ANNEX 1
MANAGING UNCERTAINTIES

Uncertainties are inevitable in any estimate of national emissions or removals. Some important causes of uncertainty are:

- *differing interpretations of source and sink category or other definitions, assumptions, units etc.*
- *use of simplified representations with "averaged" values, especially emission factors and related assumptions to represent characteristics of a given population*
- *uncertainty in the basic socio-economic activity data which drives the calculations*
- *inherent uncertainty in the scientific understanding of the basic processes leading to emissions and removals.*

A major objective of the IPCC methodology is to help national experts reduce uncertainty in their greenhouse gas inventories to the minimum level possible. However, the approach also recognises that significant uncertainties will remain despite these efforts, and that these uncertainties will vary widely:

- *between different greenhouse gases*
- *between source categories for each gas*
- *between countries reporting the same gases and sources (depending on approach, levels of detail, use of default or country specific data etc.)*

It is important to provide as thorough an understanding as possible of the uncertainties involved when estimates are provided for scientific or policy uses. A simple method for expressing the confidence or uncertainty of point estimates qualitatively *is given elsewhere in the Reporting Instructions. However it is more useful to express uncertainty* quantitatively *and systematically in the form of well developed confidence intervals. This Annex provides some initial suggestions for developing quantitative uncertainty information. However, at present, it is only possible to provide a conceptual framework which relies on users to supply statistical data or equivalent expert judgement. IPCC/OECD consider the consistent estimation of uncertainty to be critically important, and will make it the focus of future work. Individual experts are encouraged to estimate uncertainty ranges as well as possible and to report results with their inventories. This will be of assistance with the ongoing work of developing methods.*

A1.1 Sources of Uncertainty

Definitions

Use of the IPCC *Reporting Instructions* will minimise variability or uncertainty which would otherwise be introduced by issues of definition. The IPCC *Reporting Instructions* provides common definitions of source categories and other terms, units, procedures, etc. The source categories are set out in Chapter 1 Understanding the Common Reporting Framework.

Estimation Methodology

The IPCC/OECD programme has sought consensus among researchers, sectoral interest groups and national technical experts on the best practicable default estimation procedures for priority gases and sources. These default methodologies are described in Volume 2 of the *Guidelines*, the *Greenhouse Gas Inventory Workbook*. By using these methods countries can minimise variations or uncertainties in national estimates which would be introduced by a *choice* of methodology. However, it must be recognised that default methods represent a compromise between the level of detail which would be needed to create the most accurate estimates for each country and the input data likely to be available or readily obtainable in most countries. In many cases, the simplest default methods are simplifications with general default values which introduce large uncertainties into a national estimate. Within many of the default methods different optional levels of detail are provided to reflect whether users have detailed data for their national situation or have to rely strictly on general default values. There may be considerable variation in how well the general default values represent conditions of the actual population of source activities in a particular country. For example, the uncertainty relating to default carbon emission coefficients for the global population of fossil fuel combustion sources may be characterised as quite low (5-10 per cent) in the IPCC methodology; but national experts for a particular country may know that the characteristics of such fuels in their country vary widely from global average values. In such a country, use of default values would introduce a larger uncertainty. Thus, even for the simplest application of the default methods, it is not possible to provide general uncertainty values for all countries.

The *Reference Manual* provides more options, including ways of doing calculations at greater levels of detail and, in some cases, alternative methodologies. Users of the IPCC *Guidelines* may use their own methodologies if they believe these will provide more accurate results for their national situation. Alternative methods should be carefully documented and results reported in the standard IPCC source and sink categories. Documentation of alternative methods may involve presentation of new empirical data which may in turn provide a basis for the improvement of the default procedures and data. However, whichever methods are used - default methods, more detailed versions of default methods, or entirely different methods - users should determine as far as possible the ranges of uncertainty introduced by the emission factors and other input assumptions used, whatever their source.

Socio-economic Activity Data

The IPCC default methodologies identify activity data from international socio-economic data series wherever possible. International compilations of socio-economic activity data do not generally include quantitative uncertainty estimates around country-level data summaries. Some of the national sources that provide data to the international series may have quantified uncertainty for their own national data. As with uncertainty in methodology and emission factors, the inventory developers must judge the quality of activity data used in their own national inventory.

Underlying Scientific Understanding

Current scientific understanding of the various human-induced processes which lead to emissions and removals of greenhouse gases to and from the atmosphere is incomplete. In some cases, where substantial measurement data exist and have been thoroughly analysed, this understanding provides a basis for accurate calculations of global and national emissions. In many cases, however, data and analysis have not attained this state. This variation affects the uncertainty inherent in the various components of the default methods, as well as the estimates using other methodologies. Table A1-1 provides an *illustrative* assessment of the relative uncertainties in the scientific basis for global emission estimates for some key components of the IPCC methodology. The overall uncertainty ranges shown here are based on an interpretation of the uncertainty information presented by the IPCC (1992). The allocation of overall uncertainty to the emission factor and activity data components has been made for illustrative purposes only on the basis of judgement by the IPCC/OECD technical staff. These values should not be used for estimating uncertainty for a particular national inventory. They are provided to assist users of the *Guidelines* to consider relative uncertainties in the basic science underlying different components of their inventories.

TABLE A1-1 UNCERTAINTIES DUE TO EMISSION FACTORS AND ACTIVITY DATA				
1	2	3	4	5
Gas	**Source category**	**Emission factor** U_E	**Activity data** U_A	**Overall uncertainty** U_T
CO_2	Energy	7%	7%	10%
CO_2	Industrial Processes	7%	7%	10%
CO_2	Land Use Change and Forestry	33%	50%	60%
CH_4,	Biomass Burning	50%	50%	100%
CH_4	Oil and Nat. Gas Activities	55%	20%	60%
CH_4	Coal Mining and Handling Activities	55%	20%	60%
CH_4	Rice Cultivation	$^3/_4$	$^1/_4$	1
CH_4	Waste	$^2/_3$	$^1/_3$	1
CH_4	Animals	25%	10%	25%
CH_4	Animal waste	20%	10%	20%
N_2O	Industrial Processes	35%	35%	50%
N_2O	Agricultural Soils			2 orders of magnitude
N_2O	Biomass Burning			100%

Note: Individual uncertainties that appear to be greater than ± 60% are not shown. Instead judgement as to the relative importance of emission factor and activity data uncertainties are shown as fractions which sum to one.

A1.2 Procedures for Quantifying Uncertainty

Estimating Uncertainty of Components

To estimate uncertainty by source category and gas for a national inventory, it is necessary to develop information like that shown in Table A1-1, but specific to the individual country, methodology and data sources used. In scientific and process control literature the 95 per cent (± 2) confidence limit is often regarded as appropriate for range definition. Where there is sufficient information to define the underlying probability distribution for conventional statistical analysis, a 95 per cent confidence interval should be calculated as a definition of the range. Uncertainty ranges can be estimated using classical analysis (see Robinson) or the Monte Carlo technique (in Eggleston, 1993). Otherwise the range will have to be assessed by national experts.

If possible ranges should be developed separately for

- emission factors (and other assumptions in the estimation method) (column 3 of Table A1-1).
- socio-economic activity data (column 4 of Table A1-1)

Combining Uncertainties

It is necessary to derive the overall uncertainty arising from the combination of emission factor and activity data uncertainty. IPCC/OECD suggest that emission factor and activity data ranges are regarded as estimates of the 95 per cent confidence interval, expressed as a percentage of the point estimate, around each of two independent components (either from statistically based calculations or informal *ex ante* judgements).

On this interpretation (for quoted ranges extending not more than 60 per cent above or below the point estimate) the appropriate measure of overall *percentage* uncertainty U_T for the emissions estimate would be given by the square root of the sum of the squares of the *percentage* uncertainties associated with the emission factor (U_E) and the activity data (U_A). That is, for each source category:

$$U_T = \pm\sqrt{\left(U_E^{\,2} + U_A^{\,2}\right)}\text{; so long as } |U_E|,\ |U_A| < 60\%$$ [1]

For individual uncertainties greater than 60 per cent the sum of squares procedure is not valid. All that can be done is to combine limiting values to define an overall range, though this leads to upper and lower limiting values which are asymmetrical about the central estimate[2].

Estimated total emission for each gas is of course the summation $\Sigma\ C_i$ where C_i is the central estimate of the emission of the gas in the source category. The appropriate measure of *uncertainty* in total emissions in emissions units (not percentages) is then:

$$E = \pm(1/100)\cdot\sqrt{\left(\Sigma\, U_{T,i}^{\,2}\cdot C_i^{\,2}\right)}$$

where $U_{T,i}$ is the overall percentage uncertainty for the source category of the gas from Table A1-1. Source categories for which symmetrical limiting values cannot be defined (because $|U_E|$ or $|U_A|$ exceeds 60 per cent) cannot sensibly be treated in this way. The uncertainty might be handled by reporting that total emissions from gas X are estimated to be Y Mt, of which Y_1 Mt had an estimated uncertainty of ± E_1 Mt and Y_2 Mt had a range of uncertainty between - L Mt and + U Mt.

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[1] The 60% limit is imposed because the rule suggested for U_T requires σ to be less than about 30% of the central estimate, and we are interpreting the quoted range as $\pm 2\sigma$

[2] If uncertainties due to the emission factor and the activity data are ± E% and ± A% respectively, and the upper and the lower limits of overall uncertainty are U% and L% respectively, then U% = (E+A+E·A/100) and L% = (E+A-E·A/100).

A1.3 Implications

If the assumptions in Table A1.1 are correct then typical uncertainties in national emissions estimates range between:

- ± 10% for CO_2 from fossil fuels although this may be lower for some countries with good data and where source categories are well defined (IPCC, 1993; von Hippel et al., 1993)
- ± 20% and ± 100% for individual methane sources (though the overall error might be ± 30%)
- perhaps two orders of magnitude for estimates of nitrous oxide from agricultural soils

These uncertainties will affect the level of quantitative understanding of atmospheric cycles of greenhouse gases that can be derived using the summation of inventories.

The situation is less critical for monitoring emissions mitigation options, because the profile of the emissions time series will be relatively insensitive to revisions to the emissions estimation methodology. However very different levels of uncertainty for different gases will be inevitable for some time to come, and this will need to be recognised in any move towards a comprehensive approach to greenhouse gas mitigation.

A1.4 References

(IPCC) Intergovernmental Panel on Climate Change (1992), *Climate Change 1992: The Supplement to the IPCC Scientific Assessment*.

The method for combining errors in a multiplicative chain are given in many statistical textbooks, but note Jennifer Robinson's discussion (On uncertainty in the computation of global emissions from biomass burning, *Climatic Change*, 14, 243-262) about the difficulties which arise at high coefficients of variation.

H S Eggleston (1993), "Uncertainties in the estimates of emissions of VOCs from Motor Cars." Paper presented at the *TNO/EURASAP Workshop on the Reliability of VOC Emission Databases*, June 1993, Delft, The Netherlands.

IPCC (1993), "Preliminary IPCC national GHG inventories: in depth review." Report presented at the *IPCC/OECD Workshop on National GHG Inventories*, October 1993, Bracknell, UK.

von Hippel et al. (1993), "Estimating greenhouse gas emissions from fossil fuel combustion", *Energy Policy*, 691-702, June 1993.