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UK Greenhouse Gas Inventory, 1990 to 2005

Annual Report for submission under the Framework Convention on Climate Change

Annexes

Main authors Baggott SL, Cardenas L, Garnett E, Jackson J, Mobbs DC, Murrells T, Passant N, Thomson A, Watterson JD

With contributions from Adams M, Dore C, Downes MK, Goodwin J, Hobson M, Li Y, Manning A, Milne R, Thistlethwaite G, Wagner A, Walker C

April 2007

This work forms part of the Climate and Energy: Science and Analysis Research Programme of the Department for Environment, Food and Rural Affairs.

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A1 ANNEX 1: Key Sources

A1.1 KEY SOURCE ANALYSIS

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 the Key Source Category Analysis with and without LULUCF are summarised by sector and gas in **Table A1.1.5** and **Table A1.1.6** respectively. The analysis is based on the Tier 1 Level analysis and Trend analysis, performed using the data shown in **Tables A7.2.1** and **A7.2.2,** and **Tables A7.2.3** and **A7.2.4** using the same categorisation and the same estimates of uncertainty. The table indicates whether a key source arises from the level assessment or the trend assessment. The factors that make a source a key source are:

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

For example, transport fuel (1A3b) is a key source 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 were 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 results of the Level Assessment with and without LULUCF are shown in **Table A1.1.1** and **Table A1.1.2** respectively, with the key source categories shaded. The emission estimates were taken from the 2005 UK GHG inventory. 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 are shown in **Table A1.1.3** and **Table A1.1.4** respectively, with key source categories shaded. The emission estimates were taken from the 2005 UK GHG inventory. The trend parameter was calculated using absolute value of the result. An absolute function is used since 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.

There have been a number of improvements to the key source analysis this year. These are partly in response to comments made in the Fourth Centralised Review to improve the transparency of the uncertainty analysis. The improvements are discussed in **Annex 7**.

Table A 1.1.1 Key Source Analysis Based on Level of Emissions (Including LULCUF)

IPCC category	Source category	Gas	Base year emissions	Year Y emissions	Combined uncertainty range as a % of source category	Level Parameter (used to order sources)		Level / Sum(Level)*100
			Gg CO2 equiv.	Gg CO2 equiv.				
			1990	2005				%
4D	Agricultural Soils	N2O	30,407.12	25,109.90	424.00	0.1624544		53.35403
6A	Solid Waste Disposal	CH4	49,772.46	19,547.29	48.38	0.0144313		4.73961
1A(stationary)	Oil	CO2	92,135.38	60,695.19	15.13	0.0140149		4.60285
1A3b	Auto Fuel	N2O	1,025.19	5,087.17	170.02	0.0131979		4.33451
5B	5B LUCF	CO2	15,836.04	15,258.33	50.01	0.0116435		3.82401
1A1&1A2&1A4&1A5	Other Combustion	N2O	4,507.78	3,647.48	195.00	0.0108529		3.56438
5C	5C LUCF	CO2	- 6,200.25	- 7,934.29	70.01	0.0084756		2.78359
4B	Manure Management	N2O	1,583.86	1,333.65	414.00	0.0084249		2.76694
1A3b	Auto Fuel	CO2	109,425.28	119,955.89	4.48	0.0082041		2.69443
6B	Wastewater Handling	N2O	1,033.64	1,215.69	401.12	0.0074408		2.44375
2B	Nitric Acid Production	N2O	3,903.85	2,019.71	230.22	0.0070949		2.33014
5A	5A LUCF	CO2	- 12,202.57	- 15,738.00	25.02	0.0060084		1.97329
4A	Enteric Fermentation	CH4	18,421.03	15,934.42	20.00	0.0048629		1.59708
5E	5E LUCF	CO2	6,904.22	6,261.56	50.01	0.0047781		1.56926
1A	Natural Gas	CO2	108,856.98	200,293.39	1.51	0.0046249		1.51894
2	Industrial Processes	HFC	11,375.40	9,221.29	19.03	0.0026771		0.87923
1A	Coal	CO2	248,419.60	145,119.68	1.08	0.0023849		0.78327
2B5	NEU	CO2	1,843.69	2,133.25	53.85	0.0017529		0.57570
1B	Oil & Natural Gas	CO2	5,760.18	5,747.87	17.09	0.0014987		0.49221
1B2	Production, Refining & Distribution of Oil & Natural Gas	CH4	10,304.01	5,617.81	16.77	0.0014376		0.47213
4B	Manure Management	CH4	2,923.20	2,509.06	30.00	0.0011486		0.37722
1A	All Fuel	CH4	2,018.08	1,021.09	50.00	0.0007791		0.25586
1A3a	Aviation Fuel	CO2	1,272.04	2,465.00	20.27	0.0007624		0.25040
1B1	Mining & Solid Fuel Transformation	CH4	18,289.71	3,806.86	13.02	0.0007566		0.24848
1A	Other (waste)	CO2	812.62	1,959.72	21.19	0.0006336		0.20810
1A3	Other Diesel	N2O	209.00	294.55	140.01	0.0006293		0.20667
6B	Wastewater Handling	CH4	709.70	807.73	50.01	0.0006164		0.20243
2	Industrial Processes	SF6	1,029.95	1,142.82	20.02	0.0003492		0.11468
2C1	Iron&Steel Production	CO2	2,309.27	2,446.30	6.12	0.0002284		0.07501
1A4	Peat	CO2	477.00	441.91	31.62	0.0002132		0.07003
2A1	Cement Production	CO2	6,659.34	5,423.27	2.42	0.0002000		0.06568
2B	Adipic Acid Production	N2O	20,737.34	776.24	15.01	0.0001778		0.05838
2B	Ammonia Production	CO2	1,321.67	1,119.86	10.11	0.0001728		0.05675
6C	Waste Incineration	N2O	47.90	48.30	230.11	0.0001696		0.05569
6C	Waste Incineration	CO2	1,206.51	458.93	21.19	0.0001484		0.04873
2A7	Fletton Bricks	CO2	179.87	129.46	72.80	0.0001438		0.04723
1A3d	Marine Fuel	CO2	4,014.20	4,077.21	2.20	0.0001370		0.04500
1A	Lubricant	CO2	386.90	292.32	30.07	0.0001341		0.04405
1A3b	Auto Fuel	CH4	614.37	166.73	50.08	0.0001274		0.04184
2A3	Limestone & Dolomite use	CO2	1,285.33	1,260.97	5.10	0.0000981		0.03222
1A3	Other Diesel	CO2	1,759.60	2,475.29	2.20	0.0000832		0.02732
1A3d	Marine Fuel	N2O	31.25	31.61	170.01	0.0000820		0.02693
1B2	Oil & Natural Gas	N2O	42.40	45.10	111.16	0.0000765		0.02512
1A3a	Aviation Fuel	N2O	12.53	24.27	171.17	0.0000634		0.02082
2A2	Lime Production	CO2	1,191.52	738.05	5.10	0.0000574		0.01886
2	Industrial Processes	PFC	1,401.57	350.91	10.05	0.0000538		0.01767
2A4	Soda Ash Use	CO2	167.32	202.28	15.13	0.0000467		0.01534
5G	5G LUCF	CO2	- 1,455.88	96.28	30.02	0.0000441		0.01448
2B	Chemical Industry	CH4	136.17	42.21	28.28	0.0000182		0.00598
2A7	Fletton Bricks	CH4	23.60	10.83	101.98	0.0000168		0.00553
2C	Iron & Steel	N2O	11.11	8.66	118.00	0.0000156		0.00512
2C	Iron & Steel Production	CH4	16.36	17.62	50.00	0.0000134		0.00441
1B	Solid Fuel Transformation	CO2	856.42	110.07	6.01	0.0000101		0.00332
5C2	5C2 LUCF	CH4	3.08	11.97	20.02	0.0000037		0.00120
6C	Waste Incineration	CH4	134.43	3.06	50.49	0.0000024		0.00077
1A3a	Aviation Fuel	CH4	2.60	2.86	53.85	0.0000024		0.00077
5E2	5E2 LUCF	CH4	9.35	7.46	20.02	0.0000023		0.00075
1A3	Other Diesel	CH4	1.67	2.69	50.03	0.0000021		0.00067
1B1	Coke Oven Gas	N2O	2.08	0.98	118.00	0.0000018		0.00058
1A3d	Marine Fuel	CH4	1.32	1.34	50.03	0.0000010		0.00034
5C2	5C2 LUCF	N2O	0.31	1.21	20.02	0.0000004		0.00012
5E2	5E2 LUCF	N2O	0.95	0.76	20.02	0.0000002		0.00008
4F	Field Burning	CH4	266.04	-	55.90	0.0000000		0.00000
4F	Field Burning	N2O	77.76	-	231.35	0.0000000		0.00000

Table A 1.1.2 Key Source Analysis Based on Level of Emissions (Excluding LULUCF)

IPCC category	Source category	Gas	Base year emissions	Year Y emissions	Combined uncertainty range as a % of source category	Level Parameter (used to order sources)		Level / Sum(Level)*100
			Gg CO2 equiv.	Gg CO2 equiv.				
			1990	2005				%
4D	Agricultural Soils	N2O	30,407.12	25,109.90	424.00	0.1619515		59.39232
6A	Solid Waste Disposal	CH4	49,772.46	19,547.29	48.38	0.0143867		5.27601
1A(stationary)	Oil	CO2	92,135.38	60,695.19	15.13	0.0139716		5.12378
1A3b	Auto Fuel	N2O	1,025.19	5,087.17	170.02	0.0131570		4.82506
1A1&1A2&1A4&1A5	Other Combustion	N2O	4,507.78	3,647.48	195.00	0.0108194		3.96777
4B	Manure Management	N2O	1,583.86	1,333.65	414.00	0.0083988		3.08009
1A3b	Auto Fuel	CO2	109,425.28	119,955.89	4.48	0.0081787		2.99937
6B	Wastewater Handling	N2O	1,033.64	1,215.69	401.12	0.0074178		2.72032
2B	Nitric Acid Production	N2O	3,903.85	2,019.71	230.22	0.0070729		2.59385
4A	Enteric Fermentation	CH4	18,421.03	15,934.42	20.00	0.0048478		1.77783
1A	Natural Gas	CO2	108,856.98	200,293.39	1.51	0.0046106		1.69084
2	Industrial Processes	HFC	11,375.40	9,221.29	19.03	0.0026688		0.97873
1A	Coal	CO2	248,419.60	145,119.68	1.08	0.0023775		0.87191
2B5	NEU	CO2	1,843.69	2,133.25	53.85	0.0017475		0.64085
1B	Oil & Natural Gas	CO2	5,760.18	5,747.87	17.09	0.0014941		0.54792
1B2	Production, Refining & Distribution of Oil & Natural Gas	CH4	10,304.01	5,617.81	16.77	0.0014331		0.52557
4B	Manure Management	CH4	2,923.20	2,509.06	30.00	0.0011450		0.41991
1A	All Fuel	CH4	2,018.08	1,021.09	50.00	0.0007766		0.28482
1A3a	Aviation Fuel	CO2	1,272.04	2,465.00	20.27	0.0007601		0.27874
1B1	Mining & Solid Fuel Transformation	CH4	18,289.71	3,806.86	13.02	0.0007542		0.27660
1A	Other (waste)	CO2	812.62	1,959.72	21.19	0.0006317		0.23165
1A3	Other Diesel	N2O	209.00	294.55	140.01	0.0006273		0.23006
6B	Wastewater Handling	CH4	709.70	807.73	50.01	0.0006145		0.22534
2	Industrial Processes	SF6	1,029.95	1,142.82	20.02	0.0003481		0.12766
2C1	Iron&Steel Production	CO2	2,309.27	2,446.30	6.12	0.0002277		0.08350
1A4	Peat	CO2	477.00	441.91	31.62	0.0002126		0.07796
2A1	Cement Production	CO2	6,659.34	5,423.27	2.42	0.0001994		0.07311
2B	Adipic Acid Production	N2O	20,737.34	776.24	15.01	0.0001772		0.06499
2B	Ammonia Production	CO2	1,321.67	1,119.86	10.11	0.0001723		0.06317
6C	Waste Incineration	N2O	47.90	48.30	230.11	0.0001691		0.06200
6C	Waste Incineration	CO2	1,206.51	458.93	21.19	0.0001479		0.05425
2A7	Fletton Bricks	CO2	179.87	129.46	72.80	0.0001434		0.05258
1A3d	Marine Fuel	CO2	4,014.20	4,077.21	2.20	0.0001366		0.05009
1A	Lubricant	CO2	386.90	292.32	30.07	0.0001337		0.04903
1A3b	Auto Fuel	CH4	614.37	166.73	50.08	0.0001270		0.04658
2A3	Limestone & Dolomite use	CO2	1,285.33	1,260.97	5.10	0.0000978		0.03587
1A3	Other Diesel	CO2	1,759.60	2,475.29	2.20	0.0000829		0.03041
1A3d	Marine Fuel	N2O	31.25	31.61	170.01	0.0000817		0.02998
1B2	Oil & Natural Gas	N2O	42.40	45.10	111.16	0.0000763		0.02796
1A3a	Aviation Fuel	N2O	12.53	24.27	171.17	0.0000632		0.02318
2A2	Lime Production	CO2	1,191.52	738.05	5.10	0.0000572		0.02099
2	Industrial Processes	PFC	1,401.57	350.91	10.05	0.0000536		0.01967
2A4	Soda Ash Use	CO2	167.32	202.28	15.13	0.0000466		0.01708
2B	Chemical Industry	CH4	136.17	42.21	28.28	0.0000182		0.00666
2A7	Fletton Bricks	CH4	23.60	10.83	101.98	0.0000168		0.00616
2C	Iron & Steel	N2O	11.11	8.66	118.00	0.0000155		0.00570
2C	Iron & Steel Production	CH4	16.36	17.62	50.00	0.0000134		0.00491
1B	Solid Fuel Transformation	CO2	856.42	110.07	6.01	0.0000101		0.00369
6C	Waste Incineration	CH4	134.43	3.06	50.49	0.0000023		0.00086
1A3a	Aviation Fuel	CH4	2.60	2.86	53.85	0.0000023		0.00086
1A3	Other Diesel	CH4	1.67	2.69	50.03	0.0000020		0.00075
1B1	Coke Oven Gas	N2O	2.08	0.98	118.00	0.0000018		0.00065
1A3d	Marine Fuel	CH4	1.32	1.34	50.03	0.0000010		0.00037
5A	5A LUCF	CO2	-	-	25.02	0.0000000		0.00000
5B	5B LUCF	CO2	-	-	50.01	0.0000000		0.00000
5C	5C LUCF	CO2	-	-	70.01	0.0000000		0.00000
5E	5E LUCF	CO2	-	-	50.01	0.0000000		0.00000
5G	5G LUCF	CO2	-	-	30.02	0.0000000		0.00000
4F	Field Burning	CH4	266.04	-	55.90	0.0000000		0.00000
5C2	5C2 LUCF	CH4	-	-	20.02	0.0000000		0.00000
5E2	5E2 LUCF	CH4	-	-	20.02	0.0000000		0.00000
4F	Field Burning	N2O	77.76	-	231.35	0.0000000		0.00000
5C2	5C2 LUCF	N2O	-	-	20.02	0.0000000		0.00000
5E2	5E2 LUCF	N2O	-	-	20.02	0.0000000		0.00000

Table A 1.1.3 Key Source Analysis Based on Trend in Emissions (Including LULUCF)

IPCC category	Source category	Gas	Base year emissions	Year Y emissions	Combined uncertainty range as a % of source category	Trend Parameter (used to order sources)
			Gg CO2 equiv.	Gg CO2 equiv.		
			1990	2004		
1A3b	Auto Fuel	N2O	1,025.19	5,087.17	170.02	0.0219901
4D	Agricultural Soils	N2O	30,407.12	25,109.90	424.00	0.0202920
2B	Nitric Acid Production	N2O	3,903.85	2,019.71	230.22	0.0122728
6B	Wastewater Handling	N2O	1,033.64	1,215.69	401.12	0.0098867
6A	Solid Waste Disposal	CH4	49,772.46	19,547.29	48.38	0.0095293
1A1&1A2&1A4&1A5	Other Combustion	N2O	4,507.78	3,647.48	195.00	0.0011504
5B	5B LUCF	CO2	15,836.04	15,258.33	50.01	0.0008364
1A(stationary)	Oil	CO2	92,135.38	60,695.19	15.13	0.0007137
2B	Adipic Acid Production	N2O	20,737.34	776.24	15.01	0.0006812
1A3	Other Diesel	N2O	209.00	294.55	140.01	0.0004158
1B1	Mining & Solid Fuel Transformation	CH4	18,289.71	3,806.86	13.02	0.0003566
1A	All Fuel	CH4	2,018.08	1,021.09	50.00	0.0003096
2B5	NEU	CO2	1,843.69	2,133.25	53.85	0.0002995
5G	5G LUCF	CO2	- 1,455.88	96.28	30.02	0.0002158
4B	Manure Management	N2O	1,583.86	1,333.65	414.00	0.0002129
1B2	Production, Refining & Distribution of Oil & Natural Gas	CH4	10,304.01	5,617.81	16.77	0.0002091
5E	5E LUCF	CO2	6,904.22	6,261.56	50.01	0.0001885
1A3b	Auto Fuel	CH4	614.37	166.73	50.08	0.0001597
1A	Other (waste)	CO2	812.62	1,959.72	21.19	0.0001030
1A3a	Aviation Fuel	CO2	1,272.04	2,465.00	20.27	0.0001028
1A3b	Auto Fuel	CO2	109,425.28	119,955.89	4.48	0.0000990
6B	Wastewater Handling	CH4	709.70	807.73	50.01	0.0000934
6C	Waste Incineration	N2O	47.90	48.30	230.11	0.0000741
1A3a	Aviation Fuel	N2O	12.53	24.27	171.17	0.0000722
6C	Waste Incineration	CH4	134.43	3.06	50.49	0.0000509
1B	Oil & Natural Gas	CO2	5,760.18	5,747.87	17.09	0.0000459
6C	Waste Incineration	CO2	1,206.51	458.93	21.19	0.0000455
1A	Natural Gas	CO2	108,856.98	200,293.39	1.51	0.0000447
1A3d	Marine Fuel	N2O	31.25	31.61	170.01	0.0000269
2	Industrial Processes	HFC	11,375.40	9,221.29	19.03	0.0000265
4A	Enteric Fermentation	CH4	18,421.03	15,934.42	20.00	0.0000248
2A7	Fletton Bricks	CO2	179.87	129.46	72.80	0.0000218
1B2	Oil & Natural Gas	N2O	42.40	45.10	111.16	0.0000205
2	Industrial Processes	SF6	1,029.95	1,142.82	20.02	0.0000196
2A7	Fletton Bricks	CH4	23.60	10.83	101.98	0.0000172
2	Industrial Processes	PFC	1,401.57	350.91	10.05	0.0000152
1A	Coal	CO2	248,419.60	145,119.68	1.08	0.0000136
2B	Chemical Industry	CH4	136.17	42.21	28.28	0.0000105
1A4	Peat	CO2	477.00	441.91	31.62	0.0000069
1A	Lubricant	CO2	386.90	292.32	30.07	0.0000057
4B	Manure Management	CH4	2,923.20	2,509.06	30.00	0.0000057
1B	Solid Fuel Transformation	CO2	856.42	110.07	6.01	0.0000040
2C1	Iron&Steel Production	CO2	2,309.27	2,446.30	6.12	0.0000033
2A4	Soda Ash Use	CO2	167.32	202.28	15.13	0.0000025
1B1	Coke Oven Gas	N2O	2.08	0.98	118.00	0.0000020
2C	Iron & Steel	N2O	11.11	8.66	118.00	0.0000019
2C	Iron & Steel Production	CH4	16.36	17.62	50.00	0.0000017
2A2	Lime Production	CO2	1,191.52	738.05	5.10	0.0000013
1A3	Other Diesel	CO2	1,759.60	2,475.29	2.20	0.0000009
2A3	Limestone & Dolomite use	CO2	1,285.33	1,260.97	5.10	0.0000008
5C2	5C2 LUCF	CH4	3.08	11.97	20.02	0.0000007
1A3d	Marine Fuel	CO2	4,014.20	4,077.21	2.20	0.0000006
1A3	Other Diesel	CH4	1.67	2.69	50.03	0.0000006
1A3a	Aviation Fuel	CH4	2.60	2.86	53.85	0.0000003
2A1	Cement Production	CO2	6,659.34	5,423.27	2.42	0.0000002
1A3d	Marine Fuel	CH4	1.32	1.34	50.03	0.0000001
5C2	5C2 LUCF	N2O	0.31	1.21	20.02	0.0000001
5E2	5E2 LUCF	CH4	9.35	7.46	20.02	0.0000000
2B	Ammonia Production	CO2	1,321.67	1,119.86	10.11	0.0000000
5E2	5E2 LUCF	N2O	0.95	0.76	20.02	0.0000000
5A	5A LUCF	CO2	- 12,202.57	- 15,738.00	25.02	0.0000000
5C	5C LUCF	CO2	- 6,200.25	- 7,934.29	70.01	0.0000000
4F	Field Burning	CH4	266.04	-	55.90	0.0000000
4F	Field Burning	N2O	77.76	-	231.35	0.0000000

Table A 1.1.4 Key Source Analysis Based on Trend in Emissions (Excluding LULUCF)

IPCC category	Source category	Gas	Base year emissions	Year Y emissions	Combined uncertainty range as a % of source category	Trend Parameter (used to order sources)
			Gg CO2 equiv.	Gg CO2 equiv.		
			1990	2004		
4D	Agricultural Soils	N2O	30,407.12	25,109.90	424.00	0.0257645
1A3b	Auto Fuel	N2O	1,025.19	5,087.17	170.02	0.0217417
2B	Nitric Acid Production	N2O	3,903.85	2,019.71	230.22	0.0123660
6B	Wastewater Handling	N2O	1,033.64	1,215.69	401.12	0.0096163
6A	Solid Waste Disposal	CH4	49,772.46	19,547.29	48.38	0.0095560
1A1&1A2&1A4&1A5	Other Combustion	N2O	4,507.78	3,647.48	195.00	0.0013169
1A(stationary)	Oil	CO2	92,135.38	60,695.19	15.13	0.0007285
2B	Adipic Acid Production	N2O	20,737.34	776.24	15.01	0.0006793
4B	Manure Management	N2O	1,583.86	1,333.65	414.00	0.0004926
1A3	Other Diesel	N2O	209.00	294.55	140.01	0.0004074
1B1	Mining & Solid Fuel Transformation	CH4	18,289.71	3,806.86	13.02	0.0003563
1A	All Fuel	CH4	2,018.08	1,021.09	50.00	0.0003118
2B5	NEU	CO2	1,843.69	2,133.25	53.85	0.0002909
1B2	Production, Refining & Distribution of Oil & Natural Gas	CH4	10,304.01	5,617.81	16.77	0.0002105
1A3b	Auto Fuel	CH4	614.37	166.73	50.08	0.0001597
1A	Other (waste)	CO2	812.62	1,959.72	21.19	0.0001016
1A3a	Aviation Fuel	CO2	1,272.04	2,465.00	20.27	0.0001013
1A3b	Auto Fuel	CO2	109,425.28	119,955.89	4.48	0.0000958
6B	Wastewater Handling	CH4	709.70	807.73	50.01	0.0000906
1A3a	Aviation Fuel	N2O	12.53	24.27	171.17	0.0000711
6C	Waste Incineration	N2O	47.90	48.30	230.11	0.0000707
6C	Waste Incineration	CH4	134.43	3.06	50.49	0.0000507
6C	Waste Incineration	CO2	1,206.51	458.93	21.19	0.0000456
1A	Natural Gas	CO2	108,856.98	200,293.39	1.51	0.0000440
1B	Oil & Natural Gas	CO2	5,760.18	5,747.87	17.09	0.0000437
2	Industrial Processes	HFC	11,375.40	9,221.29	19.03	0.0000305
1A3d	Marine Fuel	N2O	31.25	31.61	170.01	0.0000257
2A7	Fletton Bricks	CO2	179.87	129.46	72.80	0.0000225
1B2	Oil & Natural Gas	N2O	42.40	45.10	111.16	0.0000198
2	Industrial Processes	SF6	1,029.95	1,142.82	20.02	0.0000190
2A7	Fletton Bricks	CH4	23.60	10.83	101.98	0.0000172
4A	Enteric Fermentation	CH4	18,421.03	15,934.42	20.00	0.0000169
2	Industrial Processes	PFC	1,401.57	350.91	10.05	0.0000152
1A	Coal	CO2	248,419.60	145,119.68	1.08	0.0000138
2B	Chemical Industry	CH4	136.17	42.21	28.28	0.0000105
1A4	Peat	CO2	477.00	441.91	31.62	0.0000063
1A	Lubricant	CO2	386.90	292.32	30.07	0.0000060
1B	Solid Fuel Transformation	CO2	856.42	110.07	6.01	0.0000040
2C1	Iron&Steel Production	CO2	2,309.27	2,446.30	6.12	0.0000032
4B	Manure Management	CH4	2,923.20	2,509.06	30.00	0.0000029
2A4	Soda Ash Use	CO2	167.32	202.28	15.13	0.0000024
2C	Iron & Steel	N2O	11.11	8.66	118.00	0.0000020
1B1	Coke Oven Gas	N2O	2.08	0.98	118.00	0.0000020
2C	Iron & Steel Production	CH4	16.36	17.62	50.00	0.0000016
2A2	Lime Production	CO2	1,191.52	738.05	5.10	0.0000013
1A3	Other Diesel	CO2	1,759.60	2,475.29	2.20	0.0000008
2A3	Limestone & Dolomite use	CO2	1,285.33	1,260.97	5.10	0.0000008
1A3d	Marine Fuel	CO2	4,014.20	4,077.21	2.20	0.0000006
1A3	Other Diesel	CH4	1.67	2.69	50.03	0.0000006
1A3a	Aviation Fuel	CH4	2.60	2.86	53.85	0.0000003
2A1	Cement Production	CO2	6,659.34	5,423.27	2.42	0.0000003
2B	Ammonia Production	CO2	1,321.67	1,119.86	10.11	0.0000001
1A3d	Marine Fuel	CH4	1.32	1.34	50.03	0.0000001
5A	5A LUCF	CO2	-	-	25.02	0.0000000
5B	5B LUCF	CO2	-	-	50.01	0.0000000
5C	5C LUCF	CO2	-	-	70.01	0.0000000
5E	5E LUCF	CO2	-	-	50.01	0.0000000
5G	5G LUCF	CO2	-	-	30.02	0.0000000
4F	Field Burning	CH4	266.04	-	55.90	0.0000000
5C2	5C2 LUCF	CH4	-	-	20.02	0.0000000
5E2	5E2 LUCF	CH4	-	-	20.02	0.0000000
4F	Field Burning	N2O	77.76	-	231.35	0.0000000
5C2	5C2 LUCF	N2O	-	-	20.02	0.0000000
5E2	5E2 LUCF	N2O	-	-	20.02	0.0000000

Table A 1.1.5 Key Source Category Analysis Summary (Including LULUCF)

Quantitative Method Used: Tier 1					
A		B	C	D	E
			Category	If Column C is	
IPCC Source Categories		Gas	Key Source	Yes, Criteria for	Comments
			Category	Identification	
1A	Coal	CO2			
1A(stationary)	Oil	CO2		Level	
1A	Natural Gas	CO2		Level	
1A	Other (waste)	CO2			
1A	Lubricant	CO2			
1A3a	Aviation Fuel	CO2			
1A3b	Auto Fuel	CO2		Level	
1A3d	Marine Fuel	CO2			
1A3	Other Diesel	CO2			
1A4	Peat	CO2			
1B	Solid Fuel Transformation	CO2			
1B	Oil & Natural Gas	CO2			
2A1	Cement Production	CO2			
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 LUCF	CO2		Level	
5B	5B LUCF	CO2		Level, Trend	
5C	5C LUCF	CO2		Level	
5E	5E LUCF	CO2		Level	
5G	5G LUCF	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		Level	
4B	Manure Management	CH4			
4F	Field Burning	CH4			
5C2	5C2 LUCF	CH4			
5E2	5E2 LUCF	CH4			
6A	Solid Waste Disposal	CH4		Level, Trend	high uncertainty
6B	Wastewater Handling	CH4			
6C	Waste Incineration	CH4			
1A1&1A2&1A4&1A5	Other Combustion	N2O		Level, Trend	
1A3a	Aviation Fuel	N2O			
1A3b	Auto Fuel	N2O		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		Level, Trend	
2C	Iron & Steel	N2O			
4B	Manure Management	N2O		Level	high uncertainty
4D	Agricultural Soils	N2O		Level, Trend	high uncertainty
4F	Field Burning	N2O			
5C2	5C2 LUCF	N2O			
5E2	5E2 LUCF	N2O			
6B	Wastewater Handling	N2O		Level, Trend	
6C	Waste Incineration	N2O			
2	Industrial Processes	HFC		Level	
2	Industrial Processes	PFC			
2	Industrial Processes	SF6			

Table A 1.1.6 Key Source Category Analysis Summary (Excluding LULUCF)

Quantitative Method Used: Tier 1					
A		B	C	D	E
			Category	If Column C is	
IPCC Source Categories		Gas	Key Source	Yes, Criteria for	Comments
			Category	Identification	
1A	Coal	CO2			
1A(stationary)	Oil	CO2		Level	
1A	Natural Gas	CO2		Level	
1A	Other (waste)	CO2			
1A	Lubricant	CO2			
1A3a	Aviation Fuel	CO2			
1A3b	Auto Fuel	CO2		Level	
1A3d	Marine Fuel	CO2			
1A3	Other Diesel	CO2			
1A4	Peat	CO2			
1B	Solid Fuel Transformation	CO2			
1B	Oil & Natural Gas	CO2			
2A1	Cement Production	CO2			
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 LUCF	CO2			
5B	5B LUCF	CO2			
5C	5C LUCF	CO2			
5E	5E LUCF	CO2			
5G	5G LUCF	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		Level	
4B	Manure Management	CH4			
4F	Field Burning	CH4			
5C2	5C2 LUCF	CH4			
5E2	5E2 LUCF	CH4			
6A	Solid Waste Disposal	CH4		Level, Trend	high uncertainty
6B	Wastewater Handling	CH4			
6C	Waste Incineration	CH4			
1A1&1A2&1A4&1A5	Other Combustion	N2O		Level, Trend	
1A3a	Aviation Fuel	N2O			
1A3b	Auto Fuel	N2O		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		Level, Trend	
2C	Iron & Steel	N2O			
4B	Manure Management	N2O		Level	high uncertainty
4D	Agricultural Soils	N2O		Level, Trend	high uncertainty
4F	Field Burning	N2O			
5C2	5C2 LUCF	N2O			
5E2	5E2 LUCF	N2O			
6B	Wastewater Handling	N2O		Level, Trend	
6C	Waste Incineration	N2O			
2	Industrial Processes	HFC		Level	
2	Industrial Processes	PFC			
2	Industrial Processes	SF6			

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 apply to a range of pollutants and not just CO_2.

A3 ANNEX 3: Other Detailed Methodological Descriptions

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.

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 (DTI, 2005), 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 A3.1.1** 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.

(i) *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.

(ii) *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.

(iii) *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.

(iv) *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.

(v) *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

(vi) *Slurry*
This is a slurry of coal and water used in some power stations.

(vii) *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.

(viii) *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[1].

[1] 13% in 2005 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	Petrol
	Aviation Gasoline	Aviation Spirit
	Jet Kerosene	Aviation Turbine Fuel[1] (ATF)
	Other Kerosene	Burning Oil
	Gas/Diesel Oil	Gas Oil/ DERV
	Residual Fuel Oil	Fuel Oil
	Orimulsion	Orimulsion
	Liquefied Petroleum Gas	Liquefied Petroleum Gas (LPG)
	Naphtha	Naphtha
	Petroleum Coke	Petroleum Coke
	Refinery Gas	Other Petroleum Gas (OPG)
	Other Oil: Other	Refinery Miscellaneous
	Other Oil: Other	Waste Oils
	Lubricants	Lubricants
Solid	Anthracite	Anthracite
	Coking Coal	Coal[2]
	Coal	Coal
	Coal	Slurry[3]
	Coke Oven Coke	Coke
	Patent Fuel	Solid Smokeless Fuel (SSF)
	Coke Oven Gas	Coke Oven Gas
	Blast Furnace Gas	Blast Furnace Gas
Gas	Natural Gas	Natural Gas
	Natural Gas	Sour Gas[4]
	Colliery Methane[5]	Colliery Methane
Other Fuels	Municipal Solid Waste	Municipal Solid Waste
	Industrial Waste: Scrap Tyres	Scrap Tyres
Biomass	Wood/Wood Waste	Wood
	Other Solid Biomass: Straw	Straw
	Other Solid Biomass: Poultry Litter, Meat & Bone Meal	Poultry Litter, Meat & bone meal
	Landfill Gas	Landfill Gas
	Sludge 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

Tables A3.2.1 to **A3.2.7** 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:

- 5 Land Use Change and Forestry
- Forests (NMVOC emission only reported in the NAEI)

Tables A3.2.1 to **A3.2.7** refer to NAEI base categories. Normally the NAEI is not reported in such a detailed form but in the summary UNECE/CORINAIR SNAP97, eleven-sector format or the new NRF (Nomenclature or Reporting) system used for submission to CORINAIR.

Table A 3.2.1 Mapping of IPCC Source Categories to NAEI Source Categories:

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	No comparable category
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:

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	Offshore Oil and Gas (Well Testing)
1B2a Oil ii Production	Offshore Oil and Gas
1B2a Oil iii Transport	Offshore Loading Onshore Loading
1B2a Oil iv Refining/Storage	Refineries (drainage) Refineries (tankage) Refineries (Process) 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 Production	Gasification Processes
1B2b ii Natural Gas. Transmission/Distribution	Gas Leakage
1B2ciii Venting: Combined	Offshore Oil and Gas (Venting)
1B2ciii Flaring: Combined	Offshore Flaring Refineries (Flares)

Table A 3.2.3 Mapping of IPCC Source Categories to NAEI Source Categories:

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
2A6 Road Paving with Asphalt	Road Construction
2A7 Other	Brick Manufacture (Fletton) Glass (continuous filament glass fibre) Glass (glass wool)
2B1 Ammonia Production	Ammonia Feedstock
2B2 Nitric Acid Production	Nitric Acid Production
2B3 Adipic Acid Production	Adipic Acid Production
2B4 Carbide Production	
2B5 Other	Sulphuric Acid Production Chemical Industry Chemical Industry (Carbon Black) Chemical Industry (Ethylene) Chemical Industry (Methanol) Chemical Industry (Nitric Acid Use) Chemical Industry (Pigment Manufacture) Chemical Industry (Reforming) Chemical Industry (Sulphuric Acid Use) Coal, tar and bitumen processes Solvent and Oil recovery Ship purging
2C1 Iron and Steel	Iron and Steel (other) Iron and Steel (Basic Oxygen Furnace) Iron and Steel (Electric Arc Furnace) Iron and Steel Flaring (Blast Furnace Gas) Rolling Mills (Hot & Cold Rolling)
2C2 Ferroalloys Productions	No Comparable Source Category
2C3 Aluminium Production	Non-Ferrous Metals (Aluminium Production)
2C4 SF6 Used in Aluminium and Magnesium Foundries	SF_6 Cover Gas
2C5 Other	Non-Ferrous Metals (other non-ferrous metals) Non-Ferrous Metals (primary lead/zinc) Non-Ferrous Metals (secondary Copper) Non-Ferrous Metals (secondary lead)
2D1 Pulp and Paper	Wood Products Manufacture

IPCC Source Category	NAEI Source Category
2D2 Food and Drink	Brewing (barley malting, fermentation, wort boiling) Bread Baking Cider Manufacture Other Food (animal feed; cakes, biscuits, cereals; coffee, malting, margarine and other solid fats; meat, fish and poultry; sugar) Spirit Manufacture (barley malting, casking, distillation, fermentation, maturation, spent grain drying) Wine Manufacture
2E1 Halocarbon & SF6 By-Product Emissions 2E2 Halocarbon & SF6 Fugitive Emissions	Halocarbons Production (By-Product and Fugitive)
2E3 Halocarbon & SF6 Other	Not Estimated
2F1 Refrigeration & Air Conditioning Equipment	Refrigeration Supermarket Refrigeration Mobile Air Conditioning
2F2 Foam Blowing	Foams
2F3 Fire Extinguishers	Fire Fighting
2F2 Aerosols	Metered Dose Inhalers Aerosols (Halocarbons)
2F5 Solvents	Not Occurring
2F8a One Component Foams	
2F8 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
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:

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
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

The LULUCF categories in the table below are the reporting categories used until the 2004 NIR; these categories are still used in the NAEI database to allow comparisons with previous GHG inventories, but 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. The categories will be modified in the 2005 database.

Table A 3.2.6 Mapping of IPCC Source Categories to NAEI Source Categories:

IPCC Source Category[1]	NAEI Source Category
5A Changes in Forest and Other Woody Biomass Stocks	Not estimated
5B Forest and Grassland Conversion	5B2 Deforestation
5C Abandonment of Managed Lands	Not estimated
5D CO_2 Emissions and Removals from Soil	Agricultural Soils: Limestone Agricultural Soils: Dolomite
5E Other	Not estimated

1 Categories 5A, 5B, 5C and 5E are not included in the NAEI because a time series back to 1970 is unavailable. They are included in the Green House Gas Inventory.

Table A 3.2.7 Mapping of IPCC Source Categories to NAEI Source Categories:

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. That is:

Total Emission = Emission Factor × 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:

Emission = Σ 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 DTI (2005). 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 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)
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:

- Carbon dioxide as carbon
- Methane
- Nitrous oxide
- NO_x as nitrogen dioxide
- NMVOC
- Carbon monoxide

- Sulphur dioxide

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
- Shipping Naval

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

Beginning with the 2003 inventory, a major change has been made to the estimation of CO & NO_x emissions from industrial, commercial/institutional, and domestic sources. Whereas previously a single emission factor would be applied for a given source/fuel combination, the new methodology allows 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, 2005) are also used to generate emission factors.

Tables A3.3.1 to **A3.3.4** 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 DTI (2005) are reported in terms of energy content on a gross basis.

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)
- 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 (DTI, 2005).

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.

Table A 3.3.1 Emission Factors for the Combustion of Liquid Fuels for 2005[1] (kg/t)

Fuel	Source	C[aj]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
ATF	Aircraft Military	859[a]	0.103[ad]	0.1[g]	8.5[ad]	8.2[ad]	1.1[ad]	1[z]
Burning Oil	Domestic	859[a]	0.462[g]	0.0277[g]	3.23[l]	1.85[l]	0.048[f]	0.62[z]
Burning Oil	Other Industry	859[a]	0.0924[g]	0.0277[g]	3.06[l]	0.17[l]	0.028[e]	0.62[z]
Burning Oil	Public Service, Railways (Stationary)	859[a]	0.462[g]	0.0277[g]	2.05[l]	0.16[l]	0.048[f]	0.62[z]
Burning Oil	Miscellaneous	859[a]	0.462[g]	0.0277[g]	2.70[l]	0.16[l]	0.048[f]	0.62[z]
Gas Oil	Agriculture	870[a]	0.455[g]	0.0273[g]	0[ap]	0[ap]	0.048[f]	2.9[z]
Gas Oil	Domestic	870[a]	0.455[g]	0.0273[g]	3.19[l]	1.82[l]	0.048[f]	2.9[z]
Gas Oil	Fishing, Coastal Shipping, Naval, International Marine	870[a]	0.05[ap]	0.08 [ap]	72.3 [aq]	7.4[ap]	3.5 [aq]	19.6 [ar]
Gas Oil	Iron&Steel	870[a]	0.0910[g]	0.0273[g]	25.4[l]	10.3[l]	0.028[f]	2.9[z]
Gas Oil	Refineries	870[a]	0.136[g]	0.0273[g]	4.56[k]	0.24[i]	0.028[f]	2.9[z]
Gas Oil	Other Industry	870[a]	0.0910[g]	0.0273[g]	4.34[l]	0.51[l]	0.028[f]	2.9[z]
Gas Oil	Public Service	870[a]	0.455[g]	0.0273[g]	2.44[l]	0.38[l]	0.048[f]	2.9[z]
Gas Oil	Miscellaneous	870[a]	0.455[g]	0.0273[g]	1.65[l]	0.21[l]	0.048[f]	2.9[z]
Fuel Oil	Agriculture	879[a]	0.433[g]	0.026[g]	7.69[l]	0.31[l]	0.14[f]	13.6[z]
Fuel Oil	Public Service	879[a]	0.433[g]	0.026[g]	7.57[l]	0.79[l]	0.14[f]	13.6[z]
Fuel Oil	Miscellaneous	879[a]	0.433[g]	0.026[g]	1.64[l]	0.066[l]	0.14[f]	13.6[z]
Fuel Oil	Fishing; Coastal Shipping, International Marine	879[a]	0.05[ap]	0.08 [ap]	72.3 [aq]	7.4[ap]	3.5 [aq]	52.9 [ar]
Fuel Oil	Domestic	879[a]	0.433[g]	0.026[g]	0[ap]	0[ap]	0.14[f]	13.6[z]
Fuel Oil	Iron&Steel	879[a]	0.087[g]	0.026[g]	7.25[l]	0.84[l]	0.035[f]	13.6[z]
Fuel Oil	Railways (Stationary)	879[a]	0.433[g]	0.026[g]	7.57[l]	0.79[l]	0.14[f]	13.6[z]
Fuel Oil	Other Industry	879[a]	0.087[g]	0.026[g]	7.52[l]	0.84[l]	0.035[f]	13.6[z]
Fuel Oil	Refineries (Combustion)	879[a]	0.130[g]	0.026[g]	3.45[ag]	0.94[ag]	0.035[f]	19.2[ag]
Lubricants	Other Industry	865[x]	0.091[e]	0.027[e]	4.56[k]	0.26[f]	0.14[f]	11.4[x]
Naphtha	Refineries	854[a]	0.130[an]	0.026[g]	4.62[k]	0.24[e]	0.028[e]	0.2[af]
Petrol	Refineries	855[a]	0.141[an]	0.028[g]	4.62[k]	0.24[e]	0.028[e]	0.064[z]

Table A 3.3.2 Emission Factors for the Combustion of Coal for 2005[1] (kg/t)

Source	C[aj]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Agriculture	639.1[ao]	0.011[o]	0.148[w]	4.75[l]	8.25[l]	0.05[o]	19.8[aa]
Collieries	687.3[ao]	0.011[o]	0.146[w]	4.75[l]	8.25[l]	0.05[o]	23.8[aa]
Domestic	688.0[ao]	15.7[o]	0.122[w]	3.47[l]	180.7[l]	14[o]	20.0[aa]
Iron and Steel (Combustion)	693.8[a]	0.011[o]	0.237[w]	IE	IE	0.05[o]	19.8[aa]
Lime Production (Combustion)	602.7[ao]	0.011[o]	0.215[w]	89.2[v]	27.2[v]	0.05[o]	19.8[aa]
Miscellaneous	707.6[ao]	0.011[o]	0.147[w]	4.14[l]	7.80[l]	0.05[o]	19.8[aa]
Public Service	707.6[ao]	0.011[o]	0.147[w]	4.57[l]	8.95[l]	0.05[o]	19.8[aa]
Other Industry	602.7[ao]	0.011[o]	0.215[w]	4.65[l]	2.01[l]	0.05[o]	19.8[aa]
Railways	707.6[ao]	0.011[o]	0.147[w]	4.57[l]	8.95[l]	0.05[o]	19.8[aa]
Autogenerators	602.7[ao]	0.02[o]	0.0664[w]	5.63[l]	1.61[l]	0.03[o]	19.8[aa]

Table A 3.3.3 Emission Factors for the Combustion of Solid Fuels 2005[1] (kg/t)

Fuel	Source	C[aj]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Anthracite	Domestic	818.2[ap]	2[o]	0.14[w]	3.38[k]	202.8[k]	1.7[o]	14.2[aa]
Coke	Agriculture	766.3[r]	0.011[p]	0.149[w]	51.1[l]	0[ap]	0.05[p]	19[ab]
Coke	SSF Production	766.3[r]	0.011[p]	0.228[w]	IE	IE	0.05[p]	19[ab]
Coke	Domestic	766.3[r]	5.8[o]	0.116[w]	3.04[l]	118.6[l]	4.9[o]	14.2[aa]
Coke	I&S[ak] (Sinter Plant)	766.3[r]	1.27[ae]	0.228[w]	10.5[ae]	283[ae]	0.95[ae]	10.0[ae]
Coke	I&S[ak] (Combustion)	766.3[r]	0.011[p]	0.228[w]	0.87[l]	226[l]	0.05[p]	19[ab]
Coke	Other Industry	766.3[r]	0.011[p]	0.228[w]	51.1[l]	IE	0.05[p]	19[ab]
Coke	Railways	766.3[r]	0.011[p]	0.149[w]	51.1[l]	0[ap]	0.05[p]	19[ab]
Coke	Miscellaneous; Public Service	766.3[r]	0.011[p]	0.149[w]	51.1[l]	0[ap]	0.05[p]	19[ab]
MSW	Miscellaneous	75[ah]	2.85[g]	0.038[g]	1.23[v]	0.12[v]	0.0065[v]	0.070[v]
Petroleum Coke	Domestic	930[a]	NE	NE	3.95[k]	158[k]	4.9[am]	19[ab]
Petroleum Coke	Refineries	930[a]	0.0155[ai]	0.281[w]	9.29[ag]	4.40[ag]	0.070[ai]	35.0[ag]
SSF	Agriculture; Miscellaneous; Public Service	766.3[n]	0.011[p]	0.151[w]	4.67[k]	46.7[k]	0.05[p]	19[ab]
SSF	Domestic	774.2[n]	5.8[o]	0.118[w]	3.11[k]	124.4[k]	4.9[o]	16[ab]
SSF	Other Industry	766.3[n]	0.011[p]	0.232[w]	4.67[k]	46.7[k]	0.05[p]	19[ab]
Straw	Agriculture	418[g]	4.5[g]	0.06[g]	1.5[g]	75[g]	9[g]	0
Wood	Domestic	278[g]	3[g]	0.04[g]	0.5[k]	50[g]	17[k]	0.108[f]

Table A 3.3.4 Emission Factors for the Combustion of Gaseous Fuels 2005[1] (g/GJ gross)

Fuel	Source	C[aj]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Blast Furnace Gas	Coke Production	69497[r]	112[k]	2.0[k]	79[k]	39.5[k]	5.6[k]	0
Blast Furnace Gas	I&S[ak] (Combustion), I&S[ak] (Flaring)	69497[r]	112[k]	2.0[k]	79[k]	39.5[k]	5.6[k]	0
Blast Furnace Gas	Blast Furnaces	69497[r]	112[k]	2.0[k]	31.7[v]	39.5[k]	5.6[k]	0
Coke Oven Gas	Other Sources	11074[r]	57.25[k]	2.0[k]	80.5[k]	40.0[k]	4.35[k]	232[v]
Coke Oven Gas	I&S[ak] Blast Furnaces	11074[r]	57.25[k]	2.0[k]	31.7[v]	40.0[k]	4.35[k]	232[v]
Coke Oven Gas	Coke Production	11074[r]	57.25[k]	2.0[k]	274.5[v]	40.0[k]	4.35[k]	232[v]
LPG	Domestic	16227[a]	0.896[f]	0.10[g]	64.8[f]	8.9[f]	1.55[f]	0
LPG	I&S[ak], Other Industry, Refineries, Gas Production	16227[a]	0.896[f]	0.10[g]	89.3[f]	15.2[f]	1.55[f]	0
Natural Gas	Agriculture	14013[r]	5.0[g]	0.10[g]	39.2[l]	2.13[l]	2.21[f]	0
Natural Gas	Miscellaneous	14013[r]	5.0[g]	0.10[g]	30.5[l]	10.1[l]	2.21[f]	0
Natural Gas	Public Service	14013[r]	5.0[g]	0.10[g]	54.3[l]	12.7[l]	2.21[f]	0
Natural Gas	Coke Production, SSF Prodn[al],	14013[r]	1.0[g]	0.10[g]	175.0[k]	2.37[l]	2.21[f]	0
Natural Gas	Refineries	14013[r]	1.0[g]	0.10[g]	70.0[k]	2.37[l]	2.21[f]	0
Natural Gas	Blast Furnaces	14013[r]	5.0[g]	0.10[g]	31.7[v]	2.37[l]	2.21[f]	0
Natural Gas	Domestic	14013[r]	5.0[g]	0.10[g]	69.2[l]	30.8[l]	2.21[f]	0
Natural Gas	Gas Prodn[al],	14013[r]	1.0[g]	0.10[g]	93.8[l]	17.4[l]	2.21[f]	0
Natural Gas	I&S[ak]	14013[r]	1.0[g]	0.10[g]	186[l]	179.5[l]	2.21[f]	0
Natural Gas	Railways	14013[r]	5.0[g]	0.10[g]	93.8[l]	33.8[l]	2.21[f]	0
Natural Gas	Other Industry, Nuclear Fuel	14013[r]	5.0[g]	0.10[g]	108[l]	24.9[l]	2.21[f]	0

Fuel	Source	C[aj]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
	Prodn[al], Collieries							
Natural Gas	Autogenerators	14013[r]	5.0[g]	0.10[g]	108.2[l]	21.2[l]	2.21[f]	0
Natural Gas	Ammonia (Combustion)	14013[r]	5.0[g]	0.10[g]	151.6[d]	NE	2.21[f]	0
OPG	Gas production, Other Industry	15582[a]	1.0[g]	NE	70.0[k]	2.37[i]	1.55[f]	0
OPG	Refineries (Combustion)	15582[a]	1.0[g]	NE	85.2[ag]	17.09[z]	1.55[f]	0
Colliery Methane	All Sources	13921[a]	3.6[s]	0.10[g]	70.0[k]	2.37[i]	2.21[f]	0
Sewage Gas	Public Services	27404[g]	1.0[g]	0.10[g]	39.8[f]	4.2[f]	1.44[f]	0
Landfill Gas	Miscellaneous	27404[g]	5.0[g]	0.10[g]	23.2[f]	73.0[f]	2.16[f]	0

Footnotes to **Tables A3.3.1** to **A3.3.4**

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 (2006), Invista (2006), BP Chemicals (2006)
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 Energy & Environment estimate based on application of literature emission factors at a greater level of detail than the sector listed (see Section A.3.3.1).
m	USEPA (1997)
n	British Coal (1989)
o	Brain *et al,* (1994)
p	As for coal
q	EMEP/CORINAIR (2004)
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, 2006)
w	Fynes *et al* (1994)
x	Passant (2005)
y	UKPIA (1989)
z	Emission factor derived from data supplied by UKPIA (2006)
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 (2002)
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

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 databases store 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 DTI, (2006). The values of the conversion factors used in the calculations are given in **Table A3.3.5**.

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* (DTI, 2006) 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 was 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[2].

[2] Making use, from 2000 onwards, of supplementary data from DTI because of a revision to the DUKES reporting format.

Table A 3.3.6 Emission Factors for Power Stations in 2005 [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	627.2[a]	0.02[e]	0.063[l]	6.35[n]	1.06[n]	0.0254[n]	7.48[n]
Fuel Oil	Kt/Mt	879[a]	0.130[h]	0.0260[h]	14.6[n]	3.95[n]	0.0180[n]	15.4[n]
Gas Oil	Kt/Mt	870[a]	0.136[h]	0.0273[h]	51.3[n]	13.1[n]	0.133[n]	21.5[n]
Natural gas	Kt/Mth	1.478[a]	0.000106[h]	1.06E-05[h]	0.00383[n]	0.000851[n]	0.000283[n]	2.57E-05[n]
MSW	Kt/Mt	75[d]	0.285[h]	0.038[h]	1.23[o]	0.116[o]	0.00648[o]	0.0701[o]
Sour gas	Kt/Mth	1.916[c]	0.000106[h]	1.06E-05[h]	0.00469[n]	0.0150[o]	0.000542[n]	0.000729[n]
Poultry Litter	Kt/Mt	NE	0.275[h]	0.0367[j]	1.04[n]	0.711[o]	0.00377[o]	0.773[n]
Sewage Gas	Kt/Mth	NE	0.000106[h]	1.06E-05[h]	0.00420[k]	0.000446[k]	0.000152[k]	NE
Waste Oils	Kt/Mt	864.8[b]	NE	NE	14.6[n]	3.95[n]	0.0180[n]	15.4[n]
Landfill gas	Kt/Mth	NE	0.000106[h]	1.06E-05[h]	0.00245[k]	0.00770[k]	0.000227[k]	NE

Footnotes to **A3.3.6** (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
(UKPIA (2004)-Liquid Fuels, Transco (2004) – 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 (1996a) 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, 2005), SEPA's EPER inventory (SEPA, 2005), NI DoE's ISR list (NI DoE, 2005) and direct communications with plant operators (Pers. Comms., 2005)
o Environment Agency (2005)
p USEPA (1997)
NE Not Estimated

The emission factors used for Power Stations are shown in **Table A3.3.6**. National emission estimates for SO_2, NOx, CO and NMVOC are based on estimates for each power station provided by the process operators to UK regulators (EA, SEPA, NIDoE, all 2006). 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 fulfill 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:

1) 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'.
2) 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.
3) 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 manufacturers specification (BITOR, 1995). The emissions of NOx, 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 (DTI, 2006) on the amount of waste used in heat and electricity generation and the emissions from the incinerators (Environment Agency, 2006). 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 emissions are based on estimates compiled by DTI (2000) and a carbon emission factor based on the carbon content of tyres (Ogilvie, 1995). IPCC default factors based on oil are used. In 2000, the tyre-burning plant closed down.

Also included are emissions from four plants that burnt poultry litter and wood chips and a single plant burning straw. In 2000 one of the poultry litter plants was converted to burn meat and bone meal. The carbon emissions 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, NOx, SO_2, and NMVOC are also estimated. Emission factors are based on Environment

Agency (2006) 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 straw-burning plant either by using EU ETS data or, where that is not available, based on information published on the internet by the operator of both 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 (DTI, 2005). 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 duel-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, 2006). DTI (2006) 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. 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 A3.3.1**. 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 (DTI, 2005), the emissions are reported under 1A1b Petroleum Refining rather than as a fugitive emission under 1B2. Emission factors are either based on operators' data (UKPIA, 2006) 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 **Tables A3.3.1-3.3.4**. The fuel consumption for these categories are taken from DTI (2005). 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.

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.

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 **Tables A3.3.1** to **A3.3.4**. However, the treatment of gas oil use on offshore installations is anomalous: this is accounted for within the NAEI category Coastal Shipping and is mapped to 1A3dii National Navigation, based on the reporting of gas oil use in DUKES and the absence of any detailed data to split gas oil used in coastal vessels and that used to service offshore installations. There are no double counts in these emissions.
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 Energy & Environment. 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.

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.

A3.3.5.1.2 Emission reporting categories for civil aviation

Table A3.3.7 below shows the emissions included in the emission totals for the domestic and international civil aviation categories currently reported to the FCCC and the UN/ECE. Note the reporting requirements to the UN/ECE 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

Organisation receiving emissions data	Category of emissions	LTO	Cruise
FCCC	Domestic	✓	✓
	International	m	m
UN/ECE	Domestic	✓	✓
	International	m	m

Notes

✓ emissions included in national totals

m memo items - emissions are estimated and reported, but are **not included in national totals**

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. A summary of aircraft movement data is given in **Table A3.3.8**.

- **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 DTI (2004). 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 is given in ONS (1995) and MOD (2005a) and is assumed to be aviation turbine fuel.

Table A 3.3.8 Aircraft Movement Data

	International LTOs (000s)	Domestic LTOs (000s)	International Aircraft, Gm flown	Domestic Aircraft, Gm flown
1990	410.1	311.4	635.4	97.9
1991	397.4	307.1	623.9	96.3
1992	432.8	325.1	705.8	102.0
1993	443.6	332.7	717.3	105.8
1994	461.8	312.6	792.5	101.8
1995	480.7	325.5	831.9	106.9
1996	507.1	337.5	871.4	112.6
1997	537.4	342.2	948.9	117.7
1998	575.6	355.6	1034.4	123.7
1999	609.6	363.8	1101.4	128.3
2000	646.3	367.4	1171.2	130.4
2001	653.2	376.5	1186.4	137.0
2002	650.0	374.8	1178.6	136.2
2003	669.3	375.0	1230.7	136.4
2004	700.3	397.9	1335.1	144.0
2005	706.6	409.8	1414.3	151.7

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 2005 (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 (2005)
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	1.69	0.1	4.2	1037.3	15.47
Domestic LTO	ATF	kt/Mt	0.22	0.1	9.4	13.1	2.30
Domestic Cruise	ATF	kt/Mt	-	0.1	13.4	2.7	0.63
International LTO	AS	kt/Mt	-	-	-	-	-
International LTO	ATF	kt/Mt	0.12	0.1	10.6	9.8	1.28
International Cruise	ATF	kt/Mt	-	0.1	14.3	1.1	0.51
Military aviation	ATF	kt/Mt	0.10	0.1	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
- 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.

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.

A3.3.5.1.7 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, 1997c) and the estimates of fuel consumed in the cruise (see equation above).

A3.3.5.1.8 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
- **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.

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.

A3.3.5.1.9 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 A3.3.10)**. 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.

A3.3.5.1.10 Fuel reconciliation

The estimates of aviation fuels consumed in the commodity balance table in the DTI 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. The ATF fuel consumptions presented in DTI 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 will be re-normalised each time the aircraft movement data is modified or data for another year added.

A3.3.5.1.11 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, (1997c); (IPPC Reference Manual, Overview, Page 5).

The national estimates of aviation fuels consumed in the UK are taken from DTI 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.

The UK DTI 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. The DTI have confirmed estimates in DUKES exclude Gibraltar and the other UK overseas territories. The DTI 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 DTI (2006). Emission factors are reported in **Tables A3.3.1** to **A3.3.3**.

The UK GHGI reports emissions from diesel trains in three categories: freight, intercity and regional. Emission estimates are based on train kilometres travelled and gas oil consumption by the railway sector. Gas oil consumption is estimated from data provided by the Association of Train Operating Companies (ATOC) and from other research (Netcen, 2004). Emissions from diesel trains are reported under the IPCC category 1A3c Railways.

Carbon dioxide, sulphur dioxide and nitrous oxide emissions are calculated using fuel-based emission factors and fuel consumption data. The fuel consumption is distributed according to:

- Train km data taken from SRA Operator returns and Transport Statistics of Great Britain (DfT, 2006) for the three categories;
- Assumed mix of locomotives for each category; and
- Fuel consumption factors for different types of locomotive (LRC (1998), BR (1994) and Hawkins & Coad (2004)).

Emissions of CO, NMVOC, NO_x and methane are based on the train km estimates and emission factors for different train types. The emission factors shown in **Table A3.3.11** are aggregate factors so that all factors are reported on the common basis of fuel consumption.

Table A 3.3.11 Railway Emission Factors (kt/Mt)

	C[1]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Freight	870	0.16	1.2	23.6	7.3	3.8	3.0
Intercity	870	0.09	1.2	18.0	5.7	2.3	3.0
Regional	870	0.04	1.2	33.7	3.5	1.2	3.0

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 2005 inventory

Minor changes have been made to the methodologies and data used for compiling the 2005 inventory for the road transport sector. A change in the petrol fuel consumption factors used for certain types of off-road machinery has led to a very small re-allocation of overall petrol consumption from road transport to the off-road machinery sector. This has a very small effect on estimates of CO_2 emissions from the road transport sector in all years, reducing the estimates by around 60Gg in all years from 1990 (0.2%) compared with last year's inventory estimates. Very small changes in emission estimates for other pollutants compared with last year's inventory estimates are due to minor changes in the vehicle kilometre data for traffic in Northern Ireland for the years 2002-2004.

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 DTI and corrected for consumption by off-road vehicles.

In 2005, 18.73 Mtonnes of petrol and 19.44 Mtonnes of diesel fuel (DERV) were consumed in the UK. It was estimated that of this, around 1.4% of petrol (an increase of 0.4% on the contribution estimated in last year's inventory) was consumed by off-road vehicles and machinery, leaving 18.47 Mtonnes of petrol consumed by road vehicles in 2005. According to figures in DUKES (DTI, 2006), 0.120 Mtonnes of LPG were used for transport in 2005, up from 0.112 Mtonnes the previous year. There are as yet no definitive, official national statistics on the amount of biofuel used for road transport.

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 A3.3.12**. Values for SO_2 vary annually as the sulphur-content of fuels change, and are shown in **Table A3.3.12** for 2005 fuels based on data from UKPIA (2006).

Table A 3.3.12 Fuel-Based Emission Factors for Road Transport (kg/tonne fuel)

Fuel	C[a]	SO_2[b]
Petrol	855	0.064
Diesel	863	0.062

a Emission factor in kg carbon/tonne, based on UKPIA (2005)
b 2005 emission factor calculated from UKPIA (2006) – figures on the weighted average sulphur-content of fuels delivered in the UK in 2005

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. The important equations relating fuel consumption to average speed based on the set of tailpipe CO_2, CO and total hydrocarbon (THC) emission-speed equations were developed by TRL (Barlow *et al*, 2001). The TRL equations were derived from their large database of emission measurements compiled from different sources covering different vehicle types and drive cycles. A substantial part of the emission measurements for Euro I and II standard vehicles come from test programmes funded by DfT and Defra and carried out in UK test laboratories between 1999 and 2001. The measurements were made on dynamometer test facilities under simulated real-world drive cycles.

For cars, average fuel consumption factors were calculated from UK fleet-averaged CO_2 emission factors for different car vintages (years of production) provided by DfT (2004a) following consultation with the Society of Motor Manufacturers and Traders (SMMT). Their dependence on speed used the TRL-based speed relations for vehicles categorised into each Euro standard. For LGVs, HGVs, buses and motorcycles, the inventory used fuel consumption factors expressed as g fuel per kilometre for each vehicle type and road type calculated directly from the TRL equations.

Average fuel consumption factors are shown in **Table A3.3.13** for each vehicle type, emission regulation and road type in the UK. The different emission standards are described in a later section. A normalisation procedure was used to ensure that the breakdown of petrol and diesel consumption by each vehicle type calculated on the basis of the fuel consumption factors added up to the DTI figures for total fuel consumption in the UK (adjusted for off-road consumption).

Total CO_2 emissions from vehicles running on LPG are estimated on the basis of national figures (from DTI) 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 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. It is for this same reason that LPG vehicle emission estimates are not possible for other pollutant types, because these would need to be based on traffic data and emission factors for different vehicle types rather than on fuel consumption.

Emissions from vehicles running on natural gas are not estimated at present, although the number of such vehicles in the UK is very small. Estimates are not made as there are no separate figures from DTI 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.

At present, there are no definitive centralised statistics from the DTI on the amount of biofuels consumed by road transport in the UK. The total amount is still relatively small, although it is growing each year. HMRC have statistics on the total amount of biofuels released for consumption, but according to DTI there is doubt on the amount used as road fuels. DTI have indicated that biofuels are not combined with fossil fuels in their transport fuel statistics and are currently investigating the separate provision of national statistics on biofuel consumption by road transport. At present, emissions from road transport consumption of biofuels are not included in the inventory. Carbon emissions from road transport consumption of biofuels would not be included in the national totals. Other pollutant emissions would be included in the inventory on the basis of emission factors and usage rates (amount of fuel consumed or traffic data) although the differences in emission factors for vehicles running on biofuels and those running on fossil fuels are likely to be small for these pollutants.

A3.3.5.3.3 Traffic-based emissions

Emissions of the pollutants NMVOCs, NO_x, CO, CH_4 and N_2O are calculated from measured emission factors expressed in grammes per kilometre and road traffic statistics from the Department for Transport (DfT, 2006a). 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 in 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 parc.

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

A3.3.5.3.3.1 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 affecting emissions.

Table A 3.3.13 Fuel Consumption Factors for Road Transport (in g fuel/km)

g/km	Standard	Urban	Rural	Motorway
Petrol cars	ECE 15.01	77.9	65.1	76.8
	ECE 15.02	73.1	61.0	72.0
	ECE 15.03	73.1	61.0	72.0
	ECE 15.04	66.7	55.7	65.7
	Euro I	65.4	58.2	68.2
	Euro II	63.0	59.7	72.2
	Euro III	59.2	56.1	67.8
	Euro IV	52.8	50.0	60.5
Diesel cars	Pre-Euro I	64.5	51.0	60.5
	Euro I	63.4	55.8	71.6
	Euro II	61.1	56.0	74.3
	Euro III	54.5	49.9	66.3
Petrol LGVs	Pre-Euro I	73.9	61.5	99.8
	Euro I	93.3	83.2	109.6
	Euro II	95.3	85.5	112.6
	Euro III	90.9	81.5	107.4
Diesel LGV	Pre-Euro I	95.1	95.1	138.4
	Euro I	94.9	81.9	132.6
	Euro II	95.1	82.1	132.9
	Euro III	87.4	75.5	122.1
Rigid HGVs	Pre-1988	241	225	263
	88/77/EEC	241	225	263
	Euro I	241	225	263
	Euro II	241	225	263
	Euro III	241	225	263
Artic HGVs	Pre-1988	393	317	362
	88/77/EEC	393	317	362
	Euro I	348	330	360
	Euro II	321	304	332
	Euro III	321	304	332
Buses	Pre-1988	399	178	229
	88/77/EEC	386	174	224
	Euro I	319	195	213
	Euro II	288	191	208
	Euro III	288	191	208
Mopeds, <50cc, 2st	Pre-2000	25.0	25.0	25.0
	Euro I	25.0	25.0	25.0
Motorcycles, >50cc, 2st	Pre-2000	30.1	33.1	38.2
	Euro I	30.1	33.1	38.2
Motorcycles, >50cc, 4st	Pre-2000	28.5	30.7	38.8
	Euro I	28.5	30.7	38.8

For a particular vehicle, the drive cycle over a journey is the key factor that determines the amount of pollutant emitted. 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). 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
- 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 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
- Motorway/dual carriageway

DfT estimates annual vehicle kilometres 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, 2006a). The DfT Report "Transport Statistics Great Britain" (DfT, 2006a) provides vehicle kilometres data up to 2005. No changes were made to the vehicle kilometres data from 1994 to 2004 in the 2006 publication.

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). The most recently provided data gave a revision to vehicle km data for the years 2002-2004. Combined with new data for 2005, these provided, for the first time, a consistent time-series of vehicle km data for all years between 2002 and 2005.

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 2005.

The vehicle kilometre data were grouped into the three road types mentioned above for combination with the associated hot exhaust emission factors.

Vehicle speeds by road type

Average speed data for traffic in a number of different urban areas have been published in a series of DETR reports based on measured traffic speed surveys (DETR (1998a, 1998b, 1998c, 1998d), DfT (2006a)). These data were rationalised with speed data from other DETR sources, including the 1997 National Road Traffic Forecasts (DETR, 1997), which give average speeds for different urban area sizes, and consolidated with average speed data for unconstrained rural roads and motorways published in Transport Statistics Great Britain (DfT, 2006a). They are shown in **Table A3.3.14**. The speeds are averages of speeds at different times of day and week, weighted by the level of traffic at each of these time periods where this information is known.

Weighting by the number of vehicle kilometres on each of the urban road types gives an overall average speed for urban roads of 43 kph.

Vehicle fleet composition: by age, technology and fuel type

The vehicle kilometres 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. The latter determines the type of emission regulation that applied when the vehicle 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 A3.3.15 shows the regulations that have come into force up to 2005 for each vehicle type.

The average age profile and the fraction of petrol and diesel cars and LGVs in the traffic flow each year are based on the composition of the UK vehicle fleet using DfT Vehicle Licensing Statistics. The Transport Statistics Bulletin “Vehicle Licensing Statistics: 2005” (DfT, 2006b) either gives historic trends in the composition of the UK fleet directly or provides sufficient information for this to be calculated from new vehicle registrations and average vehicle survival rates. The vehicle licensing 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 data are from the National Travel Survey (DETR, 1998e); data for HGVs of different weights are taken from the Continuous Survey of Road Goods Transport (DETR, 1996a).

The fraction of diesel cars and LGVs in the fleet was taken from data in “Vehicle Licensing Statistics: 2005” (DfT, 2006b). Year-of-first registration data for vehicles licensed in each year from 1990 to 2005 have been taken from DfT’s Vehicle Licensing Statistics to reflect the age distribution of the fleet in these years.

Table A 3.3.14 Average Traffic Speeds in Great Britain

URBAN ROADS		kph	
Central London	Major/trunk A roads	18	
	Other A roads	14	
	Minor roads	16	
Inner London	Major/trunk A roads	28	
	Other A roads	20	
	Minor roads	20	
Outer London	Major/trunk A roads	45	
	Other A roads	26	
	Minor roads	29	
Urban motorways		95	
Large conurbations	Central	34	
	Outer trunk/A roads	45	
	Outer minor roads	34	
Urban, pop >200,000	Central	37	
	Outer trunk/A roads	50	
	Outer minor roads	37	
Urban, pop >100,000	Central	40	
	Outer trunk/A roads	54	
	Outer minor roads	40	
Urban >25 sq km	Major roads	46	
	Minor roads	42	
Urban 15-25 sq km	Major roads	49	
	Minor roads	46	
Urban 5-15 sq km	Major roads	51	
	Minor roads	48	
Urban < 5sq km	Major roads	52	
	Minor roads	48	
RURAL ROADS		Lights kph	Heavies kph
Rural single carriageway	Major roads	80	75
	Minor roads	67	63
Rural dual carriageway		113	89
Rural motorway		113	92

Table A 3.3.15 Vehicles types and regulation classes

Vehicle Type	Fuel	Regulation	Approx. date into service in UK
Cars	Petrol	Pre ECE-15.00 ECE-15.00 ECE-15.01 ECE-15.02 ECE-15.03 ECE-15.04 91/441/EEC (Euro I) 94/12/EC (Euro II) 98/69/EC (Euro III) 98/69/EC (Euro IV)	 1/1/1971 1/7/1975 1/7/1976 1/7/1979 1/7/1983 1/7/1992 1/1/1997 1/1/2001 1/1/2006
	Diesel	Pre-Euro I 91/441/EEC (Euro I) 94/12/EC (Euro II) 98/69/EC (Euro III)	 1/1/1993 1/1/1997 1/1/2001
LGVs	Petrol	Pre-Euro I 93/59/EEC (Euro I) 96/69/EEC (Euro II) 98/69/EC (Euro III)	 1/7/1994 1/7/1997 1/1/2001 (<1.3t) 1/1/2002 (>1.3t)
	Diesel	Pre-Euro I 93/59/EEC (Euro I) 96/69/EEC (Euro II) 98/69/EC (Euro III)	 1/7/1994 1/7/1997 1/1/2001 (<1.3t) 1/1/2002 (>1.3t)
HGVs and buses	Diesel (All types)	Old 88/77/EEC (Pre-Euro I) 91/542/EEC (Euro I) 91/542/EEC (Euro II) 99/96/EC (Euro III)	 1/10/1988 1/10/1993 1/10/1996 1/10/2001
Motorcycles	Petrol	Pre-2000: < 50cc, >50cc (2 st, 4st) 97/24/EC: all sizes	 1/1/2000

Note: Euro IV standards for petrol cars are shown because some new cars models sold from 2001 already meet Euro IV standards even they are not required to until 2006.

Statistics are also available on the number of new registrations in each year up to 2005, 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. Particularly detailed information is available on the composition of the HGV stock by age and size.

Assumptions are made about the proportion of failing catalysts in the petrol car fleet. For first-generation catalyst cars (Euro I), it is assumed that the catalysts fail in 5% of cars fitted with them each year (for example due to mechanical damage of the catalyst unit) and that

95% of failed catalysts are repaired each year, but only for cars more than three years in age, when they first reach the age for MOT testing. Following discussions with DfT, a review of information from the Vehicle Inspectorate, TRL, the Cleaner Vehicles Task Force, industry experts and other considerations concerning durability and emission conformity requirements in in-service tests, lower failure rates are assigned to Euro II, III and IV petrol cars manufactured since 1996. The following failure rates are assumed in the inventory:

- Euro I 5%
- Euro II 1.5%
- Euro III, IV 0.5%

The inventory takes account of the early introduction of certain emission and fuel quality standards and additional voluntary measures to reduce emissions from road vehicles in the UK fleet. The Euro III 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 III 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 III standards (SMMT, 1999). Figures were not available for 1999 and 2000, but it was assumed that 5% of new car sales met Euro III 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 IV standards, increasing to 81% in 2004 even though the mandatory date of introduction of this standard is not until 2006 (DfT, 2004b). The remaining new petrol car registrations in 2001 - 2005 would meet Euro III standards.

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 principle 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.

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 2005 inventory for its effects on NOx, CO and VOC emissions.

Detailed information from DVLA was used on the composition of the motorcycle fleet in terms of engine capacity (DfT, 2006b). The information was used to calculate the proportion of motorcycles on the road less than 50cc (i.e. mopeds), >50cc, 2-stroke and >50cc, 4-stroke.

A3.3.5.3.3.2 Hot emission factors

The emission factors for NO_x, CO and NMVOCs used for pre-Euro I vehicles in the inventory are based on data from TRL (Hickman, 1998) and COPERT II, "*Computer Programme to Calculate Emissions from Road Transport*" produced by the European Topic Centre on Air Emissions for the European Environment Agency (1997). Both these sources provide emission functions and coefficients relating emission factor (in g/km) to average speed for each vehicle type and Euro emission standard derived by fitting experimental measurements to some polynomial functional form.

Emission factors for Euro I and Euro II vehicles are based on speed-emission factor relationships derived by TRL from emission test programmes carried out in the UK (Barlow *et al*, 2001). The tests were carried out on in-service vehicles on dynamometer facilities under simulated real-world drive cycles. These provided a more robust source of emission factors for these vehicle classes than had hitherto been available. The factors for NMVOCs are actually based on emission equations for total hydrocarbons (THC), the group of species that are measured in the emission tests. To derive factors for non-methane VOCS, the calculated g/km factors for methane were subtracted from the corresponding THC emission factors.

Due to lack of measured data, emission factors for Euro III vehicles (and Euro IV petrol cars) were estimated by applying scaling factors to the Euro II factors. The scale factors for light duty vehicles take into consideration the requirement for new vehicles to meet certain durability standards set in the Directives. Scaling factors were first estimated by considering how much emissions from Euro II vehicles would need to be reduced to meet the Euro III and IV limit values taking account of the characteristics and average speed of the regulatory test cycles used for type-approval of the vehicle's engine. It was then assumed that emissions from new vehicles would be a certain percentage lower than the limit value-derived figure when new so that the vehicle would not have emissions that degrade to levels higher than the limit value over the durability period of the vehicle set in the Directives. The emission degradation rates permitted for Euro III and IV light duty vehicles by Directive 98/69/EC are as follows:

Table A 3.3.16 Emission Degradation rates permitted for Euro III and IV Light-Duty Vehicles by Directive 98/69/EC

			Degradation rate
Petrol vehicles	NO_x, HC and CO	Euro III	x1.2 over 80,000km
		Euro IV	x1.2 over 100,000km
Diesel vehicles	PM	Euro III	x1.2 over 80,000km
		Euro IV	x1.2 over 100,000km
	CO	Euro III	x1.1 over 80,000km
		Euro IV	x1.1 over 100,000km

For heavy-duty vehicles, the emission scaling factors were taken from COPERT III (European Environment Agency, 2000).

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 A3.3.14**. 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 the 1997 NRTF (DETR, 1997).

For each type of vehicle, both TRL and COPERT II provide equations for different ranges of vehicle engine capacity or vehicle weight. Emission factors calculated from these equations were therefore averaged, weighted according to the proportion of the different vehicle sizes in the UK fleet, to produce a single average emission factor for each vehicle type and road type. These average emission factors are given in **Tables A3.3.19** to **23** for each of the different vehicle types and emission regulations.

Speed-dependent functions provided by TRL (Hickman, 1998) for different sizes of motorcycles were used. Prior to 2000, all motorcycles are assumed to be uncontrolled. It was also assumed that mopeds (<50cc) operate only in urban areas, while the only motorcycles on motorways are the type more than 50cc, 4-stroke. Otherwise, the number of vehicle kilometres driven on each road type was disaggregated by motorcycle type according to the proportions in the fleet. Motorcycles sold since the beginning of 2000 were assumed to meet the Directive 97/24/EC and their emission factors were reduced according to the factors given in the latest version of COPERT III (European Environment Agency, 2000). A further stage in emission reductions affecting VOC and CO occurs for >50cc motorcycles first registered from July 2004 and are referred to as 'Euro II'.

Emissions from buses were scaled down according to the proportion running on ultra-low sulphur diesel fuel in each year, the proportion fitted with oxidation catalysts or particulate traps (CRTs) 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 A3.3.17**.

Table A 3.3.17 Scale Factors for Emissions from a Euro II Bus Running on Ultra-Low Sulphur Diesel and Fitted with an Oxidation Catalyst or CRT

		NO_x	CO	NMVOCs
ULS diesel only	Urban	1.01	0.91	0.72
	Rural	0.99	1.01	1.02
ULS diesel + Oxy catalyst	Urban	0.97	0.20	0.39
	Rural	0.95	0.22	0.55
ULS diesel + CRT	Urban	0.90	0.17	0.19
	Rural	0.88	0.19	0.27

These scale factors are relative to emissions from a bus running on 500ppm S diesel and are based on analysis of fuel quality effects by Murrells (2000) and data on the effectiveness of oxidation catalysts on bus emissions by LT Buses (1998).

Similarly, the small numbers of HGVs equipped with CRTs have their emissions reduced by the amounts shown in **Table A3.3.18**. Again these vehicles will also be running on ULS diesel.

Table A 3.3.18 Scale Factors for Emissions from a Euro II HGV Running on Ultra-Low Sulphur Diesel and Fitted with an Oxidation Catalyst or CRT

		NO_x	CO	NMVOCs
ULS diesel only	Urban	0.94	0.96	0.97
	Rural	0.99	1.01	1.02
ULS diesel + CRT	Urban	0.81	0.10	0.12
	Rural	0.85	0.10	0.12

The older in-service vehicles in the test surveys that were manufactured to a particular emission standard would have covered a range of different ages. Therefore, an emission factor calculated for a particular emission standard (e.g. ECE 15.04) from the emission functions and coefficients from TRL and COPERT II is effectively an average value for vehicles of different ages which inherently takes account of possible degradation in emissions with vehicle age. However, for the more recent emission standards (Euro I and II), the vehicles would have been fairly new when the emissions were measured. Therefore, based on data from the European Auto-Oil study, the deterioration in emissions with age or mileage was taken into account for catalyst cars. It was assumed that emissions of CO and NO_X increase by 60% over 80,000 km, while emissions of NMVOCs increase by 30% over the same mileage (DETR, 1996b). Based on the average annual mileage of cars, 80,000 km corresponds to a time period of 6.15 years. Emissions from Euro III and IV light duty vehicles were assumed to degrade at rates described earlier, consideration given to the durability requirements of the Directive 98/69/EC.

For methane, factors for pre-Euro I and/or Euro I standards for each vehicle type were taken from COPERT III which provided either full speed-emission factor equations or single average factors for urban, rural and highway roads. Methane emission factors for other Euro standards were scaled according to the ratio in the THC emission factors between the corresponding Euro standards. This assumes that methane emissions are changed between each standard to the same extent as total hydrocarbons so that the methane fraction remains constant.

Emission factors for nitrous oxide (N_2O) are the road-type factors taken from COPERT III. Due to lack of available data, no distinction between different Euro standards can be discerned, except for the higher N_2O emissions arising from petrol vehicles fitted with a three-way catalyst (Euro I and on).

The uncertainties in the CH_4 and N_2O factors can be expected to be quite large. However, the emission factors used reflect the fact that three-way catalysts are less efficient in removing methane from the exhausts than other hydrocarbons and also lead to higher N_2O emissions than non-catalyst vehicles.

A3.3.5.3.3.3 Cold-Start Emissions

When a vehicle's engine is cold it emits at a higher rate than when it has warmed up to its designed operating temperature. This is particularly true for petrol engines and the effect is even more severe for cars fitted with three-way catalysts, as the catalyst does not function properly until the catalyst is also warmed up. Emission factors have been derived for cars and LGVs from tests performed with the engine starting cold and warmed up. The difference between the two measurements can be regarded as an additional cold-start penalty paid on each trip a vehicle is started with the engine (and catalyst) cold.

The procedure for estimating cold-start emissions is taken from COPERT II (European Environment Agency, 1997), taking account of the effects of ambient temperature on emission factors for different vehicle technologies and its effect on the distance travelled with the engine cold. A factor, the ratio of cold to hot emissions, is used and applied to the fraction of kilometres driven with cold engines to estimate the cold start emissions from a particular vehicle type using the following 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 II and were used with an annual mean temperature for the UK of 11°C. This is based on historic trends in Met Office data for ambient temperatures over different parts of the UK.

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

$$\beta = 0.698 - 0.051 \,.\, l_{trip} - (0.01051 - 0.000770 \,.\, l_{trip}) \,.\, t_a$$

where

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

An average trip length for the UK of 8.4 km was used, taken from Andre *et al* (1993). This gives a value for β of 0.23.

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 catalyst and non-catalyst petrol vehicles. 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.

Data for estimating cold start effects on methane and nitrous oxide emissions are not available and are probably within the noise 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 and nitrous oxide 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. Nitrous oxide emissions occur mainly as a by-product of the catalytic NO_x reduction process on the catalyst surface, so the increasing contribution to road transport emissions of this pollutant is mainly due to petrol cars with three-way catalysts. If anything, one might expect *less* emissions of N_2O to occur as the catalyst is warming up, hence there might be an overall slight overestimation of N_2O emissions in the inventory for road transport by excluding the cold start effect, but it is not possible to estimate by how much.

A3.3.5.3.3.4 Evaporative Emissions

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 procedure for estimating evaporative emissions of NMVOCs takes account of changes in ambient temperature and fuel volatility.

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.

Evaporative emissions are dependent on ambient temperature and the volatility of the fuel and, in the case of diurnal losses, on the daily *rise* in ambient temperature. Fuel volatility is usually expressed by the empirical fuel parameter known as Reid vapour pressure (RVP). For each of these mechanisms, equations relating evaporative emissions to ambient temperature and RVP were developed by analysis of empirically based formulae derived in a series of CONCAWE research studies in combination with UK measurements data reported by TRL. Separate equations were developed for vehicles with and without evaporative control systems fitted such as carbon canister devices. The overall methodology is similar to that reported by COPERT II (European Environment Agency, 1997), but the data are considered to be more UK-biased.

Evaporative emissions are calculated using monthly average temperature and RVP data. Using this information, evaporative emissions are calculated from the car fleet for each month of the year and the values summed to derive the annual emission rates. Calculating emissions on a monthly basis enables subtle differences in the seasonal fuel volatility trends and differences in monthly temperatures to be better accounted for. Monthly mean temperatures from 1970-2005 were used for the calculations based on Met Office for Central England (CET data). The monthly average, monthly average daily maximum and monthly average diurnal rise in temperatures were required. The monthly average RVP of petrol sold in the UK used historic trends data on RVP and information from UKPIA on the RVP of summer and winter blends of fuels supplied in recent years and their turnover patterns at filling stations (Watson, 2001, 2003). The average RVP of summer blends of petrol in the UK in 2005 was 68 kPa, 2kPa below the limit set by European Council Directive 98/70/EC for Member States with "arctic" summer conditions (UKPIA, 2006).

All the equations for diurnal, hot soak and running loss evaporative emissions from vehicles with and without control systems fitted developed for the inventory are shown in **Table A3.3.24**. The inventory uses equations for Euro I cars with "first generation" canister technology, based on early measurements, but equations taken from COPERT III leading to lower emissions were used for Euro II-IV cars as these better reflected the fact that modern cars must meet the 2g per test limit on evaporative emissions by the diurnal loss and hot soak cycles under Directive 98/69/EC.

For **diurnal losses**, the equations for pre-Euro I (non-canister) and Euro I cars were developed from data and formulae reported by CONCAWE (1987), TRL (1993) and ACEA (1995). Equations for Euro II-IV cars were taken from COPERT III. The equations specified in **Table A3.3.24** give diurnal loss emissions in g/vehicle.day for uncontrolled ($DL_{uncontrolled}$) and Euro I and Euro II-IV canister controlled vehicles (DL_{EU1}, $DL_{EUII\text{-}IV}$). Total annual diurnal losses were calculated from the equation:

$$E_{diurnal} = 365 \,.\, N \,.\, (DL_{uncontrolled} \,.\, F_{uncontrolled} + DL_{EU1} \,.\, F_{EUI} + DL_{EUII\text{-}IV} \,.\, F_{EUII\text{-}IV})$$

where:

N	=	number of petrol vehicles (cars and LGVs) in the UK parc
$F_{uncontrolled}$	=	fraction of vehicles not fitted with carbon canisters, assumed to be the same as the fraction of pre-Euro I vehicles
F_{EUI}	=	fraction of Euro I vehicles in the fleet

$F_{EUII-IV}$ = fraction of Euro II-IV vehicles in the fleet

For **hot soak losses**, the equations were developed from data and formulae reported by CONCAWE (1990), TRL (1993) and COPERT II. The equations specified in **Table A3.3.24** give hot soak loss emissions in g/vehicle.trip for uncontrolled ($HS_{uncontrolled}$) and Euro I and Euro II-IV canister controlled (HS_{EUI}, $HS_{EUII-IV}$) vehicles. Total annual hot soak losses were calculated from the equation:

$$E_{hot\ soak} = (VKM/\ l_{trip})\ .\ (HS_{uncontrolled}\ .\ F_{uncontrolled} + HS_{EU1}\ .\ F_{EUI} + HS_{EUII-IV}\ .\ F_{EUII-IV})$$

where

VKM = total number of vehicle kilometres driven in the UK by the petrol vehicles (cars and LGVs)
ltrip = average trip length (8.4 km in the UK)

For **running losses**, the equations were developed from data and formulae reported by CONCAWE (1990) and COPERT II.

The equations specified in **Table A3.3.24** give running loss emissions in g/vehicle.km for uncontrolled ($RL_{uncontrolled}$) and canister controlled ($RL_{controlled}$) vehicles with no distinction made between Euro I and Euro II-IV canister cars. Total annual running losses were calculated from the equation:

$$E_{running\ loss} = VKM.\ (RL_{uncontrolled}\ .\ F_{uncontrolled} + RL_{controlled}\ .\ F_{controlled})$$

where

$$\mathbf{F_{controlled} = F_{EUI} + F_{EUII-IV}}$$

Table A 3.3.19 NMVOC Emission Factors for Road Transport (in

g VOCs/km		Urban	Rural	Motorway
Petrol cars	ECE 15.01	1.748	1.116	0.936
	ECE 15.02	1.764	1.126	0.945
	ECE 15.03	1.764	1.126	0.945
	ECE 15.04	1.416	0.904	0.758
	Euro I	0.033	0.030	0.082
	Euro II	0.024	0.021	0.024
	Euro III	0.018	0.016	0.019
	Euro IV	0.018	0.015	0.018
Diesel cars	Pre-Euro I	0.139	0.074	0.041
	Euro I	0.070	0.039	0.026
	Euro II	0.057	0.026	0.017
	Euro III	0.042	0.019	0.013
Petrol LGVs	Pre-Euro I	1.356	0.735	0.812
	Euro I	0.036	0.038	0.029
	Euro II	0.022	0.025	0.019
	Euro III	0.017	0.019	0.015
Diesel LGV	Pre-Euro I	0.270	0.137	0.146
	Euro I	0.121	0.095	0.086
	Euro II	0.121	0.095	0.086
	Euro III	0.099	0.078	0.070
Rigid HGVs	Pre-1988	3.350	2.872	2.779
	88/77/EEC	1.667	1.429	1.383
	Euro I	0.609	0.487	0.435
	Euro II	0.481	0.414	0.401
	Euro III	0.329	0.283	0.274
Artic HGVs	Pre-1988	3.563	2.494	1.960
	88/77/EEC	1.415	0.990	0.778
	Euro I	1.509	1.205	1.063
	Euro II	1.244	1.067	1.021
	Euro III	0.850	0.729	0.698
Buses	Pre-1988	5.252	1.915	1.806
	88/77/EEC	1.272	0.464	0.438
	Euro I	0.945	0.402	0.362
	Euro II	0.681	0.341	0.332
	Euro III	0.465	0.233	0.227
Mopeds, <50cc, 2st	Pre-2000	12.085	18.283	25.312
	Euro I	2.659	4.022	5.569
	Euro II	2.659	4.022	5.569
Motorcycles, >50cc, 2st	Pre-2000	9.370	8.129	8.140
	Euro I	6.484	5.796	4.958
	Euro II	2.464	2.203	1.884
Motorcycles, >50cc, 4st	Pre-2000	1.627	1.068	1.055
	Euro I	0.686	0.424	0.313
	Euro II	0.261	0.161	0.119

g/km)

Table A 3.3.20 NOx Emission Factors for Road Transport (in g/km)

g NOx (as NO2 eq)/km		Urban	Rural	Motorway
Petrol cars	ECE 15.01	2.104	2.528	2.822
	ECE 15.02	1.794	2.376	3.494
	ECE 15.03	1.921	2.606	3.859
	ECE 15.04	1.644	2.211	3.164
	Euro I	0.219	0.314	0.566
	Euro II	0.195	0.209	0.316
	Euro III	0.085	0.092	0.138
	Euro IV	0.061	0.065	0.099
Diesel cars	Pre-Euro I	0.623	0.570	0.718
	Euro I	0.537	0.465	0.693
	Euro II	0.547	0.505	0.815
	Euro III	0.547	0.505	0.815
Petrol LGVs	Pre-Euro I	1.543	1.783	2.351
	Euro I	0.308	0.304	0.454
	Euro II	0.273	0.329	0.484
	Euro III	0.119	0.144	0.212
Diesel LGV	Pre-Euro I	1.332	1.254	1.549
	Euro I	1.035	0.892	1.384
	Euro II	0.983	0.848	1.315
	Euro III	0.737	0.636	0.986
Rigid HGVs	Pre-1988	12.735	13.439	13.439
	88/77/EEC	5.663	4.929	5.864
	Euro I	7.176	6.818	7.178
	Euro II	6.129	5.743	5.977
	Euro III	4.247	3.979	4.141
Artic HGVs	Pre-1988	19.479	20.555	20.555
	88/77/EEC	15.931	12.840	11.436
	Euro I	19.058	18.122	19.089
	Euro II	13.140	12.312	12.815
	Euro III	9.104	8.530	8.879
Buses	Pre-1988	16.973	13.734	13.263
	88/77/EEC	13.814	5.407	6.089
	Euro I	11.085	6.134	6.461
	Euro II	9.917	5.484	5.709
	Euro III	6.871	3.800	3.955
Mopeds, <50cc, 2st	Pre-2000	0.030	0.030	0.030
	Euro I	0.010	0.010	0.010
	Euro II	0.010	0.010	0.010
Motorcycles, >50cc, 2st	Pre-2000	0.032	0.066	0.126
	Euro I	0.025	0.029	0.051
	Euro II	0.025	0.029	0.051
Motorcycles, >50cc, 4st	Pre-2000	0.156	0.229	0.385
	Euro I	0.210	0.279	0.448
	Euro II	0.210	0.279	0.448

Table A 3.3.21 CO Emission Factors for Road Transport (in g/km)

g CO/km		Urban	Rural	Motorway
Petrol cars	ECE 15.01	18.85	11.84	14.26
	ECE 15.02	15.63	9.82	11.82
	ECE 15.03	16.40	10.30	12.41
	ECE 15.04	10.10	6.34	7.64
	Euro I	1.02	0.98	2.84
	Euro II	0.684	0.493	0.411
	Euro III	0.637	0.459	0.383
	Euro IV	0.506	0.364	0.304
Diesel cars	Pre-Euro I	0.647	0.430	0.399
	Euro I	0.282	0.147	0.196
	Euro II	0.233	0.072	0.072
	Euro III	0.148	0.046	0.046
Petrol LGVs	Pre-Euro I	13.70	10.62	31.87
	Euro I	2.064	1.245	1.401
	Euro II	0.477	0.418	0.394
	Euro III	0.444	0.389	0.367
Diesel LGV	Pre-Euro I	0.980	0.763	1.171
	Euro I	0.453	0.510	0.909
	Euro II	0.453	0.510	0.909
	Euro III	0.288	0.324	0.578
Rigid HGVs	Pre-1988	3.286	2.780	2.589
	88/77/EEC	2.526	2.137	1.990
	Euro I	1.427	1.216	1.178
	Euro II	1.156	0.977	0.910
	Euro III	0.802	0.678	0.631
Artic HGVs	Pre-1988	3.830	3.278	3.269
	88/77/EEC	2.923	2.502	2.495
	Euro I	4.001	3.409	3.303
	Euro II	3.106	2.628	2.447
	Euro III	2.155	1.823	1.698
Buses	Pre-1988	18.37	7.47	9.24
	88/77/EEC	8.159	3.319	4.102
	Euro I	2.541	1.135	1.100
	Euro II	2.106	0.916	0.853
	Euro III	1.461	0.636	0.592
Mopeds, <50cc, 2st	Pre-2000	23.81	36.46	50.80
	Euro I	2.38	3.65	5.08
	Euro II	2.38	3.65	5.08
Motorcycles, >50cc, 2st	Pre-2000	23.37	25.80	28.43
	Euro I	12.04	21.54	31.93
	Euro II	5.05	9.05	13.41
Motorcycles, >50cc, 4st	Pre-2000	20.81	22.20	30.83
	Euro I	6.97	10.01	18.38
	Euro II	2.93	4.21	7.72

Table A 3.3.22 Methane Emission Factors for Road Transport (in g/km)

g/km	Standard	Urban	Rural	Motorway
Petrol cars	ECE 15.01	0.105	0.033	0.048
	ECE 15.02	0.106	0.033	0.049
	ECE 15.03	0.106	0.033	0.049
	ECE 15.04	0.085	0.026	0.039
	Euro I	0.037	0.017	0.023
	Euro II	0.026	0.011	0.007
	Euro III	0.015	0.007	0.004
	Euro IV	0.012	0.005	0.003
Diesel cars	Pre-Euro I	0.008	0.010	0.018
	Euro I	0.004	0.005	0.011
	Euro II	0.003	0.004	0.007
	Euro III	0.002	0.002	0.005
Petrol LGVs	Pre-Euro I	0.150	0.040	0.025
	Euro I	0.036	0.017	0.027
	Euro II	0.022	0.011	0.018
	Euro III	0.013	0.006	0.011
Diesel LGV	Pre-Euro I	0.005	0.005	0.005
	Euro I	0.002	0.003	0.003
	Euro II	0.002	0.003	0.003
	Euro III	0.002	0.003	0.002
Rigid HGVs	Pre-1988	0.241	0.091	0.079
	88/77/EEC	0.120	0.045	0.039
	Euro I	0.044	0.015	0.012
	Euro II	0.035	0.013	0.011
	Euro III	0.024	0.009	0.008
Artic HGVs	Pre-1988	0.441	0.201	0.176
	88/77/EEC	0.175	0.080	0.070
	Euro I	0.187	0.097	0.096
	Euro II	0.154	0.086	0.092
	Euro III	0.108	0.060	0.064
Buses	Pre-1988	0.722	0.330	0.289
	88/77/EEC	0.175	0.080	0.070
	Euro I	0.130	0.069	0.058
	Euro II	0.094	0.059	0.053
	Euro III	0.066	0.041	0.037
Mopeds, <50cc, 2st	Pre-2000	0.219	0.219	0.219
	Euro I	0.048	0.048	0.048
	Euro II	0.048	0.048	0.048
Motorcycles, >50cc, 2st	Pre-2000	0.150	0.150	0.150
	Euro I	0.104	0.107	0.091
	Euro II	0.040	0.041	0.035
Motorcycles, >50cc, 4st	Pre-2000	0.200	0.200	0.200
	Euro I	0.084	0.079	0.059
	Euro II	0.032	0.030	0.023

Table A 3.3.23 N_2O Emission Factors for Road Transport (in g/km)

g/km	Standard	Urban	Rural	Motorway
Petrol cars	ECE 15.01	0.005	0.005	0.005
	ECE 15.02	0.005	0.005	0.005
	ECE 15.03	0.005	0.005	0.005
	ECE 15.04	0.005	0.005	0.005
	Euro I	0.053	0.016	0.035
	Euro II	0.053	0.016	0.035
	Euro III	0.053	0.016	0.035
	Euro IV	0.053	0.016	0.035
Diesel cars	Pre-Euro I	0.027	0.027	0.027
	Euro I	0.027	0.027	0.027
	Euro II	0.027	0.027	0.027
	Euro III	0.027	0.027	0.027
Petrol LGVs	Pre-Euro I	0.006	0.006	0.006
	Euro I	0.053	0.016	0.035
	Euro II	0.053	0.016	0.035
	Euro III	0.053	0.016	0.035
Diesel LGV	Pre-Euro I	0.017	0.017	0.017
	Euro I	0.017	0.017	0.017
	Euro II	0.017	0.017	0.017
	Euro III	0.017	0.017	0.017
Rigid HGVs	Pre-1988	0.03	0.03	0.03
	88/77/EEC	0.03	0.03	0.03
	Euro I	0.03	0.03	0.03
	Euro II	0.03	0.03	0.03
	Euro III	0.03	0.03	0.03
Artic HGVs	Pre-1988	0.03	0.03	0.03
	88/77/EEC	0.03	0.03	0.03
	Euro I	0.03	0.03	0.03
	Euro II	0.03	0.03	0.03
	Euro III	0.03	0.03	0.03
Buses	Pre-1988	0.03	0.03	0.03
	88/77/EEC	0.03	0.03	0.03
	Euro I	0.03	0.03	0.03
	Euro II	0.03	0.03	0.03
	Euro III	0.03	0.03	0.03
Mopeds, <50cc, 2st	Pre-2000	0.001	0.001	0.001
	Euro I	0.001	0.001	0.001
	Euro II	0.001	0.001	0.001
Motorcycles, >50cc, 2st	Pre-2000	0.002	0.002	0.002
	Euro I	0.002	0.002	0.002
	Euro II	0.002	0.002	0.002
Motorcycles, >50cc, 4st	Pre-2000	0.002	0.002	0.002
	Euro I	0.002	0.002	0.002
	Euro II	0.002	0.002	0.002

Table A 3.3.24 Equations for diurnal, hot soak and running loss evaporative emissions from vehicles with and without control systems fitted

Emission factor	Units	Uncontrolled vehicle (pre-Euro I)
Diurnal loss ($DL_{uncontrolled}$)	g/vehicle.day	$1.54 * (0.51*T_{rise} + 0.62*T_{max} + 0.22*RVP - 24.89)$
Hot soak ($HS_{uncontrolled}$)	g/vehicle.trip	$\exp(-1.644 + 0.02*RVP + 0.0752*T_{mean})$
Running loss ($RL_{uncontrolled}$)	g/vehicle.km	$0.022 * \exp(-5.967 + 0.04259*RVP + 0.1773*T_{mean})$

Emission factor	Units	Carbon canister controlled vehicle (Euro I)
Diurnal loss (DL_{EUI})	g/vehicle.day	$0.3 * (DL_{uncontrolled})$
Hot soak (HS_{EUI})	g/vehicle.trip	$0.3 * \exp(-2.41 + 0.02302*RVP + 0.09408*T_{mean})$
Running loss ($RL_{controlled}$)	g/vehicle.km	$0.1 * (RL_{uncontrolled})$

Emission factor	Units	Carbon canister controlled vehicle (Euro II-IV)
Diurnal loss ($DL_{EUII-IV}$)	g/vehicle.day	$0.2 * 9.1 * \exp(0.0158*(RVP-61.2) + 0.0574*(T_{max}-T_{rise}-22.5) + 0.0614*(T_{rise}-11.7))$
Hot soak ($HS_{EUII-IV}$)	g/vehicle.trip	0
Running loss ($RL_{controlled}$)	g/vehicle.km	$0.1 * (RL_{uncontrolled})$

where

T_{rise} = diurnal rise in temperature in ^oC
T_{max} = maximum daily temperature in ^oC
T_{mean} = annual mean temperature in ^oC
RVP = Reid Vapour Pressure of petrol in kPa

A3.3.5.4 Navigation

The UK GHGI provides emission estimates for coastal shipping, fishing, naval shipping and international marine. Coastal shipping is reported within IPCC category 1A3dii National Navigation and includes emissions from diesel use at offshore oil & gas installations. A proportion of this diesel use will be for marine transport associated with the offshore industry but some will be for use in turbines, motors and heaters on offshore installations. Detailed fuel use data is no longer available to determine emissions from diesel use in fishing vessels, as the DTI gas oil dataset has been revised in the latest inventory cycle. All emissions from fishing are now included within the coastal shipping sector, 1A3dii National Navigation.

The emissions reported under coastal shipping, naval shipping and fishing are estimated according to the base combustion module using the emission factors given in **Table A3.3.1**.

The NAEI category International Marine is the same as the IPCC category 1A3i International Marine. The estimate used is based on the following information and assumptions:

(i) Total deliveries of fuel oil, gas oil and marine diesel oil to marine bunkers are given in DTI (2005).

(ii) Naval fuel consumption is assumed to be marine diesel oil (MOD, 2004). Emissions from this source are not included here but are reported under 1A5 Other.

(iii) The fuel consumption associated with international marine is the marine bunkers total minus the naval consumption. The emissions were estimated using the emission factors shown in **Table A3.3.1**.

Emissions from 1A3i International Marine are reported for information only and are not included in national totals. Bunker fuels data for shipping are provided to the DTI by UKPIA, and are based on sale of fuels to UK operators going abroad and overseas operators (assumed to be heading abroad) (DTI 2004, per. comm.[3]).

Emissions from navigation have been revised in this year’s inventory following a review and update of emission factors for different types of shipping and a more detailed examination of their activities in UK waters. In particular, more detailed information on shipping emission factors have been used from the study done by Entec UK Ltd for the European Commissions (Entec, 2002) and from the more recent EMEP/CORINAIR Handbook (CORINAIR, 2002).

Lloyds Marine Intelligence Unit (LMIU) publishes ship arrivals at UK ports by type and dead weight for four different vessel types: tankers, Ro-Ro ferry vessels, fully cellular container vessels and other dry cargo vessels. Until now, the DUKES fuel usage for shipping was apportioned between vessel type simply using the number of port arrivals. In the 2005 inventory, fuel use between different vessel types has been apportioned on the basis of the vessels’ main engine power as well as number of port arrivals. The main engine power for the Gross Registered Tonnage (GRT) groups used in the LMIU table was estimated. Then the product of vessel (type, GRT) port visits multiplied by the estimated main engine power was calculated and summed for each of the four vessel types. The distribution of total engine

[3] DTI (2004) Personal communication from Martin Young, DTI.

power summed over a year was then used to distribute the DUKES fuel consumption among the four vessel types.

Different engine types when fuelled with fuel oil, marine gas oil or marine diesel oil have different emission factors (kg pollutant emitted /tonne of fuel used). For NOx and NMVOCs, it was possible to use data from the Entec study to produce a weighted mean emission factor for each of the four LMIU vessel types based on their average engine size and fuel type. Aggregated emission factors for the whole UK shipping activity were then calculated by weighting each vessel type's factor with the proportion of fuel consumed by each vessel type. Emissions of CH4, CO and N2O are not covered in the Entec report, so emission factors quoted in the Corinair handbook were used. Emissions of SO2 are based on the fuel sulphur content and amount of each type of fuel used.

These modifications have led to an overall increase in UK aggregate fuel-based shipping emission factors for NOx and NMVOCs, no change in the factor for CO and a reduction in the factors for CH4 and N2O.

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 DTI reported fuel use data and emission factors from **Table A3.3.1**. 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 included within the coastal shipping sector, due to the withdrawal of more detailed fuel use datasets that have historically been provided by DTI but are now determined to be of questionable accuracy.

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 A3.3.1**. 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 NAEI 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 3.2**. 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. Some changes have made to the emission factors used for certain types of machinery in the 2005 inventory leading to changes in emission estimates compared with last year's estimates. These have been made mainly for older types of petrol-engined machinery in order to get a more realistic and consistent carbon balance between their fuel consumption rates and carbon emissions in the form of CO, CH_4 and NMVOCs. Fuel consumption rates for some machinery types were increased so, as a result, estimates of the amount of petrol consumed by off-road machinery in 2004 have been increased by 37% compared with last year's estimates. Relatively small amounts of petrol are consumed by off-road machinery (the majority use diesel or gas oil as a fuel), so this large increase in estimated petrol consumption only increases total carbon emissions from the whole of the off-road machinery sector by 1.7% compared with last year's estimate for the sector in 2004. The overall fuel balance for petrol consumption has been maintained by reducing the estimates of the amount of petrol consumed by road transport, but this re-allocation leads to only a 0.4% (70 ktonnes) reduction in petrol consumption by road transport compared with last year's estimate because this sector is by far the largest consumer of petrol fuel. The changes in fuel consumption rates for certain petrol machinery were accompanied by a reduction in CO, CH_4 and NMVOC emission factors. Consequently, overall emission estimates for these pollutants for off-road machinery in 2004 decreased by 30%, 19% and 18%, respectively, compared with last year's estimates. Inventory estimates for other pollutants are unchanged.

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:

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

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 recently by AEA Energy & Environment 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 the Dti 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 in 2005. For industrial machinery, manufacturing output statistics were used to scale 2005 activity rates relative to 2004; for domestic house and garden machinery, trends in number of households were used; for airport machinery, statistics on number of take-off and landings at UK airports were used.

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 recent review by Netcen (2004b), considering the impact of Directive 2002/88/EC on emissions from these types of machinery. This year saw changes to CO, CH_4, NMVOC emission factors and fuel consumption rates for certain older types of petrol-engined machinery, as mentioned above.

Aggregated emission factors for the four main off-road machinery categories in 2005 are shown in **Table A3.3.25** by fuel type.

Table A 3.3.25 Aggregate Emission Factors for Off-Road Source Categories1 in 2005 (t/kt fuel)

Source	Fuel	C[2]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2[3]
Domestic House&Garden	DERV	863	0.165	1.36	49.87	4.51	2.67	0.062
Domestic House&Garden	Petrol	855	1.75	0.032	4.29	698	125	0.064
Agricultural Power Units	Gas Oil	870	0.157	1.28	41.94	16.1	6.39	2.90
Agricultural Power Units	Petrol	855	2.17	0.015	1.45	716	249	0.064
Industrial Off-road	Gas Oil	870	0.163	1.36	39.80	17.4	6.59	2.90
Industrial Off-road	Petrol	855	3.62	0.049	6.00	995	37.6	0.064
Aircraft Support	Gas Oil	870	0.167	1.34	40.08	12.5	5.15	2.90

1 Emission factors reported are for 2005
2 Emission factor as kg carbon/t, UKPIA (2004)
3 Based on sulphur content of fuels in 2005 from UKPIA (2006).

The emission factors used for carbon were the standard emission factors for DERV, gas oil and petrol given in **Table A3.3.1**.

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 DTI (2006). 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 A3.3.26**.

Table A 3.3.26 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

[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 1998-2004 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 A3.3.26** 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 DTI (2006).

Methane from closed coal mines is included in sector 1B1a of the UK inventory following publication of the findings of a recent study funded by Defra (Kershaw, 2005).

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 A3.3.27**.

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. It is likely that emissions will arise from the combustion of the gases produced by some SSF retorts but this combustion is not identified in the energy statistics. Process emissions from SSF plant are estimated on the basis of total production of SSF. The emission factors used are given in **Table A3.3.27** and are based on USEPA (2004) 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 number of processes in use these estimates will be very uncertain.

Data are available on the production of SSF and the fuels used (DTI, 2006). It is clear that in recent years both coke and imported petroleum coke have been used in the production of smokeless fuels. Data on the total UK imports and exports of petroleum coke are available but little information is available on its consumption. In the GHGI, it is assumed that 245 kt *per annum* of petroleum coke were used in SSF production from 1990 to 1998 based on data provided within DUKES (DTI, 1999). For 1999-2005 approximate estimates by DTI (2006) are used. The carbon content of the petroleum coke consumed is not included in the SSF carbon balance – instead it is allocated to the domestic sector as a separate fuel. Coke used by SSF manufacturers is assumed to be burnt as a fuel and is also not included in the carbon balance. The model used is not entirely satisfactory but further information would be required before a more accurate carbon balance could be developed.

Emissions from the combustion of fuels to heat the smokeless fuel retorts are reported under 1A1ci Manufacture of Solid Fuels, however process emissions and the residual carbon emission discussed above are considered to be fugitives and are reported under 1B1b Solid Fuel Transformation.

Table A 3.3.27 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]	1.39[c]	-	1.53[c]	0.0226[e]
Coke	kt/Mt coal consumed	-	-	0.02[b]		-
SSF	kt/Mt SSF made	0.0802[a]	0.0955[c]	0.0769[c]	-	0.0178[a]
SSF	kt/Mt coal consumed	-	-	-	2.57[d]	-

a EIPPCB, (2000)
b USEPA (2004)
c Factor for 2005 based on Environment Agency (2006)
d Based on mass balance but zero for 2002 (because calculated sulphur content of SSF produced was higher than the sulphur content of coal used to make the SSF).
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)

The emissions reported in this sector pertain to the offshore platforms and onshore terminals on the UK Continental Shelf Area and represented by the United Kingdom Offshore Operators Association (UKOOA). Emissions estimates for the offshore industry are based on data provided by the trade organisation, UKOOA, through their annual emissions reporting mechanism to UK regulators, the Environmental Emissions Monitoring System (EEMS). This system provides a detailed inventory of point source emissions estimates, based on operator returns for the years 1995-2004. Additional, more detailed data on CO_2 emissions from some offshore combustion processes has become available as a result of the development of the industry's National Allocation Plan pertaining to the EU Emission Trading Scheme. Therefore, for the main combustion sources in the offshore oil & gas sector, the UKOOA data from 1998 onwards is sourced via NAP estimates, replacing historic estimates previously reported via EEMS.

For years prior to 1995 (i.e. pre-EEMS), emission totals are based on an internal UKOOA summary report produced in 1998. These data were revised and reported with the 1995-2004 datasets in the UKOOA 2005 submission to the inventory. 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 were then calculated using production-weighted interpolations. Only limited data were available from operators in 1990-1994, and emission totals could only be estimated 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.

UKOOA has periodically produced operator guidance for estimating and reporting emissions from offshore oil & gas processes, with recent guidance covering CO_2 emissions from combustion processes (Russell, 2004) and other guidance for emissions of other pollutants such as CH_4, VOCs, NO_X and SO_2 (UKOOA, 2001). A spreadsheet-based tool has also been developed to improve quality and consistency of operator reports. The operators are required to report flaring and venting masses and compositions. Methodologies have been developed to estimate combustion emissions from turbines, boilers and heaters and fugitive emissions. These are calculated on a plant item-by-item basis.

For some sections of the EEMS data prior to 1999 where detailed data were not provided, estimates have been made on the basis of oil and gas throughput. However, since improvements in the reporting system have minimised the need for such assumptions, since 1999 the majority of emission estimates are based on detailed data. For example, prior to 1999, N_2O emissions were not monitored by the plant operators and hence the 1990-1998 N_2O emissions data are based on emission factors (derived from the 1999 data) and estimated production throughput data.

The data reported in the EEMS database 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 included under coastal shipping. In order to avoid double counts the UKOOA estimates have been corrected to remove diesel oil emissions.

In the NAEI, offshore emissions are estimated in the following categories each with its own methodology:

- Offshore flaring
- Offshore Oil & Gas (well testing)
- Offshore Oil & Gas (venting)
- Offshore Oil & Gas process emissions
- Offshore Loading
- Onshore loading
- Oil Terminal Storage
- Offshore 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.

A3.3.8.2.1 Offshore 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 UKOOA (2006) dataset. Data from 1995-2005 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 1999-2005, and on emission factors and production throughput data for 1990-1998.

The aggregate emission factors are given in **Table A3.3.28** and the activity data in **Table A3.3.29**. The aggregate emission factors for 1990-2005 are reported as kg pollutant/kg gas flared and are calculated from emissions and activity data reported by UKOOA in 2006.

Table A 3.3.28 Aggregate Emission Factors for Offshore Gas Flaring

	CO_2	CH_4	NO_x	CO	NMVOC	SO_2	N_2O	Units
2005	2.59	0.0093	0.0013	0.00671	0.00781	0.00015	0.00008	kg/kg
2004	2.58	0.0097	0.0015	0.00740	0.00677	0.00020	0.00008	kg/kg
2003	2.64	0.0102	0.0015	0.00751	0.00672	0.00016	0.00008	kg/kg
2002	2.64	0.0097	0.0018	0.00755	0.00698	0.00015	0.00008	kg/kg
2001	2.47	0.0099	0.0014	0.00730	0.00700	0.00022	0.00008	kg/kg
2000	2.38	0.0109	0.0013	0.00717	0.00642	0.00018	0.00008	kg/kg
1999	2.49	0.0103	0.0014	0.00760	0.00819	0.00025	0.00008	kg/kg
1998	2.51	0.0107	0.0014	0.00716	0.00901	0.00014	0.00008	kg/kg
1997	2.52	0.0107	0.0015	0.00741	0.00969	0.00014	0.00008	kg/kg
1996	2.43	0.0104	0.0014	0.00744	0.00961	0.00013	0.00008	kg/kg
1995	2.45	0.0102	0.0014	0.00745	0.00979	0.00014	0.00008	kg/kg
1994	2.18	0.0100	0.0012	0.00823	0.01166	0.00006	0.00007	kg/kg
1993	2.18	0.0106	0.0012	0.00842	0.01219	0.00006	0.00007	kg/kg
1992	2.18	0.0124	0.0013	0.00864	0.01279	0.00006	0.00007	kg/kg
1991	2.18	0.0133	0.0014	0.00888	0.01348	0.00006	0.00007	kg/kg
1990	2.18	0.0139	0.0014	0.00888	0.01289	0.00006	0.00007	kg/kg

The UKOOA data from the EEMS database do not include flaring on onshore oil production fields. These emissions are estimated by extrapolation using flaring volume data collected by DTI (2006a) and the offshore flaring factors. The onshore flaring data are shown in **Table A3.3.29** though the contribution is very small.

Flaring is reported under 1B2ciii Flaring – Combined, since many of the platforms produce both oil and gas. An estimate of NMVOC emissions from refinery flares is reported in 1B2ci Venting and Flaring: Oil. This is based on estimates supplied by UKPIA (2006).

Table A 3.3.29 Activity Data for Offshore Gas Flaring

Year	Gas Flared (kt)[1]	Gas Flared, Offshore Fields & Terminals (Mm^3)[2]	Gas Flared, Onshore Fields (Mm^3)[2]
2005	1,760	1827	13.7
2004	1,551	1896	16.7
2003	1,487	1697	21.4
2002	1,710	1665	19.1
2001	1,869	1808	11.6
2000	1,987	1814	15.0
1999	2,113	2206	4.6
1998	2,056	2110	0
1997	2,042	2122	7
1996	2,308	2539	15
1995	2,272	2388	11
1994	2,164	3282	10
1993	2,034	2461	16
1992	1,905	2468	12
1991	1,775	2531	7
1990	1,796	2793	7

1 EEMS data, UKOOA (2006)
2 DTI (2006)
3 A correction has been applied for non-reporting operators

A3.3.8.2.2 Offshore 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 UKOOA (2006) dataset. Data from 1995-2004 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 1999-2005, and on emission factors and production throughput data for 1990-1998.

The aggregate emission factors are given in **Table A3.3.30**. The aggregate emission factors for 1990-2005 are reported as kg pollutant/ kg gas used and are calculated from the emissions and activity data reported within the UKOOA 2006 dataset.

Table A 3.3.30 Aggregate Emission Factors for Offshore Own Gas Use

	CO_2	CH_4	NO_x	CO	NMVOC	SO_2	N_2O	Units
2005	2.65	0.00125	0.00882	0.00297	0.00013	0.00006	0.00021	kg/kg
2004	2.67	0.00041	0.00933	0.00168	0.00017	0.00007	0.00007	kg/kg
2003	2.66	0.00037	0.00888	0.00167	0.00013	0.00009	0.00007	kg/kg
2002	2.63	0.00039	0.00903	0.00162	0.00013	0.00009	0.00008	kg/kg
2001	2.62	0.00053	0.00709	0.00167	0.00016	0.00009	0.00008	kg/kg
2000	2.55	0.00049	0.00718	0.00166	0.00014	0.00010	0.00008	kg/kg
1999	2.70	0.00046	0.00756	0.00166	0.00014	0.00011	0.00008	kg/kg
1998	2.74	0.00024	0.00664	0.00166	0.00006	0.00008	0.00008	kg/kg
1997	2.70	0.00030	0.00686	0.00173	0.00008	0.00008	0.00008	kg/kg
1996	2.63	0.00022	0.00668	0.00169	0.00005	0.00008	0.00008	kg/kg
1995	2.62	0.00023	0.00656	0.00181	0.00005	0.00010	0.00008	kg/kg
1994	2.77	0.00036	0.00624	0.00229	0.00013	0.00004	0.00008	kg/kg
1993	2.77	0.00038	0.00665	0.00234	0.00013	0.00005	0.00008	kg/kg
1992	2.77	0.00045	0.00712	0.00240	0.00014	0.00005	0.00008	kg/kg
1991	2.77	0.00048	0.00766	0.00247	0.00015	0.00005	0.00008	kg/kg
1990	2.77	0.00050	0.00766	0.00247	0.00014	0.00005	0.00008	kg/kg

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

- Offshore own gas use: natural gas
- Gas separation plant: LPG
- Gas separation plant: OPG

Emissions are reported under 1A1cii Other Energy Industries.

A3.3.8.2.3 Well testing

This activity involves the combustion of crude oil and crude gas during well testing, and is an activity that is not included in UK Energy Statistics from the DTI. Combustion emission data for CO_2, SO_2, NO_x, CO, NMVOC, and CH_4 are taken from the UKOOA (2006) dataset. Data from 1995-2005 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 1999-2005, and on emission factors and production throughput data for 1990-1998.

The estimates of the amounts of crude oil and gas burnt are of unknown quality. Data is provided by the DTI regarding the number of wells tested annually, but the number of wells tested is only a small proportion of the number of wells explored and that proportion may vary from year to year. Also the number of wells explored varies considerably from year to year.

The aggregate emission factors are given in **Table A3.3.31**. Well testing is reported under 1B2a Oil Production since many of the wells produce oil and gas.

Table A 3.3.31 Aggregate Emission Factors for Offshore Well Testing (kt/well explored)

	C	SO_2	NO_x	CO	NMVOC	CH_4	N_2O	Units
2005	0.80	0	0.0024	0.0122	0.0149	0.0342	0.0001	Kt/well
2004	1.20	0	0.0031	0.0159	0.0179	0.0567	0.0001	Kt/well
2003	1.40	0	0.0038	0.0192	0.0222	0.0646	0.0001	Kt/well
2002	2.51	0	0.0083	0.0412	0.0522	0.0988	0.0002	Kt/well
2001	1.23	0	0.0043	0.0212	0.0274	0.0462	0.0001	Kt/well
2000	1.45	0	0.0052	0.0256	0.0335	0.0524	0.0001	Kt/well
1999	3.61	0.0001	0.0111	0.0558	0.0685	0.1513	0.0004	Kt/well
1998	3.73	0.1309	0.0120	0.0619	0.0656	0.1599	0.0004	Kt/well
1997	2.78	0.1039	0.0090	0.0461	0.0519	0.1206	0.0003	Kt/well
1996	2.34	0.0923	0.0080	0.0411	0.0462	0.1077	0.0002	Kt/well
1995	2.69	0.1000	0.0087	0.0445	0.0500	0.1167	0.0003	Kt/well
1994	7.17	0.1266	0.1601	0.0926	0.0544	0.1005	0.0003	Kt/well
1993	8.19	0.1498	0.1951	0.1083	0.0650	0.1220	0.0003	Kt/well
1992	5.29	0.1005	0.1348	0.0716	0.0440	0.0921	0.0002	Kt/well
1991	3.41	0.0675	0.0934	0.2879	0.0299	0.0635	0.0001	Kt/well
1990	2.32	0.0460	0.0636	0.0323	0.0195	0.0453	0.0001	Kt/well

A3.3.8.2.4 Other emissions from platforms and terminals

These include emissions of CH_4 and NMVOC from platforms and terminals arising from cold venting, other fugitive emissions and also from storage of crude oil at terminals. Emissions data are taken from the UKOOA (2006) dataset. Data from 1995-2005 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.

These other emissions from platforms and terminals are reported in the following NAEI categories, all mapped to 1B2a Oil ii Production: offshore oil & gas (fugitive and process emissions), offshore venting and oil terminal storage. It is not possible to split oil and gas production emissions since oil and gas are frequently produced on the same platform.

Table A 3.3.32 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 Loading emissions

This sector includes emissions of CH_4 and NMVOCs from tanker loading and unloading based on data from the UKOOA (2006) dataset. Data from 1995-2005 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.

These data are derived from operator information on the tonnage of oil shipped and site-specific emission factors, taking account for the application of abatement measures. A correction is made regarding emissions from the Seal Sands Refinery to take account of discrepancies across the time series between data provided by the operator and the Pollution Inventory (Environment Agency, 2006).

Emissions data are reported using oil shipment data taken from DTI (2006), covering the amount of crude oil shipped by tanker from:

- production sites to UK users and export
- onshore terminals to UK users and export

It is assumed that no emission occurs from the amounts of crude oil transported by pipeline. **Table A3.3.33** shows aggregate factors calculated from the amounts of oil loaded. Oil shipment data are reported in the CRF tables.

Table A 3.3.33 Aggregate Emission Factors for Crude Oil Loading and Unloading

	Onshore CH_4	Onshore NMVOC	Offshore CH_4	Offshore NMVOC	Units
2005	0.012	0.42	0.097	1.30	t/kt oil
2004	0.014	0.034	0.084	1.12	t/kt oil
2003	0.012	0.12	0.080	1.38	t/kt oil
2002	0.015	0.16	0.124	1.60	t/kt oil
2001	0.017	0.18	0.113	1.54	t/kt oil
2000	0.017	0.28	0.110	1.69	t/kt oil
1999	0.017	0.23	0.071	1.38	t/kt oil
1998	0.017	0.22	0.043	1.44	t/kt oil
1997	0.017	0.22	0.036	1.98	t/kt oil
1996	0.017	0.24	0.035	1.96	t/kt oil
1995	0.018	0.24	0.036	2.00	t/kt oil
1994	0.035	0.30	0.033	2.14	t/kt oil
1993	0.038	0.30	0.036	2.24	t/kt oil
1992	0.044	0.30	0.042	2.35	t/kt oil
1991	0.047	0.32	0.045	2.48	t/kt oil
1990	0.049	0.33	0.047	2.37	t/kt oil

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 ii Transmission/Distribution. Data on gas leakage and the methane & NMVOC content of natural gas are provided by UK Transco and four companies (newly formed in

2005) that operate the low-pressure gas distribution networks. The leakage estimates are determined in three parts:

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

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 (AGIs) etc.) is based on studies from British Gas in the early 1990s (British Gas, 1993; Williams, 1993). Emission estimates for 1997 to 2004 are derived from an industry leakage model (data provided by the four network operator companies independently due to commercial confidentiality concerns), whilst 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. The methane and NMVOC content of natural gas is shown in **Table A3.3.34**. and was provided by contacts within British Gas Research for 1990-1996 and from UK Transco from 1997 onwards (Malin, 2005). Data on NMVOC content for 2001-2003 has been estimated by interpolation due to a lack of data.

Table A 3.3.34 Methane and NMVOC Composition of Natural Gas

Period	CH_4 weight %	NMVOC weight %
1990-96[1]	84.3	8.9
1997-99[2]	77.1	14.7
2000[2]	77.6	14.7
2001[2]	77.1	14.8[3]
2002[2]	77.3	15.0[3]
2003[2]	77.4	15.2[3]
2004[2]	77.4	15.3
2005[4]	77.9	15.3

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)

A3.3.8.2.7 Petrol distribution

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.
- 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 estimate for road and rail tanker loading at refineries are supplied by UKPIA (2006). 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 DTI (2005), 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, 2006) 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 DTI (2006).

A3.3.8.2.8 Refineries and petroleum processes

The IPCC category 1B2aiv Refining and Storage reports estimates of NMVOC emissions from oil refineries. In the NAEI these are split into:

- Refineries (drainage)
- Refineries (tankage)
- Refineries (Process)

All are based on UKPIA (2006) estimates for 1994-2005. The UKPIA data refer to the following 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

- 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, 2006). No emissions data have been found for the Dundee refinery.

A3.3.8.2.9 Gasification processes

The NAEI also reports NMVOC emissions from on shore gas production facilities, refining and odourisation of natural gas, natural gas storage facilities, and processes involving reforming of natural gas and other feedstocks to produce carbon monoxide and hydrogen gases. Emissions are taken from the Pollution Inventory (Environment Agency, 2006). For the years prior to 1994, they are extrapolated based on gas throughput. Care is taken to avoid double counting with the offshore emissions.

A3.3.9 Stored carbon

In 2005, the treatment of the non-energy uses of fuels and stored carbon in the UK GHG inventory was reviewed. In previous UK GHG inventories, the UK did not use the IPCC default methodology for stored carbon in products because it was not clear what processes it represented or if it was applicable to the UK. The procedure adopted was to report emissions from the combustion of fuels only with emissions from the non-energy use of fuels assumed to be zero (i.e. the carbon is assumed to be sequestered as products), except for the following cases where emissions could be identified and included in the inventory:

- Catalytic crackers – regeneration of catalysts
- Ammonia production
- Aluminium production – consumption of anodes
- Benzoles and tars – produced in coke ovens and emissions assigned to the waste sector
- Combustion of waste lubricants and waste solvents
- Incineration of fossil carbon in products disposed of as waste.

AEA Energy & Environment estimates of the quantities of lubricants burnt are based on data from Recycling Advisory Unit, 1999; Oakdene Hollins Ltd, 2001 & BLF/UKPIA/CORA, 1994. Separate estimates are produced for the following sources:

- Power stations

- Cement kilns
- Other industry

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. Some of the unrecovered oil is now allocated to non-oxidising fates such as coating on products, leaks and disposal to landfill.

Fossil carbon destroyed in MSW incinerators and clinical waste incinerators is included in the GHG inventory, as is carbon emitted by chemical waste incinerators.

As part of our review of the base year GHG inventory estimates, the UK has reviewed the treatment of stored carbon in the UK GHG inventory and the fate of carbon from the non-energy use (NEU) of products and the breakdown of those 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 has been included in previous versions of the GHG inventory, e.g. carbon from chemical waste incinerators; most has not. A summary of the estimates of emitted/stored carbon has been produced and these have been presented in a separate technical report[4]. The study also provides subjective, qualitative commentary regarding the quality of the estimates.

The analysis also includes 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 DTI 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.

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[4] 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.

New 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.

The analysis estimates emissions from:

- the energy uses of coal tars and benzoles;
- NEU of petroleum products

Since emissions of carbon are estimated, carbon which is not emitted (i.e. stored) can be calculated from the DTI DUKES consumption data by difference. The analysis divides the various fossil fuels into six categories:

1. coal tars & benzoles
2. lubricants
3. petroleum coke
4. petroleum waxes
5. bitumen
6. chemical feedstocks (ethane, propane, butane, other gases, naphtha, industrial spirit, white spirit, middle distillate feedstock)

After considering the magnitude of the source in relation to the national totals, the uncertainty associated with emissions, and the likely forthcoming IPCC reporting requirements in the 2006 Guidelines, emissions of carbon from the following additional sources have been 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.
- Carbon in products - pesticides

A full time series of emissions has been included in the inventory.

A3.4 INDUSTRIAL PROCESSES (CRF SECTOR 2)

A3.4.1 Mineral Processes (2A)

A3.4.1.1 Cement Production (2A1)

Emission factors for the production of cement, as described **in Chapter 4,** are as follows:

Table A 3.4.1 Emission Factors for Cement Kilns based on Fuel Consumption, 2005

Fuel	C [a]	CH_4	N_2O	Units
Coal	672.9[b]	0.3[e]	0.109[h]	Kt / Mt fuel
Fuel Oil	879[b]	0.00865[f]	0.0260[f]	Kt / Mt fuel
Gas Oil	870[b]	0.0910[f]	0.0273[f]	Kt / Mt fuel
Natural Gas	1.48[b]	0.000528[f]	NE	Kt / Mtherm
Petroleum Coke	829.6[b]	0.423[g]	0.143[h]	Kt / Mt fuel
Scrap Tyres	757 [c]	0.96[f]	NE	Kt / Mt fuel
Waste Oils	864.8[d]	0.0910[i]	NE	Kt / Mt fuel
Waste Solvent	864.8[d]	NE	NE	Kt / Mt fuel
Other Waste	166.1[j]	NE	NE	Kt / Mt fuel

a Emission factor as mass carbon per unit fuel consumed
b Derived using the methods given in Baggott *et al* (2004)
c Emission factor derived from emissions reported in the PI
d Passant, N.R., 2004
e Brain, SA et al. British Coal Corp, CRE (1994)
f IPCC 1997c
g DTI (1994)
h Fynes *et al* (1994)
i As for gas oil
j Data supplied by British Cement Association, 2006

Table A 3.4.2 Emission Factors for Cement Kilns based on Clinker Production, 1990-2005

Year	CO	NO_x	NMVOC	SO_2	Units
1990-94	2.96	5.65	0.135	3.05	kt/Mt Clinker
1995	2.86	5.13	0.135	3.33	kt/Mt Clinker
1996	4.39	3.43	0.135	2.11	kt/Mt Clinker
1997	1.91	3.72	0.135	2.37	kt/Mt Clinker
1998	1.45	3.86	0.135	2.26	kt/Mt Clinker
1999	2.58	3.61	0.121	2.26	kt/Mt Clinker
2000	2.49	3.42	0.124	1.88	kt/Mt Clinker
2001	2.31	3.06	0.156	1.93	kt/Mt Clinker
2002	2.40	2.89	0.111	2.07	kt/Mt Clinker
2003	NR	NR	NR	NR	kt/Mt Clinker
2004	2.57	3.26	0.064	1.76	kt/Mt Clinker
2005	2.83	3.09	0.059	1.56	kt/Mt Clinker

NR – 2003 emission factor data are not reported due to issues of commercial confidentiality raised by the BCA.

A3.4.1.2 Lime Production (2A2)

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

Table A 3.4.3 Emission Factors for Lime Kilns based on Fuel Consumption, 2005

Fuel	C [a]	CH_4	N_2O	Units
Coal	602.7[b]	0.011[c]	0.215[e]	Kt / Mt fuel
Natural Gas	1.48[b]	0.00053[f]	1.055E-05[f]	Kt / Mtherm
Coke	766.3[d]	0.011[c]	0.228[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 Energy & Environment estimate based on carbon balance
e Fynes *et al* (1994)
f IPCC(1997) IPCC Revised 1996 Guidelines

Table A 3.4.4 Emission Factors for Lime Kilns, 2005: Indirect GHGs

Fuel	CO	NO_x	NMVOC	Units
Coal	27.19	89.17	0.05	Kt / Mt fuel
Natural Gas	0.0383	0.0162	0.00023	Kt / Mtherm
Coke	7.99	0.132	0.05	Kt / Mt fuel

A3.4.2 Chemical Industry (2B)

A3.4.2.1 Nitric Acid Production (2B2)

Table A 3.4.5 Summary of Nitric Acid Production in the UK, 1990-2005

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	0.81
1996	6	2.44	3.83	0.74
1997	6	2.35	3.78	0.90
1998	6	2.61	3.99	0.73
1999	6	2.44	6.29	0.91
2000	6	2.03	6.94	0.99
2001	5	1.65	6.62	0.66
2002	4	1.64	4.20	0.39
2003	4	1.71	4.38	0.43
2004	4	1.71	5.00	0.44
2005	4	1.71	3.80	0.37

A3.4.2.2 Adipic Acid Production (2B3)

There is only one company manufacturing adipic acid in the UK. 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, 2006). 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
- 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 2005 was 69.5 g 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 (Briggs, 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 A3.4.6**. Data on iron production are reported in ISSB (2006).

Table A 3.4.6 Emission Factors for Blast Furnaces (BF), Electric Arc Furnaces (EAF) and Basic Oxygen Furnaces (BOF), 2005

	C [a]	CH_4	N_2O	NO_x	SO_2	NMVOC	CO	Units
Blast furnaces	IE	NE	NE	NE	0.092[b]	0.12[c]	1.44[c]	kt/Mt pig iron
Electric arc furnaces	2[d]	0.01[e]	0.005[e]	0.2[e]	0.13[b]	0.09[e]	1.56[b]	kt/Mt Steel
Basic oxygen furnaces	IE	NE	NE	0.012[f]	IE	NE	5.28[b]	kt/Mt Steel
Losses of BFG/BOFG	7.3[g]	NE	NE	NE	NE	NE	NE	kt/Mtherm gas
Slag processing	NE	NE	NE	NE	8E-6[b]	NE	NE	kt/Mt Pig iron

a Emission factor as kt carbon/unit activity
b Emission factor for 2005 based on data from Corus (2006)
c IPCC (1997)
d Briggs (2005)
e EMEP/CORINAIR(1999)
f EIPPCB(2000), Corus (2001, 2000)
g AEA Energy & Environment 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 Briggs (2005). Emissions of CO from basic oxygen furnaces are based on data supplied by Corus (2006) 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 (2006).

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 AEAT (2004). Emission factors for aluminium production, as discussed in **Chapter 4**, **Section 4.16**, are shown in **Table A3.4.7.**

Table A 3.4.7 Emission Factors for Aluminium Production, 2005

	C [a]	SO_2 [b]	NO_x [b]	CO [b]	Units
Prebake	420	15.3	0.78	77.8	Kt / Mt Al
Anode Baking	IE	1.48	0.38	2.76	Kt / Mt anode

a Emission factor as kt carbon per unit activity, Walker, 1997.
b Environment Agency Pollution Inventory (2006) and SEPA (2006)
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 in AEAT (2004).

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 3.4.8 NMVOC Emission Factors for Food and Drink Processing, 2005

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 (2006)
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, 2003

g Unpublished figure provided by industry
h Based on loss rate allowed by HMCE during casking operations
i US EPA, 2004

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 AEAT (2004).

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 AEAT (2004).

A3.4.5.2 Foam Blowing (2F2)

Details of the method used to estimate emissions of F-gases from this source are given in AEAT (2004).

A3.4.5.3 Fire Extinguishers (2F3)

Details of the method used to estimate emissions of F-gases from this source are given in AEAT (2004).

A3.4.5.4 Aerosols/ Metered Dose Inhalers (2F4)

Details of the method used to estimate emissions of F-gases from this source are given in AEAT (2004).

A3.4.5.5 Solvents (2F5)

Details of the method used to estimate emissions of F-gases from this source are given in AEAT (2004).

A3.4.5.6 Semiconductor Manufacture (2F6)

Details of the method used to estimate emissions of F-gases from this source are given in AEAT (2004).

A3.4.5.7 Electrical Equipment (2F7)

Details of the method used to estimate emissions of F-gases from this source are given in AEAT (2004).

A3.4.5.8 One Component Foams (2F8A)

Details of the method used to estimate emissions of F-gases from this source are given in AEAT (2004).

A3.4.5.9 Semiconductors, Electrical and Production of Trainers (2F8B)

Details of the method used to estimate emissions of F-gases from this source are given in AEAT (2004).

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 (2006a) 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 emission factors for beef and other cattle were also calculated using the IPCC Tier 2 procedure (**Table A3.6.4**), but do not vary from year to year. The enteric emission factors for beef cattle were almost identical to the IPCC Tier 1 default so the default was used in the estimates.

The base data and emission factors for 1990-2004 are given in **Table A3.6.3** and **Table A3.6.4**. 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 A3.6.2** are reported on the basis that the animals are alive the whole year.

Table A 3.6.1 Livestock Population Data for 2005 by Animal Type

Animal Type	Number
Cattle:	
Dairy Breeding Herd	2,064,643
Dairy Heifers	437,173
Beef Herd	1,685,922
Other cattle >2 years	495,846
Other cattle 1-2 years	1,928,483
Other cattle < 1 year	2,725,063
Pigs:	
All breeding pigs	520,855
Other pigs > 50 kg	1,736,075
Other pigs 20-50 kg	1,184,321
Pigs <20 kg	1,254,217
Sheep:	
Breeding sheep	16,552,752
Other sheep	1,200,334
Lambs < 1 year	17,487,442
Goats	96,304
Horses	344,912
Deer:	33,659
Poultry (000 head):	
Broilers	111,475
Breeders	8,561
Layers	29,544
Growing Pullets	10,928
Ducks, geese and guinea fowl	2,790
Turkeys	6,935

Table A 3.6.2 Methane Emission Factors for Livestock Emissions

Animal Type	Enteric methane[a] kg CH_4/head/year	Methane from manures[a] kg CH_4/head/year
Dairy Breeding Herd	103.5[b]	25.43[b]
Beef Herd	48	2.74
Other Cattle >1 year, Dairy Heifers	48	6
Other Cattle <1 year	32.8	2.96
Pigs	1.5	3
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]

Animal Type	Enteric methane[a] kg CH_4/head/year	Methane from manures[a] kg CH_4/head/year
Deer: Calves	5.2[c]	0.13[c]
Poultry[d]	NE	0.078

a IPCC (1997)
b Emission factor for year 2005
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

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 (%)	Enteric Emission Factor (kg CH_4/head/y)	Manure Emission Factor (kg CH_4/head/y)
1990	550	14.3	4.01	88.1	21.6
1991	549	14.2	4.04	88.4	21.7
1992	564	14.5	4.06	90.1	22.1
1993	564	14.7	4.07	90.8	22.3
1994	559	14.7	4.05	90.9	22.3
1995	559	15.0	4.05	92.3	22.7
1996	563	15.1	4.08	93.2	22.8
1997	566	15.9	4.07	96.0	23.6
1998	558	16.1	4.07	96.8	23.8
1999	555	16.4	4.03	97.8	24.0
2000	563	16.6	4.03	98.7	24.2
2001	575	16.7	4.01	99.4	24.4
2002	579	17.9	3.97	102.7	25.2
2003	576	18.3	3.96	103.8	25.5
2004	579	18.1	4.00	101.8	24.9
2005	577	18.8	4.02	103.5	25.4

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 according to Steve Walton, Defra, pers. comm., from 1990 to 2004, Helen Mason, 2005

Table A 3.6.4 Beef and Other Cattle Methane Emission Factors[a]

	Beef Cattle	Other Cattle
Average Weight of Animal (kg)	500	180
Time Spent Grazing	50%	46%
GE (MJ/d)	123.3	83.4
Enteric Emission Factor (kg CH_4/head/y)	48.5[b]	32.8
Manure Emission Factor (kg CH_4/head/y)	2.74	2.96

a Digestible Energy 65%, Ash content of manure 8%
Methane producing capacity of manure 0.24 m^3/kg VS
b IPCC (1997) default (48 kg/head/y) used since calculated factor is very close to default and the difference under the Tier 2 method will not affect the accuracy of the emission factor at the required level of precision

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, 2005a) 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 A3.6.5** (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**.

Table A 3.6.5 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
Solid Storage	1	9.8	20.7
Daily Spread	0.1	14.1	23

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:

$$N_2O_{(AWMS)} = 44/28 \cdot \sum N_{(T)} \cdot Nex_{(T)} \cdot AWMS_{(W)} \cdot EF_{(AWMS)}$$

where

$N_2O_{(AWMS)}$	=	N_2O emissions from animal waste management systems (kg N_2O/yr)
$N_{(T)}$	=	Number of animals of type T
$Nex_{(T)}$	=	N excretion of animals of type T (kg N/animal/yr)
$AWMS_{(W)}$	=	Fraction of Nex that is managed in one of the different waste management systems of type W
$EF_{(AWMS)}$	=	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, 2005a). **Table A3.6.6** shows emission factors for nitrogen excretion per head for domestic livestock in the UK (Nex). These are based on N balance figures of Smith and Frost (2000) and Smith *et al.* (2000), using linear regression to interpolate between animal weights reported in their paper.

The UK methodology assumes that 20% of the total N emitted by livestock 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. Thus, the Nex factors used in the AWMS estimates (and those reported in **Table A3.6.6** and **Table A3.6.7**) exclude the fraction of N volatilising and are 20% less than if they were reported on the same basis as the 'total' Nex factors reported in the IPCC Guidelines. Values of total N excreted shown in the Common Reporting Format are not corrected in this way and are estimates of total N excreted from livestock. Nex factors for dairy cattle take account of the data of cow weight provided by Defra (S. Walton, *pers. comm.,* 1990–2004, H. Mason, 2005) and are shown in **Table A3.6.7**.

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. All of the FYM in this case has therefore been re-allocated to SSD.

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 A3.6.9 gives the N_2O emission factor for each animal waste management system ($EF_{(AWMS)}$). 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 3.6.6 Nitrogen Excretion Factors for Animals in the UK[a]

Animal Type	Emission Factor kg N/animal/year[b]
Dairy Cows	84.4[c]
Other Cattle > 2 year	60
Other Cattle 1-2 year	47
Other Cattle <1 year	11.8
Pigs < 20kg	3.0
Other Pigs 20-50 kg	7.1
Fattening & Other Pigs > 50 kg	10.7
Breeding Pigs > 50 kg	14.3
Breeding Sheep	9.2
Other Sheep <1 year	9.2[e]
Lambs	3.36[e]
Goats	7.2
Broilers	0.495
Broiler Breeders	0.899
Layers	0.589
Ducks,	0.984
Turkeys	1.052
Growing Pullets	0.106
Horses	32
Deer: Stags[d]	17.5
Deer: Hinds[d]	11.7
Deer: Calves[d]	8.64

a Smith and Frost (2000), Smith *et al.* (2000)
b Nex factors exclude 20% N volatilising as NO_x and NH_3
c Weighted average of dairy breeding herd (based on liveweight) and dairy heifers, 2004
d Sneath *et al.* (1997)
e Factor quoted assumes animal lives for a year. Emission calculation assumes animal lives for 6 months (Smith and Frost, 2000)

Table A 3.6.7 Nitrogen Excretion Factors for Dairy Cattle[a]

	Emission Factor (kg N/animal/year)
1990	80.9
1991	80.6
1992	82.7
1993	82.5
1994	81.9
1995	81.7
1996	81.9
1997	82.3
1998	81.2
1999	81.0
2000	82.0

	Emission Factor (kg N/animal/year)
2001	83.9
2002	84.6
2003	84.5
2004	84.6
2005	84.4

a Nex factors exclude 20% N volatilising as NO_x and NH_3. Weighted average of dairy breeding herd and dairy heifers in first calf.

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		
Other Cattle >1 year	6.0	23.0	20.4	50.5		
Other Cattle <1 year		22.9	22.3	54.8		
Fattening & Other Pigs > 20 kg,	29.2	5.8	64.0	1.0		
Breeding sows	35.5	7.1	28	29.3		
Pigs <20 kg	38.3	7.7	46.0	8.0		
Sheep			2.0	98.0		
Goats				96.0	4.0	
Broilers & Table Fowl (2003)				1.0	63.0	36.0
Breeders				1.0	99.0	
Layers[e]				10.0	90.0	
Pullets[e]				10.0	90.0	
Ducks, Geese & Guinea Fowl[e]				50.0	50.0	
Turkeys[e]				8.0	92.0	
Horses				96.0	4.0	
Deer: Stags[d]				100		
Deer: Hinds & Calves[d]				75.0	25.0	

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

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
Fuel	-
Other	0.005

a IPCC (1997)
b Reported under Agricultural Soils

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) Spreading animal manures on land
(vi) Manures dropped by animals grazing in the field

In addition to these, the following indirect emission sources are estimated:

(vii) Emission of N_2O from atmospheric deposition of agricultural NO_x and NH_3
(viii) Emission of N_2O from leaching of agricultural nitrate and runoff

Descriptions of the methods used are described in **Section 6.5.2**.

A3.6.3.2 Inorganic Fertiliser

Emissions from the application of inorganic fertilizer are calculated using the IPCC (1997) methodology and IPCC default emission factors. They are given by:

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

where

$N_2O_{(SN)}$ = Emission of N_2O from synthetic fertiliser application (kg N_2O/yr)
$N_{(FERT)}$ = Total use of synthetic fertiliser (kg N/yr)
$Frac_{(GASF)}$ = Fraction of synthetic fertiliser emitted as NO_x + NH_3

	=	0.1 kg NH_3-N+NO_x -N / kg synthetic N applied
EF_1	=	Emission Factor for direct soil emissions
	=	0.0125 kg N_2O-N/kg N input

annual consumption of synthetic fertilizer is estimated based on crop areas (Defra, 2006a) and fertilizer application rates (BSFP, 2006).

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 A3.6.10**.

Table A 3.6.10 Dry Mass Content and Residue Fraction of UK Crops

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 (2006a, 2006b). The total nitrous oxide emission reported also includes a contribution from improved grass calculated using a fixation rate of 4 kg N/ha/year (Lord, 1997).

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 (2006a, 2006b). The dry mass fraction of crops and residue fraction are given in **Table A3.6.10**. 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).

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. 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 A3.6.6**)
$AWMS_{(DS)}$ = 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 A3.6.6**)
$AWMS_{(W)}$ = 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 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:

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

where

$N_2O_{(DSN)}$	=	Atmospheric deposition emission of N_2O arising from synthetic fertiliser application (kg N_2O/yr)
$N_{(FERT)}$	=	Total mass of nitrogen applied as synthetic fertiliser (kg N/yr)
$Frac_{(GASF)}$	=	Fraction of total synthetic fertiliser nitrogen that is emitted as $NO_x + NH_3$
	=	0.1 kg N/ kg N
EF_4	=	N deposition emission factor
	=	0.01 kg N_2O-N/kg NH_3-N and NO_x-N emitted

The indirect contribution from waste management systems is given by:

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

where

$N_2O_{(DWS)}$	=	Atmospheric deposition emission of N_2O arising from animal wastes (kg N_2O/yr)
$N_{(EX)}$	=	Total N excreted by animals (kg N/yr), net of N volatilising as NOx and NH_3 (values in **Table A3.6.6**)
$Frac_{(GASM)}$	=	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 but no longer for the N lost in the direct emission of N_2O from animal manures as previously. The nitrogen excretion data in **Table A.3.6.6** already exclude volatilisation losses, and hence a correction is included for this.

A3.6.3.9 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:

$$N_2O_{(LSN)} = 44/28 . (N_{(FERT)} . (1-Frac_{(GASF)})- N_{(SN)}) . Frac_{(LEACH)} . EF_5$$

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)
$N_{(SN)}$	=	Direct emission of $N_2O_{(SN)}$ as nitrogen (kg N_2O-N/yr)
$Frac_{(GASF)}$	=	Fraction of total synthetic fertiliser nitrogen emitted as $NO_x + NH_3$
	=	0.1 kg N/ kg N
$Frac_{(LEACH)}$	=	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 A3.6.6**)
$N_{(F)}$ = 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.

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 A3.6.11**.

Table A 3.6.11 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, 2006b) 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 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)

The carbon uptake by the forests planted since 1920 is calculated by a carbon accounting model (Dewar & Cannell 1992, Cannell & 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 GPG LULUCF (IPCC 2003). Two types of input data and two parameter sets were required for the model (Cannell & 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 were 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.

For the estimates described here we used the combined area of new private and state planting from 1920 to 2005 for England, Scotland, Wales and Northern Ireland sub-divided into conifers and broadleaves. Restocking was dealt with in the model through the second and subsequent rotations, which occur after clearfelling at the time of Maximum Area Increment (MAI). Therefore areas restocked in each year did not need to be considered separately. 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 & Christie 1981) to describe forest growth after thinning and an expo-linear curve for growth before thinning. It was 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 has therefore been estimated by assuming all conifers in Great Britain followed the growth pattern of Yield Class 12 $m^3\ ha^{-1}\ a^{-1}$, but in Northern Ireland Yield Class 14 $m^3\ ha^{-1}\ a^{-1}$ was used. Milne *et al.* (1998) also 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. It can be shown that if forest expansion continues at the present rate, removals of atmospheric carbon will continue to increase until about 2005 and then will begin 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 A3.7.1** 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). Further work is planned for this area.

In addition to these planted forests, there are about 822,000 ha of woodland planted prior to 1921 or not of commercial importance. 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 still actively managed, but overall this category is assumed to be carbon-neutral. The possible contribution of this category to carbon emissions and removals will be considered in more detail in future reporting.

Table A 3.7.1 Afforestation rate and age distribution of conifers and broadleaves in the United Kingdom since 1921. Afforestation rates and ages of GB forests planted later than 1989 are from planting records but age distribution for GB forests planted before 1990 is from National Inventory of Woodland and Trees carried out between 1995 and 1999. Age distribution for Northern Ireland forests included in data is estimated from planting records

Period	Planting rate (000 ha a^{-1})		Age distribution	
	Conifers	Broadleaves	Conifers	Broadleaves
1921-1930	5.4	2.4	1.4%	7.9%
1931-1940	7.5	2.1	2.5%	8.5%
1941-1950	7.4	2.2	6.1%	11.9%
1951-1960	21.7	3.1	16.3%	11.6%
1961-1970	30.1	2.6	22.6%	8.4%
1971-1980	31.4	1.1	22.3%	5.9%
1981-1990	22.3	2.2	19.0%	4.9%
1991	13.4	6.8	0.9%	0.6%

Period	Planting rate (000 ha a^{-1})		Age distribution	
	Conifers	Broadleaves	Conifers	Broadleaves
1992	11.6	6.5	0.8%	0.6%
1993	10.1	8.9	0.7%	0.8%
1994	7.4	11.2	0.5%	1.0%
1995	9.5	10.5	0.7%	1.0%
1996	7.4	8.9	0.5%	0.8%
1997	7.8	9.5	0.5%	0.9%
1998	7.0	9.7	0.5%	0.9%
1999	6.6	10.1	0.5%	0.9%
2000	6.5	10.9	0.5%	1.0%
2001	4.9	13.4	0.3%	1.3%
2002	3.9	10.0	0.3%	0.9%
2003	3.7	9.3	0.3%	0.9%
2004	2.9	8.9	0.2%	0.8%
2005	2.1	9.2	0.2%	0.9%

Increases in stemwood volume were based on standard Yield Tables, as in Dewar & Cannell (1992) and Cannell & 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 A3.7.2**.

The parameters controlling the transfer of carbon into the litter pools and its subsequent decay are given in **Table A3.7.2**. 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 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.

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.

It is assumed in the carbon accounting model that harvested material from thinning and felling is made into wood products. The net change in the carbon in this pool of wood products is reported in Category 5G (**Section A3.7.9**).

A3.7.2 Land Use Change and Soils (5B2, 5C2, 5E2)

The method for assessing changes in soil carbon due to land use change uses a matrix of change from land surveys linked to a dynamic model of carbon stock change. 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 and 1998 (Haines-Young *et al.* 2000) are used. In Northern Ireland, fewer data are available to build matrices of land use change, but for 1990 to 1998 a matrix for the whole of Northern Ireland was available from the Northern Ireland Countryside Survey (Cooper & McCann 2002). The only data available for Northern Ireland pre-1990 is land use areas from The Agricultural Census and The Forest Service (Cruickshank & Tomlinson 2000). Matrices of land use change were then estimated for 1970-79 and 1980-89 using area data. The basis of the method devised was to assume that the relationship between the matrix of land use transitions for 1990 to 1998 and the area data for 1990 is the same as the relationship between the matrix and area data for each of two 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 classes of land for descriptive purposes: Forest, Grassland, Cropland, Settlements, Wetlands and Other Land. The data presently available for the UK does not distinguish wetlands from other types, so land in the UK has been placed into the five other types. The more detailed categories for the two surveys in Great Britain were combined as shown in **Tables A3.7.3** for MLC and **A3.7.4** for CS.

The area data used between 1947 and 1998 are shown in **Table A3.7.5** and Table **A3.7.6**. 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 1990 to 1999) are given in **Table A3.7.7-10**. The data for afforestation and deforestation shown in the Tables are adjusted before use for estimating carbon changes to harmonise the values with those used in the calculations for Land converted To and From Forest Land .

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	Improved grassland	Broadleaved/mixed	Built up areas	Inland rock
Horticulture	Neutral grassland	Coniferous	Gardens	Supra littoral rock
	Calcareous grassland			Littoral rock
	Acid grassland			Standing waters
	Bracken			Rivers
	Dwarf shrub heath			Sea
	Fen, marsh, swamp			
	Bogs			
	Montane			
	Supra littoral sediment			
	Littoral sediment			

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
1999-2003	*Extrapolated*	CS1990->CS1998

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
1999-2003	*Extrapolated*	NICS1990->NICS1998

Table A 3.7.7 Annual changes (000 ha) in land use in England in matrix form for 1990 to 1999. Based on land use change between 1990 and 1998 from Countryside Surveys (Haines-Young *et al.* 2000). Data have been rounded to 100 ha.

From / To	Forestland	Grassland	Cropland	Settlements
Forestland		8.9	3.4	2.1
Grassland	8.7		55.3	3.4
Cropland	0.5	62.9		0.6
Settlements	1.2	8.5	2.1	

Table A 3.7.8 Annual changes (000 ha) in land use in Scotland in matrix form for 1990 to 1999. Based on land use change between 1990 and 1998 from Countryside Surveys (Haines-Young *et al.* 2000). Data have been rounded to 100 ha.

To \ From	Forestland	Grassland	Cropland	Settlements
Forestland		11.1	0.6	0.2
Grassland	5.0		16.8	0.7
Cropland	0.1	21.4		0.3
Settlements	0.3	2.2	0.1	

Table A 3.7.9 Annual changes (000 ha) in land use in Wales in matrix form for 1990 to 1999. Based on land use change between 1990 and 1998 from Countryside Surveys (Haines-Young *et al.* 2000). Data have been rounded to 100 ha.

To \ From	Forestland	Grassland	Cropland	Settlements
Forestland		2.4	0.2	0.2
Grassland	1.5		5.5	0.6
Cropland	0.0	8.0		0.0
Settlements	0.1	1.8	0.2	

Table A 3.7.10 Annual changes (000 ha) in land use in Northern Ireland in matrix form for 1990 to 1999. Based on land use change between 1990 and 1998 from Northern Ireland Countryside Surveys (Cooper & McCann 2002). Data have been rounded to 100 ha.

To \ From	Forestland	Grassland	Cropland	Settlements
Forestland		1.6	0.0	0.0
Grassland	0.3		5.9	0.0
Cropland	0.0	3.7		0.0
Settlements	0.1	1.0	0.0	

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 A3.7.11** 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, the change is required in equilibrium carbon density from the initial to the final land use during a transition. Here, 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 most recent land use data (1990 to 1998) is used in the weighting. The averages calculated are presented in **Tables A3.7.12-15.**

Table A 3.7.12 Weighted average change in equilibrium soil carbon density (kg m^{-2}) to 1 m deep for changes between different land types in England

To \ From	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 (kg m^{-2}) to 1 m deep for changes between different land types in Scotland

To \ From	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 (kg m^{-2}) to 1 m deep for changes between different land types in Wales

To \ From	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 (kg m^{-2}) 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 A3.7.16**). 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 A3.7.17**.

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			
		Cropland	**Grassland**	**Settlement**	**Forestland**
Final	**Cropland**		*Slow*	*slow*	*slow*
	Grassland	*fast*		*slow*	*slow*
	Settlement	*fast*	*Fast*		*slow*
	Forestland	*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 (See **Section A3.7.1**). Variations from year to year in the reported net emissions reflect the trend in land use change as described by the matrices of change.

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 now based on the same area matrices used for estimating changes in carbon stocks in soils (**Section A3.7.2**). The biomass carbon density for each land type is assigned by expert judgement based on the work of Milne & Brown (1997) and these are shown in **Table A3.7.18**. Five basic land uses were assigned initial biomass carbon densities, 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 (**Tables A3.7.19-22**), 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}) to 1 m deep 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}) to 1 m deep for changes between different land types in Scotland. (Transitions to and from Forestland are considered elsewhere)

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

Table A 3.7.21 Weighted average change in equilibrium biomass carbon density (kg m-2) to 1 m deep for changes between different land types in Wales. (Transitions to and from Forestland are considered elsewhere)

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

Table A 3.7.22 Weighted average change in equilibrium biomass carbon density (kg m^{-2}) to 1 m deep for changes between different land types in orthern Ireland. (Transitions to and from Forestland are considered elsewhere)

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

A3.7.4 Biomass Burning due to deforestation (5C2, 5E2)

Levy & 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. These areas are not published, but recent figures from the Forestry Commission have been collated. These provide estimates of rural deforestation rates in England for 1990 to 2002 and for GB in 1999 to 2001. The most recent deforestation rate available for rural areas is for 2002 so rates for 2003-2005 were estimated by extrapolating forwards from the rates for 1999 to 2002

Only local planning authorities hold documentation for allowed felling for urban development, 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 (Department of Communities and Local Government, 2006, previously the Office of the Deputy Prime Minister) from the data it collects for map updating. Eleven broad land-use categories are defined, with a number of sub-categories. The data for England (1990 to 2005) were available to produce a land-use change matrix, quantifying the transitions between land-use classes. Deforestation rate was calculated as the sum of transitions from all forest classes to all non-forest classes providing estimates on non-rural deforestation.

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. However, the Ordnance Survey data come 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 was applied to the data to smooth out the between-year variation appropriately, to give a suitable estimate with annual resolution. Deforestation is not currently estimated for Northern Ireland. Rural deforestation is assumed to convert the land to Grassland use (reported in Category 5C2) and non-rural deforestation causes conversion to the Settlement land type (reported in 5E2). Information from land use change matrices indicates that conversion of forest to cropland is negligible.

On deforestation it is assumed that 60% of the standing biomass is removed as timber products and the remainder is burnt. The annual area loss rates were used in the method described in the IPCC 1996 guidelines (IPCC 1997c, 1997a, 1997b) to estimate immediate emissions of CO_2, CH_4 and N_2O from this biomass burning. Only immediate losses are considered because sites are normally completely cleared for development, leaving no debris to decay. Changes in stocks of soil carbon after deforestation are included with those due to other land use transitions as described in **Section A3.7.2**.

A3.7.5 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 in BGS (2005) 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 1994-2004 were obtained from the Fertiliser Statistics Report 2006 (Agricultural Industries Confederation 2006), and extrapolated to obtain an estimate for 2005. Percentages for 1990-1993 were assumed to be equal to those for 1994.

A3.7.6 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 A3.7.23**. 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 3.7.23 Area and carbon loss rates of UK fen wetland in 1990

	Area	Organic carbon content	Bulk density kg m^{-3}	Volume loss rate m^3 m^{-2} a^{-1}	Carbon mass loss GgC a^{-1}	Implied emission factor gC m^{-2} a^{-1}
'Thick' peat	24x10^7 m^2 (24,000 ha)	21%	480	0.0127	307	1280
'Thin' peat	126x10^7 m^2 (126,000 ha)	12%	480	0.0019	138	109
Total	**150x10^7 m^2 (150 kha)**				**445**	**297**

The emissions trend since1990 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).

A3.7.7 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).

A3.7.8 Peat extraction (5C1)

Cruickshank & Tomlinson (1997) provide initial estimates of Emissions due to peat extraction. Since their work, trends in peat extraction in Scotland and England over the period 1990 to 2005 have been estimated from activity data taken from the UK Minerals Handbook (BGS 2006). In Northern Ireland, no new data on use of peat for horticultural use has been available but a recent survey of extraction for fuel use suggested that there is no significant trend for this purpose. The contribution of emissions due to peat extraction in Northern Ireland is therefore incorporated as constant from 1990 to 2005. Peat extraction is negligible in Wales. Emissions factors are from Cruickshank & Tomlinson (1997) and are shown in **Table A3.7.24**.

Table A 3.7.24 Emission Factors for Peat Extraction

	Emission Factor kg C m^{-3}
Great Britain Horticultural Peat	55.7
Northern Ireland Horticultural Peat	44.1

A3.7.9 Harvested Wood Products (5G)

The C-Flow model adopts a simple approach to the decay of Harvested Wood Products (HWP). A carbon stock loss of 5% is assumed to be lost immediately at harvest. Subsequently, the decay time (time to 95% loss of carbon stock) of products is set equal to the rotation time for that species. This approach captures differences in wood product use: fast growing softwoods tend to be used for shorter lived products than slower growing hardwoods. Exponential single decay constants are used for HWP from conifers and broadleaves. Products from thinnings are assumed to have a lifetime (time to 95% loss) of 5 years (half life ~0.9 years). The main harvest products have a lifetime equal to rotation length. For conifers this equates to a half life of 14 years and for broadleaves a half life of 21 years. These 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 products in the UK when the model was originally developed. The mix of products may be changing in the UK and this could affect the 'true' mean value of product lifetime but there is very limited accurate data on either decay rates or volume statistics for different products. The method used in the UK takes a top-down approach by assuming that the decay of all conifer products and all broadleaf products can be approximated by separate single decay constants. Given the uncertainty on decay of products it is difficult to decide if this is better or worse than a bottom-up approach where each product is given an (uncertain) decay and combined with (uncertain) decay of other products using harvest statistics which are in themselves uncertain.

Calculated in this way, the total wood products pool from UK forests is presently increasing due to continuing expansion in forest area. The time pattern of HWP stock changes is due to the historical pattern of new planting and the resulting history of production harvesting (and thinning). The stock of carbon in HWP (from UK forests planted since 1920) has been increasing since 1990 but this rate of rise has recently reversed, reflecting a severe dip in new planting in the 1940s. The stock of carbon in HWP will fall for a few more years but will then begin to rise steeply due to harvesting of the extensive conifer forests planted between 1950 and the late 1980s.

A3.7.10 Emissions of N_2O from disturbance associated with land use conversion

Emissions of greenhouse gases other than CO_2 in the Land Use Change and Forestry Sector come from 3 types of activities: (i) biomass burning as part of deforestation producing CH_4 and N_2O emissions, (ii) application of fertilisers to forests producing N_2O and (iii) disturbance of soils due to some types of land use change producing N_2O associated with CO_2 emissions. Emissions by biomass burning are discussed in **Section 3.7.4.** Emissions from other activities were considered in Skiba (2005) but have not yet been reported in the CRF. Here we discuss these emissions in more detail with a view to their reporting in future CRF submissions.

The CRF provides two tables where emissions of N_2O associated with soil disturbance after land use change can be reported. Table 5(III) specifically provides for reporting of emissions after Forest Land or Grassland is converted to Cropland but this table is also appropriate for reporting N_2O emissions from other land use change. The exception to this is where the land treatment required for afforestation causes emissions. CRF Table 5(II) is provided for reporting emissions due to drainage of Forest Land, which would include newly afforested land. In the UK drainage of some form has occurred when new forests are planted. Methods (**Section 3.7.1**) have been developed to estimate CO_2 emissions after afforestation for the UK:

these data are suitable as the basis for estimates of N_2O emissions rather than the Tier 1 default emission rates for drained forest from the LULUCF GPG.

A3.7.10.1 Emissions of N2O due to disturbance of soils after land use change excluding afforestation.

In the UK six land use transitions cause immediate and delayed emissions of CO_2. These are:

- Forest Land to Grassland
- Forest Land to Cropland
- Forest Land to Settlement
- Grassland to Cropland
- Grassland to Settlement
- Cropland to Settlement

The method recommended in the LULUCF GPG for calculating N_2O emissions due to land use change is to use the CO_2 emission due to a specific change and then use the C:N ratio for the soils being disturbed to estimate the N lost due to the mineralisation of organic matter. The default emission factor for the N_2O pathway (1.25%) is then used to calculate the emitted flux of N_2O-N. **Table A3.7.25** shows the emissions for the period from 1990 to 2005 adopting this approach with a C:N ratio of 15:1 for all land.

Table A 3.7.25 Emissions of N_2O in the UK due to disturbance of soils after land use change estimated by the method of the LULUCF GPG

	Forest Land to Grassland	Forest Land to Cropland	Forest Land to Settlement	Grassland to Cropland	Grassland to Settlement	Cropland to Settlement	ALL LUC
	Gg N_2O	Gg N_2O	Gg N_2O	Gg N_2O	Gg N_2O	Gg N_2O	Gg N_2O
1990	0.035	0.004	0.026	4.995	2.019	0.401	7.482
1991	0.035	0.004	0.029	5.001	2.008	0.390	7.466
1992	0.035	0.004	0.031	5.006	1.997	0.378	7.452
1993	0.034	0.004	0.035	5.012	1.986	0.368	7.439
1994	0.034	0.003	0.037	5.018	1.977	0.358	7.428
1995	0.036	0.003	0.038	5.024	1.968	0.349	7.419
1996	0.037	0.003	0.039	5.031	1.960	0.340	7.410
1997	0.034	0.003	0.044	5.037	1.953	0.332	7.403
1998	0.034	0.003	0.046	5.044	1.946	0.324	7.396
1999	0.045	0.003	0.037	5.050	1.939	0.317	7.391
2000	0.050	0.002	0.033	5.057	1.933	0.310	7.386
2001	0.054	0.002	0.031	5.064	1.928	0.303	7.382
2002	0.056	0.002	0.031	5.071	1.923	0.297	7.379
2003	0.056	0.002	0.032	5.077	1.918	0.292	7.377
2004	0.054	0.002	0.035	5.084	1.913	0.286	7.375
2005	0.056	0.002	0.035	5.090	1.909	0.281	7.373

The 1990 emission rate for all land use change from Table A3.7.14 is equivalent to an emission of 2319 Gg CO_2 (using a GWP of 310) which is similar to the net uptake of CO_2 equivalents by all other activities in the UK LULUCF Sector. It is therefore of considerable importance that the methodology used is scientifically sound. On further investigation this does not appear to be the case. The LULUCF GPG methodology relies on estimating gross nitrogen loss from a gross carbon loss and a C:N ratio, but several factors suggest that this approach does not lead to reliable values. There are few measurements of C:N ratios for different land use and for different environmental conditions, making it difficult to generalise values for a whole country. More importantly, understanding of the mechanisms that cause C:N ratios to vary with different land management is weak, particularly in relation to how changes in the C:N ratio of different pools in the soil affect the gross C:N ratio. For example Pineiro *et al.* (2006) show that it is possible to obtain gross N – mineralisation changes of opposite sign depending on whether changes in whole-soil or individual pool C:N ratios are considered in a model of the effect of grazing on soil. It would therefore seem prudent to await an alternative approach to estimating N_2O emissions due to land use change before including any data in the inventory. The UK National Inventory System is currently supporting research to measure change in stocks of soil carbon and nitrogen due to ploughing of an upland grassland.

A3.7.10.2 Emissions of N_2O from disturbance of soils by afforestation

The methodology used to estimate CO_2 removals and emissions due to the establishment of forests is described in **Section 3.7.1**. Included in these estimates are emissions relating to the loss of carbon (as CO_2) as a result of disturbance of the pre-existing soil. The pattern of immediate and delayed emissions is taken to be that measured at a peatland site but the amplitude of the loss is reduced for afforestation in other locations. It could therefore be assumed that nitrogen in the soil will be lost with the carbon in proportion to the C:N ratio as suggested by the LULUCF GPG for other types of land use change that cause carbon mineralization. Area afforestation rates in the UK have been disaggregated into those for planting of conifers on organic and non-organic soils and for broadleaves (which normally occurs on mineral soils). We investigated this approach for calculating nitrogen loss by assuming that organic soils (conifer planting) had a C:N ratio of 30:1 but non-organic soils used for planting had a C:N ratio of 15:1. The N_2O emission factor was taken to be the default value of 1.25%. Emissions of N_2O estimates by this approach are presented in **Table A3.7.26**. All forests planted since 1921 are included in this approach but no explicit account of the degree of drainage in these forests is included. The fluxes measured by Hargreaves *et al.* (2003), which are the basis for the method of estimating CO_2 emissions of **Section 3.7.1,** were ~ 4 tC/ha/yr initially and estimated to fall to ~0.3 tC/ha/yr in the long term. Assuming a C:N ratio of 30:1 for peat the resulting N_2O emissions would be of the same order of magnitude as those suggested as Tier 1 Defaults in the LULUCF GPG.

Table A 3.7.26 Emissions of N_2O due to afforestation since 1921 in the UK using an adaptation of the LULUCF GPG approach for general land use change.

	Conifer organic	Conifer mineral	Broadleaf (mineral)
	Gg N2O	Gg N2O	Gg N2O
1990	0.154	0.885	0.097
1991	0.147	0.849	0.117
1992	0.139	0.812	0.135
1993	0.131	0.776	0.155
1994	0.123	0.737	0.183
1995	0.116	0.704	0.211
1996	0.111	0.678	0.230
1997	0.106	0.654	0.244
1998	0.101	0.633	0.260
1999	0.097	0.614	0.274
2000	0.093	0.597	0.288
2001	0.090	0.579	0.311
2002	0.085	0.559	0.327
2003	0.082	0.540	0.328
2004	0.078	0.523	0.326
2005	0.075	0.506	0.325

These emission rates are not as large as those found for Grassland conversion but the criticisms of using gross C:N ratios to obtain N loss also apply. A further consideration of methods will therefore be needed before data can be included in the inventory.

A3.8 WASTE (CRF SECTOR 6)

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

Degradable Organic Carbon (DOC) and Fraction Dissimilated (DOCF)

UK values for DOC and DOC_f are based on an emissions model maintained by LQM (2003) that uses updated degradable carbon input parameters with values based on well-documented US research for the USEPA's life-cycle programme (Barlaz et al., 1997). The data taken from this report relate to those waste fractions most representative of UK municipal waste, on the basis that the biochemistry of individual fractions of waste in the US will be comparable to the same fractions in the UK. This has been adapted to UK conditions and incorporated into (1) the Environment Agency's WISARD life cycle assessment model (WS Atkins, 2000); (2) the HELGA framework model (Gregory et al., 1999) and (3) GasSim (Environment Agency, 2002).

Cellulose and hemi-cellulose are known to make up approximately 91% of the degradable fraction, whilst other potential degradable fractions which *may* have a small contribution (such as proteins and lipids) are ignored. The amount of degradable carbon that produces landfill gas is determined using the mass (expressed on a percentage dry weight basis) and degradability (expressed as a percentage decomposition) of cellulose and hemi-cellulose using data provided by Barlaz et al. (1997). The input values for these parameters are provided in

Tables A3.8.1 and **A3.8.2** below for each of the waste fractions for both municipal (MSW) and commercial and industrial (C&I) waste categories, respectively. Also included are the proportions of individual waste streams that are considered to be rapidly, moderately or slowly degradable.

The moisture content of the components of the waste is derived from The National Household Waste Analysis Project (1994). This detailed report provides the range of moisture contents analysed for each of the fractions of waste collected and sampled. These fractions came from a number of different waste collection rounds, across the UK, representing different types of communities. The waste is analysed in its "as collected" form, which is then sorted and chemically analysed as separate fractions. The report also gives the averages used in the model. More recent waste arisings data collated by the Devolved Administrations, not available at the time of LQM (2003), do not include chemical analysis data.

These data are used within the model to determine the amount of degradable carbon that decays at the relevant decay rate. This process requires complete disaggregation of the waste streams into their component parts, allocation of degradability and rate of decomposition to each component and hence the application of the IPCC model approach at this disaggregated level.

Table A 3.8.1 Waste degradable carbon model parameters for MSW waste

Waste category	Fraction				Moisture content	Cellulose	Hemi-cellulose	DOC	DOC	Decomposition (DOC_f)
	Readily Degradable	Moderately Degradable	Slowly Degradable	Inert	(%)	(% Dry waste)	(% Dry waste)	(% Dry waste)	(% Wet waste)	(% Dry waste)
Paper and card	0	25	75	0	30	61.2	9.1	31.24	21.87	61.8
Dense plastics	0	0	0	100	5	0	0	0	0.00	0
Film plastics (until 1995)	0	0	0	100	30	0	0	0	0.00	0
Textiles	0	0	100	0	25	20	20	17.78	13.33	50
Misc. combustible (plus non-inert fines from 1995)	0	100	0	0	20	25	25	22.22	17.78	50
Misc. non-combustible (plus inert fines from 1995)	0	0	0	100	5	0	0	0	0.00	0
Putrescible	100	0	0	0	65	25.7	13	17.20	6.02	62
Composted putrescibles	0	50	50	0	30	0.7	0.7	0.62	0.44	57
Glass	0	0	0	100	5	0	0	0	0.00	0
Ferrous metal	0	0	0	100	5	0	0	0	0.00	0
Non-ferrous metal and Al cans	0	0	0	100	10	0	0	0	0.00	0
Non-inert fines	100	0	0	0	40	25	25	22.22	13.33	50
Inert fines	0	0	0	100	5	0	0	0	0.00	0

Notes:

1. DOC is Degradable Organic Carbon.

2. DOC_f is the portion of DOC that is converted to landfill gas.

Table A 3.8.2 Waste degradable carbon model parameters for C & I waste

Waste category	Fraction				Moisture content	Cellulose	Hemi-cellulose	DOC	DOC	Decomposition (DOC_f)
	Readily Degradable	Moderately Degradable	Slowly Degradable	Inert	(%)	(% Dry waste)	(% Dry waste)	(% Dry waste)	(% Wet waste)	(% Dry waste)
Commercial	15	57	15	13	37	76	8	37.33	23.52	85
Paper and card	0	25	75	0	30	87.4	8.4	42.58	29.80	98
General industrial waste	15	43	20	22	37	76	8	37.33	23.52	85
Food solids	79	10	0	11	65	55.4	7.2	27.82	9.74	76
Food effluent	50	5	0	45	65	55.4	7.2	27.82	9.74	76
Abattoir waste	78	10	0	12	65	55.4	7.2	27.82	9.74	76
Misc processes	0	5	5	90	20	10	10	8.89	7.11	50
Other waste	15	35	35	15	20	25	25	22.22	17.78	50
Power station ash	0	0	0	100	20	0	0	0	0	0
Blast furnace and steel slag	0	0	0	100	20	0	0	0	0	0
Construction/demolition	0	5	5	90	30	8.5	8.5	7.56	5.29	57
Sewage sludge	100	0	0	0	70	14	14	12.44	3.73	75

Notes:

1. DOC is Degradable Organic Carbon. .

2. DOC_f is the portion of DOC that is converted to landfill gas.

A3.8.2 Flaring and Energy Recovery

Flaring and energy recovery constitutes the method likely to reduce methane emissions from landfills by the largest amount, and was surveyed in 2002, as described below. It is estimated that in 2005 70% of the total landfill gas generated in the UK was flared or utilised (**Table 3.8.2**).

A3.8.2.1 Gas Utilisation

The gas utilisation data are based on comparison of information from the trade association, the Renewables Energy Association, formerly Biogas Association (Gaynor Hartnell, Pers. Comm. 2002) and current DTI figures. In addition, LQM (2003) included data on utilisation prior to the first round of the Non Fossil Fuel Obligation (NFFO) contracts (Richards and Aitchison, 1990). The first four NFFO rounds (NFFO 1-4) and the Scottish Renewables Order (SRO) round are all taken to be completed and operational schemes, since there are relatively few outstanding schemes still to be implemented. It is known that not all of the proposed early schemes were found to be economic, and no NI-NFFO (Northern Ireland-NFFO) schemes have progressed, so those known schemes have not been included in the total (Gaynor Hartnell, Pers. Comm. 2002).

This approach, comparing the trade association and Government data sources, provides a reasonable correlation, and so LQM is confident in the accuracy of its estimates of current installed capacity. The latest round of NFFO (NFFO 5) has been implemented in the forecasting model over the period 2000 – 2005, to give a reasonable lead in time for these new projects. Various industry sources have indicated in confidence that some of the proposed NFFO 5 projects are now also considered uneconomic under NFFO. Some of these have definitely been abandoned, some have been surrendered and re-started under the new renewables order, and others are likely to follow this route. These figures are likely to have only a small uncertainty, as they are directly derived from power generation figures supplied by the industry and the Department of Trade and Industry.

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. It is rare to find a flare stack with a flow measurement.

The operational capacity is derived by subtracting the back-up capacity from the total. LQM's total for generation back-up capacity remains at a fairly constant percentage of the installed generation capacity (around 60%), indicating that these figures are realistic. In the model, there is a further correction factor used in arriving at the final volume of gas flared each year, to take account of maintenance downtime (15%). In addition, it is assumed that since 1984 (i.e. three years after the first flare was commissioned) 7% of capacity in any given year is treated as replacement. This effectively gives the flare an expected 15-year operational lifetime. In 1990, the methane captured equates to 11% of the total generated, rising to 70% in 2005, averaged over the UK (**Table 3.8.3**). The downtime and replacement figures are LQM assessments following inquiries made as part of the 2002 survey.

The last input of gas utilisation data in the model is year 2005 and the last input of flare data is year 2002. Gas utilisation and flaring is assumed constant thereafter. Collection efficiency at any site is limited to 75%.

Table A 3.8.3 Amount of methane generated, captured, oxidised and emitted.

Year	Mass of waste landfilled (Mt)			Methane generated (kt)	Methane captured (kt)	Methane captured (%)	Residual methane oxidised (kt)	Residual methane oxidised (%)	Methane emitted (kt) MSW
	MSW	C&I	Combined waste streams						
1990	18.19	81.83	100.02	2947	322	10.91	263	8.91	2363
1991	18.84	81.77	100.61	3024	436	14.43	259	8.56	2329
1992	19.47	81.72	101.19	3098	576	18.58	252	8.14	2270
1993	20.09	81.66	101.76	3170	712	22.47	246	7.75	2212
1994	20.71	81.61	102.32	3240	832	25.67	241	7.43	2167
1995	23.83	81.56	105.39	3294	962	29.20	233	7.08	2099
1996	24.76	78.17	102.93	3330	1077	32.36	225	6.76	2027
1997	26.14	72.86	99.00	3352	1279	38.15	207	6.19	1866
1998	25.94	65.63	91.57	3361	1433	42.65	193	5.74	1735
1999	27.03	63.84	90.87	3371	1620	48.04	175	5.20	1577
2000	27.54	62.05	89.59	3384	1749	51.68	164	4.83	1472
2001	26.85	60.27	87.11	3394	1975	58.19	142	4.18	1277
2002	27.17	58.48	85.64	3405	2114	62.09	129	3.79	1162
2003	26.39	58.48	84.87	3415	2287	66.96	113	3.30	1016
2004	25.47	58.48	83.94	3425	2377	69.40	105	3.06	943
2005	24.17	55.48	82.65	3432	2402	69.99	103	3.01	927

A3.8.3 Wastewater Handling (6B)

A3.8.3.1 Use of the 1996 Hobson Model within the UK GHG Inventory

The NAEI estimate is based on the work of Hobson *et al* (1996) who estimated emissions of methane for the years 1990-95. Subsequent years are extrapolated on the basis of population. Sewage disposed to landfill is included in landfill emissions.

The basic activity data are the throughput of sewage sludge through the public system. The estimates are based on the UK population connected to the public sewers and estimates of the amount of sewage per head generated. From 1995 onwards the per capita production is a projection (Hobson *et al*, 1996). The main source of sewage activity data is the UK Sewage Survey (DOE, 1993). Emissions are calculated by disaggregating the throughput of sewage into 14 different routes. The routes consist of different treatment processes each with specific emission factors. The treatment routes and emission factors are shown in **Table A3.8.4.**

A3.8.3.2 Industrial Wastewater Treatment Plants

There is no separate estimate made of emissions from private wastewater treatment plants operated by companies prior to discharge to the public sewage system or rivers, as there is no available activity data for this source and it has historically been assumed to be a minor source.

Where an IPC/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, methane emissions from industrial wastewater treatment should be included within operator returns to the pollution inventories of the EA, SEPA and NIDoE, 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 this is the case across different industry sectors. 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 (whereas in some guidance, wastewater treatment is singled out as a potentially significant source of NH_3 and N_2O emissions).

A3.8.3.3 Sludge Applications to Agricultural Land

The Hobson model includes emissions of methane from sewage sludge applications to agricultural land, and these emissions are therefore included within sector 6B2, rather than within the agricultural sector as recommended in IPCC guidance. There is no double-counting of these emissions as methane emissions from sludge application to land are excluded from the agricultural inventory compiled by IGER.

A3.8.3.4 Sewage Treatment Systems Outside of the National Network

The model does not take account for sewage treatment systems that are not connected to the national network of treatment works. The emissions are all determined on a population basis, using factors that pertain to mainstream treatment systems. Differences in emissions from alternative systems such as septic tanks are not considered, as it is assumed that the vast majority of the UK population is connected to the public wastewater treatment system.

A3.8.3.5 Design of Wastewater Treatment Systems in the UK

Most UK wastewater treatment works comprise the following components as a minimum:

- Initial screening / grit removal
- Primary settlement tanks, using simple sedimentation
- 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 model.

A3.8.3.6 Emissions from Anaerobic Digestion

The model includes calculations to account for different designs of anaerobic digesters, primary and secondary digestion phases, the utilisation of digester gas flaring, CHP and venting systems, and uses emission factors derived for each design type, which include consideration of fugitive losses of methane in each case. The dataset refers to plant survey data and emission factor research from the early 1990s, and so may not be representative of current emissions research, plant design and practice.

Table A 3.8.4 Specific Methane Emission Factors for Sludge Handling (kg CH4/Mg dry solids, Hobson et al (1996))

Sludge Handling System	Gravity Thickening[1]	Long term storage	Anaerobic Digestion[2]	Agricultural Land	Landfill
Anaerobic digestion to agriculture	0.72		143	5	
Digestion, drying, agriculture	0.72		143	5	
Raw sludge, dried to agriculture	0.72			20	
Raw sludge, long term storage (3m), agriculture	0.72	36		20	
Raw sludge, dewatered to cake, to agriculture	0.72			20	
Digestion, to incinerator	0.72		143		
Raw sludge, to incinerator	0.72				
Digestion , to landfill	0.72		143		0
Compost, to agriculture	0.72			5	
Lime raw sludge, to agriculture	0.72			20	
Raw Sludge , to landfill	0.72				0
Digestion , to sea disposal	0.72		143		
Raw sludge to sea disposal	0.72				
Digestion to beneficial use (e.g. land reclamation)	0.72		143	5	

1 An emission factor of 1 kg/tonne is used for gravity thickening. Around 72% of sludge is gravity thickened hence an aggregate factor of 0.72 kg CH_4/Mg is used.

2 The factor refers to methane production, however it is assumed that 121.5 kg CH_4/Mg is recovered or flared

Table A 3.8.5 Time-Series of Methane Emission Factors for Emissions from Wastewater Handling, based on Population (kt CH_4 / million people)

Year	CH_4 Emission (kt)	CH_4 EF (kt CH_4/ million people)
1990	33.38	0.583
1991	31.27	0.544
1992	34.76	0.604
1993	34.46	0.597
1994	35.96	0.622
1995	34.33	0.593
1996	35.27	0.608
1997	36.21	0.623
1998	37.15	0.637
1999	36.02	0.616
2000	36.89	0.629
2001	37.13	0.628
2002	37.35	0.630
2003	37.58	0.631
2004	37.80	0.632
2005	38.03	0.632

Nitrous oxide emissions from the treatment of human sewage are based on the IPCC (1997c) default methodology. The most recent average protein consumption per person is based on the National Food Survey (Defra, 2006); see **Table 3.8.6**. The food survey is based on household consumption of food and so may give a low estimate.

Table A 3.8.6 Time-series of per capita protein consumptions (kg/person/yr)

Year	Protein consumption (kg/person/yr)
1990	23.0
1991	22.7
1992	22.9
1993	22.7
1994	24.6
1995	23.0
1996	23.7
1997	26.3
1998	26.0
1999	25.0
2000	25.7
2001	26.3
2002	26.0
2003	26.0
2004	25.9

Year	Protein consumption (kg/person/yr)
2005	25.8

A3.9 EMISSIONS FROM THE UK'S CROWN DEPENDENCIES AND OVERSEAS TERRITORIES

Emissions of direct greenhouse gases from the Crown Dependencies and Overseas Territories are included within the UK sector totals, consistent with the 2nd submission of the CRF for 2004. Emissions of indirect greenhouse gases from the Crown Dependencies only (excluding emissions from fuel consumption) have remained in Sector 7 of the CRF, but are allocated to the same sectors of the NIR as the direct greenhouse gas emissions. **Table A3.9.1** summarises the allocation of the emissions to the CRF and NIR source categories.

Explanations of the methodology and emissions trends are included in the following sections. Some minor revisions to some of the estimates have been carried out, and are explained in the relevant sections below. No further work has been carried out to improve the inventories for these places, and emissions for 2005 have been assumed equal to those in 2004.

Table A 3.9.1 Summary of differences in category allocations between the CRF tables and the NIR

Source	Category in CRF	Category in NIR	Notes
Power stations (All OTs, stations burning MSW from the CDs)	1A1a: Public Electricity and Heat Production (Other Fuels)	1A1a	Quantities of fuels consumed are currently not available in the detail required for the CRF, and are currently not reported. Therefore, emissions have been included under "other fuel" in the CRF in order to avoid introducing errors to the IEFs calculated from the mainland UK data. In most cases, the fuel used in gas or fuel oil.
Industrial Combustion (OTs only)	1A2f: Other - OT Industrial Combustion	1A2f	This has been included in the CRF as a separate category under 1A2f.
Road Transport (OTs only)	1A3b: Road Transport (Other Fuels)	1A3b	Quantities of fuels consumed are currently not available in the detail required for the CRF, and are currently not reported. Therefore, emissions from road transport have been included under "other fuel" in the road transport category. This enters emissions to the correct sector, without introducing errors to the IEFs from the existing data.
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 only)	1A4b: Residential (Other Fuels)	1A4b	This has been included as an "other fuel" in the CRF. Some emissions from the commercial sector are also included here, where it was difficult to disaggregate fuel use data.
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	4A	A separate category for all livestock in the OTs and CDs has been introduced.
OT and CD Manure Management	4G: Other - OT and CD Emissions from Manure Management	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 new category was therefore included in Sector 4G - Other.
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 as a separate category under 6C.
CD emissions of indirect GHGS from non-fuel combustion sources	Sector 7	Relevant categories	Emissions of indirect GHGs from all non-fuel combustion sources (ie those not included through DUKES statistics) have remained in Sector 7 due to technical difficulties in allocating them to the correct sectors,

Direct GHG emissions are included 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[5]. The relevant CDs and OTs are:

- Guernsey
- Jersey
- The Isle of Man
- The Falkland Islands
- The Cayman Islands
- Bermuda
- Montserrat
- Gibraltar

Country specific data have been sought to estimate as 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 indeed the inventory already included CO_2 from energy use in the CDs because of the coverage of the Digest of UK Energy Statistics. 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 the Overseas Territories, no data were available and it was not possible to make any estimates of emissions.

Emissions of GHGs from fuel combustion in IPCC Sector 1 (but not waste incineration) were already included in the GHG inventory from the CDs of the Channel Islands and the Isle of Man, but emissions from agriculture and waste from these CDs were not previously estimated or included before 2004. **Table A3.9.2** and **Table A3.9.3** show the new emissions included according to source category.

[5] 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.

Table A 3.9.2 Source categories included in the 2007 NIR from Crown Dependencies

Territory	GHG	Source category	Included in 2005 NIR?	Included in 2007 NIR?
Crown Dependencies				
Jersey Guernsey Isle of Man	CO_2	Stationary and Mobile Fuel Combustion	✓	✓
		1A1a Public Electricity&Heat Production (Waste Incineration)	×	✓
	CH_4	Stationary Fuel Combustion	✓	✓
		1A1a Public Electricity&Heat Production (Waste Incineration)	×	✓
		4A10 Enteric Fermentation	×	✓
		6A1 Managed Waste Disposal on Land	×	✓
		6B2 Wastewater Handling	×	✓
	N_2O	Stationary Fuel Combustion	✓	✓
		1A1a Public Electricity&Heat Production (Waste Incineration)	×	✓
		4B13 Manure Management	×	✓
		6B2 Wastewater Handling	×	✓
	F-gases	2F9 Other	×	✓

Table A 3.9.3 Source categories included in the 2007 NIR from Overseas Territories

Territory	GHG	Source category	Included in 2005 NIR?	Included in 2007 NIR?
Overseas Territories				
Bermuda Cayman Islands Falkland Islands Montserrat	CO_2	1A1a Public Electricity&Heat Production	×	✓
		1A2f Manufacturing Industry&Construction:Other	×	✓
		1C1a Civil Aviation International[6]	×	✓
		1A3b Road Transportation	×	✓
		1A4b Residential	×	✓
		1A4cii Agriculture/Forestry/Fishing:Off-road	×	✓
		6C Waste Incineration	×	✓
	CH_4	1A1a Public Electricity&Heat Production	×	✓
		1A2f Manufacturing Industry&Construction:Other	×	✓
		1C1a Civil Aviation International	×	✓
		1A3b Road Transportation	×	✓
		1A4b Residential	×	✓
		1A4cii Agriculture/Forestry/Fishing:Off-road	×	✓
		4A10 Enteric Fermentation Other	×	✓
		6A1 Managed Waste Disposal on Land	×	✓
		6B2 Wastewater Handling	×	✓
		6C Waste Incineration	×	✓
	N_2O	1A1a Public Electricity&Heat Production	×	✓
		1A2f Manufacturing Industry&Construction:Other	×	✓
		1C1a Civil Aviation International	×	✓
		1A3b Road Transportation	×	✓
		1A4b Residential	×	✓
		1A4cii Agriculture/Forestry/Fishing:Off-road	×	✓
		4B13 Manure Management Other	×	✓
		6B2 Wastewater Handling	×	✓
		6C Waste Incineration	×	✓
	F-gases		×	✓

A summary of the emissions of the direct GHGs from the UK's Crown Dependencies and Overseas Territories are given in **Table A3.9.5** and **Table A3.9.7**.

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 A3.9.4**. Data for these territories were obtained at the same time as the compilation of the UK GHG inventory for 2004 which enabled checks to be made on the data and its veracity. Emissions are summarised in **Table A3.9.5.**

[6] Emissions from aviation have been reallocated from domestic to international. These emissions were allocated to the domestic sector in error in the 2006 Inventory, and this mistake has now been rectified.

Emissions of CO_2 from fuel combustion were already included in the GHG inventory from the CDs of the Channel Islands and the Isle of Man because fuel consumptions from these areas are included in the DTI energy statistics. Emissions from non-fuel combustion sources from these CDs were not previously included in the GHG inventory.

Estimates of the indirect GHGs have been made in addition to the direct GHGs (CO, NMVOC, NO_X, and SO_2) and additional, NH_3.

Estimates of F-gas emissions from the CDs are included in the inventory this year. These were excluded in error in the 2004 inventory.

A3.9.1.1 Jersey

The largest sources of carbon emissions for Jersey are transport, mainly shipping and aviation, and power generation. Emissions from power generation have decreased steadily across the time series due to imports of electricity from France.

Agricultural activity is the main source of methane emissions, although emissions have declined from 2002 onwards. Waste is incinerated, and so there are no methane emissions from landfill sites. Default factors from the EMEP/CORINAIR Guidebook were used to estimate emissions from waste incineration as there was not enough information available to assume similar technology in Jersey and the UK.

N_2O emissions are mostly from off road transport sources and livestock manure management. Emissions from road transport increase across the time series in line with the increase in vehicle numbers and the introduction of catalysts to the vehicle fleet.

F-gas emissions are based on UK emissions, scaled by 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. No estimates were made of emissions of N_2O from agricultural soils as no data could be obtained or extrapolated for fertiliser use.

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.

A3.9.1.2 The Isle of Man

The main source of carbon emissions is power generation. Emissions from this source increased in 2004 as a new waste incinerator opened; previously waste generated on the Isle of Man was disposed to landfill. Some minor industrial sources of combustion emissions also exist; the sewage treatment plant and quarries.

The most significant methane source is agriculture, which accounted for 65% of methane emissions in 1990. The other major 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. Off road transportation and machinery is also a relatively important source.

The emissions for fuel combustion and transportation sources 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.

A3.9.1.3 Guernsey

At the beginning of the time series (towards 1990), the most important sources of carbon emissions were power generation and domestic fuel combustion. There is one power station on Guernsey. Emissions from power generation decreased from 1990 onwards as an increasing fraction of electricity was imported, so that in 2004, emissions from this source are only 37% of those in 1990. Emissions from off road transport and machinery are also significant, accounting for almost half of the emissions in 2004.

The largest methane source is from waste disposed to landfill. Emissions from most methane sources show a decrease across the time series, reflecting improved technology and a reduction in livestock numbers. Increased shipping activity has increased methane emissions. Shipping and off road machinery are also the largest source of N_2O emissions.

The estimates of emissions of non-CO_2 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 in a previous inventory for Guernsey. Aviation, 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.

Table A 3.9.4 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	2003 NAEI, EMEP/CORINAIR default factors used for waste incineration.	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 factors taken from EMEP/CORINAIR, shipping and off road machinery from 2003/2002 NAEI	Incomplete datasets were supplied in many cases - the time series were completed based on passenger number data or interpolated values. The off road machinery data was not in a detailed format - numbers for each type are best estimates
2	Industrial processes	Population and GDP	Some sources assumed zero. Per capita emission factors based on UK emissions, where appropriate.	Based on the assumption that activities such as aerosol 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	Ammonia and N_2O from manure management are based on a time series of UK emissions. Methane emissions based on IPCC guidelines	Ammonia and 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			Emissions Not Estimated (NE)
6	Waste – MSW	Landfill estimates based on population, 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, 2003 NAEI emission factor used for incinerators	Estimates of amounts of incinerated waste are based on limited data and interpolated values. Using UK per capita emissions assumes the same management techniques as for the UK
	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 3.9.5 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
1. Energy	2.07	2.11	2.18	2.16	2.16	2.24	2.36	2.39	2.46	2.38	2.27	1.97	1.96	1.92	1.93	1.93
2. Industrial Processes	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03
3. Solvent and Other Products Use	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
4. Agriculture	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.16	0.16	0.15	0.15	0.11	0.10	0.10
5. Land Use, Land Use Change and Forestry	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
6. Waste	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.07	0.07	0.06	0.06	0.05	0.05	0.04	0.02	0.02
7. Other	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
Total	**2.31**	**2.35**	**2.42**	**2.39**	**2.40**	**2.48**	**2.60**	**2.62**	**2.71**	**2.62**	**2.51**	**2.20**	**2.18**	**2.10**	**2.09**	**2.09**

Notes
The estimates of greenhouse gas emissions from IPCC Sector 1 in **Table 3.9.5** include greenhouse gas emissions derived from the data gathered directly from representatives in the CDs. These estimates are not used directly in the UK inventory to avoid double counting, because the main UK energy data already include the CDs.
Estimates have not been made of emissions from LULUCF, but this is not considered to be a significant source or sink of carbon.
Emissions of the f-gases were not included in the UK National Totals in the 2004 inventory in error. These have been included in this year's submission, although the total emission of these gases is small.

A3.9.2 Overseas Territories: Bermuda, Falklands Islands, Montserrat, the Cayman Islands and Gibraltar

Table A3.9.6 summarises the methods used to estimate emissions from the Falklands Islands, Montserrat and the Cayman Islands. Emissions from some sources are not estimated due to scarcity of data. Only estimates of the direct GHGs have been made for the OTs. Emissions are summarised in **Table A3.9.7**. The government of Bermuda has prepared its own GHG inventory estimates and methodological report, so **Table A3.9.6** only refers to the methodologies used for Falkland Islands, Montserrat and the Cayman Islands. **Table A3.9.7** does, however, include emissions estimates for Bermuda.

Emissions from aviation have been reallocated from domestic to international, since there are no flights within the OTs, between the OTs or between the OTs and the UK. This has had a small effect on the national total.

A3.9.2.1 Falklands Islands

The most significant source of carbon is from power generation and domestic heating. There are no industrial combustion sources. The off road transportation figure includes aviation fuel supplied in the islands but no information was available on shipping or off road machinery.

Methane emissions are mostly from agriculture – there are around 700,000 sheep on the island. Agriculture is also a major source of N_2O. Methane emissions from waste combustion are small, and as waste is burnt, the methane emissions from this source are small. Sewage is disposed of to sea.

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 the last four years, so the time series was extrapolated back to 1990 based on population statistics. Vehicle numbers were also only provided for one year, and the time series was generated based on population statistics also. 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 is currently uninhabitable 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.

Of the sectors calculated, road transport is the most important. Only fuel consumption figures were supplied for this sector. Emissions were calculated based on the assumption that the vehicle fleet would be made up of old petrol and diesel cars, and emissions 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

Relatively little data were available and it has only been possible to develop some basic estimates of emissions from fuel combustion sources. No estimates were made for off road transport, agriculture, domestic fuel consumption or waste treatment because there are no suitable surrogate statistics.

The major emission sources are power generation and vehicle emissions for carbon, methane and nitrous oxide. There are also significant industrial combustion emissions from the water desalination plant and the cement industry.

All estimates are based on surrogate statistics. Power generation emissions were calculated based on electricity consumption statistics sourced from the CIA world fact book; emissions from the desalination plant were derived from reported fuel use for a similar plant in Gibraltar, scaled by population; cement industry emissions were calculated by scaling UK emissions by GDP; and F-gas emissions were based on data from Gibraltar scaled by population. The only information supplied about road transport was a figure for total vehicle numbers, and an estimate of typical vehicle km. Emissions estimates were made based on road transport in Jersey, and scaled by the total number of vehicles, since the typical mileage was similar.

Since all of the data is based on assumptions and generalised statistics, the emissions calculated are all very uncertain.

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).

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 (Falkland Islands and Montserrat), electricity consumption data (Cayman Islands)	NAEI 2003	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. The information supplied from the Cayman islands was limited to the type of fuel burned for electricity generation - electricity consumption statistics were obtained from the CIA World Factbook.
	Energy - road transport	Vehicle numbers and fuel use supplied for the Falkland Islands, vehicle numbers and vehicle kilometres 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 - emissions have been calculated based on a fleet of old petrol and diesel cars.
	Energy - other mobile sources	Aircraft movements supplied for FI and Montserrat. Some off road machinery for Falklands also supplied.	EMEP/CORINAIR factors, off road machinery from NAEI 2002/2003	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. No estimates for the Cayman Islands have been made for other mobile sources.
2	Industrial processes	Population, GDP	Some sources assumed zero. Per capita emission factors based on UK/Gibraltar 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 were based on figures calculated for Gibraltar rather than for the UK - it was assumed that trends in the use of air conditioning etc would be similar.
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. In practice, for these overseas territories, this is unlikely. This source is not important for direct greenhouse gases.
5	Land use change and forestry			Emissions Not Estimated
6	Waste - MSW	Tonnes of waste incinerated (Falkland Islands), NE for Montserrat and Cayman Islands	US EPA factors for the open burning of municipal refuse, NAEI factors for clinical waste incineration	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 ands 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
1. Energy	0.98	0.99	1.00	1.02	1.03	1.04	1.05	1.05	1.05	1.08	1.10	1.12	1.13	1.14	1.15	1.15
2. Industrial Processes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3. Solvent and Other Products Use	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
4. Agriculture	0.17	0.17	0.16	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.17	0.17	0.16	0.15	0.15	0.15
5. Land Use, Land Use Change and Forestry	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
6. Waste	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
7. Other	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
Total	**1.22**	**1.23**	**1.23**	**1.26**	**1.27**	**1.29**	**1.28**	**1.28**	**1.28**	**1.32**	**1.35**	**1.37**	**1.37**	**1.37**	**1.38**	**1.38**

A3.9.2.5 Gibraltar Emissions

A greenhouse gas inventory for 2004 Gibraltar has been created which contains annual emission estimates from 1990 to 2004 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. Emission estimates of the indirect greenhouse gases have not been made. Emissions for 2005 are assumed to be equal to those in 2004. 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 A3.9.8** 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. All shipping and aviation emissions are currently classified as international, on the basis that Gibraltar has only one port and one airport.

A summary of the emissions of the direct GHGs from Gibraltar is given in **Table A3.9.9**.

Table A 3.9.8 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. Some fuel use available for industrial combustion.	2003 NAEI, EMEP/CORINAIR default factors used for waste incineration. Carbon content of some industrial fuels supplied.	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, and some data about off-road machinery.	Aircraft factors taken from EMEP/CORINAIR, shipping and off-road machinery from 2003/2002 NAEI.	Incomplete datasets were supplied in many cases - the time series were completed based on passenger number data or interpolated values. The off road machinery data was not in a detailed format - numbers for each type are best estimates.
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.
3	Solvent use	Population, GDP, vehicle and housing numbers, air conditioning usage estimates.	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. There are no direct GHG emissions from this sector.
4	Agriculture	No commercial agricultural activity. No emissions from this sector.		
5	Land use change and forestry			Emissions Not Estimated (NE).
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.	1990 NAEI emission factor used for old incinerator (used in 1990 only) 2003 NAEI emission factor used for new incinerator.	Estimates of waste incinerated between 1990 and 1993 are based on extrapolated values. Data for the remainder of the time series was provide. 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 3.9.9 Emissions of Direct GHGs (kt CO_2 equivalent) from Gibraltar

Sector	Base year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1. Energy	112.2	112.2	123.0	131.6	107.5	122.6	121.3	120.3	126.2	128.6	135.0	140.4	143.1	144.8	148.6	157.8	157.8
2. Industrial Processes	1.13	0.01	0.02	0.02	0.21	0.65	1.13	1.67	2.17	2.87	3.50	4.14	4.75	5.21	5.53	5.94	5.94
3. Solvent and Other Products Use	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
4. Agriculture	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5. Land Use Change and Forestry	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
6. Waste	5.68	5.68	4.66	4.66	4.66	5.37	5.40	5.49	5.52	5.77	5.77	6.85	0.00	0.00	0.00	0.00	0.00
7. Other	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
Total	**119.0**	**117.9**	**127.6**	**136.3**	**112.3**	**128.6**	**127.8**	**127.5**	**133.9**	**137.2**	**144.3**	**151.4**	**147.9**	**150.0**	**154.1**	**163.7**	**163.7**

Notes

No emissions from military activities, shipping or aviation are included in the above totals

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 1% lower to 3 % 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
- Non-Fuel industrial processes

In principle the IPCC Reference Total can be compared with the IPCC Table 1A Total plus the emissions arising from fuel consumption in 1B1 Solid Fuel Transformation and Table 2 Industrial Processes (Iron and Steel and Ammonia Production). The IPCC Reference totals range between 1% lower to 3 % higher than the comparable bottom up totals.

1. 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' DTI, 2005), 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 the DTI 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. Time series of UK statistical differences can be found in Table 1.1.2 at:
www.dti.gov.uk/energy/inform/energy_stats/total_energy/index.shtml

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.

2. 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.

3. 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.

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

Table A4.3.1 shows the percentage differences between the IPCC Reference Approach and the National 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 National Approach

Year	1990	1991	1992	1993	1994	1995
Percentage difference	-1.1	0.3	1.3	0.8	1.2	2.9

Year	1996	1997	1998	1999	2000	2001
Percentage difference	1.2	0.7	1.6	2.2	2.4	2.0

Year	2002	2003	2004	2005
Percentage difference	1.4	0.6	1.5	2.4

A5 ANNEX 5: Assessment of Completeness

A5.1 ASSESSMENT OF COMPLETENESS

Table A5.1.1 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; Table "Table9s1".

Table A 5.1.1 GHGs and sources not considered in the UK GHG inventory

GHG	CRF sector	Source/sink category	Reason
CO_2	2. Industrial Processes	2A5/6 Asphalt Roofing/Paving	No methodology available but considered negligible
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	5A1/5A2/5B2/5C1/5C2/5E Biomass burning by Wildfires	Methodology being developed - believed small
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	5A1/5A2 Direct N2O emissions from N fertilisation	Methodology being developed (emissions small)
N_2O	5. Land-Use Change and Forestry	5A N2O emissions from drainage of soils	Methodology being developed (emissions small)
N_2O	5. Land-Use Change and Forestry	5B2 N2O emissions from disturbance associated with LUC to Cropland	Methodology being developed (emissions small)
N_2O	5. Land-Use Change and Forestry	5A1/5A2/5B2/5C1/5C2/5E Biomass burning by Wildfires	Methodology being developed - believed small
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	5. Land-Use Change and Forestry	5A1/5A2/5B2/5C1/5C2/5E Biomass burning by Wildfires	Methodology being developed - believed small
CH_4	6. Waste	6B1 Industrial Waste Water	Activity data unavailable - most waste water treated in public system- believed small
CH_4	6. Waste	6B1 Industrial Waste Water	Activity data unavailable - most waste water treated in public system- believed small

A6 ANNEX 6: Additional Information - Quantitative Discussion of 2005 Inventory

This Annex discusses the emission estimates made in the 1990-2005 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.

A6.1 ENERGY SECTOR (1)

Figure A6.1 and **A6.2** show both emissions of direct and indirect Greenhouse Gases for the Energy sector (category 1) in the UK for the years 1990-2005. Emissions from direct greenhouse gases in this sector have declined 8% since 1990, with a decrease of 0.27% between 2004 and 2005 continuing this trend.

Tables A6.1.1 to **A6.1.4** 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 2005.

A6.1.1 Carbon Dioxide

Analysing emissions by pollutant shows that 98% of total net CO_2 emissions in 2005 came from the Energy sector (**Table A6.1.4**), 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 2% since 1990 and increased by 4% between 2004 and 2005 (**Table A6.1.1**).

Energy industries (category 1A1) were responsible for 38% of the sector's CO_2 emissions in 2005 (**Table A6.1.3**). There has been an overall decline in emissions from this sector of 12% since 1990 (**Table A6.1.1**). Although recently relatively high gas prices have led to more coal being burnt, in general since the privatisation of the power industry in 1990, there has been a move away from coal and oil generation towards combined cycle gas turbines (CCGT) and nuclear power, the latter through greater availability. During this time there has been an increase in the amount of electricity generated but a decrease in CO_2 emissions from Power stations (1A1a). This can be attributed to several reasons. Firstly, the greater efficiency of the CCGT stations compared with conventional stations – around 48% as opposed to 36%•.[7] Secondly, the calorific value of natural gas per unit mass carbon is higher than that of coal and oil and thirdly, the proportion of nuclear generated electricity supplied increasing from 21% to 23%.

[7]• Plant loads, demand and efficiency, Table 5.10, DTI (2006)

Emissions of from category 1A2 – Manufacturing Industries and Construction contributed 15% (**Table A6.1.4**) to overall net CO_2 emissions in the UK in 2005. Since 1990, these emissions have declined by 15%, (**Table A6.1.1**) 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 of natural gas from combustion.

Emissions of CO_2 from 1A3 (Transport) have increased by 11% since 1990 (**Table A6.1.1**). In 2005, this sector contributed 23% (**Table A6.1.4**) to overall CO_2 emissions within the UK. Emissions from transport are dominated by the contribution from road transport (1A3b), which in 2005 contributed 93% to the emissions from transport. Since 1990, emissions from road transport have increased by 10%. In recent years (since around 1998), although the vehicle kilometres driven have continued to increase, the rate of increase in emissions of CO_2 from road transport has slowed. In part this is due to the increasing fuel efficiency of new cars.

Emissions of CO_2 from 1A4 (Other) have increased by 2% since 1990 (**Table A6.1.1**). During this period, residential emissions have increased by over 6% and emissions from the commercial/institutional subsector have decreased by 9%. Fuel consumption data shows a trend away from coal, coke, fuel oil and gas oil towards burning oil and natural gas usage.

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 1990-2005, although they only contribute a small percentage towards emissions from the energy sector.

A6.1.2 Methane

In 2005, 21% (see **Table A6.1.4**) of total methane emissions came from the energy sector, the majority (53%, **Table A6.1.3**) from fugitive emissions from oil and natural gas (1B2). Emissions from this category have decreased by 45% since 1990 (**Table A6.1.1**). 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.

A6.1.3 Nitrous Oxide

The energy sector accounted for 23% of total N_2O emissions in the UK during 2005. Of this, a majority (60%, **Table A6.1.3**) arose from the transport sector (1A3). Between 1990 and 2005, emissions increased by over 325% (**Table A6.1.1**). This is because of the increasing numbers of petrol driven cars fitted with three-way catalytic converters. Catalytic converters 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 and hence emissions from this sector have increased.

The other major contribution towards N_2O emissions within the energy sector comes from the energy industries (1A1). Within this category, emissions from both the public electricity and petroleum refining industries have remained fairly constant and so no particular trend is apparent. Emissions from 1A1c (Manufacture of Solid Fuels and Other Energy Industries), however, have steadily increased between 1990 and 2005 - N_2O emissions have increased overall by 243% since 1990. Over this period the use of coal has decreased and the use of natural gas increased.

A6.1.4 Nitrogen Oxides

In 2005, over 99% of NO_x emissions in the UK came from the energy sector. Since 1990 emissions from this sector have decreased by 45% (**Table A6.1.1**), mostly as a result of abatement measures on power stations, three-way catalytic converters fitted to cars and stricter emission regulations on trucks. The main source of NO_x emissions is transport: in 2005, emissions from transport contributed 42% (**Table 6.4**) to the total emissions of NO_x in the UK, with 34% arising from road transport (1A3b). From 1970, emissions from transport increased (especially during the 1980s) and reached a peak in 1989 before falling by 53% (**Table A6.1.1**) since 1990. This reduction in emissions is due to the requirement since the early 1990s for new petrol cars to be fitted with catalytic converters 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 28% (**Table A6.1.4**) to total NO_x emissions in the UK during 2005. Between 1990 and 2005, emissions from this sector decreased by 46% (**Table A6.1.1**). The main reason for this was a decrease in emissions from public electricity and heat (1A1a) of 54%. 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 29% (**Table A6.1.1**) since 1990. In 2005, emissions from this sector contributed 16% (**Table A6.1.4**) to overall emissions of NO_x. Over this period, the iron and steel sector has seen a move away from the use of coal, coke and fuel oil towards natural gas and gas oil usage.

A6.1.5 Carbon Monoxide

Emissions of carbon monoxide from the energy sector contributed 93% (**Table A6.1.4**) to overall UK CO emissions in 2005. Of this, 54% of emissions (**Table A6.1.3**) occur from the transport sector. Since 1990, emissions from 1A3 have declined by almost 78% (**Table A6.1.1**), which is mainly because of the increased use of catalytic converters, although a proportion is a consequence of fuel switching in moving from petrol to diesel cars.
Emissions from sector 1A2 contributed 21% (**Table A6.1.4**) to overall emissions of CO in 2005. 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.

A6.1.6 Non Methane Volatile Organic Compounds

In 2005, 43% (**Table A6.1.4**) 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 21% (**Table A6.1.4**) towards the overall UK emissions of NMVOCs in 2005. 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 13% (**Table A6.1.4**) to overall emissions of NMVOC in the UK in 2005. Since 1990, emissions from this sector have decreased by 85% (**Table A6.1.1**) due to the increased use of catalytic converters on cars.

A6.1.7 Sulphur Dioxide

95% (**Table A6.1.4)** of emissions of sulphur dioxide came from the energy sector in 2005. 69% (**Table A6.1.3**) 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 the power stations have declined by 81%. This decline has been due to the increase in the proportion of electricity generated in nuclear plant and the use of CCGT stations and other gas fired plant. CCGTs run on natural gas and are more efficient (see **Section A6.1.1.1**) than conventional coal and oil stations and have negligible SO_2 emissions.

Emissions from Manufacturing, Industry and Construction were responsible for 17% (**Table A6.1.4**) of UK emissions of SO_2 in 2005. Since 1990, emissions from this sector have declined by 71% (**Table A6.1.1**). 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 A6.1: UK emissions of Direct Greenhouse Gases from IPCC sector 1, 1990-2005

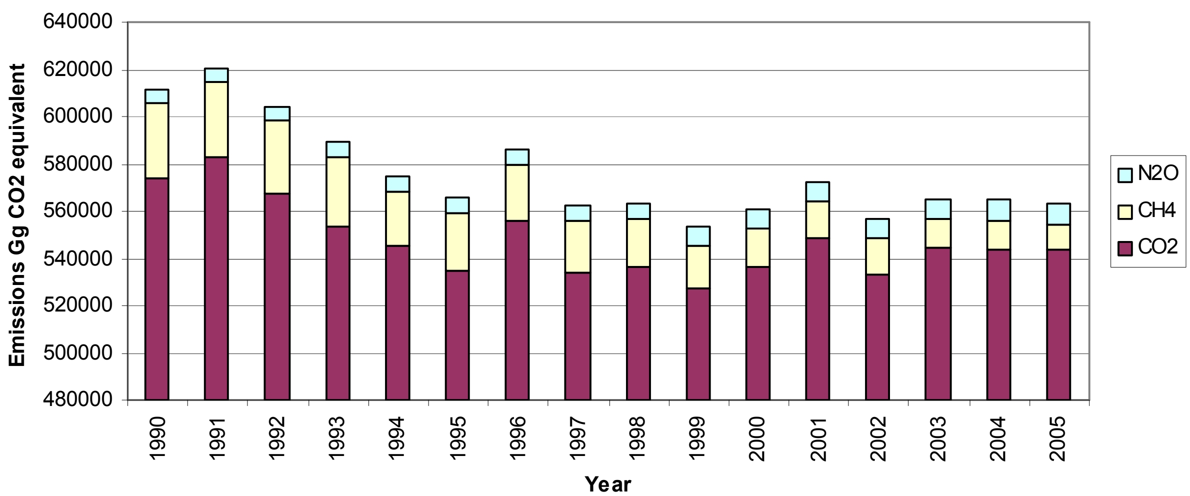

Figure A6.2: UK emissions of Indirect Greenhouse Gases from IPCC sector 1, 1990-2005

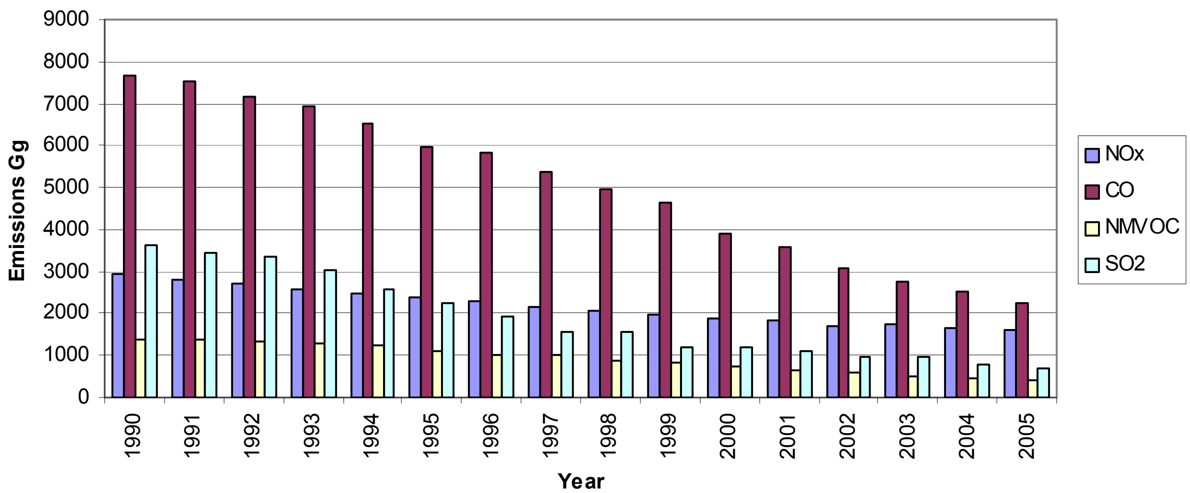

Table A 6.1.1 % Changes from 1990 to 2005 in Sector 1

% changes 1990-2005 within sector 1

	CO2	CH4	N2O	NOx	CO	NMVOC	SO2
1A1	-12%	80%	-16%	-46%	-25%	-31%	-84%
1A2	-15%	-15%	-13%	-29%	-24%	-4%	-71%
1A3	11%	-72%	325%	-53%	-78%	-85%	-54%
1A4	2%	-69%	-33%	-15%	-68%	-48%	-85%
1A5	-47%	-47%	-47%	-47%	-47%	-47%	-45%
1B1	-87%	-79%	-53%	-55%	-84%	-67%	-63%
1B2	-0.2%	-45%	6%	-78%	-42%	-47%	-84%
Overall	**-2%**	**-66%**	**57%**	**-45%**	**-71%**	**-70%**	**-81%**

Table A 6.1.2 % Changes from 2004 to 2005 in Sector 1

% changes 2004-2005 within sector 1

	CO2	CH4	N2O	NOx	CO	NMVOC	SO2
1A1	1%	64%	23%	2%	15%	-15%	-21%
1A2	1%	-1%	1%	0%	0%	1%	-5%
1A3	1%	-10%	1%	-5%	-16%	-16%	15%
1A4	-4%	-10%	-5%	-6%	-15%	-7%	-18%
1A5	-4%	-3%	-4%	-8%	-4%	-6%	-5%
1B1	-35%	-23%	-44%	-29%	-7%	13%	-10%
1B2	12.7%	-6%	15%	2%	3%	-1%	-6%
Overall	**4%**	**-12%**	**4%**	**-2%**	**-12%**	**-7%**	**-16%**

Table A 6.1.3 % Contribution to Sector 1

% contribution to sector 1

	CO2	CH4	N2O	NOx	CO	NMVOC	SO2
1A1	38%	2%	17%	28%	4%	1%	69%
1A2	16%	3%	15%	16%	23%	6%	18%
1A3	24%	2%	60%	42%	54%	31%	6%
1A4	20%	5%	7%	11%	18%	13%	5%
1A5	1%	0%	0%	1%	0%	0%	1%
1B1	0%	36%	0%	0%	0%	0%	1%
1B2	1%	53%	0%	0%	1%	48%	0%

Table A 6.1.4 % Contribution to Overall Pollutant Emissions

% contribution to overall pollutant emissions

	CO2	CH4	N2O	NOx	CO	NMVOC	SO2
1A1	38%	1%	4%	28%	4%	1%	65%
1A2	15%	1%	4%	16%	21%	3%	17%
1A3	23%	0%	14%	42%	50%	13%	6%
1A4	20%	1%	2%	11%	17%	6%	4%
1A5	1%	0%	0%	1%	0%	0%	1%
1B1	0%	8%	0%	0%	0%	0%	1%
1B2	1%	11%	0%	0%	1%	21%	0%
Overall	**98%**	**21%**	**23%**	**99.7%**	**93%**	**43%**	**95%**

A6.2 INDUSTRIAL PROCESSES SECTOR (2)

Figure A6.3 and **A6.4** show both emissions of direct and indirect Greenhouse Gases for the UK industrial processes sector in 1990-2005. Emissions from direct Greenhouse gases within this sector have decreased by 50% since 1990. **Tables A6.2.1** to **A6.2.4** 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 2005.

A6.2.1 Carbon Dioxide

The industrial processes sector is not a major source of emissions in the UK for carbon dioxide. In 2005, just 2% (**Table A6.2.4**) of UK emissions originated from this sector.

A6.2.2 Methane

Emissions of methane from the industrial processes sector are very small and have a negligible effect on overall methane emissions in the UK.

A6.2.3 Nitrous Oxide

In 2005, 7% (**Table A6.2.4**) of N_2O emissions in the UK came from the industrial processes sector. Between 1990 and 2005, emissions from this sector declined by an estimated 89% (**Table A6.2.1**) 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.

A6.2.4 Hydrofluorocarbons

Table A6.2.4 shows that the industrial processes sector was responsible for 100% of emissions of HFCs in the UK in 2005. Since 1990, emissions of HFCs have decreased by 19% (**Table A6.2.1**). The largest contribution to this sector in 2005 arises from category 2F1 – refrigeration and air conditioning equipment. In 2005, these contributed 55% (**Table A6.2.4**) 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 (30%, **Table A6.2.4**) 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 the medical use in metered does inhalers (MDI).

The remaining emissions arise from foam blowing (6%, **Table A6.2.4**), by-product emissions (4%, **Table A6.2.4**) and fire extinguishers (3%, **Table A6.2.4**). A small emission also arises from the use of HFCs as a cover gas in aluminium and magnesium foundries.

A6.2.5 Perfluorocarbons

In 2005, 100% (**Table A6.2.4**) of PFC emissions came from the industrial processes sector. Since 1990, emissions from this sector have declined by 75% (**Table A6.2.1**), although a 4% increase has occurred (**Table A6.2.2**) since 2004. Within this sector, the main contribution to emissions comes from aluminium production (44%, **Table A6.2.4**). 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 an 88% decrease (**Table A6.2.1**) due to significant improvements in process control and an increase in the rate of aluminium recycling.

The next largest emissions occur from fugitives. In 2004, this contributed 31% (**Table A6.2.4**) to overall PFC totals in the UK. The remaining contribution arises from 2F8, which includes a range of sources including the semiconductor and electronics industries. In 2004, this sector contributed 25% (**Table A6.2.4**) to overall PFC emissions in the UK .

A6.2.6 Sulphur Hexaflouride

In 2005, the industrial processes sector contributed 100% (**Table A6.2.4**) of emissions of SF_6 in the UK. Emissions arise from two main sectors. The use of SF_6 in aluminium and magnesium foundries contributed 25% (**Table A6.2.4**) towards total emissions in 2005. Emissions from 2F6 – Other contributed 75% (**Table A6.2.4)** 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 increased by 11% (**Table A6.2.1**).

A6.2.7 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 A6.2.4**).

A6.2.8 Carbon Monoxide

During 2005, emissions from the industrial sector contributed 6% (**Table A6.2.4**) 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 A6.2.3**. Since 1990, emissions from this sector have decreased by 50% **(Table A6.2.1**).

A6.2.9 Non Methane Volatile Organic Compounds

In 2005, emissions from the industrial processes sector contributed 15% (**Table A6.2.4**) to overall UK emissions of NMVOCs. The majority of emissions within this category come from the pulp and paper sector. Emissions also arise from the chemical industry.

A6.2.10 Sulphur Dioxide

In 2005, SO_2 emissions from the industrial processes sector contributed just 5% (**Table A6.2.4**) 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 38% (**Table A6.2.1**).

Figure A6.3: UK emissions of Direct Greenhouse Gases from IPCC sector 2, 1990-2005

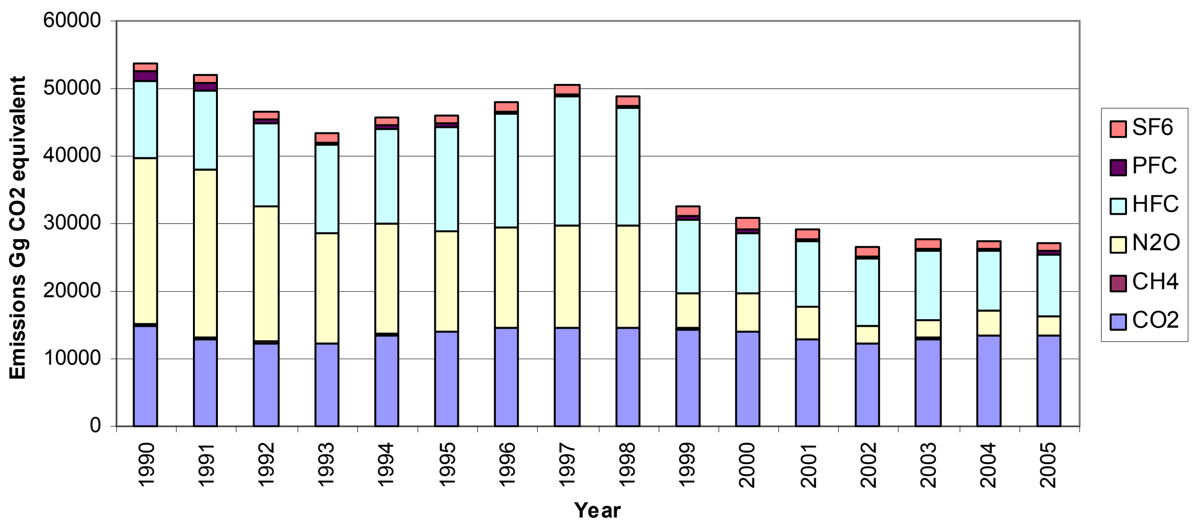

Figure A6.4: UK emissions of Indirect Greenhouse Gases from IPCC sector 2, 1990-2005

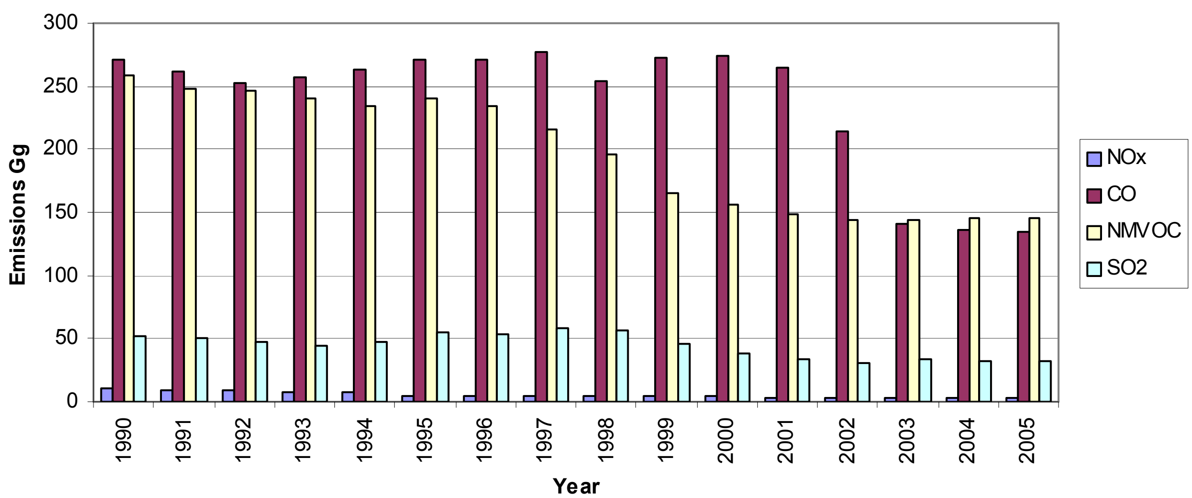

Table A 6.2.1 % Changes from 1990 to 2005 in Sector 2

% changes 1990-2005 within sector 2

	CO2	CH4	N2O	HFC	PFC	SF6	NOx	CO	NMVOC	SO2
2A1	-19%									
2A2	-38%									
2A3	-2%									
2A4	21%									
2A5										
2A6									-23%	
2A7	-28%	-54%						-19%	-31%	300%
2B1	-15%									
2B2			-48%				-92%			
2B3			-96%							
2B4										
2B5	16%	-69%					-47%	-69%	-67%	-82%
2C1	1%	8%	-22%				-22%	-35%	-23%	-58%
2C2										
2C3	26%				-88%		-57%	34%		46%
2C4						-32%				
2C5								-99%		-34%
2D1									-95%	
2D2									7%	
2E1				-97%						
2E2					911%					
2E3										
2F1				68663440%	-100%					
2F2										
2F3										
2F4				165038%						
2F5										
2F8					49%	41%				
2G										
Overall	**81%**	**-60%**	**-89%**	**-19%**	**-75%**	**11%**	**-78%**	**-50%**	**-44%**	**-38%**

Table A 6.2.2 % Changes from 2004 to 2005 in Sector 2

% changes 2004-2005 within sector 2

	CO2	CH4	N2O	HFC	PFC	SF6	NOx	CO	NMVOC	SO2
2A1	-1%									
2A2	-9%									
2A3	-8%									
2A4	13%									
2A5										
2A6									-4%	
2A7	-1%	-15%						64%	35%	4%
2B1	-11%									
2B2			-24%				-14%			
2B3			-16%							
2B4										
2B5	2%	27%					-43%	-13%	2%	-20%
2C1	25%	27%	5%				4%	-2%	-2%	26%
2C2										
2C3	2%				1%		1%	3%		10%
2C4				42%		-26%				
2C5								1%		23%
2D1									-5%	
2D2									-2%	
2E1				20%						
2E2					22%					
2E3										
2F1				0%		0%				
2F2				11%						
2F3				2%						
2F4				6%						
2F5				37%						
2F8				3%	-8%	16%				
2G										
Overall	**102%**	**18%**	**-22%**	**3%**	**4%**	**1%**	**-8%**	**-2%**	**0%**	**0%**

Table A 6.2.3 % Contribution to Sector 2

% contribution to sector 2

	CO2	CH4	N2O	HFC	PFC	SF6	NOx	CO	NMVOC	SO2
2A1	40%									
2A2	5%									
2A3	9%									
2A4	2%									
2A5										
2A6									5%	
2A7	1%	15%						3%	2%	53%
2B1	8%									
2B2			72%				26%			
2B3			28%							
2B4										
2B5	16%	60%					8%	19%	38%	21%
2C1	14%	25%	0%				50%	56%	1%	4%
2C2										
2C3	4%				44%		15%	22%		18%
2C4				0%		25%				
2C5								0%		4%
2D1									0%	
2D2									54%	
2E1				4%						
2E2					31%					
2E3										
2F1				55%		0%				
2F2				6%						
2F3				3%						
2F4				30%						
2F5				0%						
2F8				1%	25%	75%				
2G										

Table A 6.2.4 % Contribution to Overall Pollutant Emissions

% contribution to overall pollutant emissions

	CO2	CH4	N2O	HFC	PFC	SF6	NOx	CO	NMVOC	SO2
2A1	1%									
2A2	0%									
2A3	0%									
2A4	0%									
2A5										
2A6									1%	
2A7	0%	0%						0%	0%	2%
2B1	0%									
2B2			5%				0.04%			
2B3			2%							
2B4										
2B5	0%	0%					0.01%	1%	6%	1%
2C1	0%	0%	0%				0.08%	3%	0%	0%
2C2										
2C3	0%				44%		0.02%	1%		1%
2C4				0%		25%				
2C5								0%		0%
2D1									0%	
2D2									8%	
2E1				4%						
2E2					31%					
2E3										
2F1				55%		0%				
2F2				6%						
2F3				3%						
2F4				30%						
2F5				0%						
2F8				1%	25%	75%				
2G										
Overall	**2%**	**0.14%**	**7%**	**100%**	**100%**	**100%**	**0.15%**	**6%**	**15%**	**5%**

A6.3 SOLVENTS AND OTHER PRODUCT USE SECTOR (3)

Only emissions of NMVOCs occur from the solvents category. **Figure A6.5** displays total NMVOC emissions for 1990-2005. **Tables A6.3.1-6.3.4** 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 2005. Emissions from this sector contribute 41% to overall emissions of NMVOC in the UK (**Table A6.3.4**), and since 1990 emissions have declined by 41% (**Table A6.3.1**).

The largest source of emissions within the solvents sector is category 3D (solvent and other product use: other), contributing 59% of NMVOC emissions in this sector (**Table A6.3.3**).

Figure A6.5: UK emissions of NMVOC from IPCC sector 3, 1990-2005

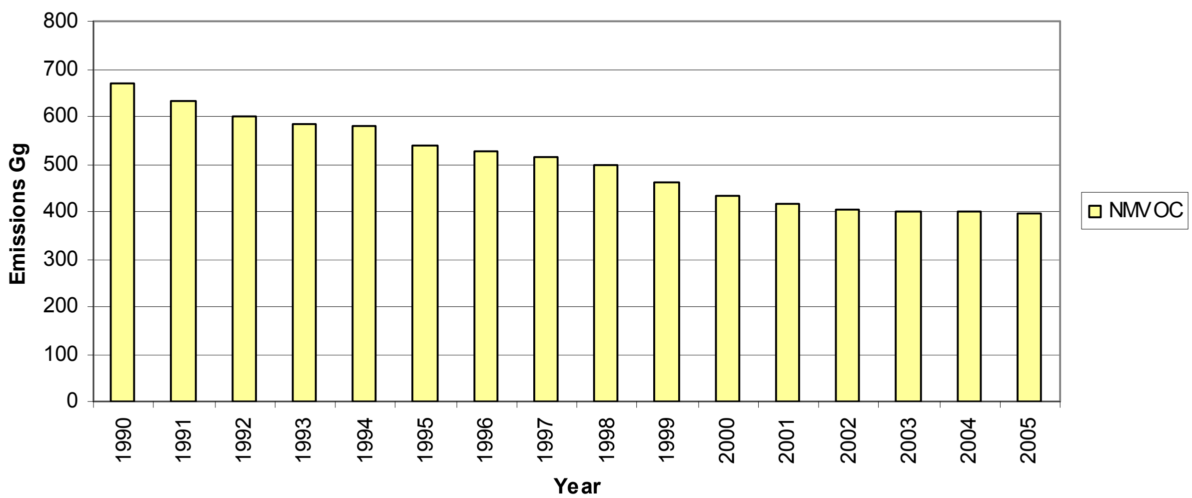

Table A 6.3.1 % Changes 1990-2005 within Sector 3

% changes 1990-2005 within sector 3

	NMVOC
3A	-43%
3B	-62%
3C	-68%
3D	-29%
Overall	**-41%**

Table A 6.3.2 % Changes 2004-2005 within Sector 3

% changes 2004-2005 within sector 3

	NMVOC
3A	1%
3B	5%
3C	2%
3D	-1%
Overall	**-0.3%**

Table A 6.3.3 % Contribution to Sector 3

% contribution to sector 3

	NMVOC
3A	30%
3B	8%
3C	4%
3D	59%

Table A 6.3.4 % Contribution to Overall Pollutant Emissions

% contribution to overall pollutant emissions

	NMVOC
3A	12%
3B	3%
3C	2%
3D	24%
Overall	**41%**

A6.4 AGRICULTURE SECTOR (4)

Figures A6.6 and **A6.7** show both emissions of direct and indirect greenhouse gases for the agricultural sector (category 4) in the UK for the years 1990-2005. Emissions of direct greenhouse gases from this sector have decreased by 16% since 1990.

Tables A6.4.1-A6.4.4 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 2005.

A6.4.1 Methane

Agriculture is the second largest source of methane in the UK, and in 2005 emissions from this sector totalled 37% (**Table A6.4.4**) of the UK total. Since 1990, methane emissions from agriculture have declined by 15% (**Table A6.4.1**). 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 A6.4.3**), and 24% of total methane emissions in 2004 (**Table A6.4.4**). Since 1990, emissions from this sector have declined by 11% (**Table A6.4.1**) and this is due to a decline in cattle numbers over this period.

A6.4.2 Nitrous Oxide

In 2005, nitrous oxide emissions from agriculture contributed 67% (**Table A6.4.4**) to the UK total emission. Of this, 95% (**Table A6.4.4**) came from the agricultural soils sector, 4D. Since 1990, emissions of N_2O from the agricultural sector have declined by 17% (**Table A6.4.1**), driven by a fall in synthetic fertiliser application and a decline in animal population over this period.

A6.4.3 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.

A6.4.4 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.

A6.4.5 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 A6.6: UK emissions of Direct Greenhouse Gases from IPCC sector 4, 1990-2005

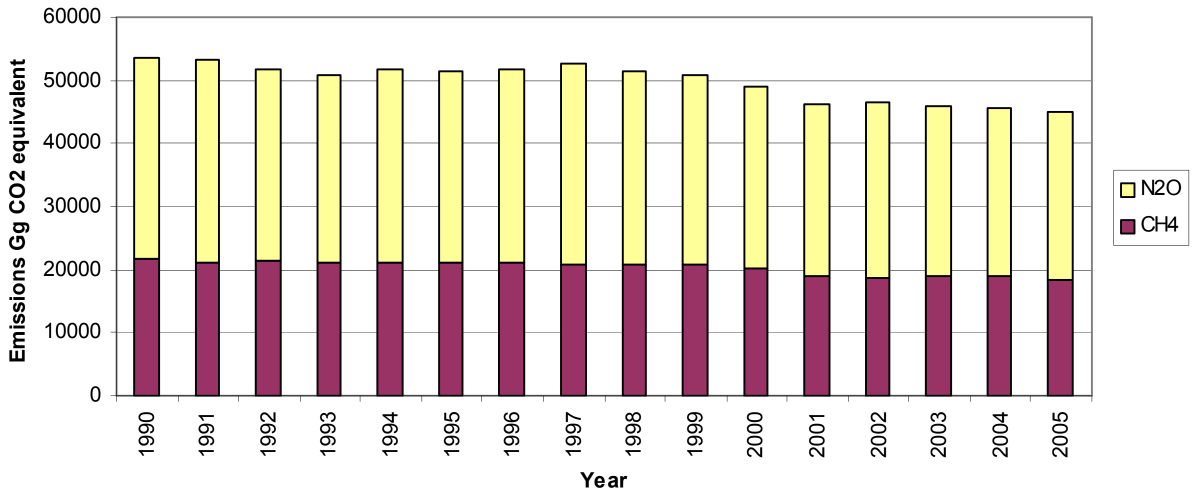

Figure A6.7: UK emissions of Indirect Greenhouse Gases from IPCC sector 4, 1990-2005

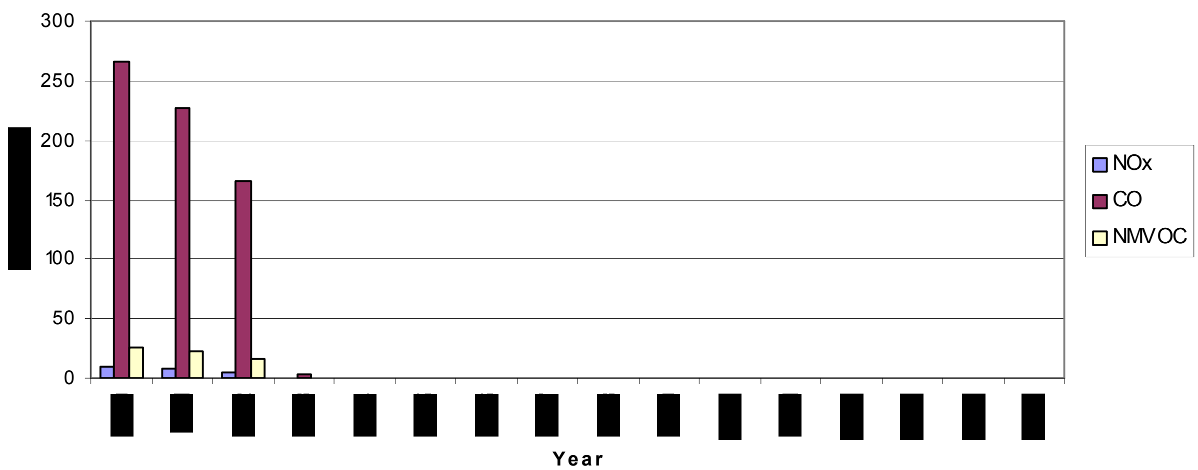

Table A 6.4.1 % Changes 1990-2005 within Sector 4

% changes 1990-2005 within sector 4

	CH4	N2O	NOx	CO	NMVOC
4A1	-11%				
4A2					
4A3	-20%				
4A4	-15%				
4A5					
4A6	71%				
4A7					
4A8	-38%				
4A9					
4A10	-21%				
4B1	-13%				
4B2					
4B3	-20%				
4B4	-15%				
4B5					
4B6	71%				
4B7					
4B8	-38%				
4B9	24%				
4B10					
4B11		-22%			
4B12		-17%			
4B13		-8%			
4B14					
4C					
4D		-17%			
4E					
4F1	-100%	-100%	-100%	-100%	-100%
4F2					
4F3					
4F4					
4F5	-100%	-100%	-100%	-100%	-100%
4G					
Overall	**-15%**	**-18%**	**-100%**	**-100%**	**-100%**

Table A 6.4.2 % Changes 2004-2005 within Sector 4

% changes 2004-2005 within sector 4

	CH4	N2O	NOx	CO	NMVOC
4A1	-2%				
4A2					
4A3	-4%				
4A4	5%				
4A5					
4A6	5%				
4A7					
4A8	-9%				
4A9					
4A10	1%				
4B1	-1%				
4B2					
4B3	-4%				
4B4	5%				
4B5					
4B6	5%				
4B7					
4B8	-9%				
4B9	-2%				
4B10					
4B11		-4%			
4B12		-3%			
4B13		0%			
4B14					
4C					
4D		-1%			
4E					
4F1					
4F2					
4F3					
4F4					
4F5					
4G					
Overall	**-2%**	**-1%**			

Table A 6.4.3 % Contribution to Sector 4

% contribution to sector 4

	CH4	N2O	NOx	CO	NMVOC
4A1	65%				
4A2					
4A3	19%				
4A4	0%				
4A5					
4A6	1%				
4A7					
4A8	1%				
4A9					
4A10	1%				
4B1	10%				
4B2					
4B3	0%				
4B4	0%				
4B5					
4B6	0%				
4B7					
4B8	2%				
4B9	2%				
4B10					
4B11		0%			
4B12		4%			
4B13		1%			
4B14					
4C					
4D		95%			
4E					
4F1					
4F2					
4F3					
4F4					
4F5					

Table A 6.4.4 % Contribution to Overall Pollutant Emissions

% contribution to overall pollutant emissions

	CH4	N2O	NOx	CO	NMVOC
4A1	24%				
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	1%				
4B9	1%				
4B10					
4B11		0%			
4B12		3%			
4B13		1%			
4B14					
4D		63%			
4E					
4F1					
4F2					
4F3					
4F4					
4F5					
Overall	**37%**	**67%**	**0%**	**0%**	**0%**

A6.5 LAND USE, LAND USE CHANGE AND FORESTRY (5)

Figures A6.8 and **A6.9** 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 1990-2005.

Tables A6.5.1 and **A6.5.2** summarise the changes observed through the time series for each pollutant.

A6.5.1 Carbon Dioxide

Figure 6.8 shows net emissions/removals of carbon dioxide. Since 1990, there has been a change in net emissions of carbon dioxide of -171%. In 2005, the total removals from this sector are greater than the emissions, so that the net value is negative. Most emissions from land-use change and forestry arise from the emissions of CO_2 from cropland (5B), whilst the majority of CO_2 removals occur in sector 5A (forestry).

A6.5.2 Methane

Emissions of methane from Land Use Change and Forestry are emitted from the grassland and settlements categories (5C and 5E). Emissions from this sector have declined by 1% since 2004 (**Table A6.5.2**), but have increased overall by 56% since 1990 (**Table A6.5.1**).

A6.5.3 Nitrous Oxide

Emissions of nitrous oxide from Land Use Change and Forestry are emitted from the grassland and settlements categories (5C and 5E). Emissions of nitrous oxide from this sector have increased by 56% since 1990 (**Table A6.5.1**), and shown a decline of 1% since 2004 (**Table A6.5.2**).

A6.5.4 Nitrogen Oxides

Emissions of nitrogen oxides from Land Use Change and Forestry are emitted from the grassland and settlements categories (5C and 5E). Emissions from this sector have declined by 1% since 2004 (**Table A6.5.2**), but have increased overall by 56% since 1990 (**Table A6.5.1**).

A6.5.5 Carbon Monoxide

Emissions of carbon monoxide from Land Use Change and Forestry are emitted from the grassland and settlements categories (5C and 5E), due to the burning of biomass.

Figure A6.8: UK net emissions/removals of Direct Greenhouse Gases from IPCC sector 5, 1990-2005

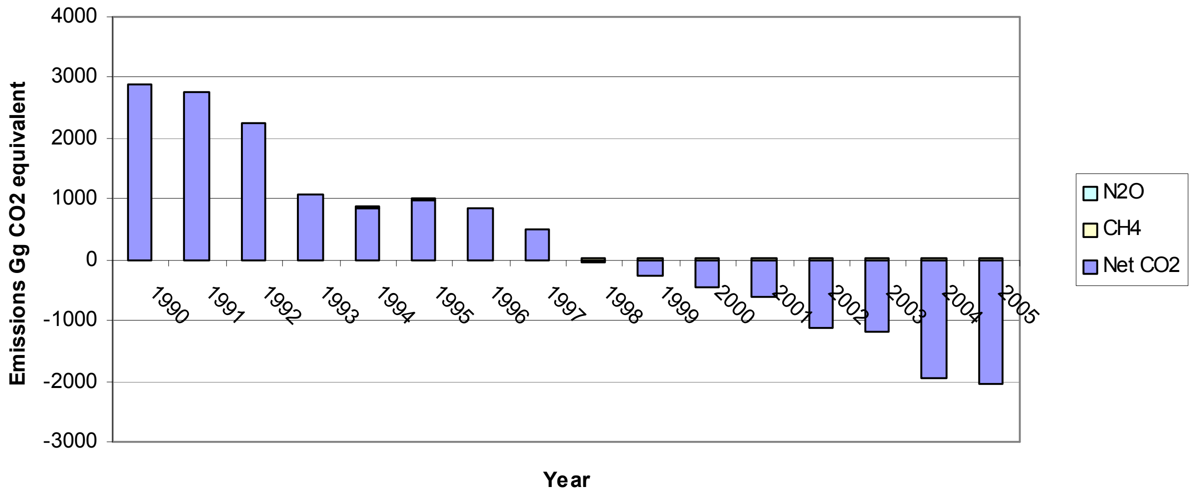

Figure A6.9: UK emissions of Indirect Greenhouse Gases from IPCC sector 5, 1990-2005

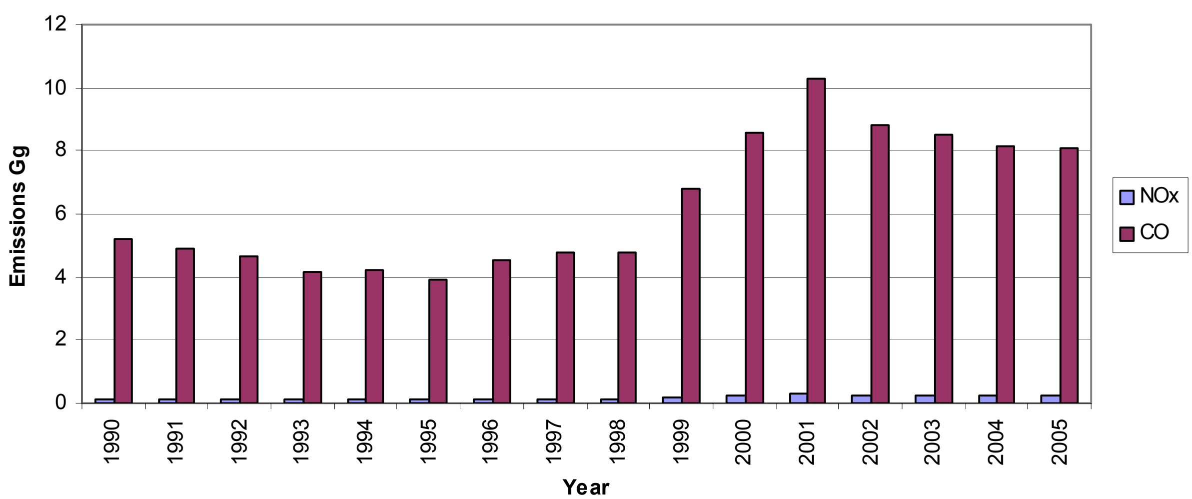

Table A 6.5.1 % Changes 1990-2005 within Sector 5

% changes 1990-2005 within sector 5

	CO2	CH4	N2O	NOx	CO
5A	29%				
5B	-4%				
5C	28%	289%	289%	289%	289%
5D					
5E	-9%	-20%	-20%	-20%	-20%
5F					
5G	-107%				
Overall	**-171%**	**56%**	**56%**	**56%**	**56%**

Table A 6.5.2 % Changes 2004-2005 within Sector 5

% changes 2004-2005 within sector 5

	CO2	CH4	N2O	NOx	CO
5A	-3%				
5B	0%				
5C	1%	1%	1%	1%	1%
5D					
5E	0%	-3%	-3%	-3%	-3%
5F					
5G	-84%				
Overall	**5%**	**-1%**	**-1%**	**-1%**	**-1%**

A6.6 WASTE (6)

Figures A6.10 and **A6.11** show emissions of both direct and indirect greenhouse gases from the waste category (sector 6) in the UK for the years 1990-2005. Emissions from direct greenhouse gases in this sector have declined by 58% since 1990. This is mostly as a result of a decline in methane emissions, although emissions of nitrous oxide have shown an increase.

Tables A6.6.1 to **A6.6.4** 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 2005.

A6.6.1 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 A6.6.4**). Since 1990, CO_2 emissions arising from the waste sector have decreased by 62% (**Table A6.6.1**), but have shown a small increase since 2004 (1.6%, **Table A6.6.2**), due to a revision to the emission factor for chemical waste incineration.

A6.6.2 Methane

Emissions of methane from the waste sector accounted for around 41% (**Table A6.6.4**) of total CH_4 emissions in the UK during 2005. 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 A6.6.3**). Emissions estimates from landfill are derived from the amount of putrescible 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 accounts for the effects of methane recovery, utilisation and flaring. Since 1990, methane emissions from landfill have declined by 61% (**Table 6.6.1**) 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.

A6.6.3 Nitrous Oxide

Nearly all nitrous oxide waste emissions in the UK occur from the wastewater handling sector (see **Table A6.6.3**). Since 1990, N_2O emissions from this sector have increased by 18% (**Table A6.6.1**). Overall, this sector contributes just 3% (**Table A6.2.4**) to overall nitrous oxide emissions.

A6.6.4 Nitrogen Oxides

Emissions of NO_X from the waste category have a negligible effect on overall UK emissions.

A6.6.5 Carbon Monoxide

Emissions of CO from the waste category have a negligible effect on overall UK emissions, contributing less than 1% during 2005 (**Table A6.2.4**).

A6.6.6 Non-Methane Volatile Organic Compounds

Emissions of NMVOC from the waste category have a very small influence (1.6%, **Table A6.24**) on overall UK emissions.

A6.6.7 Sulphur Dioxide

Emissions of SO_2 from the waste category have a negligible effect on overall UK emissions.

Figure A6.10: UK emissions of Direct Greenhouse Gases from IPCC sector 6, 1990-2005

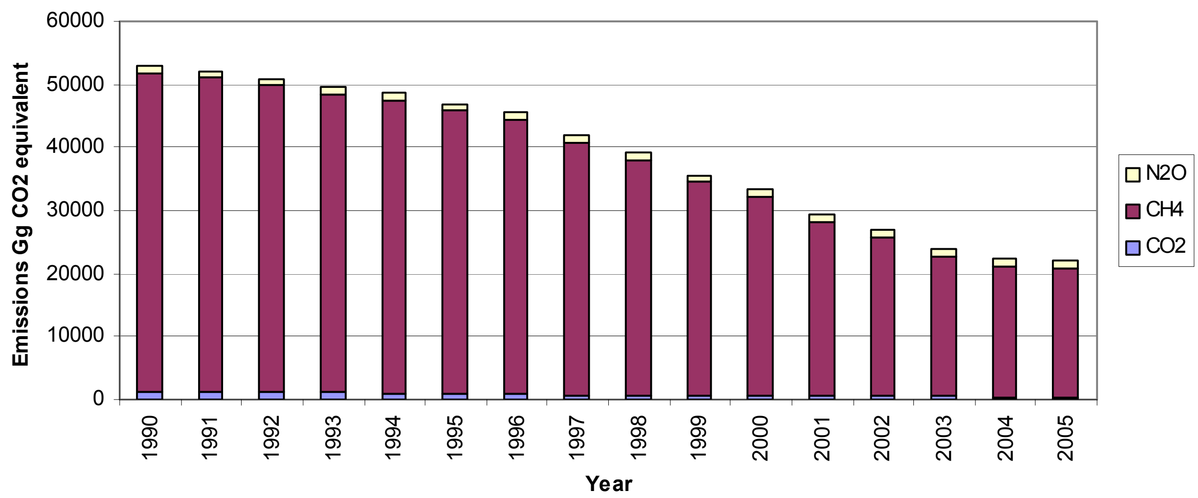

Figure A6.11: UK emissions of Indirect Greenhouse Gases from IPCC sector 6, 1990-2005

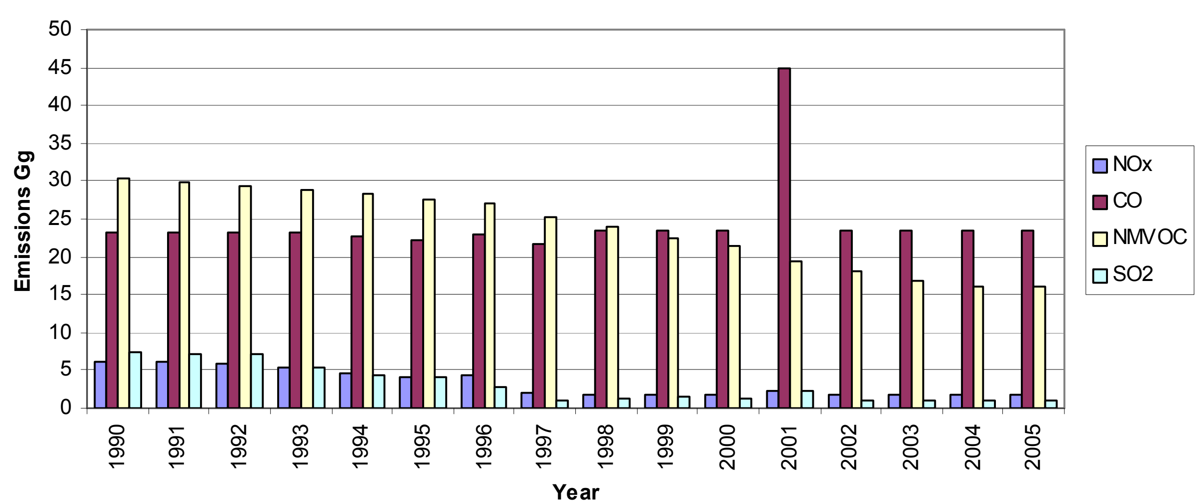

Table A 6.6.1 % Changes 1990-2005 within Sector 6

% changes 1990-2005 within sector 6

	CO2	CH4	N2O	NOx	CO	NMVOC	SO2
6A1		-61%	-18%			-61%	
6B2		14%	18%				
6C	-62%	-98%	1%	-70%	0%	2%	-88%
Overall	**-62%**	**-60%**	**17%**	**-70%**	**0%**	**-47%**	**-88%**

Table A 6.6.2 % Changes 2004-2005 within Sector 6

% changes 2004-2005 within sector 6

	CO2	CH4	N2O	NOx	CO	NMVOC	SO2
6A1		-2%	-18%			-2%	
6B2		1%	18%				
6C	2%	0%	1%	5%	0%	2%	0%
Overall	**2%**	**-2%**	**0%**	**5%**	**0%**	**0%**	**0%**

Table A 6.6.3 % Contribution to Sector 6

% contribution to sector 6

	CO2	CH4	N2O	NOx	CO	NMVOC	SO2
6A1		96%				58%	
6B2		4%	96%				
6C	100%	0%	4%	100%	100%	42%	100%

Table A 6.6.4 % Contribution to Overall Pollutant Emissions

% contribution to overall pollutant emissions

	CO2	CH4	N2O	NOx	CO	NMVOC	SO2
6A1		39%				1%	
6B2		2%	3%				
6C	0.1%	0.0%	0.1%	0.1%	1%	1%	0%
Overall	**0.1%**	**41.12%**	**3.2%**	**0.1%**	**0.97%**	**1.6%**	**0.1%**

A7 ANNEX 7: Uncertainties

Uncertainty estimates are provided using Tier 2 methods described by the IPCC. This NIR continues a number of improvements that were introduced in the 2006 submission, including presenting estimates of uncertainties according to IPCC sector in addition to presenting estimates by direct greenhouse gas.

The Monte Carlo method was reviewed and revised in this submission, taking into account guidance from the 2006 Good Practice Guidance (IPCC, 2006), from the EUMM Workshop on Uncertainties held in Finland in 2005, and from an internal review of the uncertainty work. The overall method is described below along with a summary of the changes.

A7.1 ESTIMATION OF UNCERTAINTY BY SIMULATION

A7.1.1 Overview of the method

Quantitative estimates of the uncertainties in the emissions were calculated using Monte Carlo simulation. This corresponds to the IPCC Tier 2 approach discussed in the Good Practice Guidance (IPCC, 2000). The background to this work is described in detail by Eggleston *et al* (1998) with the estimates reported here revised to reflect changes in the 2005 inventory. This section gives a brief summary of the methodology, assumptions and results of the simulation. A full description of the new model is to be published shortly.

The computational procedure was:

- A probability distribution function (PDF) was allocated to each unique emission factor and piece of activity data. The PDFs were mostly normal, log-normal or uniform. 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 and carbon dioxide sink, and the global warming potential for the years 1990 and 2005. This analysis includes both 1990 and the 'base year' emissions. In this section, the 'base year' comprises the emissions of CO_2, CH_4 and N_2O for 1990, and the emissions of HFC, PFC and SF_6 for 1995. These 'base year' emissions **are not** those calculated as part of the assessment towards the Kyoto target as the emissions do not include adjustments for Articles 3.3, 3.4 or 3.7
- 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 supply and demand for each fuel. This means that the quoted

uncertainty in **Table A7.1.1** refers to the total fuel consumption rather than the consumption by a particular sector, e.g. residential coal. Hence, to avoid underestimating uncertainties, it was necessary to correlate the uncertainties used for the same fuel in different sectors. In this submission, where possible, emissions data have been correlated by fuel activity in order to minimise underestimation as far as possible.

- The uncertainty in the trend between 1990 and 2005 according to gas was also estimated. This year correlations between years were not used, after a thorough review of the previous model it was found that it had not been performing as expected and had not been performing these correlations. Sensitivity analysis showed that the model was not particularly sensitive to year on year correlation and hence the decision was taken not to implement them in the new model in this submission. This will be kept under review however and should it become appropriate yearly correlations will be added in at a later date.
- The uncertainties for total halocarbon and SF_6 emissions were taken from the recent study on emissions and projections of HFCs, PFCs and SF_6 for the UK and constituent countries (AEAT, 2004).

A7.1.2 Review of main changes from the last submission

An internal review was completed of the Monte carlo uncertainty analysis used in the UK NIR (Abbott *et al.*, 2006). This review was commissioned following suggestions from the FCCC about improvements that the UK could make to the transparency of the UK Monte Carlo uncertainty approach. 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 FCCC comments from the Third Centralised Review, from recommendations made at the EU workshop on uncertainties in Greenhouse Gas Inventories[8], and by the IPCC 2006 Guidelines.

A7.1.2.1 Uncertainty distributions

A7.1.2.1.1 (i) 'Standard' Distributions

The majority of the distributions in the inventory are, or may be assumed to be, normal. The few datasets which are known not to fall into these categories are dealt with using custom distributions.

A7.1.2.1.2 (ii) Custom Distributions

For certain sectors where data are highly correlated or the distributions non-normal, custom correlations or functions have been used. These sectors are:

[8] EU workshop on uncertainties in Greenhouse Gas Inventories Work5-6 September, Helsinki, Finland. Ministry of the Environment, Finland. Arranged by the VTT Technical Research Centre of Finland (Jaakko Ojala, Sanna Luhtala and Suvi Monni).

- Landfill (Distribution calculated from a known data series)
- Sewage Sludge (Distribution calculated from a known data series)
- Agricultural Soils (lognormal, with the 97.5percentile being 100 times the 2.5 percentile)

A7.1.2.2 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 type and implementation of the correlations has been examined as part of the review (Abbott *et al.*, 2006), and the changes that have been made are listed below.

A7.1.2.2.1 i) By year

The review of original the model revealed that the year on year correlations had not been applied correctly, and the model was not accounting for year by year correlations. The current model appears insensitive to the year on year correlations and previous versions of the model would have been insensitive to this correlation also. However, the application of year by year correlations will be reviewed for the next submission.

A7.1.2.2.2 ii) By emission factor and activity

A7.1.2.2.3

A7.1.2.2.4 *The way that the data is obtained from the database ensures that, by aggregating appropriately, activities and emission factors are summed where possible where the emission factors or activity data should be correlated (see* ***A7.1.2.3.c*** *Aggregation). Further to this, the model links PDF's where the data are correlated to ensure that the calculation takes the relationship into account.*

A7.1.2.3 Method Changes

A number of changes have been introduced to the structure of the Monte Carlo model, and these are listed below.

a) 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.

b) Zero emissions removed

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.)
- because data had been included in the analysis for completeness where either the emission factor or the activity data were zero thus leading to a zero emission

The estimated uncertainties were unaffected when the 'zero emissions' were removed from the model.

c) Aggregation

For the new Monte Carlo model, data from the GHG inventory was aggregated 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 pertaining to 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. Where disaggregated data are used, an underestimation of uncertainty is highly likely as individual uncertainties calculated can balance each other out.

A7.1.2.4 F-gas uncertainties updated to match those used in the Error propagation model

The F-gas uncertainties in the error propagation analysis model (referred to as the Tier 1 model in earlier NIRs) were updated in the 2006 NIR with estimates taken from the recent study on emissions and projections of HFCs, PFCs and SF_6 for the UK and constituent countries (AEAT, 2004). The uncertainties in the Monte Carlo model are now identical to those used in the error propagation analysis model.

A7.1.2.5 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. Any changes to the distributions have been reflected in the new model.

A7.1.2.6 Checks

1. Checks against national totals

To ensure the emissions in the Monte Carlo model agree with the nationally reported totals, the emissions in the model were checked against the national totals both before, and after, the simulation was run.

2. Method check

The Monte Carlo model has had a major revision this year. To ensure that the assumptions and the methods used in the model were technically correct, it was reviewed by an experienced chemical engineer with a degree in mathematics and statistics.

3. Sensitivity checks

As discussed above, sensitivity tests were carried out on the models in order to determine the significance of year correlations and the inclusion of zero emission in the previous model.

4. Calculation checks

The uncertainty on the 2005 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.7.1.7** 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.

A7.1.3 Carbon Dioxide Emission Uncertainties

It was necessary to estimate the uncertainties in the activity data and the emission factors for the main sources and then combine them.

The uncertainties in the fuel activity data for major fuels were estimated from the statistical differences data in the UK energy statistics. This is explained further in section A7.2. 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. For natural gas, a correction was made to take account of leakage from the gas transmission system but for other gases this was not possible. 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. This uncertainty was reviewed in 2005. Additional error for this source is also introduced by the use of a model (see A7.2).

The uncertainties in the emission factors were based largely on expert judgement. It was possible to compare the coal emission factors used in the inventory with measurements (Fynes, 1994). Also, Transco (1998) data allowed an estimate of the uncertainty in the carbon content of natural gas. The time series data of the gross calorific value of fuels used in the UK (DTI, 2005) would also give *some indication* of the relative variability in the carbon contents. Thus the uncertainties in the fuel emission factors were based on judgements on whether they were likely to be similar or less than those of coal or natural gas.

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 (2005) 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 recalculated (Milne, 1999) for the revised source categories in the IPCC 1996 Guidelines using data from Eggleston *et al* (1998). A new carbon source – Fletton bricks – has been added, and the uncertainty based on expert assessment of the data used to make the estimate. There has been a very slight revision to the uncertainty used for cement production, based on the estimates reported in IPCC (2000). Clinical waste incineration was assumed to have the same uncertainty as MSW incineration.

The overall uncertainty was estimated as around 2% in 1990 and 2005.

The uncertainty in the trend between 1990 and 2005 was also estimated. In running this simulation it was necessary to make assumptions about the degree of correlation between sources in 1990 and 2005. If source emission factors are correlated this will have the effect of reducing the trend uncertainty. The assumptions were:

- Activity data are uncorrelated
- Emission factors of similar fuels are correlated (i.e. gas oil with gas oil, coke with coke etc)
- 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
- Process emissions from blast furnaces, coke ovens and ammonia plant were not correlated.

The trend was found to range between –8.9% and –3.7% - that is to say this analysis indicated 95% probability that CO_2 emissions in 2004 were between 4% and 9% below the level in 1990.

Table A 7.1.1 Estimated Uncertainties in for fuel based Carbon Dioxide Emissions

	1990		2005	
	UA	UE	UA	UE
Anthracite	1.5	6	0.4	6
Aviation spirit	20	3.3	20	3.3
Aviation turbine fuel	20	3.3	20	3.3
Blast furnace gas	1.5	6	0.4	6
Burning oil	6	2	9.3	2
Burning oil (premium)	6	2	9.3	2
Chemical waste	7	15	7	15
Clinical waste	7	20	7	20
Coal	1.5	1	0.4	1
Coke	3	3	1.3	3
Coke oven gas	1.5	6	0.4	6
Colliery methane	5	5	5	5
DERV	1.8	2.1	1.7	2.1
Dolomite	1	5	1	5
Fuel oil	5.5	1.7	19.7	1.7
Gas oil	1.8	1.4	1.7	1.4
Limestone	1	5	1	5
LPG	25.7	3	12.9	3
Lubricants	20	5	20	5
MSW	7	20	7	20
Naphtha	7.3	3	23.1	3
Natural gas	2.8	1.5	0.2	1.5
OPG	1.4	3	22.8	3
Orimulsion	1	2	1	2
Peat	25	25	25	25
Petrol	1	4.8	2.8	4.8
Petroleum coke	7.8	3	4.2	3
Refinery miscellaneous	11.9	3	87.3	3
Scrap tyres	15	10	15	10
Sour gas	2.8	1	0.2	1
SSF	3.3	3	8.1	3
Waste oils	20	5	20	5
Waste solvent	1	10	1	10

Table A 7.1.2 Estimated Uncertainties for non-fuel based Carbon Dioxide Emissions

	1990		2005	
Sector	UA	UE	UA	UE
1A1a	1	50	1	50
1A1c	7	4	7	4
1A2f	1	50	1	50
1A3b	1	50	1	50
1A4b	1	50	1	50
1A4c	1	50	1	50
1A5b	10	2	10	2
1B2a	1	28	1	28
1B2c	1	14	1	14
1B2c_Flaring	16	6	16	6
1B2c_Venting	16	6	16	6
2A1	1	2.2	1	2.2
2A2	1	5	1	5
2A3	1	5	1	5
2A4	15	2	15	2
2A7	20	70	20	70
2B1	10	1	10	1
2C1	1	20	1	20
2C3	1	5	1	5
5A	1	25	1	25
5B	1	45	1	50
5C	1	70	1	55
5E	1	35	1	50
5G	1	30	1	30
6C	1	50	1	50
7	50	20	50	20

A7.1.4 Methane Emission Uncertainties

In the methane inventory, combustion sources are a minor source of emissions. The review of the activity data uncertainty has been used to estimate the over all uncertainty associated with the methane emissions from these sources, although the effect of the large uncertainty associated with the emission factors in most cases outweighs this. The errors in the major sources are listed in **Tables A7.1.3 and A7.1.4**. 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.

Table A 7.1.3 Estimated Uncertainties in Methane Emissions for 1990 (only major sources are listed)

Source	Reference	Activity %	Emission Factor %	Source Uncertainty %
Coal		1.5	50	
Coke		3	50	
Petroleum coke		7.8	50	
SSF		3.3	50	
Burning oil		6	50	
Fuel oil		5.5	50	
Gas oil		1.8	50	
DERV		1.8	50	
Petrol		1	50	
Orimulsion		1	50	
Aviation turbine fuel		20	50	
Natural gas		2.8	50	
Colliery methane		5	50	
LPG		25.7	50	
OPG		1.4	50	
MSW		7	50	
Sour gas		2.8	50	
Naphtha		7.3	50	
Refinery miscellaneous		11.9	50	
Blast furnace gas		1.5	50	
Coke oven gas		1.5	50	
Town gas		0	50	
Lubricants		20	50	
Waste oils		20	50	
Scrap tyres		15	50	
Aviation spirit		20	50	
Anthracite		1.5	50	
Burning oil (premium)		6	50	
Vaporising oil		0	50	
Clinical waste		7	50	
Poultry litter		7	50	
Landfill gas		5	50	
Sewage gas		5	50	
Wood		30	50	
Straw		50	50	
Sewage sludge combustion		7	50	
Field Burning	‡	-	-	50
Landfill	Brown *et al* 1999	-	-	~48[1]
Livestock: enteric	Williams, 1993	0.1	20	Σ
Livestock: wastes	Williams, 1993	0.1	30	Σ
Coal Mining	Bennett *et al*, 1995	1.2	13	Σ

Source	Reference	Activity %	Emission Factor %	Source Uncertainty %
Offshore	‡	16	20	Σ
Gas Leakage	Williams, 1993	-	-	17-75[2]
Chemical Industry	‡	20	20	Σ
Fletton Bricks	‡	20	100	Σ
Sewage Sludge	Hobson *et al*, 1996	-	-	50

1 Skewed distribution
2 Various uncertainties for different types of main and service
‡ See text
Σ Input parameters were uncertainties of activity data and emission factors

Table A 7.1.4 Estimated Uncertainties in Methane Emissions for 2005 (only major sources are listed)

Source	Reference	Activity %	Emission Factor %	Source Uncertainty %
Coal		0.4	50	
Coke		1.3	50	
Petroleum coke		4.2	50	
SSF		8.1	50	
Burning oil		9.3	50	
Fuel oil		19.7	50	
Gas oil		1.7	50	
DERV		1.7	50	
Petrol		2.8	50	
Orimulsion		1	50	
Aviation turbine fuel		20	50	
Natural gas		0.2	50	
Colliery methane		5	50	
LPG		12.9	50	
OPG		22.8	50	
MSW		7	50	
Sour gas		0.2	50	
Naphtha		23.1	50	
Refinery miscellaneous		87.3	50	
Blast furnace gas		0.4	50	
Coke oven gas		0.4	50	
Town gas		0	50	
Lubricants		20	50	
Waste oils		20	50	
Scrap tyres		15	50	
Aviation spirit		20	50	
Anthracite		0.4	50	
Burning oil (premium)		9.3	50	

Source	Reference	Activity %	Emission Factor %	Source Uncertainty %
Vaporising oil		0	50	
Clinical waste		7	50	
Poultry litter		7	50	
Landfill gas		5	50	
Sewage gas		5	50	
Wood		30	50	
Straw		50	50	
Sewage sludge combustion		7	50	
Field Burning	‡	-	-	50
Landfill	Brown *et al* 1999	-	-	~48[1]
Livestock: enteric	Williams, 1993	0.1	20	Σ
Livestock: wastes	Williams, 1993	0.1	30	Σ
Coal Mining	Bennett *et al*, 1995	1.2	13	Σ
Offshore	‡	16	20	Σ
Gas Leakage	Williams, 1993	-	-	17-75[2]
Chemical Industry	‡	20	20	Σ
Fletton Bricks	‡	20	100	Σ
Sewage Sludge	Hobson *et al*, 1996	-	-	50

1 Skewed distribution
2 Various uncertainties for different types of main and service
‡ See text
Σ Input parameters were uncertainties of activity data and emission factors

The sources quoted in **Tables A7.1.3 and A7.1.4** 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, so in these estimates normal distributions were used rather than truncated normal.

The total emission of methane in 2005 was estimated as 2,360 Gg. The Monte Carlo analysis suggested that 95% of trials were between 1,877 Gg and 2,849 Gg. The total uncertainty was around 21%. The emission of methane in 1990 was estimated as 4,938 Gg.

The uncertainty in the trend between 1990 and 2005 was also estimated. In running this simulation it was necessary to make assumptions about the degree of correlation between sources in 1990 and 2005. If source emission factors are correlated this will have the effect of reducing the emissions. 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.

- Emission factors for animals are correlated across years for a given species.
- 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 crude estimate it was assumed that the degree of correlation should reflect the reduction. Emissions have reduced by 63% hence the degree of correlation was 37%.
- 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 fully correlated across years.
- 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.

On the basis of this analysis there is 95% probability that methane emissions in 2005 were between 34% and 65% below the level in 1990.

A7.1.5 Nitrous Oxide Emission Uncertainties

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 **Tables A7.1.5 and A7.1.6**. 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 Land Management Improvement Division of DEFRA (per. comm.). The uncertainty distribution of the calculated emission was heavily skewed with a mean emission of 128 Gg in 2005 with 95% of the values found to lie between 37 Gg and 474 Gg N_2O.

The uncertainty in the trend between 1990 and 2005 was also estimated. In running this simulation it was necessary to make assumptions about the degree of correlation between sources in 1990 and 2005. If sources are correlated this will have the effect of reducing the emissions. The assumptions were:

- 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, for reasons explained in the 2000 National Inventory Report.
- 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.

95% of the values for the trend were found to lie between -89% and 215%, that is to say the analysis indicates a 95% probability that emissions in 2004 were between 20 below and 215% above the level in 1990.

Table A 7.1.5 Estimated Uncertainties in the Nitrous Oxide Emissions for 1990[1] (only major sources are listed)

	Emission Factor Uncertainty %	Activity Rate Uncertainty %
Coke	195	1.5
Petroleum coke	118	3
SSF	118	7.8
Burning oil	118	3.3
Fuel oil	140	6
Gas oil	140	5.5
DERV	140	1.8
Petrol	170	1.8
Orimulsion	170	1
Aviation turbine fuel	140	1
Natural gas	170	20
Colliery methane	110	2.8
LPG	110	5
OPG	110	25.7
MSW	110	1.4
Sour gas	230	7
Naphtha	110	2.8
Refinery miscellaneous	140	7.3
Blast furnace gas	140	11.9
Coke oven gas	118	1.5
Town gas	118	1.5
Lubricants	118	0
Waste oils	140	20
Scrap tyres	140	20
Aviation spirit	140	15
Anthracite	170	20
Burning oil (premium)	387	1.5
Vaporising oil	140	6
Limestone	140	0
Dolomite	0	1
Clinical waste	0	1
Poultry litter	230	7
Landfill gas	230	7
Sewage gas	110	5
Wood	110	5
Straw	230	30
Sewage sludge combustion	230	50
Agricultural Soils	Log-normal[2]	0

	Emission Factor Uncertainty %	Activity Rate Uncertainty %
Wastewater Treatment	Log-normal[2]	10
Adipic Acid	15	0.5
Nitric Acid	230	10

2 Expressed as 2s/E
3 With 97.5 percentile 100 times the 2.5 percentile

Table A 7.1.6 Estimated Uncertainties in the Nitrous Oxide Emissions for 2005[1] (only major sources are listed)

	Emission Factor Uncertainty %	Activity Rate Uncertainty %
Coke	195	0.4
Petroleum coke	118	1.3
SSF	118	4.2
Burning oil	118	8.1
Fuel oil	140	9.3
Gas oil	140	19.7
DERV	140	1.7
Petrol	170	1.7
Orimulsion	170	2.8
Aviation turbine fuel	140	1
Natural gas	170	20
Colliery methane	110	0.2
LPG	110	5
OPG	110	12.9
MSW	110	22.8
Sour gas	230	7
Naphtha	110	0.2
Refinery miscellaneous	140	23.1
Blast furnace gas	140	87.3
Coke oven gas	118	0.4
Town gas	118	0.4
Lubricants	118	0
Waste oils	140	20
Scrap tyres	140	20
Aviation spirit	140	15
Anthracite	170	20
Burning oil (premium)	387	0.4
Vaporising oil	140	9.3
Limestone	140	0
Dolomite	0	1
Clinical waste	0	1
Poultry litter	230	7
Landfill gas	230	7
Sewage gas	110	5

	Emission Factor Uncertainty %	Activity Rate Uncertainty %
Wood	110	5
Straw	230	30
Sewage sludge combustion	230	50
Agricultural Soils	Log-normal[2]	0
Wastewater Treatment	Log-normal[2]	10
Adipic Acid	15	0.5
Nitric Acid	230	10

1 Expressed as 2s/E
2 With 97.5 percentile 100 times the 2.5 percentile

A7.1.6 Halocarbons and SF_6

The uncertainties in the emissions of HFCs, PFCs and SF_6 were taken from a recent publication on (AEAT, 2004). The uncertainties were estimated as 15% (17%) for HFCs, 6% (11%) for PFCs and 24% (24%) for SF_6 in 1990 (1995), and 10% for HFCs, 5.7% for PFCs and 20% for SF_6 in 2005. The uncertainties were assumed uncorrelated between 1990 and 2005. Trend uncertainties are reported in **Table A7.1.7**.

A7.1.7 GWP Weighted emissions

The uncertainty in the combined GWP weighted emission of all the greenhouse gases in 1990 was estimated as 14% and 15% in 2005. The trend in the total GWP is -15%, with 95% of the values found to lie within the range -28% and 0.5%. The uncertainty estimates for all gases are summarised in **Table A7.1.7**. 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.

In previous years, trend uncertainties from the base year to the current inventory year have also been reported here. This table has not been included this year, to aviod confusion regarding differences in the totals due to the treatment of LULUCF emissions and removals. **Base year emissions can be found in Table ES5**.

Table A 7.1.7 Summary of Monte Carlo Uncertainty Estimates 1990 - 2005

A	B	C	D	E	F	G	H	I	J
IPCC Source Category	Gas	1990 Emissions	2005 Emissions	Uncertainty in 2005 emissions as % of emissions in category		Uncertainty Introduced on national total in 2005	% change in emissions between 2005 and 1990	Range of likely % change between 2005 and 1990	
				2.5 percentile	97.5 percentile			2.5 percentile	97.5 percentile
		Gg CO2 equivalent	Gg CO2 equivalent	Gg CO2 equivalent	Gg CO2 equivalent	%	%	%	%
TOTAL	CO2 (net)	593215	555506	544196	566906	2.1%	-6.3%	-8.9%	-3.7%
	CH4	103713	49553	39411	59832	21.2%	-51%	-65%	-34%
	N2O	63217	39677	11489	146797	233.2%	-20%	-89%	215%
	HFC	11376	9221	7866	10578	15.0%	37%	10%	68%
	PFC	2735	351	331.1	370.9	5.8%	-66%	-68%	-63%
	SF6	1029.0	1143.5	865.8	1418.9	24.5%	22%	-15%	71%
	All	775284	655451	619871	761576	14.3%	-15.2%	-28.7%	0.0%

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%. This is impossible in practice, as it implies negative emissions could occur.
Emissions of CO_2 are net emissions (i.e. sum of emissions and removals).

A7.1.8 Sectoral Uncertainties

Sectoral uncertainties were calculated from the same base data used for the "by gas" analysis. Only CO_2, N_2O and CH_4 are included in the sectoral uncertainty as values for the halocarbon uncertainties are not available at sector level. Where the Monte Carlo simulation returned equal values for the mean and the 95% confidence intervals, the uncertainty introduced on the national total cannot be calculated. The emissions and uncertainties per sector are presented in **Table A7.1.8**.

Table A 7.1.8 Sectoral Uncertainty Estimates

A	B	C	D	E	F	G	H	I	J
Gas	Sector	1990 Emissions	2005 Emissions	Uncertainty in 2005 emissions as % of emissions in category		Uncertainty Introduced on national total in 2005	% change in emissions between 2005 and 1990	Range of likely % change between 2005 and 1990	
				2.5 percentile	97.5 percentile			2.5 percentile	97.5 percentile
		Gg CO2 equivalent	Gg CO2 equivalent	Gg CO2 equivalent	Gg CO2 equivalent	%	%	%	%
Total	1A1a	57529	48334	46421	50213	4.01%	15.9%	9.9%	21.4%
	1A1b	5097	5084	4521.817	5645	11.29%	0.2%	-11.5%	11.6%
	1A1c	3885	5477	5063.774	5891	7.65%	-41.0%	-52.6%	-29.6%
	1A2a	6923	5135	4907.841	5361	4.54%	25.8%	21.0%	30.3%
	1A2f	22166	19759	18308.219	21212	7.55%	10.8%	1.6%	19.4%
	1A3a	362	699	567.938	831	19.11%	-95.1%	-152.3%	-47.1%
	1A3b	31558	38008	34125.098	41906	10.46%	-20.5%	-33.6%	-7.3%
	1A3c	582	793	466.556	1119	42.07%	-43.4%	-156.6%	27.4%
	1A3d	1157	1173	1101.151	1244	6.23%	-1.4%	-9.0%	6.0%
	1A3e	108	179	99.820	258	44.98%	-75.1%	-229.8%	17.1%
	1A4a	7137	6460	6368.708	6551	1.45%	9.5%	6.9%	12.0%
	1A4b	23203	23302	22939	23669	1.61%	-0.5%	-4.3%	3.1%
	1A4c	2015	1754	1074	2430	39.49%	9.1%	-55.3%	51.8%
	1A5b	1494	788	672	905	15.05%	46.9%	34.8%	57.3%
	1B1a	18270	3797	3671	3924	3.40%	79.2%	78.5%	79.9%
	1B1b	255	41	39	43	4.51%	84.0%	83.2%	84.8%
	1B2a	1447	524	444	606	15.80%	63.6%	55.6%	70.6%
	1B2b	7955	4695	4695	4695	0.00%	41.0%	41.0%	41.0%
	1B2c_Flaring	1632	1645	1416	1881	14.44%	-1.3%	-23.2%	17.7%
	1B2c_Venting	884	365	279	460	25.44%	58.0%	41.1%	71.0%
	2A1	1816	1479	1479	1479	0.00%	18.6%	18.6%	18.6%
	2A2	325	201	191	211	5.09%	38.0%	33.6%	42.2%
	2A3	351	344	333	355	3.29%	1.9%	-2.8%	6.4%
	2A4	45.6	55.2	55	55	0.00%	-20.9%	-20.9%	-20.9%
	2A7	73	46	46	46	0.00%	36.5%	36.5%	36.5%
	2B1	360	305	301	310	1.51%	15.2%	12.3%	18.1%
	2B5	639	624	624	624	0.00%	2.3%	2.3%	2.3%
	2C1	535	539	507	571	5.99%	-0.9%	-9.7%	7.3%
	2C3	123	155	155	155	0.00%	-26.0%	-26.0%	-26.0%
	4A1	13486	11976	10269	13695	14.57%	10.7%	-8.8%	27.6%
	4A10	257.1	202.0	175	230				
	4A3	4351	3470	2789	4145	19.98%	19.4%	-5.9%	39.8%
	4A4	12	10.1	8	12	19.96%	14.0%	-13.1%	35.5%
	4A6	76	130	105	156	19.96%	-72.2%	-125.3%	-29.1%
	4A8	238	148	119	176	20.08%	37.2%	17.7%	53.2%
	4B1	2114	1841	1438	2237	22.03%	11.9%	-18.0%	36.3%
	4B11	58	45	45	45	0.00%	22.2%	22.2%	22.2%
	4B12	1280	1061	1061	1061	0.00%	17.1%	17.1%	17.1%
	4B13	245	227	227	227	0.00%	7.5%	7.5%	7.5%
	4F1	342							
	4F5	2							
	5A2	-3328	-4292	-5356	-3233	-25.18%	-31.0%	-83.4%	9.5%
	5B	216	118	76	160	36.34%	44.1%	11.5%	67.4%
	5B1	275	145	74	216	50.18%	44.2%	-6.2%	75.5%
	5B2	3824	3908	1984	5792	49.54%	-8.5%	-104.4%	52.4%
	5C	186	127	90	164	29.27%	7.6%	-33.6%	58.9%
	5C1	106	111	51	170	55.05%	-16.6%	-234.8%	59.7%
	5C2	-1980	-2389	-3697	-1108	-55.08%	-49.0%	-299.9%	53.1%
	5E	38	30	20	41	36.65%	18.7%	-22.6%	51.0%
	5E2	1855	1689	854	2524	50.04%	5.8%	-61.7%	56.0%
	5G	-398	26	19	34	29.93%	106.8%	104.3%	110.3%
	6C	511	177	72	283	60.37%	64.9%	41.6%	86.0%

A7.2 ESTIMATION OF UNCERTAINTIES USING A ERROR PROPAGATION APPROACH

The IPCC Good Practice Guidance (IPCC, 2000) 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 A7.2.1-4**. 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.

- The 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.
- 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 has been updated 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[9] as 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 DTI perform each year, and in some years, revisions to historic estimates of supply and demand will alter the uncertainty calculated from previous data.

[9] 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 UK 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 propogation 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 the UK DTI 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 DTI fuel consumption data and the additional uncertainty introduced by the model.

- We have reviewed the uncertainties associated with selected 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.

- Uncertainties for the ADs and EFs for peat combustion have been assigned using expert judgement

- Expert judgement has been used to assign uncertainties to the AD and EF of the carbon emissions in Sector 7. These carbon emissions are the sum of four new sources.

Table A7.2.5 shows the revisions that have been made to the uncertainty parameters associated with activity data and emission factors. The table contains brief notes of the reason behind the change.

The error propagation analysis, **including** LULUCF emissions, suggests an uncertainty of 17% in the combined GWP total emission in 2004 (GWP emission uncertainty of 17% in the 2003 inventory - 2005 NIR). The analysis also estimates an uncertainty of 3% in the trend between 1990 and 2004 (trend uncertainty of 2% in the 2003 inventory - 2005 NIR).

The error propagation analysis, **excluding** LULUCF emissions, suggests an uncertainty of 17% in the combined GWP total emission in 2004 (no comparable analysis was completed last year). The analysis also estimates an uncertainty of 3% in the trend between 1990 and 2004 (no comparable analysis was completed last year).

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**.

Table A 7.2.1 Summary of Error propagation Uncertainty Estimates Including LULUCF

	Source Category (Analysis with LULUCF)	Gas	Base year emissions 1990 Gg CO_2 equiv	Year Y emissions 2004 Gg CO_2 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	CO_2	248420	144359	0.4	1	1.077	0.234366	-0.085955	0.185297	-0.085955	0.104820	0.135556
1A(stationary)	Oil	CO_2	91436	61226	15	2	15.133	1.396606	-0.021327	0.078588	-0.042654	1.667111	1.667657
1A	Natural Gas	CO_2	108857	206459	0.2	1.5	1.513	0.470945	0.145820	0.265006	0.218730	0.074955	0.231217
1A	Other (waste)	CO_2	813	1921	7	20	21.190	0.061363	0.001578	0.002466	0.031554	0.024412	0.039895
1A	Lubricant	CO_2	387	356	30	2	30.067	0.016146	0.000034	0.000457	0.000069	0.019400	0.019400
1A3a	Aviation Fuel	CO_2	1309	2332	20	3.3	20.270	0.071241	0.001561	0.002993	0.005153	0.084648	0.084804
1A3b	Auto Fuel	CO_2	109638	119614	2.8	3.5	4.482	0.808150	0.033651	0.153534	0.117778	0.607963	0.619267
1A3d	Marine Fuel	CO_2	4014	3550	1.7	1.4	2.202	0.011784	0.000169	0.004556	0.000236	0.010954	0.010957
1A3	Other Diesel	CO_2	2201	2920	1.7	1.4	2.202	0.009692	0.001342	0.003748	0.001878	0.009010	0.009204
1A4	Peat	CO_2	477	442	30	10	31.623	0.021065	0.000046	0.000567	0.000459	0.024065	0.024070
1B	Solid Fuel Transformation	CO_2	856	168	0.4	6	6.013	0.001524	-0.000720	0.000216	-0.004322	0.000122	0.004324
1B	Oil & Natural Gas	CO_2	5760	5100	16	6	17.088	0.131364	0.000250	0.006546	0.001501	0.148123	0.148131
2A1	Cement Production	CO_2	6659	5456	1	2.2	2.417	0.019873	-0.000276	0.007003	-0.000607	0.009903	0.009922
2A2	Lime Production	CO_2	1192	815	1	5	5.099	0.006268	-0.000256	0.001047	-0.001278	0.001480	0.001956
2A3	Limestone & Dolomite use	CO_2	1285	1371	1	5	5.099	0.010539	0.000355	0.001760	0.001776	0.002489	0.003058
2A4	Soda Ash Use	CO_2	167	180	15	2	15.133	0.004097	0.000048	0.000231	0.000095	0.004890	0.004891
2A7	Fletton Bricks	CO_2	167	128	20	70	72.801	0.014045	-0.000018	0.000164	-0.001255	0.004646	0.004813
2B	Ammonia Production	CO_2	1322	1329	10	1.5	10.112	0.020260	0.000262	0.001706	0.000392	0.024128	0.024132
2C1	Iron&Steel Production	CO_2	2310	2089	1.2	6	6.119	0.019266	0.000157	0.002681	0.000939	0.004550	0.004646
5A	5A LUCF	CO_2	-12203	-16302	1	25	25.020	-0.614820	-0.007589	-0.020925	-0.189713	-0.029592	0.192007
5B	5B LUCF	CO_2	15842	15329	1	50	50.010	1.155564	0.002361	0.019676	0.118026	0.027826	0.121262
5C	5C LUCF	CO_2	-6193	-7836	1	70	70.007	-0.826856	-0.003289	-0.010057	-0.230227	-0.014223	0.230666
5E	5E LUCF	CO_2	6925	6248	1	50	50.010	0.470998	0.000451	0.008020	0.022533	0.011342	0.025226
5G	5G LUCF	CO_2	-1456	619	1	30	30.017	0.027999	0.002386	0.000794	0.071569	0.001123	0.071578
6C	Waste Incineration	CO_2	1205	452	7	20	21.190	0.014431	-0.000737	0.000580	-0.014749	0.005741	0.015827
7C	Other	CO_2	1844	2093	50	20	53.852	0.169875	0.000671	0.002686	0.013419	0.189941	0.190414
		CO_2	593,234.75	560,417.53									
1A	All Fuel	CH_4	2017.5342	1123.10487	0.4	50	50.002	0.084649	-0.000764	0.001442	-0.038179	0.000815	0.038187
1A3a	Aviation Fuel	CH_4	2.65613032	2.767746	20	50	53.852	0.000225	0.000001	0.000004	0.000032	0.000100	0.000106
1A3b	Auto Fuel	CH_4	614.371252	186.351209	2.8	50	50.078	0.014067	-0.000432	0.000239	-0.021616	0.000947	0.021636
1A3d	Marine Fuel	CH_4	7.62048	6.71347296	1.7	50	50.029	0.000506	0.000000	0.000009	0.000014	0.000021	0.000025
1A3	Other Diesel	CH_4	1.66785302	2.20572004	1.7	50	50.029	0.000166	0.000001	0.000003	0.000050	0.000007	0.000051
1B1	Coal Mining	CH_4	18285.666	4929.740	0.4	13	13.006	0.096648	-0.013656	0.006328	-0.177522	0.003579	0.177558
	Solid Fuel Transformation	CH_4	4.043	3.389	0.4	50	50.002	0.000255	0.000000	0.000004	-0.000003	0.000002	0.000004
1B2	Natural Gas Transmission	CH_4	7954.835	4848.541	1	15	15.033	0.109872	-0.002471	0.006223	-0.037065	0.008801	0.038095
	Offshore Oil& Gas	CH_4	2349.856	1158.501	16	20	25.612	0.044727	-0.001081	0.001487	-0.021627	0.033648	0.039999
2A7	Fletton Bricks	CH_4	22.426	12.798	20	100	101.980	0.001967	-0.000008	0.000016	-0.000809	0.000465	0.000933
2B	Chemical Industry	CH_4	136.172	32.969	20	20	28.284	0.001406	-0.000107	0.000042	-0.002130	0.001197	0.002444
2C	Iron & Steel Production	CH_4	16.357	13.834	0.4	50	50.002	0.001043	0.000000	0.000018	-0.000006	0.000010	0.000012
4A	Enteric Fermentation	CH_4	18421.026	16309.153	0.1	20	20.000	0.491685	0.000799	0.020934	0.015990	0.002961	0.016262
4B	Manure Management	CH_4	2923.202	2567.513	0.1	30	30.000	0.116106	0.000101	0.003296	0.003015	0.000466	0.003051
4F	Field Burning	CH_4	266.045	0.000	25	50	55.902	0.000000	-0.000291	0.000000	-0.014539	0.000000	0.014539
5C2	5C2 LUCF	CH_4	3.077	11.875	1	20	20.025	0.000358	0.000012	0.000015	0.000238	0.000022	0.000239
5E2	5E2 LUCF	CH_4	10.763	4.884	1	20	20.025	0.000147	-0.000005	0.000006	-0.000110	0.000009	0.000110
6A	Solid Waste Disposal	CH_4	49772.458	19822.975	15	46	48.384	1.445737	-0.028939	0.025444	-1.331195	0.539756	1.436459
6B	Wastewater Handling	CH_4	709.705	799.298	1	50	50.010	0.060254	0.000250	0.001026	0.012512	0.001451	0.012596
6C	Waste Incineration	CH_4	134.434	3.299	7	50	50.488	0.000251	-0.000143	0.000004	-0.007135	0.000042	0.007135
		CH_4	103,653.91	51,839.91									

Table A 7.2.2 Summary of Error propagation Uncertainty Estimates Including LULUCF

	Source Category	Gas	Base year emissions 1990	Year Y emissions 2004	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	4522.787	3388.914	0.4	195	195.000	0.996130	-0.000593	0.004350	-0.115730	0.002461	0.115756
1A3a	Aviation Fuel	N2O	12.960	23.029	20	170	171.172	0.005942	0.000015	0.000030	0.002617	0.000836	0.002747
1A3b	Auto Fuel	N2O	1025.188	5037.740	2.8	170	170.023	1.291111	0.005346	0.006466	0.908772	0.025605	0.909133
1A3d	Marine Fuel	N2O	78.120	68.822	1.7	170	170.008	0.017637	0.000003	0.000088	0.000502	0.000212	0.000545
1A3	Other Diesel	N2O	260.581	346.061	1.7	140	140.010	0.073035	0.000159	0.000444	0.022313	0.001068	0.022338
1B1	Coke Oven Gas	N2O	2.085	1.748	0.4	118	118.001	0.000311	0.000000	0.000002	-0.000004	0.000001	0.000004
1B2	Oil & Natural Gas	N2O	42.396	39.237	16	110	111.158	0.006574	0.000004	0.000050	0.000443	0.001140	0.001223
2B	Adipic Acid Production	N2O	25136.350	1103.290	0.5	15	15.008	0.024960	-0.026050	0.001416	-0.390746	0.001001	0.390747
2B	Nitric Acid Production	N2O	4133.694	2922.680	10	230	230.217	1.014236	-0.000767	0.003751	-0.176328	0.053054	0.184137
2C	Iron & Steel	N2O	11.107	8.278	0.4	118	118.001	0.001472	-0.000002	0.000011	-0.000179	0.000006	0.000179
4B	Manure Management	N2O	1583.857	1316.301	1	414	414.001	0.821442	-0.000042	0.001690	-0.017221	0.002389	0.017386
4D	Agricultural Soils	N2O	30407.121	25281.338	1	424	424.001	16.157978	-0.000784	0.032451	-0.332604	0.045892	0.335755
4F	Field Burning	N2O	77.762	0.000	25	230	231.355	0.000000	-0.000085	0.000000	-0.019549	0.000000	0.019549
5C2	5C2 LUCF	N2O	0.312	1.205	1	20	20.025	0.000036	0.000001	0.000002	0.000024	0.000002	0.000024
5E2	5E2 LUCF	N2O	1.092	0.496	1	20	20.025	0.000015	-0.000001	0.000001	-0.000011	0.000001	0.000011
6B	Wastewater Handling	N2O	1033.645	1209.295	10	401	401.125	0.731192	0.000422	0.001552	0.169396	0.021952	0.170812
6C	Waste Incineration	N2O	47.899	48.298	7	230	230.106	0.016753	0.000010	0.000062	0.002217	0.000614	0.002301
		N2O	68,376.96	40,796.73									
2	Industrial Processes	HFC	11375	8873	1	19	19.026	0.254479	-0.001044	0.011389	-0.019834	0.016107	0.025551
2	Industrial Processes	PFC	1401	352	1	10	10.050	0.005336	-0.001080	0.000452	-0.010797	0.000639	0.010816
2	Industrial Processes	SF6	1030	1128	1	20	20.025	0.034035	0.000322	0.001447	0.006431	0.002047	0.006749
		Halocarbon	13,806.83	10,352.92									
	TOTALS	GWP	779,072.44	663,407.09									
	Total Uncertainties%							16.6					2.59

Table A 7.2.3 Summary of Error propagation Uncertainty Estimates Excluding LULUCF

	Source Category (Analysis with LULUCF)	Gas	Base year emissions 1990 Gg CO2 equiv	Year Y emissions 2004 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	248420	144359	0.4	1	1.077	0.233688	-0.088095	0.185996	-0.088095	0.105215	0.137226
1A(stationary)	Oil	CO2	91436	61226	15	2	15.133	1.392569	-0.022077	0.078885	-0.044155	1.673406	1.673989
1A	Natural Gas	CO2	108857	206459	0.2	1.5	1.513	0.469584	0.145573	0.266006	0.218359	0.075238	0.230958
1A	Other (waste)	CO2	813	1921	7	20	21.190	0.061185	0.001578	0.002475	0.031554	0.024504	0.039951
1A	Lubricant	CO2	387	356	30	2	30.067	0.016099	0.000032	0.000459	0.000063	0.019474	0.019474
1A3a	Aviation Fuel	CO2	1309	2332	20	3.3	20.270	0.071035	0.001558	0.003004	0.005140	0.084967	0.085123
1A3b	Auto Fuel	CO2	109638	119614	2.8	3.5	4.482	0.805814	0.032975	0.154114	0.115412	0.610259	0.621076
1A3d	Marine Fuel	CO2	4014	3550	1.7	1.4	2.202	0.011750	0.000140	0.004574	0.000196	0.010996	0.010998
1A3	Other Diesel	CO2	2201	2920	1.7	1.4	2.202	0.009664	0.001330	0.003762	0.001863	0.009044	0.009234
1A4	Peat	CO2	477	442	30	10	31.623	0.021004	0.000043	0.000569	0.000425	0.024156	0.024160
1B	Solid Fuel Transformation	CO2	856	168	0.4	6	6.013	0.001519	-0.000729	0.000217	-0.004376	0.000123	0.004378
1B	Oil & Natural Gas	CO2	5760	5100	16	6	17.088	0.130985	0.000209	0.006571	0.001254	0.148683	0.148688
2A1	Cement Production	CO2	6659	5456	1	2.2	2.417	0.019816	-0.000326	0.007029	-0.000717	0.009941	0.009967
2A2	Lime Production	CO2	1192	815	1	5	5.099	0.006250	-0.000265	0.001051	-0.001327	0.001486	0.001992
2A3	Limestone & Dolomite use	CO2	1285	1371	1	5	5.099	0.010509	0.000347	0.001767	0.001735	0.002499	0.003042
2A4	Soda Ash Use	CO2	167	180	15	2	15.133	0.004085	0.000047	0.000231	0.000093	0.004909	0.004909
2A7	Fletton Bricks	CO2	167	128	20	70	72.801	0.014004	-0.000019	0.000165	-0.001345	0.004664	0.004854
2B	Ammonia Production	CO2	1322	1329	10	1.5	10.112	0.020202	0.000253	0.001713	0.000379	0.024219	0.024222
2C1	Iron&Steel Production	CO2	2310	2089	1.2	6	6.119	0.019211	0.000140	0.002691	0.000841	0.004567	0.004644
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
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	1205	452	7	20	21.190	0.014389	-0.000749	0.000582	-0.014981	0.005763	0.016051
7C	Other	CO2	1844	2093	50	20	53.852	0.169384	0.000660	0.002696	0.013200	0.190658	0.191114
		CO2	590,319.32	562,359.08									
1A	All Fuel	CH4	2017.534204	1123.10487	0.4	50	50.002	0.084405	-0.000781	0.001447	-0.039063	0.000819	0.039071
1A3a	Aviation Fuel	CH4	2.656130323	2.767746	20	50	53.852	0.000224	0.000001	0.000004	0.000032	0.000101	0.000106
1A3b	Auto Fuel	CH4	614.3712517	186.351209	2.8	50	50.078	0.014026	-0.000438	0.000240	-0.021923	0.000951	0.021943
1A3d	Marine Fuel	CH4	7.62048	6.71347296	1.7	50	50.029	0.000505	0.000000	0.000009	0.000012	0.000021	0.000024
1A3	Other Diesel	CH4	1.667853023	2.20572004	1.7	50	50.029	0.000166	0.000001	0.000003	0.000050	0.000007	0.000050
1B1	Coal Mining	CH4	18285.666	4929.740	0.4	13	13.006	0.096369	-0.013841	0.006352	-0.179935	0.003593	0.179971
	Solid Fuel Transformation	CH4	4.043	3.389	0.4	50	50.002	0.000255	0.000000	0.000004	-0.000005	0.000002	0.000006
1B2	Natural Gas Transmission	CH4	7954.835	4848.541	1	15	15.033	0.109554	-0.002539	0.006247	-0.038080	0.008835	0.039091
	Offshore Oil& Gas	CH4	2349.856	1158.501	16	20	25.612	0.044598	-0.001103	0.001493	-0.022054	0.033775	0.040337
2A7	Fletton Bricks	CH4	22.426	12.798	20	100	101.980	0.001962	-0.000008	0.000016	-0.000828	0.000466	0.000950
2B	Chemical Industry	CH4	136.172	32.969	20	20	28.284	0.001402	-0.000108	0.000042	-0.002158	0.001201	0.002470
2C	Iron & Steel Production	CH4	16.357	13.834	0.4	50	50.002	0.001040	0.000000	0.000018	-0.000012	0.000010	0.000016
4A	Enteric Fermentation	CH4	18421.026	16309.153	0.1	20	20.000	0.490264	0.000667	0.021013	0.013349	0.002972	0.013675
4B	Manure Management	CH4	2923.202	2567.513	0.1	30	30.000	0.115771	0.000079	0.003308	0.002383	0.000468	0.002429
4F	Field Burning	CH4	266.045	0.000	25	50	55.902	0.000000	-0.000294	0.000000	-0.014692	0.000000	0.014692
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	49772.458	19822.975	15	46	48.384	1.441559	-0.029413	0.025540	-1.353001	0.541794	1.457447
6B	Wastewater Handling	CH4	709.705	799.298	1	50	50.010	0.060080	0.000246	0.001030	0.012299	0.001456	0.012385
6C	Waste Incineration	CH4	134.434	3.299	7	50	50.488	0.000250	-0.000144	0.000004	-0.007211	0.000042	0.007212
		CH4	103,640.07	51,823.15									

Table A 7.2.4 Summary of Error propagation Uncertainty Estimates Excluding LULUCF

	Source Category	Gas	Base year emissions 1990 Gg CO2 equiv	Year Y emissions 2004 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
1A1&1A2&1A4 &1A5	Other Combustion	N2O	4522.787	3388.914	0.4	195	195.000	0.993251	-0.000629	0.004366	-0.122636	0.002470	0.122661
1A3a	Aviation Fuel	N2O	12.960	23.029	20	170	171.172	0.005925	0.000015	0.000030	0.002611	0.000839	0.002742
1A3b	Auto Fuel	N2O	1025.188	5037.740	2.8	170	170.023	1.287379	0.005358	0.006491	0.910925	0.025702	0.911288
1A3d	Marine Fuel	N2O	78.120	68.822	1.7	170	170.008	0.017586	0.000002	0.000089	0.000406	0.000213	0.000459
1A3	Other Diesel	N2O	260.581	346.061	1.7	140	140.010	0.072824	0.000158	0.000446	0.022130	0.001072	0.022155
1B1	Coke Oven Gas	N2O	2.085	1.748	0.4	118	118.001	0.000310	0.000000	0.000002	-0.000006	0.000001	0.000006
1B2	Oil & Natural Gas	N2O	42.396	39.237	16	110	111.158	0.006555	0.000004	0.000051	0.000410	0.001144	0.001215
2B	Adipic Acid Production	N2O	25136.350	1103.290	0.5	15	15.008	0.024888	-0.026332	0.001422	-0.394986	0.001005	0.394987
2B	Nitric Acid Production	N2O	4133.694	2922.680	10	230	230.217	1.011305	-0.000800	0.003766	-0.183967	0.053254	0.191520
2C	Iron & Steel	N2O	11.107	8.278	0.4	118	118.001	0.001468	-0.000002	0.000011	-0.000189	0.000006	0.000189
4B	Manure Management	N2O	1583.857	1316.301	1	414	414.001	0.819067	-0.000053	0.001696	-0.022096	0.002398	0.022226
4D	Agricultural Soils	N2O	30407.121	25281.338	1	424	424.001	16.111274	-0.001010	0.032573	-0.428391	0.046065	0.430861
4F	Field Burning	N2O	77.762	0.000	25	230	231.355	0.000000	-0.000086	0.000000	-0.019754	0.000000	0.019754
5C2	5C2 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	1033.645	1209.295	10	401	401.125	0.729079	0.000416	0.001558	0.166995	0.022035	0.168443
6C	Waste Incineration	N2O	47.899	48.298	7	230	230.106	0.016704	0.000009	0.000062	0.002145	0.000616	0.002232
		N2O	68,375.55	40,795.03									
2	Industrial Processes	HFC	11375	8873	1	19	19.026	0.253743	-0.001131	0.011432	-0.021494	0.016168	0.026896
2	Industrial Processes	PFC	1401	352	1	10	10.050	0.005320	-0.001094	0.000454	-0.010941	0.000642	0.010959
2	Industrial Processes	SF6	1030	1128	1	20	20.025	0.033937	0.000315	0.001453	0.006304	0.002055	0.006631
		Halocarbon	13,806.83	10,352.92									
	TOTALS	GWP	776,141.77	665,330.19									
	Total Uncertainties%							16.4					2.60

Table A 7.2.5 Revisions to Activity Data and Emission Factor Uncertainty Parameters

IPPC Sector	Fuel	GHG	AD Uncertainty		Reason	EF Uncertainty		Reason
			2003	2004		2003	2004	
1A	Coal	CO_2	1.2	0.4	Review of DTI energy data	6	1	Review of ESI CEF data
1A (Stationary)	Oil	CO_2	2	15	Review of DTI energy data	(b)	(b)	
1A	Natural Gas	CO_2	2.4	0.2	Review of DTI energy data	1	1.5	Review of TRANSCO CEF data
1A	Lubricants	CO_2	(c)	30	New fuel in this category for 2004	(c)	2	New fuel in this category for 2004
1A3a	Aviation Fuel	CO_2	50	20	Review of DTI energy data	2	3.3	Review of UKPIA CEF data
1A3b	Auto Fuel	CO_2	0.8	2.8	Review of DTI energy data	2	3.5	Review of UKPIA CEF data
1A3d	Marine Fuel	CO_2	1.4	1.7	Review of DTI energy data	2	1.4	Review of UKPIA CEF data
1A3	Other diesel	CO_2	1.4	1.7	Review of DTI energy data	2	1.4	Review of UKPIA CEF data
1A4	Peat	CO_2	(c)	30	New source for 2004	(c)	10	New source for 2004
1B	Solid Fuel Transformation	CO_2	1.2	0.4	Review of DTI energy data	(b)	(b)	
2B	Ammonia Production	CO_2	(b)	(b)		1	1.5	
5A	Land Use Change & Forestry	CO_2	(a)	1	New estimate of uncertainty for the new reporting category	(a)	25	New estimate of uncertainty for the new reporting category
5B	Land Use Change & Forestry	CO_2	(a)	1	New estimate of uncertainty for the new reporting category	(a)	50	New estimate of uncertainty for the new reporting category
5C	Land Use Change & Forestry	CO_2	(a)	1	New estimate of uncertainty for the new reporting category	(a)	70	New estimate of uncertainty for the new reporting category
5D	Land Use Change & Forestry	CO_2	(a)	No emissions in this category		(a)	No emissions in this category	
5E	Land Use Change & Forestry	CO_2	(a)	1	New estimate of uncertainty for the new reporting category	(a)	50	New estimate of uncertainty for the new reporting category
5F	Land Use Change & Forestry	CO_2	(a)	No emissions in this category		(a)	No emissions in this Category	
5G	Land Use Change & Forestry	CO_2	(a)	1	New estimate of uncertainty for the new reporting category	(a)	30	New estimate of uncertainty for the new reporting category
7C	Other	CO_2	(d)	50	New sources for 2004 assigned to Sector 7	(d)	20	New sources for 2004 assigned to Sector 7
1A (Stationary)	All Fuel	CH_4	1.2	0.4	Review of DTI energy data	(b)	(b)	
1A3a	Aviation Fuel	CH_4	50	20	Review of DTI energy data	(b)	(b)	
1A3b	Auto Fuel	CH_4	0.8	2.8	Review of DTI energy data	(b)	(b)	
1A3d	Marine Fuel	CH_4	1.4	1.7	Review of DTI energy data	(b)	(b)	
1A3	Other diesel	CH_4	1.4	1.7	Review of DTI energy data	(b)	(b)	
1B1	Coal Mining	CH_4	1.2	0.4	Review of DTI energy data	(b)	(b)	
Solid Fuel	Solid Fuel Transformation	CH_4	1.2	0.4	Review of DTI energy data	(b)	(b)	

IPPC Sector	Fuel	GHG	AD Uncertainty		Reason	EF Uncertainty		Reason
			2003	2004		2003	2004	
Transformation								
2C	Iron & Steel Production	CH_4	1.2	0.4	Review of DTI energy data	(b)	(b)	
5C2	Land Use Change & Forestry	CH_4	(a)	1	New estimate of uncertainty for the new reporting category	(a)	20	New estimate of uncertainty for the new reporting category
5E2	Land Use Change & Forestry	CH_4	(a)	1	New estimate of uncertainty for the new reporting category	(a)	20	New estimate of uncertainty for the new reporting category
1A1&1A2&1A4&1A5	Other Combustion	N_20	1.2	0.4	Review of DTI energy data	(b)	(b)	
1A3a	Aviation Fuel	N_20	50	20	Review of DTI energy data	(b)	(b)	
1A3b	Auto Fuel	N_20	0.8	2.8	Review of DTI energy data	(b)	(b)	
1A3d	Marine Fuel	N_20	0.8	1.7	Review of DTI energy data	(b)	(b)	
1A3	Other diesel	N_20	1.4	1.7	Review of DTI energy data	(b)	(b)	
1B1	Coke Oven Gas	N_20	1.2	0.4	Review of DTI energy data	(b)	(b)	
2C	Iron & Steel	N_20	1.2	0.4	Review of DTI energy data	(b)	(b)	
5C2	Land Use Change & Forestry	N_20	(a)	1	New sources for 2004 assigned to Sector 7	(a)	20	New estimate of uncertainty for the new reporting category
5E2	Land Use Change & Forestry	N_20	(a)	1	New sources for 2004 assigned to Sector 7	(a)	20	New estimate of uncertainty for the new reporting category
2	Industrial Processes	HFC	(b)	(b)		25	19	Review of uncertainties associated with F-gas model
2	Industrial Processes	PFC	(b)	(b)		19	10	Review of uncertainties associated with F-gas model
2	Industrial Processes	SF6	(b)	(b)		13	20	Review of uncertainties associated with F-gas model

Notes

CEF Carbon Emission Factor
AD Activity Data
EF Emission Factor
ESI Electricity Supply Industry
(a) Reporting nomenclature changed in the 2004 GHG inventory to correspond to the IPPC LULUCF GPG categories.
(b) No change in the values of uncertainties assigned.
(c) New category, no data for 2003
(d) No data for 2003

A8 ANNEX 8: Verification

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

A8.1 MODELLING APPROACH USED FOR THE VERIFICATION OF THE UK GHGI

In order to provide some verification of the UK Greenhouse Gas Inventory (GHGI), CESA Division of DEFRA has established continuous high-frequency observations of the Kyoto gases under the supervision of Professor Peter Simmonds of the University of Bristol at the Mace Head Atmospheric Research Station on the Atlantic Ocean coastline of Ireland (Simmonds *et al.* 1996). The Met Office employs the Lagrangian dispersion model NAME (Numerical Atmospheric dispersion Modelling Environment) (Ryall *et al*. 1998) (Jones et al. 2004) driven by 3D synoptic meteorology from the Unified Model to sort the observations made at Mace Head into those that represent Northern Hemisphere baseline air masses and those that represent regionally-polluted air masses arriving from Europe. The Mace Head observations and the hourly air origin maps are applied in an inversion algorithm to estimate the magnitude and spatial distribution of the European emissions that best support the observations (Manning *et al.* 2003). The technique has been applied to each year of the available data. For estimating methane emissions high frequency observations from the German Global Atmospheric Watch (GAW) stations, Neuglobsow and Deuselbach, have also been used to better constrain the best-fit solutions.

The inversion (best-fit) technique, simulated annealing, is used to fit the model emissions to the observations. It assumes that the emissions from each grid box are uniform in both time and space over the duration of the fitting period. This implies that the release is independent of meteorological factors such as temperature and diurnal cycles, and that in its industrial production and use there is no definite cycle or intermittency. The geographical area defined as UK within the NAME estimates includes the coastal waters around the UK. A 'best fit' solution has been determined for each gas for each six month period (Jan-Jun 1995, Feb-Jul 1995,… Jul-Dec 2006) where sufficient data exist. The uncertainty ranges have been estimated by solving multiple times with a random noise perturbation applied to the observations and by using two different statistical methods to assess best-fit. The annual estimates have been calculated by taking the mean of all of the solutions weighted by the overlap of the solution period with the year in question.

A8.2 METHANE

In **Table A8.2.1**, the comparison is made between the emission estimates made for the UK with the NAME dispersion model and the GHGI emission estimates for the period 1995-2006 inclusive (where available).

Methane has a natural (biogenic) component, it is estimated that 22% of the annual global emission (Nilsson *et al*. 2001) is released from wetlands. Usually natural emissions are strongly dependent on a range of meteorological factors such as temperature and diurnal /

annual and growth / decay cycles. Such non-uniform emissions will add to the uncertainties (estimated to be ±500 Gg yr^{-1} with three measurement stations and ±800 Gg yr^{-1} with one station) associated with the NAME-derived emission estimates. Due to the relatively strong local (within 50km) influence of biogenic emissions, time periods when local emissions will be significant (low wind speeds, low boundary layers) have been removed from the data set prior to applying the inversion technique.

The GHGI trend is monotonically downwards whereas the NAME estimates show no clear trend. It must be remembered however that the GHGI totals only include anthropogenic emissions whereas the NAME estimates are total emissions combining both anthropogenic and biogenic releases however biogenic emissions in the UK are thought to be low. The overall mean UK emissions estimated using the inversion methodology is 2600 or 3100 Gg yr^{-1} depending on the number of stations used compared to the GHGI average of 3300 Gg yr^{-1}.

Table A 8.2.1 Verification of the UK emission inventory estimates for methane in Gg yr^{-1} for 1995-2005. NAME[1] are estimates using 3 observing stations (data only available until 2004) and NAME[2] are estimates only using Mace Head data (NAME[1] uncertainty ±500 Gg yr^{-1}, NAME[2] uncertainty ±800 Gg yr^{-1}).

Gas	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
CH_4 – NAME[1]	2600	3200	2600	2100	2300	2400	2100	2700	2900	2600		
CH_4 – NAME[2]	3600	3000	2900	2600	3200	2600	3100	3500	3000	2900	3600	2900
CH_4 - GHGI	4290	4180	3940	3720	3470	3260	2970	2830	2540	2460	2350	

A8.3 NITROUS OXIDE

The main activities in Europe resulting in the release of nitrous oxide are agricultural 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.

Late in 1998, DuPont introduced technology at its adipic acid plant in Wilton, north east England. It has been estimated that this has cut its emissions of N_2O by 90%, from 46 thousand tonne yr^{-1} to around 6 thousand tonne yr^{-1} (DEFRA, 2000).

Table A8.3.1 shows the NAME and the GHGI emission estimates for the UK for nitrous oxide for the period 1995-2006. The NAME estimates show a declining UK total, the average UK emission 1995-1998 is estimated to be 170 Gg yr^{-1} whereas the average UK emission 2000-2006 is estimated to be 140 Gg yr^{-1}. The GHGI estimates show a sharp decline (40 Gg) between 1998 and 1999 in line with the introduction of the clean technology at the DuPont plant.

The nature of the nitrous oxide emissions challenges the NAME technique assumption of uniformity of release both in time and space. The uncertainty of the estimates is calculated to be ±40 Gg yr^{-1}. 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.

Table A 8.3.1 **Verification of the UK emission inventory estimates for nitrous oxide in Gg yr^{-1} for 1995-2004 (NAME uncertainty ±40 Gg yr^{-1})**

Gas	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
N_2O -NAME	170	190	150	180	170	140	150	150	120	150	140	100
N_2O- GHGI	170	170	180	180	140	140	130	130	130	130	130	

A8.4 HYDROFLUOROCARBONS

A8.4.1 HFC-134a

Table A8.4.1 shows the NAME and the GHGI emission estimates for the UK for HFC-134a for the period 1995-2006. The GHGI shows an earlier increase in emission compared to the NAME estimates, the NAME estimates begin their rise in 1999 whereas the GHGI estimates began to rise from 1995. In the last two years the NAME estimates have fallen, a trend not shown in the GHGI.

Table A 8.4.1 **Verification of the UK emission inventory estimates for HFC-134a in Gg yr^{-1} for 1995-2006. The NAME estimates have a calculated error of** ±0.4 Gg yr^{-1}.

Gas	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
HFC-134a –NAME	0.9	1.1	1.3	0.9	1.5	1.6	2.4	2.3	3.0	2.8	2.4	2.5
HFC-134a – GHGI	0.7	1.1	1.6	2.3	2.2	2.6	2.9	3.2	3.4	3.6	3.7	

A8.4.2 HFC-152a

Table A8.4.2 shows the NAME and the GHGI emission estimates for the UK for HFC-152a for the period 1995-2006. Again the NAME estimates show a later rise compared to the GHGI estimates, with NAME estimating a rise in 2001/02 compared to the GHGI which indicates a step increase in emissions in 1997/98. In 2005/06 the NAME estimates indicate a reduction in emissions, this is not shown in the GHGI.

Table A 8.4.2 **Verification of the UK emission inventory estimates for HFC-152a in Gg yr^{-1} for 1995-2006. The NAME estimates have a calculated error of** ±0.06 Gg yr^{-1}.

Gas	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
HFC-152a –NAME	0.04	0.07	0.07	0.06	0.08	0.10	0.14	0.19	0.20	0.18	0.10	0.10
HFC-152a – GHGI	0.03	0.06	0.12	0.16	0.14	0.16	0.17	0.16	0.17	0.16	0.16	

A8.4.3 HFC-125

NAME emission estimates for the UK for HFC-125 for the period 1998-2006 are shown below in **Table A8.4.3**, The estimates show a positive trend in emissions.

Table A 8.4.3 Verification of the UK emission inventory estimates for HFC-125 in Gg yr^{-1} for 1998-2004. The NAME estimates have a calculated error of ±0.10 Gg yr^{-1}.

Gas	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
HFC-125 –NAME				0.16	0.37	0.26	0.36	0.35	0.43	0.54	0.48	0.60

A1.1.1 HFC-365

NAME emission estimates for the UK for HFC-365 for the period 2003-2006 are shown below in **Table A8.4.4**. The estimates show a strong positive trend in emissions.

Table A 8.4.4 Verification of the UK emission inventory estimates for HFC-365a in Gg yr^{-1} for 1995-2004. The NAME estimates have a calculated error of ±0.07 Gg yr-1.

Gas	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
HFC-365 –NAME									0.13	0.28	0.46	0.66

A9 ANNEX 9: IPCC Sectoral Tables of GHG Emissions

The tables in this Annex present summary data for UK greenhouse gas emissions for the years 1990-2005, 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, therefore small emissions of indirect greenhouse gases from the UK Crown Dependencies appear in Sector 7, as detailed in **Table 3.11.1**.

A9.1 SUMMARY TABLES

Tables A9.1.1 to **Tables A9.1.16** present UK GHG emissions as **summary reports** for national greenhouse gas inventories (**IPCC Table 7A**).

Table A 9.1.1 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		PFCs		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	**593,222.26**	**4,935.58**	**205.27**	**12.28**	**11,375.40**	**73.47**	**1,401.57**	**0.10**	**0.04**	**2,965.77**	**8,215.91**	**2,383.79**	**3,687.20**
1. Energy	**574,176.19**	**1,487.23**	**18.81**							**2,939.39**	**7,650.97**	**1,399.04**	**3,627.61**
A. Fuel Combustion — Reference Approach	564,094.63												
Sectoral Approach	567,559.60	125.62	18.66							2,925.47	7,591.13	1,017.97	3,599.16
1. Energy Industries	236,428.72	6.75	6.08							851.57	131.46	8.12	2,872.49
2. Manufacturing Industries and Construction	99,553.54	15.45	5.22							377.14	676.22	27.86	420.01
3. Transport	116,841.39	29.52	4.12							1,439.45	5,525.40	874.85	94.09
4. Other Sectors	109,451.12	73.75	3.09							215.14	1,244.69	104.25	203.24
5. Other	5,284.82	0.15	0.16							42.18	13.37	2.89	9.33
B. Fugitive Emissions from Fuels	6,616.59	1,361.61	0.14							13.92	59.84	381.07	28.46
1. Solid Fuels	856.42	870.94	0.01							0.58	38.35	0.33	20.68
2. Oil and Natural Gas	5,760.18	490.67	0.14							13.34	21.49	380.74	7.78
2. Industrial Processes	**14,958.00**	**8.39**	**79.52**	**12.28**	**11,375.40**	**73.47**	**1,401.57**	**0.10**	**0.04**	**10.94**	**270.36**	**258.64**	**52.22**
A. Mineral Products	9,483.37	1.12	IE,NO							IE,NE,NO	5.31	13.08	4.27
B. Chemical Industry	3,165.36	6.48	79.49	NO	NO	NO	NO	NO	NO	8.49	81.90	165.77	39.02
C. Metal Production	2,309.27	0.78	0.04				1,332.75		0.02	2.46	183.15	2.05	8.93
D. Other Production	NE									NE	NE	77.74	NE
E. Production of Halocarbons and SF_6					11,373.73		10.90		NA,NO				
F. Consumption of Halocarbons and SF_6				12.28	1.67	73.47	57.92	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**		**NA,NE,NO**							**NO**	**NO**	**667.41**	**NO**
4. Agriculture		**1,029.06**	**103.45**							**9.07**	**266.04**	**26.06**	**NO**
A. Enteric Fermentation		877.19											
B. Manure Management		139.20	4.88									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils		NE	98.09									NO	
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	0.23							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**2,881.56**	**0.59**	**0.00**							**0.15**	**5.18**	**NA**	**NA**
A. Forest Land	-12,202.57	NE,NO	NE,NO							NO	NO		
B. Cropland	15,836.04	NA,NE,NO	NA,NE,NO							NO	NO		
C. Grassland	-6,200.25	0.15	0.00							0.04	1.28		
D. Wetlands	IE,NE,NO	NE,NO	NE,NO							NO	NO		
E. Settlements	6,904.22	0.45	0.00							0.11	3.90		
F. Other Land	NA,NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-1,455.88	NE	NE							NE	NE	NA	NA
6. Waste	**1,206.51**	**2,410.31**	**3.49**							**6.14**	**23.32**	**30.24**	**7.29**
A. Solid Waste Disposal on Land	NA,NE,NO	2,370.12								NA,NE	NA,NE	23.63	
B. Waste-water Handling		33.80	3.33							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	1,206.51	6.40	0.15							6.14	23.32	6.61	7.29
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)***	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**0.08**	**0.03**	**2.40**	**0.08**
Memo Items:													
International Bunkers	**22,354.59**	**0.39**	**0.67**							**226.81**	**28.61**	**12.51**	**90.72**
Aviation	15,674.29	0.28	0.50							75.08	13.08	5.17	3.00
Marine	6,680.29	0.10	0.17							151.73	15.53	7.35	87.72
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**2,980.26**												

Table A 9.1.2 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		PFCs		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	**600,025.30**	**4,897.92**	**205.13**	**12.28**	**11,854.09**	**82.77**	**1,170.89**	**0.10**	**0.05**	**2,836.58**	**8,066.56**	**2,303.32**	**3,500.40**
1. Energy	**583,096.49**	**1,503.80**	**18.81**							**2,812.69**	**7,549.33**	**1,370.14**	**3,442.71**
A. Fuel Combustion — Reference Approach	580,707.02												
Sectoral Approach	576,881.05	127.99	18.68							2,799.09	7,466.74	988.74	3,417.53
1. Energy Industries	235,948.88	6.44	6.05							752.40	130.40	8.04	2,677.15
2. Manufacturing Industries and Construction	99,617.64	15.23	5.10							361.35	630.31	26.42	433.55
3. Transport	116,171.95	29.08	4.23							1,415.33	5,342.34	844.72	91.17
4. Other Sectors	120,850.16	77.13	3.17							229.32	1,352.92	106.98	205.98
5. Other	4,292.42	0.12	0.13							40.69	10.77	2.59	9.68
B. Fugitive Emissions from Fuels	6,215.43	1,375.81	0.14							13.60	82.59	381.39	25.18
1. Solid Fuels	519.42	895.22	0.00							0.41	35.63	0.31	17.49
2. Oil and Natural Gas	5,696.02	480.59	0.14							13.19	46.97	381.09	7.69
2. Industrial Processes	**12,973.82**	**7.89**	**80.02**	**12.28**	**11,854.09**	**82.77**	**1,170.89**	**0.10**	**0.05**	**9.82**	**261.19**	**247.75**	**50.43**
A. Mineral Products	8,088.81	0.91	IE,NO							IE,NE,NO	4.30	12.62	3.46
B. Chemical Industry	3,201.29	6.45	79.99	NO	NO	NO	NO	NO	NO	7.68	80.13	155.63	38.35
C. Metal Production	1,683.72	0.53	0.03				1,095.57		0.02	2.14	176.75	1.92	8.62
D. Other Production	NE									NE	NE	77.57	NE
E. Production of Halocarbons and SF_6					11,841.76		10.91		NA,NO				
F. Consumption of Halocarbons and SF_6				12.28	12.33	82.77	64.41	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**		**NA,NE,NO**							**NO**	**NO**	**630.74**	**NO**
4. Agriculture		**1,012.23**	**102.84**							**7.76**	**227.78**	**22.52**	**NO**
A. Enteric Fermentation		864.02											
B. Manure Management		137.36	4.86									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils		NE	97.53									NO	
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	0.23							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**2,754.55**	**0.56**	**0.00**							**0.14**	**4.89**	**NA**	**NA**
A. Forest Land	-12,714.63	NE,NO	NE,NO							NO	NO		
B. Cropland	15,995.53	NA,NE,NO	NA,NE,NO							NO	NO		
C. Grassland	-6,151.93	0.16	0.00							0.04	1.37		
D. Wetlands	IE,NE,NO	NE,NO	NE,NO							NO	NO		
E. Settlements	6,835.77	0.40	0.00							0.10	3.52		
F. Other Land	NA,NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-1,210.20	NE	NE							NE	NE	NA	NA
6. Waste	**1,200.45**	**2,373.44**	**3.45**							**6.08**	**23.34**	**29.92**	**7.17**
A. Solid Waste Disposal on Land	NA,NE,NO	2,335.46								NA,NE	NA,NE	23.29	
B. Waste-water Handling		31.68	3.30							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	1,200.45	6.30	0.15							6.08	23.34	6.63	7.17
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)***	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**0.09**	**0.03**	**2.26**	**0.08**
Memo Items:													
International Bunkers	**21,907.20**	**0.33**	**0.65**							**219.20**	**27.16**	**11.54**	**86.67**
Aviation	15,446.82	0.23	0.49							72.58	12.16	4.44	3.93
Marine	6,460.38	0.10	0.16							146.63	15.01	7.10	82.74
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**3,138.43**												

Table A 9.1.3 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		PFCs		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	**583,063.96**	**4,825.39**	**185.03**	**13.46**	**12,323.56**	**93.79**	**573.60**	**0.10**	**0.05**	**2,752.54**	**7,608.86**	**2,237.87**	**3,412.05**
1. Energy	**567,396.99**	**1,483.19**	**18.78**							**2,731.94**	**7,163.72**	**1,345.36**	**3,358.01**
A. Fuel Combustion — Reference Approach	569,401.47												
Sectoral Approach	560,826.95	119.88	18.63							2,718.43	7,109.07	960.15	3,334.06
1. Energy Industries	224,836.92	6.19	5.74							737.03	127.58	7.65	2,563.85
2. Manufacturing Industries and Construction	96,633.61	14.54	5.13							352.46	641.44	26.20	468.67
3. Transport	117,492.90	27.88	4.59							1,365.32	5,111.41	820.26	94.37
4. Other Sectors	117,776.74	71.16	3.04							225.70	1,218.38	103.61	198.02
5. Other	4,086.79	0.11	0.12							37.93	10.26	2.44	9.15
B. Fugitive Emissions from Fuels	6,570.04	1,363.32	0.15							13.51	54.65	385.21	23.95
1. Solid Fuels	450.00	887.17	0.00							0.35	32.44	0.28	16.04
2. Oil and Natural Gas	6,120.04	476.14	0.15							13.16	22.20	384.93	7.91
2. Industrial Processes	**12,256.88**	**8.33**	**65.07**	**13.46**	**12,323.56**	**93.79**	**573.60**	**0.10**	**0.05**	**8.86**	**251.91**	**246.15**	**46.92**
A. Mineral Products	7,547.57	0.82	IE,NO							IE,NE,NO	3.85	12.54	3.10
B. Chemical Industry	3,258.85	7.06	65.04	NO	NO	NO	NO	NO	NO	6.87	79.38	154.02	35.68
C. Metal Production	1,450.46	0.46	0.03				490.38		0.02	1.99	168.68	1.89	8.14
D. Other Production	NE									NE	NE	77.71	NE
E. Production of Halocarbons and SF_6					12,310.08		10.96		NA,NO				
F. Consumption of Halocarbons and SF_6				13.46	13.48	93.79	72.25	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**		**NA,NE,NO**							**NO**	**NO**	**598.19**	**NO**
4. Agriculture		**1,015.45**	**97.69**							**5.63**	**165.25**	**16.72**	**NO**
A. Enteric Fermentation		870.24											
B. Manure Management		137.34	4.80									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils		NE	92.51									NO	
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	0.23							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**2,250.84**	**0.53**	**0.00**							**0.13**	**4.65**	**NA**	**NA**
A. Forest Land	-13,340.09	NE,NO	NE,NO							NO	NO		
B. Cropland	16,001.10	NA,NE,NO	NA,NE,NO							NO	NO		
C. Grassland	-6,260.53	0.17	0.00							0.04	1.50		
D. Wetlands	IE,NE,NO	NE,NO	NE,NO							NO	NO		
E. Settlements	6,769.96	0.36	0.00							0.09	3.15		
F. Other Land	NA,NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-919.60	NE	NE							NE	NE	NA	NA
6. Waste	**1,159.24**	**2,317.89**	**3.48**							**5.90**	**23.29**	**29.33**	**7.04**
A. Solid Waste Disposal on Land	NA,NE,NO	2,276.67								NA,NE	NA,NE	22.70	
B. Waste-water Handling		35.17	3.34							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	1,159.24	6.05	0.15							5.90	23.29	6.63	7.04
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)***	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**0.09**	**0.03**	**2.10**	**0.08**
Memo Items:													
International Bunkers	**23,838.06**	**0.32**	**0.71**							**232.98**	**28.70**	**11.88**	**90.58**
Aviation	17,087.14	0.22	0.54							79.44	12.98	4.45	5.44
Marine	6,750.92	0.11	0.17							153.55	15.72	7.43	85.15
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**3,553.92**												

Table A 9.1.4 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		PFCs		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	**568,129.64**	**4,678.82**	**170.60**	**630.99**	**13,001.42**	**106.82**	**490.72**	**0.10**	**0.05**	**2,577.26**	**7,201.97**	**2,128.18**	**3,066.03**
1. Energy	**553,746.46**	**1,405.31**	**18.82**							**2,563.40**	**6,913.30**	**1,274.82**	**3,016.01**
A. Fuel Combustion Reference Approach	552,160.69												
Sectoral Approach	546,858.40	117.48	18.66							2,549.87	6,859.78	893.35	2,992.45
1. Energy Industries	207,078.24	5.92	4.97							628.21	117.52	7.49	2,213.08
2. Manufacturing Industries and Construction	95,709.28	14.57	4.91							352.90	639.34	26.55	465.83
3. Transport	118,710.82	26.50	5.55							1,304.22	4,770.28	754.10	91.98
4. Other Sectors	121,219.13	70.38	3.10							229.45	1,322.19	102.86	213.45
5. Other	4,140.93	0.12	0.12							35.09	10.44	2.34	8.10
B. Fugitive Emissions from Fuels	6,888.07	1,287.83	0.16							13.53	53.52	381.47	23.56
1. Solid Fuels	344.83	825.64	0.00							0.39	30.36	0.26	15.43
2. Oil and Natural Gas	6,543.24	462.19	0.16							13.14	23.15	381.20	8.13
2. Industrial Processes	**12,239.07**	**7.13**	**52.44**	**630.99**	**13,001.42**	**106.82**	**490.72**	**0.10**	**0.05**	**8.05**	**257.69**	**240.45**	**44.65**
A. Mineral Products	7,571.84	0.69	IE,NO							IE,NE,NO	3.24	12.09	2.61
B. Chemical Industry	3,302.26	6.01	52.42	NO	NO	NO	NO	NO	NO	6.06	81.54	148.28	33.85
C. Metal Production	1,364.97	0.44	0.03				381.33		0.02	1.99	172.91	1.89	8.19
D. Other Production	NE									NE	NE	78.19	NE
E. Production of Halocarbons and SF_6					12,779.93		27.23		NA,NO				
F. Consumption of Halocarbons and SF_6				630.99	221.49	106.82	82.17	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**		**NA,NE,NO**							**NO**	**NO**	**581.71**	**NO**
4. Agriculture		**1,007.22**	**95.87**							**0.12**	**3.53**	**0.47**	**NO**
A. Enteric Fermentation		869.03											
B. Manure Management		138.03	4.82									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils		NE	90.82									NO	
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	0.22							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**1,068.24**	**0.47**	**0.00**							**0.12**	**4.14**	**NA**	**NA**
A. Forest Land	-13,714.07	NE,NO	NE,NO							NO	NO		
B. Cropland	15,577.24	NA,NE,NO	NA,NE,NO							NO	NO		
C. Grassland	-6,670.64	0.13	0.00							0.03	1.15		
D. Wetlands	IE,NE,NO	NE,NO	NE,NO							NO	NO		
E. Settlements	6,717.71	0.34	0.00							0.08	2.99		
F. Other Land	NA,NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-841.99	NE	NE							NE	NE	NA	NA
6. Waste	**1,075.87**	**2,258.68**	**3.46**							**5.48**	**23.29**	**28.79**	**5.28**
A. Solid Waste Disposal on Land	NA,NE,NO	2,218.45								NA,NE	NA,NE	22.12	
B. Waste-water Handling		34.87	3.32							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	1,075.87	5.36	0.15							5.48	23.29	6.68	5.28
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)***	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**0.09**	**0.04**	**1.94**	**0.09**
Memo Items:													
International Bunkers	**24,872.45**	**0.32**	**0.75**							**236.38**	**29.45**	**12.03**	**89.90**
Aviation	18,189.06	0.22	0.58							84.36	13.89	4.67	4.63
Marine	6,683.39	0.11	0.17							152.02	15.56	7.36	85.27
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**3,705.44**												

Table A 9.1.5 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		PFCs		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		**560,335.50**	**4,344.72**	**174.54**	**2,512.95**	**14,014.66**	**122.25**	**490.65**	**0.09**	**0.05**	**2,486.56**	**6,802.88**	**2,065.23**	**2,633.86**
1. Energy		**545,097.01**	**1,108.64**	**19.70**							**2,474.46**	**6,512.18**	**1,224.23**	**2,581.87**
A. Fuel Combustion	Reference Approach	545,945.38												
	Sectoral Approach	537,990.62	102.75	19.53							2,460.92	6,457.33	837.85	2,559.21
1. Energy Industries		202,502.89	6.11	4.75							589.31	125.96	8.25	1,884.19
2. Manufacturing Industries and Construction		96,356.39	15.29	4.97							365.97	663.16	28.48	394.00
3. Transport		118,869.56	24.93	6.75							1,249.52	4,500.65	708.09	95.36
4. Other Sectors		116,301.98	56.31	2.94							223.28	1,157.56	90.82	177.94
5. Other		3,959.80	0.11	0.12							32.84	10.00	2.21	7.72
B. Fugitive Emissions from Fuels		7,106.39	1,005.89	0.17							13.54	54.85	386.38	22.66
1. Solid Fuels		163.25	547.72	0.00							0.44	30.84	0.26	14.31
2. Oil and Natural Gas		6,943.14	458.16	0.16							13.10	24.01	386.12	8.35
2. Industrial Processes		**13,454.07**	**8.69**	**53.05**	**2,512.95**	**14,014.66**	**122.25**	**490.65**	**0.09**	**0.05**	**7.33**	**263.77**	**233.77**	**47.60**
A. Mineral Products		8,474.75	0.77	IE,NO							IE,NE,NO	3.65	12.61	5.45
B. Chemical Industry		3,339.97	7.36	53.02	NO	NO	NO	NO	NO	NO	5.26	86.26	139.96	34.06
C. Metal Production		1,639.35	0.56	0.03				345.16		0.02	2.07	173.86	1.95	8.09
D. Other Production		NE									NE	NE	79.24	NE
E. Production of Halocarbons and SF_6						13,264.93		49.01		NA,NO				
F. Consumption of Halocarbons and SF_6					2,512.95	749.73	122.25	96.49	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**		**NA,NE,NO**							**NO**	**NO**	**577.06**	**NO**
4. Agriculture			**1,012.50**	**98.06**							**NA,NO**	**NA,NO**	**NA,NO**	**NO**
A. Enteric Fermentation			873.48											
B. Manure Management			139.02	4.86									NO	
C. Rice Cultivation			NA,NO										NA,NO	
D. Agricultural Soils			NE	92.97									NO	
E. Prescribed Burning of Savannas			NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues			NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other			NA	0.23							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry		**862.89**	**0.49**	**0.00**							**0.12**	**4.25**	**NA**	**NA**
A. Forest Land		-14,192.63	NE,NO	NE,NO							NO	NO		
B. Cropland		15,630.79	NA,NE,NO	NA,NE,NO							NO	NO		
C. Grassland		-6,613.50	0.14	0.00							0.03	1.22		
D. Wetlands		IE,NE,NO	NE,NO	NE,NO							NO	NO		
E. Settlements		6,671.01	0.35	0.00							0.09	3.03		
F. Other Land		NA,NE,NO	NE,NO	NE,NO							NO	NO		
G. Other		-632.78	NE	NE							NE	NE	NA	NA
6. Waste		**921.54**	**2,214.40**	**3.72**							**4.55**	**22.65**	**28.31**	**4.30**
A. Solid Waste Disposal on Land		NA,NE,NO	2,174.10								NA,NE	NA,NE	21.67	
B. Waste-water Handling			36.38	3.60							NA,NE	NA,NE	NA,NE	
C. Waste Incineration		921.54	3.92	0.12							4.55	22.65	6.64	4.30
D. Other		NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)***		**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**0.10**	**0.04**	**1.85**	**0.09**
Memo Items:														
International Bunkers		**25,186.14**	**0.30**	**0.76**							**229.96**	**28.18**	**11.43**	**81.69**
Aviation		18,934.52	0.20	0.60							87.80	13.63	4.55	6.02
Marine		6,251.61	0.10	0.16							142.16	14.55	6.88	75.67
Multilateral Operations		**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass		**4,914.03**												

Table A 9.1.6 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		PFCs		SF_6		NO_x	CO	NMVOC	SO_2
				P	A	P	A	P	A				
	(Gg)			CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals	**550,779.50**	**4,300.48**	**170.42**	**5,532.60**	**15,500.27**	**140.50**	**470.84**	**0.10**	**0.05**	**2,383.91**	**6,283.89**	**1,925.79**	**2,321.69**
1. Energy	**535,023.90**	**1,149.43**	**20.48**							**2,374.99**	**5,986.29**	**1,118.53**	**2,262.95**
A. Fuel Combustion — Reference Approach	543,531.40												
Sectoral Approach	526,384.97	87.59	20.28							2,360.64	5,931.23	760.48	2,245.56
1. Energy Industries	199,429.23	5.52	4.62							555.00	122.66	8.24	1,714.48
2. Manufacturing Industries and Construction	93,128.97	15.58	4.83							351.71	675.46	29.00	308.87
3. Transport	117,850.27	22.95	7.99							1,204.36	4,224.48	641.73	82.90
4. Other Sectors	112,090.34	43.44	2.73							216.55	898.84	79.30	131.67
5. Other	3,886.18	0.11	0.12							33.03	9.80	2.20	7.64
B. Fugitive Emissions from Fuels	8,638.92	1,061.84	0.20							14.35	55.06	358.05	17.40
1. Solid Fuels	225.84	599.65	0.00							0.47	30.89	0.26	10.79
2. Oil and Natural Gas	8,413.09	462.19	0.20							13.88	24.17	357.79	6.61
2. Industrial Processes	**13,892.10**	**6.73**	**47.99**	**5,532.60**	**15,500.27**	**140.50**	**470.84**	**0.10**	**0.05**	**4.62**	**271.33**	**240.89**	**54.47**
A. Mineral Products	8,607.81	0.77	IE,NO							IE,NE,NO	3.64	11.93	9.67
B. Chemical Industry	3,346.05	5.26	47.95	NO	NO	NO	NO	NO	NO	2.40	88.36	147.72	36.71
C. Metal Production	1,938.24	0.70	0.03				286.29		0.02	2.22	179.33	2.02	8.09
D. Other Production	NE									NE	NE	79.22	NE
E. Production of Halocarbons and SF_6					13,980.68		70.79		NA,NO				
F. Consumption of Halocarbons and SF_6				5,532.60	1,519.59	140.50	113.77	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**		**NA,NE,NO**							**NO**	**NO**	**536.98**	**NO**
4. Agriculture		**1,000.22**	**98.46**							**NA,NO**	**NA,NO**	**NA,NO**	**NO**
A. Enteric Fermentation		863.97											
B. Manure Management		136.25	4.79									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils		NE	93.44									NO	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other		NA	0.23							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**991.78**	**0.45**	**0.00**							**0.11**	**3.93**	**NA**	**NA**
A. Forest Land	-13,948.21	NE,NO	NE,NO							NO	NO		
B. Cropland	15,770.72	NA,NE,NO	NA,NE,NO							NO	NO		
C. Grassland	-6,540.86	0.16	0.00							0.04	1.36		
D. Wetlands	IE,NE,NO	NE,NO	NE,NO							NO	NO		
E. Settlements	6,610.00	0.29	0.00							0.07	2.57		
F. Other Land	NA,NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-899.87	NE	NE							NE	NE	NA	NA
6. Waste	**871.73**	**2,143.66**	**3.49**							**4.09**	**22.30**	**27.61**	**4.17**
A. Solid Waste Disposal on Land	NA,NE,NO	2,105.32								NA,NE	NA,NE	20.99	
B. Waste-water Handling		34.75	3.37							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	871.73	3.59	0.12							4.09	22.30	6.62	4.17
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)***	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**0.10**	**0.04**	**1.78**	**0.09**
Memo Items:													
International Bunkers	**26,843.66**	**0.30**	**0.81**							**245.69**	**29.74**	**11.99**	**91.59**
Aviation	20,133.79	0.19	0.64							93.06	14.11	4.60	5.13
Marine	6,709.87	0.11	0.17							152.63	15.62	7.39	86.47
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**5,239.55**												

Table A 9.1.7 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		PFCs		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		**572,473.33**	**4,185.63**	**171.75**	**8,707.95**	**16,734.46**	**162.12**	**493.42**	**0.06**	**0.05**	**2,308.25**	**6,134.86**	**1,820.79**	**1,973.40**
1. Energy		**556,272.93**	**1,095.45**	**21.44**							**2,299.14**	**5,836.80**	**1,031.61**	**1,916.35**
A. Fuel Combustion	Reference Approach	555,802.60												
	Sectoral Approach	547,009.56	90.18	21.24							2,287.74	5,782.77	689.63	1,897.75
1. Energy Industries		200,887.28	5.77	4.36							510.24	121.64	8.82	1,440.25
2. Manufacturing Industries and Construction		94,324.01	16.09	4.71							327.69	683.97	29.24	246.08
3. Transport		122,651.16	21.71	9.25							1,183.08	4,048.43	568.11	69.97
4. Other Sectors		125,342.12	46.52	2.80							233.67	919.14	81.28	133.76
5. Other		3,804.99	0.11	0.11							33.05	9.59	2.18	7.69
B. Fugitive Emissions from Fuels		9,263.36	1,005.27	0.20							11.40	54.03	341.98	18.61
1. Solid Fuels		366.77	556.22	0.00							0.45	30.87	0.26	11.49
2. Oil and Natural Gas		8,896.60	449.05	0.20							10.95	23.16	341.72	7.12
2. Industrial Processes		**14,463.52**	**7.92**	**47.69**	**8,707.95**	**16,734.46**	**162.12**	**493.42**	**0.06**	**0.05**	**4.49**	**270.58**	**234.67**	**54.19**
A. Mineral Products		8,883.80	0.72	IE,NO							IE,NE,NO	3.40	10.69	10.16
B. Chemical Industry		3,354.28	6.41	47.65	NO	NO	NO	NO	NO	NO	2.25	85.45	140.57	35.72
C. Metal Production		2,225.45	0.79	0.03				282.17		0.02	2.24	181.72	2.07	8.30
D. Other Production		NE									NE	NE	81.34	NE
E. Production of Halocarbons and SF_6						14,320.56		77.14		NA,NO				
F. Consumption of Halocarbons and SF_6					8,707.95	2,413.90	162.12	134.12	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**		**NA,NE,NO**							**NO**	**NO**	**525.89**	**NO**
4. Agriculture			**1,008.49**	**99.01**							**NA,NO**	**NA,NO**	**NA,NO**	**NO**
A. Enteric Fermentation			871.39											
B. Manure Management			137.10	4.84									NO	
C. Rice Cultivation			NA,NO										NA,NO	
D. Agricultural Soils			NE	93.94									NO	
E. Prescribed Burning of Savannas			NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues			NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other			NA	0.23							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry		**850.22**	**0.52**	**0.00**							**0.13**	**4.56**	**NA**	**NA**
A. Forest Land		-13,720.06	NE,NO	NE,NO							NO	NO		
B. Cropland		15,802.53	NA,NE,NO	NA,NE,NO							NO	NO		
C. Grassland		-6,789.12	0.18	0.00							0.05	1.60		
D. Wetlands		IE,NE,NO	NE,NO	NE,NO							NO	NO		
E. Settlements		6,577.97	0.34	0.00							0.08	2.96		
F. Other Land		NA,NE,NO	NE,NO	NE,NO							NO	NO		
G. Other		-1,021.09	NE	NE							NE	NE	NA	NA
6. Waste		**886.66**	**2,073.25**	**3.61**							**4.39**	**22.88**	**26.90**	**2.77**
A. Solid Waste Disposal on Land		NA,NE,NO	2,033.63								NA,NE	NA,NE	20.27	
B. Waste-water Handling			35.69	3.48							NA,NE	NA,NE	NA,NE	
C. Waste Incineration		886.66	3.93	0.13							4.39	22.88	6.63	2.77
D. Other		NA	NA	NA							NA	NA	NA	NA
7. Other *(please specify)*		**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**0.10**	**0.04**	**1.71**	**0.10**
Memo Items:														
International Bunkers		**28,679.69**	**0.30**	**0.86**							**266.02**	**31.89**	**12.90**	**99.31**
Aviation		21,346.39	0.19	0.68							99.20	14.81	4.83	5.43
Marine		7,333.29	0.12	0.18							166.82	17.07	8.08	93.87
Multilateral Operations		**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass		**5,478.57**												

Table A 9.1.8 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		PFCs		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	**549,536.99**	**3,954.62**	**176.27**	**13,027.14**	**19,200.36**	**187.70**	**417.02**	**0.05**	**0.05**	**2,156.82**	**5,662.85**	**1,756.98**	**1,640.56**
1. Energy	**533,975.08**	**1,041.99**	**22.11**							**2,149.81**	**5,358.72**	**1,002.06**	**1,581.24**
A. Fuel Combustion — Reference Approach	532,150.19												
Sectoral Approach	526,983.83	85.71	21.93							2,145.03	5,309.50	632.50	1,562.40
1. Energy Industries	188,059.90	6.14	3.88							436.07	62.58	8.62	1,146.44
2. Manufacturing Industries and Construction	95,160.98	16.71	4.66							326.36	671.38	29.50	234.65
3. Transport	124,094.61	19.95	10.54							1,126.74	3,717.41	513.71	57.92
4. Other Sectors	116,037.63	42.81	2.74							221.80	849.02	78.50	115.16
5. Other	3,630.71	0.10	0.11							34.06	9.11	2.18	8.23
B. Fugitive Emissions from Fuels	6,991.25	956.28	0.18							4.78	49.22	369.56	18.84
1. Solid Fuels	459.63	532.68	0.00							0.38	30.86	0.26	11.40
2. Oil and Natural Gas	6,531.63	423.60	0.18							4.40	18.36	369.30	7.44
2. Industrial Processes	**14,559.58**	**6.43**	**48.29**	**13,027.14**	**19,200.36**	**187.70**	**417.02**	**0.05**	**0.05**	**4.85**	**277.52**	**216.33**	**58.11**
A. Mineral Products	9,704.52	0.71	IE,NO							IE,NE,NO	3.35	10.13	13.41
B. Chemical Industry	2,893.16	5.04	48.26	NO	NO	NO	NO	NO	NO	2.60	86.33	124.21	34.02
C. Metal Production	1,961.90	0.69	0.03				220.26		0.02	2.25	187.84	2.12	10.68
D. Other Production	NE									NE	NE	79.87	NE
E. Production of Halocarbons and SF_6					15,622.21		38.34		NA,NO				
F. Consumption of Halocarbons and SF_6				13,027.14	3,578.15	187.70	158.42	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**		**NA,NE,NO**							**NO**	**NO**	**511.69**	**NO**
4. Agriculture		**996.58**	**101.93**							**NA,NO**	**NA,NO**	**NA,NO**	**NO**
A. Enteric Fermentation		859.87											
B. Manure Management		136.71	4.84									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils		NE	96.86									NO	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other		NA	0.23							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**501.60**	**0.54**	**0.00**							**0.14**	**4.76**	**NA**	**NA**
A. Forest Land	-13,511.59	NE,NO	NE,NO							NO	NO		
B. Cropland	15,543.03	NA,NE,NO	NA,NE,NO							NO	NO		
C. Grassland	-6,892.84	0.15	0.00							0.04	1.33		
D. Wetlands	IE,NE,NO	NE,NO	NE,NO							NO	NO		
E. Settlements	6,559.92	0.39	0.00							0.10	3.44		
F. Other Land	NA,NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-1,196.92	NE	NE							NE	NE	NA	NA
6. Waste	**500.73**	**1,909.08**	**3.94**							**1.91**	**21.80**	**25.25**	**1.11**
A. Solid Waste Disposal on Land	NA,NE,NO	1,872.34								NA,NE	NA,NE	18.66	
B. Waste-water Handling		36.63	3.87							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	500.73	0.11	0.07							1.91	21.80	6.59	1.11
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other *(please specify)*	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**0.10**	**0.04**	**1.65**	**0.10**
Memo Items:													
International Bunkers	**30,921.32**	**0.31**	**0.93**							**291.97**	**34.41**	**14.03**	**117.91**
Aviation	22,697.92	0.18	0.72							105.36	15.31	4.99	7.22
Marine	8,223.40	0.13	0.21							186.62	19.10	9.03	110.70
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**5,761.72**												

Table A 9.1.9 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		PFCs		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	**551,281.68**	**3,732.47**	**175.38**	**17,891.74**	**17,293.01**	**193.40**	**421.04**	**0.05**	**0.05**	**2,082.21**	**5,257.37**	**1,608.09**	**1,619.42**
1. Energy	**536,320.24**	**954.28**	**23.33**							**2,075.94**	**4,974.91**	**890.85**	**1,561.20**
A. Fuel Combustion — Reference Approach	539,213.68												
Sectoral Approach	529,730.41	85.12	23.15							2,071.72	4,926.49	560.44	1,544.22
1. Energy Industries	191,626.42	6.12	3.96							430.63	77.19	6.02	1,187.56
2. Manufacturing Industries and Construction	93,319.11	16.15	4.61							324.29	645.21	29.45	207.66
3. Transport	123,321.40	18.27	11.83							1,069.24	3,391.05	444.23	50.79
4. Other Sectors	118,269.47	44.49	2.66							221.77	804.97	78.99	92.17
5. Other	3,194.00	0.09	0.10							25.79	8.07	1.76	6.03
B. Fugitive Emissions from Fuels	6,589.83	869.15	0.18							4.22	48.42	330.41	16.98
1. Solid Fuels	158.41	454.48	0.00							0.38	30.75	0.26	9.46
2. Oil and Natural Gas	6,431.42	414.67	0.18							3.84	17.68	330.15	7.52
2. Industrial Processes	**14,509.25**	**4.56**	**49.19**	**17,891.74**	**17,293.01**	**193.40**	**421.04**	**0.05**	**0.05**	**4.15**	**254.20**	**196.48**	**56.89**
A. Mineral Products	9,629.21	0.71	IE,NO							IE,NE,NO	3.35	9.93	13.09
B. Chemical Industry	3,093.17	3.22	49.16	NO	NO	NO	NO	NO	NO	2.49	68.81	104.77	34.37
C. Metal Production	1,786.87	0.63	0.03				217.11		0.02	1.66	182.03	2.02	9.44
D. Other Production	NE									NE	NE	79.76	NE
E. Production of Halocarbons and SF_6					12,357.47		42.51		NA,NO				
F. Consumption of Halocarbons and SF_6				17,891.74	4,935.54	193.40	161.42	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**		**NA,NE,NO**							**NO**	**NO**	**495.16**	**NO**
4. Agriculture		**994.57**	**98.87**							**NA,NO**	**NA,NO**	**NA,NO**	**NO**
A. Enteric Fermentation		857.71											
B. Manure Management		136.86	4.87									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils		NE	93.77									NO	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other		NA	0.23							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**-53.09**	**0.54**	**0.00**							**0.14**	**4.77**	**NA**	**NA**
A. Forest Land	-13,406.21	NE,NO	NE,NO							NO	NO		
B. Cropland	15,428.32	NA,NE,NO	NA,NE,NO							NO	NO		
C. Grassland	-7,290.80	0.16	0.00							0.04	1.39		
D. Wetlands	IE,NE,NO	NE,NO	NE,NO							NO	NO		
E. Settlements	6,521.47	0.39	0.00							0.10	3.38		
F. Other Land	NA,NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-1,305.87	NE	NE							NE	NE	NA	NA
6. Waste	**505.29**	**1,778.51**	**3.98**							**1.87**	**23.45**	**24.02**	**1.23**
A. Solid Waste Disposal on Land	NA,NE,NO	1,740.79								NA,NE	NA,NE	17.35	
B. Waste-water Handling		37.58	3.82							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	505.29	0.15	0.16							1.87	23.45	6.67	1.23
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other *(please specify)*	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**0.11**	**0.04**	**1.58**	**0.10**
Memo Items:													
International Bunkers	**34,234.43**	**0.32**	**1.03**							**319.96**	**37.41**	**15.20**	**119.19**
Aviation	25,260.68	0.18	0.80							116.77	16.61	5.36	8.03
Marine	8,973.75	0.14	0.22							203.19	20.80	9.84	111.16
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**5,797.07**												

Table A 9.1.10 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		PFCs		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	**541,984.80**	**3,481.46**	**142.13**	**22,761.51**	**10,860.63**	**224.58**	**398.80**	**0.05**	**0.06**	**1,969.10**	**4,928.23**	**1,457.35**	**1,226.97**
1. Energy	**527,429.19**	**866.16**	**24.13**							**1,962.61**	**4,625.67**	**805.85**	**1,179.19**
A. Fuel Combustion — Reference Approach	533,711.47												
Sectoral Approach	521,164.74	87.10	23.96							1,958.02	4,584.60	502.63	1,169.45
1. Energy Industries	181,248.50	7.23	3.50							391.94	70.00	7.57	871.24
2. Manufacturing Industries and Construction	94,535.56	15.80	4.67							314.33	636.41	28.97	171.51
3. Transport	124,164.23	16.67	13.08							1,004.20	3,064.65	383.81	38.62
4. Other Sectors	118,066.83	47.32	2.61							220.10	805.61	80.47	81.77
5. Other	3,149.63	0.09	0.09							27.45	7.93	1.81	6.32
B. Fugitive Emissions from Fuels	6,264.45	779.05	0.17							4.59	41.07	303.22	9.74
1. Solid Fuels	112.08	380.84	0.00							0.32	23.94	0.26	8.01
2. Oil and Natural Gas	6,152.37	398.21	0.17							4.27	17.13	302.96	1.73
2. Industrial Processes	**14,358.89**	**3.76**	**17.31**	**22,761.51**	**10,860.63**	**224.58**	**398.80**	**0.05**	**0.06**	**4.41**	**272.17**	**165.89**	**46.24**
A. Mineral Products	9,140.58	0.59	IE,NO							IE,NE,NO	1.56	8.57	8.94
B. Chemical Industry	3,127.33	2.44	17.28	NO	NO	NO	NO	NO	NO	2.70	65.62	74.24	28.97
C. Metal Production	2,090.98	0.73	0.03				190.59		0.03	1.71	204.99	1.93	8.34
D. Other Production	NE									NE	NE	81.16	NE
E. Production of Halocarbons and SF_6					5,381.50		19.50		NA,NO				
F. Consumption of Halocarbons and SF_6				22,761.51	5,479.13	224.58	188.72	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**		**NA,NE,NO**							**NO**	**NO**	**461.68**	**NO**
4. Agriculture		**992.08**	**96.83**							**NA,NO**	**NA,NO**	**NA,NO**	**NO**
A. Enteric Fermentation		857.28											
B. Manure Management		134.80	4.86									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils		NE	91.74									NO	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other		NA	0.23							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**-267.48**	**0.78**	**0.01**							**0.19**	**6.78**	**NA**	**NA**
A. Forest Land	-13,504.37	NE,NO	NE,NO							NO	NO		
B. Cropland	15,329.25	NA,NE,NO	NA,NE,NO							NO	NO		
C. Grassland	-7,282.64	0.39	0.00							0.10	3.43		
D. Wetlands	IE,NE,NO	NE,NO	NE,NO							NO	NO		
E. Settlements	6,458.28	0.38	0.00							0.10	3.35		
F. Other Land	NA,NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-1,268.01	NE	NE							NE	NE	NA	NA
6. Waste	**464.20**	**1,618.69**	**3.85**							**1.78**	**23.57**	**22.42**	**1.44**
A. Solid Waste Disposal on Land	NA,NE,NO	1,582.09								NA,NE	NA,NE	15.77	
B. Waste-water Handling		36.44	3.70							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	464.20	0.16	0.16							1.78	23.57	6.65	1.44
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)***	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**0.11**	**0.04**	**1.51**	**0.10**
Memo Items:													
International Bunkers	**33,949.86**	**0.27**	**1.03**							**272.21**	**32.63**	**12.71**	**85.21**
Aviation	27,446.47	0.17	0.87							125.26	17.59	5.60	6.11
Marine	6,503.39	0.10	0.16							146.95	15.04	7.11	79.10
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**6,410.95**												

Table A 9.1.11 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		PFCs		SF_6		NO_x	CO	NMVOC	SO_2
					P	A	P	A	P	A				
		(Gg)			CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals		**550,045.27**	**3,265.47**	**140.34**	**28,731.94**	**9,117.19**	**260.51**	**498.42**	**0.08**	**0.08**	**1,896.66**	**4,227.71**	**1,336.84**	**1,215.22**
1. Energy		**536,074.95**	**787.41**	**25.29**							**1,890.43**	**3,921.87**	**726.02**	**1,175.80**
A. Fuel Combustion	Reference Approach	543,929.41												
	Sectoral Approach	530,401.23	74.96	25.13							1,886.80	3,882.42	419.90	1,166.93
1. Energy Industries		191,834.98	7.80	3.91							420.77	81.49	8.33	904.41
2. Manufacturing Industries and Construction		94,692.14	15.22	4.61							304.12	536.42	28.46	161.67
3. Transport		123,482.80	14.87	14.06							920.40	2,568.27	310.81	29.18
4. Other Sectors		117,475.00	36.98	2.47							215.09	688.90	70.58	65.52
5. Other		2,916.31	0.08	0.09							26.42	7.33	1.71	6.16
B. Fugitive Emissions from Fuels		5,673.72	712.45	0.16							3.64	39.45	306.12	8.86
1. Solid Fuels		102.36	333.43	0.00							0.31	24.42	0.20	7.31
2. Oil and Natural Gas		5,571.35	379.01	0.16							3.32	15.03	305.92	1.55
2. Industrial Processes		**13,948.81**	**3.46**	**17.90**	**28,731.94**	**9,117.19**	**260.51**	**498.42**	**0.08**	**0.08**	**4.06**	**273.74**	**156.49**	**38.14**
A. Mineral Products		8,656.46	0.59	IE,NO							IE,NE,NO	2.75	9.79	10.51
B. Chemical Industry		3,309.60	2.20	17.87	NO	NO	NO	NO	NO	NO	2.43	82.51	65.60	20.09
C. Metal Production		1,982.75	0.68	0.03				257.88		0.05	1.63	188.48	1.77	7.53
D. Other Production		NE									NE	NE	79.33	NE
E. Production of Halocarbons and SF_6						2,676.52		23.08		NA,NO				
F. Consumption of Halocarbons and SF_6					28,731.94	6,440.68	260.51	217.46	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**		**NA,NE,NO**							**NO**	**NO**	**431.44**	**NO**
4. Agriculture			**959.13**	**93.18**							**NA,NO**	**NA,NO**	**NA,NO**	**NO**
A. Enteric Fermentation			829.34											
B. Manure Management			129.79	4.58									NO	
C. Rice Cultivation			NA,NO										NA,NO	
D. Agricultural Soils			NE	88.37									NO	
E. Prescribed Burning of Savannas			NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues			NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other			NA	0.23							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry		**-449.01**	**0.98**	**0.01**							**0.24**	**8.56**	**NA**	**NA**
A. Forest Land		-13,804.88	NE,NO	NE,NO							NO	NO		
B. Cropland		15,339.05	NA,NE,NO	NA,NE,NO							NO	NO		
C. Grassland		-7,445.60	0.59	0.00							0.15	5.15		
D. Wetlands		IE,NE,NO	NE,NO	NE,NO							NO	NO		
E. Settlements		6,412.51	0.39	0.00							0.10	3.41		
F. Other Land		NA,NE,NO	NE,NO	NE,NO							NO	NO		
G. Other		-950.08	NE	NE							NE	NE	NA	NA
6. Waste		**470.53**	**1,514.50**	**3.97**							**1.82**	**23.50**	**21.38**	**1.18**
A. Solid Waste Disposal on Land		NA,NE,NO	1,477.02								NA,NE	NA,NE	14.72	
B. Waste-water Handling			37.32	3.81							NA,NE	NA,NE	NA,NE	
C. Waste Incineration		470.53	0.16	0.16							1.82	23.50	6.66	1.18
D. Other		NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)***		**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**0.11**	**0.04**	**1.51**	**0.11**
Memo Items:														
International Bunkers		**35,971.45**	**0.23**	**1.10**							**266.02**	**31.92**	**12.09**	**73.21**
Aviation		30,248.71	0.14	0.96							136.76	18.69	5.83	6.92
Marine		5,722.74	0.09	0.14							129.26	13.23	6.26	66.29
Multilateral Operations		**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass		**6,572.84**												

Table A 9.1.12 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		PFCs		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	**560,862.69**	**2,980.65**	**133.63**	**34,253.40**	**9,714.32**	**157.40**	**425.53**	**0.07**	**0.06**	**1,827.32**	**3,879.30**	**1,235.32**	**1,119.27**
1. Energy	**548,201.10**	**752.63**	**26.54**							**1,821.46**	**3,560.05**	**651.33**	**1,083.74**
A. Fuel Combustion — Reference Approach	553,844.92												
Sectoral Approach	542,620.30	69.21	26.39							1,817.78	3,532.12	360.70	1,073.96
1. Energy Industries	201,768.69	8.05	4.14							444.16	80.57	7.35	823.12
2. Manufacturing Industries and Construction	94,501.73	14.06	4.67							292.00	573.42	28.29	161.42
3. Transport	123,099.40	13.13	15.05							840.29	2,200.03	256.54	23.11
4. Other Sectors	120,328.58	33.88	2.44							216.41	670.74	66.86	60.56
5. Other	2,921.90	0.08	0.09							24.91	7.37	1.66	5.76
B. Fugitive Emissions from Fuels	5,580.80	683.42	0.15							3.68	27.93	290.63	9.78
1. Solid Fuels	101.68	301.86	0.00							0.25	13.68	0.17	8.16
2. Oil and Natural Gas	5,479.12	381.56	0.15							3.43	14.24	290.46	1.62
2. Industrial Processes	**12,767.81**	**2.87**	**15.54**	**34,253.40**	**9,714.32**	**157.40**	**425.53**	**0.07**	**0.06**	**3.03**	**264.12**	**148.65**	**33.09**
A. Mineral Products	7,853.04	0.58	IE,NO							IE,NE,NO	2.54	9.22	9.03
B. Chemical Industry	3,397.92	1.87	15.52	NO	NO	NO	NO	NO	NO	1.61	81.54	57.19	16.28
C. Metal Production	1,516.86	0.42	0.02				223.22		0.03	1.42	180.05	1.58	7.79
D. Other Production	NE									NE	NE	80.66	NE
E. Production of Halocarbons and SF_6					2,451.94		54.05		NA,NO				
F. Consumption of Halocarbons and SF_6				34,253.40	7,262.37	157.40	148.26	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**		**NA,NE,NO**							**NO**	**NO**	**414.48**	**NO**
4. Agriculture		**903.94**	**87.46**							**NA,NO**	**NA,NO**	**NA,NO**	**NO**
A. Enteric Fermentation		778.99											
B. Manure Management		124.96	4.39									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils		NE	82.81									NO	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other		NA	0.25							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**-602.54**	**1.17**	**0.01**							**0.29**	**10.27**	**NA**	**NA**
A. Forest Land	-14,348.00	NE,NO	NE,NO							NO	NO		
B. Cropland	15,286.51	NA,NE,NO	NA,NE,NO							NO	NO		
C. Grassland	-7,469.66	0.77	0.01							0.19	6.78		
D. Wetlands	IE,NE,NO	NE,NO	NE,NO							NO	NO		
E. Settlements	6,373.85	0.40	0.00							0.10	3.49		
F. Other Land	NA,NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	-445.23	NE	NE							NE	NE	NA	NA
6. Waste	**496.31**	**1,320.03**	**4.08**							**2.42**	**44.81**	**19.38**	**2.32**
A. Solid Waste Disposal on Land	NA,NE,NO	1,282.31								NA,NE	NA,NE	12.77	
B. Waste-water Handling		37.56	3.93							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	496.31	0.16	0.16							2.42	44.81	6.61	2.32
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)***	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**0.12**	**0.05**	**1.48**	**0.11**
Memo Items:													
International Bunkers	**35,904.85**	**0.22**	**1.10**							**277.58**	**32.52**	**12.54**	**74.83**
Aviation	29,485.96	0.12	0.94							132.50	17.67	5.51	7.50
Marine	6,418.89	0.10	0.16							145.08	14.85	7.02	67.33
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**7,261.41**												

Table A 9.1.13 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		PFCs		SF_6		NO_x	CO	NMVOC	SO_2
				P	A	P	A	P	A				
	(Gg)			CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals	**544,486.11**	**2,837.52**	**128.93**	**41,805.57**	**9,944.75**	**154.38**	**322.72**	**0.07**	**0.06**	**1,720.83**	**3,344.81**	**1,157.18**	**1,001.54**
1. Energy	**532,984.71**	**734.17**	**27.11**							**1,716.38**	**3,097.41**	**590.12**	**969.38**
A. Fuel Combustion — Reference Approach	534,365.90												
Sectoral Approach	527,357.87	60.47	26.96							1,712.29	3,076.58	315.48	962.37
1. Energy Industries	200,033.88	7.26	4.00							439.40	77.40	7.90	750.87
2. Manufacturing Industries and Construction	86,143.26	12.89	4.54							267.62	510.70	27.35	140.44
3. Transport	125,109.43	11.64	16.02							776.67	1,915.43	216.62	20.62
4. Other Sectors	113,014.66	28.59	2.32							204.86	565.31	61.96	45.18
5. Other	3,056.63	0.09	0.09							23.75	7.74	1.65	5.25
B. Fugitive Emissions from Fuels	5,626.84	673.70	0.15							4.09	20.84	274.63	7.01
1. Solid Fuels	107.95	301.96	0.00							0.26	7.11	0.13	5.81
2. Oil and Natural Gas	5,518.89	371.74	0.14							3.82	13.73	274.50	1.21
2. Industrial Processes	**12,144.35**	**2.76**	**8.61**	**41,805.57**	**9,944.75**	**154.38**	**322.72**	**0.07**	**0.06**	**2.30**	**215.01**	**144.36**	**31.12**
A. Mineral Products	7,662.03	0.59	IE,NO							IE,NE,NO	2.54	9.60	11.93
B. Chemical Industry	3,310.68	1.89	8.60	NO	NO	NO	NO	NO	NO	1.10	39.05	53.13	12.98
C. Metal Production	1,171.63	0.29	0.02				158.48		0.04	1.20	173.43	1.36	6.21
D. Other Production	NE									NE	NE	80.27	NE
E. Production of Halocarbons and SF_6					1,989.67		57.35		NA,NO				
F. Consumption of Halocarbons and SF_6				41,805.57	7,955.08	154.38	106.88	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**		**NA,NE,NO**							**NO**	**NO**	**403.07**	**NO**
4. Agriculture		**894.99**	**89.15**							**NA,NO**	**NA,NO**	**NA,NO**	**NO**
A. Enteric Fermentation		771.32											
B. Manure Management		123.68	4.26									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils		NE	84.63									NO	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other		NA	0.25							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**-1,124.42**	**1.01**	**0.01**							**0.25**	**8.80**	**NA**	**NA**
A. Forest Land	-15,045.16	NE,NO	NE,NO							NO	NO		
B. Cropland	15,312.53	NA,NE,NO	NA,NE,NO							NO	NO		
C. Grassland	-7,765.93	0.67	0.00							0.17	5.89		
D. Wetlands	IE,NE,NO	NE,NO	NE,NO							NO	NO		
E. Settlements	6,326.72	0.33	0.00							0.08	2.91		
F. Other Land	NA,NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	47.42	NE	NE							NE	NE	NA	NA
6. Waste	**481.47**	**1,204.58**	**4.06**							**1.79**	**23.53**	**18.19**	**0.92**
A. Solid Waste Disposal on Land	NA,NE,NO	1,166.64								NA,NE	NA,NE	11.62	
B. Waste-water Handling		37.79	3.90							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	481.47	0.16	0.16							1.79	23.53	6.58	0.92
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)***	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**0.12**	**0.05**	**1.44**	**0.11**
Memo Items:													
International Bunkers	**34,282.49**	**0.20**	**1.05**							**249.72**	**29.71**	**11.37**	**64.41**
Aviation	28,933.72	0.11	0.92							128.99	17.35	5.52	6.07
Marine	5,348.77	0.08	0.13							120.73	12.36	5.84	58.34
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**7,507.45**												

Table A 9.1.14 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		PFCs		SF_6		NO_x	CO	NMVOC	SO_2
				P	A	P	A	P	A				
	(Gg)			CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals	**556,393.73**	**2,552.96**	**127.92**	**47,036.84**	**10,256.38**	**157.57**	**286.52**	**0.06**	**0.06**	**1,728.06**	**2,934.93**	**1,061.63**	**990.81**
1. Energy	**544,160.96**	**593.18**	**27.85**							**1,723.32**	**2,762.74**	**500.74**	**956.06**
A. Fuel Combustion — Reference Approach	542,214.07												
Sectoral Approach	538,798.53	58.25	27.73							1,720.11	2,740.19	277.97	947.55
1. Energy Industries	208,316.31	7.22	4.23							466.56	85.07	6.53	745.61
2. Manufacturing Industries and Construction	87,358.65	13.73	4.52							272.93	492.16	27.09	128.14
3. Transport	126,494.25	10.30	16.63							756.12	1,654.78	183.08	30.78
4. Other Sectors	113,814.19	26.90	2.25							206.47	501.00	59.89	39.33
5. Other	2,815.12	0.08	0.09							18.02	7.18	1.37	3.69
B. Fugitive Emissions from Fuels	5,362.43	534.93	0.13							3.20	22.55	222.77	8.51
1. Solid Fuels	111.87	259.87	0.00							0.28	10.74	0.12	7.28
2. Oil and Natural Gas	5,250.56	275.07	0.12							2.92	11.81	222.65	1.23
2. Industrial Processes	**12,953.14**	**2.86**	**9.10**	**47,036.84**	**10,256.38**	**157.57**	**286.52**	**0.06**	**0.06**	**2.59**	**140.13**	**143.54**	**33.71**
A. Mineral Products	7,854.49	0.62	IE,NO							IE,NE,NO	2.67	9.24	16.26
B. Chemical Industry	3,250.90	1.65	9.08	NO	NO	NO	NO	NO	NO	1.19	37.06	52.14	9.90
C. Metal Production	1,847.74	0.59	0.02				126.00		0.03	1.40	100.39	1.57	7.54
D. Other Production	NE									NE	NE	80.59	NE
E. Production of Halocarbons and SF_6					1,851.90		55.71		NA,NO				
F. Consumption of Halocarbons and SF_6				47,036.84	8,404.47	157.57	104.81	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**		**NA,NE,NO**							**NO**	**NO**	**399.22**	**NO**
4. Agriculture		**897.52**	**86.89**							**NA,NO**	**NA,NO**	**NA,NO**	**NO**
A. Enteric Fermentation		774.45											
B. Manure Management		123.07	4.21									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils		NE	82.48									NO	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other		NA	0.20							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**-1,180.80**	**0.97**	**0.01**							**0.24**	**8.51**	**NA**	**NA**
A. Forest Land	-15,645.81	NE,NO	NE,NO							NO	NO		
B. Cropland	15,384.48	NA,NE,NO	NA,NE,NO							NO	NO		
C. Grassland	-7,558.97	0.63	0.00							0.16	5.55		
D. Wetlands	IE,NE,NO	NE,NO	NE,NO							NO	NO		
E. Settlements	6,302.22	0.34	0.00							0.08	2.96		
F. Other Land	NA,NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	337.28	NE	NE							NE	NE	NA	NA
6. Waste	**460.43**	**1,058.43**	**4.07**							**1.80**	**23.51**	**16.73**	**0.93**
A. Solid Waste Disposal on Land	NA,NE,NO	1,020.26								NA,NE	NA,NE	10.16	
B. Waste-water Handling		38.01	3.92							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	460.43	0.16	0.16							1.80	23.51	6.57	0.93
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)***	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**0.12**	**0.05**	**1.40**	**0.12**
Memo Items:													
International Bunkers	**34,776.33**	**0.19**	**1.07**							**247.88**	**29.27**	**11.18**	**67.40**
Aviation	29,640.62	0.11	0.94							132.17	17.42	5.58	7.16
Marine	5,135.71	0.08	0.13							115.70	11.84	5.60	60.24
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**8,351.57**												

Table A 9.1.15 Summary Report For National Greenhouse Gas Inventories (IPCC TABLE 7A) – 2004

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 emissions/removals (Gg)	CH_4 (Gg)	N_2O (Gg)	HFCs P (CO_2 eq. Gg)	HFCs A (CO_2 eq. Gg)	PFCs P (CO_2 eq. Gg)	PFCs A (CO_2 eq. Gg)	SF_6 P (Gg)	SF_6 A (Gg)	NO_x (Gg)	CO (Gg)	NMVOC (Gg)	SO_2 (Gg)
Total National Emissions and Removals	**555,906.03**	**2,464.59**	**130.44**	**49,768.33**	**8,947.54**	**157.74**	**336.12**	**0.05**	**0.05**	**1,663.67**	**2,699.84**	**1,007.61**	**835.66**
1. Energy	**544,021.84**	**576.55**	**28.29**							**1,658.76**	**2,531.51**	**446.97**	**802.09**
A. Fuel Combustion – Reference Approach	586,516.21												
Sectoral Approach	538,753.81	55.60	28.16							1,655.56	2,512.86	244.91	792.13
1. Energy Industries	207,306.43	7.41	4.12							453.34	85.23	6.53	583.24
2. Manufacturing Industries and Construction	84,594.94	13.27	4.46							266.28	512.69	26.59	128.86
3. Transport	127,937.10	9.17	17.30							716.83	1,433.66	152.67	37.38
4. Other Sectors	116,012.12	25.66	2.19							195.05	473.95	57.49	37.22
5. Other	2,903.23	0.08	0.09							24.06	7.33	1.62	5.43
B. Fugitive Emissions from Fuels	5,268.04	520.95	0.13							3.20	18.65	202.07	9.95
1. Solid Fuels	168.08	234.90	0.01							0.36	6.61	0.10	8.60
2. Oil and Natural Gas	5,099.95	286.05	0.13							2.84	12.04	201.97	1.35
2. Industrial Processes	**13,367.18**	**2.85**	**11.53**	**49,768.33**	**8,947.54**	**157.74**	**336.12**	**0.05**	**0.05**	**2.67**	**136.72**	**145.25**	**32.45**
A. Mineral Products	7,959.05	0.61	NE							NE	2.62	9.51	16.40
B. Chemical Industry	3,356.38	1.59	11.51	NO	NO	NO	NO	NO	NO	1.11	28.91	53.79	8.64
C. Metal Production	2,051.75	0.66	0.03				152.36		0.02	1.56	105.19	1.62	7.41
D. Other Production	NE									NE	NE	80.33	NE
E. Production of Halocarbons and SF_6					283.41		90.23		NA,NO				
F. Consumption of Halocarbons and SF_6				49,768.33	8,662.96	157.74	93.53	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	**IE,NE**		**IE,NE,NO**							**NO**	**NO**	**397.97**	**NO**
4. Agriculture		**898.94**	**86.54**							**NA,NO**	**NA,NO**	**NA,NE,NO**	**NO**
A. Enteric Fermentation		776.36											
B. Manure Management		122.59	4.21									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils		NA,NE	82.12									NA,NE	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other		NA	0.20							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**-1,934.52**	**0.93**	**0.01**							**0.23**	**8.16**	**NA**	**NA**
A. Forest Land	-16,302.03	NE,NO	NE,NO							NO	NO		
B. Cropland	15,315.74	NA,NE,NO	NA,NE,NO							NO	NO		
C. Grassland	-7,857.62	0.57	0.00							0.14	4.95		
D. Wetlands	IE,NE,NO	NE,NO	NE,NO							NO	NO		
E. Settlements	6,290.57	0.37	0.00							0.09	3.21		
F. Other Land	NA,NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	618.82	NE	NE							NE	NE	NA	NA
6. Waste	**451.53**	**985.32**	**4.08**							**1.78**	**23.36**	**16.08**	**0.91**
A. Solid Waste Disposal on Land	NA,NE,NO	946.93								NA,NE	NA,NE	9.43	
B. Waste-water Handling		38.24	3.92							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	451.53	0.15	0.16							1.78	23.36	6.65	0.91
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)***	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**0.23**	**0.09**	**1.34**	**0.22**
Memo Items:													
International Bunkers	**38,998.74**	**0.20**	**1.20**							**280.05**	**32.40**	**12.45**	**78.22**
Aviation	33,123.66	0.10	1.05							147.69	18.85	6.04	8.63
Marine	5,875.08	0.09	0.15							132.35	13.55	6.41	69.59
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**9,357.62**												

Table A 9.1.16 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		PFCs		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	**555,906.03**	**2,464.59**	**130.44**	**49,768.33**	**8,947.54**	**157.74**	**336.12**	**0.05**	**0.05**	**1,663.67**	**2,699.84**	**1,007.61**	**835.66**
1. Energy	**543,633.54**	**505.68**	**29.46**							**1,621.84**	**2,239.86**	**416.47**	**672.69**
A. Fuel Combustion — Reference Approach	588,091.20												
Sectoral Approach	537,775.60	56.89	29.31							1,618.68	2,221.31	215.90	663.68
1. Energy Industries	209,235.04	12.18	5.08							461.55	97.94	5.58	461.92
2. Manufacturing Industries and Construction	85,092.59	13.16	4.53							267.45	514.28	26.85	122.77
3. Transport	129,254.48	8.27	17.54							683.59	1,198.61	128.26	43.14
4. Other Sectors	111,405.12	23.21	2.08							183.86	403.42	53.69	30.69
5. Other	2,788.38	0.08	0.08							22.21	7.05	1.52	5.17
B. Fugitive Emissions from Fuels	5,857.94	448.79	0.15							3.16	18.55	200.57	9.01
1. Solid Fuels	110.07	181.28	0.00							0.26	6.16	0.11	7.75
2. Oil and Natural Gas	5,747.87	267.51	0.15							2.90	12.40	200.46	1.26
2. Industrial Processes	**13,453.43**	**3.36**	**9.05**	**53,276.51**	**9,221.29**	**146.95**	**350.91**	**0.05**	**0.05**	**2.45**	**134.17**	**144.95**	**32.41**
A. Mineral Products	7,754.03	0.52	NE							NE	4.28	9.75	17.07
B. Chemical Industry	3,253.11	2.01	9.02	NO	NO	NO	NO	NO	NO	0.84	25.21	54.92	6.91
C. Metal Production	2,446.30	0.84	0.03				154.58		0.01	1.61	104.67	1.58	8.43
D. Other Production	NE									NE	NE	78.70	NE
E. Production of Halocarbons and SF_6					340.87		110.28		NA,NO				
F. Consumption of Halocarbons and SF_6				53,276.51	8,878.75	146.95	86.06	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	**IE,NE**		**IE,NE,NO**							**NO**	**NO**	**396.80**	**NO**
4. Agriculture		**878.26**	**85.30**							**NA,NO**	**NA,NO**	**NA,NE,NO**	**NO**
A. Enteric Fermentation		758.78											
B. Manure Management		119.48	4.10									NO	
C. Rice Cultivation		NA,NO										NA,NO	
D. Agricultural Soils		NA,NE	81.00									NA,NE	
E. Prescribed Burning of Savannas		NA	NA							NO	NO	NO	
F. Field Burning of Agricultural Residues		NA,NO	NA,NO							NA,NO	NA,NO	NA,NO	
G. Other		NA	0.20							NA	NA	NA	NO
5. Land Use, Land-Use Change and Forestry	**-2,056.12**	**0.92**	**0.01**							**0.23**	**8.09**	**NA**	**NA**
A. Forest Land	-15,738.00	NE,NO	NE,NO							NO	NO		
B. Cropland	15,258.33	NA,NE,NO	NA,NE,NO							NO	NO		
C. Grassland	-7,934.29	0.57	0.00							0.14	4.99		
D. Wetlands	IE,NE,NO	NE,NO	NE,NO							NO	NO		
E. Settlements	6,261.56	0.36	0.00							0.09	3.11		
F. Other Land	NA,NE,NO	NE,NO	NE,NO							NO	NO		
G. Other	96.28	NE	NE							NE	NE	NA	NA
6. Waste	**458.93**	**969.43**	**4.08**							**1.87**	**23.37**	**16.04**	**0.91**
A. Solid Waste Disposal on Land	NA,NE,NO	930.82								NA,NE	NA,NE	9.27	
B. Waste-water Handling		38.46	3.92							NA,NE	NA,NE	NA,NE	
C. Waste Incineration	458.93	0.15	0.16							1.87	23.37	6.77	0.91
D. Other	NA	NA	NA							NA	NA	NA	NA
7. Other ***(please specify)***	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**0.23**	**0.09**	**1.34**	**0.22**
Memo Items:													
International Bunkers	**40,867.39**	**0.19**	**1.26**							**288.23**	**32.93**	**12.66**	**83.69**
Aviation	35,007.85	0.10	1.11							156.33	19.43	6.28	9.12
Marine	5,859.54	0.09	0.15							131.89	13.50	6.38	74.57
Multilateral Operations	**NE**	**NE**	**NE**							**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**9,206.51**												

A10 Annex 10: Supplementary information for estimates of greenhouse gas emissions by sources and removals by sinks resulting from activities under Article 3.3 and 3.4 of the Kyoto Protocol

The supplementary information in this Annex is provided in accordance with Decisions 15/CP.10 (FCCC/CP/2004/10/Add.2). The UK will use entire commitment period accounting for activities under Article 3.3 and 3.4, reporting in 2014. The methodologies for estimating emissions and removals from such activities are under development, but are described here for information.

A10.1 GENERAL INFORMATION

A10.1.1 Definition of forest

Article 3.3 of the Kyoto Protocol requires Parties to account for Afforestation, Reforestation and Deforestation (ARD) since 1990 in meeting their emissions reduction commitments. The UK has chosen the following definition of forest and single minimum values:

A definition of 'forest' as agreed with the Forestry Commission comprising:

- a minimum area of 0.1 hectares;
- a minimum width of 20 metres;
- tree crown cover of at least 20 per cent, or the potential to achieve it;
- a minimum height of 2 metres, or the potential to achieve it.

These single minimum values are used for reporting UK forestry statistics (Forestry Commission, 2006) and the UK's greenhouse gas inventory submitted under the UNFCCC. The definitions are consistent with information provided by the UK to the FAO. However, if an international enquiry uses a different minimum definition, for example 0.5 ha in the Global Forest Resource Assessment 2005, the UK areas are adjusted (explicitly or implicitly) to this different definition (FAO, 2005).

A10.1.2 Elected activities under Article 3.4

The UK has chosen to elect Forest Management (FM) as an activity under Article 3.4. In accordance with the Annex to Decision 16/CMP.1, credits from Forest

Management are capped in the first commitment period. For the UK the cap is a relatively modest 0.37 MtC (1.36 MtCO2) per year, or 6.78 MtCO2 for the whole commitment period.

A10.1.3 Description of how the definitions of each activity under Article 3.3 and 3.4 have been implemented and applied consistently over time

The areas of forest land reported for AR and FM under the Kyoto protocol equal the area reported under 5A2 (Land converted to Forest Land) in the UNFCCC greenhouse gas inventory. The Afforestation/Reforestation area is land that has been converted to forested land since 1990 (inclusive), while the Forest Management area is the area converted to forest land between 1921 and 1989. In the UK Land converted to Forest Land is considered to stay in that category beyond the 20 default period in order to take account of the long term soil carbon dynamics. Deforestation since 1990 is taken to be the land area permanently converted from forest land to either grassland or settlement (conversion to cropland is estimated to be negligible based on land use surveys). All ARD and FM definitions are consistent with those used in the UNFCCC inventory and updates to methodologies over time have been back-calculated to 1990 to ensure consistency over time.

The afforestation and reforestation datasets are provided by the Forestry Commission (the national forestry agency) and are consistent with the definition of forest given above. There is an assumption of restocking after harvesting on the national estate, although open habitat can make up 13-20% of stand area on restocking. A felling license is required for felling outside the national forest estate; there is a legal requirement to restock under such a license unless an unconditional felling license is granted (in which case this would be formally reported as deforestation). Therefore, Afforestation and Reforestation under Article 3.3 can be considered together. Information on deforestation activities is assembled from data provided by the Forestry Commission and by the Ordnance Survey (the national cartographic agency) through the UK government. To the best of knowledge, these definitions have been applied consistently over time, although larger uncertainty is associated with deforestation as compared with afforestation.

A10.1.4 Precedence conditions and hierarchy among Art. 3.4 activities

Not applicable, as only Forest Management has been elected as an Article 3.4 activity.

A10.2 LAND-RELATED INFORMATION

A10.2.1 Spatial assessment unit used

The spatial assessment units used for the voluntary submission of the Kyoto Protocol LULUCF tables in April 2007 are the four countries of the UK: England, Scotland, Wales and Northern Ireland. A methodology for reporting using units of 20 x 20km grid cells is in development. In this draft method, the location of ARD and FM land will be statistically determined for the 852 grid cells covering the UK (GPG LULUCF Reporting Method 1). Each 20x20km cell has a unique identification code produced from the coordinates of the lower left corner of the cell (using the Ordnance Survey British National Grid projection and the Northern Irish grid projection for Northern Ireland cells).

A10.2.2 Methodology used to develop the land transition matrix

Several datasets are either available, or will become available, for the assessment of ARD and FM activities in the UK (**Table A10.2.1**). The UK GHGI currently uses the national planting statistics from 1921 to the present, which are provided by the Forestry Commission and the Northern Ireland Forest Service for each of the countries in the UK. This data is used for the estimation of AR and FM in the LULUCF tables submitted here. Estimates of Deforestation are made using the Unconditional Felling Licences and the Land Use Change Statistics (LUCS), a survey of land converted to developed use.

The relationship between the currently used datasets and the land transition matrix is shown in **Table A10.2.2**. With current methods it is not possible to assess the split in the Deforestation area between areas under Afforestation/ Reforestation and Forest Management although it is reasonable to assume that there will be little Deforestation on areas afforested since 1990. The relationship between data sources and the proposed land transition matrix at the 20km grid scale is shown in **Table A10.2.3**.

Table A 10.2.1 Data sources on ARD and FM activities (additional data sources may become available in the future)

Activity	Dataset	Available scale	Time period	Details
AR & FM	Annual planting statistics	Country (England, Scotland, Wales, Northern Ireland)	1921-present	New planting on previously non-forested land. Updated annually. Categorized into conifer and broadleaved woodland.
AR	Grant-aided woodland database	Local administrative unit/NI counties	1995-present	Private woodland planted with grant aid since 1995. Categorized into conifer and broadleaved planting.
AR & FM	Forestry Commission management database	20km grid cells	1995-present	Database of state woodland planting since 1995, indicating the rotation (1st rotation will be Afforestation, 2nd or greater rotations are restocking). Categorised by species.
AR & FM	National Inventory of Woodland and Trees (NIWT)	20km grid cells (sample statistics)	1995	Grid cell database includes the area and planting decade of each species within the grid cell. A digital map of woodland over 2ha is also available.
ARD, FM	NIWT2	20km grid cells (sample statistics)	Planned for 2009-2017	Update of the 1995 NIWT. A partial repeat of the grid cell analysis should be available by 2013. An update of the digital map will be available, initially from 2009, which can be used to asses deforestation since NIWT1.

Activity	Dataset	Available scale	Time period	Details
D	Forestry Commission Unconditional Felling Licence data	England only (data from other countries should become available)	1990-2002	Unconditional Felling Licences are issued for felling without restocking. Used to estimate deforestation in rural areas (primarily for heathland restoration). English data is extrapolated to GB scale and to current reporting year. Omits felling for development purposes, e.g. construction of wind turbines.
D	Land Use Change Statistics (survey of land converted to developed uses)	England only (data from other countries should become available)	1990-2003 (updated in 2007)	Estimates of the conversion of forest to urban/developed land use. Based on Ordnance Survey map updates, identifying changes through aerial surveys and other reporting, expected to capture most changes within five years. English data is extrapolated to GB scale and to current reporting year.

Table A 10.2.2 Land transition matrix using national datasets

To / From	Article 3.3		Article 3.4
	Afforestation/ Reforestation	Deforestation	Forest Management
Afforestation /Reforestation	New planting since 1990 (national planting statistics).	Not estimated at present.	
Deforestation		Unconditional felling licences/LUCS	
Forest Management		Unconditional felling licences/LUCS	Forest planted 1921-1989 (national planting statistics) and NIWT.

Table A 10.2.3 Proposed land transition matrix with the 20km grid for end of commitment period accounting

To / From	Article 3.3		Article 3.4
	Afforestation/ Reforestation	Deforestation	Forest Management
Afforestation /Reforestation	1990-1995: national planting statistics, spatially distributed in proportion to NIWT data on planting in 1990s. 1995-2012: FC management database and grant-aided woodland database.	Comparison between NIWT and NIWT2 forest cover map. Unconditional felling licences.	
Deforestation		NIWT vs. NIWT2 forest cover map.	
Forest Management		NIWT vs. NIWT2 forest cover map. Unconditional felling licences	Use NIWT and NIWT2.

A10.2.3 Identification of geographical locations

Figure 1 shows the spatial units used for the 2007 voluntary submission (country-level) and the proposed units for subsequent submissions (20km grid cells). In future, these will be submitted electronically.

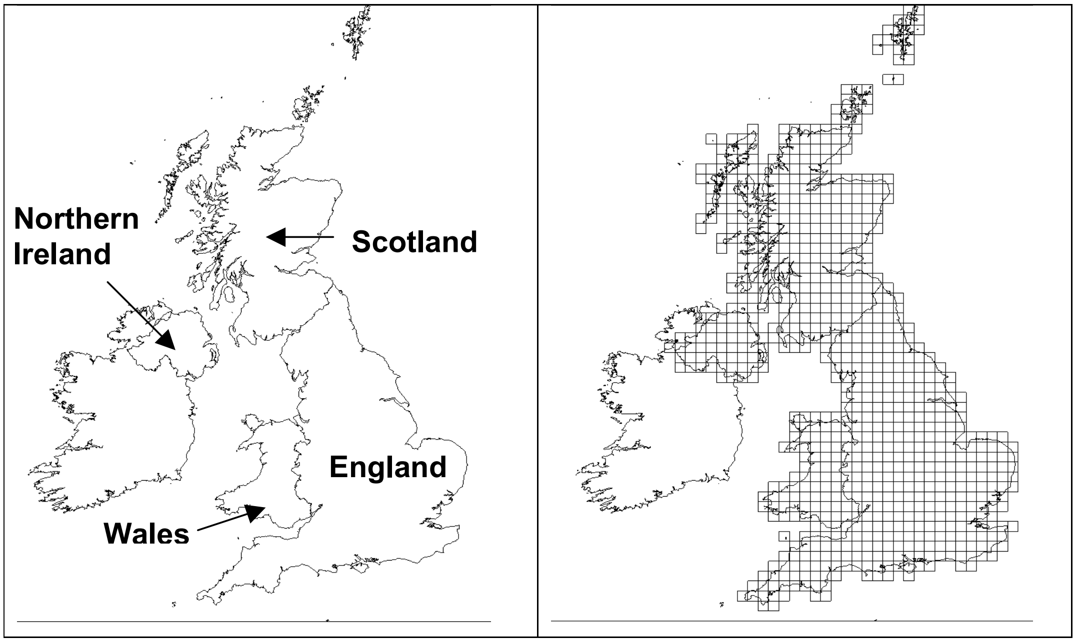

Figure A10.1: Spatial units used for reporting Kyoto protocol LULUCF activities: (left) the four countries of the UK, (right) 20 x 20km grid cells covering the UK.

A10.3 ACTIVITY-SPECIFIC INFORMATION

A10.3.1 Methods for carbon stock change and GHG emission and removal estimates

A10.3.2 Description of methodologies and assumptions

Carbon uptake by UK forests is estimated by a carbon accounting model, C-Flow ((Cannell and Dewar, 1995; Dewar and Cannell, 1992; Milne et al., 1998). The model estimates the net change in pools of carbon in standing trees, litter and soil in conifer and broadleaf forests and in harvested wood products. The methodologies and assumptions are described in the UK's National Inventory Report, Annex 3.7.

A10.3.3 Justification for omitting pools or fluxes

No pools or fluxes are omitted although the below-ground biomass and dead wood carbon pools are currently not reported separately but included in the soil and litter carbon pools respectively. It should be possible to modify the C-Flow model so that it produces estimates for these carbon pools for future reporting.

The area included in Forest Management only includes those areas of forest that were newly planted between 1921 and 1990 (1394 kha or c.50% of the UK forest area). The area of forest established before 1920 (c. 820 kha) is reported in the CRF for the national greenhouse gas inventory but is assumed to be in carbon balance, i.e. zero flux. Uncertainty as to the management and date of first establishment of pre-1921 woodlands (which are predominantly broadleaf) makes it difficult to estimate appropriate model parameters. The omission of pre-1920 forests will have no effect on the number of credits that the UK can claim under Article 3.4, as these are capped for the first commitment period.

Emissions from fertilization and liming of forest land are not currently estimated. Applications of fertilizer and lime since 1990 are estimated by the Forestry Commission to be negligible due to economic factors. A methodology for estimating emissions of N2O from the spreading of sewage sludge on forest land is under consideration (see Annex 3.7.10 for further details).

Emissions of N2O from areas in Forest Management due to the drainage of soils are not currently estimated, although a methodology is under development (Annex 3.7.10).

At present, emissions of greenhouse gases due to biomass burning are only estimated for Deforestation. Hopefully, biomass burning will diminish as the use of woodfuel as a source of bioenergy becomes more commonplace. Damage to existing forests by accidental fires (fire resulting from natural causes is very rare) is not a serious problem in the UK (Forestry Commission, 2002). Data on the occurrence of fires are available for state-owned woodland to 2004, but not for privately-owned woodland. The Forestry Commission is apparently investigating the possibility of enhanced reporting of woodland fires from 2007-2008 as one of its indicators of sustainable forestry. It can be assumed that wildfires will not result in permanent deforestation. This area will be kept under review, and a methodology for emission estimation will be developed once improved data becomes available.

A10.3.4 Factoring out

The CFlow model in principle assumes constant weather and management conditions and therefore ‘factoring out’ of such influences is not required.

A10.3.5 Recalculations since last submission

Not applicable in this instance.

A10.3.6 Uncertainty estimates

To be decided. A full uncertainty analysis of the LULUCF sector in the UNFCCC greenhouse gas inventory will be completed by 2009: improved uncertainty estimates for Article 3.3 and 3.4 activities will be derived from this work.

A10.3.7 Information on other methodological issues

Measurement intervals. Emissions and removals are reported annually but compiled from data sources with different measurement intervals. The national planting statistics are produced annually and drive the model C-Flow, which also produces outputs at the annual scale (see Annex 3.7. for more detail). The deforestation activity data is estimated using a five year running mean. The estimated numbers will be verified using the NIWT (1995-1998) and preliminary results from NIWT2 (2009-2017).

Choice of methods. The methods used to estimate emissions and removals from ARD and FM activities are of the same tier as those used in the UNFCCC inventory.

Disturbances. Damage from wildfire and windblow are not reported in the UNFCCC inventory, although they have limited occurrences in the UK (FAO, 2005; Forestry Commission, 2002). There are currently insufficient data to include the effects of these disturbances in the inventory although this is being kept under review and a methodology will be developed in time.

Inter-annual variability. The method used to estimate emissions and removals from AR and FM is based on the C-Flow model. This model is not sensitive to inter-annual variation in environmental conditions so these will not affect the annual growth and decay rates. There is an ongoing research project to look at the variation in management conditions across the UK forest estate and over time.

A10.3.8 Accounting issues

Not applicable for this submission.

A10.4 ARTICLE 3.3

A10.4.1 Information that demonstrates that activities began after 1990 and before 2012 and are directly human-induced

Under the current methodology, the Forestry Commission and the Forest Service of Northern Ireland provide annual data on new planting (on land that has not previously been forested). This information is provided for each country in the UK and the time series extends back before 1990. Data are provided for both state and private woodlands: the private woodland planting is divided between grant-aided and non-grant-aided. Estimates of non-grant-aided woodland planting and restocking are reported annually, for inclusion in planting statistics, although the Forestry Commission have doubts about their completeness and accuracy Their assessment is that non-grant-aided new woodland has arisen by natural regeneration and is all broadleaved. This assumption can be verified against the NIWT2 at a later date. Only state and grant-aided woodland areas are currently included in the assessment of Article 3.3 activities as these are directly human-induced.

Under the proposed method, the grant-aided woodland database and the Forestry Commission management database will be used to estimate areas of Article 3.3 activities. These data have currently been provided for 1995 to the latest year available (2006) and will be updated annually. Preliminary comparisons have shown good agreement between these data sources and the national planting statistics. It may be possible to extend the FC management database back to 1990 but the grant-aided database is incomplete before 1995. The time-series gap between 1990 and 1995 will be filled by taking the national planting statistics and distributing them between the 20km grid cells in proportion with the distribution of post-1990 planting age woodland in the NIWT.

A10.4.2 Information on how harvesting or forest disturbance followed by re establishment is distinguished from deforestation

The data sources used for estimating Deforestation do not allow for confusion between harvesting or forest disturbance and deforestation. The unconditional felling licences used for the estimation of rural deforestation are only given when no restocking will occur, and the survey of land converted to developed use describes the conversion of forest land to the settlement category, which precludes re-establishment. The NIWT2, which will be partially completed by the end of the first commitment period, will be used to verify deforestation estimates made using these data sources.

A10.4.3 Information on the size and location of forest areas that have lost forest cover but are not yet classified as deforested

Restocking is assumed for forest areas that have lost forest cover through harvesting or forest disturbance, unless there is deforestation as described above. As such, information on the size and location of forest areas that have lost forest cover is not explicitly collected. However, it should be possible to assess such areas through the comparison of the NIWT and NIWT2 at the end of the first commitment period.

A10.5 ARTICLE 3.4

A10.5.1 Information that demonstrates that activities have occurred since 1990 and are human-induced

All managed forests (planted between 1921 and 1989) are included in this category. The C-Flow model is used to calculate emissions from this forest area after 1990 that have arisen from thinning, harvesting and restocking. A current research project is examining the impact of management upon carbon stock changes in UK forests in more detail.

A10.5.2 Information relating to Forest Management: (i) that the forest definition is consistent; and (ii) that forest management is a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological, economic and social functions of the forest in a sustainable manner

Data used for estimating emissions from Forest Management is supplied by the Forestry Commission and complies with their definition of forest land, which is the one used for Article 3.3 and 3.4 activities.

The UK has a system of certification for sustainable woodland management under the Forest Stewardship Council (FSC). Forest statistics published in 2006 by the Forestry Commission record that 73% of softwood removals in 2005 were from certified sources. Such removals will almost entirely come from post-1920 conifer woodland reported under Forest Management. The management practices in certified woodlands are reviewed annually. All state-owned forests are certified and an increasing proportion of non-state-owned woodlands are becoming certified. The total certified area in March 2006 was 1233 kha (Forestry Commission, 2006). This does not include all woodland that is managed in a sustainable manner, such as smaller or non-timber producing woodlands where certification is not considered worthwhile. In particular, it may omit many broadleaved woodlands even though they are managed for their social and environmental benefits (Forestry Commission, 2002). In the UK's country report to the Global Forest Resource Assessment 2005 (FAO, 2005) 83% of UK forests are managed for production, 18% are managed for conservation of biodiversity (these have protected status) and 55% have a social service function (public access).

A10.6 OTHER INFORMATION

A10.6.1 Key category analysis

At present all categories relating to Article 3.3 and Forest Management under Article 3.4 are considered to be key categories. Afforestation and Reforestation activities are a component of the key UNFCCC category 5A2 and removals from this category are also likely to increase over time as a result of tree planting schemes partially focussed on climate change mitigation. Deforestation is the only significant net source in the Kyoto Protocol inventory and the data used in the reporting of deforestation are probably the most uncertain of the data sources used. Forest Management is the majority component of the key UNFCCC category 5A2 and is therefore a key category based on contribution alone.

A10.7 INFORMATION RELATING TO ARTICLE 6

Not applicable to UK forests.

A11 Annex 11: End User Emissions

A11.1 INTRODUCTION

This Annex explains the concept of a final user or end user, summarises the final user calculation methodology with simple examples, and contains tables of greenhouse gas emissions according to final user from 1990 to 2005.

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[10]. The data tables presented later provide the final user emissions in greater detail.

The purpose of the final user calculations is to allocate emissions from fuel producers to fuel users - this allows the emission estimates of a consumer of fuel to include the emissions from the production of the fuel 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 Defra with information for their policy support needs.

The tables in this Annex present summary data for UK greenhouse gas emissions for the years 1990-2005, inclusive. These data are updated annually to reflect revisions in the methods used to estimate emissions, and the availability of new information. These adjustments 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 for the relevant NC sectors in these tables.

A11.2 DEFINITION OF FINAL USERS

The final user[11] 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. In this National Inventory Report, we use the term final user although there is no difference between a final user and an end user in the two major UK inventories[12]. The IPCC and UNECE do not define a final user and they do not require a final user analysis.

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

[11] 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 DTI publication DUKES are used, which enable a distinction to be made.

[12] The term final user is used in this greenhouse gas inventory report and in the UK National Atmospheric Emissions Inventory (NAEI). The NAEI presents emissions of greenhouses gases, UK air quality strategy

The emissions included in the final user categories can be illustrated with an example of two final users - domestic and road transport:

- Emissions in the **domestic** final user category include:

  1. Direct emissions from domestic premises, for example, from burning gas, coal or oil for space heating, and in addition,
  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 (metals and organic compounds would also be released from brake and tyre wear but these are not relevant to a greenhouse gas inventory), and in addition,
  2. Emissions refineries producing motor fuels, including refining, storage, flaring and extraction of oil; and from the distribution and supply of motor fuels.

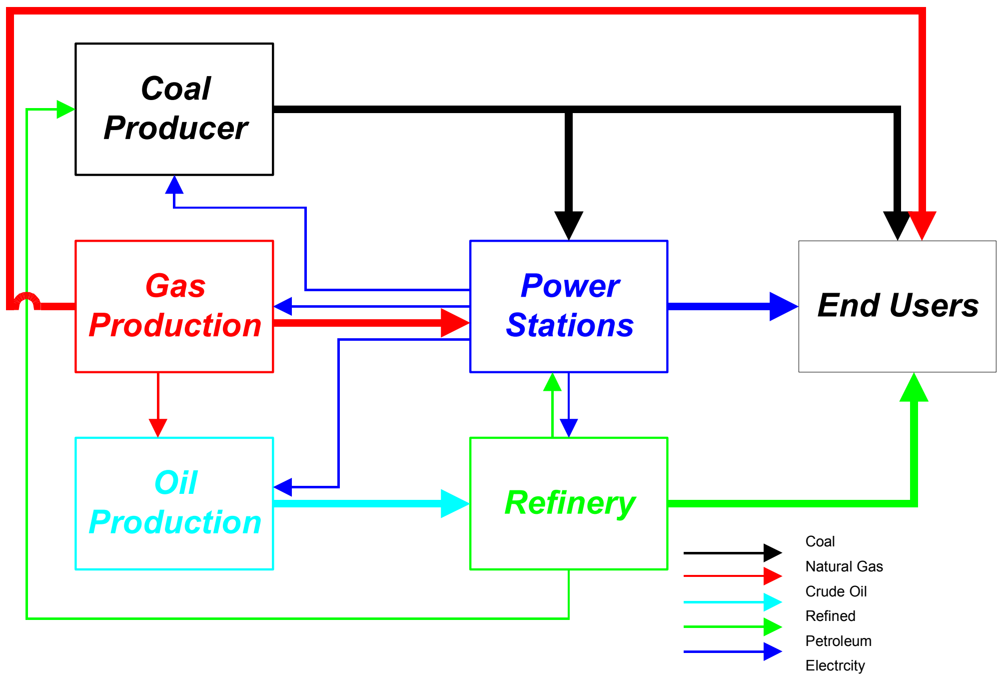
A11.3 OVERVIEW OF THE FINAL USERS CALCULATIONS

As fuel producers use fuel from other producers, they are allocated emissions from each other and these have then to be reallocated to final users. This circularity results in an iterative approach being used to estimate emissions from categories of final users.

Figure A11.1 shows an extremely simplified view of the fuel flows in the UK (the fuels used in the greenhouse gas inventories have hundreds of fuel 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 from collieries come from electricity generated in power stations and some from refineries.

pollutants, acidifying pollutants and ozone precursors, base cations, persistent organic pollutants, and heavy metals.

Figure A11.1 **Very simplified fuel flows for a final user calculation.** (The fuel flow paths demsonstrates the circulaity in energy flows and hence the need for an iterative approach to estimating emissions.)



Emissions from final users have been calculated using an iterative approach, which is summarised in the three steps below:

1. Emissions are calculated for each sector for each fuel.
2. Emissions from fuel producers are then distributed to those sectors who use the fuel according to the energy content[13] 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 emissions from fuel producers will have decreased. The sum of emissions from fuel producers in a particular year as a percentage of the total emissions is then calculated. If this percentage, for any year, exceeds a predetermined value (say 1% or 0.01%)[14] 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.

[13] 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.

[14] In the model used to determine emissions from final users, the value of this percentage cane be adjusted. The tables presented later in this Appendix were calculated for a convergence at 0.01%.

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,
- The same code will cover all likely situations and will be driven by tabular data stored in the database.

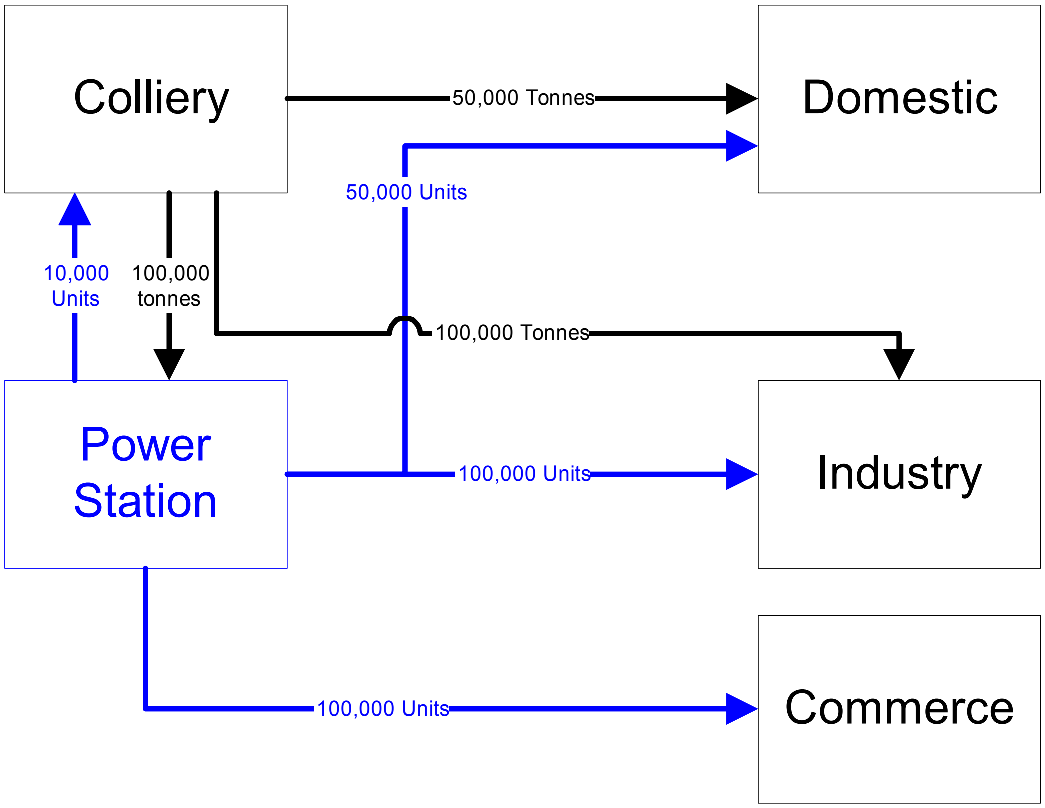
A11.4 EXAMPLE FINAL USER CALCULATION

The following simple example illustrates the methodology used to calculate emissions according to final users. The units in this example are arbitrary, and an indirect greenhouse gas, sulphur dioxide, has been used in the example.

The example in **Figure A11.2** has two fuel producers, *power stations* and *collieries*, and three final users, *domestic*, *industry* and *commercial*. We have made the following assumptions for simplicity:

- The only fuels used are coal and electricity
- Coal is the only source of sulphur dioxide emissions (released from burning coal in power stations to produce electricity and from burning coal in the home for space heating)
- Commerce uses no coal and so has zero 'direct' emissions.

Figure A11.2 Fuel use in the example calculation



In **Figure A11.2**, the tonnes refer to tonnes of coal burnt (black arrows), and the units refer to units of electricity consumed (blue arrows).

In this simple example, the coal extracted by the colliery is burnt in the power station to produce electricity for the final users. Industry and domestic users also directly burn coal. Although the colliery uses electricity produced by the power station, it is not considered to be 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 A11.4.1 summarises the outputs during this example final user calculation.

Table A 11.4.1 Example of the outputs during a final user calculation
(The two fuel producers are power stations and collieries, and the three final users are, domestic, industry and commercial)

			Sector						
			Colliery	**Power Station**	**Domestic**	**Industry**	**Commerce**	**Unallocated emissions as percentage of total emission**	**Total emission of SO_2 (tonnes)**
Coal use (tonnes)	Mass		100	100,000	50,000	100,000	0		
	Energy content		25,000	25,000,000	12,500,000	25,000,000	0		
Electricity use (arbitrary units)	Energy units		10,000		50,000	100,000	100,000		
Emissions of SO_2 (tonnes)	Initial		1.00	1000.00	500.00	1000.00	0.00	40.02	2501.00
	Emissions after Iteration step	1	38.46	0.40	692.51	1385.02	384.62	1.55	2501.00
		2	0.02	15.38	700.28	1400.55	384.77	0.62	2501.00
		3	0.59	0.01	703.24	1406.48	390.69	0.02	2501.00
		4	0.00	0.24	703.36	1406.72	390.69	0.01	2501.00
		5	0.01	0.00	703.40	1406.81	390.78	0.00	2501.00
		6	0.00	0.00	703.41	1406.81	390.78	0.00	2501.00

The initial sulphur dioxide emissions are 1% 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:

- (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 384.62 tonnes of sulphur dioxide emissions allocated to it, mainly from derived from power stations. Emissions allocated to the domestic 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 (2501.00 tonnes of sulphur dioxide) 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 A11.3 Comparison of 'direct' and final user emissions of sulphur dioxide according the sectors considered in the final user example

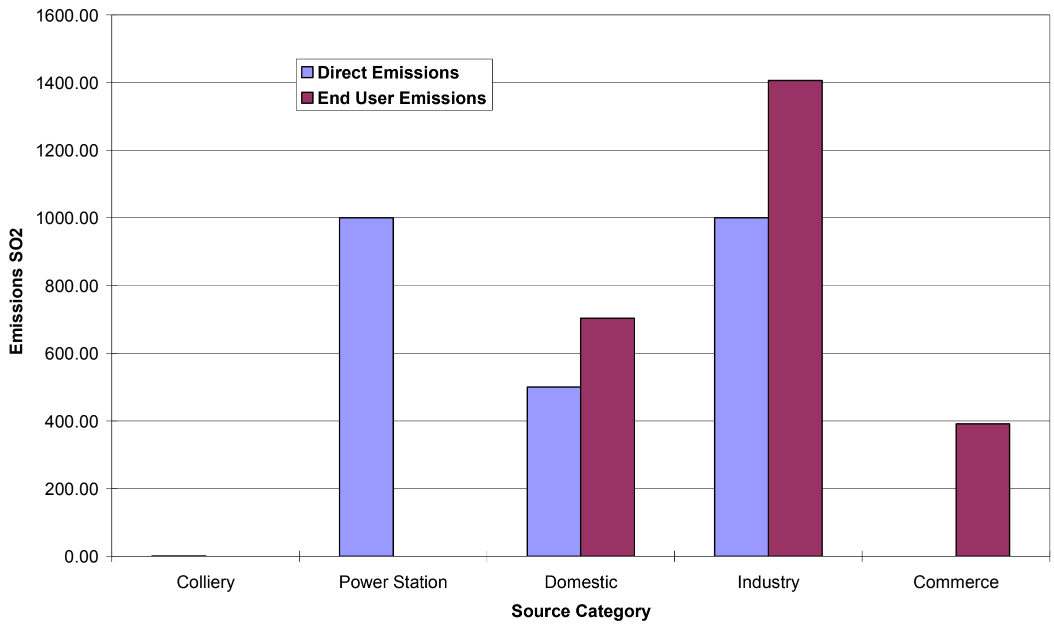


Figure A11.3 compares the quantities of 'direct' and final user sulphur dioxide emitted from each sector at the end of the final user calculation. The 'direct' emissions of sulphur dioxide are from the combustion of coal in the sectors. The 'direct' and final user emissions are from two distinct calculations 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' and all the final user emissions, summed across all the sectors, are identical.

There are relatively large direct emissions of sulphur dioxide from power station, domestic and industry sectors. The final user emissions from the power stations and colliery are zero because these two sectors are not final users. The sulphur dioxide emissions from these two sectors have been reallocated to the domestic, industry and commerce sectors. This reallocation means the final user emissions for the domestic and industry sectors are greater than their 'direct' emissions.

A11.5 FINAL USER CALCULATION METHODOLOGY FOR THE UK GREENHOUSE GAS INVENTORY

The approach divides fuel user emissions into 7 categories (see **Table A11.5.1** – first column – "Final user group"). 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 11.5.1 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	
2. Coal	Coal storage & transport	Coal
	Collieries	Anthracite
	Deep-mined coal	
	Open-cast coal	
3. Natural gas	Gas separation plant (combustion)	Natural gas
	Gas leakage	
	Gas production	
4. Electricity	Nuclear fuel production	Electricity
	Power stations	
5. Petroleum	Off shore flaring	Naphtha
	Offshore loading	Burning oil (premium)
	Offshore oil & gas (venting)	Burning oil
	Offshore oil & gas (well testing)	Aviation turbine fuel
	Offshore oil and gas	Aviation spirit
	Offshore own gas use	Derv
	Oil terminal storage	Fuel oil
	Onshore loading	Gas oil
	Petroleum processes	OPG
	Refineries (Combustion)	Refinery misc.
	Refineries (drainage)	Petrol
	Refineries (flares)	Petroleum coke
	Refineries (process)	Wide-cut gasoline
	Refineries (road/rail loading)	Vaporizing oil
	Refineries (tankage)	LPG
	Refinery (process)	
	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 their proportion of the energy produced by a given sector. This approach is followed to allow for sectors such as petroleum where different products are made in a refinery. For years up to 1989 mass is used, as the database used to calculate the inventory does not contain calorific value data prior to this date.
- 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. Thus these emissions are properly part of the UK inventory even if the use of the fuel produces emissions that cannot be included in the UK inventory as they are used outside the UK.
- No allowance is made for the emission from the production of fuels 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.
- 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 11.5.2 Final user category, IPCC sectors, and NAEI source names and activity names used in the emission calculation

NCFormat	IPCC sectors	Source Name	Activity Name
Agriculture	1A4ci_Agriculture/Forestry/Fishing:Stationary	Agriculture - stationary combustion	Coal Fuel oil Natural gas Straw
	1A4cii_Agriculture/Forestry/Fishing:Off-road	Agricultural engines	Lubricants
		Agriculture - mobile machinery	Gas oil Petrol
		OvTerr Other Mobile (all)- Cayman, Falkland, Montserrat, Bermuda and Gibraltar	Non-fuel combustion
	2B5_Chemical_Industry_Other	Agriculture - agrochemicals use	Carbon in pesticides
	4A10_Enteric_Fermentation_Deer	Agriculture livestock - deer enteric	Non-fuel combustion
	4A10_Enteric_Fermentation_Other_(OTs)	OvTerr Agriculture CH4 (all)- Guernsey, Jersey, IOM	Non-fuel combustion
		OvTerr Agriculture CH4 (all)- Cayman, Falkland, Montserrat, Bermuda and Gibraltar	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
	4B11_Liquid_Systems	Agriculture livestock - manure liquid systems	Non-fuel combustion
	4B12_Solid_Storage_and_Drylot	Agriculture livestock - manure solid storage and dry lot	Non-fuel combustion
	4B13_Manure_Management_Other_(OTs)	OvTerr Agriculture N2O (all)- Guernsey, Jersey, IOM	Non-fuel combustion
		OvTerr Agriculture N2O (all)- Cayman, Falkland, Montserrat, Bermuda and Gibraltar	Non-fuel combustion
	4B13_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
	4B9a_Manure_Management_Deer	Agriculture livestock - deer wastes	Non-fuel combustion
	4D_Agricultural_Soils	Agricultural soils	Non-fuel crops Non-fuel fertilizer
	4F1_Field_Burning_of_Agricultural_Residues	Field burning	Barley residue Oats residue Wheat residue

NCFormat	IPCC sectors	Source Name	Activity Name
	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 Natural gas
		Other industrial combustion	Burning oil Coal Coke Coke oven gas Colliery methane Fuel oil Gas oil LPG Lubricants Natural gas OPG

NCFormat	IPCC sectors	Source Name	Activity Name
			SSF Wood
		OvTerr Industrial Combustion (all)- Cayman, Falkland, Montserrat, Bermuda and Gibraltar	Non-fuel combustion
	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
	1A4ci_Agriculture/Forestry/Fishing:Stationary	Miscellaneous industrial/commercial combustion	Burning oil
	2B5_Carbon from NEU of products	Other industrial combustion	Energy recovery - chemical industry
	2C1_Iron&Steel	Blast furnaces	Coal
	2F1_Refrigeration_and_Air_Conditioning_Equipment	Commercial Refrigeration	Refrigeration and Air Conditioning - Disposal Refrigeration and Air Conditioning - Lifetime Refrigeration and Air Conditioning - Manufacture
		Domestic Refrigeration	Refrigeration and Air Conditioning - Disposal Refrigeration and Air Conditioning - Lifetime Refrigeration and Air Conditioning - Manufacture
		Industrial Refrigeration	Refrigeration and Air Conditioning - Lifetime Refrigeration and Air Conditioning - Manufacture
		Mobile Air Conditioning	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

NCFormat	IPCC sectors	Source Name	Activity Name
			- Lifetime Refrigeration and Air Conditioning - Manufacture
		Stationary Air Conditioning	Refrigeration and Air Conditioning - Lifetime Refrigeration and Air Conditioning - Manufacture
		OvTerr F-gas emissions (all)- Cayman, Falkland, Montserrat, Bermuda and Gibraltar	Non-fuel combustion
	2F2_Foam_Blowing	Foams	Non-fuel combustion
	2F3_Fire_Extinguishers	Firefighting	Non-fuel combustion
	2F5_Solvents	Precision cleaning - HFC	Non-fuel combustion
	2F8_Other_(one_component_foams)	One Component Foams	Non-fuel combustion
	2F8_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	(excluded as not a final user)	(excluded as not a final user)	(excluded as not a final user)
Exports	1A3di_International_Marine	Shipping - international IPCC definition	Fuel oil Gas oil
	Aviation_Bunkers	Aircraft - international cruise	Aviation turbine fuel
		Aircraft - international take off and landing	Aviation turbine fuel
	non-IPCC	Exports	Aviation turbine fuel Burning oil Coke DERV Electricity Fuel oil Petrol SSF
Industrial Process	1A2a_Manufacturing_Industry&Construction:I&S	Sinter production	Coke
	1B1b_Solid_Fuel_Transformation	Iron and steel - flaring	Coke oven gas
	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

NCFormat	IPCC sectors	Source Name	Activity Name
		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)
		Iron and steel - flaring	Blast furnace gas
		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
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
Residential	1A4b_Residential	Domestic combustion	Anthracite Burning oil Coal Coke Fuel oil Gas oil LPG

NCFormat	IPCC sectors	Source Name	Activity Name
			Natural gas Peat Petroleum coke SSF Wood
		OvTerr Commercial/Residential Combustion (all)- Cayman, Falkland, Montserrat, Bermuda, Gibraltar	Non-fuel combustion
	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 turbine fuel
		Aircraft - domestic take off and landing	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
		Road transport - buses and coaches - urban driving	DERV
		Road transport - cars - cold start	DERV
		Road transport - cars - evaporative	Petrol
		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

NCFormat	IPCC sectors	Source Name	Activity Name
		Road transport - HGV rigid - rural driving	DERV
		Road transport - HGV rigid - urban driving	DERV
		Road transport - LGVs - cold start	DERV
		Road transport - LGVs - evaporative	Petrol
		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 driving	Petrol
		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) - evaporative	Petrol
		Road transport - mopeds (<50cc 2st) - urban driving	Petrol
		Road transport - motorcycle (>50cc 2st) - evaporative	Petrol
		Road transport - motorcycle (>50cc 2st) - rural driving	Petrol
		Road transport - motorcycle (>50cc 2st) - urban driving	Petrol
		Road transport - motorcycle (>50cc 4st) - evaporative	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
		OvTerr Road Transport (all)- Cayman, Falkland, Montserrat, Bermuda and Gibraltar	Non-fuel combustion
	1A3c_Railways	Railways - freight	Gas oil
		Railways - intercity	Gas oil
		Railways - regional	Gas oil
	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
	1A5b_Other:Mobile	Aircraft - military	Aviation turbine fuel
		Shipping - naval	Gas oil

NCFormat	IPCC sectors	Source Name	Activity Name
	non-IPCC	Railways - stationary combustion	Electricity
Waste Management	1A1a_Public_Electricity&Heat_Production	OvTerr Waste incineration (all)- Guernsey, Jersey, IOM	Non-fuel combustion
	6A1_Managed_Waste_Disposal_on_Land	Landfill	Non-fuel combustion
		OvTerr Landfill (all)- Guernsey, Jersey, IOM	Non-fuel combustion
		OvTerr Landfill (all)- Cayman, Falkland, Montserrat, Bermuda and Gibraltar	Non-fuel combustion
	6B2_Wastewater_Handling	OvTerr Sewage Treatment (all)- Guernsey, Jersey, IOM	Non-fuel domestic
		Sewage sludge decomposition	Non-fuel domestic
		OvTerr Sewage Treatment (all)- Cayman, Falkland, Montserrat, Bermuda and Gibraltar	Non-fuel combustion
	6C_Waste_Incineration	Incineration	MSW
		Incineration - chemical waste	Chemical waste
		Incineration - clinical waste	Clinical waste
		Incineration - sewage sludge	Sewage sludge combustion
		OvTerr Waste incineration (all)- Cayman, Falkland, Montserrat, Bermuda and Gibraltar	Non-fuel combustion
Land Use Change	5A2_Land Converted to Forest Land	Land converted to Forest Land	Non-fuel combustion
	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
	5C_Grassland (Biomass burning)	Grassland - Biomass Burning	Biomass
	5C_Liming	Grassland - Liming	Dolomite Limestone
	5C1_Grassland Remaining Grassland	Grassland remaining Grassland	Non-fuel combustion
	5C2_Land converted to grassland	Land converted to Grassland	Non-fuel combustion
	5E_Settlements (Biomass burning)	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

A11.6 DETAILED EMISSIONS ACCORDING TO FINAL USER CATEGORIES

The final user categories in the data tables in the summary are as close as possible to those given in the National Communications.

The percentage changes presented in these tables are calculated from emission estimates held at full precision. The emission estimates quoted in the table are values rounded from estimates held at full precision. The percentages quoted in these tables may therefore differ slightly from percentages that can be calculated from the emission estimates presented in the tables.

The base year for hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride is 1995. For carbon dioxide, methane and nitrous oxide, the base year is 1990.

Notes

- To convert from emissions of carbon to carbon dioxide, multiply by (44/12)
- LULUCF Land Use Land Use Change and Forestry

Table A 11.6.1 Final user emissions from Agriculture, by gas, MtC

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Carbon dioxide	2.393	2.393	2.398	2.348	2.283	2.278	2.248	2.250	2.149	2.112	2.064	1.978
Methane	5.976	5.976	5.881	5.898	5.845	5.860	5.793	5.836	5.764	5.748	5.728	5.536
Nitrous oxide	8.910	8.910	8.858	8.423	8.268	8.453	8.487	8.534	8.782	8.520	8.344	8.031
HFCs												
PFCs												
SF_6												
Total greenhouse gas emissions	17.279	17.279	17.137	16.669	16.396	16.591	16.528	16.620	16.695	16.381	16.136	15.545

Final user category	2001	2002	2003	2004	2005
Carbon dioxide	2.061	2.010	1.992	1.937	1.937
Methane	5.171	5.176	5.184	5.062	5.062
Nitrous oxide	7.687	7.495	7.461	7.353	7.353
HFCs					
PFCs					
SF_6					
Total greenhouse gas emissions	14.918	14.681	14.637	14.351	14.351

Table A 11.6.2 Final user emissions from Business, by gas, MtC

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Carbon dioxide	61.500	61.500	60.847	57.172	55.071	54.301	53.380	53.835	52.105	52.009	51.301	53.293
Methane	3.509	3.509	3.451	3.347	3.194	2.455	2.664	2.473	2.441	2.197	2.000	1.860
Nitrous oxide	0.689	0.689	0.669	0.649	0.601	0.594	0.578	0.554	0.529	0.525	0.509	0.522
HFCs	0.031	0.016	0.018	0.020	0.022	0.026	0.031	0.037	0.043	0.044	0.051	0.059
PFCs	0.303	0.000	0.000	0.000	0.052	0.172	0.303	0.459	0.625	0.800	0.985	1.170
SF_6	0.222	0.165	0.178	0.190	0.202	0.206	0.222	0.229	0.217	0.216	0.202	0.192
Total greenhouse gas emissions	66.254	65.879	65.163	61.377	59.143	57.756	57.177	57.587	55.960	55.791	55.048	57.098

Final user category	2001	2002	2003	2004	2005
Carbon dioxide	54.696	51.257	52.775	51.923	52.403
Methane	1.764	1.759	1.420	1.347	1.170
Nitrous oxide	0.540	0.522	0.529	0.520	0.537
HFCs	0.040	0.029	0.029	0.026	0.023
PFCs	1.346	1.536	1.597	1.657	1.672
SF_6	0.182	0.181	0.178	0.202	0.233
Total greenhouse gas emissions	58.570	55.283	56.527	55.675	56.039

Table A 11.6.3 Final user emissions from Industrial Processes, by gas, MtC

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Carbon dioxide	4.763	4.763	4.112	3.909	3.872	4.182	4.312	4.504	4.525	4.491	4.466	4.242
Methane	0.465	0.465	0.447	0.446	0.439	0.353	0.380	0.391	0.400	0.336	0.307	0.261
Nitrous oxide	6.743	6.743	6.784	5.520	4.453	4.504	4.076	4.051	4.103	4.178	1.484	1.532
HFCs	3.813	3.102	3.230	3.357	3.485	3.618	3.813	3.906	4.261	3.370	1.468	0.730
PFCs	0.097	0.366	0.302	0.137	0.111	0.107	0.097	0.098	0.071	0.071	0.057	0.077
SF_6	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.117	0.129	0.187	0.298
Total greenhouse gas emissions	15.998	15.556	14.990	13.485	12.476	12.881	12.796	13.066	13.476	12.575	7.968	7.140

Final user category	2001	2002	2003	2004	2005
Carbon dioxide	3.814	3.490	3.754	3.850	3.868
Methane	0.199	0.175	0.151	0.141	0.120
Nitrous oxide	1.332	0.744	0.788	0.993	0.783
HFCs	0.669	0.543	0.505	0.078	0.093
PFCs	0.076	0.059	0.050	0.066	0.072
SF_6	0.206	0.231	0.183	0.106	0.078
Total greenhouse gas emissions	6.295	5.241	5.430	5.234	5.016

Table A 11.6.4 Final user emissions from Land Use Land Use Change and Forestry, by gas, MtC

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Carbon dioxide	0.786	0.786	0.751	0.614	0.291	0.235	0.270	0.232	0.137	-0.014	-0.073	-0.122
Methane	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.006
Nitrous oxide	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
HFCs												
PFCs												
SF_6												
Total greenhouse gas emissions	0.790	0.790	0.755	0.617	0.294	0.238	0.273	0.235	0.140	-0.011	-0.068	-0.116

Final user category	2001	2002	2003	2004	2005
Carbon dioxide	-0.164	-0.307	-0.322	-0.528	-0.561
Methane	0.007	0.006	0.006	0.005	0.005
Nitrous oxide	0.001	0.001	0.001	0.001	0.001
HFCs					
PFCs					
SF_6					
Total greenhouse gas emissions	-0.157	-0.300	-0.316	-0.522	-0.555

Table A 11.6.5 Final user emissions from Public Sector, by gas, MtC

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Carbon dioxide	7.972	7.972	8.816	9.240	7.593	7.509	7.289	7.530	6.857	6.701	6.466	6.231
Methane	0.474	0.474	0.525	0.571	0.451	0.351	0.372	0.352	0.324	0.284	0.255	0.225
Nitrous oxide	0.052	0.052	0.056	0.057	0.043	0.039	0.035	0.034	0.029	0.027	0.024	0.024
HFCs												
PFCs												
SF_6												
Total greenhouse gas emissions	8.498	8.498	9.397	9.868	8.087	7.900	7.695	7.915	7.210	7.012	6.746	6.479

Final user category	2001	2002	2003	2004	2005
Carbon dioxide	6.403	5.748	5.704	5.913	5.912
Methane	0.216	0.206	0.159	0.161	0.144
Nitrous oxide	0.025	0.021	0.022	0.021	0.022
HFCs					
PFCs					
SF_6					
Total greenhouse gas emissions	6.644	5.976	5.884	6.094	6.079

Table A 11.6.6 Final user emissions from Residential, by gas, MtC

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Carbon dioxide	42.523	42.523	45.183	43.497	42.464	41.023	39.242	42.566	38.520	39.996	38.769	39.940
Methane	3.168	3.168	3.313	3.246	3.100	2.379	2.299	2.253	2.015	1.901	1.755	1.563
Nitrous oxide	0.246	0.246	0.256	0.239	0.220	0.205	0.183	0.179	0.153	0.157	0.143	0.146
HFCs	0.111	0.000	0.003	0.004	0.008	0.032	0.111	0.200	0.351	0.546	0.510	0.586
PFCs												
SF_6												
Total greenhouse gas emissions	46.048	45.938	48.755	46.986	45.793	43.640	41.835	45.197	41.039	42.599	41.176	42.236

Final user category	2001	2002	2003	2004	2005
Carbon dioxide	41.800	40.382	41.240	41.655	40.639
Methane	1.522	1.499	1.170	1.148	1.015
Nitrous oxide	0.157	0.143	0.146	0.141	0.142
HFCs	0.635	0.634	0.695	0.705	0.749
PFCs					
SF_6					
Total greenhouse gas emissions	44.113	42.658	43.251	43.649	42.545

Table A 11.6.7 Final user emissions from Transport, by gas, MtC

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Carbon dioxide	39.031	39.031	38.469	38.935	39.673	39.692	39.676	41.088	41.237	40.848	40.960	40.738
Methane	0.635	0.635	0.602	0.604	0.581	0.553	0.575	0.533	0.498	0.470	0.415	0.386
Nitrous oxide	0.402	0.402	0.408	0.439	0.522	0.622	0.730	0.836	0.944	1.052	1.158	1.244
HFCs												
PFCs												
SF_6												
Total greenhouse gas emissions	40.067	40.067	39.479	39.978	40.776	40.867	40.981	42.457	42.679	42.370	42.533	42.369

Final user category	2001	2002	2003	2004	2005
Carbon dioxide	40.753	41.671	43.017	42.936	43.351
Methane	0.390	0.352	0.347	0.335	0.300
Nitrous oxide	1.326	1.410	1.467	1.520	1.581
HFCs					
PFCs					
SF_6					
Total greenhouse gas emissions	42.470	43.433	44.831	44.791	45.232

Table A 11.6.8 Final user emissions from Waste Management, by gas, MtC

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Carbon dioxide	0.334	0.334	0.332	0.321	0.299	0.257	0.243	0.247	0.142	0.144	0.133	0.135
Methane	13.804	13.804	13.593	13.275	12.936	12.682	12.277	11.874	10.933	10.186	9.270	8.673
Nitrous oxide	0.295	0.295	0.292	0.295	0.293	0.315	0.296	0.306	0.334	0.337	0.326	0.336
HFCs												
PFCs												
SF_6												
Total greenhouse gas emissions	14.433	14.433	14.217	13.891	13.528	13.254	12.816	12.427	11.409	10.666	9.729	9.144

Final user category	2001	2002	2003	2004	2005
Carbon dioxide	0.142	0.138	0.132	0.136	0.138
Methane	7.560	6.899	6.061	5.643	5.552
Nitrous oxide	0.346	0.344	0.345	0.346	0.346
HFCs					
PFCs					
SF_6					
Total greenhouse gas emissions	8.047	7.380	6.539	6.125	6.036

Table A 11.6.9 Final user emissions from all National Communication categories, MtC

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Agriculture	17.279	17.279	17.137	16.669	16.396	16.591	16.528	16.620	16.695	16.381	16.136	15.545
Business	66.254	65.879	65.163	61.377	59.143	57.756	57.177	57.587	55.960	55.791	55.048	57.098
Energy Supply	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Exports	2.735	2.735	2.990	3.250	3.669	3.611	3.844	4.161	4.502	4.345	3.961	3.799
Industrial Process	15.998	15.556	14.990	13.485	12.476	12.881	12.796	13.066	13.476	12.575	7.968	7.140
Public	8.498	8.498	9.397	9.868	8.087	7.900	7.695	7.915	7.210	7.012	6.746	6.479
Residential	46.048	45.938	48.755	46.986	45.793	43.640	41.835	45.197	41.039	42.599	41.176	42.236
Transport	40.067	40.067	39.479	39.978	40.776	40.867	40.981	42.457	42.679	42.370	42.533	42.369
Waste Management	14.433	14.433	14.217	13.891	13.528	13.254	12.816	12.427	11.409	10.666	9.729	9.144
LULUCF	0.790	0.790	0.755	0.617	0.294	0.238	0.273	0.235	0.140	-0.011	-0.068	-0.116
Total greenhouse gas emissions	212.104	211.176	212.884	206.121	200.162	196.737	193.945	199.666	193.110	191.729	183.229	183.693

Final user category	2001	2002	2003	2004	2005
Agriculture	14.835	14.918	14.681	14.637	14.351
Business	58.570	55.283	56.527	55.675	56.039
Energy Supply	0.000	0.000	0.000	0.000	0.000
Exports	3.667	4.271	3.590	3.910	3.993
Industrial Process	6.295	5.241	5.430	5.234	5.016
Public	6.644	5.976	5.884	6.094	6.079
Residential	44.113	42.658	43.251	43.649	42.545
Transport	42.470	43.433	44.831	44.791	45.232
Waste Management	8.047	7.380	6.539	6.125	6.036
LULUCF	-0.157	-0.300	-0.316	-0.522	-0.555
Total greenhouse gas emissions	184.485	178.860	180.417	179.594	178.735

Table A 11.6.10 Final user emissions, Carbon, MtC

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Agriculture	2.393	2.393	2.398	2.348	2.283	2.278	2.248	2.250	2.149	2.112	2.064	1.978
Business	61.500	61.500	60.847	57.172	55.071	54.301	53.380	53.835	52.105	52.009	51.301	53.293
Energy Supply	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Exports	2.486	2.486	2.734	2.983	3.397	3.341	3.552	3.877	4.201	4.063	3.728	3.577
Industrial Process	4.763	4.763	4.112	3.909	3.872	4.182	4.312	4.504	4.525	4.491	4.466	4.242
Public	7.972	7.972	8.816	9.240	7.593	7.509	7.289	7.530	6.857	6.701	6.466	6.231
Residential	42.523	42.523	45.183	43.497	42.464	41.023	39.242	42.566	38.520	39.996	38.769	39.940
Transport	39.031	39.031	38.469	38.935	39.673	39.692	39.676	41.088	41.237	40.848	40.960	40.738
Waste Management	0.334	0.334	0.332	0.321	0.299	0.257	0.243	0.247	0.142	0.144	0.133	0.135
LULUCF	0.786	0.786	0.751	0.614	0.291	0.235	0.270	0.232	0.137	-0.014	-0.073	-0.122
Total greenhouse gas emissions	161.788	161.788	163.643	159.017	154.944	152.819	150.213	156.129	149.874	150.350	147.814	150.012

Final user category	2001	2002	2003	2004	2005
Agriculture	2.069	2.061	2.010	1.992	1.937
Business	54.696	51.257	52.775	51.923	52.403
Energy Supply	0.000	0.000	0.000	0.000	0.000
Exports	3.451	4.056	3.434	3.733	3.810
Industrial Process	3.814	3.490	3.754	3.850	3.868
Public	6.403	5.748	5.704	5.913	5.912
Residential	41.800	40.382	41.240	41.655	40.639
Transport	40.753	41.671	43.017	42.936	43.351
Waste Management	0.142	0.138	0.132	0.136	0.138
LULUCF	-0.164	-0.307	-0.322	-0.528	-0.561
Total greenhouse gas emissions	152.963	148.496	151.744	151.611	151.497

Table A 11.6.11 Final user emissions, Methane, MtC

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Agriculture	5.976	5.976	5.881	5.898	5.845	5.860	5.793	5.836	5.764	5.748	5.728	5.536
Business	3.509	3.509	3.451	3.347	3.194	2.455	2.664	2.473	2.441	2.197	2.000	1.860
Energy Supply	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Exports	0.232	0.232	0.236	0.246	0.249	0.247	0.267	0.258	0.270	0.253	0.205	0.192
Industrial Process	0.465	0.465	0.447	0.446	0.439	0.353	0.380	0.391	0.400	0.336	0.307	0.261
Public	0.474	0.474	0.525	0.571	0.451	0.351	0.372	0.352	0.324	0.284	0.255	0.225
Residential	3.168	3.168	3.313	3.246	3.100	2.379	2.299	2.253	2.015	1.901	1.755	1.563
Transport	0.635	0.635	0.602	0.604	0.581	0.553	0.575	0.533	0.498	0.470	0.415	0.386
Waste Management	13.804	13.804	13.593	13.275	12.936	12.682	12.277	11.874	10.933	10.186	9.270	8.673
LULUCF	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.006
Total greenhouse gas emissions	28.267	28.267	28.052	27.636	26.797	24.883	24.630	23.972	22.649	21.377	19.939	18.702

Final user category	2001	2002	2003	2004	2005
Agriculture	5.222	5.171	5.176	5.184	5.062
Business	1.764	1.759	1.420	1.347	1.170
Energy Supply	0.000	0.000	0.000	0.000	0.000
Exports	0.190	0.185	0.132	0.151	0.135
Industrial Process	0.199	0.175	0.151	0.141	0.120
Public	0.216	0.206	0.159	0.161	0.144
Residential	1.522	1.499	1.170	1.148	1.015
Transport	0.390	0.352	0.347	0.335	0.300
Waste Management	7.560	6.899	6.061	5.643	5.552
LULUCF	0.007	0.006	0.006	0.005	0.005
Total greenhouse gas emissions	17.071	16.251	14.622	14.115	13.503

Table A 11.6.12 Final user emissions, Nitrous Oxide, MtC

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Agriculture	8.910	8.910	8.858	8.423	8.268	8.453	8.487	8.534	8.782	8.520	8.344	8.031
Business	0.689	0.689	0.669	0.649	0.601	0.594	0.578	0.554	0.529	0.525	0.509	0.522
Energy Supply	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Exports	0.017	0.017	0.019	0.021	0.023	0.022	0.025	0.026	0.030	0.030	0.028	0.029
Industrial Process	6.743	6.743	6.784	5.520	4.453	4.504	4.076	4.051	4.103	4.178	1.484	1.532
Public	0.052	0.052	0.056	0.057	0.043	0.039	0.035	0.034	0.029	0.027	0.024	0.024
Residential	0.246	0.246	0.256	0.239	0.220	0.205	0.183	0.179	0.153	0.157	0.143	0.146
Transport	0.402	0.402	0.408	0.439	0.522	0.622	0.730	0.836	0.944	1.052	1.158	1.244
Waste Management	0.295	0.295	0.292	0.295	0.293	0.315	0.296	0.306	0.334	0.337	0.326	0.336
LULUCF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Total greenhouse gas emissions	17.355	17.355	17.343	15.643	14.423	14.756	14.409	14.521	14.903	14.827	12.016	11.865

Final user category	2001	2002	2003	2004	2005
Agriculture	7.545	7.687	7.495	7.461	7.353
Business	0.540	0.522	0.529	0.520	0.537
Energy Supply	0.000	0.000	0.000	0.000	0.000
Exports	0.026	0.030	0.024	0.026	0.048
Industrial Process	1.332	0.744	0.788	0.993	0.783
Public	0.025	0.021	0.022	0.021	0.022
Residential	0.157	0.143	0.146	0.141	0.142
Transport	1.326	1.410	1.467	1.520	1.581
Waste Management	0.346	0.344	0.345	0.346	0.346
LULUCF	0.001	0.001	0.001	0.001	0.001
Total greenhouse gas emissions	11.297	10.901	10.815	11.028	10.812

Table A 11.6.13 Final user emissions, HFC, MtC

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Agriculture												
Business	0.303	0.000	0.000	0.000	0.052	0.172	0.303	0.459	0.625	0.800	0.985	1.170
Energy Supply												
Exports												
Industrial Process	3.813	3.102	3.230	3.357	3.485	3.618	3.813	3.906	4.261	3.370	1.468	0.730
Public												
Residential	0.111	0.000	0.003	0.004	0.008	0.032	0.111	0.200	0.351	0.546	0.510	0.586
Transport												
Waste Management												
LULUCF												
Total greenhouse gas emissions	4.227	3.102	3.233	3.361	3.546	3.822	4.227	4.564	5.236	4.716	2.962	2.487

Final user category	2001	2002	2003	2004	2005
Agriculture					
Business	1.346	1.536	1.597	1.657	1.672
Energy Supply					
Exports					
Industrial Process	0.669	0.543	0.505	0.078	0.093
Public					
Residential	0.635	0.634	0.695	0.705	0.749
Transport					
Waste Management					
LULUCF					
Total greenhouse gas emissions	2.649	2.712	2.797	2.440	2.515

Table A 11.6.14 Final user emissions, PFC, MtC

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Agriculture												
Business	0.031	0.016	0.018	0.020	0.022	0.026	0.031	0.037	0.043	0.044	0.051	0.059
Energy Supply												
Exports												
Industrial Process	0.097	0.366	0.302	0.137	0.111	0.107	0.097	0.098	0.071	0.071	0.057	0.077
Public												
Residential												
Transport												
Waste Management												
LULUCF												
Total greenhouse gas emissions	0.128	0.382	0.319	0.156	0.134	0.134	0.128	0.135	0.114	0.115	0.109	0.136

Final user category	2001	2002	2003	2004	2005
Agriculture					
Business	0.040	0.029	0.029	0.026	0.023
Energy Supply					
Exports					
Industrial Process	0.076	0.059	0.050	0.066	0.072
Public					
Residential					
Transport					
Waste Management					
LULUCF					
Total greenhouse gas emissions	0.116	0.088	0.078	0.092	0.096

Table A 11.6.15 Final user emissions, SF_6, MtC

Final user category	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Agriculture												
Business	0.222	0.165	0.178	0.190	0.202	0.206	0.222	0.229	0.217	0.216	0.202	0.192
Energy Supply												
Exports												
Industrial Process	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.117	0.129	0.187	0.298
Public												
Residential												
Transport												
Waste Management												
LULUCF												
Total greenhouse gas emissions	0.338	0.281	0.294	0.307	0.318	0.323	0.338	0.345	0.334	0.344	0.389	0.490

Final user category	2001	2002	2003	2004	2005
Agriculture					
Business	0.182	0.181	0.178	0.202	0.233
Energy Supply					
Exports					
Industrial Process	0.206	0.231	0.183	0.106	0.078
Public					
Residential					
Transport					
Waste Management					
LULUCF					
Total greenhouse gas emissions	0.389	0.412	0.361	0.308	0.312