Appendix 1: Uncertainties in the UK and DA GHG inventory estimates

Introduction

The uncertainties in the UK Inventory are estimated using a Monte Carlo simulation. Eggleston et al (1998) and Salway et al (2001) describe this in detail. The method involves estimating the uncertainties in the activity data and the emission factors for all the emission source categories and then using a Monte Carlo simulation package to calculate the uncertainty in the emission totals. In order to apply a similar approach to the DA GHG inventories, it is necessary to estimate uncertainties for the DA activity data (i.e. fuel consumption, production data). The same emission factors are used in the DA inventories as in the UK Inventory, so their uncertainties are known. In the UK Inventory uncertainties in the activity data for fuel use are estimated on the basis of the statistical differences between fuel supply and demand data reported in the energy statistics. However, such data is not available for the DA-specific activity data used. Moreover, for some sources, no direct activity data is available at all, and it has been necessary to distribute the UK data using surrogate data (e.g. employment statistics). In such cases, it is impossible to say whether the surrogate statistics are an accurate indicator of fuel consumption.

DA GHGI Uncertainty Estimation

The uncertainties in the DA GHG inventories are also estimated using a Monte Carlo simulation. In order to simplify the calculations, the source categories are broader than those used in the UK GHG Inventory simulation. In the DA inventory simulation, the combustion categories are effectively the total consumption of a particular fuel. This contrasts with the UK simulation where there is a further disaggregation into sectoral categories (e.g. power stations, refineries). The rationale for this is that it is more practicable to estimate the uncertainty in the total consumption of a fuel in a region than to attempt to estimate uncertainties in diverse sectors where in some cases surrogates have been used.

For each of the broad source categories, an estimate of the activity uncertainty has been made for Scotland, Wales, Northern Ireland, and Unallocated emissions. The approach adopted was to estimate a factor to scale the UK uncertainty with, based on knowledge of the relative uncertainties of the DA estimates to each other, and to the UK total.

The factors used to weight the uncertainties for each of the DAs have been reviewed as part of the model update. The DA inventories have evolved since the uncertainty model was set up, and so some of the assumptions that were previously used are now no longer relevant. For example, different methods used to be used for fuel sales data in Northern Ireland and therefore the Northern Ireland estimate was assumed to be less uncertain than the other DAs. Now that DECC regional energy statistics are used across all four DAs, this difference in uncertainty is no longer assumed.

It is important to note that the uncertainties in the inventories for the UK, England, Scotland, Wales, Northern Ireland, Unallocated are inter-dependent, because:-

UK Emissions = [England + Scotland + Wales + Northern Ireland + Unallocated]

Therefore uncertainties from the UK, Scotland, Wales, Northern Ireland, and Unallocated emissions are estimated using the model, and uncertainty in the English emissions are calculated.

In many of the non-combustion sources (e.g. industrial processes, coal mines) the overall uncertainty is dominated by the emission factor and the uncertainty in the activity data is not a determining factor. Therefore, there is unlikely to be any significant variation in uncertainties between DAs. In these

cases, a low uncertainty for the activity data (say 1%) may be assumed for each DA, whilst the UK uncertainty for the emission factor is applied.

For sources where the UK total is made up as a sum of the DA totals, such as agriculture or LULUCF, no additional uncertainty is introduced in the process of deriving the UK split, and therefore the UK uncertainty parameters are applied directly to the DA estimates.

In the case of halocarbons and SF_6 emissions it is not considered feasible to attempt to assume varying uncertainties across the DAs. The F-gas uncertainties have been considered at a sector level. This means that the uncertainty for each sector emission at UK level has been applied to the DA estimates, so that the overall uncertainty for each of the F-gases reflects the mix of sources that are the most significant for each of the DAs, and their relative uncertainties.

Trend Uncertainty Analysis

The DA uncertainty model has been extended to provide estimates of the uncertainty in the emissions trend. The model uses, where possible, the same principles as the UK uncertainty model, however, these estimates are currently indicative since it will take further improvement work to refine the estimates fully.

In order to estimate the uncertainty on the trend, it was necessary to make an estimate of the uncertainty in the base year (1990 for CO_2, CH_4 and N_2O, and 1995 for the F-gases). This estimate is made for the UK Inventory, as part of the analysis presented in the National Inventory Report (Brown *et al*., 2012). Therefore, it was possible to make the DA uncertainty estimates using the method described above in conjunction with the UK estimates for the base year. The DA weighting factors were reviewed as part of this process, because changes to the source data and methods used across the time series mean that it is not always appropriate to apply the same weighting factor in the latest year as in the base year.

In addition to the estimation of the uncertainty in each year, it was also necessary to consider correlations between sources across years. The UK uncertainty model considers correlations in the estimates of

- N_2O from agriculture;
- CH_4 from landfills;
- CH_4 from leakage from the gas distribution network; and
- N_2O from waste water treatment.

These correlations have been replicated in the DA model. The uncertainty in the trend is particularly sensitive to the correlation in emissions from agricultural soils.

The uncertainty in the trend between 2009 and 2010 has been considered. However, the correlations between activity data and emission factors between adjacent years are not currently well understood, and it has therefore not been possible to produce a meaningful estimate at this time.

DA GHG Inventory Uncertainty Analysis Results

As a result of the activity data gaps in the DA inventories, the estimates will be more uncertain than for the UK inventory. Expert judgement has been used to assess the degree of additional uncertainty due to the use of proxy activity data, informed by the comparison of the new datasets such as EUETS and the DECC regional energy statistics with historic data. Overall data quality and sector allocations are improving, but for some source sectors, significant uncertainties remain, even at UK level.

The uncertainty estimates for the 1990-2010 DA GHG inventories are reported in Table A1.1.below.

The table presents the central estimate from the Monte Carlo simulation for each GHG and for each DA, for the base year and the latest year and the estimated uncertainty on the total. In addition, the central estimate of the trend (expressed as the percentage change from the base year) is presented together with the 5 and 95 percentile estimates.

Table A1.1 Estimated Uncertainties in the DA GHG Inventories: Base Years, 2010 and Trend

	Base Year		Latest Year (2010)		Trend (Base Year to 2010)		
Gas (kt CO_2e)	Central Estimate	Uncertainty Introduced on total	Central Estimate	Uncertainty Introduced on total	Central Estimate	2.5 Percentile	97.5 Percentile
Scotland							
Carbon Dioxide CO_2	50,942	10%	41,339	10%	-19%	-29%	-7%
Methane CH_4	11,860	31%	5,581	22%	-52%	-67%	-33%
Nitrous Oxide N_2O	6,666	260%	5,016	271%	-28%	-47%	-17%
HFC	113	8%	1,182	7%	952%	851%	1060%
PFC	87	17%	49	58%	-43%	-76%	-8%
SF_6	31	17%	47	20%	52%	16%	95%
Total	69,699	26%	53,214	27%	-24%	-32%	-14%
Wales							
Carbon Dioxide CO_2	43,165	3%	39,058	3%	-9%	-13%	-6%
Methane CH_4	7,305	19%	3,885	16%	-46%	-59%	-33%
Nitrous Oxide N_2O	4,040	285%	3,056	281%	-25%	-40%	-10%
HFC	60	8%	578	7%	869%	774%	973%
PFC	147	5%	3	60%	-98%	-99%	-96%
SF_6	83	17%	44	15%	-47%	-58%	-34%
Total	54,799	21%	46,623	19%	-15%	-19%	-11%
Northern Ireland							
Carbon Dioxide CO_2	16,746	8%	14,654	7%	-12%	-21%	-3%
Methane CH_4	3,679	20%	2,857	17%	-22%	-40%	0%
Nitrous Oxide N_2O	3,466	266%	2,555	297%	-35%	-63%	-17%
HFC	39	8%	379	7%	886%	791%	990%
PFC	1	20%	-	N/A	-100%	-100%	-100%
SF_6	2	20%	5	19%	167%	101%	247%
Total	23,932	39%	20,450	38%	-14%	-22%	-7%

(table continued below)

	Base Year		Latest Year (2010)		Trend (Base Year to 2010)		
Gas (kt CO_2e)	Central Estimate	Uncertainty Introduced on total	Central Estimate	Uncertainty Introduced on total	Central Estimate	2.5 Percentile	97.5 Percentile
England							
Carbon Dioxide CO_2	463,955	2%	383,227	2%	-17%	-19%	-15%
Methane CH_4	72,416	25%	27,728	23%	-61%	-72%	-47%
Nitrous Oxide N_2O	52,882	146%	24,524	251%	-60%	-83%	-28%
HFC	15,105	14%	12,084	6%	-20%	-31%	-6%
PFC	227	7%	168	15%	-26%	-38%	-14%
SF_6	1,123	17%	594	16%	-47%	-58%	-34%
Total	605,709	13%	448,325	14%	-26%	-30%	-23%
Unallocated							
Carbon Dioxide CO_2	14,112	13%	16,145	4%	15%	1%	32%
Methane CH_4	1,855	24%	1,027	26%	-44%	-61%	-22%
Nitrous oxide N_2O	263	105%	300	102%	43%	-70%	313%
HFC	-	N/A	-	N/A	N/A	N/A	N/A
PFC	-	N/A	-	N/A	N/A	N/A	N/A
SF_6	-	N/A	-	N/A	N/A	N/A	N/A
Total	16,231	12%	17,472	4%	8%	-5%	23%
UK							
Carbon Dioxide CO_2	588,920	2%	494,424	2%	-16%	-18%	-14%
Methane CH_4	97,116	24%	41,078	21%	-57%	-69%	-43%
Nitrous Oxide N_2O	67,318	170%	35,450	257%	-55%	-79%	-26%
HFC	15,318	14%	14,229	7%	-7%	-19%	9%
PFC	462	7%	220	21%	-52%	-63%	-42%
SF_6	1,239	17%	689	15%	-44%	-56%	-30%
Total	770,372	15%	586,090	16%	-24%	-28%	-21%

Notes

1. Uncertainty is defined as ± 2×(standard deviation)/mean %, which closely approximates the 95% confidence interval.
2. Base years are 1990 for carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O); 1995 for HFCs, PFCs and SF_6.
3. The uncertainty model takes emission estimates by gas for each source, applies an uncertainty distribution for that source and calculates a statistical mean, presented above as the central estimate. The emissions data in this table are taken from the Monte Carlo model output. The central estimates by gas for 1990 and the latest inventory year are very similar but not identical to the emission estimates in the DA inventories.