Appendix 7
Waste

CONTENTS

1. Landfill

The NAEI category Landfill maps directly on to 6A1 Landfills for methane emissions. Emissions are reported from managed landfills only, as open dumps and unmanaged landfills are considered insignificant in the UK.

The UK method conforms to good practice since a first order decay (Tier 2) methodology is used based on estimates of historical data on waste quantities, composition and disposal practices over several decades.

The UK method is based on equations 4 and 5 in the Revised 1996 IPCC guidelines (IPCC, 1997) (pp 6.10-6.11) which are compatible with equations 5.1 and 5.2 in the Good Practice Guidance (IPCC, 2000). A slightly different version of equation 5.1 is used, which takes into account the fact that the model uses a finite time interval (one year). The full derivation of the equations used is given in Appendix 2 of Brown *et al* (1999).

The UK method divides the waste stream into four categories of waste: rapidly degrading, moderately degrading, slowly degrading and inert waste. These categories each have a separate decay rate. The decay rates are based on data from the Netherlands and range from 0.05 (slowly degrading waste) to 0.185 (rapidly degrading waste), which lie within the range of 0.03 to 0.2 quoted in the Good Practice Guidance.

The model extends back to 1945, which gives a time period of around 4 half lives for the slowest of the three decay rates (0.05, half life 14 years). This lies within the range of 3 to 5 half lives recommended by the Good Practice Guidance.

The model distinguishes between four separate categories of landfill site with different degrees of gas collection control:

- closed sites;
- sites with no gas collection;
- sites with limited collection;
- sites with comprehensive collection.

Each site type has different gas collection and oxidation rates. As recommended, the model attempts to take into account changes in landfill practice over past decades by altering the proportion of waste disposed of to each of these categories of site in past years, and also by modifying the gas collection rate over time where appropriate. The model also simulates retrofitting of sites, i.e. upgrading from a site with no gas control or limited gas control to one with comprehensive gas control.

The estimates of historical waste disposal and composition data are based on various data sources, described fully in Brown *et al* (1999). As recommended in the Good Practice Guidance, estimates for municipal waste are based on population where data are absent.

As recommended in the Good Practice Guidance, the estimates of waste disposal quantities include commercial and industrial waste, demolition and construction waste and sewage sludge, as well as municipal waste. For industrial and commercial waste, the data are based on national estimates from a recent survey, although the survey was incomplete at the time of finalising the model estimates. The data were extrapolated to cover past years based on employment rates in the industries concerned.

All sites in the UK are managed, and therefore have a methane correction factor of 1.0. However, as described above, differences in oxidation rates have been simulated by the practice of dividing waste disposal sites into four types as described above.

Degradable organic carbon (DOC) was estimated based on a national study, as recommended in the Good Practice Guidance. However the figures used were based on expert opinion rather than measured data.

The fraction of degradable organic carbon dissimilated (DOC_F) was assumed to be 60%. At the time when the model was set up, the IPCC recommended default value was 77%, but there were indications that this could be an overestimate, so a lower figure was used. The new IPCC recommended range quoted in the Guidance is 50-60%.

The fraction of CH_4 in landfill gas is generally taken to be 50%, which is in line with the Guidance. For old shallow sites it is taken to be 30% to reflect a higher degree of oxidation.

The fraction of methane recovered was assumed to be 85% for sites with full gas control and 40% for sites with limited gas control. The estimates are not derived from metering data, as recommended by the Guidance, as such data were not readily available at the time of the study. A panel of UK industry experts selected the figures.

The oxidation factor is assumed to be 10% for all site types. Recovered methane is subtracted before applying the oxidation factor. This is in line with the Guidance.

The emissions of pollutants from the flare stacks were not estimated but those from electricity generation and heat generation were. Emissions from electricity generation are considered under Power Stations and emissions from heat generation are included under Miscellaneous and are discussed in Appendix 1.

An estimate of NMVOC emissions from landfills was made using an emission factor of 0.01 t NMVOC/ t methane produced which is equivalent to 5.65g NMVOC/ m^3 landfill gas (Passant, 1993).

Neither the GHGI nor the NAEI reports carbon dioxide emissions from the anaerobic decay of landfilled waste since this is considered to be part of the carbon cycle and is not a net source.

The estimates include the contribution of sewage disposed of to landfill.

2. Waste Water Treatment

The NAEI category Sewage is mapped on to the IPCC category 6B2 Domestic and Commercial Wastewater. There is no estimate made of emissions from private wastewater treatment plants operated by companies prior to discharge to the public sewage system or rivers. 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 of to landfill is included in landfill emissions.

The methodology of the UK model differs in some respects from the IPCC default methodology. The main differences are that it considers wastewater and sewage together rather than separately. It also considers domestic, commercial and industrial wastewater together rather than separately. Emissions are based on empirical emission factors derived from the literature expressed in kg CH_4/tonne dry solids rather than the BOD default factors used by IPCC. The model however complies with the IPCC Good Practice Guidance as a national model (IPCC, 2000).

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 its own emission factor. The treatment routes and emission factors are shown in Table 1. The allocation of sludge to the treatment routes is reported for each year on the CRF tables attached to this report as a CD ROM.

The model accounts for recovery of methane and its subsequent utilization and flaring by estimating the proportion of anaerobic digester emissions that are recovered.

Table 1 Specific Methane Emission Factors for Sludge Handling kg Ch_4/Mg dry solids, Hobson *et al* (1996)

Sludge Handling System	Gravity Thick-ening[1]	Long term storage	Anaerobic Digestion[2]	Agricul - tural 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

Nitrous oxide emissions from the treatment of human sewage are based on the IPCC (1997c) default methodology. The average protein consumption per person is based on the National Food Survey (DEFRA, 2001). These range from 22.7 to 23.7 g protein/person/day. The food survey is based on household consumption of food and so may give a low estimate.

3. Waste Incineration

The NAEI estimates emissions from the categories municipal solid waste (MSW) incineration and sewage incineration. Included in the inventory for the first time are the categories clinical incineration and cremation. However the coverage of these new sources is incomplete due to a lack of emission factor data. The waste incineration categories are mapped onto the single NAEI category 6C Waste Incineration. The emission factors used are shown in Table 3.

Table 3 Emission Factors for Waste Incineration (kg/t waste)

		C[1]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
MSW(old)	kg/t	75[a]	0.0008[d]	0.03[f]	1.8[c]	0.709[c]	0.0231[d]	1.36[c]
MSW(new)	kg/t	75[a]	0.0008[d]	0.03[f]	1.07[g]	0.133[g]	0.018[g]	0.096[g]
Cremation	kg/body	0	NE	NE	0.308[h]	0.141[h]	0.013[h]	0.0544[h]
Clinical	kg/t	228[f]	0.0008[d]	0.03[f]	1.78[h]	1.48[h]	NE	1.09[h]
Sewage	kg/t	0	0.39[b]	0.8[f]	2.5[b]	15.5[b]	0.84[b]	2.3[e]

1 Emission factor as kg carbon/ t waste
a Royal Commission on Environmental Pollution (1993)
b EMEP/CORINAIR (1996).
c Clayton *et al.* (1991)
d Estimated from THC data in CRI (Environment Agency, 1997) assuming 3.3% methane split given in EMEP/CORINAIR (1996)
e EMEP/CORINAIR (1996). A factor of 14 kt/Mt is used prior to 1996.
f IPCC (2000)
g Emission factor for 2000, Environment Agency (2001)
h EMEP/CORINAIR (1999)
NE Not estimated

The arisings of waste and their method of disposal are not known with any reliability. The estimates of municipal solid waste disposed of to incinerators are based on incinerator capacity (Patel *et al.*, 2000; EFW, 2001). The amounts of sewage sludge incinerated are reported in DEFRA (2001a). Data on cremations are published by the Cremation Society of Great Britain (CSGB, 2001). Under IPCC guidelines, incineration refers only to plant that do not generate electricity or heat. From the end of 1996, MSW incinerators in the UK had to meet new standards. As a result, many incinerators closed down, were renovated or new ones built. From 1997 onwards all MSW incinerators generated electricity or heat and are classified as either power stations or under 1A4 Other Combustion so no emissions are reported under Incineration: MSW. In previous inventories emissions from incinerators included some plant which generated heat. In the new inventory, these plant are reported under miscellaneous or 1A4 Other Combustion. Emission factors for modern incinerators based on 1999 data are reported as MSW (new) for comparison with the emission factors used for old incinerators. The emission factors given for MSW (old) pertain to old incinerators prior to 1993. Emission factors for the years 1993-2000 were derived from the Pollution Inventory (Environment Agency, 2001). The reported emissions of carbon dioxide exclude those deriving from recently photosynthesised carbon. It was assumed that the proportion of recently photosynthesised carbon was 75% of the total carbon content of the waste (Brown, 1995) and this assumption is reflected in the factors in Table 3.

Emissions of carbon dioxide from clinical waste incineration have been included in the Inventory. The emission factor is a default taken from IPCC (2000) and the activity is based on Smyllie *et al* (1996).

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Appendix 8 Uncertainties

CONTENTS

1. Estimation of Uncertainty by Simulation

Quantitative estimates of the uncertainties in the emissions were calculated using direct simulation, a technique similar to Monte Carlo Simulation. This corresponds to the IPCC Tier 2 approach discussed in the Good Practice Guidance (IPCC, 2000). This work is described in detail by Eggleston *et al* (1998) though the estimates reported here have been revised to reflect changes in the 2000 Inventory. This section gives a brief summary of the methodology, assumptions and results of the simulation.

The general computational procedure was:

- An uncertainty distribution was allocated to each emission factor and activity rate. The distributions used were either normal, log-normal or uniform. The parameters of the distributions were set by analysing the available data on emission factors and activity data or expert judgement.
- A calculation was set up to estimate the emission of each gas, carbon dioxide sink, and the global warming potential for the years 1990 and 2000. Using the software tool @RISK™, each uncertainty distribution was sampled 20000 times and the emission calculations performed to formulate 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.
- For methane and nitrous oxide, it was assumed that there was no correlation between emission factors for the same fuels applied to different sources. For CO_2 emission factors for natural gas, gas oil, kerosene, fuel oil, motor gasoline, LPG, OPG, MSW and aviation fuel were correlated with those for the same fuel used in different sources.
- 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 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. A further refinement was to correlate the data used for the same fuels to calculate emissions of carbon dioxide, methane and nitrous oxide. These modifications to the methodology were introduced in the 2000 inventory.
- The uncertainty in the trend between 1990 and 2000 was also estimated. This will be influenced by the degree of correlation of activity data and emission factors between 1990 and 2000. Generally it was assumed that activity data from different years were not correlated, but certain emission factors were. These correlations are discussed in subsequent sections.
- To simplify the calculations the uncertainties for total halocarbon and SF_6 emissions were taken from Eggleston *et al* (1998).

1.1 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 were estimated from the statistical differences data in DTI (1996). 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 other uncertainties for minor fuels (colliery methane, orimulsion, SSF, petroleum coke) and non-fuels (limestone, dolomite and clinker) were estimated based on judgements based on their relative uncertainty compared with the known fuels. The high uncertainty in the aviation fuel consumption reflects the uncertainty in the split between domestic and international aviation fuel consumption.

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 some recent 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, 1996) 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 SCOPEC (2001) 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 SCOPEC. 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 2.7% in 1990 and 2.2% in 2000. In spite of the revisions to the methodology, there appears to have been little change in uncertainty from the 1999 inventory.

The uncertainty in the trend between 1990 and 2000 was also estimated. In running this simulation it was necessary to make assumptions about the degree of correlation between

sources in 1990 and 2000. 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.
- Process emissions from blast furnaces, coke ovens and ammonia plant were not correlated.

The trend was found to range between -6.5% and -9.2%

Table 1 Estimated Uncertainties in Carbon Dioxide Inventory[1]

Source	Activity Uncertainty %	Emission Factor Uncertainty %	Uncertainty in Emission %
Coal (including derived gases)	1.2	6	‡
Coke	5.6	3	‡
Petroleum Coke	5	3	‡
SSF	3	3	‡
Burning Oil	6	2	‡
Fuel Oil	4	2	‡
Gas Oil/Diesel Oil	1.4	2	‡
Motor Spirit (Gasoline)	0.8	2	‡
Orimulsion	1	2	‡
Aviation Fuel (Domestic)	50	2	‡
Lubricants	25	5	‡
Natural Gas	2.4	1	‡
Colliery Methane	5	5	‡
LPG	24	3	‡
OPG	1.1	3	‡
Scrap Tyres	15	10	‡
Waste Oils	15	5	‡
Ammonia Production	-	-	5
Cement	1	2.2	‡
Lime/Limestone/Dolomite	1	5	‡
Soda Ash Use	15	2	‡
Fletton Bricks	20	70	‡
Flaring	16	6	‡
Other Offshore	-	-	28
Natural Gas (offshore)	2.4	6	‡
Iron & Steel Processes	1	20	‡
Aluminium Production	1	5	‡
Waste (MSW and Clinical)	7	20	21
5A Forest Biomass Change[2]	-	-	30
5D Soils[2]	-	-	60
5E Other[2]	-	-	50

1 Expressed as 2s/E
2 Uniform distribution used
‡ Input parameters were uncertainties of activity data and emission factors.

1.2 METHANE EMISSION UNCERTAINTIES

In the methane inventory, combustion sources are a minor source of emissions. The uncertainty in methane combustion emission factors will outweigh the activity errors so an uncertainty of 50% was assumed for combustion sources as a whole. The errors in the major sources are listed in Table 2. These are mainly derived from the source documents for the estimates or from the Watt Committee Report (Williams, 1993). The uncertainty in offshore

emissions has been revised since improved estimates of the activity data are now available. The methane factors were assumed to have an uncertainty of 20% since the flaring factors are based on test measurements. Two new sources of methane have been included; these are Fletton bricks and sources in the chemical industry. The brick uncertainty was judged to be very high at 100% and the industrial releases were judged to have uncertainties of around 20% both on the activity and the emission factor.

Table 2 Estimated Uncertainties in the Methane Inventory

Source	Reference	Activity	Emission Factor	Source Uncertainty %
Fuel Combustion	‡		50	✳
Field Burning	‡	-	-	50
Landfill	Brown *et al* 1999	-	-	~48[1]
Livestock: enteric	Williams, 1993	0.1	20	✳
Livestock: wastes	Williams, 1993	0.1	30	✳
Coal Mining	Bennett *et al*, 1995	1.2	13	✳
Offshore	‡	16	20	✳
Gas Leakage	Williams, 1993	-	-	17-75[2]
Chemical Industry	‡	20	20	✳
Fletton Bricks	‡	20	100	✳
Sewage Sludge	Hobson *et al*, 1996	-	-	50

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

The sources quoted in Table 2 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 is higher. 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 2000 was estimated as 2427 Gg. The Monte Carlo analysis suggested that 95% of trials were between 2110 Gg and 3302 Gg. The uncertainty was around 21%. The emission of methane in 1990 was estimated as 3645 Gg. The Monte Carlo analysis suggested that 95% of trials were between 3061 Gg and 4410 Gg. The uncertainty was around 18%.

The uncertainty in the trend between 1990 and 2000 was also estimated. In running this simulation it was necessary to make assumptions about the degree of correlation between sources in 1990 and 2000. 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 similar fuels are correlated in the same year.
- Emission factors used for animals are correlated between the same species.
- Landfill emissions were partly correlated 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 41% hence the degree of correlation was 59%.
- Offshore emissions are not correlated since they are based on separate studies using emission factors that reflected the processes in use at the time.
- Gas leakage emissions were correlated.
- Emissions from deep mines were not correlated 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.

The trend was found to range between -18% and -43%

1.3 NITROUS OXIDE EMISSION UNCERTAINTIES

The analysis of the uncertainties in the nitrous oxide emissions is particularly difficult because emissions arise from a diverse collection of sources and little data are available to form an assessment of the uncertainties in each source. Emission factor data for the combustion sources are scarce and for some fuels are not available. The parameter uncertainties are shown in Table 3. The uncertainty assumed for agricultural soils uses a lognormal distribution since it 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. The uncertainty distribution of the calculated emission was heavily skewed with a mean emission of 141Gg in 2000 within a range of 35 Gg to 514 Gg N_2O.

The uncertainty in the trend between 1990 and 2000 was also estimated. In running this simulation it was necessary to make assumptions about the degree of correlation between sources in 1990 and 2000. 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. This is a revision to the previous methodology since by the end of 2000 only 5 of the original 8 plant were operating. Moreover, two of these have had abatement systems fitted. Hence, it was judged that the mix of plant was significantly different between 1990 and 2000.
- 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.

The trend was found to range between -13% and -74%

Table 3: Estimated Uncertainties in the Nitrous Oxide Emissions[1]

	Emission Factor Uncertainty %	Activity Rate Uncertainty %
Agricultural Soils	Log-normal[2]	0
Wastewater Treatment	Log-normal[2]	10
Adipic Acid	15	0.5
Nitric Acid	230	10
Coal	195	1.2
Anthracite	387	1.2
Coke	118	5.6
Patent Fuel	118	3
Burning Oil	140	6
Gas Oil	140	1.4
Fuel Oil	140	4
Gasoline	170	0.8
Auto Diesel	170	1.4
Orimulsion	140	1
LPG	110	24
OPG	110	1.1
Aviation Fuel (domestic)	170	50
Natural Gas	110	2.4
Colliery Methane	110	5
Lubricants	140	25
Biogas	110	5
Offshore Sources	110	1
Field burning	230	25
Poultry Litter	230	7
Scrap Tyres, Waste Oils	140	15
Sewage, MSW and Clinical Incineration	230	7
Wood	230	30
Straw	230	50

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

1.4 HALOCARBONS AND SF6

The uncertainties in the emissions of HFCs, PFCs and SF_6 were taken from Eggleston *et al* (1998). The uncertainties were estimated as 25% for HFCs, 19% for PFCs and 13% for SF_6 in 1990. Trend uncertainties are reported in Table 4

1.5 GWP WEIGHTED EMISSIONS

The uncertainty in the combined GWP weighted emission of all the greenhouse gases in 2000 was estimated as 15% and in 1990, 13.9%. The trend in the total GWP is -13.2% within the

range -10% and -16%. The uncertainty estimates for all gases are summarised in Table 4. 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. Hence the increase in uncertainty since 1990.

Table 4: Summary of Tier 2 Uncertainty Estimates

A	B	C	D	E	F	G	H	I	J
IPCC Source Category	Gas	1990 Emissions	2000 Emissions	Uncertainty in 2000 emissions as % of emissions in category		Uncertainty Introduced in national total in 2000[a]	% change in emissions between 2000 and base year	Range of likely % change between 2000 and 1990	
				2.5 percentile	97.5 percentile			2.5 percentile	97.5 percentile
		Gg CO_2 equivalent	Gg CO_2 equivalent	Gg CO_2 equivalent	Gg CO_2 equivalent	%	%	%	%
TOTAL	CO_2	592496	546097	534310	557730	2.2%	-7.8%	-9.2%	-6.5%
	CH_4	76535	50592	44314	69350	21%	-33%	-43%	-18%
	N_2O	67873	43834	10710	9400	b	-35%	-74%	-13%
	HFC	11374	9316	7020	11575	25%	-18%	-43%	17%
	PFC	2281	668	547	793	19%	-71%	-78%	-62%
	SF_6	724	1540	1346	1736	13%	113%	77%	155%
	All	751283	652408	613785	767000	15%	-13%	-16%	-10%

a Calculated as 2s/E where s is the standard deviation and E is the mean, calculated in the simulation.

b Not quoted because distribution is highly skewed.

2. Estimation of Uncertainties using a Tier 1 Approach

The IPCC Good Practice Guidance (IPCC, 2000) defines Tier 1 and Tier 2 approaches to estimating uncertainties in national greenhouse gas inventories. The Monte Carlo approach described above corresponds to Tier 2 whilst Tier 1 provides for a simplified calculation method based on the error propagation equations. The results of the Tier 1 approach are shown in Table 5. In the Tier 1 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 Tier 2 approach are not exactly the same as those used in the Monte Carlo Simulation since the Tier 1 source categorisation is far less detailed. However, the values used were chosen to agree approximately with those used in the Monte Carlo Simulation. The Tier 2 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. The standard deviation was then estimated as (97.5 percentile –mean)/2.

The Tier 1 approach suggests an uncertainty of 18% in the combined GWP total emission in 2000. The analysis also estimates an uncertainty of 2% in the trend between 1990 and 2000.

Table 5: Tier 1 Uncertainty Calculation and Reporting

	Source Category	Gas	Base year emissions 1990	Year Y emissions 2000	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty range as % of national total in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced trend in total emissions by source category
			Gg CO2 equiv	Gg CO2 equiv	%	%	%	%	%	%	%	%	%
	A	B	C	D	E	F	G	H	I	J	K	L	M
1A	Coal	CO2	237762	129472	1.2	6	6.119	1.220508	-0.100771	0.172335	-0.604629	0.292462	0.671647
1A(stationary)	Oil	CO2	91621	60301	2	2	2.828	0.262762	-0.026300	0.080263	-0.050600	0.227019	0.232590
1A	Natural Gas	CO2	110249	207967	2.4	1	2.600	0.833034	0.149809	0.276815	0.149809	0.939542	0.951411
1A	Other (waste)	CO2	194	827	7	20	21.190	0.026985	0.000877	0.001100	0.017545	0.010892	0.020651
1A3a	Aviation Fuel	CO2	2158	3330	50	2	50.040	0.256696	0.001950	0.004432	0.003900	0.313392	0.313416
1A3b	Auto Fuel	CO2	109039	116656	0.8	2	2.154	0.383814	0.028508	0.153944	0.057016	0.174168	0.183263
1A3d	Marine Fuel	CO2	3461	2648	1.4	2	2.441	0.009959	-0.000456	0.003524	-0.000911	0.006978	0.007037
1A3	Other Diesel	CO2	1923	1413	1.4	2	2.441	0.005314	-0.000330	0.001881	-0.000660	0.003724	0.003782
1B	Solid Fuel Transformation	CO2	3000	2303	1.2	6	6.119	0.021706	-0.000386	0.003065	-0.002313	0.005201	0.005692
1B	Oil & Natural Gas	CO2	9138	5509	16	6	17.088	0.145033	-0.003175	0.007333	-0.019050	0.165925	0.167015
2A1	Cement Production	CO2	6659	5780	1	2.2	2.417	0.021519	0.000035	0.007693	0.000077	0.010880	0.010880
2A2	Lime Production	CO2	1192	1291	1	6	6.099	0.010146	0.000349	0.001719	0.001743	0.002431	0.002991
2A3	Limestone & Dolomite use	CO2	1369	1191	1	5	5.099	0.009364	0.000010	0.001585	0.000051	0.002242	0.002242
2A4	Soda Ash Use	CO2	167	143	15	2	15.133	0.003395	-0.000002	0.000190	-0.000004	0.004040	0.004040
2A7	Flatton Bricks	CO2	241	129	20	70	72.801	0.014463	-0.000106	0.000172	-0.007391	0.004955	0.008843
2B	Ammonia Production	CO2	1358	1389	10	1	10.050	0.021511	0.000287	0.001849	0.000287	0.026152	0.026154
2C1	Iron&Steel Production	CO2	3161	3187	1.2	6	6.119	0.030045	0.000607	0.004242	0.003640	0.007199	0.008067
5A	5A LUCF	CO2	-9466	-10553	1	30	30.017	-0.488000	-0.003172	-0.014046	-0.095156	-0.019864	0.097206
5D	5D LUCF	CO2	15439	11441	1	60	60.008	1.057710	-0.002526	0.015228	-0.151571	0.021536	0.153094
5E	5E LUCF	CO2	2808	2466	1	50	50.010	0.190003	0.000053	0.003382	0.002651	0.004642	0.005346
6C	MSW Incineration	CO2	812	208	7	20	21.190	0.006796	-0.000656	0.000277	-0.013126	0.002743	0.013412
		CO2 Total	592496	546097									
1A	All Fuel	CH4	1906.93866	1728.263635	1.2	50	50.014	0.133188	0.000107	0.002300	0.005372	0.003904	0.006641
1A3a	Aviation Fuel	CH4	2.48515697	3.074803199	50	50	70.711	0.000395	0.000001	0.000004	0.000062	0.000289	0.000296
1A3b	Auto Fuel	CH4	621.450616	327.3448552	0.8	50	50.006	0.025219	-0.000279	0.000436	-0.013946	0.000493	0.013956
1A3d	Marine Fuel	CH4	6.664896	5.098464	1.4	50	50.020	0.000393	-0.000001	0.000007	-0.000044	0.000013	0.000046
1A3	Other Diesel	CH4	2.56007102	1.276997895	1.4	50	50.020	0.000098	-0.000001	0.000002	-0.000062	0.000003	0.000062
1B1	Coal Mining	CH4	17202.706	5564.745	1.2	13	13.055	0.111905	-0.012373	0.007407	-0.160852	0.012570	0.161343
	Solid Fuel Transformation	CH4	0.530	0.146	1.2	50	50.014	0.000011	0.000000	0.000000	-0.000021	0.000000	0.000021
1B2	Natural Gas Transmission	CH4	8360.402	6891.463	1	15	15.033	0.161926	-0.000308	0.009306	-0.004626	0.013161	0.013950
	Offshore Oil& Gas	CH4	2418.601	1276.825	16	20	25.612	0.050382	-0.001082	0.001700	-0.021637	0.038455	0.044125
2A7	Flatton Bricks	CH4	23.620	12.342	20	100	101.980	0.001939	-0.000011	0.000016	-0.001074	0.000465	0.001170
2B	Chemical Industry	CH4	140.915	53.414	20	20	28.284	0.002328	-0.000091	0.000071	-0.001819	0.002011	0.002712
2C	Iron & Steel Production	CH4	16.361	14.088	1.2	50	50.014	0.001086	0.000000	0.000019	-0.000003	0.000032	0.000032
4A	Enteric Fermentation	CH4	19078.104	18137.415	0.1	20	20.000	0.558864	0.002202	0.024142	0.044031	0.003414	0.044164
4B	Manure Management	CH4	2329.319	2208.584	0.1	30	30.000	0.102078	0.000261	0.002940	0.007831	0.000416	0.007842
4F	Field Burning	CH4	266.045	0.000	25	60	55.902	0.000000	-0.000306	0.000000	-0.015297	0.000000	0.015297
6A	Solid Waste Disposal	CH4	23457.000	13860.000	15	45	48.384	1.033141	-0.008524	0.018448	-0.382123	0.391350	0.554000
6B	Wastewater Handling	CH4	701.022	774.648	1	50	50.010	0.059684	0.000225	0.001031	0.011246	0.001458	0.011340
6C	Waste Incineration	CH4	0.655	1.716	7	50	50.488	0.000133	0.000002	0.000002	0.000077	0.000023	0.000080
		CH4 total	76595	50980									

Table 5: Tier 1 Uncertainty Calculation and Reporting (Continued)

	Source Category	Gas	Base year emissions 1990	Year Y emissions 2000	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
1A2&1A2&1A4& 1A5	Other Combustion	N2O	4131.817	3893.603	1.2	195	195.004	1.199784	0.000564	0.005316	0.109999	0.009021	0.110368
1A3a	Aviation Fuel	N2O	21.238	32.761	50	170	177.200	0.008944	0.000019	0.000044	0.003261	0.003083	0.004488
1A3b	Auto Fuel	N2O	1027.346	3949.151	0.8	170	170.002	1.034315	0.004075	0.005257	0.692757	0.005947	0.692782
1A3d	Marine Fuel	N2O	68.324	52.266	0.8	170	170.002	0.013689	-0.000009	0.000070	-0.001531	0.000079	0.001533
1A3	Other Diesel	N2O	228.178	168.110	1.4	140	140.007	0.036261	-0.000039	0.000224	-0.005410	0.000443	0.005428
1B1	Coke Oven Gas	N2O	1.879	0.517	1.2	118	118.006	0.000084	-0.000001	0.000001	-0.000174	0.000001	0.000174
1B2	Oil & Natural Gas	N2O	93.659	46.667	16	110	111.158	0.007992	-0.000045	0.000062	-0.005002	0.001406	0.005196
2B	Adipic Acid Production	N2O	25136.353	1638.970	0.5	15	15.008	0.037896	-0.026716	0.002182	-0.400744	0.001543	0.400747
2B	Nitric Acid Production	N2O	4133.725	4542.669	10	230	230.217	1.611189	0.001293	0.006047	0.297327	0.085511	0.308379
2C	Iron & Steel	N2O	11.106	8.971	1.2	118	118.006	0.001631	-0.000001	0.000012	-0.000098	0.000020	0.000100
4B	Manure Management	N2O	1513.721	1433.973	1	424	424.001	0.936706	0.000168	0.001909	0.071197	0.002699	0.071248
4D	Agricultural Soils	N2O	30363.015	26785.044	1	424	424.001	17.496649	0.000746	0.035652	0.316379	0.050420	0.320371
4F	Field Burning	N2O	77.762	0.000	26	230	231.355	0.000000	-0.000089	0.000000	-0.020588	0.000000	0.020588
6B	Wastewater Handling	N2O	1033.301	1127.098	10	401	401.125	0.696525	0.000312	0.001500	0.126085	0.021216	0.126871
6C	Waste Incineration	N2O	41.328	54.148	7	230	230.106	0.019196	0.000025	0.000072	0.005646	0.000713	0.005691
		N2O Total	67673	43834									
2	Industrial Processes	HFC	11374	6206	1	25	25.020	0.239201	-0.004819	0.008260	-0.120481	0.011681	0.121046
2	Industrial Processes	PFC	2281	678	1	19	19.026	0.019879	-0.001720	0.000903	-0.032687	0.001277	0.032712
2	Industrial Processes	SF6	724	1314	1	13	13.038	0.026388	0.000916	0.001749	0.011914	0.002474	0.012168
		Halocarbon & SF6 Total	14379	8198									
	TOTALS	GWP	751283	649089									
	Total Uncertainties%							17.8					1.68

3. Key Source Analysis

The Good Practice Guidance (2000) requires that a key source analysis be made to identify the key source categories in the inventory. The results of the analysis are reported in Table 6. The analysis is based on the Tier 2 level analysis and trend analysis. The key source analysis was performed on the data shown in Table 5 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 which make a source a key source are:

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

For example: auto oil combustion is a key source of carbon dioxide because it is large; landfill methane is key because it is large, has a high uncertainty and shows a significant trend. Sources and sinks from land use change and forestry have been included in the key source analysis since they are significant and have a high uncertainty.

There have been few changes to the list of key sources from the 1999 Inventory. Aviation fuel has become key along with 5E Other LUCF. HFC emissions which were marginally key have been displaced.

Table 6 Source Category Analysis Summary

Quantitive Method Used: Tier 2					
A IPCC Source Categories		B Gas	C Category Key Source Category	D If Column C is Yes, Criteria for Identification	E Comments
1A	Coal	CO2	Yes	Level	
1A(stationary)	Oil	CO2	Yes	Level	
1A	Natural Gas	CO2	Yes	Level	
1A	Other (waste)	CO2	No		
1A3a	Aviation Fuel	CO2	Yes	Level, Trend	
1A3b	Auto Fuel	CO2	Yes	Level	
1A3d	Marine Fuel	CO2	No		
1A3	Other Diesel	CO2	No		
1B	Solid Fuel Transformation	CO2	No		
1B	Oil & Natural Gas	CO2	No		
2A1	Cement Production	CO2	No		
2A2	Lime Production	CO2	No		
2A3	Limestone & Dolomite use	CO2	No		
2A4	Soda Ash Use	CO2	No		
2A7	Fletton Bricks	CO2	No		
2B	Ammonia Production	CO2	No		
2C1	Iron&Steel Production	CO2	No		
5A	Land Use Change & Forestry	CO2	Yes	Level	high uncertainty
5D	Land Use Change & Forestry	CO2	Yes	Level, Trend	high uncertainty
5E	Land Use Change & Forestry	CO2	Yes	Trend	
6C	MSW Incineration	CO2	No		
1A	All Fuel	CH4	No		
1A3a	Aviation Fuel	CH4	No		
1A3b	Auto Fuel	CH4	No		
1A3d	Marine Fuel	CH4	No		
1A3	Other Diesel	CH4	No		
1B1	Coal Mining	CH4	No		
	Solid Fuel Transformation	CH4	No		
1B2	Natural Gas Transmission	CH4	No		
	Offshore Oil& Gas	CH4	No		
2A7	Fletton Bricks	CH4	No		
2B	Chemical Industry	CH4	No		
2C	Iron & Steel Production	CH4	No		
4A	Enteric Fermentation	CH4	Yes	Level	
4B	Manure Management	CH4	No		
4F	Field Burning	CH4	No		
6A	Solid Waste Disposal	CH4	Yes	Level, Trend	high uncertainty
6B	Wastewater Handling	CH4	No		
6C	Waste Incineration	CH4	No		
1A2&1A2&1A4&1A5	Other Combustion	N2O	Yes	Trend	
1A3a	Aviation Fuel	N2O	No		
1A3b	Auto Fuel	N2O	Yes	Trend	
1A3d	Marine Fuel	N2O	No		
1A3	Other Diesel	N2O	No		
1B1	Coke Oven Gas	N2O	No		
1B2	Oil & Natural Gas	N2O	No		
2B	Adipic Acid Production	N2O	No		
2B	Nitric Acid Production	N2O	Yes	Level, Trend	
2C	Iron & Steel	N2O	No		
4B	Manure Management	N2O	Yes	Level, Trend	high uncertainty
4D	Agricultural Soils	N2O	Yes	Trend	high uncertainty
4F	Field Burning	N2O	No		
6B	Wastewater Handling	N2O	Yes	Trend	
6C	Waste Incineration	N2O	No		
2	Industrial Processes	HFC	No		
2	Industrial Processes	PFC	No		
2	Industrial Processes	SF6	No		

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Appendix 9 Quality Assurance and Quality Control

CONTENTS

1. Introduction

This Appendix summarizes the UK national inventory system and the current QA/QC system used in the compilation of the National Atmospheric Emissions Inventory (NAEI) and the UK Greenhouse Gas Inventory (GHGI). The current system complies with the Tier 1 procedures outlined in the Good Practice Guidance (IPCC, 2000). Plans are underway to develop the system and extend the range of activities so that the system complies with Tier 2.

2. The UK National Inventory System

The Department for Environment, Food and Rural Affairs (DEFRA) is responsible for submitting the UK's greenhouse gas inventory (GHGI) to the UNFCCC and the EU Monitoring Mechanism. AEA Technology compiles the GHGI on behalf of DEFRA and the devolved administrations.

Figure 1 summarises the UK national inventory system.

The GHGI is compiled using the same database as the National Atmospheric Emissions Inventory (NAEI). The NAEI is the air emissions inventory for the UK and includes emission estimates for a wide range of important pollutants. These include: greenhouse gases, regional pollutants leading to acid deposition and photochemical pollution, persistent organic pollutants and other toxic pollutants such as heavy metals. The NAEI is available at www.aeat.co.uk/netcen/airqual

Energy statistics required for compilation of the NAEI and the GHGI are obtained from the Digest of UK Energy Statistics (DUKES), compiled and published by the Department of Trade and Industry (DTI). DUKES is available at www.dti.gov.uk/epa/dukes.htm

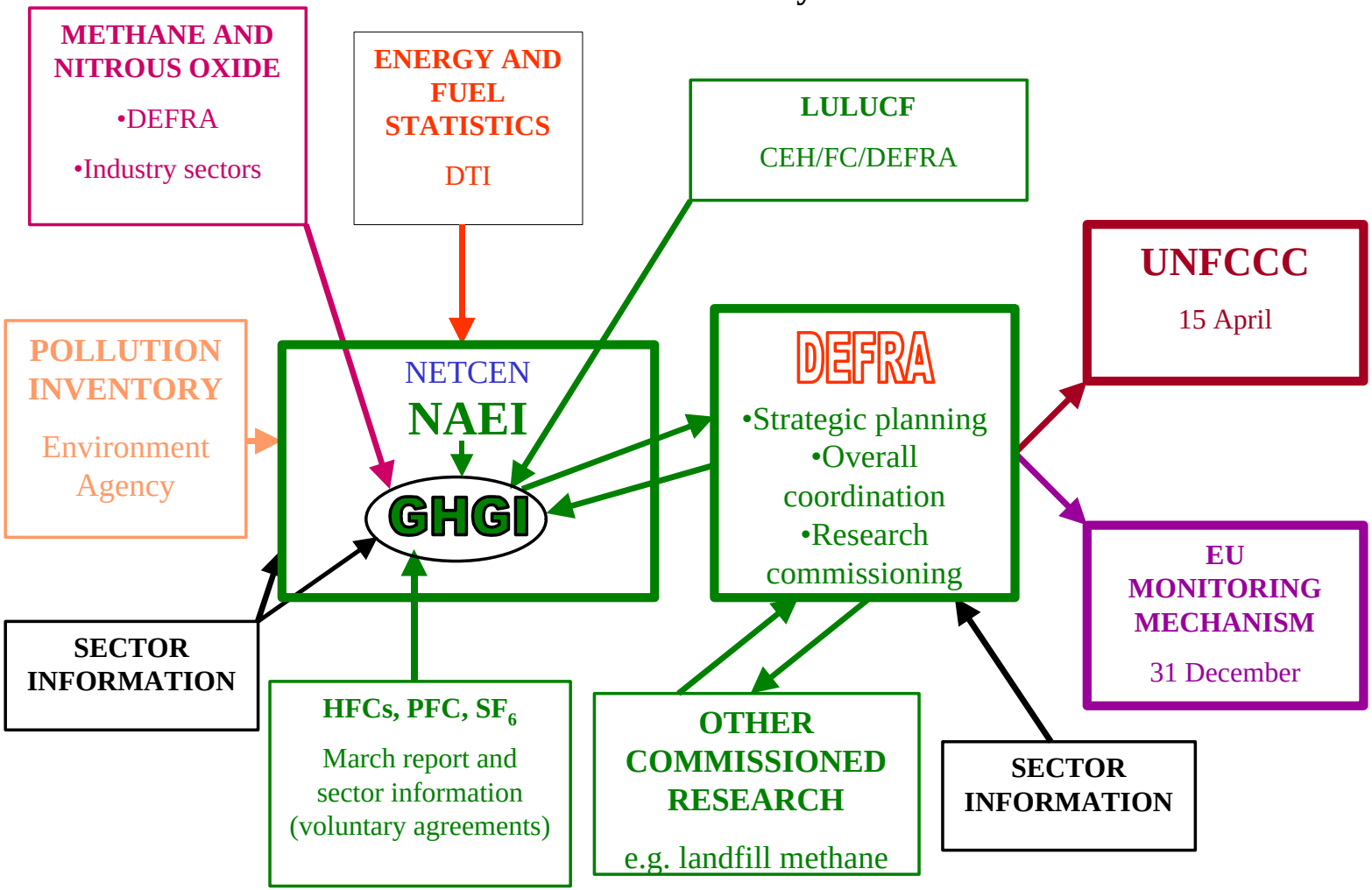
Information on industrial processes is provided either directly to AEA Technology by the individual sectors responsible for emissions or from the Environment Agency's Pollution Inventory (PI). The PI is the only statutory part of the national system. Large companies are required to report emissions of key pollutants to the Environment Agency[1] (a non-departmental public body). The PI is also used to help confirm some information provided voluntarily by companies directly to AEA Technology.

The Institute for Grassland and Environmental Research (IGER) compiles the inventory for agricultural emissions using agricultural statistics from DEFRA.

The Centre for Ecology and Hydrology (CEH) compiles estimates of emissions and removals from LUCF using DEFRA land-use data and information on forestry from the Forestry Commission (a non-departmental public body).

[1] The Environment Agency for England and Wales

Figure 1: National System for Preparing the UK GHG Inventory



DEFRA also funds research contracts to provide emissions estimates for certain sources. For example, AEA Technology provides landfill methane emissions estimates. Emissions of HFCs, PFCs and SF_6 were compiled by an independent consultancy (EnvirosMarch) in consultation with industry.

The GHGI is compiled according to IPCC Good Practice. Each year the inventory is updated to include the latest data available. Improvements to the methodology are made and are backdated to ensure a consistent time series. Methodological changes are made to take account of new data sources, or new methodologies developed by IPCC or CORINAIR, or new research, or specific research programmes sponsored by DEFRA.

3. QA/QC System used for the UK Greenhouse Gas Inventory

3.1 DESCRIPTION OF THE CURRENT SYSTEM

The National Atmospheric Emissions Inventory and the UK Greenhouse Gas Inventory are compiled and maintained by the National Environmental Technology Centre of AEA Technology plc. Whilst significant parts of the inventory (i.e. agriculture, land use change and forestry and halocarbons and sulphur hexafluoride emissions) are compiled by other agencies and contractors, NETCEN is the *Inventory Agency* responsible for co-ordinating QA/QC activities.

The system has developed over the years. A new on-line database system was adopted for the 1997 Inventory in 1998 and since then developments have proceeded to build QA/QC procedures into the on-line system. The database consists essentially of a table of activity data and a table of emission factors for the NAEI base source categories. These are then multiplied together to produce emissions according to the IPCC and CORINAIR formats to be generated.

The Inventory has been subject to ISO 9000 since 1994 and is liable to audit by Lloyds and the AEAT internal QA auditors. The NAEI has been audited favourably by Lloyds on two occasions in the last four years. The emphasis of these audits was on authorisation of personnel to work on inventories, document control, data tracking and spreadsheet checking. As part of the Inventory management structure there is a nominated officer responsible for the QA/QC system –*the QA/QC Co-ordinator*.

The system incorporates the following activities which are carried out each year as the inventory is compiled:

1. Documentation

- Data received by NETCEN are logged, numbered and should be traceable back to their source from anywhere in the system.
- The inventory is held as an Access database of activity data and emission factors. Within the database these data fields are referenced to the data sources, or the spreadsheet used to calculate the data. For fuel consumption data, the DUKES (DTI, 2001) table numbers are identified.
- There is an on-line system of manuals, which defines timetables, procedures for updating the database, document control, checking procedures and procedures for updating the methodology manual.
- There is an on-line methodology manual which is updated as the inventory data are entered. This contains details of the methodology used, emission factor and activity data sources, discussion of the rationale for choice of methodology and emission factors.
- An annual report outlining the methodology of the inventory, data sources and changes made is produced.

2. Database

- The classification of source categories is controlled by a formatting table in the database which is used to generate emissions tabulated in the IPCC format. Other simple queries can be used to dump all emissions data contained in the database. These can be compared against the tabulated output to check that all sources are output and that the totals are correct. A consistency check between IPCC output and CORINAIR formatted output is made. Data in the CRF reporting tool are checked against the database totals.
- All fields in the database are labelled automatically with an NAEI source/fuel category, the CORINAIR SNAP code and the units used. A comment field linked to each data entry provides further description and the data source or spreadsheet used to calculate it.

3. Checking

- ISO 6000 requires that spreadsheet calculations are checked and the checks applied are described. Also the data sources used for calculations must be referenced on the spreadsheet.
- Data entry into the database is checked. It is not always possible for all data entries to be checked by a second person. However, a major proportion of the activity data are entered and checked by third persons.
- A system has been developed to check the fuel entries in the database. Queries will abstract and total the fuel conssumptions for each fuel. These totals are then checked against the totals reported in DTI (2001).
- The final checks on the inventory involve a consistency check against the previous inventory for the same year. A designated auditor identifies sources where there have been significant changes or new sources. Inventory staff are required to explain these changes in the inventory to satisfy the auditor.
- A further final check is made on the inventory comparing the emissions of the latest year with those of the previous year (within the same version). A designated checker identifies sources where there have been significant changes. Inventory staff are required to explain these changes in the inventory to satisfy the checker. This is some what more detailed than

the recalculation explanations required by Table 8 in the CRF, because it is based on the more disaggregated source sectors used in the NAEI database.

4. Recalculation

- When revisions are made to the methodologies of the estimates, emissions for all previous years are recalculated as a matter of course.

5. Uncertainties

- Estimates are made of the uncertainties in the estimates according to Tier 1 and Tier 2 procedures.
- A ranking exercise is performed according to Tier 2 procedures to identify key source categories.

6. Archiving

- At the end of each reporting cycle, all the database files, spreadsheets, on-line manual, electronic source data, paper source data, output files are in effect frozen and archived. An annual report outlining the methodology if the inventory and data sources is produced. Electronic information is stored on hard disks which are regularly backed up. Paper information is being archived in a Lektreiver ® system and a database of all items in the archive is being compiled

The system outlined above complies with the Tier 1 procedures outlined in Table 8.1 of the Good Practice Guidance (IPCC, 2000). However, following the release of the Good Practice Guidance a review of the QA/QC procedures has been carried out (Salway, 2001) and a QA/QC plan has been developed to extend the current procedures to comply with Tier 2. This involves extending some of the existing procedures and adopting new ones. The QA/QC plan is discussed further in Section 3.

3.2 SPECIAL QA/QC ACTIVITIES UNDERTAKEN IN 2000-2002

This section describes certain specific activities relating to QA/QC that were carried out in the last year. These will in future arise from the QA/QC plan but are not necessarily carried out on an annual basis. The activities were:

- *Halocarbons and Sulphur Hexafluoride Verification*. A study was carried out to verify the inventory of halocarbons and sulphur hexafluoride, (Salway *et al*, 2001). This entailed the collection of top down and bottom up data on the consumption of fluids by the fluid bank. The comparison with the existing inventory gave good agreement (15-20%) between major sources.
- *QA/QC Review*. A review was carried out of the QA/QC procedures used in the Inventory and how they complied with the Good Practice Guidance, (Salway, 2001). Areas where improvements were required were identified.
- *Landfill Review*. An internal expert review of the methodology used in the estimation of landfill methane was carried out to see how it compared with the Good Practice Guidance (Salway, 2001). The review found that the methodology and model parameters were in accord with the Guidelines. The activity data and methods used to extrapolate the data were largely in accord with the Guidance, but that certain parameters were based on expert judgement rather than actual measured data.

- *Acid Plant Documentation*. Following the review of QA/QC procedures the questionnaire sent to operators of adipic acid and nitric acid plant was revised to improve the level of supporting documentation for adipic acid and nitric acid plant. This involved requesting data on the number, type, utilisation, abatement systems, plant emission factors, and utilisation. However, the response from the operators was incomplete with not all the background information being provided.
- *Carbon Emission Factor Review*. The Good Practice Guidance advises that carbon factors should be collected from fuel producers and industrial users. Whilst the response was rather limited, the data compared well with the petroleum factors currently in use. However, it was clear that the factors used in the oil industry for LPG (i.e. butane and propane) were significantly lower than the UK default. As a result of this comparison, the UK default was revised in the 1999 Inventory (2001 submission) based on an 80%/20% by weight mixture of propane and butane. There was some evidence that the coal factors in use do not account for the increase in the proportion of imported coal used in the UK. There is evidence to suggest that the carbon content of imported coal is higher than home produced. The possibility of a sampling and measurement project is under consideration.
- *Methane Emissions from Closed Mines*. A review was undertaken of methane emissions from closed mines, (Sage, 2001). This source is not included in the UK Inventory because it was believed to be negligible. The review concentrated on assessing the various estimates of these emissions to see whether this source should be included in the Inventory (See Appendix 3). As a result, DEFRA is planning research to establish a more reliable estimate of closed mine emissions.
- *Energy Data Harmonisation*. The In-Depth review of the 1999 Inventory held in May 2001 highlighted certain discrepancies between the energy data reported in the CRF and the data held by Eurostat for the UK. Consequently DTI sponsored a review of the use of the DTI energy statistics (DTI, 2000) in the preparation of the carbon inventory, and those reported to European Energy Agency. The outcome of the review was to confirm the Inventories' interpretation and use of the energy statistics and to recommend certain changes in the questionnaire submitted to IEA. (Simmons, 2002).
- *Expert Peer Review of Fuel Combustion Sources of Carbon Dioxide*. An expert peer review of the key fuel combustion sources of carbon dioxide is scheduled to begin in April 2002.

4. Future Development of the QA/QC System

The review discussed in the previous section identified areas where the current QA/QC system could be improved and the need for additional activities to comply with Tier 2. These developments are now included in the QA/QC plan, elements of which are described in this Section. The QA/QC plan will be included in the on-line manual system.

4.1 IMPROVEMENTS TO THE SYSTEM

4.1.1 Compliance of National Statistical Agencies

Many of the data received by NETCEN come from other government departments, agencies, research establishments or consultants. Some of these organisations (e.g. DTI, MAFF and BGS)

would qualify as the *National Statistical Agencies* referred to in the Guidance. Other organisations (e.g. CEH, Enviros March) compile significant parts of the Inventory. Currently the QA/QC procedures in use at NETCEN do not extend to QA/QC procedures used at these data suppliers. The Good Practice Guidance defines as good practice that the Inventory Agency should confirm that *National Statistical Agencies* have implemented adequate QC procedures along the lines indicated in Table 8.1 of the Good Practice Guidelines. Hence, we have contacted these organisations and inviting them to show how their systems comply with IPCC Good Practice Guidance. The QA procedures used by DEFRA for agricultural data collection and archiving are outlined in Appendix 5 Agriculture and those used by the Centre for Ecology and Hydrology for preparing the land use change and forestry estimates are discussed in Appendix 6.

4.1.2 Documentation and Review

The Inventory is documented both by the on-line Manual and the Annual Report. The on-line Manual tends to include more detail which is inappropriate to the annual report. The Good Practice Guidance highlights the need for review of methodologies during inventory compilation. Hence the on-line manual is being developed along these lines:

- *Completeness*. The manual will be extended to include material on potential emission sources, which are not estimated in the Inventory. This will include reasons for not including these sources and some assessment of their magnitude.
- *Source Review Documentation*. The manual tends to describe the methodologies in use, past revisions, emission factors and activity data sources. It is intended that the scope should be expanded to include more detail on the choice of methodology and the choice of emission factors. This will include evidence that internal review of emission sources takes place.

4.1.3 External Peer Review

Tier 2 of the Good Practice Guidance requires that key sources should be subjected to external peer review. During 2002, the UK will implement a programme of peer reviews by experts outside of the organisation responsible for the estimates. The first peer review on CO_2 emissions from coal, oil and gas combustion is due to commence in April. The programme for the external peer review is shown in Table 1.

Table 1. QA/QC Activities Schedule

	2000/2001[1]	2001/2002	2002/2003	2003/2004
Special Activities	QA/QC Review Halocarbon Verification Closed Mines Review	Energy Data Harmonisation Review	Update Halocarbon Inventory Update Landfill (CH_4) (including QA/QC procedures)	
On-going Activities	On-Going Tier 1 Activities	On-Going Tier 1 Activities	On Going Tier 1 Activities	On-Going Tier 1 Activities
	Carbon Factor Review	Carbon Factor Review(update)	Carbon Factor Review(update)	Carbon Factor Review(update)
	Acid Plant Documentation	Acid Plant Documentation (update)	Acid Plant Documentation (update)	Acid Plant Documentation (update)
		Document Completeness		
	Document Source Reviews	Document Source Reviews	Document Source Reviews	Document Source Reviews
		External Agencies QA/QC	External Agencies QA/QC follow up	
External Peer Review	National Report	UNFCCC In-Depth Review National Report Combustion Sources- coal, oil and gas (CO_2)	National Report Agricultural Soils (N_2O) Manure Management (N_2O) Enteric Fermentation (CH_4	National Report Nitric Acid (N_2O) LUCF 5A, 5D & 5E (CO_2) Wastewater (N_2O) Landfill (CH_4)

1 Refers to period between inventory submission i.e. April to April

5. References

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Appendix 10

Verification of the UK Estimates of the Kyoto Gases

CONTENTS

1. Introduction

In order to provide some verification of the UK Greenhouse Gas Inventory (GHGI), the Global Atmosphere Divison 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 Meteorological Office employs a sophisticated Lagrangian dispersion (NAME) 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 Lagrangian dispersion model is then used to estimate the magnitude and spatial distribution of the European emissions required to support the observations (Ryall *et al.* 2001).

2. Methane

In Table 1, the comparison is made between the emission estimates made for the UK with the Lagrangian dispersion model and the GHGI emission inventory estimates for the period 1995-2000. Both sets of estimates clearly overlap, verifying that the GHGI estimates are accurate to at least ± 10 % or better. The GHGI estimates show a monotonic downward trend over the 1995-2000 period. The dispersion model estimates though not inconsistent with this, show considerable year-on-year variability that results from the influence of weather conditions on methane emissions. Hence, it is not yet clear whether the Mace Head observations support the monotonic decline in UK emissions seen in the GHGI estimates.

Table 1. Verification of the UK Emission Inventory Estimates for Methane.

Year	GHGI emissions , Gg yr^{-1}	NAME model emissions, Gg yr^{-1}
1995	3028	2956
1996	2960	2948
1997	2852	2771
1998	2724	2710
1999	2589	3318
2000	2427	2450

3. Nitrous Oxide

In Table 2, emission estimates for nitrous oxide for the period 1995-2000 are presented from the GHGI inventory and from the Lagrangian dispersion model. The GHGI estimates appear to be about ± 15 % higher than those from the Lagrangian dispersion and show a slightly

increasing trend followed by a sharp decline of about 30% between 1998 and 1999. The Lagrangian dispersion model estimates show significant year-on-year variability and, hence, although they fall from 1999 to 2000 further work will be needed to establish whether they support the step change seen in the GHGI estimates.

Table 2. Verification of the UK Emission Inventory Estimates for Nitrous Oxide.

Year	GHGI emissions , Gg yr^{-1}	NAME model emissions, Gg yr^{-1}
1995	184	131
1996	191	145
1997	196	159
1998	187	148
1999	145	150
2000	141	119

4. Hydrofluorocarbons

The GHGI provides an estimate of the total emissions of HFCs for the period 1995-2000 together with estimates for HFC 134a and HFC 152a. These data are shown in Table 3 alongside the Lagrangian dispersion model estimates, required to support the Mace Head observations of the individual HFC species. The inventory estimates for HFC 134a show a close agreement with the estimates derived from the Lagrangian dispersion model in earlier years but diverge more in later years. There appears to be agreement between the HFC 152a estimates, however, there are only two years of data are available. There is no separate GHGI for HFC 125. Further work on verification of these gases continues.

Table 3. Verification of the UK Emission Inventory Estimates for HFCs.

Year	Total HFC emissions in GHGI Gg yr^{-1}	HFC134a emissions in GHGI Gg yr^{-1}	HFC 134a in NAME model, Gg yr^{-1}	HFC152a emissions in GHGI Gg yr^{-1}	HFC 152a in NAME model, Gg yr^{-1}	HFC125 emissions in GHGI Gg yr^{-1}	HFC 125 in NAME model, Gg yr^{-1}
1995	1.956	0.5	0.5	0.03	-	NSI	-
1996	2.472	0.9	0.7	0.06	-	NSI	-
1997	3.067	1.2	0.7	0.08	-	NSI	-
1998	3.660	1.5	-	0.1	-	NSI	0.2
1999	2.954	1.7	1.1	0.1	0.1	NSI	0.2
2000	3.368	2.0	0.9	0.1	0.1	NSI	0.2

5. References

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