrapolating forwards from the historical time series.

The rural and non-rural values for England were each scaled up to GB scale, assuming that England accounted for 72 per cent of deforestation, based on the distribution of licensed felling between England and the rest of GB in 1999 to 2002. Deforestation is not currently estimated for Northern Ireland as there is no activity data available. Additional data sources are being investigated and we will report estimates for Northern Ireland in the next inventory submission.

On 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 and soil carbon stock changes are calculated using the same method as other land use transitions. The harvested wood products carbon produced as a result of deforestation are reported in 5G. 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 (5A2)

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**).

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 2005-2009 is extrapolated using a Burg regression equation based on the trend and variability of the 1990-2004 dataset (**Table A 3.7.23**). 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 2009.

Table A 3.7.23 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%
2008	427*	35	462*	0.0562%
2009	270*	18	288*	0.0354%

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 3.7.24**).

Table A 3.7.24 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	95.9	97.9	80.4
2000	102.5	79.5	102.1	106.7	88.5
2005	110.7	93.5	120.0	116.4	101.3
2009	115.3	103.4	131.4	119.1	109.7

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)

The method for estimating CO_2 emissions due to the application of lime and related compounds is that described in the IPCC 1996 Guidelines. 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.

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 2009) 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 UK LUCF GHG Inventory.

Lime is applied to both grassland and cropland. The annual percentages of arable and grassland areas receiving lime in Great Britain for 1994-2009 were obtained from the Fertiliser Statistics Report (Agricultural Industries Confederation 2006), and the British Survey of Fertiliser Practice (BSFP 2010). These data are produced annually and used to update the inventory. Percentages for 1990-1993 were assumed to be equal to those for 1994.

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 A3.7.25**. 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 3.7.25 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	$24 \times 10^7\ m^2$ (24,000 ha)	21%	480	0.0127	307	1280
'Thin' peat	$126 \times 10^7\ m^2$ (126,000 ha)	12%	480	0.0019	138	109
Total	**$150 \times 10^7\ m^2$ (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.

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.**). Estimates for 1992-2006 were interpolated and the estimate for 2009 was assumed to be the same as that for 2008.

Table A.3.7.26 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 2009 (**Table A.3.7.**) were estimated using the Directory of Mines and Quarries point locations with Google Earth imagery (see **Chapter 7**, **Section 7.5.2**). All sites in England and Wales were assumed to be horticultural peat production. Sites in southern Scotland were assumed to be horticultural, and those in northern Scotland were assumed to be fuel peat production (based on peat type and ownership of sites in several cases indicated that the peat was used for whisky production). A time series was constructed using linear interpolation between the two points. 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 two sites are recorded in the Directory of Mines and Quarries. The area of these sites was used for the whole of the time period.

Table A.3.7. 27 Activity data for peat extraction sites in England, Scotland and Wales

Country	Area in 1991, ha	Area in 2009, ha
England	5854	4573
Scotland	1734	1290
Horticultural	*1174*	*1021*
Fuel	*560*	*269*
Wales	479	479

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.

Annual production in Great Britain is inferred from extractor sales by volume as published in the "Annual Minerals Raised Inquiry" report (DCLG website). 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 3.7.25**). Annual production is highly variable because extraction methods depend on suitable summer weather for drying peat.

A value of 0.0557 tonnes C m^{-3} is used for Great Britain to estimate emissions from extracted volumes based on previous work by Cruikshank and Tomlinson (1997). This is slightly lower than the default emission factor of 0.07 tonnes C m^{-3} air-dry peat for nutrient-poor peats.

Table A 3.7.25 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	496,000	0	243,000	21,000
2009*	496,000	0	243,000	21,000

* The latest statistics were not published in time for inclusion in this submission, so the volumes for 2009 were carried forward from 2008

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 = 0.0508

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) for the first time in this inventory submission. 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 GHGI from those UK Crown Dependencies (CDs) and Overseas Territories (OTs) which have joined, or are likely to join, the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol. Currently, these are: Guernsey, Jersey, the Isle of Man, the Falkland Islands, the Cayman Islands, Bermuda, Montserrat and Gibraltar. The 2009 figures have been rolled forward from the 2006 projections, as no updated information has been made available. An MSc project to calculate LULUCF net emissions/removals for the OTs and CDs was 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 ($6km^2$), and will have little impact on overall numbers. A lack of suitable data for the Caribbean territories (discussed in the 1990-2006 NIR) makes it impossible to create inventories for them at the present time.

Information on the area of each IPCC land category, dominant management practices, land use change, soil types and climate types were compiled for each OT/CD from statistics and personal communications from their government departments and global land/soil cover databases. This allowed Tier 1 level inventories to be constructed for the four OT/CDs already mentioned, and a Tier 3 approach for Forest Land on the Isle of Man (using the C-Flow model also used for the UK). The estimates have high uncertainty and may not capture all relevant activities.

Net emissions/removals from the OTs/CDs are now reported under the relevant sub-categories of Sector 5.

A3.8 WASTE (CRF SECTOR 6)

A3.8.1 Solid Waste Disposal on Land (6A)

A summary of activity data in terms of quantities of biodegradable waste sent to landfill is given in chapter eight. This appendix provides further details on the methodology used to determine emission factors and gas collection.

Waste composition

The material composition of waste sent to landfill has been updated as part of the latest revision of the UK's assessment model. The revised waste components for LA-controlled and C&I waste are listed in **Table A 3.8.1**.

The amount of Degradable Organic Carbon (DOC) contributed by each material is calculated according to its estimated biochemical composition, as described by Eunomia[9]. This is based on the amounts of cellulose, hemicelluloses, lignin, starch, sugar, proteins, readily-soluble materials, fats and fibre in each component (based on a review of the literature) and their respective carbon content. The fraction of each material that degrades (DOC_F) is based on evidence from landfill reactor studies and is estimated using the following approach:

- For food waste, 70% of the non-lignin fraction is considered degradable along with 15% of the lignin,
- For garden waste, 65% of the non-lignin fraction is considered degradable along with 10% of the lignin;
- For all other degradable materials 65% of the non-lignin fraction is considered degradable along with 5% of the lignin.
- For textiles, the existing assumptions used for the 2008 NIR were retained due to the lack of biochemical and composition data.

The resultant dissimilable degradable organic carbon (DDOC) content of the waste components, calculated as DDOC = DOC x DOC_F, is also shown in **Table A 3.8.1**.

In the methodology used for the 2008 NIR reporting, waste components were 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 Good Practice Guidance[10].

A revised approach to allocating waste components to these pools has been implemented. 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 decay rates for the three pools have been retained from the 2008 methodology. This approach has been endorsed by the peer reviewers.

The quantities of LA-controlled and C&I waste sent to landfill are shown in **Table A 3.8.2**, below, as is the amount of methane generated annually since 1990, based on the updated MELMod data and methodology. Also shown in the table are the amounts of methane recovered, used for power generation, flared, oxidised and emitted to the atmosphere.

[9] "Inventory Improvement Project – UK Landfill Methane Emissions Model" – Final Report to Defra by Eunomia Consulting and Research, January 2011. http://decc.gov.uk/publications/DirectoryListing.aspx?tags=40

[10] Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (2006). Chapter 3 - Solid Waste Disposal. http://www.ipcc-nggip.iges.or.jp/

Table A 3.8.1 Revised categories of waste components adopted since 1995 (Local Authority –controlled waste) and since 1997 (Commercial & Industrial waste)

Local Authority –controlled waste components	Dissimilable Degradable Organic Carbon (DDOC) (% fresh weight)	Commercial & Industrial (C&I) waste materials (including construction and demolition waste)	Dissimilable Degradable Organic Carbon (DDOC) (% fresh weight)
Paper	16.1	Paper and Card	16.11
Card	15.17	(not used)	-
Textiles (and footwear)	15.63	Textiles / Carpet and Underlay	15.63
Miscellaneous combustibles	8.89	Miscellaneous combustibles	8.89
Food	8.49	Food	7.40
(not used)	-	Food effluent / Biodeg Ind Sludges (from 1997)	7.40
Non-inert fines	6.67	(not used)	-
Garden	8.72	Garden	8.72
Soil and other organic waste (as composted putrescibles)	0.25	(not used)	-
Wood	12.53	Wood	8.11
Sanitary / disposable nappies	4.30	Sanitary	4.30
Furniture (a)	9.14	Furniture (d)	9.46
Mattresses (b)	8.79	(not used)	-
Other (c)	0.00	Other (c)	0.00

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 landfill

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 scarce and of poor quality. The current inventory is based on the estimates of gas collection efficiency developed by Golders (2005)[11] 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 was agreed with peer reviewers of the latest review of the assessment model input data undertaken by Eunomia. Further work is being 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. Current estimates for methane recovered are given in **Table A 3.8.2**.

Regulatory guidance[12] 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. 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 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

11 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

12 See “Guidance on the management of landfill gas” The Environment Agency and Scottish Environment Protection Agency 2004.

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.[13]. 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)[14].

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[15], although this does not appear to be included in the current (2010) 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, 2010), is given in **Table A 3.8.2**.

[13] Ofgem (Office for Gas and Electricity Markets) . http://www.ofgem.gov.uk/Sustainability/Environment/Pages/Environment.aspx

[14] Data from "Copy of dukes7_1_1.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

[15] SITA 2008 Powered by waste – creating fuel from landfill gas. http://www.sita.co.uk/downloads/Gasrec-web.pdf

A3.8.2.2 Flaring

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.

Furthermore, 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[16].

Further work is on-going to improve estimates of landfill gas flare utilisation. 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.

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.

16 "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 (a)	Methane captured (b)		Methane used for power generation (c)		Methane flared (d)		Residual methane oxidised (e)		Methane emitted (f)	
	LA-controlled waste	C&I waste	LA-controlled + C&I waste	Gg	Gg	%	Gg	%	Gg	%	Gg	%	Gg	%
1990	18.19	74.64	92.83	3,322	359	11%	33	1%	326	10%	296	8.9%	2,667	80%
1991	18.84	73.97	92.80	3,294	467	14%	50	2%	417	13%	283	8.6%	2,545	77%
1992	19.47	73.30	92.77	3,267	591	18%	90	3%	501	15%	268	8.2%	2,408	74%
1993	20.09	72.62	92.72	3,240	705	22%	107	3%	598	18%	253	7.8%	2,281	70%
1994	20.71	71.95	92.66	3,213	796	25%	124	4%	672	21%	242	7.5%	2,176	68%
1995	26.46	71.28	97.74	3,200	901	28%	135	4%	766	24%	230	7.2%	2,070	65%
1996	25.75	70.61	96.36	3,180	992	31%	170	5%	822	26%	219	6.9%	1,969	62%
1997	26.98	69.82	96.80	3,159	1,163	37%	220	7%	942	30%	200	6.3%	1,797	57%
1998	26.67	67.44	94.11	3,137	1,292	41%	284	9%	1,008	32%	184	5.9%	1,660	53%
1999	27.56	66.36	93.92	3,116	1,448	46%	409	13%	1,039	33%	167	5.4%	1,501	48%
2000	27.57	65.37	92.94	3,098	1,551	50%	525	17%	1,026	33%	155	5.0%	1,392	45%
2001	28.06	61.74	89.81	3,084	1,741	56%	602	20%	1,139	37%	134	4.4%	1,208	39%
2002	27.63	64.17	91.79	3,067	1,851	60%	643	21%	1,208	39%	122	4.0%	1,095	36%
2003	26.24	65.56	91.80	3,041	1,980	65%	786	26%	1,194	39%	106	3.5%	954	31%
2004	25.05	63.10	88.15	3,004	2,029	68%	961	32%	1,068	36%	98	3.2%	878	29%
2005	22.66	60.13	82.79	2,955	2,016	68%	1,030	35%	986	33%	94	3.2%	846	29%
2006	21.33	55.67	77.01	2,895	1,978	68%	1,062	37%	916	32%	92	3.2%	826	29%
2007	19.72	51.53	71.25	2,830	1,937	68%	1,122	40%	814	29%	89	3.2%	804	28%
2008	17.63	47.56	65.19	2,755	1,889	69%	1,142	41%	748	27%	87	3.1%	779	28%
2009	15.96	49.04	65.00	2,686	1,847	69%	1,189	44%	658	24%	84	3.1%	756	28%

Notes

a. Methane generated is based on the revised data in MELMod UK as updated by Eunomia (2011).

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, 2010)[14]), 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 timeseries 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 only been made available for the year 2008, and hence the Implied Emission Factors from 2008 have been applied to the activity data across all years. The use of such a limited dataset is not ideal, and the uncertainties in the emission estimates, especially for earlier years in the timeseries, are regarded as high. Further work is proposed 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 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. Since 1997, each company in England and Wales has reported this level of detail to the industry regulator, OFWAT. In Scotland the data are available since 2002, from the Water Commissioner for Scotland, In Northern Ireland, fully disaggregated data are only available from the water regulator, UREGNI, since 2007. Further research is needed to seek out additional data from the early 2000s in Scotland and Northern Ireland.

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.

Six of the UK water companies have shared their 2008 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 6 companies and the activity data reported for 2008, emission factors for each sub-source have been calculated and then applied across all UK sources and all years of the time series. These emission factors are shown in **Table A 3.8.2** below The emission factor derived for disposal to agriculture has also been applied to the activity data on sewage sludge disposal to land reclamation.

Note that nitrous oxide emissions are accounted using a separate method (see **Section A1.1.3.2**. 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 Specific Methane Emission Factors for Sludge Treatment (kg CH_4/kt dry solids) from Reported 2008 Emissions and Activities

Sludge Treatment Route	Methane Emission factor (kg CH_4/kt dry solids)
Treatment	2,700
Digestion	140
Compost	2,600
Agriculture	1,400

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 1990-2009 timeseries. 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
2007	1,817	0.009
2008	1,815	0.009
2009	1,706	0.009

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, 2009); see **Table A 3.8.4**. For the purposes of the 2009 estimates within the inventory, the Expenditure and Food Survey 2009 was not available in time, and therefore the data for 2008 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. This new data and methodology used improves the consistency in the method and overcomes the step change in the reported data between 1996 and 1997 experienced in the previous one.

The total Nitrous Oxide emissions are, finally, 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).

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	28.5

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 NI DoE, 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

Review of the time series of protein consumption
The protein consumption time series has been revised (Defra, 2010) to provide a more consistent representation of the trends during the 1990s.

Improvements to generating estimates from wastewater treatment
The research during 2010 has engaged with the carbon management experts within UK water companies, water industry policy leads with in Defra, as well as the industry regulators (OFWAT, Water Commissioner for Scotland and UREGNI), and the UK Water Industry Research (UKWIR) panel that develops industry reporting tools. This research has gathered new data on methane and nitrous oxide emissions from several water companies, split out according to sub-source, as outlined in the methodology text above. Six UK water companies have provided new emissions data, and the aggregated factors from their reported activities and emissions have been developed and applied across UK-wide activity statistics available from OFWAT, WCS and UREGNI. Underlying activity data that are available from all UK water companies for recent years include: Total Volume Sludge Disposed + Disposal routes (treatment, digestion, composting, agricultural disposal and land reclamation), trade effluent load, total annual load and equivalent population served.

For nitrous oxide emissions from sewage treatment, a consistent time series of protein consumption has been identified and is now in use across the time series, retaining the previous estimation methodology. Consultation with the water industry has identified new data on nitrous oxide emissions from some sources within waste water treatment works, but the scope of these industry data are not thought to be comprehensive, and hence have been disregarded at this stage; further work is needed to confirm the scope of industry estimates and derive new estimates that are based on a more detailed analysis of the UK water industry treatment and disposal systems than the current method provides.

During 2010, UK water company research has included a study (as yet unpublished) on nitrous oxide emissions at a new treatment works which found that the emissions varied depending on load coming into the works, amount of aeration and other factors. The value for nitrous oxide emissions was found to be within the range currently used by the IPCC. However, based on the study findings and the wide range of processes used to treat sewage in the UK, it is anticipated that to improve the overall UK figure would require very extensive and costly new research.

A3.8.4 Source-Specific Planned Improvements

Although good progress has been made in this inventory cycle to improve the methodology for methane emissions from waste water treatment and sewage sludge disposal, further industry consultation is planned to:

i) Further investigate the data available from the UKWIR spreadsheet tool, seeking to ensure that the emission factors applied to the June Returns activity data are representative of the industry activity and emissions from all across the UK;
ii) Seek data inputs from more of the UK water companies, building on the example of those that reported emissions data this year;
iii) Obtain industry feedback on how to improve the emission estimates from earlier in the timeseries, reviewing the current approach of back-extrapolation of emission factors from more recent research which introduces additional uncertainty;

iv) Investigate further the ongoing 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.

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

Emissions from the UK Overseas Territories (OTs) were first included in the UK Greenhouse Gas Inventory in the 1990-2004 inventory, published in 2006. Emissions from fuel use the UK Crown Dependencies (CDs), however, have always been included in the UK inventory because their fuel use is included in the UK energy statistics, produced by DECC. Emissions from non-fuel sources were introduced into the inventory at the same time as the estimates for the OTs.

For the 1990-2007 greenhouse gas inventory, submitted in 2009, a number of improvements were made to the method used to include emissions from the OTs and CDs in the UK inventory database. These changes were described in the 2009 NIR. These methods continue to be used.

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 for the relevant fuels now includes the component of emissions from the OTs and CDs. In previous years, the OT emissions were included as a separate estimate and the CDs were assumed to be part of the UK total (fuels used for power generation in the CDs has been reallocated from the UK's Other Industry sector, as explained above).
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 for the relevant fuels now includes the component of emissions from the OTs and CDs. In previous years, the OT emissions were included as a separate estimate and the CDs were assumed to be part of the UK total.
Road Transport (OTs and CDs)	1A3b: Road Transport (Other Fuels)	1A3b	The activity data and emissions data in the CRF for the relevant fuels now includes the component of emissions from the OTs and CDs. In previous years, the OT emissions were included as a separate estimate and the CDs were assumed to be part of the UK total. The assumption that the CDs were included as part of the UK total was only true for CO_2 – for other GHGs, the emissions are calculated based on vkm and therefore these emissions are additional for this inventory.
Memo items: Aviation (OTs only)	Footnoted	1C1a	It was not possible to include emissions from aviation under 1C1a in the CRF because there was no option to create another fuel category, and adding the OT emissions to the UK figures would affect the IEFs. Emissions are therefore displayed as a footnote. This does not affect the national total.
Residential and Commercial Combustion (OTs and CDs)	1A4a and 1A4b	1A4a and 1A4b	The activity data and emissions data in the CRF for the relevant fuels now includes the component of emissions from the OTs and CDs. In previous years, the OT emissions were included as a separate estimate and the CDs were assumed to be part of 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 have been reallocated to sector 5 (previously reported under sector 7)
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	6C3: Other - OT and CD MSW 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 Crown Dependencies (CDs) and Overseas Territories (OTs) which have joined the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol[17]. The relevant CDs and OTs are:

- Guernsey;
- Jersey;
- The Isle of Man;
- The Falkland Islands;
- The Cayman Islands;
- Bermuda;
- Montserrat; and
- 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. 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, and the inventory already included all emissions from energy use in the CDs because of the coverage of the Digest of UK Energy Statistics, although separate estimates of CD fuel combustion are also now made. In these cases it was possible make estimates of the emissions using 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 such as waste treatment in some of the Overseas Territories, no data were available and it was not possible to make any estimates of emissions.

17 Emissions from the UK military bases in Cyprus 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 2009 are the commercial and domestic sectors and road transport. Emissions from power generation make up 9% of total CO_2 emissions, much of Jersey's electricity is imported from France.

Agricultural activity is the main source of methane emissions, accounting for around 82% of total methane emissions in 2009. Waste is incinerated, and so there are no methane emissions from landfill sites. These emissions were estimated using emission factors from the GHGi, and the process for estimating emissions from waste incineration in Jersey was fully integrated with the UK spreadsheets this year.

N_2O emissions only make up a small proportion of the total emissions in Jersey.

F-gas emissions are based on UK emissions, scaled using proxy statistics such as population or GDP. There are no emissions from industrial sources 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 we consider the uncertainty on these emissions to be low and probably similar in magnitude to the uncertainties on UK emissions from these sources.

Emissions from livestock were based on an incomplete time series, and rely on extrapolated figures, introducing greater uncertainty for this sector. 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 CO_2 from LULUCF were calculated for the 1990 to 2006 inventory. These estimates were not updated for the current inventory, and emissions in 2007 to 2009 have been rolled from 2006.

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 56% to total CO_2 emissions. Residential and commercial combustion are also significant sources, accounting for a further 34% of total emissions. Some minor industrial sources of combustion emissions also exist - the sewage treatment plant and quarries. Significant improvements were made to estimates from fuel combustion in the Isle of Man for the 2008 inventory, to ensure that all fuels were covered, including the natural gas pipeline (this is additional to the fuel use presented in the UK energy statistics).

The most significant methane source is agriculture, which accounted for 97% of methane emissions in 2009. The only other significant source was waste treatment and disposal to landfill, until the incinerator replaced the landfill sites.

N_2O emissions arise mainly from agricultural practices – livestock manure management. No estimate has 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, and so estimates have a fairly low uncertainty. Emissions from landfill, sewage treatment, and F-gas use rely on UK data scaled to population and therefore assume similar characteristics and usage patterns to the UK.

Emissions and removals from LULUCF have been estimated this year. The LULUCF sector in the Isle of Man is a net source when calculated using Tier 1 methods and stable over time.

A3.9.1.3 Guernsey

The largest single source of CO_2 in 2009 was power stations, which accounts for 29% of CO_2 emissions in 2009. The time series of emissions from power stations reflect the changing proportion of electricity imported from France. The next largest source is road transport, accounting for 24% of CO_2 emissions in 2009.

The largest methane source is from waste disposed to landfill. Major improvements were made to these estimates for the 2008 greenhouse gas inventory.

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 out 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 CO_2 from LULUCF were calculated for the 1990 to 2006 inventory. These estimates were not updated for the current inventory, and emissions in 2007 to 2009 have been rolled from 2006.

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	1990-2009 GHGi emission factors used for all sources	In some cases time series were incomplete - other years were based on extrapolated/interpolated values. Fuel imports for Guernsey were not always broken down into different fuel classes - this information was derived from data in a previous report (2002).
	Energy - road transport	Time series of vehicle numbers and fuel consumption supplied, age profile and vehicle km data 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.
	Energy - other mobile sources	Aircraft and 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 passenger number data or interpolated values.
2	Industrial processes	Population, GDP	Some sources assumed zero. Per capita emission factors based on UK emissions, where appropriate.	Based on the assumption that activities such as MDI use and refrigeration will be similar to the UK, whilst industrial sources will not be present. Industrial process emissions are assumed to be zero.
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.
4	Agriculture	Livestock statistics supplied	N_2O from manure management are based on a time series of UK emissions. Methane emissions based on IPCC guidelines	N_2O emissions assume similar farm management practices as for the UK. Some of the farming statistics time series were incomplete - other years were based on interpolated values
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.	Differing amounts of data were supplied for each CD, which has meant that the same methodologies could not be used for all.
6	Waste – MSW	Landfill estimates based on population or waste amounts, 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	Estimates of amounts of incinerated waste are based on limited data and interpolated values. The emission model that has been implemented for Guernsey has improved estimates for this source.

Secto r	Source name	Activity data	Emission factors	Notes
	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.

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
1. Energy	1.44	1.50	1.54	1.52	1.54	1.60	1.71	1.76	1.84	1.73	1.61	1.37	1.37	1.26	1.29	1.37	1.41	1.51	1.42	1.46
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	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05
3. Solvent and Other Products Use																				
4. Agriculture	0.14	0.14	0.14	0.13	0.14	0.14	0.13	0.14	0.14	0.14	0.14	0.14	0.14	0.10	0.10	0.10	0.12	0.13	0.13	0.12
5. Land Use, Land Use Change and Forestry	0.03	0.04	-0.03	0.04	0.03	0.03	0.02	0.00	0.03	0.03	0.04	0.03	0.01	0.04	0.04	0.04	0.01	0.01	0.01	0.01
6. Waste	0.13	0.14	0.14	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.08	0.08	0.07	0.06	0.04	0.05	0.05	0.05	0.05	0.05
7. Other																				
Total	**1.74**	**1.81**	**1.80**	**1.82**	**1.84**	**1.90**	**2.00**	**2.04**	**2.16**	**2.06**	**1.91**	**1.65**	**1.61**	**1.50**	**1.51**	**1.61**	**1.64**	**1.75**	**1.66**	**1.69**

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
Aviation spirit	Mt	0.01	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
Aviation turbine fuel	Mt	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.08	0.08	0.08	0.08	0.09	0.09	0.08	0.09	0.08	0.08
Burning oil	Mt	0.21	0.23	0.22	0.23	0.23	0.25	0.27	0.31	0.31	0.28	0.32	0.28	0.31	0.32	0.30	0.31	0.30	0.32	0.29	0.33
Coal	Mt	0.12	0.12	0.10	0.11	0.10	0.10	0.10	0.09	0.07	0.05	0.04	0.04	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
DERV	Mt	0.07	0.08	0.08	0.08	0.09	0.09	0.11	0.12	0.13	0.12	0.13	0.12	0.14	0.15	0.15	0.15	0.16	0.18	0.18	0.19
Fuel oil	Mt	0.47	0.51	0.58	0.55	0.57	0.59	0.59	0.55	0.59	0.59	0.45	0.26	0.20	0.09	0.11	0.09	0.14	0.18	0.14	0.14
Gas oil	Mt	0.12	0.12	0.13	0.12	0.12	0.13	0.13	0.15	0.19	0.13	0.12	0.13	0.16	0.14	0.12	0.13	0.12	0.14	0.13	0.13
LPG	Mth	25.65	27.50	24.11	24.93	24.37	25.37	28.63	60.01	60.97	60.47	60.57	59.47	58.49	54.68	37.82	39.43	39.24	36.14	36.40	36.44
MSW	Mt	0.19	0.19	0.20	0.20	0.20	0.21	0.22	0.22	0.23	0.24	0.25	0.24	0.24	0.24	0.41	0.38	0.40	0.40	0.40	0.39
Natural gas	Mth	0	0	0	0	0	0	0	0	0	0	0	0	0	19.86	57.12	97.24	91.41	106.0	110.9	110.9
Petrol	Mt	0.23	0.23	0.23	0.23	0.23	0.22	0.26	0.24	0.24	0.23	0.21	0.24	0.22	0.22	0.22	0.22	0.22	0.21	0.20	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
Dairy Cattle	15888	15888	15888	15682	15477	15729	14990	15330	15890	15950
Non-dairy Cattle	28663	30164	31665	27134	27710	28333	28346	27049	28639	29292
Sheep	151764	150972	150180	154483	161798	160228	157432	162159	174345	178705
Goats	91	91	91	91	91	91	74	74	74	74
Horses	74	74	74	74	74	74	0	0	0	0
Swine	4854	5774	6694	5419	5037	5411	5130	6714	7071	6449
Poultry	84048	77855	71662	76675	73469	46481	60080	58356	54552	51071

Animal Type	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Dairy Cattle	16186	15416	14525	15426	14590	14335	14138	13155	12624	11704
Non-dairy Cattle	29176	28562	28438	13873	14828	15562	24089	32450	32617	30150
Sheep	176259	168867	171264	91952	85521	90536	137438	146541	149605	145906
Goats	95	103	65	63	41	57	79	71	79	76
Horses	0	0	0	0	428	465	858	597	743	801
Swine	4609	3413	3578	1337	1391	1148	1310	1444	1212	1380
Poultry	46448	42295	46091	50217	48087	58160	58229	56851	59496	53373

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 has prepared its own GHG inventory estimates and methodological report for 1990 to 2000, and has provided more data for the estimates of emissions from 2001-2009, 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 most significant source of CO_2 is domestic heating. There are no industrial combustion sources. Estimates have been made for aviation, but no data were available to calculate emissions from shipping or off road machinery.

Methane emissions are mostly from agriculture – there are around 500,000 sheep on the island. Agriculture is also a major source of N_2O. Methane emissions from waste disposal are small, as waste is burnt. Sewage is disposed of to sea.

The LULUCF sector in the Falkland Islands is a net source (stable 1990-2000 and increasing to 2005) when calculated using Tier 1 methods. This is due to the requirement to estimate emissions from organic soil under Cropland. The Cropland area in the Falklands is very small but is the only active variable in the Inventory when Tier 1 methods are used. Consistent information on land use in the Falklands is available since 1984. 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 complete time series of annual fuel consumptions, and can therefore be considered fairly reliable. Domestic fuel consumption statistics, however, were only provided for certain years, so the time series was extrapolated back to 1990 based on population statistics. Vehicle numbers were not provided for all years, so this time series was also generated based on population statistics. We consider the uncertainties associated with emissions from domestic fuel consumption and transport to be high, with the greatest uncertainties earlier in the time series.

A3.9.2.2 Montserrat

Only limited activity data were supplied for Montserrat, so it was not possible to make estimates of GHG emissions from all 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 and F-gases. No information was supplied about shipping. There was also no information supplied about the disposal of waste, treatment of sewage, or livestock numbers. Since emissions from different waste disposal and sewage treatment techniques vary greatly, there is no way of calculating a reliable estimate based on any surrogate statistics. It is also difficult to predict livestock figures without any indication of the importance of agriculture to the island. 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. 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 figure calculated for the road transport sector. Power generation is the other major source.

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 and more qualitative information about the likely emission sources on the Islands.

The largest CO_2 emission source is power generation, accounting for 51% of emissions in 2009. 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 2009. 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 from landfill were the main source of 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 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	1990-2009 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.
	Energy - road transport	Vehicle numbers and fuel use supplied for the Falkland Islands, vehicle numbers and vehicle kilometres and fuel use for the Cayman Islands, fuel use for Montserrat.	Factors for vehicle types based on UK figures	Vehicle numbers have only been supplied for one year (time series are based on population), and the age profiles are based on UK figures - which may not be appropriate. Emissions for Montserrat are subject to a greater degree of uncertainty as there is no information about vehicle types or numbers.
	Energy - other mobile sources	Aircraft movements supplied for FI and Montserrat.	EMEP/CORINAIR factors	It has not been possible to make any estimates of emissions from shipping activities for any of these - no information was supplied, and the use of any surrogate statistics would not be suitable for this source.
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 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.
5	Land use change and forestry	Land use data	Tier 1 data	Data were only available to estimate emissions from the Falklands.
6	Waste - MSW	Tonnes of waste incinerated (Falkland Islands), NE for Montserrat and Cayman Islands, waste generation (Bermuda)	US EPA factors for the open burning of municipal refuse, NAEI factors for clinical waste incineration and MSW incineration in Bermuda	Information on the amount of waste incinerated was limited. No information about the type of waste treatment was available for Montserrat or the Cayman Islands.
	Waste - Sewage treatment	NO (Falkland Islands), NE (Cayman Islands and Montserrat)		Sewage from the Falkland Islands is disposed of to sea. Emissions Not Estimated (NE) for the Cayman Islands and Montserrat, as no information was available.

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
1. Energy	1.14	1.13	1.13	1.14	1.17	1.19	1.18	1.19	1.28	1.30	1.32	1.41	1.44	1.44	1.50	1.53	1.63	1.78	1.67	1.69
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	0.03	0.03	0.03
3. Solvent and Other Products Use																				
4. Agriculture	0.17	0.17	0.16	0.17	0.17	0.17	0.16	0.17	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.14	0.14	0.14	0.13	0.13
5. Land Use, Land Use Change and Forestry	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	0.02	0.01	0.03	0.03	0.03	0.03	0.03
6. Waste	0.09	0.10	0.10	0.10	0.10	0.15	0.15	0.15	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.17	0.17	0.17	0.18	0.17
7. Other																				
Total	**1.42**	**1.41**	**1.40**	**1.42**	**1.45**	**1.52**	**1.51**	**1.53**	**1.62**	**1.64**	**1.66**	**1.76**	**1.78**	**1.80**	**1.85**	**1.89**	**2.00**	**2.15**	**2.03**	**2.04**

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
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
Aviation turbine fuel	Mt	0.05	0.04	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.06	0.06
Burning oil	Mt	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	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
DERV	Mt	0.16	0.15	0.15	0.14	0.14	0.13	0.13	0.12	0.16	0.15	0.14	0.19	0.19	0.17	0.22	0.30	0.32	0.39	0.32	0.36
Fuel oil	Mt	0.27	0.27	0.28	0.28	0.30	0.31	0.30	0.32	0.34	0.36	0.47	0.50	0.51	0.53	0.51	0.53	0.58	0.60	0.62	0.62
Gas oil	Mt	0.26	0.27	0.27	0.27	0.27	0.28	0.27	0.27	0.27	0.27	0.18	0.18	0.19	0.19	0.20	0.20	0.21	0.21	0.21	0.21
LPG	Mth	7.59	7.62	7.66	7.70	7.75	7.79	7.54	7.38	7.03	7.15	7.26	7.31	8.23	8.48	8.57	8.67	8.74	9.00	9.08	9.24
MSW	Mt	0.00	0.00	0.00	0.00	0.00	0.17	0.17	0.17	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.19	0.19	0.19	0.19
Natural gas	Mth	67.57	70.77	73.97	77.17	80.37	83.57	86.78	89.14	91.50	93.86	96.22	98.59	101.2	101.2	101.2	95.51	100.7	108.3	96.56	76.80
Petrol	Mt	0.20	0.20	0.20	0.20	0.21	0.21	0.21	0.21	0.22	0.23	0.22	0.23	0.22	0.22	0.25	0.18	0.17	0.20	0.17	0.18

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
Dairy Cattle	400	400	400	400	400	400	400	400	400	400
Non-dairy Cattle	1553	1553	1438	228	1764	1751.6	1777.5	1844.4	1914.9	1952.7
Sheep	739999	729449	712755	721352	727002	717571	685756	707519	707696	708082
Goats	405	405	569	556	730	839.82	926.02	1042.7	1172.5	1289
Horses	2217	2165	2111	1987	2009	2069	1974	1890	1888	1945
Swine	766	786	628	570	763	781.55	825.86	871.42	904.2	945.91
Poultry	12400	12400	15000	15000	10500	10636	10846	11037	11210	11368
Deer	0	0	0	0	0	0	0	0	0	0

Animal Type	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Dairy Cattle	1354	1687	1272	1118	1145	1299	1254	1170	1202	868
Non-dairy Cattle	5842.3	5494.2	5890	6404.4	7082.4	6988	7433	7290	6934	6601
Sheep	642825	612925	583457	586567	580864	533551	530109	510085	504720	478625
Goats	1199.1	1117.4	1043.1	975.5	1551.1	2710	2290	2792	2943	2603
Horses	1624	1664.9	1592.6	1613.3	1525.9	1612.5	1563.2	1500.9	1550.7	1536.6
Swine	1068.2	969.81	943.28	920.16	856.06	880	1321	1423	1315	1452
Poultry	14640	13939	13698	13852	13816	14525	16363	15160	14714	14814
Deer	0	0	0	0	0	0	124	155	169	184

A3.9.2.5 Gibraltar Emissions

A greenhouse gas inventory for Gibraltar has been created which contains annual emission estimates from 1990 to 2009 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, aircraft, 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 were calculated using default factors from the EMEP/CORINAIR guidebook, since the information available about aircraft movements from Gibraltar was limited.

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 have now been classified as domestic for the first time in the 2009 inventory.

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 domestic, commercial and institutional combustion and so estimates made. Fuel use available for industrial combustion.	Emission factors from the 1990 – 2009 GHGI	In some cases time series were incomplete - other years were based on extrapolated (on population)/interpolated values.
	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.
	Energy - other mobile sources	Aircraft and shipping movements supplied	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.
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.
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.
6	Waste - MSW	Incineration estimates based on limited data on the amount of waste incinerated up to 2001. After 2001, waste transported to Spain to be land filled.	Emission factors taken from 1990-2007 GHGI	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.
	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
1. Energy	0.21	0.21	0.22	0.19	0.20	0.20	0.19	0.20	0.20	0.21	0.22	0.23	0.23	0.23	0.25	0.26	0.25	0.24	0.26	0.27
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
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
7. Other																				
Total	**0.21**	**0.22**	**0.23**	**0.20**	**0.21**	**0.21**	**0.20**	**0.21**	**0.21**	**0.22**	**0.23**	**0.23**	**0.23**	**0.24**	**0.25**	**0.26**	**0.25**	**0.25**	**0.26**	**0.27**

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
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
Aviation turbine fuel	Mt	0.03	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	0.02	0.02	0.02
DERV	Mt	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	0.02	0.02	0.02	0.02	0.02	0.02
Fuel oil	Mt	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Gas oil	Mt	0.06	0.07	0.08	0.06	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.09	0.09	0.09	0.10	0.10	0.11	0.11	0.12
MSW	Mt	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0	0	0	0	0	0	0	0	0
Natural gas	Mth	18.82	18.91	19.10	19.05	17.75	17.51	20.03	18.40	18.75	18.88	19.29	20.46	20.20	20.88	21.39	20.45	19.56	18.91	19.20	17.90
Petrol	Mt	0.02	0.02	0.03	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	0.02

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 uses the bottom-up (sectoral) approach based on the combustion of fuels in different economic sectors and estimates of non-combustion emissions from other known sectors to produce detailed sectoral inventories of the 10 pollutants. In addition, estimates are also provided of carbon dioxide emissions using the IPCC Reference Approach. This is a top down inventory calculated from national statistics on production, imports, exports and stock changes of crude oil, natural gas and solid fuels. It is based on a different set of statistics and methodology and produces estimates around between 2% lower to 2% higher than the bottom-up approach when categories not included in the Reference Approach are removed from the Sectoral Approach estimate.

A4.2 DISCREPANCIES BETWEEN THE IPCC REFERENCE AND SECTORAL APPROACH

The UK GHGI contains a number of sources not accounted for in the IPCC Reference Approach and so gives a higher estimate of CO_2 emissions. The sources not included in the Reference Approach are:

- 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 totals range between 2% lower to 2% higher than the comparable bottom up totals.

The IPCC Reference Approach is based on statistics of production, imports, exports and stock changes of fuels whilst the Sectoral Approach uses fuel consumption data. The two sets of statistics can be related using mass balances (see the publication 'Digest of UK Energy Statistics' DECC, 2010), but these show that some fuel is unaccounted for. This fuel is reported in DUKES as statistical differences – these differences 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, and generally manages to meet this target, not only for total supply but by fuel.

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

1. The sectoral approach only includes emissions from the non-energy use of fuel where they can be specifically identified and estimated such as with fertilizer 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 and stock changes 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 wholly 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.

The improvement programme under the NISC includes an item to review the Reference Approach, with a reconfiguring the spreadsheet used to include waste incineration. These changes will be reported on in the 2012 inventory submission.

A4.3 TIME SERIES OF DIFFERENCES IN THE IPCC REFERENCE AND SECTORAL INVENTORIES

Table A 4.3.1 shows the percentage differences between the IPCC Reference Approach and the Sectoral Approach. These percentages include a correction for the fact that a significant proportion of fuel consumption emissions occur in the 2C Metal Production and 2B1 Ammonia Production sectors.

Table A 4.3.1 Modified comparison of the IPCC Reference Approach and the Sectoral Approach

Year	1990	1991	1992	1993	1994	1995
Percentage difference	-1.6	-0.2	0.8	0.2	0.4	1.9

Year	1996	1997	1998	1999	2000	2001
Percentage difference	0.0	-0.2	0.8	1.3	2.2	0.8

Year	2002	2003	2004	2005	2006	2007
Percentage difference	0.4	0.0	0.1	0.9	1.2	0.3

Year	2008	2009
Percentage difference	0.4	1.0

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
CO_2	2. Industrial Processes	2A4 – soda ash production	Emissions from fuels used in soda ash production are reported elsewhere. 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
CO_2	2. Industrial Processes	2C2 Ferroalloys Production	Source considered negligible in the UK
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 - provided for information
CO_2	5. Land-Use Change and Forestry	5C1 Grassland remaining Grassland - Carbon stock change in living biomass	Emissions believed small
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 CO2 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
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
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
N_2O	3. Solvent and Other Product Use	3D Other –Anaesthesia	Activity not readily available – believed small
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

GHG	CRF sector	Source/sink category	Reason
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
N_2O	6. Waste	6C2 Chemical	High temperature combustion processes, methane and N2O emissions insignificant
N_2O	6. Waste	6C2 Accidental fires (vehicles)	No suitable emission factor available
CH_4	1. Energy	1C2 Multilateral Operations	Data unavailable
CH_4	2. Industrial Processes	2B1 Ammonia Production	Manufacturers do not report emission - believed negligible
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
CH_4	2. Industrial Processes	2C3 Aluminium	Methodology not available but considered negligible
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
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 2010. The data are given in standard electronic format (SEF). Further reference can be made to document SEF_GB_2011_1_15-2-44 5-1-2011.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

Account type	Unit type					
	AAUs	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**
Party holding accounts	2956145800	NO	NO	23301	NO	NO
Entity holding accounts	239617021	714134	NO	19466508	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	2497	NO	NO	610996	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	3456620292	762472	NO	24705924	NO	NO

Table A 6.2.2 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							10936	NO	NO	511719	NO	NO
Sub-total		NO	NO				10936	NO	NO	511719	NO	NO

Table A 6.2.3 Annual external transactions

	Additions – Unit type: AAUs	ERUs	RMUs	CERs	tCERs	lCERs	Subtractions – Unit type: AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Transfers and acquisitions												
CDM	NO	NO	NO	25435111	NO	NO	NO	NO	NO	NO	NO	NO
AU	NO	NO	NO	1	NO	NO	NO	NO	NO	1	NO	NO
AT	4729678	667493	NO	678462	NO	NO	1927415	280000	NO	1933486	NO	NO
BE	6671707	150000	NO	253000	NO	NO	1103521	306293	NO	820839	NO	NO
BG	76000	83989	NO	NO	NO	NO	NO	100000	NO	307527	NO	NO
CZ	13520599	394069	NO	586129	NO	NO	6778225	1061542	NO	666142	NO	NO
DK	28721086	217046	NO	7983540	NO	NO	77655043	472243	NO	9272413	NO	NO
EE	176000	NO	NO	NO	NO	NO	4052290	NO	NO	NO	NO	NO
FI	7246641	84200	NO	29000	NO	NO	11674835	169200	NO	1453393	NO	NO
FR	189882662	1437822	NO	28872593	NO	NO	1.58E+08	1474373	NO	25193028	NO	NO
DE	126566603	2521115	NO	16191312	NO	NO	91133620	4698558	NO	34829891	NO	NO
GR	2041578	NO	NO	61688	NO	NO	288625	21342	NO	257318	NO	NO
HU	1214989	24387	NO	948894	NO	NO	1926838	NO	NO	194839	NO	NO
IE	5785925	NO	NO	2929013	NO	NO	1359449	715000	NO	5210182	NO	NO
IT	95382910	NO	NO	9044294	NO	NO	37369888	1079347	NO	7448230	NO	NO
JP	NO	50000	NO	1462851	NO	NO	5340	NO	NO	1503476	NO	NO
LV	188974	NO	NO	NO	NO	NO	451514	NO	NO	320000	NO	NO
LI	1821510	63659	NO	663000	NO	NO	11891738	NO	NO	NO	NO	NO
LT	749656	462045	NO	50000	NO	NO	1088056	23317	NO	329133	NO	NO
LU	NO	NO	NO	54858	NO	NO	NO	NO	NO	210000	NO	NO
NL	28003797	1773516	NO	11625425	NO	NO	32759546	689068	NO	19366593	NO	NO
NZ	1000	110246	NO	100002	NO	NO	NO	NO	NO	619002	NO	NO
NO	7018916	NO	NO	309655	NO	NO	3363686	248567	NO	3078169	NO	NO
PL	7466116	273653	NO	116588	NO	NO	7119511	252153	NO	1703679	NO	NO
PT	3199475	NO	NO	NO	NO	NO	384733	NO	NO	1478292	NO	NO
RO	13766154	NO	NO	734460	NO	NO	3582667	NO	NO	2270864	NO	NO
SK	2150063	NO	NO	NO	NO	NO	9000	NO	NO	829481	NO	NO
SI	347500	NO	NO	266501	NO	NO	11000	5000	NO	194001	NO	NO
ES	27095990	204776	NO	6601692	NO	NO	7118555	1231235	NO	4268158	NO	NO
SE	4234026	NO	NO	1886838	NO	NO	1634621	325186	NO	230000	NO	NO
CH	868987	6810438	NO	36874982	NO	NO	952772	180000	NO	18203118	NO	NO
UA	104072	1258152	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
EU	508009	NO	NO	NO	NO	NO	633525	NO	NO	303069	NO	NO
Sub-total	579540623	16586606	NO	1.54E+08	NO	NO	4.64E+08	13332424	NO	1.42E+08	NO	NO

Additional information

	Additions: AAUs	ERUs	RMUs	CERs	tCERs	lCERs	Subtractions: AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Independently verified ERUs								NO				

Table A 6.2.4 Total annual transactions

Total (Sum of tables 2a and 2b)	579540623	16586606	NO	1.54E+08	NO	NO	4.65E+08	13332424	NO	1.43E+08	NO	NO

Table A 6.2.5 Expiry, cancellation and replacement

	Expiry, cancellation and requirement to replace		Replacement					
	Unit type		Unit type					
Transaction or event type	**tCERs**	**lCERs**	**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 6.2.6 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	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 6.2.7 Summary information on additions and subtractions

	Additions						Subtractions					
	Unit type						Unit type					
Starting values	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**
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)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	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	1400413395	17943254	NO	411468877	NO	NO	1240845378	13926600	NO	376620103	NO	NO
Total	4812494025	17943254	NO	411468877	NO	NO	1240845378	13926600	NO	376620103	NO	NO

Table A 6.2.8 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 6.2.9 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)	NO	NO	NO	NO	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	260854974	48338	NO	4605119	NO	NO

Table A 6.2.10 Memo item: Corrective transactions relating to additions and subtractions

	Additions						Subtractions					
	Unit type						Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs

Table A 6.2.11 Memo item: Corrective transactions relating to replacement

	Requirement for replacement		Replacement					
	Unit type		Unit type					
	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs

Table A 6.2.12 Memo item: Corrective transactions relating to retirement

	Retirement					
	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs

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:

1. Registry v4.3 Release Notes
2. Registry v5.1 Release Notes
3. Registry v4.3 Regression Tests
4. Registry v5.1 Regression Tests
5. Registry v4.3 Test Report
6. Registry v5.1 Test Report
7. Registry v4.3 Test Plans
8. Registry v5.1 Test Plans
9. CITL Test Plan and Results v4.3
10. CITL Test Plan and Results v5.1
11. CITL Approval Email

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 for this inventory submission. This follows 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[18], 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);
    - 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.

[18] 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).

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

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 for sections present the uncertainties in emissions, and the trend in emissions according to gas. The F-gases are grouped into one section.

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 2009, 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 2009. 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			2009		
Fuel		Activity uncertainty (%)	Emission factor uncertainty (%)	Uncertainty in emission (%)	Activity uncertainty (%)	Emission factor uncertainty (%)	Uncertainty in emission (%)
Anthracite		1.5	6	‡	0.2	6	‡
Aviation spirit		20	3.3	‡	20	3.3	‡
Aviation turbine fuel		20	3.3	‡	20	3.3	‡
Blast furnace gas		1.5	6	‡	0.2	6	‡
Burning oil		6	2	‡	1.3	2	‡
Chemical waste		50	100	‡	50	100	‡
Clinical waste		7	20	‡	7	20	‡
Clinker production		1	5	‡	1	5	‡
Coal		1.5	1	‡	0.2	1	‡
Coke		3	3	‡	0.1	3	‡
Coke oven gas		1.5	6	‡	0.2	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	‡	3.7	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	‡	2	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	‡	0.2	1.5	‡
OPG		1.4	15	‡	0.8	5	‡
Orimulsion		1	2	‡	not used	not used	‡
Peat		25	25	‡	25	25	‡
Petrol		1	4.8	‡	0.6	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	‡
Sour gas		not used	not used	‡	0.2	1	‡
SSF		3.3	3	‡	0.6	3	‡

	1990			2009		
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	not used	not used	‡	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			2009		
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	0.4	1.5		0.4	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 2009**.

The central estimate of total CO_2 emissions in 2009 was estimated as 475,790 Gg. The Monte Carlo analysis suggested that 95% of the values were between 467,849 Gg and 483,495 Gg.

A7.2.1.4 Uncertainty in the Trend

The uncertainty in the trend between 1990 and 2009 was estimated. In running this simulation it was necessary to make assumptions about the degree of correlation between sources in 1990 and 2009. 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 2009 were between **18% and 21%** 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			2009		
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	‡
Anthracite			50	‡		50	‡

		1990			2009		
Source	Reference	Activity %	Emission Factor %	Source Uncertainty %	Activity %	Emission Factor %	Source Uncertainty %
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 **21% in 2009**.

The central estimate of total CH_4 emissions in 2009 was estimated as 43,802 Gg CO_2 equivalent. The Monte Carlo analysis suggested that 95% of the values were between 37,345 and 52,020 Gg CO_2 equivalent.

A7.2.2.4 Uncertainty in the Trend

The uncertainty in the trend between 1990 and 2009 was estimated. In running this simulation it was necessary to make assumptions about the degree of correlation between sources in 1990 and 2009. 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 2009 were between **35% and 76%** 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			2009		
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		2	50	
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 overall uncertainty was estimated as around 272% in 2009.

The central estimate of total N_2O emissions in 2009 was estimated as 34,647 Gg CO_2 equivalent. The Monte Carlo analysis suggested that 95% of the values were between 9,025 and 100,113 Gg CO_2 equivalent.

A7.2.3.4 Uncertainty in the Trend

The uncertainty in the trend between 1990 and 2009 was also estimated. In running this simulation it was necessary to make assumptions about the degree of correlation between sources in 1990 and 2009. 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 2009 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
- Adipic acid emissions were assumed not to be correlated because of the large reduction in emissions due to the installation of abatement plant in 1998.

This analysis indicates that there is a 95% probability that N_2O emissions in 2009 were between **35% 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).

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

2009

- 11% for HFCs
- 31% for PFCs
- 16% for SF_6

A7.2.4.3 Uncertainty in the Trend

This analysis indicates that there is a 95% probability that emissions in 2009 differed from those in 1990 by the following percentages

- -18% to +13% for HFCs
- -92% to -87% for PFCs
- -31% to -25% 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 **16%** in 1990 and **17%** in 2009.

A7.3.2 Uncertainty in the Trend

This analysis indicates that there is a 95% probability that the total GWP GHG emissions in 2009 were between 25% and 31% 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 - 2009

IPCC Source Category	Gas	1990 Emissions	2009 Emissions	Uncertainty in 1990 emissions as % of emissions in category		Uncertainty introduced on national total in 1990	Uncertainty in 2009 emissions as % of emissions in category		Uncertainty introduced on national total in 2009	% change in emissions between 2009 and 1990	Range of likely % change between 2009 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)	591105	475790	581479	600670	2%	467849	483495	2%	-20%	-21%	-18%
	CH_4	110414	43802	88868	138688	28%	37345	52020	21%	-60%	-70%	-48%
	N_2O	68410	34647	30464	157108	176%	9025	100113	272%	-56%	-76%	-35%
	HFC	11383	10928	9973	12801	15%	9909	11934	11%	-3%	-18%	13%
	PFC	1402	147	1346	1457	5%	110	184	31%	-90%	-92%	-87%
	SF_6	1029	662	887	1173	17%	573	749	16%	-35%	-47%	-22%
	All	783743	565976	733796	877013	16%	535412	632235	17%	-28%	-31%	-25%

Notes
Uncertainty calculated as 2s/E where s is the standard deviation and E is the mean, calculated in the simulation.
N_2O quoted but distribution is highly skewed and uncertainty quoted 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. The error propagation approach will be updated for the next (2012) inventory submission to account for these improvements. 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 2009)
	1990	**2009**	
Error propagation	783,298	565,984	4.9
Monte Carlo	783,743	565,976	6.3 [a]

Notes

CI Confidence Interval

[a] 2.5th percentile, -20%, 97.5th percentile, -15.6%. 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	2009 Emissions	Uncertainty in 2009 emissions as % of emissions in category		Uncertainty Introduced on national total in 2009	% change in emissions between 1990 and 2009	Range of likely % change between 1990 and 2009	
				2.5 percentile	97.5 percentile			2.5 percentile	97.5 percentile
1A1a	GWP weighted total	205,823	152,248	151,034	153,546	1%	-26%	-27%	-25%
1A1b	GWP weighted total	17,640	14,946	14,666	15,230	2%	-15%	-18%	-13%
1A1c	GWP weighted total	14,044	15,566	15,383	15,770	2%	11%	8%	14%
1A2a	GWP weighted total	24,452	14,676	14,144	15,213	4%	-40%	-43%	-37%
1A2f	GWP weighted total	77,544	54,201	53,551	55,006	2%	-30%	-32%	-29%
1A3a	GWP weighted total	1,529	2,143	1,793	2,486	20%	42%	11%	76%
1A3b	GWP weighted total	111,636	114,174	111,940	116,431	2%	2%	-1%	6%
1A3c	GWP weighted total	1,592	2,141	2,016	2,334	9%	35%	21%	50%
1A3d	GWP weighted total	1,764	1,528	1,507	1,550	2%	-13%	-16%	-10%
1A3e	GWP weighted total	254	496	464	544	10%	96%	73%	119%
1A4a	GWP weighted total	26,510	17,673	17,466	17,882	1%	-33%	-35%	-32%
1A4b	GWP weighted total	79,699	74,461	73,666	75,253	1%	-7%	-9%	-4%
1A4c	GWP weighted total	5,781	4,560	4,294	4,967	9%	-21%	-29%	-12%
1A5b	GWP weighted total	5,340	2,451	2,165	2,733	14%	-54%	-61%	-46%
1B1a	GWP weighted total	18,273	2,860	2,656	3,065	9%	-84%	-86%	-82%
1B1b	GWP weighted total	878	157	154	160	2%	-82%	-83%	-82%
1B2a	GWP weighted total	1,269	585	499	671	18%	-54%	-63%	-43%
1B2b	GWP weighted total	9,508	4,608	4,546	4,671	2%	-52%	-53%	-50%
1B2c_Flaring	GWP weighted total	4,480	4,160	3,677	4,644	14%	-7%	-22%	11%
1B2c_Venting	GWP weighted total	884	552	440	671	25%	-37%	-54%	-16%
2A1	GWP weighted total	7,295	3,721	3,646	3,795	2%	-49%	-50%	-48%
2A2	GWP weighted total	1,192	627	590	664	7%	-47%	-52%	-43%
2A3	GWP weighted total	1,317	1,195	1,137	1,253	6%	-9%	-16%	-2%
2A4	GWP weighted total	168	185	148	223	25%	12%	-18%	48%
2A7	GWP weighted total	204	79	49	120	55%	-58%	-79%	-29%

IPCC Source Category	Gas	1990 Emissions	2009 Emissions	Uncertainty in 2009 emissions as % of emissions in category		Uncertainty Introduced on national total in 2009	% change in emissions between 1990 and 2009	Range of likely % change between 1990 and 2009	
				2.5 percentile	97.5 percentile			2.5 percentile	97.5 percentile
2B1	GWP weighted total	1,322	801	791	811	2%	-39%	-41%	-38%
2B2	GWP weighted total	3,883	1,108	351	2,470	129%	-59%	-93%	15%
2B3	GWP weighted total	20,735	71	62	80	15%	-100%	-100%	-100%
2B5	GWP weighted total	1,730	1,985	1,325	2,701	42%	19%	-29%	83%
2C1	GWP weighted total	1,887	814	776	853	6%	-57%	-60%	-54%
2C3	GWP weighted total	1,783	451	432	470	5%	-75%	-76%	-73%
2E1	GWP weighted total	11,371	104	92	117	14%	-99%	-99%	-99%
2E2	GWP weighted total	11	11	10	13	15%	6%	-12%	25%
2F1	GWP weighted total	0	7,444	6,531	8,359	15%	3735263%	2655694%	5283480%
2F2	GWP weighted total	0	288	216	359	30%	NA	NA	NA
2F3	GWP weighted total	0	202	169	235	20%	NA	NA	NA
2F4	GWP weighted total	12	2,786	2,366	3,201	18%	23668%	18923%	29081%
2F5	GWP weighted total	0	95	76	114	25%	NA	NA	NA
2F8	GWP weighted total	661	656	561	750	18%	0%	NA	NA
4A1	GWP weighted total	13,676	11,731	9,792	13,660	20%	-13%	-32%	8%
4A10	GWP weighted total	9	6	5	7	20%	-26%	-42%	-7%
4A3	GWP weighted total	4,506	3,237	2,705	3,769	20%	-27%	-43%	-9%
4A4	GWP weighted total	12	11	9	12	20%	-9%	-29%	14%
4A6	GWP weighted total	77	143	119	167	20%	87%	47%	135%
4A8	GWP weighted total	238	149	124	173	20%	-37%	-50%	-21%
4B1	GWP weighted total	2,152	1,772	1,330	2,223	31%	-16%	-43%	19%
4B3	GWP weighted total	109	78	58	98	31%	-26%	-50%	4%
4B4	GWP weighted total	0	0	0	0	30%	27%	-14%	79%
4B6	GWP weighted total	6	11	8	14	31%	89%	29%	166%
4B8	GWP weighted total	1,123	701	525	875	30%	-36%	-56%	-10%
4B9	GWP weighted total	225	254	190	318	30%	16%	-21%	62%

IPCC Source Category	Gas	1990 Emissions	2009 Emissions	Uncertainty in 2009 emissions as % of emissions in category		Uncertainty Introduced on national total in 2009	% change in emissions between 1990 and 2009	Range of likely % change between 1990 and 2009	
				2.5 percentile	97.5 percentile			2.5 percentile	97.5 percentile
4B10	GWP weighted total	0.22	0.16	0.12	0.20	30%	-25%	-49%	5%
Agriculture - N2O	GWP weighted total	35,474	27,020	1,957	92,119	348%	-24%	-25%	-23%
5A	GWP weighted total	-12,142	-12,702	-15,346	-10,131	-25%	6%	-22%	41%
5B	GWP weighted total	16,478	13,320	8,039	18,569	48%	-15%	-55%	39%
5C	GWP weighted total	-6,260	-8,650	-12,148	-5,850	-45%	48%	-21%	146%
5D	GWP weighted total	426	283	169	400	0%	-28%	-64%	24%
5E	GWP weighted total	7,068	6,050	3,538	8,563	50%	-11%	-52%	39%
5G	GWP weighted total	-1,639	-2,403	-2,999	-1,808	-30%	50%	3%	108%
6A1	GWP weighted total	56,040	16,003	9,948	23,919	54%	-69%	-85%	-47%
6B2	GWP weighted total	1,542	1,711	427	5,084	309%	14%	-11%	46%
6C	GWP weighted total	1,395	347	264	438	31%	-75%	-82%	-67%
Grand Total	GWP weighted total	783,754	565,974	535,495	631,964	17%	-28%	-31%	-25%

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[19] 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.

[19] 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 2009.

The error propagation analysis, **excluding** LULUCF emissions, suggests an uncertainty of 19% in the combined GWP total emission in 2009.

A7.6.4 Uncertainty in the Trend

The analysis, **including** LULUCF emissions, estimates an uncertainty of 2.5% in the trend between the base year and 2009.

The analysis, **excluding** LULUCF emissions, estimates an uncertainty of 2.4% in the trend between the base year and 2009.

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 Gg CO2 equiv	Year Y emissions 2009 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	248166	111465	0.4	1	1.077	0.212111	-0.085017	0.141698	-0.085017	0.080156	0.116846
1A(stationary)	Oil	CO2	92201	50820	15	2	15.133	1.358782	-0.019704	0.064604	-0.039407	1.370460	1.371027
1A	Natural Gas	CO2	108985	182792	0.2	1.5	1.513	0.488731	0.132504	0.232370	0.198757	0.065724	0.209341
1A	Other (waste)	CO2	212	1566	7	20	21.190	0.058638	0.001797	0.001991	0.035935	0.019710	0.040986
1A	Lubricant	CO2	387	198	30	2	30.067	0.010499	-0.000103	0.000251	-0.000205	0.010660	0.010662
1A	Combined Fuel	CO2	0	0	15	15	21.213	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1A3a	Aviation Fuel	CO2	1510	2119	20	3.3	20.270	0.075892	0.001313	0.002694	0.004333	0.076191	0.076314
1A3b	Auto Fuel	CO2	109570	112987	2.8	3.5	4.482	0.894773	0.043354	0.143632	0.151737	0.568753	0.588647
1A3b	Combined Fuel	CO2	0	0	15	15	21.213	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1A3d	Marine Fuel	CO2	1643	1448	1.7	1.4	2.202	0.005634	0.000338	0.001841	0.000473	0.004425	0.004450
1A3	Other Diesel	CO2	1647	2356	1.7	1.4	2.202	0.009168	0.001488	0.002995	0.002084	0.007201	0.007496
1A4	Peat	CO2	476	47	30	10	31.623	0.002650	-0.000375	0.000060	-0.003747	0.002558	0.004537
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	150	0.4	6	6.013	0.001594	-0.000593	0.000191	-0.003555	0.000108	0.003557
1B	Oil & Natural Gas	CO2	5778	4599	16	6	17.088	0.138864	0.000562	0.005847	0.003373	0.132301	0.132344
2A1	Cement Production	CO2	7295	3720	1	2.2	2.417	0.015886	-0.001943	0.004730	-0.004274	0.006689	0.007938
2A2	Lime Production	CO2	1192	627	1	5	5.099	0.005645	-0.000293	0.000797	-0.001466	0.001127	0.001849
2A3	Limestone & Dolomite use	CO2	1317	1195	1	5	5.099	0.010763	0.000314	0.001519	0.001568	0.002148	0.002659
2A4	Soda Ash Use	CO2	167	185	15	2	15.133	0.004945	0.000082	0.000235	0.000164	0.004988	0.004990
2A7	Fletton Bricks	CO2	180	74	20	70	72.801	0.009487	-0.000071	0.000094	-0.004952	0.002652	0.005618
2B	Ammonia Production	CO2	1322	801	10	1.5	10.112	0.014316	-0.000190	0.001019	-0.000285	0.014406	0.014408
2B5	NEU	CO2	1563	1914	50	20	53.852	0.182090	0.001003	0.002433	0.020066	0.172028	0.173194
2C1	Iron&Steel Production	CO2	2309	1193	1.2	6	6.119	0.012901	-0.000595	0.001517	-0.003571	0.002574	0.004402
5A	5A LUCF	CO2	-12155	-12723	1	25	25.020	-0.562428	-0.005057	-0.016174	-0.126421	-0.022873	0.128474
5B	5B LUCF	CO2	15695	12692	1	50	50.010	1.121494	0.001780	0.016135	0.088978	0.022818	0.091857
5C	5C LUCF	CO2	-6260	-8650	1	70	70.007	-1.069867	-0.005270	-0.010996	-0.368901	-0.015550	0.369229
5D	5D LUCF	CO2	422	282	1	50	50.010	0.024917	-0.000028	0.000358	-0.001387	0.000507	0.001477
5E	5E LUCF	CO2	7038	6054	1	50	50.010	0.534960	0.001259	0.007696	0.062951	0.010884	0.063885
5G	5G LUCF	CO2	-1637	-2402	1	30	30.017	-0.127411	-0.001557	-0.003054	-0.046701	-0.004319	0.046900
6C	Waste Incineration	CO2	1212	297	7	20	21.190	0.011120	-0.000731	0.000378	-0.014627	0.003738	0.015097
		CO2 Total	591,090.91	475,807.27									
1A	All Fuel	CH4	2078.744043	1005.713475	0.4	50	50.002	0.088849	-0.000623	0.001278	-0.031140	0.000723	0.031148
1A3a	Aviation Fuel	CH4	3.301023257	1.23497542	20	50	53.852	0.000118	-0.000001	0.000002	-0.000072	0.000044	0.000085
1A3b	Auto Fuel	CH4	634.3553239	89.61097299	2.8	50	50.078	0.007929	-0.000466	0.000114	-0.023314	0.000451	0.023319
1A3b	Combined Fuel	CH4	0	0	15	30	33.541	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1A3d	Marine Fuel	CH4	0.542267276	0.475542835	1.7	50	50.029	0.000042	0.000000	0.000001	0.000005	0.000001	0.000006
1A3	Other Diesel	CH4	3.163979778	4.358201581	1.7	50	50.029	0.000385	0.000003	0.000006	0.000132	0.000013	0.000133
1B1	Coal Mining	CH4	18285.666	2867.188	0.4	13	13.006	0.065887	-0.013077	0.003645	-0.170001	0.002062	0.170013
	Solid Fuel Transformation	CH4	4.043	0.328	0.4	50	50.002	0.000029	-0.000003	0.000000	-0.000164	0.000000	0.000164
1B2	Natural Gas Transmission	CH4	8505.883	4293.861	1	15	15.033	0.114051	-0.002321	0.005458	-0.034817	0.007719	0.035662
	Offshore Oil& Gas	CH4	1817.038	972.290	16	20	25.612	0.043999	-0.000426	0.001236	-0.008519	0.027968	0.029236
2A7	Fletton Bricks	CH4	23.602	5.518	20	100	101.980	0.000994	-0.000015	0.000007	-0.001457	0.000198	0.001471
2B	Chemical Industry	CH4	169.425	76.271	20	20	28.284	0.003812	-0.000058	0.000097	-0.001160	0.002742	0.002978
2C	Iron & Steel Production	CH4	16.357	6.658	0.4	50	50.002	0.000588	-0.000006	0.000008	-0.000325	0.000005	0.000325
4A	Enteric Fermentation	CH4	18527.342	15263.069	0.1	20	20.000	0.539353	0.002456	0.019403	0.049127	0.002744	0.049204
4B	Manure Management	CH4	3607.756	2816.723	0.1	30	30.000	0.149301	0.000281	0.003581	0.008426	0.000506	0.008441
4F	Field Burning	CH4	266.045	0.000	25	50	55.902	0.000000	-0.000243	0.000000	-0.012167	0.000000	0.012167
5A	5A LUCF	CH4	4.298	9.475	1	20	20.025	0.000335	0.000008	0.000012	0.000162	0.000017	0.000163
5B	5B LUCF	CH4	0.132	0.461	1	50	50.010	0.000041	0.000000	0.000001	0.000023	0.000001	0.000023
5C2	5C2 LUCF	CH4	2.945	13.823	1	20	20.025	0.000489	0.000015	0.000018	0.000298	0.000025	0.000299
5E2	5E2 LUCF	CH4	9.252	2.888	1	20	20.025	0.000102	-0.000005	0.000004	-0.000096	0.000005	0.000096
6A	Solid Waste Disposal	CH4	56216.709	16052.768	15	46	48.384	1.372291	-0.030989	0.020407	-1.425511	0.432892	1.489791
6B	Wastewater Handling	CH4	287.266	345.314	1	50	50.010	0.030512	0.000176	0.000439	0.008811	0.000621	0.008833
6C	Waste Incineration	CH4	134.433	6.144	7	50	50.488	0.000548	-0.000115	0.000008	-0.005757	0.000077	0.005758
		CH4 total	110,598.30	43,834.17									

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 2009	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	4675.836	3079.561	0.4	195	195.000	1.061011	-0.000362	0.003915	-0.070566	0.002215	0.070601
1A3a	Aviation Fuel	N2O	14.862	20.860	20	170	171.172	0.006309	0.000013	0.000027	0.002197	0.000750	0.002322
1A3b	Auto Fuel	N2O	1176.842	978.746	2.8	170	170.023	0.294018	0.000168	0.001244	0.028529	0.004927	0.028951
1A3b	Combined Fuel	N2O	0.000	0.000	15	30	33.541	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1A3d	Marine Fuel	N2O	12.808	11.232	1.7	170	170.008	0.003374	0.000003	0.000014	0.000436	0.000034	0.000437
1A3	Other Diesel	N2O	195.322	277.830	1.7	140	140.010	0.068728	0.000175	0.000353	0.024435	0.000849	0.024450
1B1	Coke Oven Gas	N2O	2.085	0.169	0.4	118	118.001	0.000035	-0.000002	0.000000	-0.000200	0.000000	0.000200
1B2	Oil & Natural Gas	N2O	42.396	36.764	16	110	111.158	0.007220	0.000008	0.000047	0.000875	0.001057	0.001373
2B	Adipic Acid Production	N2O	20737.345	71.021	0.5	15	15.008	0.001883	-0.018872	0.000090	-0.283080	0.000064	0.283080
2B	Nitric Acid Production	N2O	3903.850	1106.700	10	230	230.217	0.450156	-0.002164	0.001407	-0.497641	0.019896	0.498038
2C	Iron & Steel	N2O	11.107	4.961	0.4	118	118.001	0.001034	-0.000004	0.000006	-0.000455	0.000004	0.000455
4B	Manure Management	N2O	2759.235	2056.293	1	414	414.001	1.504119	0.000090	0.002614	0.037384	0.003697	0.037566
4D	Agricultural Soils	N2O	32091.462	24905.173	1	424	424.001	18.657448	0.002307	0.031660	0.978159	0.044774	0.979184
4F	Field Burning	N2O	77.762	0.000	25	230	231.355	0.000000	-0.000071	0.000000	-0.016359	0.000000	0.016359
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	1.945	1	20	20.025	0.000069	-0.000003	0.000002	-0.000052	0.000003	0.000053
5B	5B LUCF	N2O	781.769	633.042	1	50	50.010	0.055935	0.000090	0.000805	0.004485	0.001138	0.004627
5C2	5C2 LUCF	N2O	0.299	1.403	1	20	20.025	0.000050	0.000002	0.000002	0.000030	0.000003	0.000030
5D2	5D2 LUCF	N2O	3.979	0.538	1	20	20.025	0.000019	-0.000003	0.000001	-0.000059	0.000001	0.000059
5E2	5E2 LUCF	N2O	0.939	0.293	1	20	20.025	0.000010	0.000000	0.000000	-0.000010	0.000001	0.000010
6B	Wastewater Handling	N2O	1250.627	1376.637	10	401	401.125	0.975651	0.000606	0.001750	0.243059	0.024749	0.244316
6C	Waste Incineration	N2O	47.902	43.558	7	230	230.106	0.017709	0.000012	0.000055	0.002659	0.000548	0.002714
		N2O Total	67,792.00	34,606.73									
2	Industrial Processes	HFC	15458	10927	1	19	19.026	0.367333	-0.000247	0.013891	-0.004698	0.019645	0.020199
2	Industrial Processes	PFC	462	147	1	10	10.050	0.002612	-0.000236	0.000187	-0.002356	0.000264	0.002371
2	Industrial Processes	SF6	1239	662	1	20	20.025	0.023415	-0.000292	0.000841	-0.005844	0.001190	0.005964
		Halocarbon & SF6 Total	17,159.05	11,736.12									
	TOTALS	GWP	786,640.25	565,984.29									
	Total Uncertainties%							19.0					2.47

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	Year Y emissions 2009	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	248166	111465	0.4	1	1.077	0.210592	-0.088225	0.142406	-0.088225	0.080557	0.119470
1A(stationary)	Oil	CO2	92201	50820	15	2	15.133	1.349052	-0.020839	0.064927	-0.041677	1.377309	1.377940
1A	Natural Gas	CO2	108985	182792	0.2	1.5	1.513	0.485231	0.131941	0.233531	0.197911	0.066053	0.208642
1A	Other (waste)	CO2	212	1566	7	20	21.190	0.058218	0.001803	0.002001	0.036067	0.019809	0.041149
1A	Lubricant	CO2	387	198	30	2	30.067	0.010424	-0.000107	0.000253	-0.000215	0.010713	0.010715
1A	Combined Fuel	CO2	0	0	15	15	21.213	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1A3a	Aviation Fuel	CO2	1510	2119	20	3.3	20.270	0.075348	0.001303	0.002707	0.004299	0.076572	0.076693
1A3b	Auto Fuel	CO2	109570	112987	2.8	3.5	4.482	0.888365	0.042338	0.144350	0.148184	0.571596	0.590492
1A3b	Combined Fuel	CO2	0	0	15	15	21.213	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1A3d	Marine Fuel	CO2	1643	1448	1.7	1.4	2.202	0.005593	0.000321	0.001850	0.000449	0.004447	0.004470
1A3	Other Diesel	CO2	1647	2356	1.7	1.4	2.202	0.009102	0.001477	0.003010	0.002068	0.007237	0.007527
1A4	Peat	CO2	476	47	30	10	31.623	0.002631	-0.000382	0.000061	-0.003819	0.002571	0.004604
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	150	0.4	6	6.013	0.001583	-0.000605	0.000192	-0.003631	0.000108	0.003633
1B	Oil & Natural Gas	CO2	5778	4599	16	6	17.088	0.137870	0.000500	0.005876	0.003000	0.132962	0.132996
2A1	Cement Production	CO2	7295	3720	1	2.2	2.417	0.015772	-0.002035	0.004753	-0.004476	0.006722	0.008076
2A2	Lime Production	CO2	1192	627	1	5	5.099	0.005605	-0.000308	0.000801	-0.001541	0.001132	0.001912
2A3	Limestone & Dolomite use	CO2	1317	1195	1	5	5.099	0.010685	0.000300	0.001526	0.001502	0.002158	0.002629
2A4	Soda Ash Use	CO2	167	185	15	2	15.133	0.004910	0.000081	0.000236	0.000161	0.005012	0.005015
2A7	Fletton Bricks	CO2	180	74	20	70	72.801	0.009420	-0.000073	0.000094	-0.005119	0.002665	0.005771
2B	Ammonia Production	CO2	1322	801	10	1.5	10.112	0.014213	-0.000206	0.001024	-0.000309	0.014478	0.014481
2B5	NEU	CO2	1563	1914	50	20	53.852	0.180786	0.000991	0.002445	0.019815	0.172888	0.174020
2C1	Iron&Steel Production	CO2	2309	1193	1.2	6	6.119	0.012808	-0.000624	0.001525	-0.003745	0.002587	0.004552
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	1212	297	7	20	21.190	0.011040	-0.000749	0.000379	-0.014973	0.003756	0.015437
		CO2 Total	587,988.30	480,553.27									
1A	All Fuel	CH4	2078.744043	1005.713475	0.4	50	50.002	0.088213	-0.000649	0.001285	-0.032466	0.000727	0.032474
1A3a	Aviation Fuel	CH4	3.301023257	1.23497542	20	50	53.852	0.000117	-0.000001	0.000002	-0.000075	0.000045	0.000087
1A3b	Auto Fuel	CH4	634.3553239	89.61097299	2.8	50	50.078	0.007872	-0.000476	0.000114	-0.023788	0.000453	0.023792
1A3b	Combined Fuel	CH4	0	0	15	30	33.541	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1A3d	Marine Fuel	CH4	0.542267276	0.475542835	1.7	50	50.029	0.000042	0.000000	0.000001	0.000005	0.000001	0.000005
1A3	Other Diesel	CH4	3.163979778	4.358201581	1.7	50	50.029	0.000382	0.000003	0.000006	0.000131	0.000013	0.000132
1B1	Coal Mining	CH4	18285.666	2867.188	0.4	13	13.006	0.065415	-0.013348	0.003663	-0.173525	0.002072	0.173538
	Solid Fuel Transformation	CH4	4.043	0.328	0.4	50	50.002	0.000029	-0.000003	0.000000	-0.000167	0.000000	0.000167
1B2	Natural Gas Transmission	CH4	8505.883	4293.861	1	15	15.033	0.113234	-0.002428	0.005486	-0.036427	0.007758	0.037244
	Offshore Oil& Gas	CH4	1817.038	972.290	16	20	25.612	0.043684	-0.000449	0.001242	-0.008970	0.028107	0.029504
2A7	Fletton Bricks	CH4	23.602	5.518	20	100	101.980	0.000987	-0.000015	0.000007	-0.001491	0.000199	0.001504
2B	Chemical Industry	CH4	169.425	76.271	20	20	28.284	0.003784	-0.000060	0.000097	-0.001204	0.002756	0.003008
2C	Iron & Steel Production	CH4	16.357	6.658	0.4	50	50.002	0.000584	-0.000007	0.000009	-0.000336	0.000005	0.000336
4A	Enteric Fermentation	CH4	18527.342	15263.069	0.1	20	20.000	0.535491	0.002260	0.019500	0.045202	0.002758	0.045286
4B	Manure Management	CH4	3607.756	2816.723	0.1	30	30.000	0.148232	0.000242	0.003599	0.007250	0.000509	0.007268
4F	Field Burning	CH4	266.045	0.000	25	50	55.902	0.000000	-0.000248	0.000000	-0.012377	0.000000	0.012377
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	56216.709	16052.768	15	46	48.384	1.362464	-0.031777	0.020509	-1.461719	0.435056	1.525089
6B	Wastewater Handling	CH4	287.266	345.314	1	50	50.010	0.030293	0.000174	0.000441	0.008694	0.000624	0.008716
6C	Waste Incineration	CH4	134.433	6.144	7	50	50.488	0.000544	-0.000117	0.000008	-0.005862	0.000078	0.005862
		CH4 total	110,581.67	43,807.53									

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 2009	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	4675.836	3079.561	0.4	195	195.000	1.053413	-0.000416	0.003934	-0.081182	0.002226	0.081212
1A3a	Aviation Fuel	N2O	14.862	20.860	20	170	171.172	0.006264	0.000013	0.000027	0.002180	0.000754	0.002306
1A3b	Auto Fuel	N2O	1176.842	978.746	2.8	170	170.023	0.291912	0.000155	0.001250	0.026419	0.004951	0.026879
1A3b	Combined Fuel	N2O	0.000	0.000	15	30	33.541	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1A3d	Marine Fuel	N2O	12.808	11.232	1.7	170	170.008	0.003350	0.000002	0.000014	0.000413	0.000034	0.000415
1A3	Other Diesel	N2O	195.322	277.830	1.7	140	140.010	0.068236	0.000173	0.000355	0.024249	0.000853	0.024264
1B1	Coke Oven Gas	N2O	2.085	0.169	0.4	118	118.001	0.000035	-0.000002	0.000000	-0.000203	0.000000	0.000203
1B2	Oil & Natural Gas	N2O	42.396	36.764	16	110	111.158	0.007169	0.000008	0.000047	0.000827	0.001063	0.001347
2B	Adipic Acid Production	N2O	20737.345	71.021	0.5	15	15.008	0.001870	-0.019200	0.000091	-0.287995	0.000064	0.287995
2B	Nitric Acid Production	N2O	3903.850	1106.700	10	230	230.217	0.446933	-0.002218	0.001414	-0.510235	0.019996	0.510626
2C	Iron & Steel	N2O	11.107	4.961	0.4	118	118.001	0.001027	-0.000004	0.000006	-0.000472	0.000004	0.000472
4B	Manure Management	N2O	2759.235	2056.293	1	414	414.001	1.493348	0.000060	0.002627	0.024712	0.003715	0.024990
4D	Agricultural Soils	N2O	32091.462	24905.173	1	424	424.001	18.523846	0.001957	0.031818	0.829940	0.044998	0.831159
4F	Field Burning	N2O	77.762	0.000	25	230	231.355	0.000000	-0.000072	0.000000	-0.016642	0.000000	0.016642
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
6B	Wastewater Handling	N2O	1250.627	1376.637	10	401	401.125	0.968664	0.000595	0.001759	0.238628	0.024873	0.239921
6C	Waste Incineration	N2O	47.902	43.558	7	230	230.106	0.017582	0.000011	0.000056	0.002548	0.000551	0.002607
		N2O Total	66,999.44	33,969.50									
2	Industrial Processes	HFC	15458	10927	1	19	19.026	0.364702	-0.000422	0.013960	-0.008027	0.019743	0.021312
2	Industrial Processes	PFC	462	147	1	10	10.050	0.002593	-0.000242	0.000188	-0.002420	0.000266	0.002434
2	Industrial Processes	SF6	1239	662	1	20	20.025	0.023248	-0.000308	0.000846	-0.006152	0.001196	0.006267
		Halocarbon & SF6 Total	17,159.05	11,736.12									
	TOTALS	GWP	782,728.46	570,066.41									
	Total Uncertainties%							18.8					2.41

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 1990-2009, 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 8.1.20** 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	**588,372.11**	**5,244.12**	**218.39**	**11.88**	**11,385.55**	**73.47**	**1,401.47**	**0.10**	**0.04**	**2,681.18**	**8,987.57**	**2,701.64**	**3,710.82**
1. Energy	**568,757.61**	**1,491.08**	**19.69**							**2,652.68**	**8,409.60**	**1,710.74**	**3,648.65**
A. Fuel Combustion — Reference Approach [2]	561,308.78												
Sectoral Approach [2]	562,123.34	128.57	19.55							2,638.76	8,349.76	1,146.36	3,620.20
1. Energy Industries	234,194.15	9.61	6.51							848.36	132.61	8.28	2,875.22
2. Manufacturing Industries and Construction	99,941.85	15.45	5.25							404.46	737.60	28.23	446.01
3. Transport	113,795.04	30.21	4.49							1,134.59	6,317.74	1,003.88	91.08
4. Other Sectors	108,907.48	73.15	3.14							212.39	1,148.43	103.75	201.73
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	1,362.51	0.14							13.92	59.84	564.38	28.46
1. Solid Fuels	856.42	870.94	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	**15,345.33**	**9.97**	**79.52**	**11.88**	**11,385.55**	**73.47**	**1,401.47**	**0.10**	**0.04**	**13.33**	**281.66**	**265.35**	**54.80**
A. Mineral Products	10,151.47	1.12	NE							NE	5.31	13.08	4.27
B. Chemical Industry	2,884.58	8.07	79.49	NO	NO	NO	NO	NO	NO	8.49	82.15	172.98	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	77.24	NE
E. Production of Halocarbons and SF_6					11,373.73		10.90		NA,NO				
F. Consumption of Halocarbons and SF_6				11.88	11.83	73.47	57.82	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**							**NO**	**NO**	**666.21**	**NO**
4. Agriculture		**1,055.41**	**112.45**							**9.07**	**266.04**	**26.06**	**NO**
A. Enteric Fermentation		871.98											
B. Manure Management		170.76	8.67									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils[4]		IE,NA,NE	103.52									IE,NA,NE	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		12.67	0.25							9.07	266.04	26.06	
G. Other		NA	NA							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	[5] **3,056.89**	**1.23**	**2.56**							**0.20**	**6.93**	**NA,NO**	**NA**
A. Forest Land	[5] -12,155.07	0.20	0.02							0.05	1.79	NO	
B. Cropland	[5] 15,694.56	0.01	2.52							0.00	0.05	NO	
C. Grassland	[5] -6,260.40	0.14	0.00							0.03	1.23	NO	
D. Wetlands	[5] 422.26	NE,NO	0.01							NO	NO	NO	
E. Settlements	[5] 7,038.07	0.88	0.01							0.11	3.86	NO	
F. Other Land	[5] NE,NO	NE,NO	NE,NO							NO	NO	NO	
G. Other	[5] -1,682.53	NE	NE							NE	NE	NA	NA
6. Waste	**1,212.29**	**2,686.43**	**4.17**							**5.91**	**23.34**	**33.28**	**7.36**
A. Solid Waste Disposal on Land	[6] NA,NE,NO	2,666.77								NA,NE,NO	NA,NE,NO	26.67	
B. Waste-water Handling		13.26	4.02							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	[6] 1,212.29	6.40	0.15							5.91	23.34	6.61	7.36
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	**24,729.02**	**0.45**	**0.72**							**274.22**	**34.53**	**12.21**	**101.95**
Aviation	15,638.49	0.31	0.50							75.13	13.41	5.64	2.99
Marine	9,090.53	0.14	0.23							199.09	21.12	6.57	98.96
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**2,980.13**												

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	**595,479.65**	**5,122.88**	**218.24**	**11.88**	**11,853.64**	**82.77**	**1,170.74**	**0.10**	**0.05**	**2,580.81**	**9,201.03**	**2,646.30**	**3,549.15**
1. Energy	**578,017.36**	**1,508.16**	**19.60**							**2,555.11**	**8,670.02**	**1,706.44**	**3,488.85**
A. Fuel Combustion — Reference Approach (2)	577,838.17												
Sectoral Approach (2)	571,784.49	131.45	19.46							2,541.52	8,587.42	1,152.30	3,463.67
1. Energy Industries	231,979.22	9.53	6.50							749.62	131.34	8.14	2,678.44
2. Manufacturing Industries and Construction	102,149.98	15.28	5.14							399.53	690.67	26.75	486.19
3. Transport	113,025.76	29.99	4.47							1,132.60	6,492.84	1,008.88	84.38
4. Other Sectors	120,337.11	76.54	3.22							222.44	1,261.80	106.65	208.43
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	1,376.71	0.14							13.60	82.59	554.15	25.18
1. Solid Fuels	519.42	895.22	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	**13,235.90**	**9.48**	**80.02**	**11.88**	**11,853.64**	**82.77**	**1,170.74**	**0.10**	**0.05**	**11.84**	**272.00**	**254.52**	**53.06**
A. Mineral Products	8,631.66	0.91	NE							NE	4.31	12.62	3.46
B. Chemical Industry	2,920.52	8.03	79.99	NO	NO	NO	NO	NO	NO	7.68	80.29	162.84	40.97
C. Metal Production	1,683.72	0.53	0.03				1,095.57		0.02	4.16	187.41	1.92	8.63
D. Other Production (3)	NE									NE	NE	77.13	NE
E. Production of Halocarbons and SF_6					11,841.76		10.91		NA,NO				
F. Consumption of Halocarbons and SF_6				11.88	11.89	82.77	64.26	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**							**NO**	**NO**	**630.73**	**NO**
4. Agriculture		**1,039.26**	**111.91**							**7.76**	**227.78**	**22.52**	**NO**
A. Enteric Fermentation		858.90											
B. Manure Management		169.52	8.67									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils(4)		IE,NA,NE	103.03									IE,NA,NE	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		10.85	0.21							7.76	227.78	22.52	
G. Other		NA	NA							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	(5) **3,020.16**	**1.30**	**2.56**							**0.22**	**7.87**	**NA,NO**	**NA**
A. Forest Land	(5) -12,628.78	0.35	0.02							0.09	3.02	NO	
B. Cropland	(5) 15,898.33	0.01	2.52							0.00	0.06	NO	
C. Grassland	(5) -6,223.32	0.15	0.00							0.04	1.31	NO	
D. Wetlands	(5) 428.86	NE,NO	0.01							NO	NO	NO	
E. Settlements	(5) 6,962.30	0.80	0.01							0.10	3.48	NO	
F. Other Land	(5) NE,NO	NE,NO	NE,NO							NO	NO	NO	
G. Other	(5) -1,417.21	NE	NE							NE	NE	NA	NA
6. Waste	**1,206.23**	**2,564.68**	**4.14**							**5.87**	**23.35**	**32.09**	**7.24**
A. Solid Waste Disposal on Land	(6) NA,NE,NO	2,545.08								NA,NE,NO	NA,NE,NO	25.45	
B. Waste-water Handling		13.25	3.99							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	(6) 1,206.23	6.35	0.15							5.87	23.35	6.64	7.24
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	**24,448.99**	**0.40**	**0.72**							**271.01**	**33.77**	**11.44**	**94.78**
Aviation	15,369.58	0.26	0.49							72.93	12.68	4.93	3.92
Marine	9,079.41	0.14	0.23							198.08	21.09	6.51	90.86
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**3,138.30**												

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	**578,499.74**	**4,968.19**	**196.92**	**13.02**	**12,323.11**	**93.79**	**573.24**	**0.10**	**0.05**	**2,523.23**	**8,795.66**	**2,573.20**	**3,467.30**
1. Energy	**562,277.10**	**1,488.00**	**19.23**							**2,500.79**	**8,339.28**	**1,674.69**	**3,410.54**
A. Fuel Combustion — Reference Approach [2]	566,661.67												
Sectoral Approach [2]	555,689.85	123.78	19.08							2,487.28	8,284.64	1,116.30	3,386.59
1. Energy Industries	220,757.70	9.56	6.22							735.57	128.91	7.77	2,565.69
2. Manufacturing Industries and Construction	99,074.10	14.58	5.17							389.66	700.31	26.47	524.70
3. Transport	114,447.04	29.00	4.47							1,111.63	6,311.00	977.35	86.63
4. Other Sectors	117,324.22	70.52	3.10							215.61	1,134.16	102.94	203.76
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	1,364.22	0.15							13.51	54.65	558.39	23.95
1. Solid Fuels	450.00	887.17	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	**12,546.41**	**9.92**	**65.07**	**13.02**	**12,323.11**	**93.79**	**573.24**	**0.10**	**0.05**	**10.97**	**262.45**	**252.92**	**49.65**
A. Mineral Products	8,117.87	0.82	NE							NE	3.85	12.54	3.10
B. Chemical Industry	2,978.08	8.64	65.04	NO	NO	NO	NO	NO	NO	6.87	79.58	161.23	38.40
C. Metal Production	1,450.46	0.46	0.03				490.38		0.02	4.10	179.01	1.89	8.15
D. Other Production [3]	NE									NE	NE	77.26	NE
E. Production of Halocarbons and SF_6					12,310.08		10.96		NA,NO				
F. Consumption of Halocarbons and SF_6				13.02	13.03	93.79	71.89	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**							**NO**	**NO**	**598.15**	**NO**
4. Agriculture		**1,042.10**	**105.80**							**5.63**	**165.25**	**16.72**	**NO**
A. Enteric Fermentation		864.79											
B. Manure Management		169.44	8.06									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils[4]		IE,NA,NE	97.59									IE,NA,NE	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		7.87	0.16							5.63	165.25	16.72	
G. Other		NA	NA							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	(5) **2,511.20**	**0.97**	**2.56**							**0.15**	**5.37**	**NA,NO**	**NA**
A. Forest Land	(5) -13,306.37	0.09	0.02							0.02	0.77	NO	
B. Cropland	(5) 15,941.21	0.01	2.52							0.00	0.06	NO	
C. Grassland	(5) -6,327.08	0.16	0.00							0.04	1.43	NO	
D. Wetlands	(5) 422.96	NE,NO	0.01							NO	NO	NO	
E. Settlements	(5) 6,890.13	0.71	0.00							0.09	3.12	NO	
F. Other Land	(5) NE,NO	NE,NO	NE,NO							NO	NO	NO	
G. Other	(5) -1,109.65	NE	NE							NE	NE	NA	NA
6. Waste	**1,165.03**	**2,427.22**	**4.26**							**5.67**	**23.31**	**30.72**	**7.11**
A. Solid Waste Disposal on Land	(6) NA,NE,NO	2,408.03								NA,NE,NO	NA,NE,NO	24.08	
B. Waste-water Handling		13.10	4.11							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	(6) 1,165.03	6.09	0.15							5.67	23.31	6.64	7.11
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	**26,234.36**	**0.40**	**0.77**							**281.94**	**35.07**	**11.54**	**93.95**
Aviation	16,988.25	0.25	0.54							79.72	13.57	4.89	5.40
Marine	9,246.11	0.15	0.23							202.23	21.50	6.64	88.54
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**3,553.76**												

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	**563,549.97**	**4,754.47**	**181.84**	**782.43**	**13,120.83**	**106.82**	**489.51**	**0.10**	**0.05**	**2,376.33**	**8,468.35**	**2,452.20**	**3,126.72**
1. Energy	**548,532.62**	**1,410.30**	**18.59**							**2,360.58**	**8,167.90**	**1,593.39**	**3,073.87**
A. Fuel Combustion — Reference Approach [2]	549,372.50												
Sectoral Approach [2]	541,627.57	121.57	18.43							2,347.05	8,114.38	1,055.74	3,050.31
1. Energy Industries	204,694.00	9.83	5.49							646.06	119.83	7.69	2,241.33
2. Manufacturing Industries and Construction	96,424.72	14.56	4.94							382.80	697.92	26.77	498.72
3. Transport	115,602.63	27.43	4.72							1,070.49	6,038.86	917.74	83.12
4. Other Sectors	120,765.28	69.63	3.15							215.39	1,247.33	101.79	222.25
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	1,288.73	0.16							13.53	53.52	537.65	23.56
1. Solid Fuels	344.83	825.64	0.00							0.39	30.36	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	**12,542.50**	**8.71**	**52.44**	**782.43**	**13,120.83**	**106.82**	**489.51**	**0.10**	**0.05**	**10.26**	**268.18**	**247.19**	**47.45**
A. Mineral Products	8,156.04	0.69	NE							NE	3.24	12.09	2.61
B. Chemical Industry	3,021.49	7.59	52.42	NO	NO	NO	NO	NO	NO	6.06	81.78	155.49	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	77.71	NE
E. Production of Halocarbons and SF_6					12,779.93		27.23		NA,NO				
F. Consumption of Halocarbons and SF_6				782.43	340.89	106.82	80.96	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**							**NO**	**NO**	**581.66**	**NO**
4. Agriculture		**1,034.85**	**104.01**							**0.12**	**3.53**	**0.47**	**NO**
A. Enteric Fermentation		863.95											
B. Manure Management		170.73	8.13									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils[4]		IE,NA,NE	95.87									IE,NA,NE	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		0.17	0.00							0.12	3.53	0.47	
G. Other		NA	NA							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	(5) **1,393.20**	**0.96**	**2.56**							**0.15**	**5.44**	**NA,NO**	**NA**
A. Forest Land	(5) -13,658.38	0.15	0.01							0.04	1.35	NO	
B. Cropland	(5) 15,556.85	0.01	2.53							0.00	0.05	NO	
C. Grassland	(5) -6,755.84	0.12	0.00							0.03	1.09	NO	
D. Wetlands	(5) 416.49	NE,NO	0.01							NO	NO	NO	
E. Settlements	(5) 6,836.92	0.68	0.00							0.08	2.96	NO	
F. Other Land	(5) NE,NO	NE,NO	NE,NO							NO	NO	NO	
G. Other	(5) -1,002.84	NE	NE							NE	NE	NA	NA
6. Waste	**1,081.65**	**2,299.64**	**4.24**							**5.22**	**23.30**	**29.49**	**5.40**
A. Solid Waste Disposal on Land	(6) NA,NE,NO	2,281.15								NA,NE,NO	NA,NE,NO	22.81	
B. Waste-water Handling		13.09	4.10							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	(6) 1,081.65	5.41	0.15							5.22	23.30	6.68	5.40
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	**27,329.80**	**0.39**	**0.81**							**286.17**	**35.73**	**11.62**	**92.98**
Aviation	18,195.07	0.24	0.58							85.27	14.49	5.00	4.63
Marine	9,134.73	0.14	0.23							200.90	21.24	6.62	88.35
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**3,705.28**												

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	**557,765.57**	**4,359.02**	**185.47**	**2,291.18**	**14,042.77**	**122.25**	**485.87**	**0.09**	**0.05**	**2,282.02**	**8,014.70**	**2,365.49**	**2,663.93**
1. Energy	**541,805.28**	**1,114.57**	**18.99**							**2,267.99**	**7,712.29**	**1,519.62**	**2,609.00**
A. Fuel Combustion — Reference Approach [(2)]	543,628.23												
Sectoral Approach [(2)]	534,682.13	107.78	18.83							2,254.45	7,657.44	977.87	2,586.34
1. Energy Industries	202,658.93	11.27	5.45							599.47	130.91	8.56	1,888.44
2. Manufacturing Industries and Construction	95,943.29	15.27	4.96							392.05	746.89	28.67	408.83
3. Transport	116,150.65	25.62	5.30							1,025.65	5,660.85	849.25	88.06
4. Other Sectors	115,969.46	55.51	2.99							207.01	1,108.80	89.72	196.32
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	1,006.79	0.17							13.54	54.85	541.75	22.66
1. Solid Fuels	163.25	547.72	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	**13,809.42**	**10.28**	**53.05**	**2,291.18**	**14,042.77**	**122.25**	**485.87**	**0.09**	**0.05**	**9.58**	**274.49**	**240.48**	**50.51**
A. Mineral Products	9,110.87	0.77	NE							NE	3.65	12.61	5.45
B. Chemical Industry	3,059.19	8.95	53.02	NO	NO	NO	NO	NO	NO	5.26	86.42	147.18	36.96
C. Metal Production	1,639.35	0.56	0.03				345.16		0.02	4.32	184.42	1.95	8.09
D. Other Production [(3)]	NE									NE	NE	78.74	NE
E. Production of Halocarbons and SF_6					13,264.93		49.01		NA,NO				
F. Consumption of Halocarbons and SF_6				2,291.18	777.84	122.25	91.71	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**							**NO**	**NO**	**576.99**	**NO**
4. Agriculture		**1,040.51**	**106.64**							**NA,NO**	**NA,NO**	**NA,NE,NO**	**NO**
A. Enteric Fermentation		868.57											
B. Manure Management		171.94	8.27									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils[(4)]		IE,NA,NE	98.37									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	NA							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	(5) **1,223.55**	**0.95**	**2.56**							**0.15**	**5.27**	**NA,NO**	**NA**
A. Forest Land	(5) -14,137.69	0.12	0.01							0.03	1.07	NO	
B. Cropland	(5) 15,641.08	0.01	2.53							0.00	0.05	NO	
C. Grassland	(5) -6,803.46	0.13	0.00							0.03	1.16	NO	
D. Wetlands	(5) 518.51	NE,NO	0.01							NO	NO	NO	
E. Settlements	(5) 6,798.34	0.68	0.00							0.09	2.99	NO	
F. Other Land	(5) NE,NO	NE,NO	NE,NO							NO	NO	NO	
G. Other	(5) -793.23	NE	NE							NE	NE	NA	NA
6. Waste	**927.31**	**2,192.72**	**4.23**							**4.30**	**22.64**	**28.40**	**4.42**
A. Solid Waste Disposal on Land	(6) NA,NE,NO	2,175.59								NA,NE,NO	NA,NE,NO	21.76	
B. Waste-water Handling		13.16	4.11							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	(6) 927.31	3.98	0.12							4.30	22.64	6.64	4.42
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	**27,249.74**	**0.35**	**0.81**							**270.41**	**33.50**	**10.78**	**80.90**
Aviation	18,942.77	0.22	0.60							88.86	14.18	4.84	6.02
Marine	8,306.96	0.13	0.21							181.55	19.32	5.94	74.87
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**4,914.26**												

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	**549,335.77**	**4,280.12**	**181.33**	**4,590.00**	**15,447.38**	**140.50**	**461.90**	**0.10**	**0.05**	**2,177.02**	**7,507.65**	**2,181.72**	**2,356.59**
1. Energy	**532,641.76**	**1,156.03**	**19.45**							**2,165.84**	**7,190.66**	**1,369.45**	**2,294.70**
A. Fuel Combustion — Reference Approach [2]	541,296.14												
Sectoral Approach [2]	523,986.30	93.29	19.25							2,151.49	7,135.60	907.09	2,277.30
1. Energy Industries	200,277.05	11.30	5.34							563.77	129.86	8.91	1,715.21
2. Manufacturing Industries and Construction	92,642.76	15.55	4.82							374.37	753.66	29.15	325.29
3. Transport	115,338.24	23.80	6.20							985.58	5,376.48	789.56	76.38
4. Other Sectors	111,842.08	42.53	2.77							197.36	865.81	77.81	156.00
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	1,062.74	0.20							14.35	55.06	462.37	17.40
1. Solid Fuels	225.84	599.65	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	**14,234.19**	**8.31**	**47.99**	**4,590.00**	**15,447.38**	**140.50**	**461.90**	**0.10**	**0.05**	**6.94**	**282.40**	**248.08**	**57.56**
A. Mineral Products	9,230.68	0.77	NE							NE	3.64	11.93	9.67
B. Chemical Industry	3,065.28	6.84	47.95	NO	NO	NO	NO	NO	NO	2.40	88.61	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	78.71	NE
E. Production of Halocarbons and SF_6					13,980.68		70.79		NA,NO				
F. Consumption of Halocarbons and SF_6				4,590.00	1,466.71	140.50	104.83	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**							**NO**	**NO**	**536.87**	**NO**
4. Agriculture		**1,027.49**	**107.05**							**NA,NO**	**NA,NO**	**NA,NE,NO**	**NO**
A. Enteric Fermentation		859.35											
B. Manure Management		168.15	8.09									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils[4]		IE,NA,NE	98.96									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	NA							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	(5) **1,582.33**	**1.70**	**2.56**							**0.35**	**12.27**	**NA,NO**	**NA**
A. Forest Land	(5) -13,696.06	0.96	0.02							0.24	8.38	NO	
B. Cropland	(5) 15,802.30	0.01	2.53							0.00	0.06	NO	
C. Grassland	(5) -6,801.01	0.15	0.00							0.04	1.29	NO	
D. Wetlands	(5) 592.98	NE,NO	0.01							NO	NO	NO	
E. Settlements	(5) 6,725.86	0.58	0.00							0.07	2.54	NO	
F. Other Land	(5) NE,NO	NE,NO	NE,NO							NO	NO	NO	
G. Other	(5) -1,041.73	NE	NE							NE	NE	NA	NA
6. Waste	**877.49**	**2,086.59**	**4.29**							**3.90**	**22.31**	**27.32**	**4.33**
A. Solid Waste Disposal on Land	(6) NA,NE,NO	2,069.54								NA,NE,NO	NA,NE,NO	20.70	
B. Waste-water Handling		13.41	4.16							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	(6) 877.49	3.65	0.12							3.90	22.31	6.63	4.33
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	**28,696.80**	**0.34**	**0.85**							**284.42**	**34.42**	**11.25**	**91.13**
Aviation	20,139.19	0.21	0.64							94.40	14.51	4.94	5.13
Marine	8,557.61	0.13	0.22							190.01	19.91	6.31	86.00
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**5,239.40**												

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	**571,226.85**	**4,137.43**	**181.05**	**7,296.21**	**16,625.09**	**162.12**	**479.90**	**0.06**	**0.05**	**2,089.22**	**7,561.92**	**2,103.41**	**2,011.11**
1. Energy	**554,178.26**	**1,102.25**	**18.79**							**2,078.21**	**7,248.05**	**1,309.67**	**1,951.58**
A. Fuel Combustion — Reference Approach[2]	552,984.38												
Sectoral Approach[2]	544,898.62	96.08	18.59							2,066.81	7,194.01	874.00	1,932.97
1. Energy Industries	202,441.40	12.12	5.16							520.59	130.53	9.55	1,443.20
2. Manufacturing Industries and Construction	93,699.88	16.04	4.70							348.40	772.96	29.35	261.70
3. Transport	119,806.09	22.28	5.77							960.37	5,394.25	753.86	62.82
4. Other Sectors	125,146.27	45.54	2.84							207.04	886.69	79.61	160.88
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	1,006.17	0.20							11.40	54.03	435.68	18.61
1. Solid Fuels	366.77	556.22	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	**14,787.54**	**9.51**	**47.69**	**7,296.21**	**16,625.09**	**162.12**	**479.90**	**0.06**	**0.05**	**6.67**	**282.13**	**241.77**	**56.63**
A. Mineral Products	9,488.59	0.72	NE							NE	3.40	10.69	10.16
B. Chemical Industry	3,073.51	8.00	47.65	NO	NO	NO	NO	NO	NO	2.25	85.69	148.08	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	80.93	NE
E. Production of Halocarbons and SF_6					14,320.56		77.13		NA,NO				
F. Consumption of Halocarbons and SF_6				7,296.21	2,304.53	162.12	120.60	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**		**NE,NO**							**NO**	**NO**	**525.64**	**NO**
4. Agriculture		**1,037.93**	**107.60**							**NA,NO**	**NA,NO**	**NA,NE,NO**	**NO**
A. Enteric Fermentation		868.57											
B. Manure Management		169.36	8.07									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils[4]		IE,NA,NE	99.53									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	NA							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	[5] **1,368.64**	**1.35**	**2.56**							**0.25**	**8.86**	**NA,NO**	**NA**
A. Forest Land	[5] -13,568.26	0.50	0.01							0.12	4.36	NO	
B. Cropland	[5] 15,867.43	0.01	2.53							0.00	0.07	NO	
C. Grassland	[5] -6,970.71	0.17	0.00							0.04	1.51	NO	
D. Wetlands	[5] 510.77	NE,NO	0.01							NO	NO	NO	
E. Settlements	[5] 6,715.32	0.67	0.00							0.08	2.93	NO	
F. Other Land	[5] NE,NO	NE,NO	NE,NO							NO	NO	NO	
G. Other	[5] -1,185.91	NE	NE							NE	NE	NA	NA
6. Waste	**892.41**	**1,986.40**	**4.41**							**4.09**	**22.88**	**26.33**	**2.90**
A. Solid Waste Disposal on Land	[6] NA,NE,NO	1,969.10								NA,NE,NO	NA,NE,NO	19.69	
B. Waste-water Handling		13.31	4.28							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	[6] 892.41	3.99	0.13							4.09	22.88	6.63	2.90
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	**30,799.27**	**0.36**	**0.92**							**310.15**	**37.20**	**12.05**	**96.45**
Aviation	21,308.55	0.21	0.68							100.28	15.12	5.11	5.42
Marine	9,490.71	0.15	0.24							209.88	22.08	6.94	91.02
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**5,478.49**												

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		**547,118.71**	**3,876.13**	**184.25**	**10,496.86**	**18,968.29**	**187.70**	**398.05**	**0.05**	**0.05**	**1,952.51**	**7,070.62**	**2,018.16**	**1,652.80**
1. Energy		**530,620.90**	**1,048.84**	**18.14**							**1,943.30**	**6,748.90**	**1,258.60**	**1,591.96**
A. Fuel Combustion	Reference Approach (2)	529,307.27												
	Sectoral Approach (2)	523,169.73	91.31	17.96							1,938.52	6,699.67	801.60	1,573.13
1. Energy Industries		189,975.90	12.23	4.70							440.67	71.05	7.53	1,144.39
2. Manufacturing Industries and Construction		92,397.28	16.62	4.56							338.81	761.71	29.51	226.56
3. Transport		121,337.41	20.52	5.81							934.15	5,039.60	686.28	52.22
4. Other Sectors		115,828.43	41.84	2.79							193.65	818.20	76.70	145.30
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	957.54	0.18							4.78	49.22	457.00	18.84
1. Solid Fuels		459.63	532.68	0.00							0.38	30.86	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		**14,903.51**	**8.02**	**48.29**	**10,496.86**	**18,968.29**	**187.70**	**398.05**	**0.05**	**0.05**	**7.17**	**289.49**	**223.77**	**59.71**
A. Mineral Products		10,329.23	0.71	NE							NE	3.35	10.13	13.41
B. Chemical Industry		2,612.38	6.62	48.26	NO	NO	NO	NO	NO	NO	2.60	86.78	132.14	35.62
C. Metal Production		1,961.90	0.69	0.03				220.26		0.02	4.57	199.36	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					10,496.86	3,346.07	187.70	139.47	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**							**NO**	**NO**	**511.23**	**NO**
4. Agriculture			**1,006.92**	**110.90**							**NA,NO**	**NA,NO**	**NA,NE,NO**	**NO**
A. Enteric Fermentation			840.24											
B. Manure Management			166.68	8.15									NO	
C. Rice Cultivation			NA,NO										NA,NO	
D. Agricultural Soils (4)			IE,NA,NE	102.75									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	NA							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry		(5) **1,087.84**	**1.58**	**2.56**							**0.30**	**10.43**	**NA,NO**	**NA**
A. Forest Land		(5) -13,318.86	0.66	0.01							0.16	5.72	NO	
B. Cropland		(5) 15,632.06	0.01	2.53							0.00	0.06	NO	
C. Grassland		(5) -7,033.83	0.14	0.00							0.04	1.26	NO	
D. Wetlands		(5) 455.89	NE,NO	0.01							NO	NO	NO	
E. Settlements		(5) 6,717.41	0.78	0.01							0.10	3.40	NO	
F. Other Land		(5) NE,NO	NE,NO	NE,NO							NO	NO	NO	
G. Other		(5) -1,364.84	NE	NE							NE	NE	NA	NA
6. Waste		**506.46**	**1,810.77**	**4.36**							**1.74**	**21.80**	**24.56**	**1.13**
A. Solid Waste Disposal on Land		(6) NA,NE,NO	1,796.69								NA,NE,NO	NA,NE,NO	17.97	
B. Waste-water Handling			13.92	4.28							NA,NE	NA,NE	NA,NE	
C. Waste Incineration		(6) 506.46	0.16	0.07							1.74	21.80	6.59	1.13
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		**32,936.81**	**0.37**	**0.98**							**336.00**	**39.63**	**13.03**	**113.77**
Aviation		22,660.85	0.21	0.72							106.47	15.77	5.35	7.20
Marine		10,275.97	0.16	0.26							229.53	23.86	7.67	106.57
Multilateral Operations		**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass		**5,761.69**												

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		**549,906.80**	**3,650.17**	**182.35**	**14,276.50**	**16,751.47**	**193.40**	**388.13**	**0.05**	**0.05**	**1,915.17**	**6,787.24**	**1,874.23**	**1,631.00**
1. Energy		**534,030.68**	**961.82**	**18.24**							**1,907.02**	**6,490.14**	**1,157.91**	**1,570.70**
A. Fuel Combustion	Reference Approach (2)	537,557.08												
	Sectoral Approach (2)	526,951.01	91.80	18.06							1,902.79	6,441.72	744.51	1,559.87
1. Energy Industries		194,652.75	13.45	4.94							442.48	88.80	5.58	1,187.49
2. Manufacturing Industries and Construction		91,844.66	16.10	4.45							338.12	727.12	29.41	201.62
3. Transport		120,847.45	18.87	5.88							911.03	4,848.29	631.36	47.60
4. Other Sectors		116,412.15	43.29	2.69							187.37	769.43	76.82	119.81
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	870.03	0.18							4.22	48.42	413.40	10.83
1. Solid Fuels		158.41	454.48	0.00							0.38	30.75	0.26	9.46
2. Oil and Natural Gas		6,921.26	415.54	0.18							3.84	17.68	413.14	1.37
2. Industrial Processes		**14,871.06**	**6.14**	**49.19**	**14,276.50**	**16,751.47**	**193.40**	**388.13**	**0.05**	**0.05**	**6.15**	**265.76**	**198.35**	**59.06**
A. Mineral Products		10,271.82	0.71	NE							NE	3.35	9.93	13.09
B. Chemical Industry		2,812.40	4.80	49.16	NO	NO	NO	NO	NO	NO	2.49	69.16	107.12	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					14,276.50	4,634.34	193.40	137.56	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**							**NO**	**NO**	**494.69**	**NO**
4. Agriculture			**1,006.97**	**107.95**							**NA,NO**	**NA,NO**	**NA,NE,NO**	**NO**
A. Enteric Fermentation			839.55											
B. Manure Management			167.42	8.38									NO	
C. Rice Cultivation			NA,NO										NA,NO	
D. Agricultural Soils (4)			IE,NA,NE	99.57									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	NA							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry		(5) **494.05**	**1.29**	**2.56**							**0.22**	**7.88**	**NA,NO**	**NA**
A. Forest Land		(5) -13,276.20	0.36	0.01							0.09	3.17	NO	
B. Cropland		(5) 15,540.57	0.01	2.53							0.00	0.06	NO	
C. Grassland		(5) -7,332.90	0.15	0.00							0.04	1.31	NO	
D. Wetlands		(5) 350.93	NE,NO	0.01							NO	NO	NO	
E. Settlements		(5) 6,680.29	0.76	0.01							0.09	3.34	NO	
F. Other Land		(5) NE,NO	NE,NO	NE,NO							NO	NO	NO	
G. Other		(5) -1,468.64	NE	NE							NE	NE	NA	NA
6. Waste		**511.01**	**1,673.95**	**4.42**							**1.78**	**23.46**	**23.27**	**1.24**
A. Solid Waste Disposal on Land		(6) NA,NE,NO	1,659.92								NA,NE,NO	NA,NE,NO	16.60	
B. Waste-water Handling			13.82	4.26							NA,NE	NA,NE	NA,NE	
C. Waste Incineration		(6) 511.01	0.20	0.16							1.78	23.46	6.67	1.24
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		**35,986.16**	**0.37**	**1.07**							**355.19**	**42.11**	**13.54**	**107.01**
Aviation		25,235.59	0.21	0.80							118.03	17.19	5.72	8.02
Marine		10,750.57	0.17	0.27							237.16	24.92	7.82	98.99
Multilateral Operations		**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass		**5,823.17**												

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] 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		**540,714.69**	**3,396.06**	**148.07**	**17,895.95**	**9,987.45**	**224.58**	**367.54**	**0.05**	**0.06**	**1,823.91**	**6,444.61**	**1,697.34**	**1,248.47**
1. Energy		**525,265.82**	**870.12**	**17.74**							**1,815.70**	**6,130.83**	**1,044.37**	**1,198.44**
A. Fuel Combustion	Reference Approach (2)	532,356.57												
	Sectoral Approach (2)	519,228.26	92.72	17.57							1,811.12	6,092.86	679.21	1,188.70
1. Energy Industries		185,055.40	13.44	4.48							397.88	81.03	4.97	875.14
2. Manufacturing Industries and Construction		92,447.24	15.75	4.44							325.21	708.88	28.94	161.28
3. Transport		122,033.78	17.31	5.90							880.83	4,515.13	565.42	38.37
4. Other Sectors		116,542.22	46.13	2.65							181.96	779.90	78.53	110.61
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	777.40	0.17							4.59	37.97	365.17	9.74
1. Solid Fuels		112.08	380.84	0.00							0.32	23.94	0.26	8.01
2. Oil and Natural Gas		5,925.47	396.56	0.17							4.27	14.03	364.90	1.73
2. Industrial Processes		**14,740.75**	**5.35**	**17.31**	**17,895.95**	**9,987.45**	**224.58**	**367.54**	**0.05**	**0.06**	**6.30**	**282.88**	**167.57**	**48.58**
A. Mineral Products		9,803.22	0.59	NE							NE	1.56	8.57	8.94
B. Chemical Industry		2,846.55	4.03	17.28	NO	NO	NO	NO	NO	NO	2.69	66.06	76.41	31.30
C. Metal Production		2,090.98	0.73	0.03				187.75		0.03	3.61	215.26	1.93	8.34
D. Other Production (3)		NE									NE	NE	80.66	NE
E. Production of Halocarbons and SF_6						4,881.55		19.50		NA,NO				
F. Consumption of Halocarbons and SF_6					17,895.95	5,105.90	224.58	160.29	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**							**NO**	**NO**	**463.73**	**NO**
4. Agriculture			**1,004.08**	**106.09**							**NA,NO**	**NA,NO**	**NA,NE,NO**	**NO**
A. Enteric Fermentation			841.44											
B. Manure Management			162.63	8.67									NO	
C. Rice Cultivation			NA,NO										NA,NO	
D. Agricultural Soils(4)			IE,NA,NE	97.42									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	NA							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry		(5) **238.53**	**1.22**	**2.56**							**0.21**	**7.30**	**NA,NO**	**NA**
A. Forest Land		(5) -13,438.43	0.06	0.01							0.01	0.50	NO	
B. Cropland		(5) 15,467.23	0.01	2.53							0.00	0.11	NO	
C. Grassland		(5) -7,377.04	0.38	0.00							0.09	3.34	NO	
D. Wetlands		(5) 468.33	NE,NO	0.01							NO	NO	NO	
E. Settlements		(5) 6,634.51	0.76	0.01							0.09	3.34	NO	
F. Other Land		(5) NE,NO	NE,NO	NE,NO							NO	NO	NO	
G. Other		(5) -1,516.08	NE	NE							NE	NE	NA	NA
6. Waste		**469.59**	**1,515.30**	**4.37**							**1.69**	**23.60**	**21.67**	**1.46**
A. Solid Waste Disposal on Land		(6) NA,NE,NO	1,501.07								NA,NE,NO	NA,NE,NO	15.01	
B. Waste-water Handling			14.01	4.21							NA,NE	NA,NE	NA,NE	
C. Waste Incineration		(6) 469.59	0.22	0.16							1.69	23.60	6.66	1.46
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		**35,342.24**	**0.30**	**1.07**							**299.51**	**36.26**	**11.44**	**70.71**
Aviation		27,391.95	0.18	0.87							126.42	17.85	5.80	6.10
Marine		7,950.28	0.12	0.20							173.09	18.41	5.64	64.61
Multilateral Operations		**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass		**6,411.18**												

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	**547,882.61**	**3,167.29**	**144.65**	**22,876.21**	**8,698.54**	**260.51**	**466.39**	**0.08**	**0.08**	**1,784.94**	**5,683.19**	**1,560.69**	**1,252.73**
1. Energy	**533,548.31**	**791.66**	**17.87**							**1,777.00**	**5,365.54**	**941.30**	**1,210.54**
A. Fuel Combustion — Reference Approach [2]	545,632.68												
Sectoral Approach [2]	527,812.94	78.88	17.72							1,773.80	5,328.11	588.94	1,201.68
1. Energy Industries	195,507.06	12.51	4.93							429.24	92.51	6.77	933.08
2. Manufacturing Industries and Construction	92,200.99	15.22	4.35							313.40	599.61	28.50	145.84
3. Transport	121,301.84	15.19	5.85							836.16	3,957.97	484.18	28.86
4. Other Sectors	115,886.74	35.88	2.50							170.90	670.69	68.23	90.85
5. Other	2,916.31	0.08	0.09							24.10	7.33	1.26	3.04
B. Fugitive Emissions from Fuels	5,735.37	712.78	0.15							3.20	37.43	352.36	8.86
1. Solid Fuels	102.36	333.43	0.00							0.31	24.42	0.20	7.31
2. Oil and Natural Gas	5,633.01	379.35	0.15							2.89	13.00	352.15	1.55
2. Industrial Processes	**14,296.69**	**5.04**	**17.90**	**22,876.21**	**8,698.54**	**260.51**	**466.39**	**0.08**	**0.08**	**5.91**	**283.81**	**163.36**	**40.99**
A. Mineral Products	9,285.12	0.59	NE							NE	2.75	9.79	10.51
B. Chemical Industry	3,028.83	3.78	17.87	NO	NO	NO	NO	NO	NO	2.43	83.28	72.89	22.94
C. Metal Production	1,982.75	0.68	0.03				257.46		0.05	3.48	197.78	1.77	7.53
D. Other Production [3]	NE									NE	NE	78.91	NE
E. Production of Halocarbons and SF_6					2,619.64		23.08		NA,NO				
F. Consumption of Halocarbons and SF_6				22,876.21	6,078.90	260.51	185.85	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**							**NO**	**NO**	**435.44**	**NO**
4. Agriculture		**962.35**	**101.80**							**NA,NO**	**NA,NO**	**NA,NE,NO**	**NO**
A. Enteric Fermentation		809.08											
B. Manure Management		153.27	7.97									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils[4]		IE,NA,NE	93.84									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	NA							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	[5] **-438.71**	**1.57**	**2.50**							**0.29**	**10.29**	**NA,NO**	**NA**
A. Forest Land	[5] -13,698.05	0.20	0.01							0.05	1.75	NO	
B. Cropland	[5] 15,061.46	0.02	2.47							0.00	0.17	NO	
C. Grassland	[5] -7,574.92	0.57	0.00							0.14	4.96	NO	
D. Wetlands	[5] 464.18	NE,NO	0.01							NO	NO	NO	
E. Settlements	[5] 6,581.75	0.78	0.01							0.10	3.42	NO	
F. Other Land	[5] NE,NO	NE,NO	NE,NO							NO	NO	NO	
G. Other	[5] -1,273.13	NE	NE							NE	NE	NA	NA
6. Waste	**476.32**	**1,406.66**	**4.57**							**1.73**	**23.55**	**20.59**	**1.20**
A. Solid Waste Disposal on Land	[6] NA,NE,NO	1,392.45								NA,NE,NO	NA,NE,NO	13.92	
B. Waste-water Handling		13.99	4.41							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	[6] 476.32	0.23	0.16							1.73	23.55	6.67	1.20
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	**37,403.12**	**0.26**	**1.14**							**291.40**	**35.32**	**10.98**	**56.65**
Aviation	30,213.21	0.15	0.96							138.02	18.68	6.02	6.91
Marine	7,189.91	0.11	0.18							153.38	16.64	4.96	49.73
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**6,715.57**												

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	**560,013.72**	**2,891.85**	**136.48**	**27,848.00**	**9,335.83**	**157.40**	**386.42**	**0.07**	**0.06**	**1,748.94**	**5,328.49**	**1,460.49**	**1,145.57**
1. Energy	**547,364.81**	**757.24**	**17.91**							**1,741.61**	**4,997.41**	**870.71**	**1,109.54**
A. Fuel Combustion — Reference Approach[2]	551,420.85												
Sectoral Approach[2]	541,433.93	73.53	17.76							1,738.23	4,970.71	514.89	1,099.77
1. Energy Industries	206,196.34	13.42	5.20							455.49	92.20	5.61	829.71
2. Manufacturing Industries and Construction	92,113.55	14.07	4.35							300.50	634.38	28.46	156.07
3. Transport	121,401.00	13.30	5.66							792.26	3,576.28	415.28	25.69
4. Other Sectors	118,801.14	32.66	2.47							167.32	660.48	64.31	85.31
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	683.71	0.15							3.38	26.70	355.81	9.78
1. Solid Fuels	101.68	301.86	0.00							0.25	13.68	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	**13,078.99**	**4.69**	**15.54**	**27,848.00**	**9,335.83**	**157.40**	**386.42**	**0.07**	**0.06**	**4.64**	**273.31**	**150.27**	**33.69**
A. Mineral Products	8,446.83	0.58	NE							NE	2.54	9.22	9.07
B. Chemical Industry	3,117.14	3.68	15.52	NO	NO	NO	NO	NO	NO	1.62	82.24	59.30	16.83
C. Metal Production	1,515.02	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				27,848.00	6,948.41	157.40	114.78	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**							**NO**	**NO**	**420.82**	**NO**
4. Agriculture		**904.02**	**95.98**							**NA,NO**	**NA,NO**	**NA,NE,NO**	**NO**
A. Enteric Fermentation		758.33											
B. Manure Management		145.69	7.76									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils[4]		IE,NA,NE	88.22									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	NA							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	[5] **-928.21**	**1.90**	**2.44**							**0.37**	**12.89**	**NA,NO**	**NA**
A. Forest Land	[5] -14,207.99	0.28	0.01							0.07	2.42	NO	
B. Cropland	[5] 14,698.04	0.03	2.41							0.01	0.22	NO	
C. Grassland	[5] -7,628.69	0.75	0.01							0.19	6.58	NO	
D. Wetlands	[5] 503.28	NE,NO	0.01							NO	NO	NO	
E. Settlements	[5] 6,548.82	0.84	0.01							0.10	3.68	NO	
F. Other Land	[5] NE,NO	NE,NO	NE,NO							NO	NO	NO	
G. Other	[5] -841.66	NE	NE							NE	NE	NA	NA
6. Waste	**498.14**	**1,224.01**	**4.61**							**2.33**	**44.88**	**18.70**	**2.34**
A. Solid Waste Disposal on Land	[6] NA,NE,NO	1,208.37								NA,NE,NO	NA,NE,NO	12.08	
B. Waste-water Handling		15.48	4.45							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	[6] 498.14	0.16	0.16							2.33	44.88	6.61	2.34
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	**36,843.91**	**0.24**	**1.12**							**288.91**	**34.67**	**10.66**	**54.37**
Aviation	29,448.88	0.12	0.94							133.71	17.55	5.66	7.49
Marine	7,395.03	0.12	0.19							155.20	17.12	5.00	46.88
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**7,388.13**												

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		**542,486.84**	**2,748.30**	**131.23**	**35,171.23**	**9,509.70**	**154.38**	**320.66**	**0.07**	**0.06**	**1,660.51**	**4,686.42**	**1,370.79**	**1,018.19**
1. Energy		**531,277.40**	**738.53**	**17.66**							**1,655.94**	**4,427.80**	**793.17**	**985.93**
A. Fuel Combustion	Reference Approach (2)	533,474.46												
	Sectoral Approach (2)	525,620.05	66.09	17.51							1,652.22	4,408.21	448.11	978.92
1. Energy Industries		203,543.65	13.90	5.26							447.47	90.35	7.82	751.34
2. Manufacturing Industries and Construction		83,710.95	12.87	4.27							281.25	573.31	27.69	131.50
3. Transport		123,947.87	11.92	5.54							749.95	3,184.98	352.46	26.51
4. Other Sectors		111,360.95	27.31	2.35							151.98	551.83	58.87	66.67
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	672.44	0.15							3.73	19.59	345.06	7.02
1. Solid Fuels		107.95	301.96	0.00							0.26	7.11	0.13	5.81
2. Oil and Natural Gas		5,549.40	370.47	0.14							3.46	12.48	344.93	1.21
2. Industrial Processes		**12,487.87**	**4.79**	**8.98**	**35,171.23**	**9,509.70**	**154.38**	**320.66**	**0.07**	**0.06**	**2.43**	**223.24**	**147.70**	**31.32**
A. Mineral Products		8,287.55	0.59	NE							NE	2.53	9.60	12.00
B. Chemical Industry		3,028.84	3.92	8.96	NO	NO	NO	NO	NO	NO	1.09	39.82	56.93	13.05
C. Metal Production		1,171.48	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					35,171.23	7,475.47	154.38	112.82	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**							**NO**	**NO**	**412.39**	**NO**
4. Agriculture			**892.34**	**97.57**							**NA,NO**	**NA,NO**	**NA,NE,NO**	**NO**
A. Enteric Fermentation			749.35											
B. Manure Management			142.99	7.46									NO	
C. Rice Cultivation			NA,NO										NA,NO	
D. Agricultural Soils(4)			IE,NA,NE	90.12									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	NA							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry		(5) **-1,775.58**	**1.70**	**2.38**							**0.33**	**11.76**	**NA,NO**	**NA**
A. Forest Land		(5) -14,894.59	0.24	0.01							0.06	2.05	NO	
B. Cropland		(5) 14,425.29	0.02	2.36							0.01	0.21	NO	
C. Grassland		(5) -7,800.14	0.73	0.01							0.18	6.37	NO	
D. Wetlands		(5) 335.85	NE,NO	0.01							NO	NO	NO	
E. Settlements		(5) 6,463.45	0.72	0.00							0.09	3.13	NO	
F. Other Land		(5) NE,NO	NE,NO	NE,NO							NO	NO	NO	
G. Other		(5) -305.44	NE	NE							NE	NE	NA	NA
6. Waste		**497.14**	**1,110.94**	**4.64**							**1.80**	**23.63**	**17.53**	**0.94**
A. Solid Waste Disposal on Land		(6) NA,NE,NO	1,095.07								NA,NE,NO	NA,NE,NO	10.95	
B. Waste-water Handling			15.70	4.48							NA,NE	NA,NE	NA,NE	
C. Waste Incineration		(6) 497.14	0.16	0.16							1.80	23.63	6.58	0.94
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		**34,776.02**	**0.21**	**1.06**							**252.31**	**30.82**	**9.61**	**45.96**
Aviation		28,930.70	0.11	0.92							130.19	17.30	5.61	6.07
Marine		5,845.32	0.09	0.15							122.12	13.52	4.00	39.89
Multilateral Operations		**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass		**7,639.51**												

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]		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		**552,304.58**	**2,470.14**	**129.20**	**40,745.94**	**10,389.06**	**157.57**	**277.33**	**0.06**	**0.06**	**1,630.95**	**4,192.74**	**1,245.87**	**996.67**
1. Energy		**540,729.63**	**598.72**	**17.43**							**1,626.30**	**4,009.08**	**666.42**	**962.03**
A. Fuel Combustion	Reference Approach [2]	541,439.13												
	Sectoral Approach [2]	535,355.36	63.24	17.30							1,623.37	3,987.64	388.44	953.52
1. Energy Industries		211,087.40	13.10	5.28							470.34	95.96	5.94	743.99
2. Manufacturing Industries and Construction		84,857.40	13.72	4.27							276.08	553.99	27.52	120.33
3. Transport		123,749.04	10.66	5.37							709.44	2,839.71	296.84	26.36
4. Other Sectors		112,499.35	25.67	2.29							144.19	489.99	56.81	59.56
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	535.48	0.13							2.93	21.44	277.98	8.51
1. Solid Fuels		111.87	259.87	0.00							0.28	10.74	0.12	7.28
2. Oil and Natural Gas		5,262.40	275.61	0.12							2.65	10.70	277.87	1.23
2. Industrial Processes		**13,290.45**	**5.78**	**9.41**	**40,745.94**	**10,389.06**	**157.57**	**277.33**	**0.06**	**0.06**	**2.57**	**149.25**	**156.81**	**33.72**
A. Mineral Products		8,473.82	0.62	NE							NE	2.67	9.24	16.37
B. Chemical Industry		2,969.14	4.57	9.38	NO	NO	NO	NO	NO	NO	1.13	37.63	65.88	9.86
C. Metal Production		1,847.49	0.59	0.02				110.91		0.03	1.44	108.95	1.57	7.49
D. Other Production [3]		NE									NE	NE	80.12	NE
E. Production of Halocarbons and SF_6						1,981.33		55.71		NA,NO				
F. Consumption of Halocarbons and SF_6					40,745.94	8,407.73	157.57	110.71	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**							**NO**	**NO**	**406.51**	**NO**
4. Agriculture			**893.17**	**95.42**							**NA,NO**	**NA,NO**	**NA,NE,NO**	**NO**
A. Enteric Fermentation			753.26											
B. Manure Management			139.91	7.34									NO	
C. Rice Cultivation			NA,NO										NA,NO	
D. Agricultural Soils[4]			IE,NA,NE	88.08									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	NA							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry		(5) **-2,162.54**	**1.62**	**2.33**							**0.31**	**10.84**	**NA,NO**	**NA**
A. Forest Land		(5) -15,484.86	0.20	0.01							0.05	1.73	NO	
B. Cropland		(5) 14,211.42	0.02	2.31							0.01	0.19	NO	
C. Grassland		(5) -7,893.82	0.64	0.00							0.16	5.63	NO	
D. Wetlands		(5) 541.31	NE,NO	0.00							NO	NO	NO	
E. Settlements		(5) 6,436.09	0.75	0.01							0.09	3.29	NO	
F. Other Land		(5) NE,NO	NE,NO	NE,NO							NO	NO	NO	
G. Other		(5) 27.31	NE	NE							NE	NE	NA	NA
6. Waste		**447.04**	**970.85**	**4.61**							**1.76**	**23.57**	**16.12**	**0.91**
A. Solid Waste Disposal on Land		(6) NA,NE,NO	954.35								NA,NE,NO	NA,NE,NO	9.54	
B. Waste-water Handling			16.34	4.45							NA,NE	NA,NE	NA,NE	
C. Waste Incineration		(6) 447.04	0.16	0.16							1.76	23.57	6.58	0.91
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		**36,522.36**	**0.22**	**1.11**							**276.39**	**33.38**	**10.39**	**55.81**
Aviation		29,626.35	0.11	0.94							133.06	17.43	5.66	7.16
Marine		6,896.01	0.11	0.17							143.33	15.95	4.73	48.65
Multilateral Operations		**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass		**8,532.36**												

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	**551,435.38**	**2,385.21**	**131.12**	**44,749.28**	**9,428.88**	**157.74**	**342.42**	**0.05**	**0.05**	**1,583.03**	**3,887.85**	**1,152.60**	**830.36**
1. Energy	**540,491.23**	**583.66**	**17.16**							**1,578.16**	**3,712.53**	**595.08**	**796.81**
A. Fuel Combustion — Reference Approach (2)	543,203.46												
Sectoral Approach (2)	535,210.95	61.33	17.03							1,575.24	3,695.02	342.75	786.85
1. Energy Industries	209,431.92	13.64	5.10							452.73	97.00	6.10	584.51
2. Manufacturing Industries and Construction	83,256.57	13.39	4.37							278.35	587.98	28.42	118.18
3. Transport	125,151.71	9.59	5.29							684.41	2,543.81	251.62	26.35
4. Other Sectors	114,318.00	24.63	2.18							135.30	458.56	55.30	54.18
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	522.33	0.13							2.92	17.51	252.33	9.95
1. Solid Fuels	168.08	234.90	0.01							0.36	6.61	0.10	8.61
2. Oil and Natural Gas	5,112.20	287.44	0.13							2.56	10.90	252.23	1.35
2. Industrial Processes	**13,750.38**	**5.36**	**12.11**	**44,749.28**	**9,428.88**	**157.74**	**342.42**	**0.05**	**0.05**	**2.90**	**141.49**	**135.92**	**32.70**
A. Mineral Products	8,622.09	0.61	NE							NE	2.61	9.36	16.55
B. Chemical Industry	3,074.79	4.09	12.08	NO	NO	NO	NO	NO	NO	1.25	29.03	44.96	8.77
C. Metal Production	2,053.49	0.66	0.03				153.04		0.02	1.65	109.85	1.62	7.38
D. Other Production (3)	NE									NE	NE	79.98	NE
E. Production of Halocarbons and SF_6					444.68		90.23		NA,NO				
F. Consumption of Halocarbons and SF_6				44,749.28	8,983.03	157.74	99.15	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**							**NO**	**NO**	**406.29**	**NO**
4. Agriculture		**899.99**	**94.98**							**NA,NO**	**NA,NO**	**NA,NE,NO**	**NO**
A. Enteric Fermentation		759.15											
B. Manure Management		140.84	7.19									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils(4)		IE,NA,NE	87.79									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	NA							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	(5) **-3,225.09**	**1.55**	**2.28**							**0.30**	**10.44**	**NA,NO**	**NA**
A. Forest Land	(5) -16,108.07	0.26	0.01							0.06	2.29	NO	
B. Cropland	(5) 13,869.99	0.02	2.26							0.00	0.16	NO	
C. Grassland	(5) -8,123.68	0.56	0.00							0.14	4.90	NO	
D. Wetlands	(5) 392.78	NE,NO	0.00							NO	NO	NO	
E. Settlements	(5) 6,384.09	0.71	0.00							0.09	3.09	NO	
F. Other Land	(5) NE,NO	NE,NO	NE,NO							NO	NO	NO	
G. Other	(5) 359.81	NE	NE							NE	NE	NA	NA
6. Waste	**418.86**	**894.64**	**4.59**							**1.67**	**23.39**	**15.32**	**0.85**
A. Solid Waste Disposal on Land	(6) NA,NE,NO	877.81								NA,NE,NO	NA,NE,NO	8.78	
B. Waste-water Handling		16.68	4.43							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	(6) 418.86	0.15	0.16							1.67	23.39	6.54	0.85
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	**40,246.61**	**0.23**	**1.23**							**308.94**	**36.53**	**11.57**	**75.92**
Aviation	32,490.72	0.10	1.03							145.40	18.62	6.00	8.47
Marine	7,755.89	0.12	0.19							163.54	17.91	5.57	67.46
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**9,646.81**												

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		**548,514.81**	**2,307.55**	**127.29**	**50,050.49**	**10,196.79**	**146.95**	**261.42**	**0.05**	**0.05**	**1,548.81**	**3,481.04**	**1,078.16**	**697.09**
1. Energy		**537,945.90**	**528.24**	**17.10**							**1,544.60**	**3,307.90**	**532.73**	**663.42**
A. Fuel Combustion	Reference Approach [2]	543,923.50												
	Sectoral Approach [2]	532,074.84	57.72	16.95							1,541.46	3,289.37	301.78	654.49
1. Energy Industries		209,792.32	13.17	5.27							466.72	101.90	5.66	463.53
2. Manufacturing Industries and Construction		83,331.89	13.11	4.32							272.65	561.31	27.80	115.03
3. Transport		126,009.57	8.69	5.14							652.20	2,228.76	213.17	26.65
4. Other Sectors		110,205.17	22.67	2.14							128.07	390.52	53.96	46.00
5. Other		2,735.89	0.07	0.08							21.82	6.88	1.18	3.28
B. Fugitive Emissions from Fuels		5,871.06	470.53	0.15							3.14	18.53	230.95	8.93
1. Solid Fuels		111.98	194.72	0.00							0.24	6.13	0.11	7.67
2. Oil and Natural Gas		5,759.08	275.81	0.15							2.90	12.40	230.84	1.26
2. Industrial Processes		**13,945.83**	**4.88**	**9.53**	**50,050.49**	**10,196.79**	**146.95**	**261.42**	**0.05**	**0.05**	**2.57**	**142.83**	**129.62**	**32.86**
A. Mineral Products		8,513.37	0.51	NE							NE	4.28	9.61	17.25
B. Chemical Industry		2,974.57	3.53	9.50	NO	NO	NO	NO	NO	NO	1.00	25.23	40.14	7.22
C. Metal Production		2,457.89	0.84	0.03				60.02		0.01	1.57	113.31	1.59	8.39
D. Other Production [3]		NE									NE	NE	78.29	NE
E. Production of Halocarbons and SF_6						442.32		110.28		NA,NO				
F. Consumption of Halocarbons and SF_6					50,050.49	9,752.56	146.95	91.13	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**		**NE,NO**							**NO**	**NO**	**400.85**	**NO**
4. Agriculture			**910.75**	**93.75**							**NA,NO**	**NA,NO**	**,NA,NE,NO**	**NO**
A. Enteric Fermentation			768.18											
B. Manure Management			142.57	6.99									NO	
C. Rice Cultivation			NA,NO										NA,NO	
D. Agricultural Soils[4]			IE,NA,NE	86.76									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	NA							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry		[5] **-3,740.98**	**1.12**	**2.23**							**0.20**	**7.03**	**NA,NO**	**NA**
A. Forest Land		[5] -15,587.08	0.06	0.01							0.01	0.49	NO	
B. Cropland		[5] 13,530.54	0.01	2.21							0.00	0.12	NO	
C. Grassland		[5] -8,374.31	0.42	0.00							0.10	3.64	NO	
D. Wetlands		[5] 442.51	NE,NO	0.00							NO	NO	NO	
E. Settlements		[5] 6,329.10	0.64	0.00							0.08	2.78	NO	
F. Other Land		[5] NE,NO	NE,NO	NE,NO							NO	NO	NO	
G. Other		[5] -81.74	NE	NE							NE	NE	NA	NA
6. Waste		**364.06**	**862.55**	**4.68**							**1.44**	**23.28**	**14.97**	**0.81**
A. Solid Waste Disposal on Land		[6] NA,NE,NO	845.64								NA,NE,NO	NA,NE,NO	8.46	
B. Waste-water Handling			16.78	4.52							NA,NE	NA,NE	NA,NE	
C. Waste Incineration		[6] 364.06	0.14	0.16							1.44	23.28	6.52	0.81
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		**43,446.32**	**0.24**	**1.32**							**331.90**	**38.90**	**12.50**	**88.44**
Aviation		35,201.38	0.11	1.12							157.18	19.87	6.43	9.17
Marine		8,244.94	0.13	0.21							174.72	19.03	6.07	79.27
Multilateral Operations		**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass		**11,114.46**												

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	**545,086.64**	**2,238.47**	**121.37**	**54,826.43**	**10,538.03**	**146.10**	**305.85**	**0.04**	**0.04**	**1,491.02**	**3,274.80**	**1,031.53**	**662.45**
1. Energy	**535,289.80**	**495.92**	**17.08**							**1,486.97**	**3,061.69**	**492.75**	**629.48**
A. Fuel Combustion — Reference Approach[2]	542,716.21												
Sectoral Approach[2]	530,256.96	55.77	16.96							1,484.20	3,041.06	272.77	620.77
1. Energy Industries	214,382.95	11.29	5.47							471.63	102.05	5.81	440.26
2. Manufacturing Industries and Construction	81,827.28	13.27	4.34							260.87	567.58	27.14	106.73
3. Transport	126,207.28	7.97	5.04							613.66	1,985.51	184.61	25.35
4. Other Sectors	105,017.61	23.16	2.02							116.46	378.81	54.01	45.03
5. Other	2,821.83	0.08	0.08							21.57	7.11	1.20	3.40
B. Fugitive Emissions from Fuels	5,032.84	440.15	0.13							2.78	20.63	219.98	8.70
1. Solid Fuels	138.77	180.42	0.00							0.26	10.01	0.13	7.75
2. Oil and Natural Gas	4,894.07	259.73	0.12							2.51	10.62	219.85	0.95
2. Industrial Processes	**13,404.43**	**4.70**	**7.66**	**54,826.43**	**10,538.03**	**146.10**	**305.85**	**0.04**	**0.04**	**2.26**	**178.16**	**122.85**	**32.21**
A. Mineral Products	8,568.78	0.83	NE							NE	4.67	9.58	18.39
B. Chemical Industry	2,709.20	3.21	7.63	NO	NO	NO	NO	NO	NO	0.95	26.26	33.85	5.78
C. Metal Production	2,126.45	0.66	0.02				128.38		0.01	1.31	147.24	1.64	8.04
D. Other Production[3]	NE									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				54,826.43	10,148.38	146.10	87.24	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**							**NO**	**NO**	**401.06**	**NO**
4. Agriculture		**893.27**	**89.77**							**NA,NO**	**NA,NO**	**NA,NE,NO**	**NO**
A. Enteric Fermentation		752.50											
B. Manure Management		140.78	6.90									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils[4]		IE,NA,NE	82.87									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	NA							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	[5] **-3,910.92**	**1.59**	**2.18**							**0.33**	**11.79**	**NA,NO**	**NA**
A. Forest Land	[5] -14,953.53	0.65	0.01							0.16	5.58	NO	
B. Cropland	[5] 13,335.54	0.02	2.16							0.00	0.14	NO	
C. Grassland	[5] -8,466.09	0.47	0.00							0.12	4.07	NO	
D. Wetlands	[5] 459.92	NE,NO	0.00							NO	NO	NO	
E. Settlements	[5] 6,227.79	0.46	0.00							0.06	2.00	NO	
F. Other Land	[5] NE,NO	NE,NO	NE,NO							NO	NO	NO	
G. Other	[5] -514.55	NE	NE							NE	NE	NA	NA
6. Waste	**303.33**	**842.98**	**4.68**							**1.46**	**23.16**	**14.87**	**0.77**
A. Solid Waste Disposal on Land	[6] NA,NE,NO	825.91								NA,NE,NO	NA,NE,NO	8.26	
B. Waste-water Handling		16.94	4.52							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	[6] 303.33	0.14	0.16							1.46	23.16	6.61	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	**46,260.82**	**0.27**	**1.40**							**382.43**	**44.52**	**14.31**	**112.15**
Aviation	35,632.58	0.11	1.13							159.32	19.98	6.52	10.98
Marine	10,628.24	0.17	0.27							223.11	24.53	7.79	101.17
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**11,467.01**												

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	**536,418.46**	**2,168.27**	**119.76**	**59,290.79**	**10,498.47**	**148.36**	**221.02**	**0.04**	**0.03**	**1,409.06**	**3,055.12**	**1,001.84**	**585.62**
1. Energy	**525,828.18**	**453.30**	**16.55**							**1,404.81**	**2,840.94**	**470.00**	**555.13**
A. Fuel Combustion — Reference Approach [2]	529,360.60												
Sectoral Approach [2]	520,575.02	56.53	16.42							1,402.20	2,819.16	249.77	543.62
1. Energy Industries	210,081.82	11.72	5.07							438.31	101.91	4.19	369.49
2. Manufacturing Industries and Construction	80,425.22	13.03	4.36							257.86	553.04	27.44	102.50
3. Transport	127,186.40	7.22	4.95							574.31	1,768.49	161.92	18.89
4. Other Sectors	100,006.94	24.48	1.95							107.20	388.47	54.77	44.91
5. Other	2,874.64	0.08	0.09							24.51	7.24	1.45	7.83
B. Fugitive Emissions from Fuels	5,253.16	396.77	0.13							2.61	21.79	220.24	11.50
1. Solid Fuels	197.58	126.20	0.00							0.25	10.52	0.13	11.14
2. Oil and Natural Gas	5,055.59	270.57	0.13							2.35	11.26	220.11	0.37
2. Industrial Processes	**14,529.55**	**5.38**	**8.91**	**59,290.79**	**10,498.47**	**148.36**	**221.02**	**0.04**	**0.03**	**2.49**	**178.57**	**122.97**	**29.72**
A. Mineral Products	8,799.81	0.88	NE							NE	3.44	9.96	15.86
B. Chemical Industry	3,071.02	3.63	8.88	NO	NO	NO	NO	NO	NO	1.07	29.16	32.38	5.92
C. Metal Production	2,658.72	0.87	0.03				83.43		0.01	1.42	145.96	1.70	7.95
D. Other Production [3]	NE									NE	NE	78.92	NE
E. Production of Halocarbons and SF_6					175.60		54.56		NA,NO				
F. Consumption of Halocarbons and SF_6				59,290.79	10,320.53	148.36	83.02	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**							**NO**	**NO**	**394.36**	**NO**
4. Agriculture		**887.25**	**87.51**							**NA,NO**	**NA,NO**	**,NA,NE,NO**	**NO**
A. Enteric Fermentation		748.72											
B. Manure Management		138.53	6.82									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils[4]		IE,NA,NE	80.68									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	NA							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	(5) **-4,265.64**	**1.66**	**2.14**							**0.36**	**12.61**	**NA,NO**	**NA**
A. Forest Land	(5) -14,045.90	0.74	0.01							0.18	6.37	NO	
B. Cropland	(5) 13,173.63	0.02	2.12							0.00	0.14	NO	
C. Grassland	(5) -8,597.44	0.49	0.00							0.12	4.30	NO	
D. Wetlands	(5) 318.39	NE,NO	0.00							NO	NO	NO	
E. Settlements	(5) 6,174.93	0.41	0.00							0.05	1.79	NO	
F. Other Land	(5) NE,NO	NE,NO	NE,NO							NO	NO	NO	
G. Other	(5) -1,289.24	NE	NE							NE	NE	NA	NA
6. Waste	**326.37**	**820.70**	**4.65**							**1.41**	**23.00**	**14.51**	**0.77**
A. Solid Waste Disposal on Land	(6) NA,NE,NO	803.97								NA,NE,NO	NA,NE,NO	8.04	
B. Waste-water Handling		16.60	4.50							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	(6) 326.37	0.13	0.16							1.41	23.00	6.47	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	**45,644.07**	**0.26**	**1.38**							**395.04**	**43.09**	**15.57**	**148.04**
Aviation	35,492.20	0.10	1.13							158.39	19.69	6.50	9.80
Marine	10,151.87	0.16	0.25							236.65	23.39	9.07	138.24
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**12,753.03**												

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	**523,880.79**	**2,109.71**	**117.32**	**64,210.58**	**10,778.04**	**150.70**	**208.49**	**0.03**	**0.03**	**1,247.73**	**2,876.66**	**926.61**	**497.53**
1. Energy	**514,448.01**	**440.90**	**15.47**							**1,243.61**	**2,674.74**	**420.81**	**467.54**
A. Fuel Combustion — Reference Approach[2]	519,987.36												
Sectoral Approach[2]	509,938.81	57.10	15.37							1,241.27	2,656.75	232.23	455.59
1. Energy Industries	204,271.54	11.59	4.73							350.83	101.70	4.49	290.23
2. Manufacturing Industries and Construction	78,137.80	12.27	4.17							240.38	531.85	26.23	94.33
3. Transport	122,733.96	6.38	4.43							524.72	1,597.10	142.96	16.69
4. Other Sectors	102,037.51	26.79	1.96							102.91	419.14	57.18	47.26
5. Other	2,758.00	0.08	0.08							22.43	6.96	1.37	7.08
B. Fugitive Emissions from Fuels	4,509.20	383.79	0.11							2.34	17.99	188.58	11.94
1. Solid Fuels	236.17	132.97	0.00							0.24	8.40	0.13	10.24
2. Oil and Natural Gas	4,273.03	250.83	0.10							2.10	9.59	188.45	1.70
2. Industrial Processes	**13,842.75**	**4.89**	**7.81**	**64,210.58**	**10,778.04**	**150.70**	**208.49**	**0.03**	**0.03**	**2.44**	**166.24**	**118.20**	**29.27**
A. Mineral Products	7,782.75	0.78	NE							NE	4.43	9.82	17.14
B. Chemical Industry	2,996.92	3.13	7.78	NO	NO	NO	NO	NO	NO	0.73	24.14	26.16	4.31
C. Metal Production	3,063.08	0.97	0.03				117.94		0.00	1.71	137.67	1.61	7.83
D. Other Production[3]	NE									NE	NE	80.62	NE
E. Production of Halocarbons and SF_6					125.86		11.67		NA,NO				
F. Consumption of Halocarbons and SF_6				64,210.58	10,625.95	150.70	78.88	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**							**NO**	**NO**	**373.37**	**NO**
4. Agriculture		**866.15**	**87.40**							**NA,NO**	**NA,NO**	**NA,NE,NO**	**NO**
A. Enteric Fermentation		730.99											
B. Manure Management		135.16	6.63									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils[4]		IE,NA,NE	80.77									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	NA							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	(5) **-4,690.88**	**1.67**	**2.10**							**0.37**	**13.11**	**NA,NO**	**NA**
A. Forest Land	(5) -13,504.63	0.70	0.01							0.17	6.04	NO	
B. Cropland	(5) 12,845.07	0.02	2.08							0.01	0.18	NO	
C. Grassland	(5) -8,635.45	0.62	0.00							0.15	5.46	NO	
D. Wetlands	(5) 282.11	NE,NO	0.00							NO	NO	NO	
E. Settlements	(5) 6,105.99	0.33	0.00							0.04	1.43	NO	
F. Other Land	(5) NE,NO	NE,NO	NE,NO							NO	NO	NO	
G. Other	(5) -1,783.97	NE	NE							NE	NE	NA	NA
6. Waste	**280.90**	**796.11**	**4.54**							**1.30**	**22.57**	**14.23**	**0.72**
A. Solid Waste Disposal on Land	(6) NA,NE,NO	779.34								NA,NE,NO	NA,NE,NO	7.79	
B. Waste-water Handling		16.65	4.40							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	(6) 280.90	0.11	0.14							1.30	22.57	6.43	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	**45,706.51**	**0.27**	**1.37**							**420.46**	**45.25**	**16.51**	**173.23**
Aviation	34,254.97	0.10	1.09							152.52	18.88	6.24	10.29
Marine	11,451.54	0.18	0.29							267.95	26.37	10.27	162.94
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**15,433.92**												

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		**472,455.74**	**2,068.99**	**111.36**	**68,030.57**	**10,852.24**	**153.13**	**147.07**	**0.03**	**0.03**	**1,081.86**	**2,270.04**	**823.97**	**397.22**
1. Energy		**467,256.76**	**439.48**	**14.15**							**1,078.54**	**2,117.56**	**344.70**	**383.79**
A. Fuel Combustion	Reference Approach (2)	472,284.60												
	Sectoral Approach (2)	462,507.29	52.16	14.03							1,076.20	2,098.54	176.84	374.70
1. Energy Industries		179,979.29	11.84	4.26							319.73	92.21	4.25	223.33
2. Manufacturing Industries and Construction		67,392.12	10.30	3.60							203.94	464.10	22.61	86.32
3. Transport		117,818.52	4.49	4.12							437.85	1,118.06	93.05	15.37
4. Other Sectors		94,890.83	25.47	1.99							93.86	418.06	55.70	43.05
5. Other		2,426.52	0.07	0.07							20.83	6.10	1.23	6.64
B. Fugitive Emissions from Fuels		4,749.48	387.32	0.12							2.34	19.02	167.86	9.08
1. Solid Fuels		150.05	136.55	0.00							0.13	7.91	0.11	8.64
2. Oil and Natural Gas		4,599.43	250.77	0.12							2.21	11.10	167.75	0.44
2. Industrial Processes		**9,708.80**	**4.21**	**3.82**	**68,030.57**	**10,852.24**	**153.13**	**147.07**	**0.03**	**0.03**	**1.72**	**119.46**	**110.21**	**12.71**
A. Mineral Products		5,800.45	0.26	NE							NE	1.66	6.92	6.39
B. Chemical Industry		2,715.07	3.63	3.80	NO	NO	NO	NO	NO	NO	0.67	13.21	20.62	1.74
C. Metal Production		1,193.28	0.32	0.02				60.59		0.00	1.05	104.60	1.18	4.58
D. Other Production (3)		NE									NE	NE	81.49	NE
E. Production of Halocarbons and SF_6						104.47		11.46		NA,NO				
F. Consumption of Halocarbons and SF_6					68,030.57	10,734.46	153.13	75.03	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**							**NO**	**NO**	**355.07**	**NO**
4. Agriculture			**852.07**	**86.78**							**NA,NO**	**NA,NO**	**NA,NE,NO**	**NO**
A. Enteric Fermentation			718.73											
B. Manure Management			133.33	6.44									NO	
C. Rice Cultivation			NA,NO										NA,NO	
D. Agricultural Soils(4)			IE,NA,NE	80.34									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	NA							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry		(5) **-4,789.46**	**1.41**	**2.06**							**0.30**	**10.44**	**NA,NO**	**NA**
A. Forest Land		(5) -12,722.83	0.45	0.01							0.09	3.29	NO	
B. Cropland		(5) 12,692.32	0.02	2.04							0.01	0.19	NO	
C. Grassland		(5) -8,649.61	0.66	0.00							0.16	5.76	NO	
D. Wetlands		(5) 281.99	NE,NO	0.00							NO	NO	NO	
E. Settlements		(5) 6,054.36	0.28	0.00							0.03	1.20	NO	
F. Other Land		(5) NE,NO	NE,NO	NE,NO							NO	NO	NO	
G. Other		(5) -2,445.69	NE	NE							NE	NE	NA	NA
6. Waste		**279.63**	**771.83**	**4.57**							**1.30**	**22.57**	**13.99**	**0.72**
A. Solid Waste Disposal on Land		(6) NA,NE,NO	755.70								NA,NE,NO	NA,NE,NO	7.56	
B. Waste-water Handling			16.02	4.43							NA,NE	NA,NE	NA,NE	
C. Waste Incineration		(6) 279.63	0.11	0.14							1.30	22.57	6.43	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		**43,446.93**	**0.26**	**1.31**							**395.78**	**42.54**	**15.55**	**158.34**
Aviation		32,782.74	0.09	1.04							146.99	17.98	6.01	8.54
Marine		10,664.19	0.17	0.27							248.80	24.56	9.54	149.80
Multilateral Operations		**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass		**16,430.68**												

A9 ANNEX 9: Additional Information Quantitative Discussion of 2009 Inventory

This Annex discusses the emission estimates made in the 1990-2009 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 1990-2009. Emissions from direct greenhouse gases in this sector have declined 20% since 1990. A decline in emissions of around 9% is also seen between 2008 and 2009. This is driven mostly by decreases in the power generation (1A1a) and other industrial combustion (1A2f) categories, and may be as a result of the recent economic downturn.

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 2009.

A9.1.1 Carbon Dioxide

Analysing emissions by pollutant shows that 99% of total net CO_2 emissions in 2009 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 18% since 1990 (**Table A 9.1.1**) and have also shown a decrease of 9% between 2008 and 2009 (**Table A 9.1.2**).

Energy industries (category 1A1) were responsible for 39% of the sector's CO_2 emissions in 2009 (**Table A 9.1.3**). There has been an overall decline in emissions from this sector of 18% 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.

Overall, between 1990 and 2009, there has been a 19% increase in the amount of electricity generated but a 26% 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 2009 they operated at 47% 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 from this sector showed a 13% decrease from 2008 to 2009, due to a decrease in electricity demand and increased use of nuclear power compared with the previous year.

Emissions of from category 1A2 – Manufacturing Industries and Construction contributed 15% (**Table A 9.1.4**) to overall net CO_2 emissions in the UK in 2009. Since 1990, these emissions have declined by 23%, (**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 2009, this sector contributed 26% (**Table A 9.1.4**) to overall CO_2 emissions within the UK. Emissions from transport are dominated by road transport (1A3b), which in 2009 contributed 95% 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 for the last two years have decreased by 4% each year. This may be as a result of recent economic downturn. Emissions from domestic aviation have increased by 40% since 1990, but have shown a decrease of 21% 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) have decreased by 13% since 1990 (**Table A 9.1.1**). During this period, residential emissions have decreased by 5% and emissions from the commercial/institutional subsector have decreased by 33%. 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). Between 2008 and 2009, residential emissions decreased by 6% which is mainly to do with a decrease in gas consumption, thought to be due to a combination of warmer shoulder heating season, poorer economic climate and increasing energy efficiency measures. There has been a decrease of 12% in the commercial/institutional subsector between 2008 and 2009 which has also been mainly due to a decrease 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 1990-2009, although they only contribute a small percentage towards emissions from the energy sector.

[1] Plant loads, demand and efficiency, Table 5.10, DECC (2009)

A9.1.2 Methane

In 2009, 21% (see **Table A 9.1.4**) of total methane emissions came from the energy sector, the majority (57%, **Table A 9.1.3**) from fugitive emissions from oil and natural gas (1B2). Emissions from this category have decreased by 49% since 1990 (**Table A 9.1.1**). Sources 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 13% of total N_2O emissions in the UK during 2009. Of this, a majority (30%, **Table A 9.1.3**) arose from energy industries (1A1). Within this category, emissions from public electricity production have shown a 47% decrease, whilst emissions from petroleum refining have increased by 21%. Emissions from 1A1c (Manufacture of Solid Fuels and Other Energy Industries) have increased by 24% between 1990 and 2009. N_2O emissions have decreased overall by 49% 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) (29%, **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 2009 is actually 8% (**Table A 9.1.1**) and a 7% decrease was observed between 2008 and 2009.

A9.1.4 Nitrogen Oxides

In 2009, over 99% of NO_x emissions in the UK came from the energy sector. Since 1990 emissions from this sector have decreased by 59% (**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 2009, emissions from transport contributed 41% (**Table A 9.1.4**) to the total emissions of NO_x in the UK, with 33% arising from road transport (1A3b). From 1970, emissions from transport increased (especially during the 1980s) and reached a peak in 1989 before falling by 66% (**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 23% (**Table A 9.1.4**) to total NO_x emissions in the UK during 2009. Between 1990 and 2009, emissions from this sector decreased by 62% (**Table A 9.1.1**). The main reason for this was a decrease in emissions from public electricity and heat (1A1a) of 67%. 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 50% (**Table A 9.1.1**) since 1990. In 2009, emissions from this sector contributed 19% (**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 93% (**Table A 9.1.4**) to overall UK CO emissions in 2009. Of this, 53% of emissions (**Table A 9.1.3**) occur from the transport sector. Since 1990, emissions from 1A3 have declined by 82% (**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 2009. 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 2009, 42% (**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 20% (**Table A 9.1.4**) towards the overall UK emissions of NMVOCs in 2009. This includes emissions from gas leakage, which comprise around 10% of the total for the energy sector. Remaining emissions arise from oil transportation, refining, storage and offshore.

Emissions from transport (1A3) contribute 27% (**Table A 9.1.4**) to overall emissions of NMVOC in the UK in 2009. Since 1990, emissions from this sector have decreased by 91% (**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 2009. 58% (**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 22% (**Table A 9.1.4**) of UK emissions of SO_2 in 2009. Since 1990, emissions from this sector have declined by 81% (**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, 1990-2009

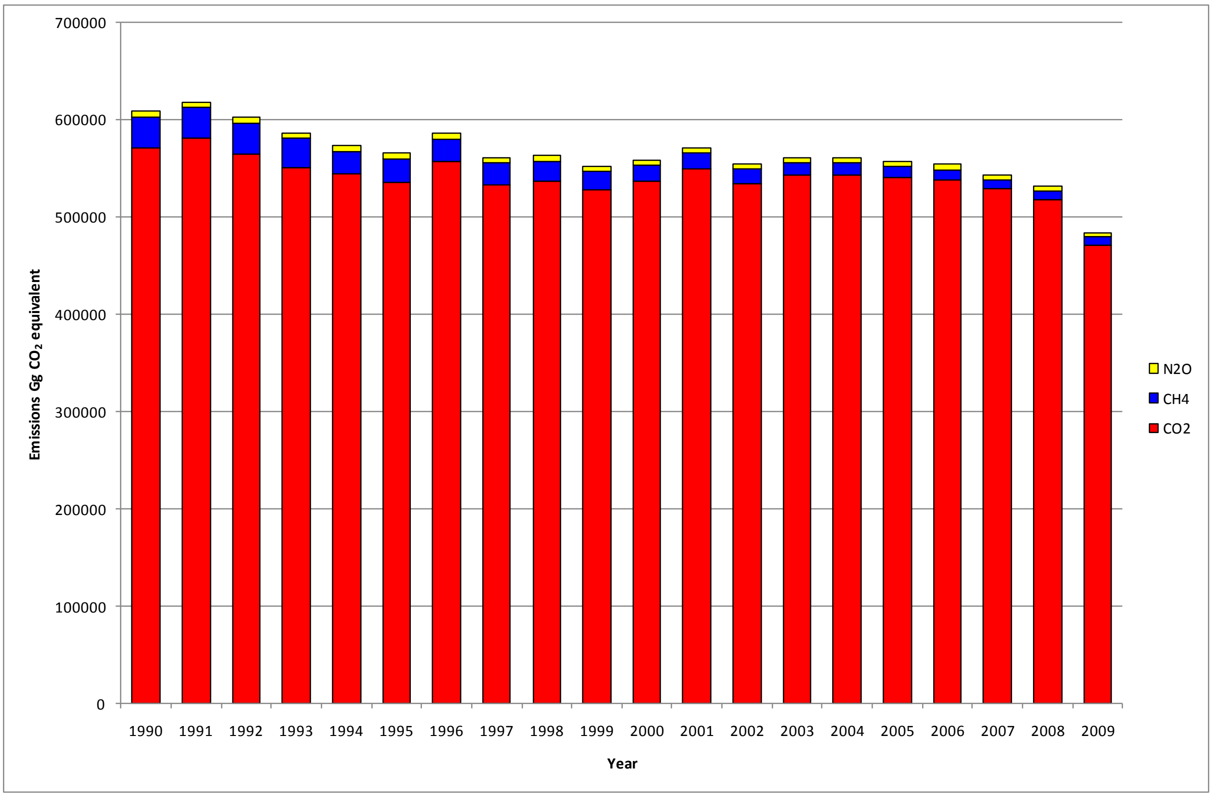


Figure A 9.1.2 UK emissions of Indirect Greenhouse Gases from IPCC sector 1, 1990-2009

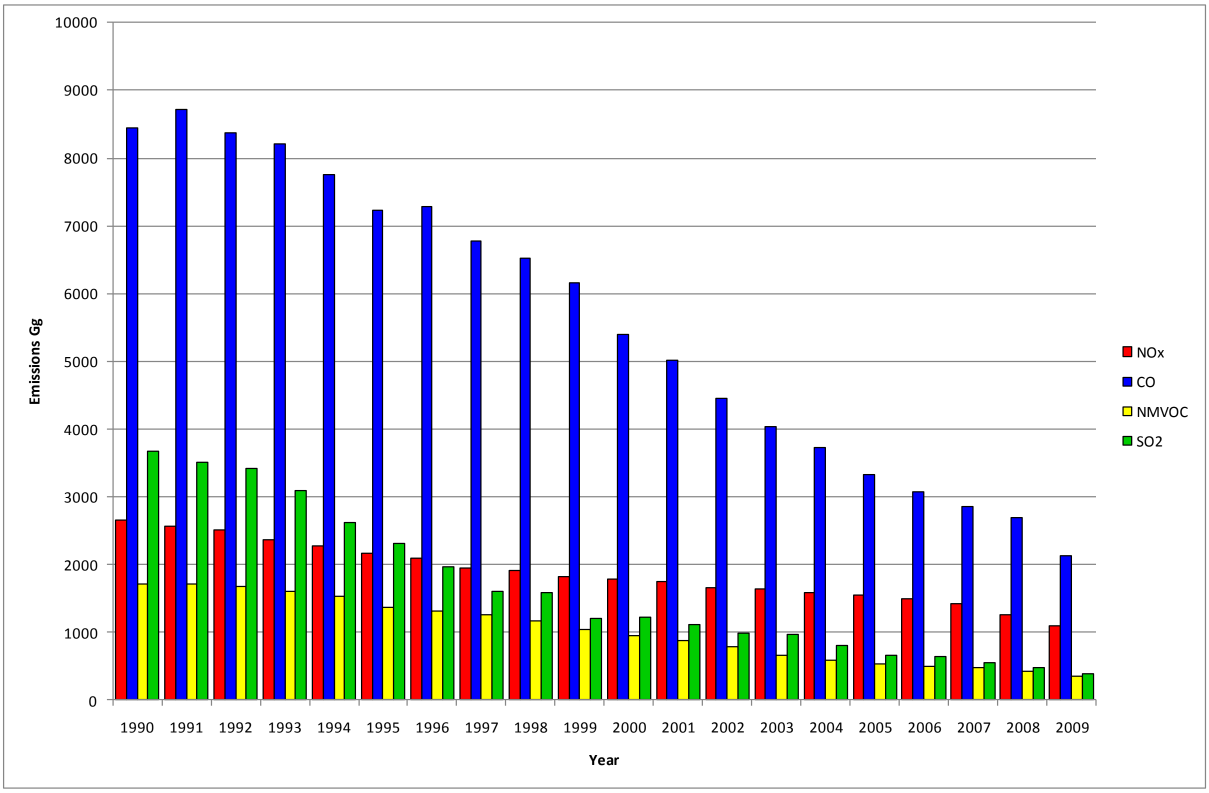


Table A 9.1.1 % Changes from 1990 to 2009 in Sector 1

	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
1A1	-23%	23%	-35%	-62%	-30%	-49%	-92%
1A2	-32%	-33%	-31%	-50%	-37%	-20%	-81%
1A3	4%	-85%	-8%	-61%	-82%	-91%	-83%
1A4	-13%	-65%	-37%	-56%	-64%	-46%	-79%
1A5	-54%	-55%	-55%	-47%	-54%	-44%	8%
1B1	-82%	-84%	-92%	-78%	-79%	-67%	-58%
1B2	-20%	-49%	-13%	-83%	-48%	-70%	-94%
Overall	**-18%**	**-71%**	**-28%**	**-59%**	**-75%**	**-80%**	**-89%**

Table A 9.1.2 % Changes from 2008 to 2008 in Sector 1

	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
1A1	-12%	2%	-10%	-9%	-9%	-5%	-23%
1A2	-14%	-16%	-14%	-15%	-13%	-14%	-8%
1A3	-4%	-30%	-7%	-16%	-30%	-35%	-8%
1A4	-7%	-5%	1%	-9%	0%	-3%	-9%
1A5	-12%	-13%	-12%	-7%	-12%	-10%	-6%
1B1	-36%	3%	-82%	-48%	-6%	-14%	-16%
1B2	8%	0%	14%	5%	16%	-11%	-74%
Overall	**-9%**	**-0.33%**	**-9%**	**-13%**	**-21%**	**-18%**	**-18%**

Table A 9.1.3 % Contribution to Sector 1

	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
1A1	39%	3%	30%	30%	4%	1%	58%
1A2	14%	2%	25%	19%	22%	7%	22%
1A3	25%	1%	29%	41%	53%	27%	4%
1A4	20%	6%	14%	9%	20%	16%	11%
1A5	1%	0%	1%	2%	0%	0%	2%
1B1	0%	31%	0%	0%	0%	0%	2%
1B2	1%	57%	1%	0%	1%	49%	0%

Table A 9.1.4 % Contribution to Overall Pollutant Emissions

	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
1A1	38%	1%	4%	30%	4%	1%	56%
1A2	14%	0%	3%	19%	20%	3%	22%
1A3	25%	0%	4%	41%	49%	11%	4%
1A4	20%	1%	2%	9%	18%	7%	11%
1A5	1%	0%	0%	2%	0%	0%	2%
1B1	0%	7%	0%	0%	0%	0%	2%
1B2	1%	12%	0%	0%	0%	20%	0%
Overall	**99%**	**21%**	**13%**	**100%**	**93%**	**42%**	**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 1990-2009. Emissions from direct Greenhouse gases within this sector have decreased by 58% 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 2009.

A9.2.1 Carbon Dioxide

The industrial processes sector is not a major source of emissions in the UK for carbon dioxide. In 2009, just 2.0% (**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 2009, 3% (**Table A 9.2.4**) of N_2O emissions in the UK came from the industrial processes sector. Between 1990 and 2009, 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 2009. Since 1990, emissions of HFCs have decreased by 4% (**Table A 9.2.1**). The largest contribution to this sector in 2009 arises from category 2F1 – refrigeration and air conditioning equipment. In 2009, these contributed 68% (**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 (25%, **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 (3%, **Table A 9.2.4**), by-product emissions (1%, **Table A 9.2.4**) and fire extinguishers (2%, **Table A 9.2.4**). A small emission also arises from the use of HFCs as a cover gas in aluminium and magnesium foundries.

A9.2.5 Perfluorocarbons

In 2009, 100% (**Table A 9.2.4**) of PFC emissions came from the industrial processes sector. Since 1990, emissions from this sector have declined by 90% (**Table A 9.2.1**). Within this sector, the main contribution to emissions comes from aluminium production (41%, **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 95% 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 2009, this sector contributed 49% (**Table A 9.2.4**) to overall PFC emissions in the UK .The remaining contribution arises from fugitive emissions from PFC manufacture and refrigeration/air condition. In 2009, these sources contributed 8% and 2% respectively (**Table A 9.2.4**) to overall PFC totals in the UK.

A9.2.6 Sulphur Hexaflouride

In 2009, the industrial processes sector contributed 100% (**Table A 9.2.4**) of emissions of SF_6 in the UK. Emissions arise from two main sectors. The use of SF_6 in magnesium foundries contributed 12% (**Table A 9.2.4**) towards total emissions in 2009. Emissions from 2F8 – Other contributed 88% (**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 36% (**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 2009, emissions from the industrial sector contributed 5% (**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 58% (**Table A 9.2.1**).

A9.2.9 Non Methane Volatile Organic Compounds

In 2009, emissions from the industrial processes sector contributed 13% (**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 2009, 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, 1990-2009

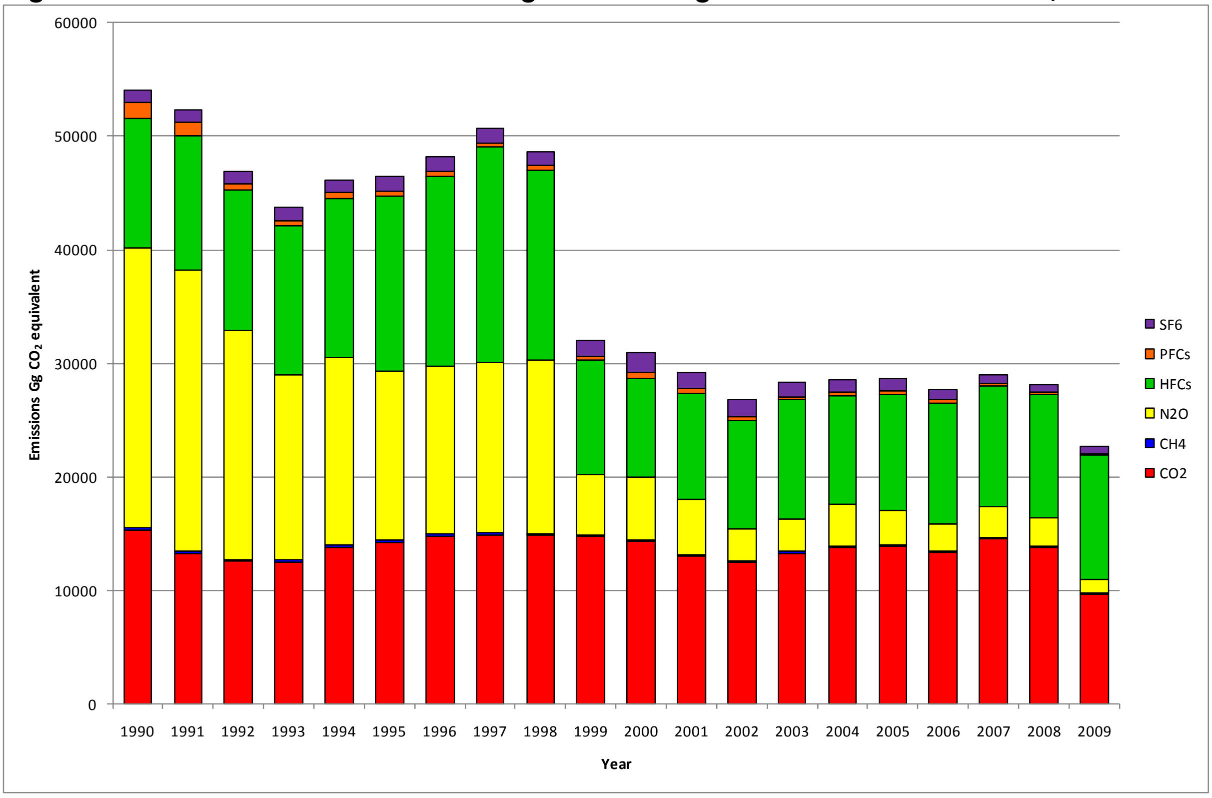


Figure A 9.2.2 Emissions of indirect greenhouse gases from IPCC sector 2, 1990-2009

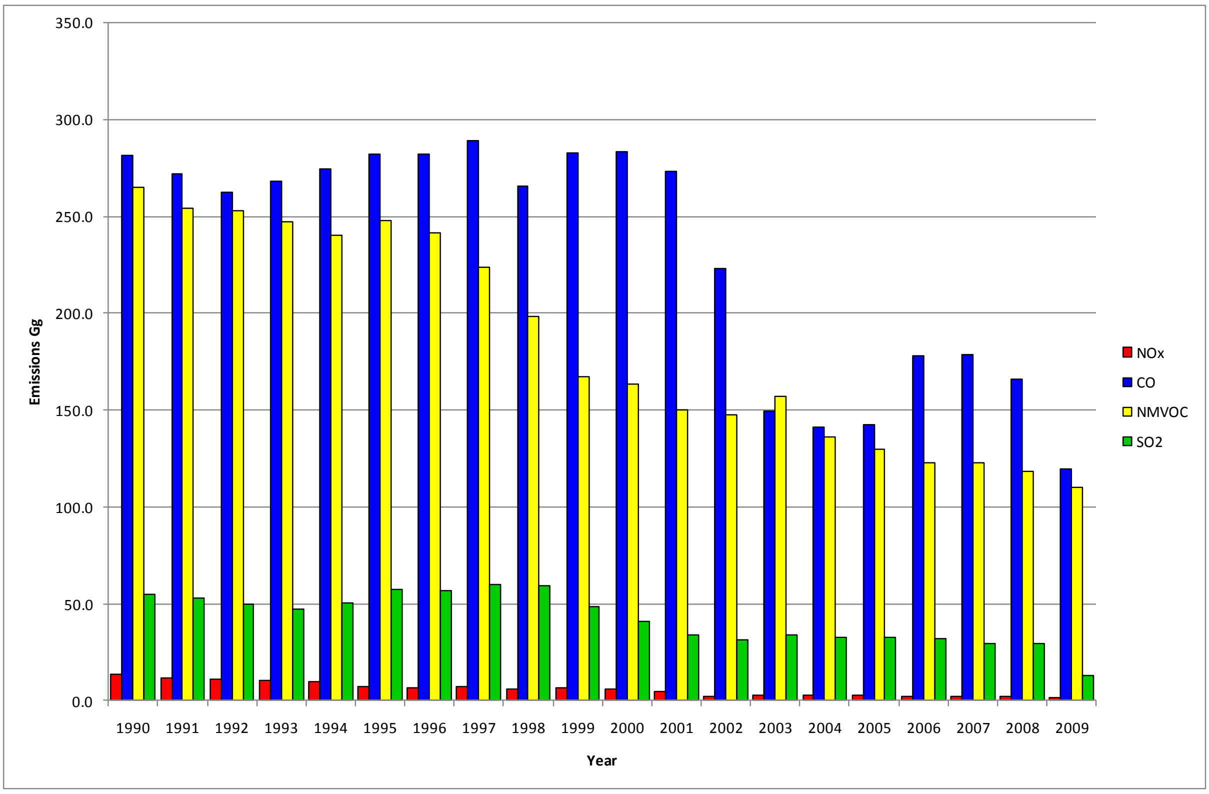


Table A 9.2.1 % Changes from 1990 to 2009 in Sector 2

	CO_2	CH_4	N_2O	HFC	PFC	SF_6	NOx	CO	NMVOC	SO_2
2A1	-49%									
2A2	-47%									
2A3	-9%									
2A4	11%									
2A5										
2A6									-45%	
2A7	-59%	-77%						-69%	-54%	50%
2B1	-39%									
2B2			-72%				-97%			
2B3			-99.7%							
2B4										
2B5	22%	-55%					9%	-84%	-88%	-96%
2C1	-57%	-59%	-55%				-80%	-40%	-42%	-68%
2C2										
2C3	-13%				-95%		-69%	28%		-45%
2C4						-82%				
2C5								-97%		-24%
2D1									-96%	
2D2									11%	
2E1				-99%						
2E2					5%					
2E3										
2F1				23455%	1821%					
2F2										
2F3										
2F4				23455%						
2F5										
2F8										
2F9					25%	-3%				
2G										
Overall	**-37%**	**-58%**	**-95%**	**-4%**	**-90%**	**-36%**	**-87%**	**-58%**	**-58%**	**-77%**

Table A 9.2.2 % Changes from 2008 to 2009 in Sector 2

	CO_2	CH_4	N_2O	HFC	PFC	SF_6	NOx	CO	NMVOC	SO_2
2A1	-28%									
2A2	0%									
2A3	-21%									
2A4	-13%									
2A5										
2A6									-21%	
2A7	-68%	-66%						-63%	-49%	-63%
2B1	-28%									
2B2			-24%				-17%			
2B3			-93%							
2B4										
2B5	1%	16%					-1%	-45%	-21%	-60%
2C1	-69%	-67%	-50%				-43%	-27%	-26%	-37%
2C2										
2C3	-22%				-49%		-21%	-18%		-55%
2C4				-49%		-12%				
2C5								82%		8%
2D1									0%	
2D2									1%	
2E1				-17%						
2E2					-2%					
2E3										
2F1				3%	-3%	-1%				
2F2				5%						
2F3				1%	-46%					
2F4				-3%						
2F5				15%						
2F8										
2F9				-100%	-5%	-6%				
2G										
Overall	**-30%**	**-14%**	**-51%**	**1%**	**-29%**	**-7%**	**-29%**	**-28%**	**-7%**	**-57%**

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	38%									
2A2	6%									
2A3	12%									
2A4	2%									
2A5										
2A6									5%	
2A7	1%	6%						1%	1%	50%
2B1	8%									
2B2			94%				15%			
2B3			6%							
2B4										
2B5	20%	86%					24%	11%	19%	14%
2C1	8%	8%	0%				45%	63%	1%	8%
2C2										
2C3	4%				41%		16%	23%		18%
2C4				0%		12%				
2C5								1%		11%
2D1									0%	
2D2									74%	
2E1				1%						
2E2					8%					
2E3										
2F1				68%	2%	0%				
2F2				3%						
2F3				2%	0%					
2F4				25%						
2F5				1%	0%					
2F8										
2F9				0%	49%	88%				
2G										

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%									
2A4	0%									
2A5										
2A6									1%	
2A7	0%	0%						0%	0%	2%
2B1	0%									
2B2			3%				0%			
2B3			0%							
2B4										
2B5	0%	0%					0%	1%	2%	0%
2C1	0%	0%	0%				0%	3%	0%	0%
2C2										
2C3	0%				41%		0%	1%		1%
2C4				0%		12%				
2C5								0%		0%
2D1									0%	
2D2									10%	
2E1				1%						
2E2					8%					
2E3										
2F1				68%	2%	0%				
2F2				3%						
2F3				2%	0%					
2F4				25%						
2F5				1%	0%					
2F8										
2F9				0%	49%	88%				
2G										
Overall	**2.04%**	**0.21%**	**7%**	**100%**	**100%**	**100%**	**0.16%**	**5%**	**13%**	**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 1990-2009. **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 2009. Emissions from this sector contribute 43% to overall emissions of NMVOC in the UK (**Table A 9.3.4**), and since 1990 emissions have declined by 47% (**Table A 9.3.1**).

The largest source of emissions within the solvents sector is category 3D (solvent and other product use: other), contributing 65% of NMVOC emissions in this sector (**Table A 9.3.3**).

Figure A 9.3.1 Emissions of NMVOC from IPCC Sector 3, 1990-2009

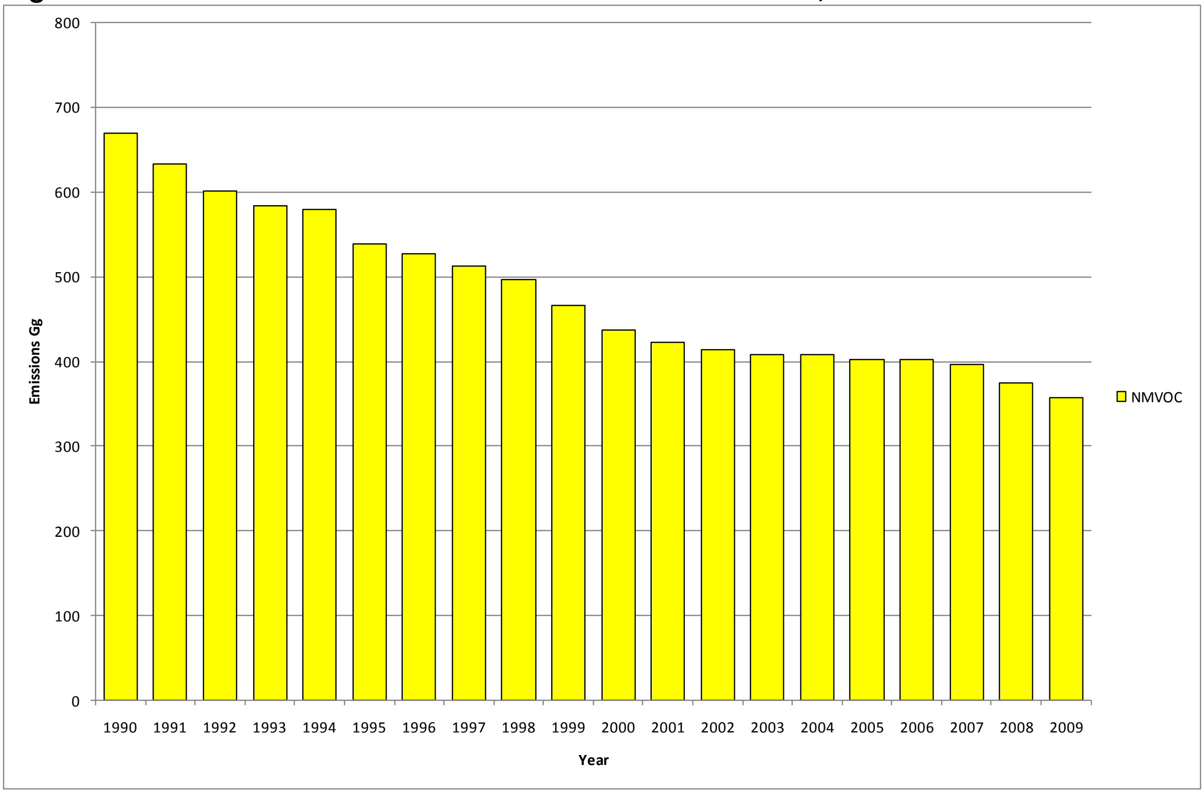


Table A 9.3.1 % Changes 1990-2009 within Sector 3

	NMVOC
3A	-61%
3B	-65%
3C	-75%
3D	-29%
Overall	**-47%**

Table A 9.3.2 % Changes 2008-2009 within Sector 3

	NMVOC
3A	-15%
3B	-1%
3C	-8%
3D	-1%
Overall	**-5%**

Table A 9.3.3 % Contribution to Sector 3

	NMVOC
3A	23%
3B	8%
3C	3%
3D	65%

Table A 9.3.4 % Contribution to Overall Pollutant Emissions

	NMVOC
3A	10%
3B	4%
3C	1%
3D	28%
Overall	43%

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 1990-2009. Emissions of direct greenhouse gases from this sector have decreased by 21% 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 2009.

A9.4.1 Methane

Agriculture is the largest source of methane in the UK, and in 2009 emissions from this sector totalled 41% (**Table A 9.4.4**) of the UK total. Since 1990, methane emissions from agriculture have declined by 19% (**Table A 9.4.1**). The largest single source within the agricultural sector is 4A1 – enteric fermentation from cattle. This accounts for 65% of methane emissions from this sector (**Table A 9.4.3**), and 27% of total methane emissions in 2009 (**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 2009, nitrous oxide emissions from agriculture contributed 78% (**Table A 9.4.4**) to the UK total emission. Of this, 92% (**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 23% (**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, 1990-2009

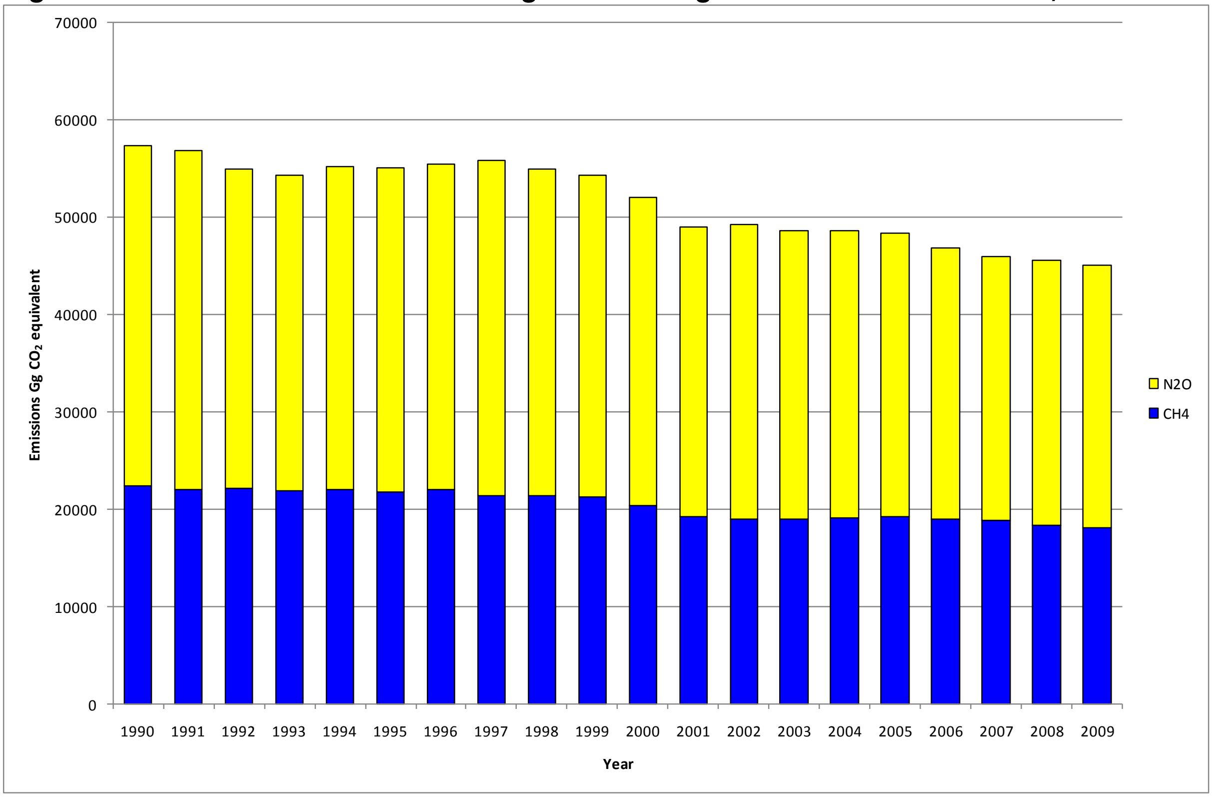


Figure A 9.4.2 Emissions of indirect greenhouse gases from IPCC sector 4, 1990-2009

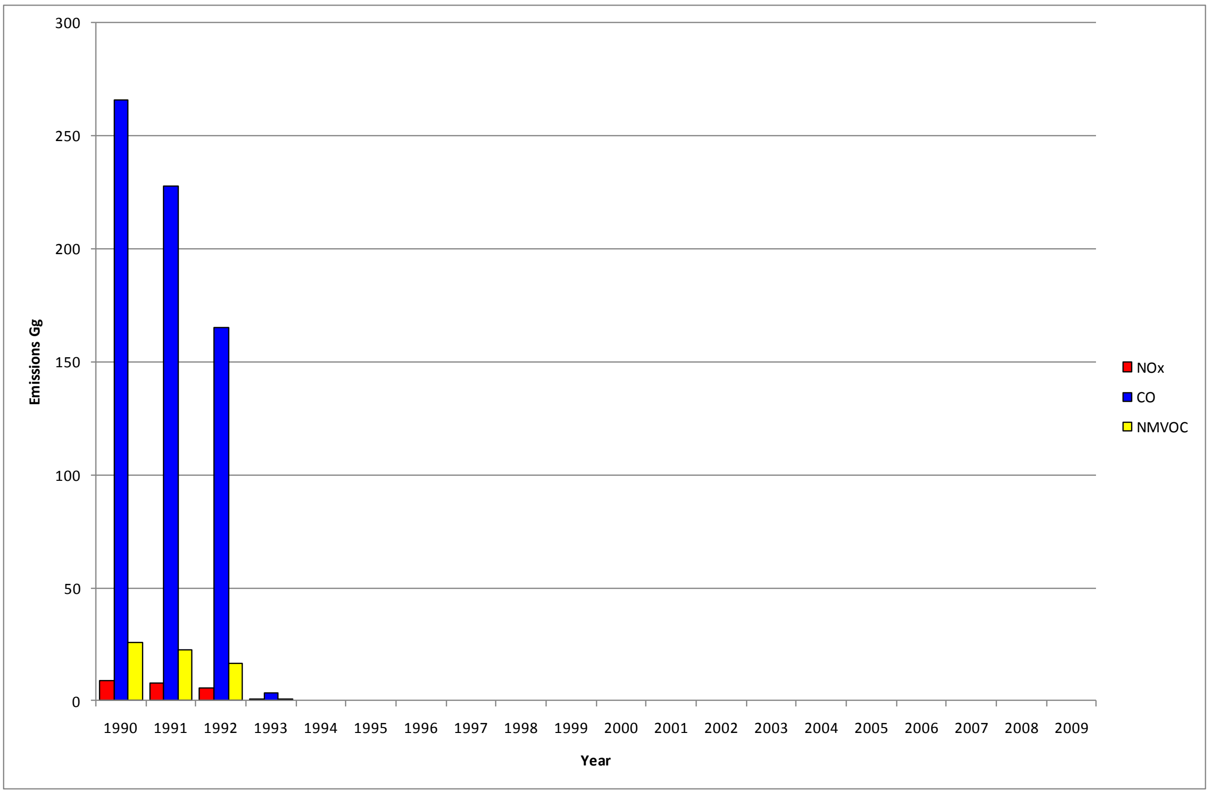


Table A 9.4.1 % Changes 1990-2009 within Sector 4

	CH_4	N_2O	NO_x	CO	NMVOC
4A1	-14%				
4A2					
4A3	-28%				
4A4	-10%				
4A5					
4A6	85%				
4A7					
4A8	-37%				
4A9					
4A10					
4B1	-18%				
4B2					
4B3	-28%				
4B4	24%				
4B5					
4B6	85%				
4B7					
4B8	-37%				
4B9	13%				
4B10					
4B11					
4B12		-24%			
4B13		-23%			
4B14		-31%			
4C					
4D		-22%			
4E					
4F1	-100%	-100%	-100%	-100%	-100%
4F2					
4F3					
4F4					
4F5	-100%	-100%	-100%	-100%	-100%
4G					
Overall	**-19%**	**-23%**	**-100%**	**-100%**	**-100%**

Table A 9.4.2 % Changes 2008-2009 within Sector 4

	CH_4	N_2O	Nox	CO	NMVOC
4A1	-1%				
4A2					
4A3	-4%				
4A4	5%				
4A5					
4A6	2%				
4A7					
4A8	0%				
4A9					
4A10					
4B1	-1%				
4B2					
4B3	-4%				
4B4	19%				
4B5					
4B6	2%				
4B7					
4B8	0%				
4B9	-4%				
4B10					
4B11					
4B12		-2%			
4B13		-1%			
4B14		-7%			
4C					
4D		-1%			
4E					
4F1					
4F2					
4F3					
4F4					
4F5					
4G					
Overall	**-2%**	**-1%**			

Table A 9.4.3 % Contribution to Sector 4

	CH_4	N_2O	NOx	CO	NMVOC
4A1	65%				
4A2					
4A3	18%				
4A4	0%				
4A5					
4A6	1%				
4A7					
4A8	1%				
4A9					
4A10	0%				
4B1	10%				
4B2	0%				
4B3	0%				
4B4	0%				
4B5					
4B6	0%				
4B7					
4B8	4%				
4B9	1%				
4B10	0%				
4B11					
4B12		0%			
4B13		5%			
4B14		2%			
4C					
4D		92%			
4E					
4F1	0%	0%			
4F2					
4F3					
4F4					
4F5	0%	0%			
4G					

Table A 9.4.4 % Contribution to Overall Pollutant Emissions

	CH_4	N_2O	NOx	CO	NMVOC
4A1	27%				
4A2					
4A3	7%				
4A4	0%				
4A5					
4A6	0%				
4A7					
4A8	0%				
4A9					
4A10	0%				
4B1	4%				
4B2					
4B3	0%				
4B4	0%				
4B5					
4B6	0%				
4B7					
4B8	2%				
4B9	1%				
4B10	0%				
4B11					
4B12		0%			
4B13		4%			
4B14		2%			
4D					
4E		72%			
4F1					
4F2	0%	0%	0%	0%	0%
4F3					
4F4					
4F5					
4G	0%	0%	0%	0%	0%
Overall					

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 1990-2009.

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 2009, the UK was a net sink, therefore showing a decrease in emissions of 253%.

A9.5.2 Methane

Emissions of methane from Land Use Change and Forestry are emitted from forestry, grassland and settlements categories (5A, 5C and 5E). Emissions from this sector have decreased by 16% since 2008 (**Table A 9.5.2**), although have increased overall by 14% since 1990 (**Table A 9.5.1**).

A9.5.3 Nitrous Oxide

Emissions of nitrous oxide from Land Use Change and Forestry are emitted from forestry, grassland and settlements categories (5A, 5C and 5E). Emissions of nitrous oxide from this sector have decreased by 20% since 1990 (**Table A 9.5.1**), and shown a decline of 2% since 2008 (**Table A 9.5.2**).

A9.5.4 Nitrogen Oxides

Emissions of nitrogen oxides from Land Use Change and Forestry are emitted from forestry, grassland and settlements categories (5A, 5C and 5E). Emissions from this sector have decreased by 16% since 2008 (**Table A 9.5.2**), and have increased overall by 60% 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, grassland and settlements categories (5A, 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, 1990-2009

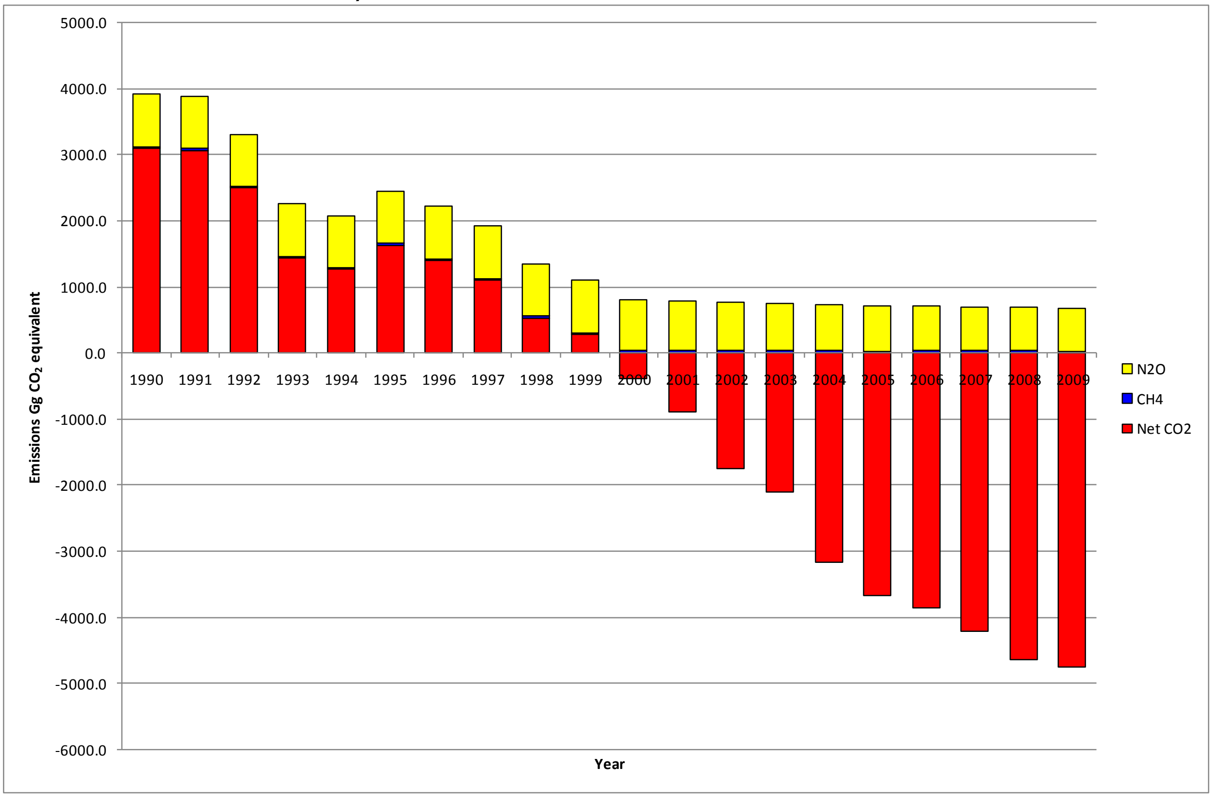


Figure A 9.5.2 Emissions of indirect greenhouse gases from IPCC sector 5, 1990-2009

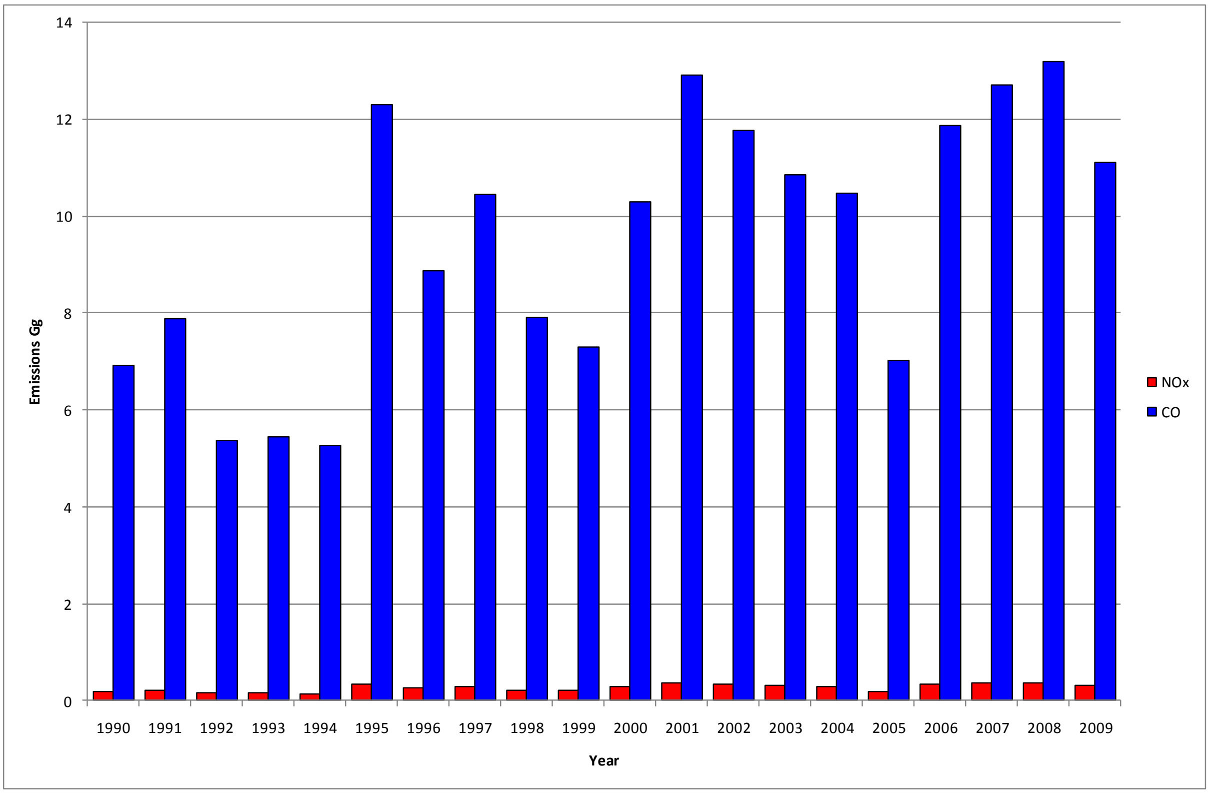


Table A 9.5.1 % Changes 1990-2009 within Sector 5

	CO_2	CH_4	N_2O	NOx	CO
5A	5%	120%	-65%	120%	120%
5B	-19%	250%	-19%	250%	250%
5C	38%	369%	369%	369%	369%
5D	-33%		-86%		
5E	-14%	-69%	-69%	-69%	-69%
5F					
5G	47%				
Overall	**-253%**	**14%**	**-20%**	**60%**	**60%**

Table A 9.5.2 % Changes 2008-2009 within Sector 5

	CO_2	CH_4	N_2O	NOx	CO
5A	-6%	-36%	-30%	-36%	-36%
5B	-1%	6%	-2%	6%	6%
5C	0%	6%	6%	6%	6%
5D	0%		-3%		
5E	-1%	-16%	-16%	-16%	-16%
5F					
5G	38%				
Overall	**2%**	**-16%**	**-2%**	**-16%**	**-16%**

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 1990-2009. Emissions from direct greenhouse gases in this sector have declined by 69% since 1990. This is mostly as a result of a decline in methane emissions, although emissions of nitrous oxide have shown an increase.

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 2009.

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 2008 (**Table A 9.6.2**).

A9.6.2 Methane

Emissions of methane from the waste sector accounted for around 37% (**Table A 9.6.4**) of total CH_4 emissions in the UK during 2009. 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 71% (**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 UK occur from the wastewater handling sector (see **Table A 9.6.3**). Since 1990, N_2O emissions from this sector have increased by 9% **Table** A 9.6.1). Overall, this sector contributes just 4% (**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 2009 (**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 2% (**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, 1990-2009

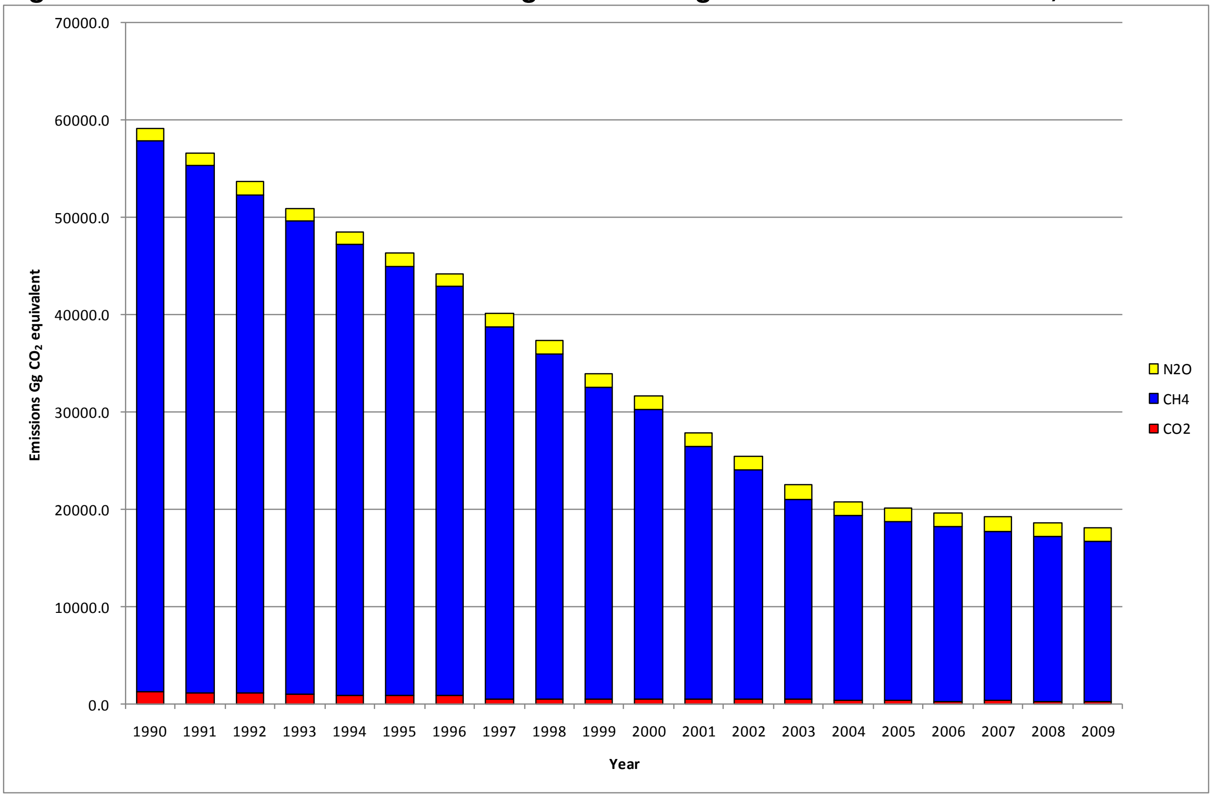


Figure A 9.6.2 Emissions of indirect greenhouse gases from IPCC sector 6, 1990-2009

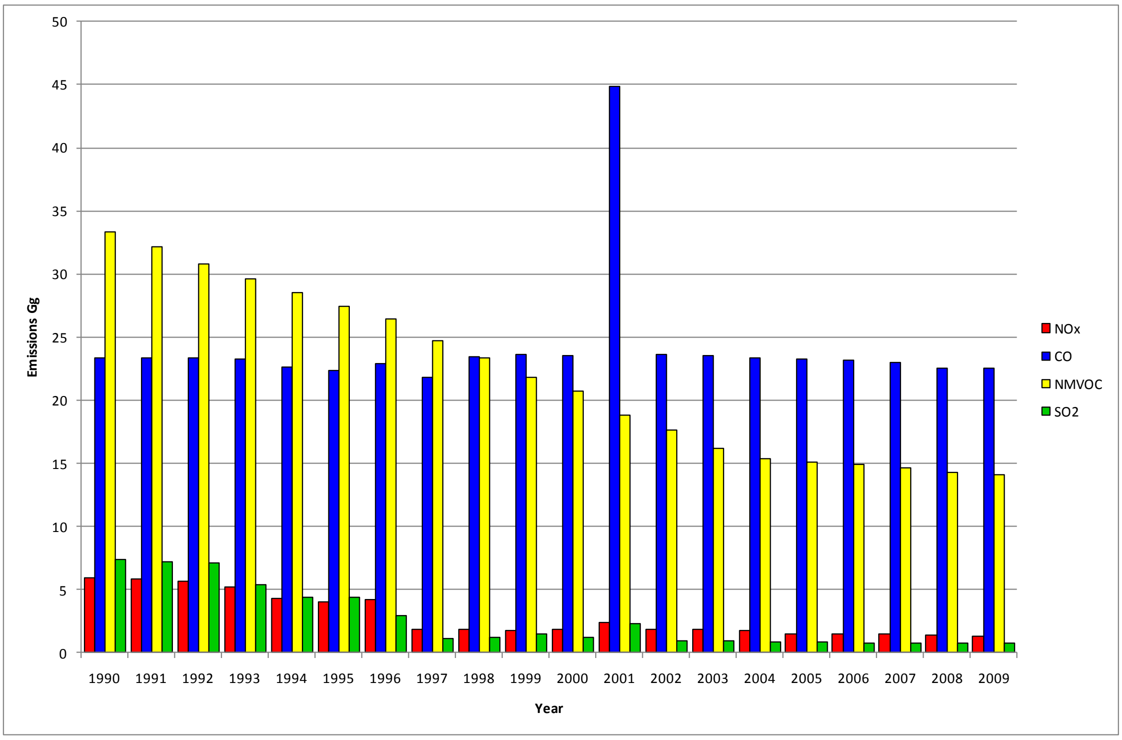


Table A 9.6.1 % Changes 1990-2009 within Sector 6

	CO_2	CH_4	N_2O	NOx	CO	NMVOC	SO_2
6A1		-71%				-71%	
6B2		20%	10%				
6C	-76%	-95%	-9%	-77%	-3%	-3%	-90%
Overall	**-76%**	**-71%**	**9%**	**-77%**	**-3%**	**-58%**	**-90%**

Table A 9.6.2 % Changes 2008-2009 within Sector 6

	CO_2	CH_4	N_2O	NOx	CO	NMVOC	SO_2
6A1		-3.02%				-3.02%	
6B2		-3.98%	0.56%				
6C	-0.40%	0.23%	0.01%	-1%	-0.01%	0.00%	-0.22%
Overall	**-0.40%**	**-3.04%**	**0.54%**	**-0.84%**	**-0.01%**	**-1.66%**	**-0.22%**

Table A 9.6.3 % Contribution to Sector 6

	CO_2	CH_4	N_2O	NOx	CO	NMVOC	SO_2
6A1		98%				54%	
6B2		2%	97%				
6C	100%	0%	3%	100%	100%	46%	100%

Table A 9.6.4 % Contribution to Overall Pollutant Emissions

	CO_2	CH_4	N_2O	NOx	CO	NMVOC	SO_2
6A1		37%				1%	
6B2		1%	4%				
6C	0.06%	0.01%	0.13%	0.12%	1%	1%	0.18%
Overall	**0.06%**	**37%**	**4%**	**0.12%**	**1%**	**2%**	**0.18%**

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. The 'bottom-up' EDGAR (Emissions Database for Global Atmospheric Research) estimates for the UK are also presented, if available. EDGAR is an EU project that provides global past and present day anthropogenic emissions of greenhouse gases by country (and on a spatial grid) (http://edgar.jrc.ec.europa.eu/index.php).

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 and EDGAR 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).

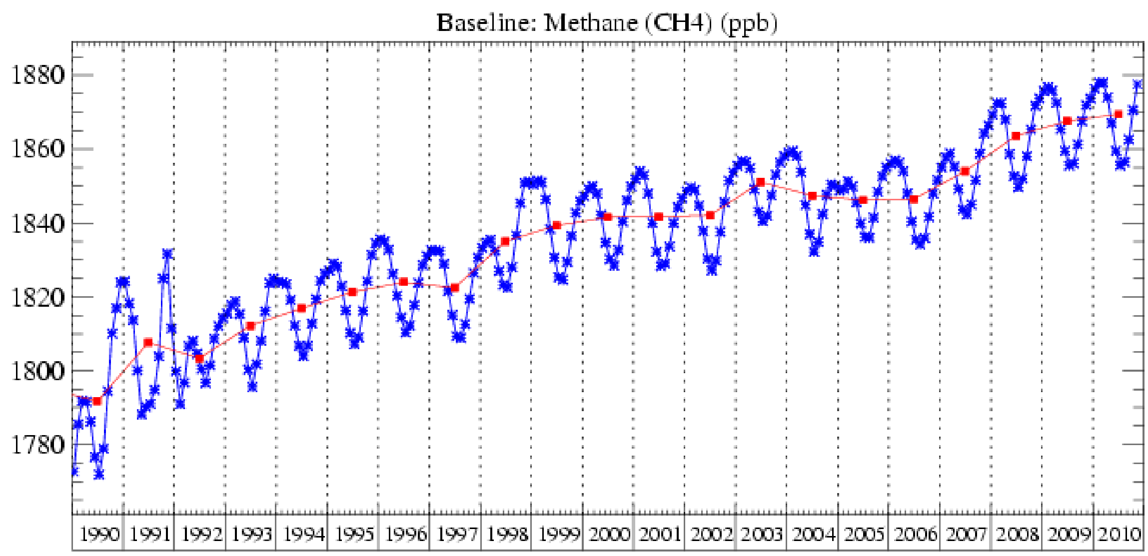
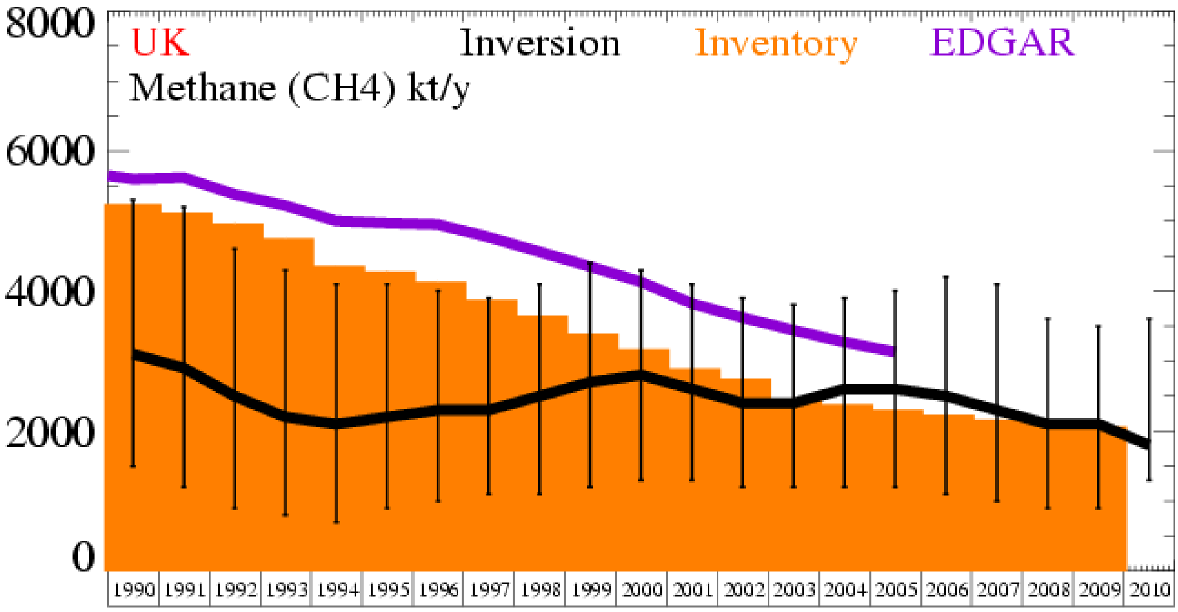


Figure A 10.2.2 **Verification of the UK emission inventory estimates for methane in Gg yr-1 for 1990-2010. GHGI estimates are shown in orange. EDGAR estimates shown in purple. NAME-inversion estimates are shown in black. NAME-inversion uncertainties are shown with the black whisker lines showing 5th, median, and 95th percentiles. Note: 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).

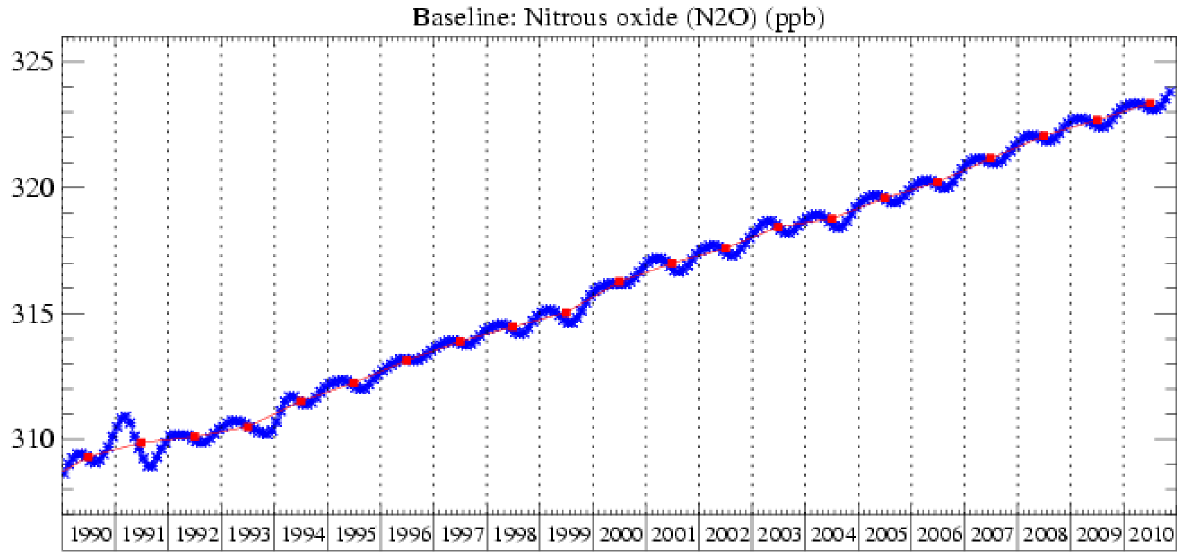
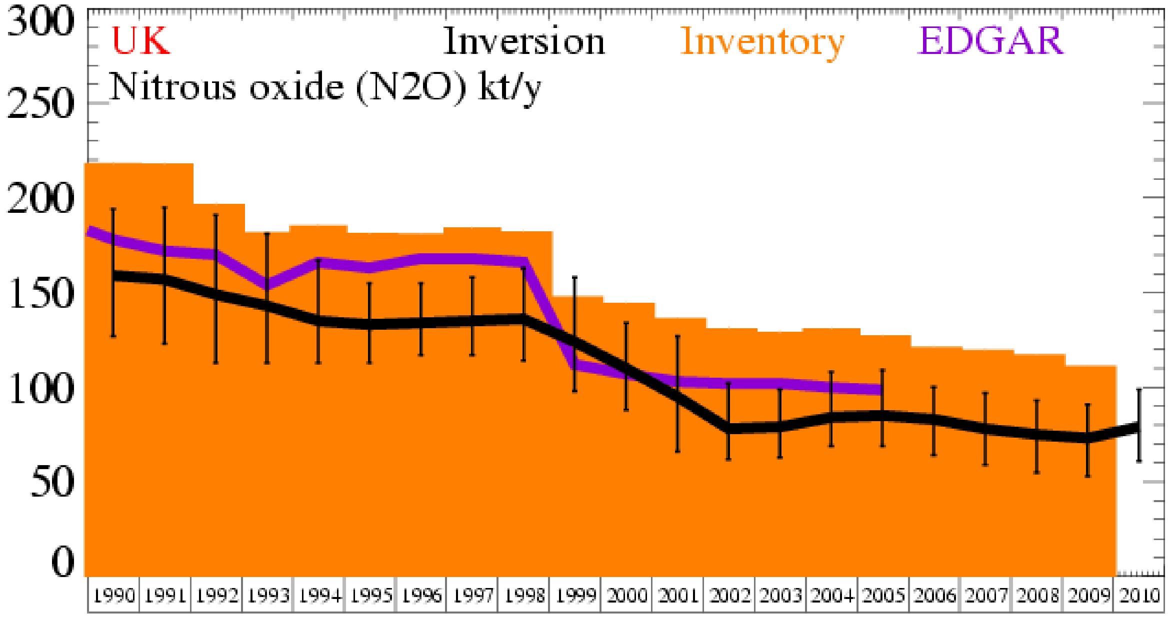


Figure A 10.3.2 Verification of the UK emission inventory estimates for nitrous oxide in Gg yr-1 for 1990-2010. GHGI estimates are shown in orange. EDGAR estimates shown in purple. NAME-inversion estimates are shown in black. NAME-inversion uncertainties are shown with the black whisker lines showing 5th, median, and 95th percentiles. Note: 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).

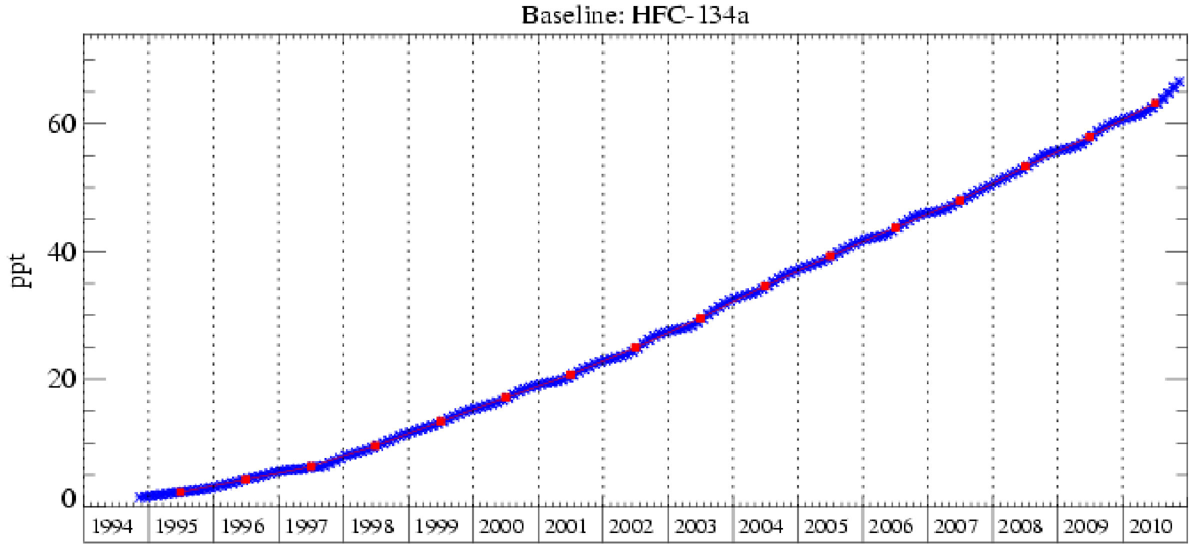
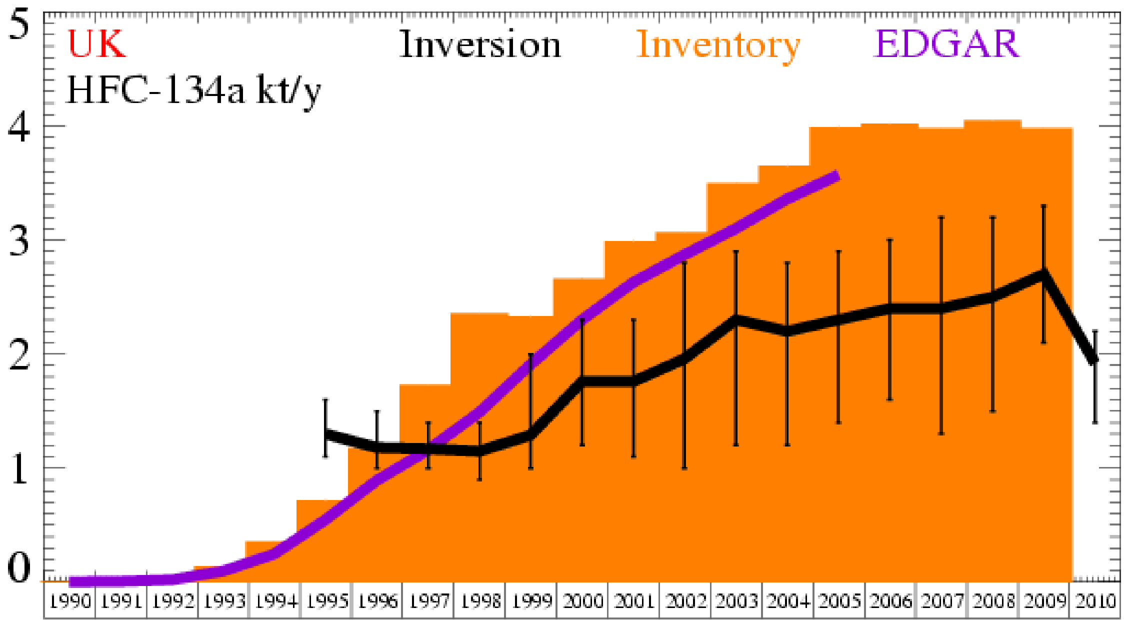


Figure A 10.4.2 shows the NAME-inversion and GHGI emission estimates for the UK for HFC-134a for the period 1990 onwards. The GHGI shows an earlier increase in emission compared to the NAME-inversion estimates. The NAME-inversion estimates begin their rise in 1999-2000 whereas the GHGI estimates began to rise from 1994.

Figure A 10.4.2 Verification of the UK emission inventory estimates for HFC-134a in Gg yr-1 for 1990-2010. GHGI estimates are shown in orange. EDGAR estimates shown in purple. NAME-inversion estimates are shown in black. NAME-inversion uncertainties are shown with the black whisker lines showing 5th, median, and 95th percentiles. Note: 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 is shows a rise from the mid-1990s until 2008 and then a levelling-off of concentration.

Figure A 10.4.3 Monthly and annual Northern Hemisphere trend in HFC-152a estimated from Mace Head observations (ppt).

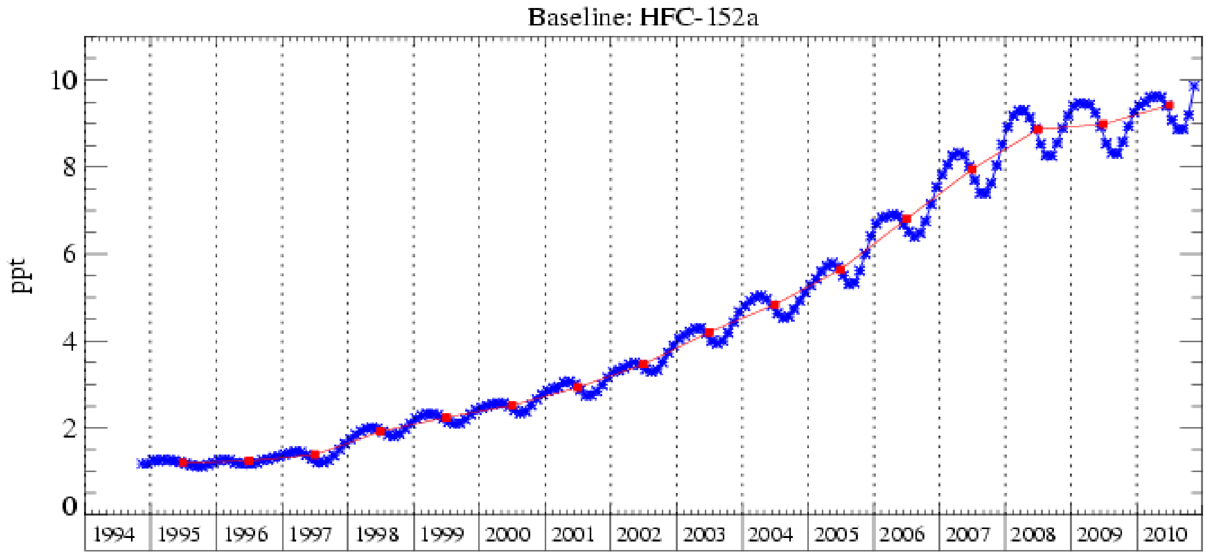
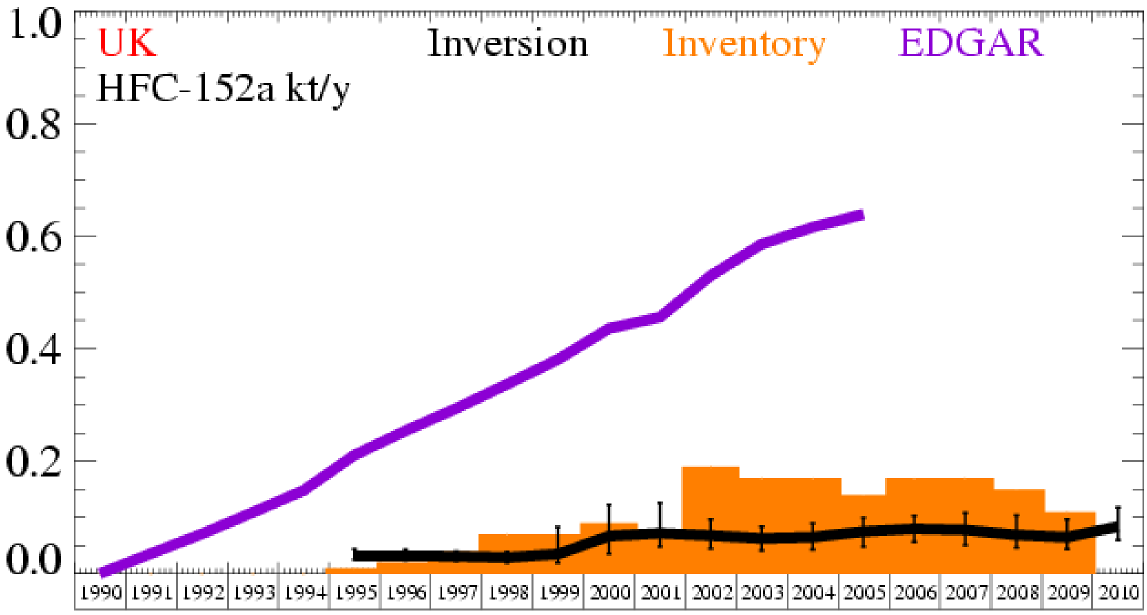


Figure A 10.4.4 shows the NAME-inversion and the GHGI emission estimates for the UK for HFC-152a for the period 1990 onwards. From 2002 the GHGI estimates are twice those estimated through the inversion modelling. The EDGAR estimates are considerably higher than both other inventories.

Figure A 10.4.4 Verification of the UK emission inventory estimates for HFC-152a in Gg yr-1 for 1990-2010. GHGI estimates are shown in orange. EDGAR estimates shown in purple. NAME-inversion estimates are shown in black. NAME-inversion uncertainties are shown with the black whisker lines showing 5th, median, and 95th percentiles. Note: 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**. All three estimates suggest that the emissions of HFC-125 from the UK have increased significantly from the mid-1990s.

Figure A 10.4.5 Monthly and annual Northern Hemisphere trend in HFC-125 estimated from Mace Head observations (ppt).

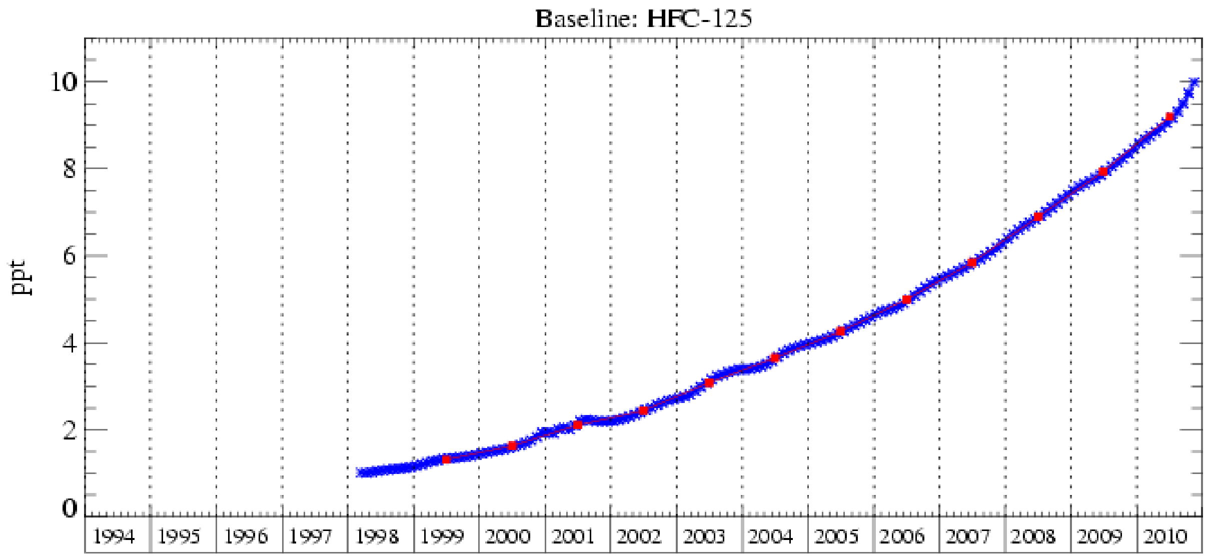
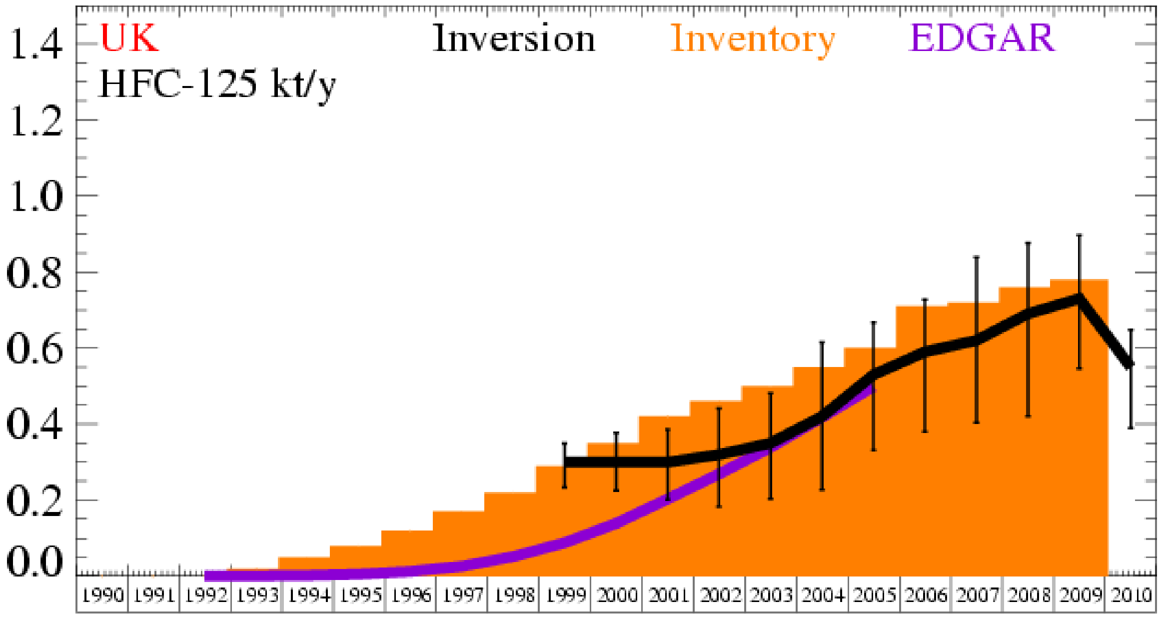


Figure A 10.4.6 Verification of the UK emission inventory estimates for HFC-125 in Gg yr-1 for 1990-2010. GHGI estimates are shown in orange. EDGAR estimates shown in purple. NAME-inversion estimates are shown in black. NAME-inversion uncertainties are shown with the black whisker lines showing 5th, median, and 95th percentiles. Note: 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 and EDGAR estimates. All three estimates are closely aligned and show the UK emissions increasing year on year from the early 1990s.

Figure A 10.4.7 Monthly and annual Northern Hemisphere trend in HFC-143a estimated from Mace Head observations (ppt).

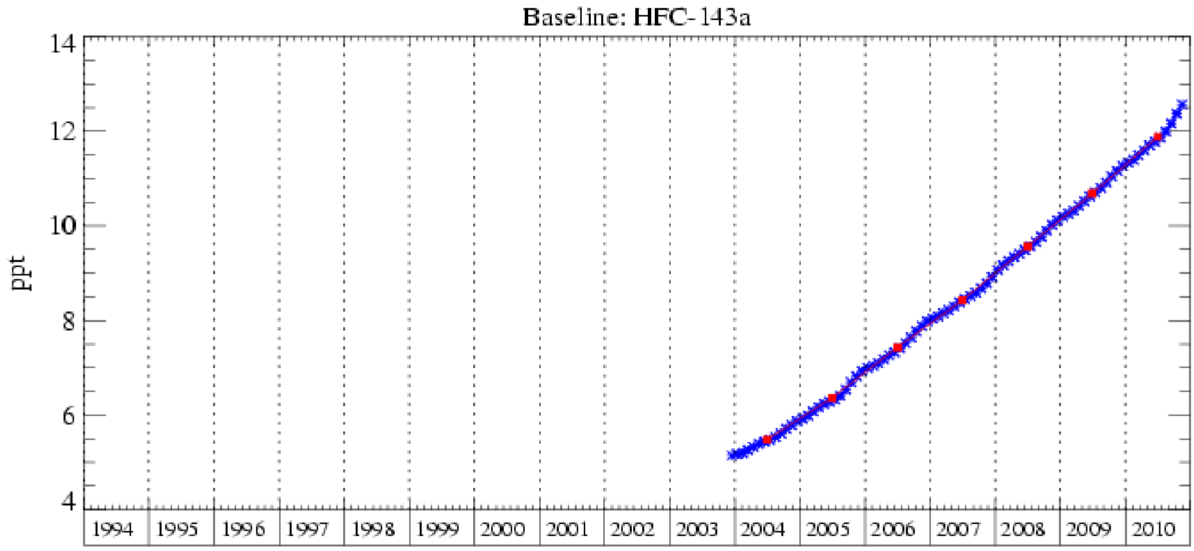
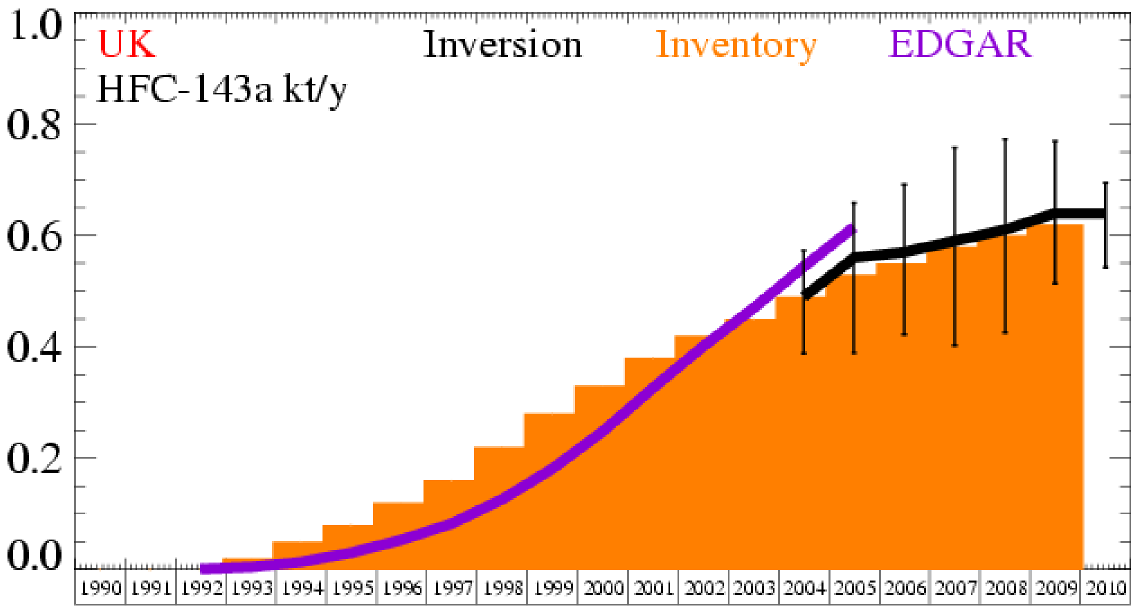


Figure A 10.4.8 Verification of the UK emission inventory estimates for HFC-143a in Gg yr-1 for 1990-2010. GHGI estimates are shown in orange. EDGAR estimates shown in purple. NAME-inversion estimates are shown in black. NAME-inversion uncertainties are shown with the black whisker lines showing 5th, median, and 95th percentiles. Note: 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).

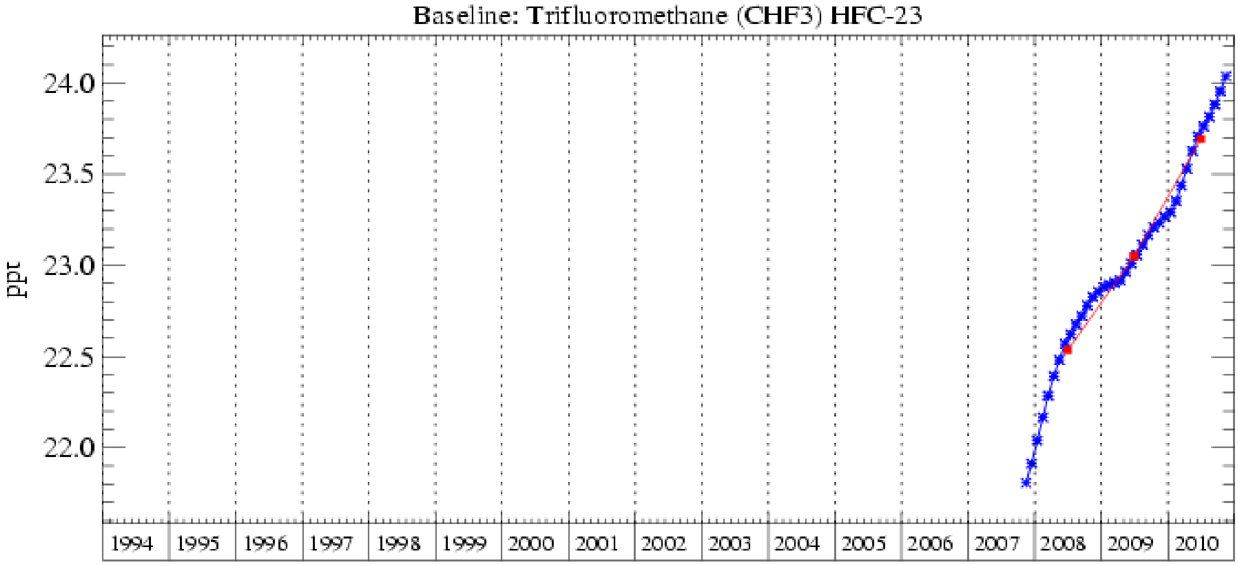
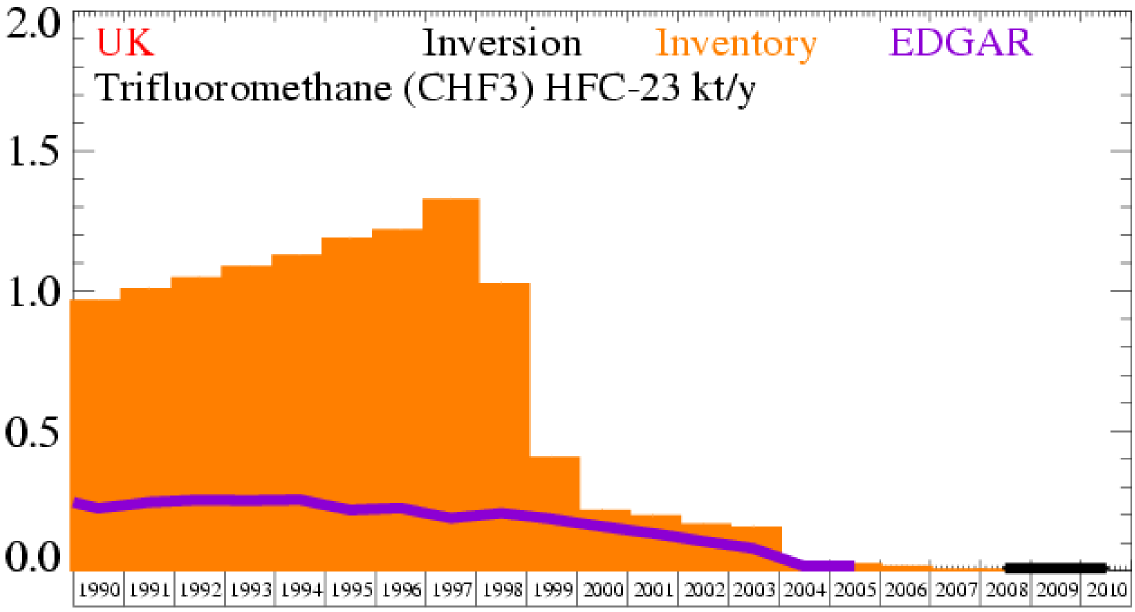


Figure A 10.4.10 Verification of the UK emission inventory estimates for HFC-23 in Gg yr-1 for 1990-2010. GHGI estimates are shown in orange. EDGAR estimates shown in purple. NAME-inversion estimates are shown in black. NAME-inversion uncertainties are shown with the black whisker lines showing 5th, median, and 95th percentiles. Note: 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 GHGI and NAME-inversion emission estimates are very closely aligned and different to those estimated through EDGAR.

Figure A 10.4.11 Monthly and annual Northern Hemisphere trend in HFC-32 estimated from Mace Head observations (ppt).

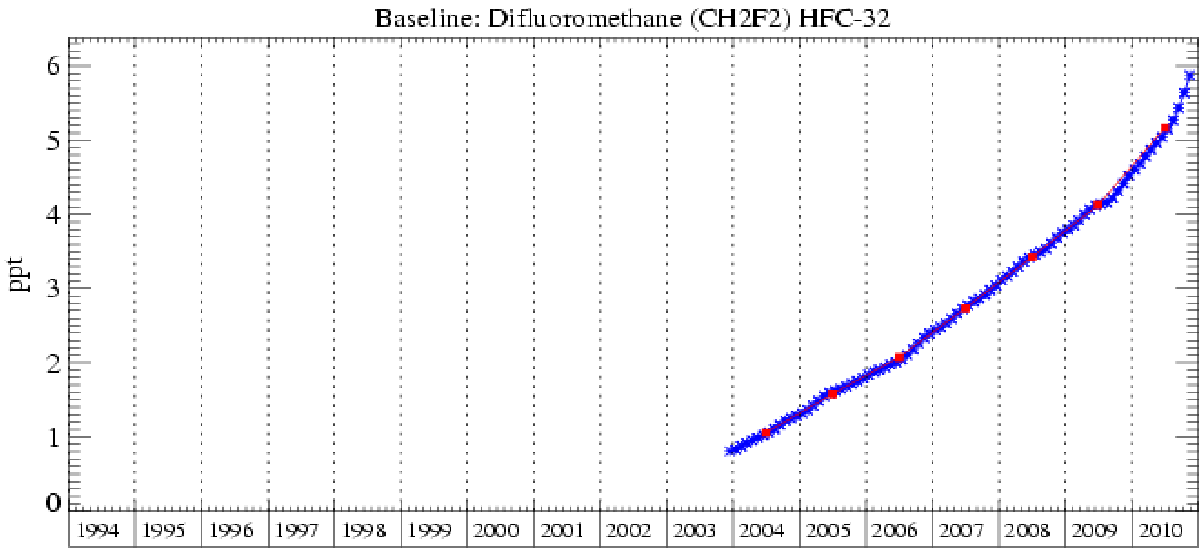
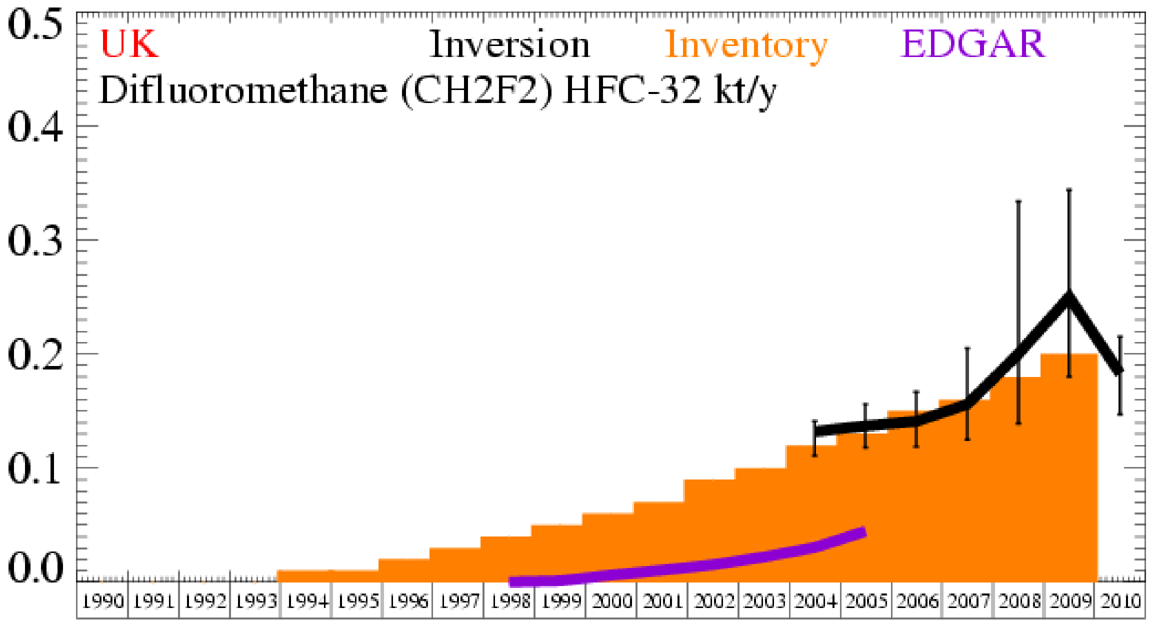


Figure A 10.4.12 Verification of the UK emission inventory estimates for HFC-32 in Gg yr-1 for 1990-2010. GHGI estimates are shown in orange. EDGAR estimates shown in purple. NAME-inversion estimates are shown in black. NAME-inversion uncertainties are shown with the black whisker lines showing 5th, median, and 95th percentiles. Note: 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, GHGI and EDGAR estimates of UK emissions of PFC-14 are shown in **Figure A 10.5.2**. The NAME estimates are double those reported in the GHGI, except in 2008 where the agreement is good. 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).

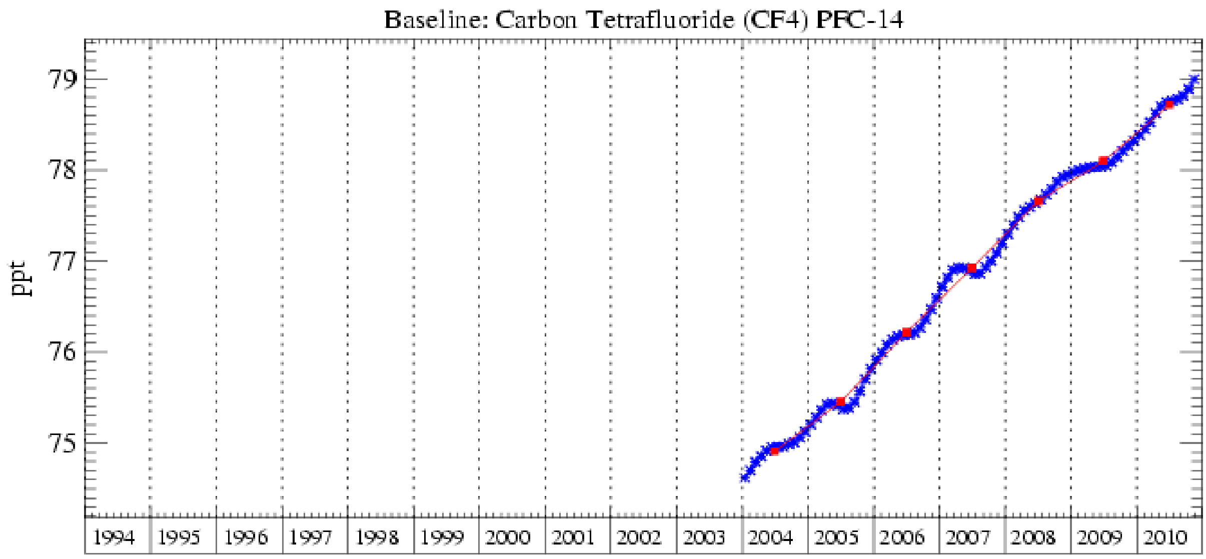
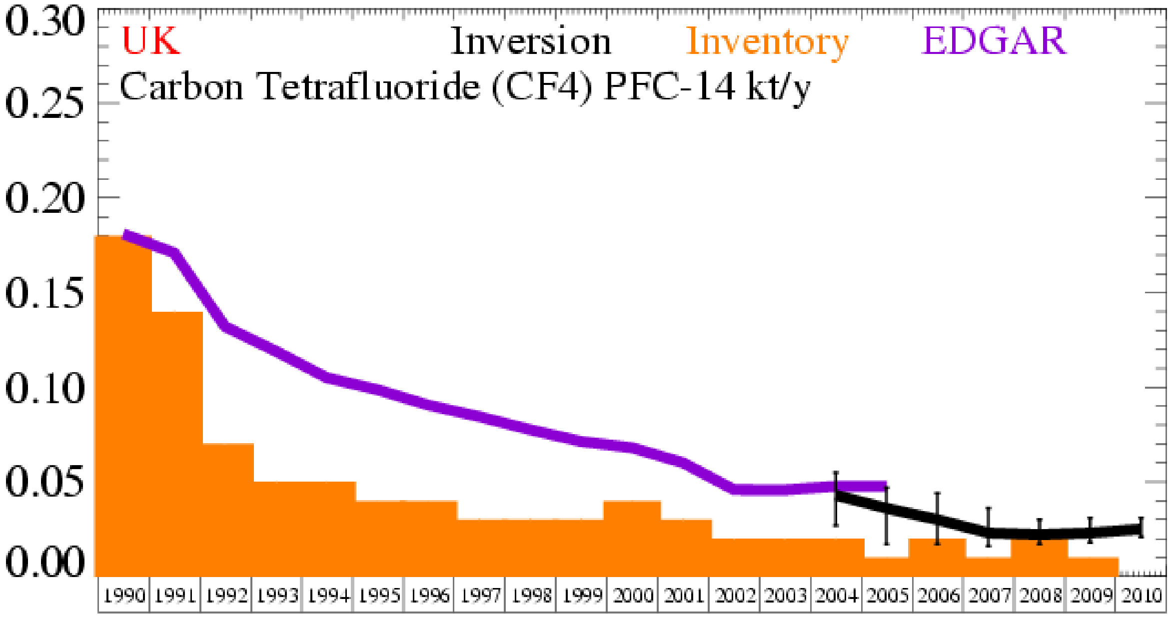


Figure A 10.5.2 Verification of the UK emission inventory estimates for PFC-14 in Gg yr-1 for 1990-2010. GHGI estimates are shown in orange. EDGAR estimates shown in purple. NAME-inversion estimates are shown in black. NAME-inversion uncertainties are shown with the black whisker lines showing 5th, median, and 95th percentiles. Note: 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).

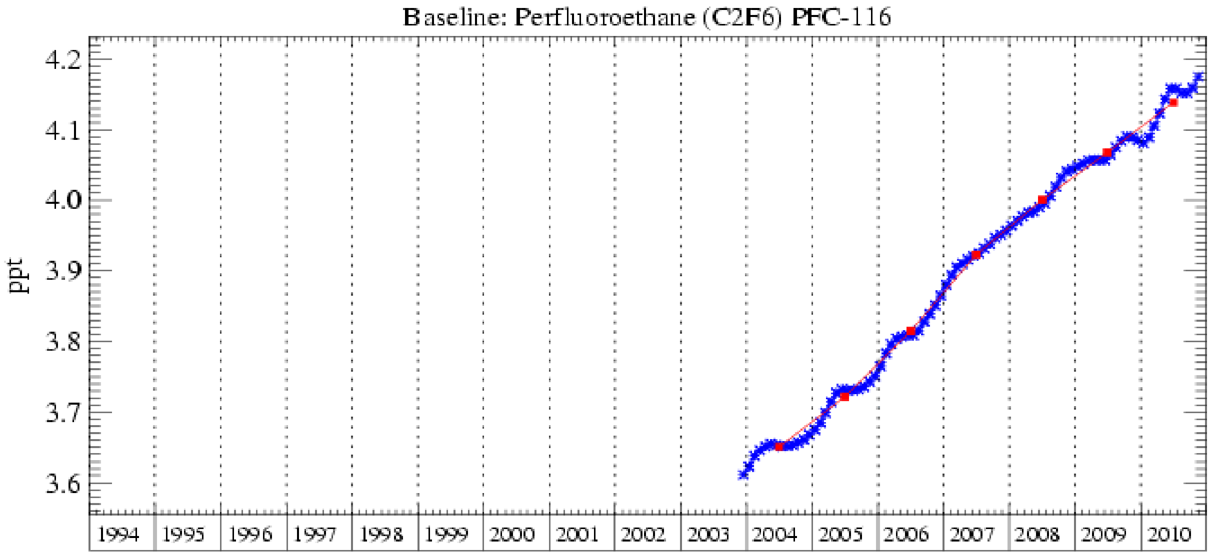
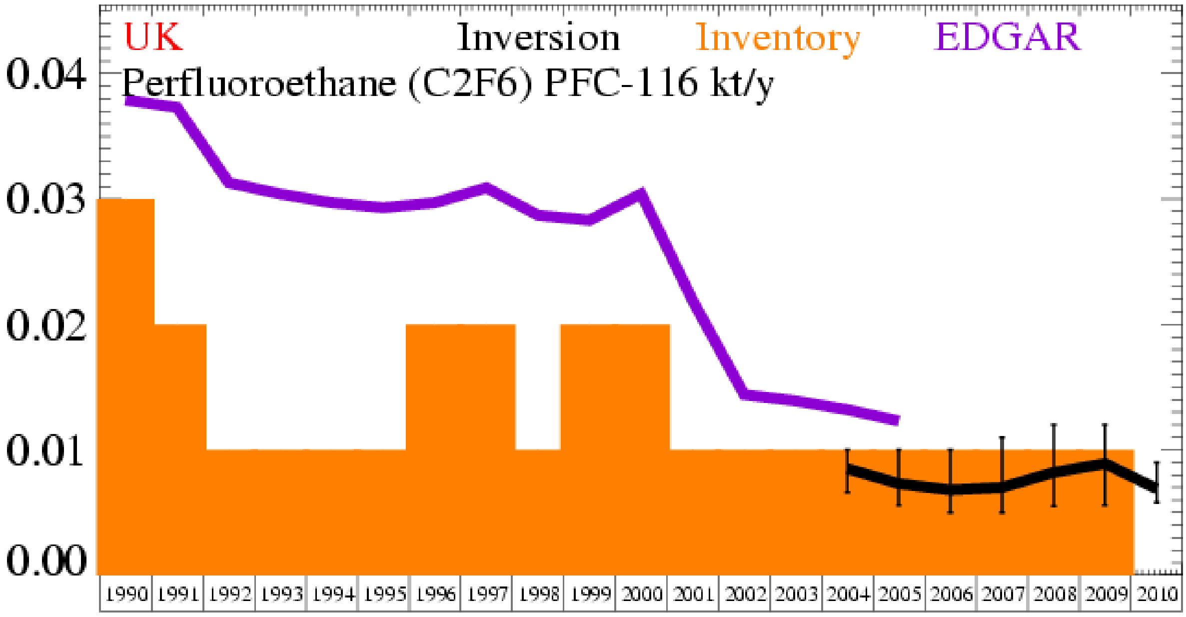


Figure A 10.5.4 Verification of the UK emission inventory estimates for PFC-116 in Gg yr-1 for 1990-2010. GHGI estimates are shown in orange. EDGAR estimates shown in purple. NAME-inversion estimates are shown in black. NAME-inversion uncertainties are shown with the black whisker lines showing 5th, median, and 95th percentiles. Note: 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).

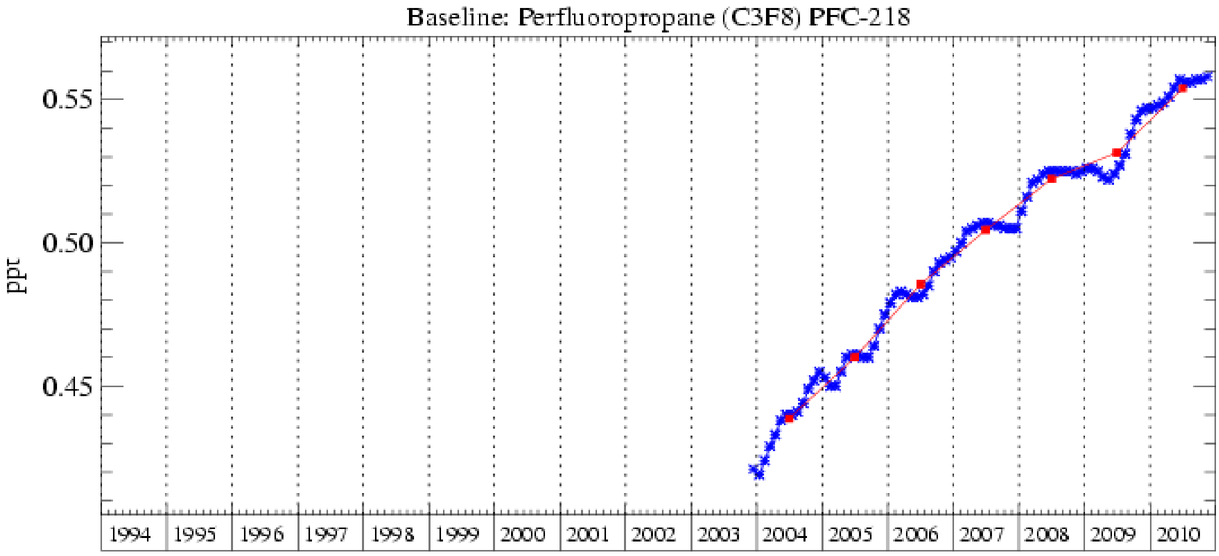
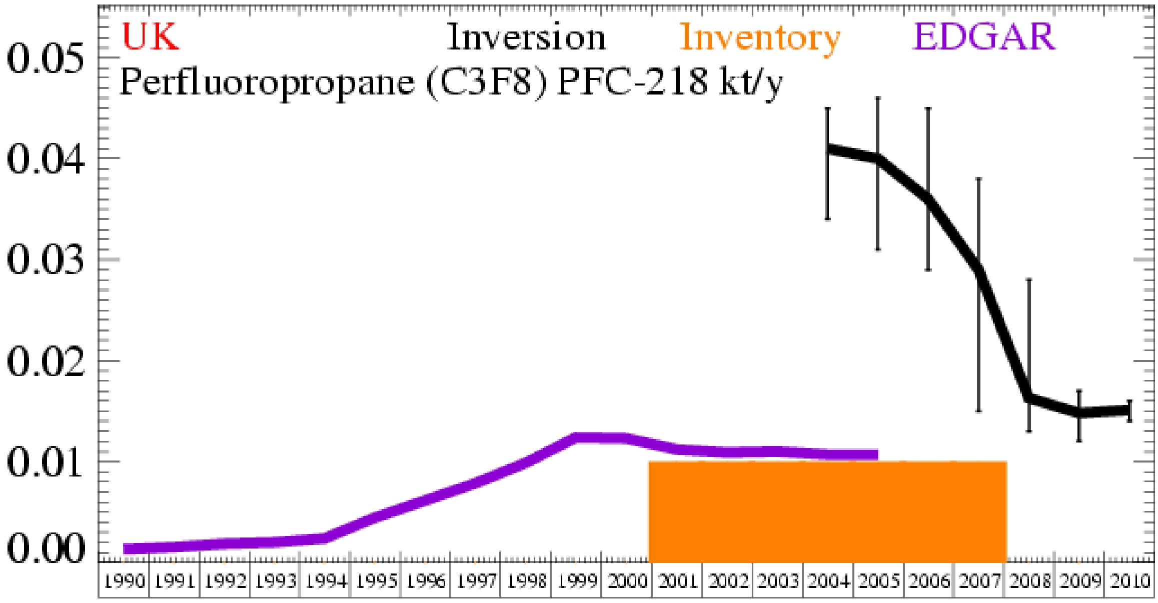


Figure A 10.5.6 Verification of the UK emission inventory estimates for PFC-218 in Gg yr-1 for 1990-2010. GHGI estimates are shown in orange. EDGAR estimates shown in purple. NAME-inversion estimates are shown in black. NAME-inversion uncertainties are shown with the black whisker lines showing 5th, median, and 95th percentiles. Note: 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 SF6 estimated from Mace Head observations (ppt).

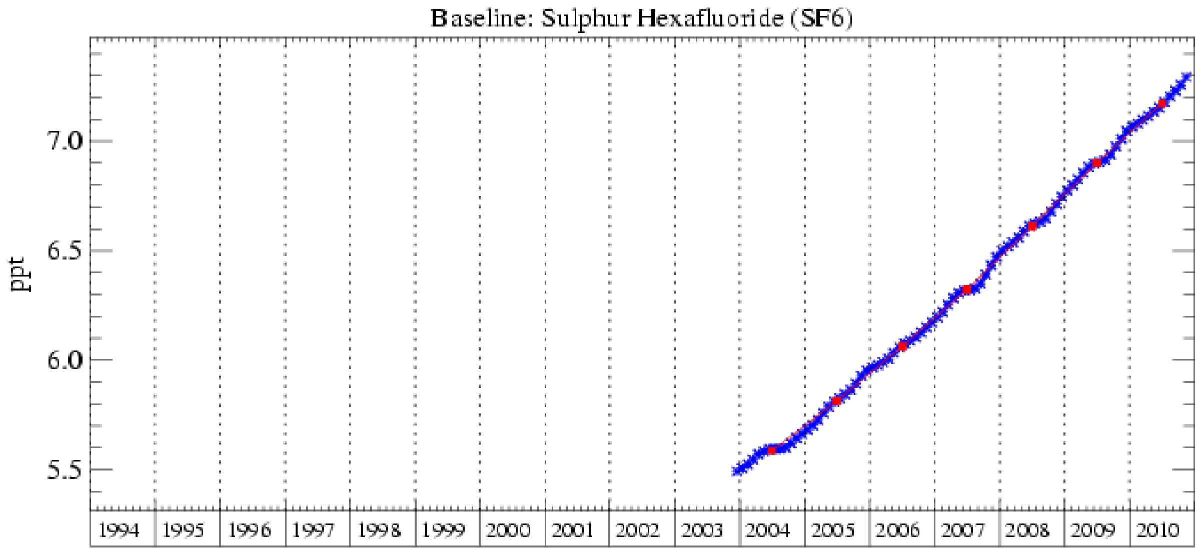
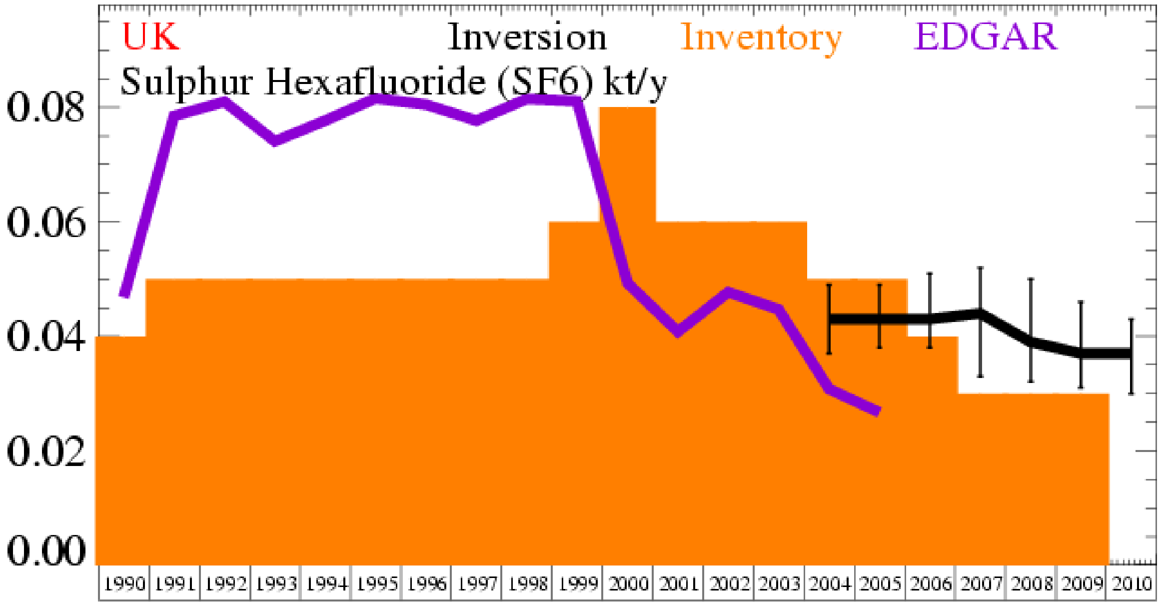


Figure A 10.6.2 **Verification of the UK emission inventory estimates for SF_6 in Gg yr-1 for 1990-2010. GHGI estimates are shown in orange. EDGAR estimates shown in purple. NAME-inversion estimates are shown in black. NAME-inversion uncertainties are shown with the black whisker lines showing 5th, median, and 95th percentiles. Note: kt yr-1 is equivalent to 1 Gg yr-1.**



A11 ANNEX 11: Analysis of EU ETS Data

A11.1 INTRODUCTION

The EU Emission Trading Scheme (EU ETS) 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 EU ETS has operated since 2005, and there are now 5 years' worth of data on fuel use and emissions across major UK industrial plant, for 2005-2009.

The data reported under the EU ETS includes quantities of fuels consumed, carbon contents, calorific values and emissions of CO_2. Data for individual installations are treated as commercially confidential by the UK regulatory authorities and so only aggregated emissions data are presented here.

EU ETS processes are collectively responsible for a major proportion of UK emissions of carbon dioxide and so the EU ETS data has the potential to be an extremely important source of information to support the UK GHG inventory. However, operators of processes which were included in the UK Emission Trading Scheme (UK ETS), or which had a Climate Change Agreement (CCA) could choose to be exempt from the EU ETS. The UK ETS exemptions were valid until the end of 2006, whilst the CCA exemptions were valid until the end of 2007. These exemptions mean that the 2005 to 2007 EU ETS data gave an incomplete picture of total UK fuels consumed and carbon dioxide emitted by several major industrial sectors.

From the 2008 EU ETS dataset onwards, all of the major plant opt-outs will have ceased, and a more complete picture of fuel use and emissions across heavy industry in the UK is available. Note however, that emissions from smaller combustion devices in the industrial, commercial and public sectors will not be reported, since they are outside the scope of the EU ETS. This limitation will continue to restrict how much of the EU ETS data can be used to cross-check and directly inform the GHGI. However, from the 2008 dataset onwards, 100% of sector emissions should be covered for several major industrial sectors:

- Power stations;
- Oil refineries;
- Coke ovens;
- Integrated steelworks;
- Cement kilns; and
- Lime kilns.

In the case of coke ovens and integrated steelworks, the EU ETS reporting format does not provide a breakdown of emissions for the sectors reported within the GHGI: estimates of emissions from coke ovens, blast furnaces and sinter plants are not provided explicitly. In addition, the scope of reporting of EU ETS does not cover 100% of iron & steel sites or activities, as some secondary steel processes are excluded from the scope of EU ETS reporting. These two factors make the analysis and comparison of the EU ETS and the GHGI estimates much more uncertain for these sectors. The EU ETS data has, however, been useful as a quality check for the use of fuels within the iron and steel sector.

This annex summarises what data are available in the 2005 to 2009 EU ETS datasets for power stations and refineries, and identifies which EU ETS fuel quality data (i.e. CO_2 emission factors) have been used within the GHGI. Data for the 'other industrial combustion' sector are also briefly described as an example of an area of the GHGI where use of EU ETS data is more problematic.

A11.2 PROCESSING OF EU ETS DATA

In order to be able to compare EU ETS data with GHGI data it was necessary to:

1) allocate each of the installations named in the EU ETS dataset to one of the emission sectors reported in the GHGI; and
2) allocate each fuel used by each installation to one of the fuel types used in the GHGI.

Task 1 was straightforward, while the allocation of fuels to GHGI categories was, occasionally, quite uncertain. The uncertainties largely centred on the allocation of fuels to GHGI fuel categories such as LPG, OPG, gas oil and fuel oil, and were due to the use of abbreviations or other ambiguous names for fuels within the EU ETS reporting system. There were also some instances where gas oil was specified as the fuel, but where it was possible that fuel oil was actually used, and vice versa.

The level of coverage of the EU ETS data can be seen in **Table A 11.2.1.** The number of sites in each sector which are included in the ETS dataset for 2005 and 2009 are given, together with AEA's estimate of the total number of installations in that sector throughout the UK in those years.

Table A 11.2.1 Numbers of installations included in the EU ETS datasets

Sector	Number of installations			
	2005		2009	
	EU ETS	UK total	EU ETS	UK total
Power stations (fossil fuel, > 75MWe)	60	60	62	62
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	13	13
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]	379	5000[a]
Combustion – commercial sector	28	1000[a]	33	1000[a]
Combustion – public sector	169	1000[a]	120	1000[a]

[a] These estimates are not intended to be particularly accurate but are 'order of magnitude' figures, offered in order to show that the number of installations in the UK is likely to be considerably higher than the number of installations reporting in the EU ETS at present.

Data were included 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 eight stations are not included in the EU ETS data, 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) and for combustion processes (due to CCA/UKETS opt-outs and the fact that numerous combustion plant are too small to be required to join the EU ETS). All cement kilns are included in 2009 and all but two lime kilns, which are excluded.

A11.3 ANALYSIS OF EU ETS DATA FOR POWER STATIONS

Table A 11.3.1 summarises data given in the EU ETS datasets for the major fuels burnt by major power stations and coal burnt by autogenerators. The percentage of emissions that were based on use of 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). The table then gives the average emission factor for all EUETS emissions that were based on use of the Tier 3 factors.

Table A 11.3.1 EU ETS data for Coal, Fuel Oil and Natural Gas burnt at Power Stations and Autogenerators (Emission Factors in ktonne / Mtonne for Coal & Fuel Oil and ktonne / Mtherm for Natural Gas)

Year	Fuel	% Tier 3	Average Carbon Emission Factor (Tier 3 sites only)
2005	Coal	99	615.6
2006		100	615.6
2007		100	615.4
2008		100	614.0
2009		100	610.5
2005	Fuel oil / Waste oil[a]	59	860.2
2006		66	873.3
2007		70	871.2
2008		92	869.5
2009		97	872.7
2005	Natural gas	52	1.443
2006		76	1.465
2007		95	1.464
2008		97	1.467
2009		100	1.464
2005	Sour gas	100	-[b]
2006		100	-[b]
2007		100	-[b]
2008		-	n.a.
2009		100	-[b]
2005	Coal - autogenerators	100	594.3
2006		100	596.3
2007		100	594.5
2008		100	581.3
2009		100	600.6

[a] It is not possible to distinguish between fuel oil and waste oil in the EU ETS data, so all emissions have been reported under fuel oil.
[b] Emission factors can be calculated for 2005-2007 and for 2009, but are based on data for a limited number of sites and are therefore confidential.

The EU ETS data shown are regarded as good quality data, since a high proportion of emissions are based on Tier 3 emission factors (i.e. verified emissions based on fuel analysis to ISO17025). The EU ETS based emission factors presented above have therefore been 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. Small quantities of sour gas were burnt at one power station in 2005-2007 and 2009 and EU ETS Tier 3 emission factors are available and therefore used. Due to the confidentiality of the data, the emission factors are not shown.

A11.4 ANALYSIS OF EU ETS DATA FOR REFINERIES

Similar data to that shown in **Table A 1.3.1** for power stations are shown for oil refineries in **Table A 11.4.1** and **Table A 11.4.2.** The main fuels in refineries are fuel oil and OPG and emissions also occur due to the burning off of 'petroleum coke' deposits on catalysts used in processes such as catalytic cracking. In the latter case, emissions in the EU ETS are not generally based on activity data and emission factors but are instead based on direct measurement of carbon emitted. This is due to the technical difficulty in measuring the quantity of petroleum coke burnt and the carbon content. **Table A 11.4.2** also shows the carbon emission that would be obtained if the previous inventory method were being used. This involves the use of petroleum coke consumption data from UK energy statistics (DECC, 2010) and an emission factor of 930 kt C / Mt petroleum coke taken from Baggott *et al*, 2004.

Table A 11.4.1 EU ETS Data for Fuel Oil & OPG burnt at Refineries (Emission Factors in ktonne / Mtonne for Fuel Oil and ktonne / Mtherm for OPG)

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
2005	OPG	60	1.495
2006		58	1.469
2007		58	1.511
2008		82	1.483
2009		81	1.489

Table A 11.4.2 EU ETS Derived Data for Carbon Emissions from Petroleum Coke burnt at Refineries (in Mtonnes)

Year	Fuel	% Tier 3	Emission from EUETS	Emission, based on DUKES[b]
2005	Petroleum Coke	-[a]	1.273	1.123
2006		-[a]	1.338	1.263
2007		-[a]	1.350	1.300
2008		-[a]	1.282	1.271
2009		-[a]	1.263	1.311

[a] It was unclear from the data received how much of the emission was based on a Tier 3 approach.
[b] Using an emission factor of 930 kt/Mt of petroleum coke burnt (figure suggested by the refinery industry).

Emission factors for fuel oil generated from EU ETS data have been adopted in the GHGI, with the exception of data for 2005, where Tier 3 methods were used for only 25% of fuel.

Carbon factors can be derived for OPG based on moderate levels of Tier 3 reporting for 2005-2007, but levels of more than 80% for 2008 onwards. There is some uncertainty regarding the allocation of EU ETS fuels to the OPG fuel category, and the derived emission factors for 2006 and 2007 are significantly different to the values for 2005 and 2008-2009. For these reasons, only the data for 2008 – 2009 are used. For earlier years, the mean of the 2008 and 2009 figures is used.

Emission data for petroleum coke are higher in 2005-2008 than would be obtained using DUKES activity data, and an appropriate emission factor, and lower in 2009. This is especially noticeable for 2005, where the petroleum coke consumption given in DUKES would have to be more than 100% carbon in order to generate the carbon emissions given in the EU ETS. Consultation with energy statisticians has identified that the figures given in DUKES are subject to considerable uncertainty and, as a result, the EU ETS data have been used instead.

A11.5 ANALYSIS OF EUETS DATA FOR INDUSTRIAL COMBUSTION SOURCES

Table A 11.5.1 gives data for industrial combustion of coal, fuel oil and natural gas.

Table A 11.5.1 EU ETS data for Coal, Fuel Oil and Natural Gas burnt by Industrial Combustion Plant (Emission Factors in ktonne / Mtonne for Coal & Fuel Oil and ktonne / Mtherm for Natural Gas)

Year	Fuel	% Tier 3	Average Carbon Emission Factor (Tier 3 sites only)	GHGI Carbon Emission Factor
2005	Coal	98	607.1	631.1
2006		98	603.0	631.1
2007		99	613.5	645.4
2008		94	596.8	640.6
2009		91	595.7	652.5

Year	**Fuel**	**% Tier 3**	**Average Carbon Emission Factor (Tier 3 sites only)**	**GHGI Carbon Emission Factor**
2005	Fuel oil	17	864.7	879.0
2006		27	865.3	879.0
2007		20	865.7	879.0
2008		18	870.7	879.0
2009		30	867.8	879.0
2005	Natural gas	13	1.593	1.478
2006		32	1.449	1.478
2007		43	1.469	1.477
2008		35	1.504	1.474
2009		44	1.496	1.474

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 EU ETS and that the EU ETS data are not fully representative of UK fuels as a whole. This is also true for EU ETS data for fuel oil and natural gas but here, in addition, very little of the EU ETS data are based on Tier 3 factors. Therefore, none of these data have been used directly in the compilation of the GHGI estimates.

Data for coal burnt in lime kilns are available for 2007 onwards, although in 2007 only 50% of the data was based on Tier 3 reporting, and hence these data have been disregarded. However, in 2008 the level of Tier 3 analysis of coal in the lime sector within EUETS increases to 81%, with 100% Tier 3 reporting in 2009, and therefore these operator data have been used directly to inform GHGI estimates in those years.

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:

Lime kilns / coal
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 (2005-9), and emission factors for OPG burnt at refineries (just for 2008-9 where there is a high percentage of Tier 3 reporting), are also applied to all other sources using these fuels.

A11.6 ANALYSIS OF EUETS DATA FOR CEMENT PROCESS SOURCES

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 other statistics that are provided from the British Cement Association (BCA) regarding clinker production and the non-combustion emissions associated with UK cement production. However, it must be noted that due to the CCA opt-outs the EUETS dataset only has complete coverage of the UK cement sector for 2008 and 2009, so there is a very limited dataset to work with, and firm conclusions cannot be drawn at this stage from the EUETS information. Note also that the BCA data on clinker production is commercially confidential.

From the detailed EUETS site-specific calculations for the UK cement sector, it is evident that sites use a range of estimation methods to derive the EUETS emissions from process sources, using a range of activity data and emission factors to reflect the different process designs and sub-sources of process CO_2 emissions. The activity data used within the EUETS by cement kiln operators include:

- Mass of cement clinker produced
- Mass of raw meal used to manufacture clinker
- Mass of cement kiln dust manufactured

The industry-wide estimates provided by the BCA 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:

Table A 11.6.1 Comparison of Cement Sector Carbon Dioxide Emissions within the UK GHGI and the EUETS for 2008-9

	2008	**2009**
GHGI CO_2 emissions (kt)	5202.6	3720.5
Sum of EUETS CO_2 emissions (kt)	5163.1	3677.0
EUETS / GHGI (%)	99.2	98.8

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 CO2eq) – National Statistics coverage

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Energy Supply	272.13	269.83	258.71	241.13	233.54	233.90	235.52	220.01	222.56	209.86
Transport	122.06	120.26	121.46	122.74	123.27	122.63	126.95	128.26	127.32	128.40
Residential	80.76	89.56	86.91	90.92	86.51	82.26	93.87	87.35	90.06	89.71
Business	112.38	116.58	112.18	110.70	110.22	107.65	110.17	107.54	108.03	109.63
Public	14.07	14.99	15.63	14.25	13.87	13.67	14.74	14.34	12.71	12.50
Industrial Process	54.29	52.39	47.03	43.41	45.30	44.81	45.61	47.14	43.87	26.86
Agriculture	62.96	62.49	60.71	60.01	61.01	60.83	61.30	61.56	60.45	59.81
Land Use Change	3.91	3.88	3.30	2.25	2.07	2.44	2.21	1.91	1.34	1.09
Waste Management	59.05	56.48	53.59	50.81	48.40	46.14	44.10	40.00	37.15	33.77
Total	**781.60**	**786.46**	**759.52**	**736.22**	**724.19**	**714.33**	**734.47**	**708.12**	**703.51**	**671.62**
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Energy Supply	218.63	228.72	225.59	229.95	228.01	227.93	231.14	226.10	219.20	195.01
Transport	127.33	127.36	129.89	129.42	130.64	131.13	131.35	132.37	127.57	122.20
Residential	90.14	92.56	89.10	90.20	91.69	87.82	85.22	81.47	83.39	78.60
Business	110.50	111.18	101.44	103.76	102.39	103.15	100.87	99.09	97.37	85.86
Public	11.75	12.16	10.34	10.18	11.10	11.04	9.99	9.29	9.35	8.20
Industrial Process	24.43	21.82	18.51	19.33	18.84	17.99	16.52	17.87	16.36	10.39
Agriculture	57.25	54.29	54.49	53.77	53.53	53.38	51.48	50.49	50.03	49.49
Land Use Change	0.41	-0.10	-0.99	-1.37	-2.44	-2.99	-3.19	-3.55	-3.99	-4.11
Waste Management	31.51	27.71	25.33	22.33	20.67	19.98	19.51	19.05	18.45	17.95
Total	**671.95**	**675.70**	**653.69**	**657.57**	**654.42**	**649.43**	**642.90**	**632.18**	**617.73**	**563.58**

Table A 12.1.2 Summary table of GHG emissions by Gas (Mt CO2eq) – National Statistics coverage

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2	589.66	596.82	579.82	564.94	559.16	550.79	572.79	548.72	551.61	542.31
CH_4	110.38	107.84	104.59	100.08	91.78	90.13	87.13	81.64	76.90	71.56
N_2O	67.74	67.70	61.09	56.41	57.54	56.26	56.17	57.16	56.58	45.95
HFCs	11.39	11.85	12.32	13.12	14.05	15.45	16.63	18.98	16.77	10.01
PFCs	1.40	1.17	0.57	0.49	0.49	0.46	0.48	0.40	0.39	0.37
SF_6	1.03	1.08	1.12	1.17	1.18	1.24	1.27	1.23	1.26	1.43
Total	**781.60**	**786.46**	**759.52**	**736.22**	**724.19**	**714.33**	**734.47**	**708.12**	**703.51**	**671.62**
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
CO_2	549.37	561.25	543.70	553.45	552.60	549.74	546.32	537.77	525.13	473.73
CH_4	66.71	60.92	57.89	52.01	50.20	48.59	47.16	45.69	44.45	43.59
N_2O	44.89	42.36	40.73	40.08	40.68	39.49	37.66	37.17	36.41	34.56
HFCs	8.72	9.36	9.54	10.42	9.47	10.24	10.58	10.54	10.82	10.90
PFCs	0.47	0.39	0.32	0.28	0.34	0.26	0.31	0.22	0.21	0.15
SF_6	1.80	1.42	1.51	1.32	1.13	1.11	0.87	0.79	0.71	0.66
Total	**671.95**	**675.70**	**653.69**	**657.57**	**654.42**	**649.43**	**642.90**	**632.18**	**617.73**	**563.58**

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
Energy Supply	271.61	269.27	258.05	240.52	232.92	233.25	234.87	219.41	221.92	209.21
Transport	121.59	119.79	120.99	122.26	122.79	122.14	126.41	127.71	126.76	127.86
Residential	80.45	89.24	86.61	90.61	86.21	81.94	93.54	86.94	89.64	89.33
Business	112.17	116.35	111.99	110.49	110.01	107.42	109.90	107.24	107.71	109.36
Public	14.07	14.99	15.63	14.25	13.87	13.67	14.74	14.34	12.71	12.50
Industrial Process	54.29	52.39	47.03	43.41	45.30	44.81	45.61	47.14	43.87	26.86
Agriculture	62.82	62.35	60.56	59.88	60.87	60.69	61.16	61.42	60.31	59.66
Land Use Change	3.88	3.84	3.33	2.21	2.04	2.41	2.19	1.91	1.31	1.06
Waste Management	58.91	56.34	53.45	50.68	48.28	46.02	43.97	39.87	37.02	33.64
Total	**779.78**	**784.58**	**757.65**	**734.32**	**722.28**	**712.35**	**732.39**	**706.00**	**701.26**	**669.47**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Energy Supply	218.14	228.51	225.38	229.81	227.78	227.67	230.84	225.75	218.84	194.67
Transport	126.77	126.78	129.31	128.82	130.03	130.51	130.75	131.75	126.96	121.60
Residential	89.76	92.20	88.73	89.85	91.38	87.48	84.88	81.12	83.06	78.24
Business	110.19	110.84	101.09	103.44	102.07	102.84	100.56	98.74	97.09	85.53
Public	11.75	12.16	10.34	10.18	11.10	11.04	9.99	9.29	9.35	8.20
Industrial Process	24.43	21.82	18.51	19.33	18.84	17.99	16.52	17.87	16.36	10.39
Agriculture	57.11	54.15	54.36	53.67	53.43	53.28	51.36	50.36	49.90	49.37
Land Use Change	0.37	-0.13	-1.00	-1.41	-2.49	-3.03	-3.20	-3.57	-4.01	-4.12
Waste Management	31.42	27.63	25.26	22.26	20.63	19.93	19.46	19.00	18.40	17.90
Total	**669.95**	**673.95**	**651.97**	**655.96**	**652.79**	**647.71**	**641.15**	**630.32**	**615.96**	**561.79**

Table A 12.2.2 Summary table of GHG emissions by Gas (Mt CO2eq) – UK Only

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2	588.14	595.24	578.25	563.33	557.54	549.11	571.01	546.90	549.68	540.48
CH_4	110.13	107.58	104.33	99.84	91.54	89.88	86.88	81.40	76.65	71.32
N_2O	67.70	67.65	61.04	56.37	57.49	56.21	56.12	57.12	56.53	45.90
HFCs	11.39	11.85	12.32	13.12	14.04	15.45	16.62	18.97	16.75	9.99
PFCs	1.40	1.17	0.57	0.49	0.49	0.46	0.48	0.40	0.39	0.37
SF_6	1.03	1.08	1.12	1.17	1.18	1.24	1.27	1.23	1.26	1.43
Total	**779.78**	**784.58**	**757.65**	**734.32**	**722.28**	**712.35**	**732.39**	**706.00**	**701.26**	**669.47**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2	547.63	559.77	542.24	552.05	551.16	548.23	544.81	536.15	523.60	472.16
CH_4	66.51	60.73	57.71	51.87	50.09	48.46	47.01	45.53	44.30	43.45
N_2O	44.84	42.31	40.68	40.05	40.65	39.46	37.62	37.13	36.37	34.52
HFCs	8.70	9.33	9.51	10.38	9.42	10.19	10.53	10.49	10.77	10.85
PFCs	0.47	0.39	0.32	0.28	0.34	0.26	0.31	0.22	0.21	0.15
SF_6	1.80	1.42	1.51	1.32	1.13	1.11	0.87	0.79	0.71	0.66
Total	**669.95**	**673.95**	**651.97**	**655.96**	**652.79**	**647.71**	**641.15**	**630.32**	**615.96**	**561.79**

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 2009.

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[20].

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 1990-2009, 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 have been included in the totals as a separate row. There is not enough information available to reallocate emissions from energy supply in the Overseas Territories.

A13.2 DEFINITION OF FINAL USERS

The final user[21] 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:
  1. Direct emissions from domestic premises, for example, from burning gas, coal or oil for space heating.

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

[21] 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.

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:

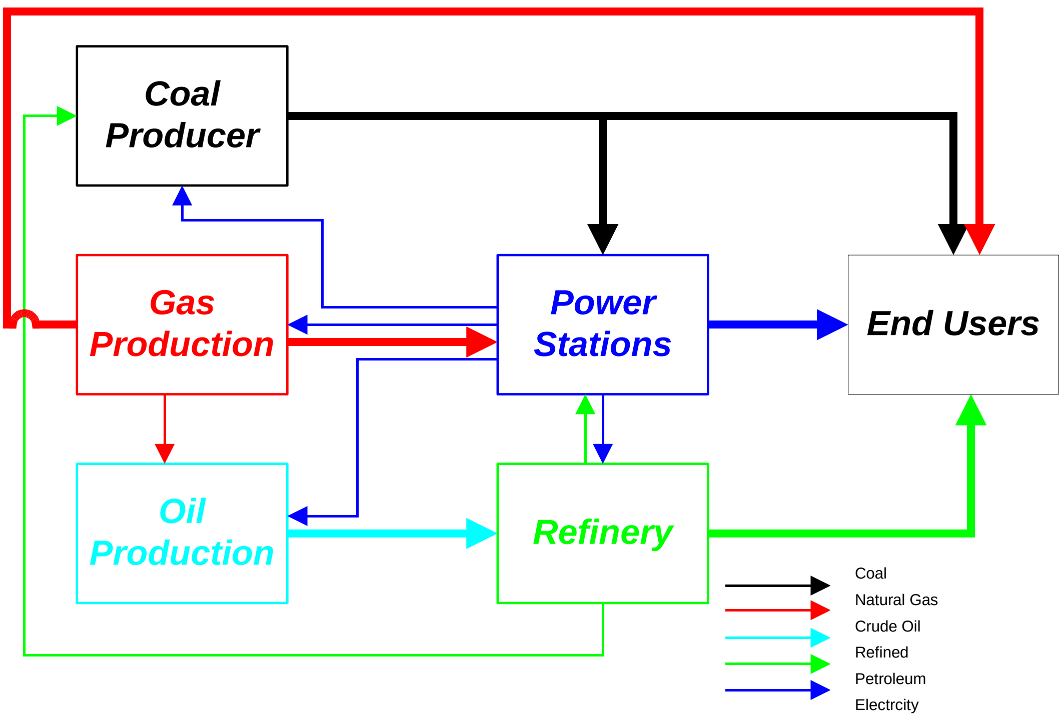
1. Direct emissions from motor vehicle exhausts.
2. Emissions refineries producing motor fuels, including refining, storage, flaring and extraction of oil; and from the distribution and supply of motor fuels.

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[22] 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%)[23] 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.

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

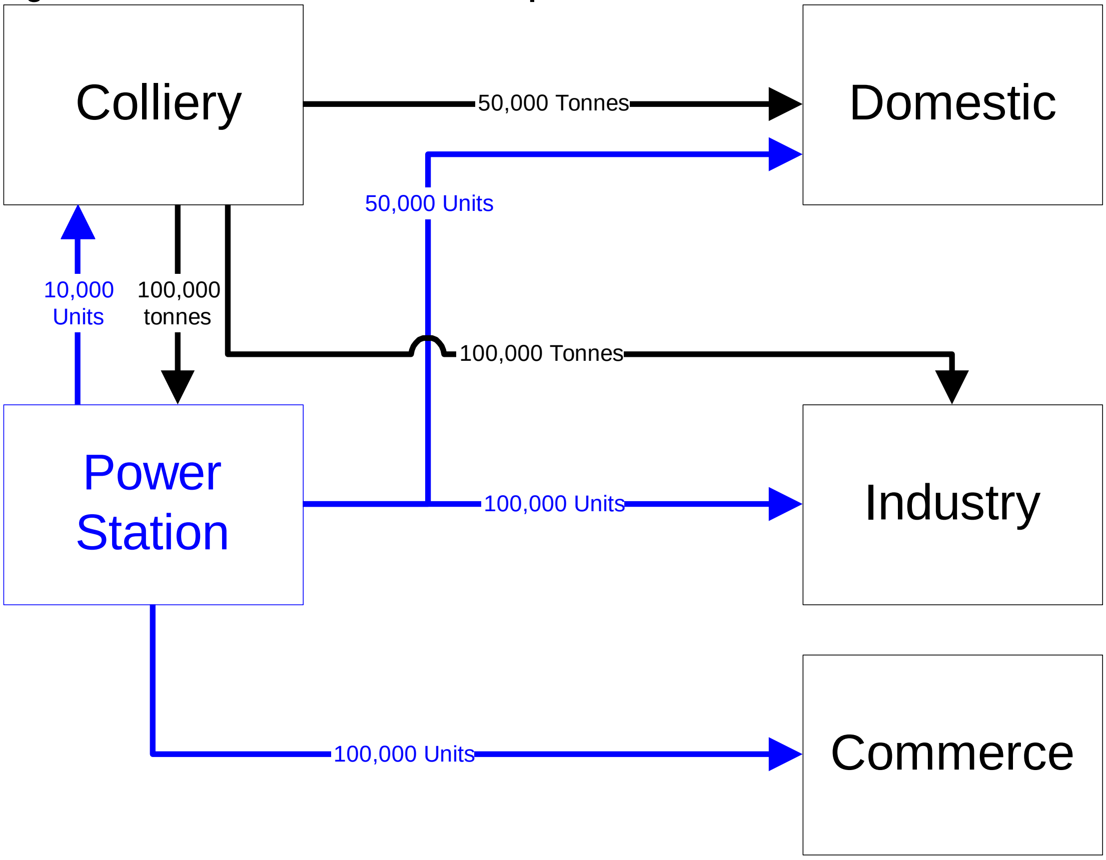
The following example illustrates the methodology used to calculate emissions according to final users. The units in this example are arbitrary.

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.

[22] 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.
[23] 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%.

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					Unallocated emissions as percentage of total emission	Total emission of carbon (tonnes)
			Colliery	**Power Station**	**Residential**	**Industrial**	**Commercial**		
Coal use (tonnes)	Mass		100	100,000	50,000	100,000	0		
Coal use (tonnes)	Energy content		25,000	25,000,000	12,500,000	25,000,000	0		
Electricity use (arbitrary units)	Energy units		10,000		50,000	100,000	100,000		
Emissions of carbon (tonnes)	Initial		70	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

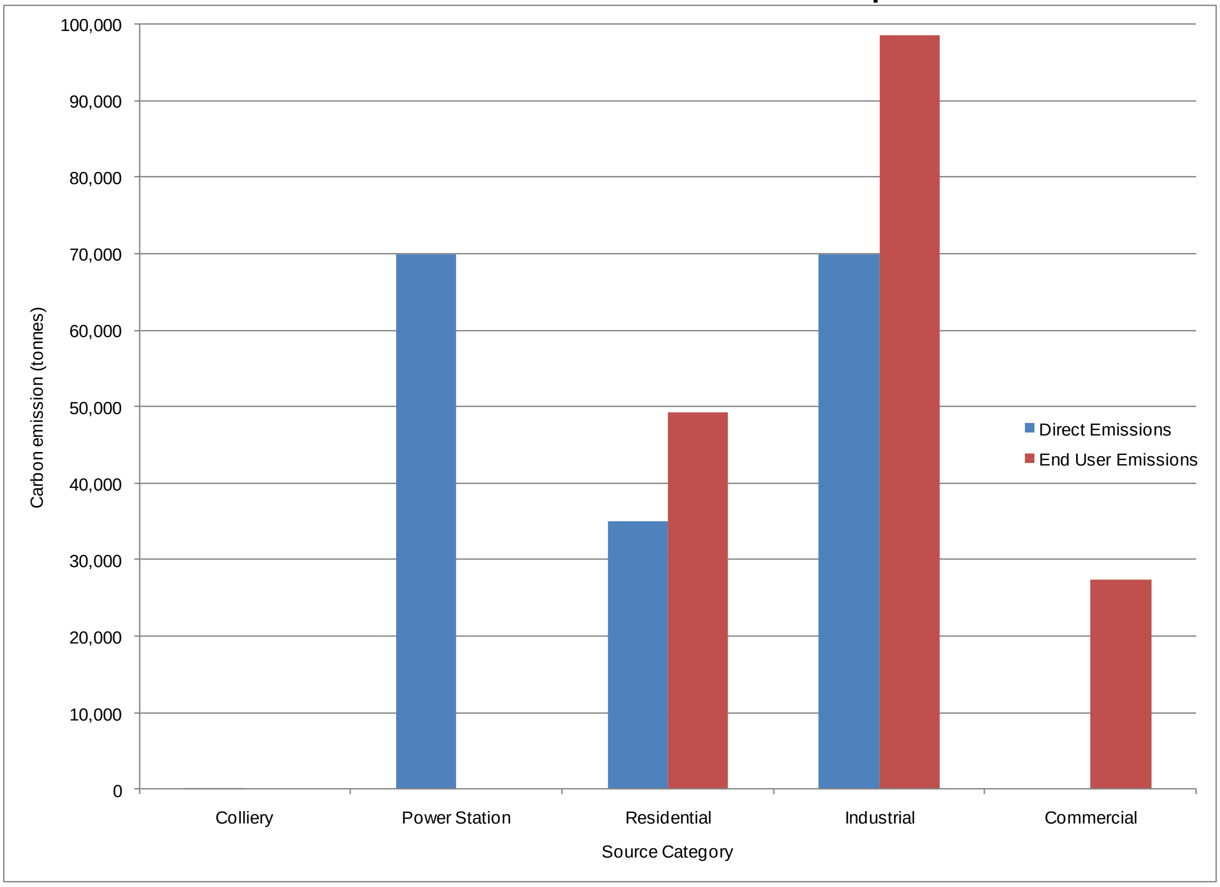


Figure A13.4.2 compares the quantities of direct and final user carbon emitted from each sector at the end of the final user calculation. The direct emissions of carbon are from the combustion of coal in the sectors. The direct and final user emissions are from two distinct calculations and must be considered 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
		Agriculture livestock - other poultry wastes	Non-fuel combustion

NC Category	IPCC Category	Source Name	Activity Name
	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
	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

NC Category	IPCC Category	Source Name	Activity Name
			Natural gas
		Other industrial combustion	Burning oil Coal Coke Coke oven gas Colliery methane Fuel oil Gas oil LPG 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

NC Category	IPCC Category	Source Name	Activity Name
			Conditioning - Manufacture
		Domestic Refrigeration	Refrigeration and Air Conditioning - Disposal
			Refrigeration and Air Conditioning - Lifetime
			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

NC Category	IPCC Category	Source Name	Activity Name
			Refrigeration and Air Conditioning - Manufacture
		Stationary Air Conditioning	Refrigeration and Air Conditioning - Disposal 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

NC Category	IPCC Category	Source Name	Activity Name
		Nuclear fuel production	Natural gas
		Gas Production - combustion at gas separation plant	LPG OPG
		Oil Production - gas combustion	Natural gas
	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

NC Category	IPCC Category	Source Name	Activity Name
Industrial Process	1A2a_Manufacturing_Industry&Construction:I&S	Sinter production	Coke
	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

NC Category	IPCC Category	Source Name	Activity Name
Land Use Change	5A_Forest Land (Biomass Burning - wildfires)	Forest Land - Biomass burning	Biomass
	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-CO2 emissions from drainage of soils and wetlands	Non-CO2 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
		Road transport - buses and coaches - rural driving	DERV

NC Category	IPCC Category	Source Name	Activity Name
		Road transport - buses and coaches - urban driving	DERV
		Road transport - cars - cold start	DERV
		Road transport - cars - motorway driving	DERV
		Road transport - cars - rural driving	DERV
		Road transport - cars - urban driving	DERV
		Road transport - cars non catalyst - cold start	Petrol
		Road transport - cars non catalyst - motorway driving	Petrol
		Road transport - cars non catalyst - rural driving	Petrol
		Road transport - cars non catalyst - urban driving	Petrol
		Road transport - cars with catalysts - cold start	Petrol
		Road transport - cars with catalysts - motorway driving	Petrol
		Road transport - cars with catalysts - rural driving	Petrol
		Road transport - cars with catalysts - urban driving	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
		Road transport - LGVs - motorway driving	DERV
		Road transport - LGVs - rural driving	DERV
		Road transport - LGVs - urban driving	DERV
		Road transport - LGVs non catalyst - cold start	Petrol
		Road transport - LGVs non catalyst - motorway driving	Petrol
		Road transport - LGVs non catalyst - rural	Petrol

NC Category	IPCC Category	Source Name	Activity Name
		driving	
		Road transport - LGVs non catalyst - urban driving	Petrol
		Road transport - LGVs with catalysts - cold start	Petrol
		Road transport - LGVs with catalysts - motorway driving	Petrol
		Road transport - LGVs with catalysts - rural driving	Petrol
		Road transport - LGVs with catalysts - urban driving	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 driving	Petrol
		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
	1A3e_Other_Transportation	Aircraft - support vehicles	Gas oil
	1A4a_Commercial/Institutional	Railways - stationary combustion	Burning oil Coal Fuel oil Natural gas

NC Category	IPCC Category	Source Name	Activity Name
	1A4ciii_Fishing	Fishing vessels	Gas oil
	1A5b_Other:Mobile	Aircraft - military	Aviation turbine fuel
		Shipping - naval	Gas oil
	non-IPCC	Railways - regional	Electricity
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. Emissions from the Overseas Territories are included in the totals, but not in the individual sectors.

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

Table A 13.6.1 Final user emissions from Agriculture, by gas, $MtCO_2$ equivalent

Greenhouse Gas	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Carbon dioxide	8.74	8.74	8.73	8.55	8.35	8.37	8.26	8.27	7.94	7.81	7.63	7.32
Methane	22.54	22.54	22.21	22.27	22.09	22.16	21.90	22.10	21.44	21.43	21.35	20.46
Nitrous oxide	35.51	35.51	35.34	33.45	32.89	33.70	33.83	34.01	35.03	34.11	33.52	32.17
HFCs												
PFCs												
SF_6												
Total greenhouse gas emissions	**66.79**	**66.79**	**66.28**	**64.26**	**63.33**	**64.23**	**63.99**	**64.38**	**64.41**	**63.35**	**62.50**	**59.95**

Greenhouse Gas	2001	2002	2003	2004	2005	2006	2007	2008	2009
Carbon dioxide	7.67	7.62	7.57	7.36	7.21	6.97	6.79	6.70	6.34
Methane	19.24	19.00	18.96	19.10	19.31	18.96	18.83	18.40	18.10
Nitrous oxide	30.36	30.85	30.17	30.00	29.62	28.36	27.64	27.61	27.42
HFCs									
PFCs									
SF_6									
Total greenhouse gas emissions	**57.27**	**57.47**	**56.70**	**56.46**	**56.14**	**54.29**	**53.27**	**52.71**	**51.86**

Table A 13.6.2 Final user emissions from Business, by gas, $MtCO_2$ equivalent

Greenhouse Gas	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Carbon dioxide	228.37	228.37	226.76	213.06	204.63	201.35	198.30	200.20	191.81	192.95	190.21	197.52
Methane	13.28	13.28	13.03	12.63	12.08	9.36	10.19	9.48	9.33	8.41	7.58	7.04
Nitrous oxide	2.59	2.59	2.52	2.44	2.27	2.24	2.18	2.10	1.98	1.96	1.89	1.93
HFCs	1.07	0.0	0.00	0.00	0.31	0.67	1.07	1.53	2.00	2.54	3.18	3.87
PFCs	0.10	0.1	0.06	0.07	0.08	0.09	0.10	0.12	0.14	0.14	0.16	0.19
SF_6	0.81	0.6	0.65	0.70	0.74	0.76	0.81	0.84	0.80	0.79	0.74	0.71
Total greenhouse gas emissions	**246.23**	**244.91**	**243.02**	**228.90**	**220.11**	**214.47**	**212.66**	**214.27**	**206.05**	**206.79**	**203.75**	**211.25**

Greenhouse Gas	2001	2002	2003	2004	2005	2006	2007	2008	2009
Carbon dioxide	202.92	189.90	195.73	193.77	190.98	192.81	189.07	183.33	156.24
Methane	6.70	6.62	5.37	5.12	4.59	4.30	3.78	3.72	3.57
Nitrous oxide	1.99	1.95	1.96	1.97	1.96	2.02	1.98	1.87	1.61
HFCs	4.54	5.16	5.79	6.34	6.77	7.18	7.54	7.79	7.99
PFCs	0.11	0.11	0.11	0.10	0.09	0.09	0.08	0.08	0.08
SF6	0.67	0.66	0.65	0.74	0.86	0.69	0.64	0.62	0.58
Total greenhouse gas emissions	**216.94**	**204.40**	**209.62**	**208.03**	**205.24**	**207.08**	**203.10**	**197.41**	**170.08**

Table A 13.6.3 Final user emissions from Industrial Processes, by gas, $MtCO_2$ equivalent

Greenhouse Gas	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Carbon dioxide	17.33	17.33	15.15	14.53	14.44	15.60	15.98	16.59	16.76	16.67	16.56	15.73
Methane	1.71	1.71	1.66	1.66	1.64	1.34	1.44	1.47	1.50	1.27	1.16	0.99
Nitrous oxide	24.73	24.73	24.88	20.24	16.33	16.52	14.95	14.86	15.04	15.32	5.44	5.62
HFCs	13.98	11.4	11.84	12.31	12.78	13.26	13.98	14.32	15.62	12.12	4.88	2.62
PFCs	0.36	1.3	1.11	0.50	0.41	0.39	0.36	0.36	0.26	0.25	0.21	0.28
SF_6	0.43	0.4	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.47	0.69	1.09
Total greenhouse gas emissions	**58.52**	**56.90**	**55.06**	**49.67**	**46.02**	**47.54**	**47.13**	**48.02**	**49.62**	**46.10**	**28.94**	**26.33**

Greenhouse Gas	2001	2002	2003	2004	2005	2006	2007	2008	2009
Carbon dioxide	14.26	13.24	14.04	14.36	14.38	13.81	15.03	13.93	9.55
Methane	0.77	0.69	0.62	0.57	0.49	0.45	0.41	0.42	0.40
Nitrous oxide	4.88	2.84	2.98	3.82	3.02	2.43	2.82	2.48	1.22
HFCs	2.39	2.03	1.98	0.45	0.44	0.39	0.18	0.15	0.12
PFCs	0.27	0.21	0.17	0.24	0.17	0.22	0.14	0.13	0.07
SF_6	0.76	0.85	0.67	0.39	0.25	0.18	0.15	0.09	0.08
Total greenhouse gas emissions	**23.33**	**19.86**	**20.46**	**19.83**	**18.76**	**17.48**	**18.73**	**17.20**	**11.44**

Table A 13.6.4 Final user emissions from Land Use Land Use Change and Forestry, by gas, $MtCO_2$ equivalent

Greenhouse Gas	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Carbon dioxide	3.09	3.09	3.06	2.48	1.43	1.25	1.61	1.38	1.09	0.52	0.27	-0.40
Methane	0.03	0.03	0.03	0.02	0.02	0.02	0.04	0.03	0.03	0.03	0.03	0.03
Nitrous oxide	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.77
HFCs												
PFCs												
SF_6												
Total greenhouse gas emissions	**3.91**	**3.91**	**3.88**	**3.30**	**2.25**	**2.07**	**2.44**	**2.21**	**1.91**	**1.34**	**1.09**	**0.41**

Greenhouse Gas	2001	2002	2003	2004	2005	2006	2007	2008	2009
Carbon dioxide	-0.90	-1.77	-2.13	-3.18	-3.70	-3.90	-4.25	-4.68	-4.78
Methane	0.04	0.04	0.03	0.03	0.02	0.03	0.03	0.04	0.03
Nitrous oxide	0.76	0.74	0.72	0.71	0.69	0.68	0.66	0.65	0.64
HFCs									
PFCs									
SF_6									
Total greenhouse gas emissions	**-0.10**	**-0.99**	**-1.37**	**-2.44**	**-2.99**	**-3.19**	**-3.55**	**-3.99**	**-4.11**

Table A 13.6.5 Final user emissions from Public Sector, by gas, $MtCO_2$ equivalent

Greenhouse Gas	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Carbon dioxide	29.92	29.92	32.80	34.38	28.57	28.34	27.65	28.56	26.20	24.50	23.70	22.94
Methane	1.80	1.80	1.99	2.17	1.72	1.36	1.45	1.37	1.28	1.11	0.99	0.87
Nitrous oxide	0.20	0.20	0.21	0.22	0.17	0.16	0.14	0.14	0.12	0.11	0.10	0.10
HFCs												
PFCs												
SF_6												
Total greenhouse gas emissions	**31.92**	**31.92**	**35.01**	**36.77**	**30.46**	**29.86**	**29.24**	**30.06**	**27.59**	**25.73**	**24.79**	**23.91**

Greenhouse Gas	2001	2002	2003	2004	2005	2006	2007	2008	2009
Carbon dioxide	23.71	21.23	21.39	22.15	21.48	20.23	19.59	19.36	17.19
Methane	0.85	0.80	0.62	0.63	0.58	0.51	0.46	0.45	0.45
Nitrous oxide	0.10	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.07
HFCs									
PFCs									
SF_6									
Total greenhouse gas emissions	**24.66**	**22.12**	**22.10**	**22.87**	**22.14**	**20.83**	**20.13**	**19.88**	**17.70**

Table A 13.6.6 Final user emissions from Residential, by gas, $MtCO_2$ equivalent

Greenhouse Gas	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Carbon dioxide	156.59	156.59	165.60	159.63	157.06	152.41	146.49	158.85	144.01	149.57	145.70	150.25
Methane	12.24	12.24	12.76	12.53	11.98	9.29	9.03	8.80	7.91	7.46	6.81	6.08
Nitrous oxide	0.95	0.95	0.98	0.93	0.86	0.82	0.73	0.72	0.62	0.65	0.60	0.62
HFCs	0.40	0.01	0.01	0.01	0.03	0.12	0.40	0.78	1.36	2.11	1.95	2.24
PFCs												
SF_6												
Total greenhouse gas emissions	**170.18**	**169.79**	**179.35**	**173.10**	**169.93**	**162.63**	**156.65**	**169.15**	**153.90**	**159.79**	**155.06**	**159.19**

Greenhouse Gas	2001	2002	2003	2004	2005	2006	2007	2008	2009
Carbon dioxide	157.61	151.91	155.72	156.62	155.96	155.73	149.48	151.43	139.50
Methane	5.96	5.80	4.59	4.48	4.22	4.00	3.66	3.65	3.71
Nitrous oxide	0.66	0.63	0.62	0.60	0.62	0.64	0.59	0.58	0.54
HFCs	2.43	2.35	2.65	2.68	3.02	3.01	2.82	2.88	2.78
PFCs									
SF_6									
Total greenhouse gas emissions	**166.67**	**160.70**	**163.58**	**164.39**	**163.83**	**163.38**	**156.56**	**158.54**	**146.53**

Table A 13.6.7 Final user emissions from Transport, by gas, $MtCO_2$ equivalent

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Carbon dioxide	135.89	135.89	134.03	135.78	137.78	139.09	139.13	144.25	145.33	144.39	144.74	143.27
Methane	1.64	1.64	1.57	1.58	1.51	1.46	1.47	1.39	1.30	1.25	1.14	1.07
Nitrous oxide	1.60	1.60	1.59	1.59	1.68	1.87	2.16	2.04	2.05	2.09	2.09	2.09
HFCs												
PFCs												
SF_6												
Total greenhouse gas emissions	**139.13**	**139.13**	**137.19**	**138.95**	**140.97**	**142.42**	**142.76**	**147.68**	**148.69**	**147.73**	**147.97**	**146.43**

Greenhouse Gas	2001	2002	2003	2004	2005	2006	2007	2008	2009
Carbon dioxide	143.69	147.48	146.27	145.88	147.13	145.80	146.75	141.19	135.53
Methane	1.05	1.01	0.87	0.86	0.72	0.68	0.71	0.59	0.61
Nitrous oxide	2.02	2.00	1.94	1.88	1.84	1.81	1.76	1.58	1.48
HFCs									
PFCs									
SF_6									
Total greenhouse gas emissions	**146.76**	**150.49**	**149.07**	**148.61**	**149.69**	**148.29**	**149.22**	**143.36**	**137.62**

Table A 13.6.8 Final user emissions from Waste Management, by gas, $MtCO_2$ equivalent

Greenhouse Gas	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Carbon dioxide	1.21	1.21	1.20	1.16	1.08	0.92	0.87	0.89	0.50	0.51	0.46	0.47
Methane	56.54	56.54	53.99	51.10	48.41	46.17	43.94	41.84	38.15	35.28	31.94	29.62
Nitrous oxide	1.30	1.30	1.29	1.32	1.32	1.31	1.33	1.37	1.35	1.37	1.36	1.42
HFCs												
PFCs												
SF_6												
Total greenhouse gas emissions	**59.05**	**59.05**	**56.48**	**53.59**	**50.81**	**48.40**	**46.14**	**44.10**	**40.00**	**37.15**	**33.77**	**31.51**

Greenhouse Gas	2001	2002	2003	2004	2005	2006	2007	2008	2009
Carbon dioxide	0.50	0.50	0.45	0.42	0.36	0.30	0.33	0.28	0.28
Methane	25.78	23.39	20.45	18.82	18.16	17.75	17.28	16.76	16.25
Nitrous oxide	1.43	1.44	1.43	1.43	1.45	1.45	1.45	1.41	1.42
HFCs									
PFCs									
SF_6									
Total greenhouse gas emissions	**27.71**	**25.33**	**22.33**	**20.67**	**19.98**	**19.51**	**19.05**	**18.45**	**17.95**

Table A 13.6.9 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	66.79	66.28	64.26	63.33	64.23	63.99	64.38	64.41	63.35	62.50	59.95
Business	246.23	244.91	243.02	228.90	220.11	214.47	212.66	214.27	206.05	206.79	203.75	211.25
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	9.20	9.20	10.18	10.97	12.34	12.57	13.30	14.61	15.96	15.53	13.75	12.97
Industrial Process	58.52	56.90	55.06	49.67	46.02	47.54	47.13	48.02	49.62	46.10	28.94	26.33
LULUCF	3.91	3.91	3.88	3.30	2.25	2.07	2.44	2.21	1.91	1.34	1.09	0.41
Public	31.92	31.92	35.01	36.77	30.46	29.86	29.24	30.06	27.59	25.73	24.79	23.91
Residential	170.18	169.79	179.35	173.10	169.93	162.63	156.65	169.15	153.90	159.79	155.06	159.19
Transport	139.13	139.13	137.19	138.95	140.97	142.42	142.76	147.68	148.69	147.73	147.97	146.43
Waste Management	59.05	59.05	56.48	53.59	50.81	48.40	46.14	44.10	40.00	37.15	33.77	31.51
Overseas Territories	1.71	1.71	1.69	1.67	1.67	1.71	1.80	1.78	1.79	1.91	1.91	1.95
Total greenhouse gas emissions	**786.65**	**783.31**	**788.15**	**761.19**	**737.89**	**725.90**	**716.13**	**736.25**	**709.92**	**705.42**	**673.53**	**673.90**

Final user category	2001	2002	2003	2004	2005	2006	2007	2008	2009
Agriculture	57.27	57.47	56.70	56.46	56.14	54.29	53.27	52.71	51.86
Business	216.94	204.40	209.62	208.03	205.24	207.08	203.10	197.41	170.08
Energy Supply	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exports	12.47	14.33	15.08	16.00	16.64	15.22	15.68	14.17	14.52
Industrial Process	23.33	19.86	20.46	19.83	18.76	17.48	18.73	17.20	11.44
LULUCF	-0.10	-0.99	-1.37	-2.44	-2.99	-3.19	-3.55	-3.99	-4.11
Public	24.66	22.12	22.10	22.87	22.14	20.83	20.13	19.88	17.70
Residential	166.67	160.70	163.58	164.39	163.83	163.38	156.56	158.54	146.53
Transport	146.76	150.49	149.07	148.61	149.69	148.29	149.22	143.36	137.62
Waste Management	27.71	25.33	22.33	20.67	19.98	19.51	19.05	18.45	17.95
Overseas Territories	2.04	2.07	2.10	2.18	2.24	2.34	2.49	2.39	2.41
Total greenhouse gas emissions	**677.75**	**655.76**	**659.67**	**656.60**	**651.67**	**645.24**	**634.67**	**620.12**	**565.99**

Table A 13.6.10 Final user emissions, Carbon, $MtCO_2$ equivalent

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Agriculture	8.74	8.74	8.73	8.55	8.35	8.37	8.26	8.27	7.94	7.81	7.63	7.32
Business	228.37	228.37	226.76	213.06	204.63	201.35	198.30	200.20	191.81	192.95	190.21	197.52
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	8.52	8.52	9.49	10.24	11.59	11.82	12.50	13.80	15.09	14.68	13.03	12.26
Industrial Process	17.33	17.33	15.15	14.53	14.44	15.60	15.98	16.59	16.76	16.67	16.56	15.73
LULUCF	3.09	3.09	3.06	2.48	1.43	1.25	1.61	1.38	1.09	0.52	0.27	-0.40
Public	29.92	29.92	32.80	34.38	28.57	28.34	27.65	28.56	26.20	24.50	23.70	22.94
Residential	156.59	156.59	165.60	159.63	157.06	152.41	146.49	158.85	144.01	149.57	145.70	150.25
Transport	135.89	135.89	134.03	135.78	137.78	139.09	139.13	144.25	145.33	144.39	144.74	143.27
Waste Management	1.21	1.21	1.20	1.16	1.08	0.92	0.87	0.89	0.50	0.51	0.46	0.47
Overseas Territories	1.43	1.43	1.41	1.40	1.40	1.43	1.48	1.46	1.47	1.58	1.58	1.62
Total greenhouse gas emissions	**591.09**	**591.09**	**598.24**	**581.21**	**566.34**	**560.58**	**552.27**	**574.25**	**550.19**	**553.19**	**543.89**	**550.98**

Final user category	2001	2002	2003	2004	2005	2006	2007	2008	2009
Agriculture	7.67	7.62	7.57	7.36	7.21	6.97	6.79	6.70	6.34
Business	202.92	189.90	195.73	193.77	190.98	192.81	189.07	183.33	156.24
Energy Supply	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exports	11.79	13.60	14.40	15.22	15.95	14.57	14.98	13.59	13.87
Industrial Process	14.26	13.24	14.04	14.36	14.38	13.81	15.03	13.93	9.55
LULUCF	-0.90	-1.77	-2.13	-3.18	-3.70	-3.90	-4.25	-4.68	-4.78
Public	23.71	21.23	21.39	22.15	21.48	20.23	19.59	19.36	17.19
Residential	157.61	151.91	155.72	156.62	155.96	155.73	149.48	151.43	139.50
Transport	143.69	147.48	146.27	145.88	147.13	145.80	146.75	141.19	135.53
Waste Management	0.50	0.50	0.45	0.42	0.36	0.30	0.33	0.28	0.28
Overseas Territories	1.71	1.74	1.76	1.84	1.90	2.00	2.15	2.05	2.08
Total greenhouse gas emissions	**562.96**	**545.44**	**555.21**	**554.44**	**551.64**	**548.33**	**539.92**	**527.18**	**475.81**

Table A 13.6.11 Final user emissions, Methane, $MtCO_2$ equivalent

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Agriculture	22.54	22.54	22.21	22.27	22.09	22.16	21.90	22.10	21.44	21.43	21.35	20.46
Business	13.28	13.28	13.03	12.63	12.08	9.36	10.19	9.48	9.33	8.41	7.58	7.04
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	0.63	0.63	0.67	0.66	0.70	0.67	0.56	0.55
Industrial Process	1.71	1.71	1.66	1.66	1.64	1.34	1.44	1.47	1.50	1.27	1.16	0.99
LULUCF	0.03	0.03	0.03	0.02	0.02	0.02	0.04	0.03	0.03	0.03	0.03	0.03
Public	1.80	1.80	1.99	2.17	1.72	1.36	1.45	1.37	1.28	1.11	0.99	0.87
Residential	12.24	12.24	12.76	12.53	11.98	9.29	9.03	8.80	7.91	7.46	6.81	6.08
Transport	1.64	1.64	1.57	1.58	1.51	1.46	1.47	1.39	1.30	1.25	1.14	1.07
Waste Management	56.54	56.54	53.99	51.10	48.41	46.17	43.94	41.84	38.15	35.28	31.94	29.62
Overseas Territories	0.23	0.23	0.23	0.23	0.23	0.23	0.26	0.26	0.26	0.27	0.27	0.27
Total greenhouse gas emissions	**110.61**	**110.61**	**108.06**	**104.82**	**100.31**	**92.01**	**90.39**	**87.39**	**81.90**	**77.17**	**71.83**	**66.98**

Final user category	2001	2002	2003	2004	2005	2006	2007	2008	2009
Agriculture	19.24	19.00	18.96	19.10	19.31	18.96	18.83	18.40	18.10
Business	6.70	6.62	5.37	5.12	4.59	4.30	3.78	3.72	3.57
Energy Supply	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exports	0.52	0.56	0.50	0.59	0.49	0.47	0.52	0.42	0.48
Industrial Process	0.77	0.69	0.62	0.57	0.49	0.45	0.41	0.42	0.40
LULUCF	0.04	0.04	0.03	0.03	0.02	0.03	0.03	0.04	0.03
Public	0.85	0.80	0.62	0.63	0.58	0.51	0.46	0.45	0.45
Residential	5.96	5.80	4.59	4.48	4.22	4.00	3.66	3.65	3.71
Transport	1.05	1.01	0.87	0.86	0.72	0.68	0.71	0.59	0.61
Waste Management	25.78	23.39	20.45	18.82	18.16	17.75	17.28	16.76	16.25
Overseas Territories	0.26	0.26	0.26	0.25	0.26	0.26	0.26	0.26	0.25
Total greenhouse gas emissions	**61.18**	**58.14**	**52.27**	**50.46**	**48.85**	**47.41**	**45.94**	**44.71**	**43.84**

Table A 13.6.12 Final user emissions, Nitrous Oxide, $MtCO_2$ equivalent

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Agriculture	35.51	35.51	35.34	33.45	32.89	33.70	33.83	34.01	35.03	34.11	33.52	32.17
Business	2.59	2.59	2.52	2.44	2.27	2.24	2.18	2.10	1.98	1.96	1.89	1.93
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	0.08	0.08	0.10	0.10	0.12	0.12	0.13	0.15	0.17	0.18	0.16	0.17
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	0.17	0.16	0.14	0.14	0.12	0.11	0.10	0.10
Residential	0.95	0.95	0.98	0.93	0.86	0.82	0.73	0.72	0.62	0.65	0.60	0.62
Transport	1.60	1.60	1.59	1.59	1.68	1.87	2.16	2.04	2.05	2.09	2.09	2.09
Waste Management	1.30	1.30	1.29	1.32	1.32	1.31	1.33	1.37	1.35	1.37	1.36	1.42
Overseas Territories	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Total greenhouse gas emissions	**67.79**	**67.79**	**67.75**	**61.14**	**56.46**	**57.59**	**56.31**	**56.22**	**57.21**	**56.63**	**46.00**	**44.94**

Final user category	2001	2002	2003	2004	2005	2006	2007	2008	2009
Agriculture	30.36	30.85	30.17	30.00	29.62	28.36	27.64	27.61	27.42
Business	1.99	1.95	1.96	1.97	1.96	2.02	1.98	1.87	1.61
Energy Supply	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exports	0.15	0.18	0.18	0.19	0.19	0.19	0.18	0.16	0.17
Industrial Process	4.88	2.84	2.98	3.82	3.02	2.43	2.82	2.48	1.22
LULUCF	0.76	0.74	0.72	0.71	0.69	0.68	0.66	0.65	0.64
Public	0.10	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.07
Residential	0.66	0.63	0.62	0.60	0.62	0.64	0.59	0.58	0.54
Transport	2.02	2.00	1.94	1.88	1.84	1.81	1.76	1.58	1.48
Waste Management	1.43	1.44	1.43	1.43	1.45	1.45	1.45	1.41	1.42
Overseas Territories	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Total greenhouse gas emissions	**42.41**	**40.78**	**40.14**	**40.73**	**39.54**	**37.71**	**37.22**	**36.46**	**34.61**

Table A 13.6.13 Final user emissions, HFC, $MtCO_2$ equivalent

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Agriculture												
Business	1.07	0.00	0.00	0.00	0.31	0.67	1.07	1.53	2.00	2.54	3.18	3.87
Energy Supply												
Exports												
Industrial Process	13.98	11.37	11.84	12.31	12.78	13.26	13.98	14.32	15.62	12.12	4.88	2.62
Public												
Residential												
Transport	0.40	0.01	0.01	0.01	0.03	0.12	0.40	0.78	1.36	2.11	1.95	2.24
Waste Management												
LULUCF												
Overseas Territories	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.02
Total greenhouse gas emissions	**15.46**	**11.39**	**11.85**	**12.32**	**13.12**	**14.05**	**15.46**	**16.64**	**18.99**	**16.78**	**10.02**	**8.74**

Final user category	2001	2002	2003	2004	2005	2006	2007	2008	2009
Agriculture									
Business	4.54	5.16	5.79	6.34	6.77	7.18	7.54	7.79	7.99
Energy Supply									
Exports									
Industrial Process	2.39	2.03	1.98	0.45	0.44	0.39	0.18	0.15	0.12
Public									
Residential									
Transport	2.43	2.35	2.65	2.68	3.02	3.01	2.82	2.88	2.78
Waste Management									
LULUCF									
Overseas Territories	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03
Total greenhouse gas emissions	**9.38**	**9.56**	**10.45**	**9.49**	**10.27**	**10.61**	**10.57**	**10.85**	**10.93**

Table A 13.6.14 Final user emissions, PFC, $MtCO_2$ equivalent

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Agriculture												
Business	0.10	0.06	0.06	0.07	0.08	0.09	0.10	0.12	0.14	0.14	0.16	0.19
Energy Supply												
Exports												
Industrial Process	0.36	1.34	1.11	0.50	0.41	0.39	0.36	0.36	0.26	0.25	0.21	0.28
Public												
Residential												
Transport												
Waste Management												
LULUCF												
Overseas Territories	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total greenhouse gas emissions	**0.46**	**1.40**	**1.17**	**0.57**	**0.49**	**0.49**	**0.46**	**0.48**	**0.40**	**0.39**	**0.37**	**0.47**

Final user category	2001	2002	2003	2004	2005	2006	2007	2008	2009
Agriculture									
Business	0.11	0.11	0.11	0.10	0.09	0.09	0.08	0.08	0.08
Energy Supply									
Exports									
Industrial Process	0.27	0.21	0.17	0.24	0.17	0.22	0.14	0.13	0.07
Public									
Residential									
Transport									
Waste Management									
LULUCF									
Overseas Territories	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total greenhouse gas emissions	**0.39**	**0.32**	**0.28**	**0.34**	**0.26**	**0.31**	**0.22**	**0.21**	**0.15**

Table A 13.6.15 Final user emissions, SF_6, $MtCO_2$ equivalent

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Agriculture												
Business	0.81	0.60	0.65	0.70	0.74	0.76	0.81	0.84	0.80	0.79	0.74	0.71
Energy Supply												
Exports												
Industrial Process	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.47	0.69	1.09
Public												
Residential												
Transport												
Waste Management												
LULUCF												
Overseas Territories	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total greenhouse gas emissions	**1.24**	**1.03**	**1.08**	**1.12**	**1.17**	**1.18**	**1.24**	**1.27**	**1.23**	**1.26**	**1.43**	**1.80**

Final user category	2001	2002	2003	2004	2005	2006	2007	2008	2009
Agriculture									
Business	0.67	0.66	0.65	0.74	0.86	0.69	0.64	0.62	0.58
Energy Supply									
Exports									
Industrial Process	0.76	0.85	0.67	0.39	0.25	0.18	0.15	0.09	0.08
Public									
Residential									
Transport									
Waste Management									
LULUCF									
Overseas Territories	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total greenhouse gas emissions	**1.43**	**1.51**	**1.32**	**1.13**	**1.11**	**0.87**	**0.79**	**0.71**	**0.66**